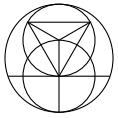
Side by Side

Volume Two: Computation, the Cosmos, Time and Mind



Side by Side

Twenty-Four Models of the Universe

Volume Two: Computation, the Cosmos, Time and Mind

Forrest Landry

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Links in the text name the book files of the physics collection of the Immanent Metaphysics, and they work when this book sits in the same folder as those files; *Category Theory and the Immanent Metaphysics* lies in the mathematics set.

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Volume One, The Quantum and the Arena (ISBN 979-8-90710-081-7, DOI https://doi.org/10.67291/ERWV7848), holds Parts One and Two, with the sealed record of 1 November 2026.

Terms of the Collection

Each chapter of this book can be read alone. The terms below belong to the physics collection of the Immanent Metaphysics and are used across the chapters; they are defined here once, in the words the chapters use.

Abiding. In *The Weight of Possibility*, the share of a factor's curvature that holds fast in a registration as a term of its own, and by which it reduces a count of classes.

Arena. The context of physics, the geometry of space and time within which content is found; on the collection's account, what gravitation is.

Axioms. The three axioms of the Immanent Metaphysics, stated in *An Immanent Metaphysics*, aphorism 1.3-1, concern the three modalities. The first axiom holds that the immanent is more fundamental than the omniscient and the transcendent, and that the omniscient and the transcendent are conjugate to one another. The second axiom is the directed cycle of the three roles of comparison, an order of precedence and not of clock time, converging from many to one at each step. The third axiom makes the three distinct, inseparable and not interchangeable. The first axiom was formulated before the Incommensuration Theorem, and the theorem was afterward shown to entail all three.

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable; consciousness is the bound triple taken as one act.

Content and context. In every comparison, what is found and the arena it is found in; in physics, quantum matter and the geometry of general relativity.

Content instance and context instance. The two instances of the internal space: as content it has no size and carries no spectrum of masses; as context it has radii, and its six directions are held at the modal boundary.

Decoherence. The spreading of the relative phase of two alternatives into an environment that registers which alternative is the case, after which they no longer interfere in measurements on the system alone.

Entangling phase. The phases of the two joint alternatives in which both masses are near or both far, less the phases of the two in which one is near and the other far.

Far region. The region far from the bodies, where the geometry of every alternative is flat and one measure of time serves them all; the collection's common term for the phase of two alternatives.

Finding. An interaction that registers which alternative is the case, made by any comparer, an instrument or an environment, with no mind needed.

Gathered. Said of choice: brought together from many acts of comparison into one persisting stance. "A photodiode's single undetermined click is choice at its least gathered; a living person is choice gathered across every channel of perception into one persisting stance".

Gyration. The unit of the dark matter on the collection's account: a conserved excitation of the six held internal dimensions, of about the Planck mass.

Hard randomness. An outcome that no prior specification fixes, however complete.

Held. Kept at the same size and shape at every point, as the six internal dimensions are, each standing at the modal boundary.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. It is a structural fact about the nature of knowing.

Modal boundary. The Planck curvature, at which the descriptions of content and context exchange dominance.

Modalities. The three roles of comparison: the immanent (held in the act), the omniscient (held as structure laid out), the transcendent (implicit, held in the stance). In the example the Bohr chapter uses, the measurement is immanent, the particle omniscient and the wave transcendent.

Order of depth. Metaphysics, physics, computation, mathematics, ordered by what each presupposes.

Per-alternative geometry. Each alternative of the matter carries its own classical geometry, and the relative phases of the alternatives are kept.

Performed, surveyed, implied. The three ways a claim can be held: by what happens in the act of engaging it; from a vantage with many cases in view; in the stance a practice proceeds from.

Planck curvature. The curvature whose radius is the Planck length, the scale at which an object's gravitational size equals its quantum size; it is not a least length.

Root Tautology. Comparison, interaction and relation are one act under three names.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Sealed prediction. A prediction as worded in the collection's dated register, fixed before the measurement that decides it is made.

Sealed record. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*, fixed at its date and not revised.

Short names. "The Passage" is *The Gravitational Passage*; "the Companion" is *The Gravitational Companion*; "the collection" is the physics collection of the Immanent Metaphysics, also called physics from comparison.

Six internal dimensions. The internal space $\mathbb{C}P^2 \times S^2$, a complex projective plane and a sphere, also called the six dimensions of possibility; held at the modal boundary, they are the range from which each finding is one selection, and nothing travels through them.

Six intrinsics. The parts of every comparison, in three pairs: same and different, content and context, the subjective and the objective. The Deutsch chapter calls a different set of six, the grid of six measures every comparison carries, by its own name.

Stance. The side from which a comparison is made; it belongs to every comparison, human or not.

Structural arrow. The direction of time as the direction in which comparison proceeds: from the range of what could be found, to the act, to the record.

Superdeterminism. A deterministic completion of quantum mechanics in which the settings of an experiment are fixed together with the states of what is measured, so that statistical independence fails.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

Three ways of validation. Measurement (first person), agreement (second person) and proof (third person); only measurement and proof validate truth.

FROM VOLUME ONE

Where the Accounts Part

Section I

Twenty-Four Models, One Record

This section and the tables that follow are reprinted from Volume One, so that each volume can be read alone.

Every account of physics claims the universe. Most claim it one piece at a time: a theory of the quantum, a theory of gravitation, a theory of the dark matter, a theory of the mind. This book sets twenty-four of those claims side by side, and holds each to the same record.

The record is the register of forty-two predictions sealed on 1 November 2026, The Registered Predictions of Physics from Comparison (DOI https://doi.org/10.67291/RQQS3025). It is fixed at its date and is not revised. It says, prediction by prediction, what experiment and observation will find: whether two masses become entangled through gravitation, what the ratio of the dark matter to the ordinary matter is, whether the equation of state of the vacuum is exactly -1, whether any new kind of particle will be found. It says, for each, what measurement decides it.

The first of the twenty-four models is physics from comparison, the physics of the Immanent Metaphysics. Its ground is the Incommensuration Theorem, which is a structural fact about the nature of knowing: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison. Its first axiom was formulated in or before 1991; the Incommensuration Theorem and the ethics in 1996; most of its physics in 1997 and 1998. *An Immanent Metaphysics* was published in 2001. Its physics is set out across the books of the collection, and its predictions are the sealed record.

The other twenty-three are the models of the people who built them. Two of the twenty-three are joint: the constructor-theoretic argument of Chiara Marletto and Vlatko Vedral, and modified Newtonian dynamics as Mordehai Milgrom founded it and Stacy McGaugh has carried it. Some of the twenty-three are models of the whole universe; some are models of the quantum, of the cosmos, or of life and mind, which the whole universe contains. Each is credited plainly, and where a model reached a result first, or where measurement has borne it out, the chapter says so. Other accounts appear in these

chapters only in passing, among them Carlo Rovelli's relational quantum mechanics, Bohmian mechanics, QBism and the string program; setting them beside the collection is work for another day.

The reader keeps score. Each of the twenty-three parts from physics from comparison at a step, a premise or a measurement that can be named in one sentence, and the experiments now under way will settle several of those partings within years. Each chapter that follows sets one model beside physics from comparison and finds the step where the two part. At each parting it says which of three things holds: one side's step does not follow from its premises, and a case shows it; both steps follow, and the two rest on different premises, stated as one sentence with what settles it; or a measurement already made contradicts one side's premise. Each chapter ends with a register of that model's predictions set beside the sealed record, and those registers are the appendices of the volumes.

How the book is laid out

This first part gives the disputes, one short section each, and the table of where every model stands. The parts that follow give each model in its own chapter, grouped by the question it most bears on, and in each part in the order in which the models were put forward.

Volume One, The Quantum and the Arena, holds Part Two: Niels Bohr, David Deutsch, Roger Penrose, Gerard 't Hooft, Nicolas Gisin, Anton Zeilinger, Sabine Hossenfelder, Chiara Marletto and Vlatko Vedral, Sean Carroll, and Jonathan Oppenheim. These are the models of what a finding is, what the quantum state is, and what gravitation does to a superposition.

Volume Two, Computation, the Cosmos, Time and Mind, holds three parts. Part Three, Discreteness and Computation: John Archibald Wheeler, Julian Barbour, Lee Smolin, Max Tegmark and Stephen Wolfram. Part Four, The Cosmos and the Dark Component: Arthur Eddington, George Ellis, Mordehai Milgrom and Stacy McGaugh, and Erik Verlinde. Part Five, Time, Life and Mind: Ilya Prigogine, Robert Rosen, Giulio Tononi and Karl Friston.

Each volume's appendices open with the prediction matrix, which lists for each of the forty-two sealed predictions the models of that volume that agree and the models that differ. Each person's register follows as its own appendix. Volume One also holds the sealed record itself.

Section XVI

Where Each Model Stands

The tables below set every model against every question. Each cell gives that model's answer in a few words, as its chapter states it; "silent" means the model makes no claim on the question. Physics from comparison is the first row of each table.

The quantum and gravitation

Model	Is the geometry quantized?	Does gravity entangle two masses?	Does a superposition end of its own accord?
Physics from comparison	No; the geometry is the context	Yes, phase 0.314 radians	No; only a finding ends one
Bohr	silent	silent	silent
Deutsch	Yes; the field is one more system	Yes	No
Penrose	Not in the usual way	No; collapse comes first	Yes, about 0.012 seconds
't Hooft	silent	silent	silent
Gisin	silent	silent	Yes; collapse is real
Zeilinger	silent	silent	No
Hossenfelder	silent	silent	silent
Marletto and Vedral	Yes, as a non-classical mediator	Yes	silent
Carroll	Yes; space emerges from the state	Yes	No
Oppenheim	No; classical, with diffusion	No	Yes; decoherence with diffusion
Wheeler	Yes, at every scale	Yes	No
Barbour	Yes; one more configuration	silent	No
Smolin	Yes; discrete area and volume	silent	silent
Tegmark	silent	silent	No
Wolfram	silent	silent	silent

Model	Is the geometry quantized?	Does gravity entangle two masses?	Does a superposition end of its own accord?
Eddington	silent	silent	silent
Ellis	silent	silent	silent
Milgrom and McGaugh	silent	silent	silent
Verlinde	No	silent	Yes, in models built on his
Prigogine	silent	silent	silent
Rosen	silent	silent	silent
Tononi	silent	silent	silent
Friston	silent	silent	silent

Steps, statistics and determinism

Model	Is there a least length or a rule beneath?	Do the Born weights hold everywhere?	Is the world fully determined?
Physics from comparison	No; the arena is continuous	Yes, everywhere	No
Bohr	silent	Yes	No
Deutsch	silent	Yes	Yes, as a whole
Penrose	silent	silent	silent
't Hooft	Yes; a deterministic automaton	Yes	Yes
Gisin	silent	Yes	No
Zeilinger	silent	Yes	No
Hossenfelder	No energy-dependent speed	Correlations in time in her test	Yes; superdeterministic
Marletto and Vedral	silent	Yes	silent
Carroll	silent	Yes	Yes, as a whole
Oppenheim	silent	silent	silent
Wheeler	Yes; a foam	Yes	silent
Barbour	silent	silent	silent
Smolin	Yes; steps, or a deformed symmetry	From the record of precedents	No

Model	Is there a least length or a rule beneath?	Do the Born weights hold everywhere?	Is the world fully determined?
Tegmark	silent	Yes	Yes, across the many worlds
Wolfram	Yes; one discrete rule	Yes	Yes; one rule fixes all
Eddington	silent	silent	silent
Ellis	silent	Yes	No
Milgrom and McGaugh	silent	silent	silent
Verlinde	silent	silent	silent
Prigogine	silent	silent	No
Rosen	silent	silent	silent
Tononi	silent	silent	silent
Friston	silent	Yes	silent

The early universe and the dark matter

Model	Did a long inflation happen?	Is space flat?	What is the dark matter?
Physics from comparison	No	Yes, to 10−5	Gyrations of about the Planck mass
Bohr	silent	silent	silent
Deutsch	silent	silent	silent
Penrose	No; one epoch to the next	Begins even (Weyl curvature hypothesis)	Erebons of about the Planck mass, which decay
't Hooft	silent	silent	silent
Gisin	silent	silent	silent
Zeilinger	silent	silent	silent
Hossenfelder	silent	silent	silent
Marletto and Vedral	silent	silent	silent
Carroll	Possibly, spawned from de Sitter space	silent	A dark force explored

Model	Did a long inflation happen?	Is space flat?	What is the dark matter?
Oppenheim	silent	silent	Diffusion of a classical geometry
Wheeler	silent	No; closed	silent
Barbour	silent	silent	silent
Smolin	silent	silent	silent
Tegmark	Yes, eternal	Yes	An axion, varying by region
Wolfram	silent	silent	silent
Eddington	silent	silent	silent
Ellis	One option among others	No; an emergent closed space	silent
Milgrom and McGaugh	silent	Yes	None in galaxies; the law changes
Verlinde	silent	silent	Apparent, from horizon entropy
Prigogine	silent	silent	silent
Rosen	silent	silent	silent
Tononi	silent	silent	silent
Friston	silent	silent	silent

Acceleration, vacuum and dimension

Model	Is there a constant of acceleration?	Is the vacuum energy constant?	How many dimensions has space?
Physics from comparison	No; scale set by formation; no external field effect	Yes, exactly -1	Three, by necessity
Bohr	silent	silent	silent
Deutsch	silent	silent	silent
Penrose	silent	Yes	silent
't Hooft	silent	silent	silent
Gisin	silent	silent	silent
Zeilinger	silent	silent	silent
Hossenfelder	silent	silent	silent

Model	Is there a constant of acceleration?	Is the vacuum energy constant?	How many dimensions has space?
Marletto and Vedral	silent	silent	silent
Carroll	silent	silent	silent
Oppenheim	silent	silent	silent
Wheeler	silent	silent	silent
Barbour	silent	silent	silent
Smolin	Yes; from the de Sitter temperature	silent	silent
Tegmark	silent	Yes	Three here
Wolfram	silent	silent	Emergent; may vary
Eddington	silent	Yes	silent
Ellis	silent	Perhaps an effect of inhomogeneity	silent
Milgrom and McGaugh	Yes; an external field effect	Yes	silent
Verlinde	Yes; set at the horizon	silent	silent
Prigogine	silent	silent	silent
Rosen	silent	silent	silent
Tononi	silent	silent	silent
Friston	silent	silent	silent

Time, mind and the constants

Model	Where does the arrow of time come from?	What are life and mind to physics?	Can the constants be derived?
Physics from comparison	Beneath the laws, in the order of findings	Acts of comparison; the brain near criticality	Pure numbers of the structure; others measured
Bohr	silent	silent	silent
Deutsch	silent	silent	silent
Penrose	The even beginning of each epoch	Orchestrated reduction	silent
't Hooft	silent	silent	silent

Model	Where does the arrow of time come from?	What are life and mind to physics?	Can the constants be derived?
Gisin	silent	silent	silent
Zeilinger	silent	silent	silent
Hossenfelder	silent	silent	silent
Marletto and Vedral	Irreversibility in tasks	silent	silent
Carroll	A special past state	silent	silent
Oppenheim	silent	silent	silent
Wheeler	silent	silent	silent
Barbour	A Janus point; time not fundamental	silent	silent
Smolin	Time real; laws evolve	silent	silent
Tegmark	silent	silent	silent
Wolfram	silent	silent	silent
Eddington	silent	silent	Yes, by counting
Ellis	An evolving block	silent	silent
Milgrom and McGaugh	silent	silent	silent
Verlinde	silent	silent	silent
Prigogine	The arrow comes first	Structures far from equilibrium	silent
Rosen	silent	Organisms no machine simulates	silent
Tononi	silent	Integrated information	silent
Friston	silent	Free energy minimized	silent

PART THREE

Discreteness and Computation

These are the models that build the world from discrete steps or from computation: John Archibald Wheeler, Julian Barbour, Lee Smolin, Max Tegmark and Stephen Wolfram.

John Archibald Wheeler

The Participant and the Act

John Archibald Wheeler and Physics from Comparison

Abstract

John Archibald Wheeler saw, earlier and more boldly than any physicist of his century, that the observer takes part in what is found: that a phenomenon becomes a phenomenon only when an irreversible act brings it to a close; that what physics finds are answers to yes-or-no questions; that there is no tower of turtles beneath the world; and that physics, observer-participancy and information close in a loop. The physics collection of the Immanent Metaphysics holds every one of these, on its own ground. One comparison is one bit; a measurement brings into being a record that is never undone; and the descent of grounds ends at a structure that holds its own ground. Wheeler's loop of three is the directed cycle of the collection's second axiom, in the same direction. The collection completes Wheeler in two places: it counts the act of comparing as a third term beside the two things compared, and it says what every finding contains: the six intrinsics of comparison, in three pairs, same and different, content and context, and the subjective and the objective. It parts from him in two main places. Information and the thing it is about come together from one act, because a comparison is always on something, so information is not prior to interaction. The arena of physics is the context of every finding and is not quantized, so the Wheeler–DeWitt equation, which puts the arena into the quantum state, is the plainest form of a category error: quantization, the treatment that belongs to content, applied to the geometry of space and time, which is the context. Four further partings follow from these two: the collection keeps a continuum and laws, against Wheeler's refusals "No continuum" and "No laws"; it finds no mass made of geometry alone, against the hope of "mass without mass"; and it reads "No space, no time" as a product of quantizing the arena. The canonical program that the equation began stands as an achievement. A final section before the Summary takes the three predictions, sealed in a dated record on 1 November 2026, on which the collection and Wheeler's physics differ. For each, it sets the argument behind the prediction beside Wheeler's own reasoning and

finds where the two part. Wheeler's estimate of the foam carries a formula for small fluctuations past the edge where the formula holds. The canonical program and the collection rest on opposite premises about the geometry, and Wheeler's superspace, which lays out at once every geometry a slice of space could have, gives the quantized geometry a structure and not a context. His closed universe differs from the collection's flat one only if space closes as a sphere does, and the two then part at one premise: whether the total content of the universe fixes the curvature of space.

I. Wheeler's Questions

Wheeler's working life spanned the physics of the twentieth century. With Niels Bohr in 1939 he worked out the mechanism of nuclear fission, treating the nucleus as a charged drop of liquid (Bohr and Wheeler 1939). In the 1950s he turned to general relativity and made it a working science again: he built *geons*, bundles of electromagnetic or gravitational waves held together by their own gravity, as a model of mass made of geometry alone, and with Charles Misner he wrote of "mass without mass" and "charge without charge" (Wheeler 1955; Misner and Wheeler 1957). He taught a generation, and with Misner and Kip Thorne wrote the textbook *Gravitation* (1973). He popularized the name black hole in 1967 (Wheeler and Ford 1998), and summed up general relativity in two clauses: spacetime tells matter how to move; matter tells spacetime how to curve. The equation of canonical quantum gravity carries his name and Bryce DeWitt's; in it, the quantum state of the geometry of space satisfies one constraint and contains no time.

In his later work he turned to the question beneath all of this work: how the world could come from acts of observation. In 1978 he proposed the *delayed-choice experiment* (Wheeler 1978): a single photon is let into an interferometer, and only after the photon has passed the first beam splitter does the experimenter choose whether to measure which path it took or to let its two paths interfere. In 1989, in "Information, Physics, Quantum: The Search for Links" (Wheeler 1990), he stated the program he called *it from bit*: that every it, "every particle, every field of force, even the spacetime continuum itself",

derives its function, its meaning and its very existence "from the apparatus-elicited answers to yes or no questions, binary choices, bits". He called the world "a participatory universe", and he described it as a loop:

> "Physics gives rise to observer-participancy; observer-participancy gives rise to information; and information gives rise to physics".

He insisted that "no elementary quantum phenomenon is a phenomenon until, in Bohr's words, 'It has been brought to a close' by 'an irreversible act of amplification'". He set out four refusals ("No tower of turtles", "No laws", "No continuum", "No space, no time") and five clues, among them "No question? No answer!". His aim, in his own words, was to "derive everything from nothing, all law from no law".

The physics collection of the Immanent Metaphysics begins where Wheeler's program pointed. Its single premise is the *Root Tautology*: comparison, interaction and relation are one act under three names. From the parts that every act of comparison must contain it proves the *Incommensuration Theorem*: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. The Basis of Physics, Essay 12, Section IX, names the kinship directly: Wheeler's program and the approaches built on information "have looked for something more fundamental than either space-time or the quantum state", and the Root Tautology "is a starting point of that kind: comparison is the most elementary act of information". The sections below set out what Wheeler saw that the collection holds, where the collection completes him, and where it parts from him, and why.

II. What Wheeler Saw

The phenomenon closed by an act

Wheeler's first insight is that a phenomenon becomes a fact only when an irreversible act closes it. The collection holds the same, and gives the act its structure. Causality Without Determinism, Chapter 4, Section IV, opens with a stopwatch: "Before a stopwatch is clicked, the race has no measured time. After the click, there is a before and an after that the record fixes, and the record will never be unclicked". Every measurement, the chapter goes on, brings three distinctions into actuality, one in each modality: past and future, here and there, and the one outcome among the possible ones. Wheeler's "irreversible act of amplification" is the click of the stopwatch, and the collection says what the click makes actual.

The collection agrees too that the click makes the fact it closes, and does not merely reveal a fact that was there before. In The Quantum Passage, Chapter 9, Section IV, the update of the state upon measurement is "an epistemic update: the comparison has occurred, and the result is now part of the omniscient content", and it is "not a physical process". Epistemic means concerning knowing, and the omniscient content is what is held as structure laid out, the knowable pattern the system presents; what changes is the laid-out record, shared and the same for everyone who has the outcome.

The answer as a bit

Wheeler's second insight is that what physics finds are answers to yes-or-no questions. Comparison; The Necessary Basis, Chapter 1, Section IV, reaches the same from the meaning of comparison:

> "To compare is to find whether two things are the same or different, in some respect. A comparison yields a verdict, same or different: a choice between two. A choice between two is one bit: one binary digit, one binary degree of freedom. So one comparison is one bit".

Wheeler found the bit by looking at what an apparatus returns. The collection finds it by asking what any comparison returns, so the bit holds for every comparison, whether an instrument, an atom or a person makes it.

The participant

Wheeler's third insight is that the observer takes part. The collection defines the observer so that the insight holds without any appeal to minds: "an observer is a comparer, a position inside the world, which a mind may occupy but which is not defined as a mind" (Comparison; The Necessary Basis, Chapter 1, Key Concepts). A thermostat, a circuit and a person all compare. Wheeler's participatory universe is, in the collection's terms, a universe in which every finding is made from inside it, by something that takes part in an interaction.

No tower of turtles

Wheeler's first refusal was "No tower of turtles": no endless descent of laws resting on deeper laws. The collection's foundational volume takes its title from the same image. The Last Turtle, Chapter 9, Section VII: mathematics meets the question of its own ground by ascending without end, while "the metaphysics meets the question by closing"; its three axioms describe their own content and the process by which they are derived, and "the third order of self-description collapses into the second". "So the descent of grounds is not turtles all the way down. It ends at a structure that holds its own ground, and every discipline above it rests on it. The last turtle is not another turtle. It is the ground". Wheeler asked for a world with no tower of turtles. The collection gives the reason there is none: the ground is the act of comparison, and any attempt to place something beneath it must itself compare.

III. The Loop of Three

Wheeler's loop has three members: physics gives rise to observer-participancy, observer-participancy gives rise to information, and information gives rise to physics. The collection also finds three, in a directed cycle. Its three roles of comparison, the *modalities*, are the *immanent* (what is held in the act itself, now), the *omniscient* (what is held as structure laid out, every case in view at once) and the *transcendent* (what is implicit, held in the stance from which an act proceeds and never held outright). The second axiom orders them in a cycle, and Category Theory and the Immanent Metaphysics, Pro-

position 9.14, gives its direction: from the immanent to the omniscient, from the omniscient to the transcendent, and from the transcendent back to the immanent. In plain words, the second axiom says that the three roles stand in an order of precedence, and not of clock time: many possibilities stand behind one act, many acts behind one laid-out finding, and many findings behind one new range of possibility, so the order runs round with no first member. Measurement, Chapter 4, Section VIII, names its three transitions in plain words: "from the stance to the act, from the act to the laid-out finding, and from the laid-out finding to a new stance".

Wheeler's three members take the three roles. Observer-participancy is the act: the immanent. Information, the answers laid down, is the laid-out finding: the omniscient, which Physics Is Not Math, Chapter 9, Section III, names as the role of a claim "held as structure laid out". Physics, the world that every act starts from and that no finding holds whole, is the stance's ground: the transcendent. Here "physics" in Wheeler's loop is read as the world that physics studies, and not as its laws: laws are structure laid out, which the collection places in the omniscient role (Section V), while the physics of the loop is what gives rise to the act. Wheeler's loop then runs from the transcendent to the immanent (physics gives rise to observer-participancy), from the immanent to the omniscient (observer-participancy gives rise to information), and from the omniscient back to the transcendent (information gives rise to physics). That is the cycle of the second axiom, in the same direction. Wheeler drew the loop as a self-excited circuit; the collection proves the cycle as the structure that every act of comparison has. The same cycle, in the same direction, is found in Roger Penrose's three worlds of mathematics, matter and mind, so two of the century's most original physicists each found the cycle of the three roles, from opposite ends of physics.

IV. Where the Collection Completes Wheeler

The act as the third term

Wheeler's program has two members in each exchange: a question put and an answer returned, an apparatus and a bit. The collection counts a third. Comparison; The Necessary Basis, Chapter 1, Section III, puts it with two stones:

"There is stone A. There is stone B. And there is you, the one looking. ... Without you, without the comparator, without the act of comparing, the two stones simply exist. There is no relation between them. The reason is not that the relation is 'really there' but unobserved; the reason is that a relation requires something that relates". The act of relating is a term in its own right, distinct from both things related and inseparable from them. Wheeler's observer-participant stands where the act of relating stands, and his loop shows that he felt the weight of that third term. The collection gives the act of relating a place in the structure of every finding, so that the act is counted wherever a bit is.

The register given a structure

Wheeler's clue "No question? No answer!" says that an answer exists only relative to a question asked. The collection says what every question has to contain. A verdict is same or different; it is a verdict on something, a content; it is given in some respect that is not the thing judged, a context; and it is given from a position, so that it has a subjective and an objective side. These are the six intrinsics of comparison, in three pairs, each pair inseparable and no pair interchangeable. Every finding is registered with that structure, and the principle of identity the collection uses rests on it: "a difference that no comparison can register is no difference", where a comparison registers what reaches it, "as a finding, a signal or a record" (At the Edge of Reality, Chapter 11). Wheeler's bit is the verdict; the six intrinsics are what the bit is a bit of.

V. Where the Roads Part

The it and the bit come from one act

Wheeler's slogan puts the bit before the it. The collection puts the act of comparison first, before both. Julian Barbour, answering Wheeler in 2015, insisted that "probabilities without things are pure nothings". Objections from Physics, Answered, holds the point Barbour presses: every comparison is on something, since "the verdict is on something, in some respect that is not the thing judged", "so a comparison with nothing to be about is no comparison". In the one act of comparison a thing is met and a verdict on it is given, and the col-

lection makes neither the thing nor the verdict the source of the other. The Quantum Passage, Chapter 4, Section V, states the consequence for existence: "Existence without any interaction is therefore non-existence". So both come from the act, the it as the content met and the bit as the verdict given, and neither comes from the other.

The collection also says what character information has when it is taken as a floor beneath physics. The Basis of Physics, Essay 12, Section IX: "What the cross-modal reach adds is that information is not a neutral substrate. It has modal character, and a program that treats information as the common floor beneath both theories will find, I expect, that the floor has the same two conjugate aspects the theories had, and will have to choose which one to perfect". Information, taken as a substrate of yes-or-no answers, is discrete and symmetric, the character of content. Content and context are inseparable, as two of the six intrinsics that every comparison contains (Section IV), and the theorem excludes a content without a context; a world built from information alone would be exactly that: content with no context.

The continuum and the laws

The collection holds both a continuum and laws, and so it parts from two of Wheeler's refusals, "No continuum" and "No laws". The theorem leaves two pairings standing, symmetry with discontinuity and continuity with asymmetry, and the continuum belongs to the second. Incommensuration, Chapter 14, Section V: "Both symmetry and continuity are absolute endpoint extensions of the single concept of comparison, and neither can be built out of the other". The arena of physics is continuous and content is discrete, each in its own character, and neither can be composed from the other; so no continuum can be built from bits.

Wheeler and the collection agree that laws are not imposed from outside. Where Wheeler sought to derive law from no law, the collection places laws where they are found: "A law exists; a measurement is real" (Comparison; The Necessary Basis, Chapter 10, Section II). To exist is to stand as structure, laid out and the same in every instance; to be real is to be given in an actual act of comparison. A law is what stays the same across acts of comparison: a

symmetry, laid out from the acts. So the collection derives law from the structure of comparison, which is more than nothing and less than an imposed code; it is what every act of finding already contains.

For the same reason the collection keeps its account of the particles apart from Wheeler's participatory universe. The Kinds of Particle holds that at the microscopic limit "what measurement finds is the structural skeleton of measurement itself, reflected back as physical content", and states plainly that this "is not the observer effect, not the participatory universe of Wheeler, and not the it-from-bit program". The structure found is the structure of every comparison, not the choices of a particular observer.

VI. Geometry, the Wheeler–DeWitt Equation and the Arena

Wheeler's geometrodynamics is the strongest statement ever made that geometry is physics. It had two aims: to show gravity as the geometry of spacetime, and to build matter out of geometry. The collection agrees with the first aim without reserve: gravity is the geometry of spacetime, the arena of every finding, and matter and arena act on one another as Wheeler's two clauses say. The View from Inside takes his summary as the head of a chapter.

The collection parts from the hope of "mass without mass". A geon is mass made of geometry alone: content built from context. In the collection, content and context are distinct, inseparable and not interchangeable, and mass is one relation of a content to its context, met as pattern, as inertia and as weight (Objections from Physics, Answered). Mass needs a content as much as it needs the context in which it is weighed; a mass made of context alone would be the context taking the character of content, which the theorem excludes.

The Wheeler–DeWitt equation is where the two roads part most sharply. The Unquantized Arena, Chapter 6, Section VI, sets it out: the canonical program writes general relativity in Hamiltonian form, with the metric of a slice of space as its variable, and promotes the constraints of the theory to operators acting on a wave functional of spatial metrics; the Hamiltonian constraint becomes the Wheeler–DeWitt equation, and "the equation contains no time parameter". The quantum state, which in every other quantum theory evolves

in the time of an arena, has nothing in which to evolve, and that is the problem of time (Isham 1993). The book's verdict is plain: "I read it as the category error in its plainest form. The context in which things happen has been put into the quantum state, instead of serving as the arena in which the state evolves". Proposed resolutions recover a time by choosing some quantity to serve as a clock, and "each such choice restores, within the description, a part of the context that the quantization removed". The Unquantized Arena, Proposition 6.3, states exactly how the arena stands: it has no least step, and nothing is a quantum of the arena itself, at any scale; the arena is not quantized. So Wheeler's "No space, no time" is a product of quantizing the arena, and not a feature of the world; and his spacetime foam, the arena seething at the smallest scale, is excluded along with the quantized arena. The book closes the section by crediting the canonical program: "The canonical program gave gravity its Hamiltonian form and the algebra of constraints on which every later canonical approach builds. That achievement stands".

VII. The Delayed Choice

Wheeler's delayed-choice experiment was performed with single photons in 2007 by Vincent Jacques and colleagues (Jacques and others 2007), and the result was the one quantum mechanics predicts: when the second beam splitter is inserted after the photon has entered, interference is seen; when it is withheld, which-path behavior is seen. Wheeler had read his experiment, before it was performed, as showing that a choice made now decides what may be said about the photon's past.

The collection reads the result more simply. The late choice decides which comparison is made: one that registers the photon's path, or one that registers the relation between its two paths. The path and the relation each become a fact only when a comparison registers it, because a difference that no comparison can register is no difference. Every record already made stays as it was, since the record "will never be unclicked", and nothing is sent backward. What the late choice seems to reach in the past is not a record already made; it is the range of findings still possible, the transcendent, which no comparison

holds whole, and the choice selects which finding comes out of that range. So the experiment shows what Wheeler said it shows, that only the act closes the phenomenon, and the experiment shows this with no reach into the past.

VIII. Where the Predictions Part, and Why

The sealed record of 1 November 2026, the dated register of the collection's predictions, sets three of those predictions against what Wheeler's physics expects. For each, this section sets the argument of the book that the sealed prediction rests on beside Wheeler's own reasoning, and finds the first step at which the two part. The aim is to find the step at which the two arguments part, and what would decide between them.

The arena at the smallest scale

The sealed prediction. "The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else". It was registered on 1 November 2026 as Prediction 5 of *The Registered Predictions of Physics from Comparison*.

The argument of the book. The prediction rests on The Unquantized Arena, Proposition 6.3: the arena has no least length, area or duration, and nothing is a quantum of the arena itself, at any scale. The argument has two steps: "A least step of the arena would be a discontinuity in its findings, and by the law of continuity and Proposition 4.2 the findings of the arena have none at their foundation. A quantum of the arena itself, at any scale, would be the arena in the mode pair of content, which is the mode exchange that Proposition 6.1 excludes". In the book's terms a description of content has two forms, and the mode exchange is the passage between them, which is what quantization is; the law of continuity is the law that context is governed by continuity, as content is governed by symmetry (The Unquantized Arena, Chapter 6, Section II). Proposition 6.1 rests in turn on the Incommensuration Theorem and on one identification, that gravity is the context of physics and not part of its content. The book then reads the Planck scale, the scale at which an object's gravitational size equals its quantum size. In The Unquantized Arena, Chapter 9, Section IV, the effective field theory of the small waves

of geometry reaches the edge of its domain at the Planck scale: "Where the perturbation and the background become comparable, the separation of a wave from the geometry it travels on no longer holds. The diagnosis expects the description of small waves to reach the edge of its domain there, and it does not expect a quantized metric that continues past that edge". Two Theories, One World, Chapter 15, gives the same reading of the Planck length in plain words: "It is a bound on findings, not a step of space".

Wheeler's argument. Wheeler's foam came from an estimate he made in 1957 (Wheeler 1957), which Steven Carlip's review sets out in four steps (Carlip 2022). The smallest quantum excitation of the geometry that fits in a region is a quantum whose wavelength is the size of the region. Its energy, spread through the region, gives an energy density. General relativity gives the energy density of a small fluctuation of the geometry in the same region. Setting the two equal gives the size of the fluctuation, as a fraction of the geometry itself: the Planck length divided by the size of the region. So at the Planck length the fluctuation is as large as the geometry, and Wheeler concluded that space there is a foam whose topology changes from place to place.

Where they part. Both arguments find the same edge. Wheeler's estimate reaches a fluctuation as large as the geometry at the Planck length, and the book finds the description of small waves losing its order at the same scale. They part on what lies past the edge. For Wheeler, the geometry is a quantum variable at every scale, so the edge is a place where the geometry itself fluctuates without limit. For the book, the geometry is the arena, which quantization does not reach, so the edge is the end of a description, and the arena keeps no least step beyond it.

Whose step, and what decides it. Wheeler's last step takes a premise that the steps before it do not supply. His third step uses the energy of a small fluctuation, and that formula holds only while the fluctuation is small beside the geometry. At the Planck length the fluctuation the estimate yields is no longer small, so the estimate shows where its own formula stops holding, and it cannot show what the geometry is beyond that point. Carlip makes the same observation of the estimate (Carlip 2022). The same form of argument, run on a neutral case, gives the same result. The four-fermion theory of the

weak interaction gave amplitudes that grow with energy, and an estimate of the same kind marked the energy at which the theory loses its consistency; what physics found beyond that edge was a new description, with the W and Z bosons, and not the old theory carried on into disorder. So the foam rests on a further premise: that the geometry stays a quantum variable past the edge of the description of its small waves. The book's steps follow from its premises: given the law of continuity and the identification of gravity as context, a least step of the arena, or a quantum of it, is excluded. What separates the two accounts is therefore a premise, which can be put in one sentence: is the geometry of spacetime a quantum variable at every scale, or is it the arena of every finding, to which quantization does not apply?

Two things bear on that premise, and neither settles it. Measurement reaches the models built later on Wheeler's foam, which state a rate at which their effects grow with distance. The timing of high-energy photons from gamma-ray bursts excludes a speed of light that depends on energy at first order, up to about ten times the Planck energy (Cao and others 2024); the sharpness of the X-ray images of distant quasars excludes the random-walk model of the foam, and their detection at the highest energies appears to exclude the holographic model (Perlman and others 2015). Each result agrees with the sealed prediction. Wheeler's foam in his own form named no rate, so no measurement yet made reaches it. A later model that states a rate can be tested, and so can the spectrum of area or volume, which the sealed record names among the deciding observations (Appendix B, Wheeler 1). The low-energy marks of gravity do not decide the premise either. The Unquantized Arena, Chapter 5, Section IX, takes up Weinberg's derivation of the equality of gravitational and inertial mass from a massless quantum of spin two (Weinberg 1964), and finds that "Weinberg's derivation and Proposition 5.3 therefore agree". The marks that identify gravity as context are marks that a description of small waves by quanta also carries, so they agree with both premises; what decides between the two premises is the argument that gravity is the context of physics, at the Planck scale, where the description by quanta and the arena meet. The books answer two related arguments. Two Theories, One World, Chapter 15, answers the argument for a least length from probes: a probe able to resolve a region as small as the Planck length would carry so much energy into the region that it would make a black hole

larger than the region probed. The Unquantized Arena, Chapter 9, answers the argument from the edge of the description of small waves. Neither book names Wheeler's estimate of 1957; the reading given in this section applies those two answers to that estimate.

Quanta of the geometry itself

The sealed prediction. "No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter". It was registered on 1 November 2026 as Prediction 3.

The argument of the book. Section VI above set out the book's reading of the Wheeler–DeWitt equation. The argument beneath it is The Unquantized Arena, Proposition 6.2: "To quantize the arena is to apply to context the treatment that belongs to content". Its steps: quantization, which the book calls the mode exchange, belongs to descriptions of content (Proposition 4.4); the arena is context; and by Proposition 6.1 the mode exchange does not apply to the arena. Proposition 9.1 gives the scope. The effective theory "quantizes a description: the description of the small waves of a classical geometry about its background, which holds below the Planck curvature", and its quanta are "never quanta of the arena, of space-time or of the geometry". For the canonical equation the book adds a step of its own (Chapter 6, Section VI): "A continuous formalism needs a context in which its smooth evolution is laid out. Once the arena is itself the state, the formalism has no context left, and its evolution has no parameter".

Wheeler's argument. The canonical program, to which Wheeler and Bryce DeWitt gave its quantum form, runs in three steps (DeWitt 1967; Misner, Thorne and Wheeler 1973, Chapter 43). General relativity can be written in Hamiltonian form, with the geometry of a slice of space as the variable whose motion the theory describes (Dirac 1958; Arnowitt, Deser and Misner 1959). A Hamiltonian system with constraints is quantized by turning its constraints into conditions on a quantum state. So the state of the universe is a wave functional of the geometries of space, and it obeys the Wheeler–DeWitt equation. Wheeler met the absence of time with a new arena, the space of all the geometries a slice of space can have, which he named superspace: "The arena must be a larger object: superspace" (Wheeler 1974, p. 9, as quoted by Giulini

2009). The quantum dynamics of the geometry is laid out over superspace, and time, on his reading, is not part of the foundation; one of his four refusals of 1989 was "No space, no time".

Where they part. They part first on the same premise as over the foam, whether the geometry of space is a quantum variable at every scale, now asked of the whole geometry and not only of its small waves. Wheeler takes the geometry of space as a variable to be quantized like any other; the book takes it as the arena, to which the mode exchange does not apply. The two then part a second time, over the missing time. Wheeler gives the quantum geometry a new arena, superspace, and lets time go from the foundation. The book reads the missing time as the sign that the context has been removed.

Whose step, and what decides it. Each argument follows from its premises. Given that every Hamiltonian system with constraints is quantized by turning its constraints into conditions on a state, the Wheeler–DeWitt equation follows; given that quantization belongs to content and the geometry is context, Proposition 6.2 follows. The premise in dispute is the one named over the foam: is the geometry of spacetime a quantum variable at every scale, or the arena of every finding, to which quantization does not apply?

The second parting is argued in the same section of the book. The book's sentence "the formalism has no context left" describes an equation with no arena, and Wheeler's answer was that the equation has an arena, superspace. The Unquantized Arena, Chapter 6, Section VI, answers Wheeler, crediting him for superspace (Wheeler 1968) and for offering it as the arena (Wheeler 1974, as quoted by Giulini 2009), and crediting DeWitt for its metric (DeWitt 1967): "Superspace gives the quantized geometry a structure and not a context". "Every geometry the slice could have is laid out in superspace at once, so superspace is a space of alternatives laid out, and what is laid out once found is content, while the context is the setting within which the act of comparison proceeds". Were superspace the context of physics, "it would be the further setting in which the two descriptions of the arena are compared", and "that setting would be the context of physics in the arena's place, and the geometry of spacetime would become one content within it". "Superspace supplies no parameter either. Nothing in superspace orders one of its points be-

fore another, so a wave functional over it changes along no parameter of its own". The programs that recover a time from superspace choose as a clock the direction of DeWitt's metric in which the volume of space changes, and "that choice is one of the clocks named above, and it restores within the description a part of the context that the quantization removed". "The conclusion stands: once the arena is itself the state, its evolution has no parameter". The book keeps what Wheeler and DeWitt built: "Wheeler and DeWitt gave the quantized geometry its space of states and its metric, and the account takes superspace as exactly that". So the second parting follows from the first premise: if the geometry is a variable to be quantized, superspace is its arena; if the geometry is the context, superspace is the space of its alternatives, and the time is missing because the context is missing. The sealed record says that below the Planck curvature the collection's account and the effective field theory of gravity, the quantized description of small waves, give the same result for every experiment now proposed, so no measurement now proposed reaches the difference. The difference is settled by argument, at the identification of the geometry as context, and by any future measurement of the scattering of gravitational waves near the Planck curvature.

A flat space or a closed one

The sealed prediction. "The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}". It was registered on 1 November 2026 as Prediction 9. In the collection's cosmology, set out in *The Gravitational Passage* and *The Compactification*, the history of the universe is a cycle of epochs, and the turn is the passage from the end of one epoch to the beginning of the next, where the interiors of the black holes of the old epoch end together and a new exterior begins; the restoration is that beginning, in which the geometry of space and time is set up anew as the context of the new epoch. The length of the turn is the length the turn itself sets, which the book puts at the order of the Planck length; the de Sitter radius is the length the cosmological constant sets, the radius of the horizon that the constant alone would give.

The argument of the book. The Gravitational Passage, Chapter 18, Section IX, fixes the curvature, and The Compactification, Chapter 6, Section VI, repeats the argument. "A radius of spatial curvature is a length". The curvature enters the equation of the expansion as a constant that the law of the geometry does not fix: "it is a constant of integration, set once by the state from which the history begins and carried unchanged thereafter" (Misner, Thorne and Wheeler 1973, Chapter 27). "So the radius of curvature belongs to the state that the restoration sets, and it can be built only from what that state holds". "The metric has no prior identity, and no total of the old content passes, since no comparison of the new epoch registers the mass of the old interiors". "No length of the old epoch passes the turn, and no count passes it either". The cosmological constant "belongs to the law of the geometry, fixed once as its constant term", and at the turn "it acts as nothing at all". So the state holds "the length of the turn, of the order of the Planck length", "the pure numbers of its structure, of order one", and "the size of the departures, about 10^{-5}". A radius built from the length of the turn and the de Sitter radius together, such as the length halfway between them in powers of ten, is the length of the turn multiplied by a pure number near 10^{30}, and "It would need the de Sitter radius in the state, where the constant does not act, or a pure number near 10^{30} in the state, where the only numbers that large are counts, and no count passes the turn". "So the radius is of the order of the length of the turn, or there is none". "A radius of the Planck length would close the new epoch within a few Planck times or leave it dominated by curvature, and neither epoch produces the structure that the cycle requires". "The homogeneous model of the new epoch is therefore spatially flat, and the geometry found is curved only by its departures, at their own size, about 10^{-5}". "A radius equal to the de Sitter radius would leave a curvature of about 10^{-64} today, so that length too, were it in the state, would leave no curvature to measure". "The argument uses nothing of the cosmological constant, neither its value nor its sign".

Wheeler's argument. Wheeler held the universe closed for reasons he drew from Mach's principle, which he described as "conceived as the requirement that the universe be closed" (Wheeler 1962, as quoted by de Swart 2019). Mashhoon and Wesson summarize the reasoning: Mach's principle im-

plied "a finite spatially bounded universe as a plausible way of avoiding unascertainable boundary conditions in cosmology" (Mashhoon and Wesson 2011, citing Misner, Thorne and Wheeler 1973, pages 543 to 549). A closed universe has no infinity, so its geometry, and the inertia of every body in it, is set by what the universe contains; in an open universe the inertia of a body would depend on conditions set at infinity, which nothing in the universe determines. In the closed models of Friedmann, which Wheeler used, closure means positive curvature and a density above the critical density, and that is why he pressed the question of the missing mass (de Swart 2019).

Where they part. Both arguments refuse to take the geometry of the whole from outside it. Wheeler refuses boundary conditions at infinity; the book refuses the new epoch any prior identity of its metric. They part on what the content can fix. For Wheeler, the geometry of the whole is set by the whole of what it contains, so the total of its mass fixes its curvature. For the book, the content of a new epoch begins at the turn and no total of content passes into it, so the curvature can be set only by a length that the state of the new epoch holds.

Whose step, and what decides it. Wheeler's argument reaches closure, and its step from closure to positive curvature takes a further premise. A flat space can close on itself, as the surface of a torus is flat and finite, and a flat space closed in that way has no infinity and needs no boundary condition there. So Mach's principle, as Wheeler used it, asks that space be finite, and positive curvature follows only with the further premise that space closes in the simplest way, as a sphere does. Wheeler's requirement of a finite space and the book's flat space are separated only by that first premise. The Weight of Possibility, Chapter 3, Section II, counts the open space as one, "whatever it is beyond the horizon", and Prediction 23 of the sealed record asks only that no closed path going around the universe be shorter than the diameter of the horizon. A flat space closed on a scale beyond every horizon meets Wheeler's condition and the sealed Predictions 9 and 23 together. In the closed models of Friedmann that Wheeler used, closing as a sphere comes with a second premise: that the total content of the universe fixes the curvature of space, so that a density above the critical density closes it. The sealed prediction rests on the denial of that second premise: no total of content passes the turn, so

the curvature of a new epoch can be set only by a length its own state holds. The book's own steps follow from their premises. So the premise in dispute between the book and Wheeler's closed models is the second, and it is one sentence: does the total content of the universe fix the curvature of space, or does no total of content reach the geometry of a new epoch?

Measurement decides between positive curvature and flatness. In the sealed record's words, the deciding measurements are those of "DESI and Euclid, which measure the curvature of space with the matter fraction", and "A curvature confirmed at the level of 10^{-3} refutes it". The microwave background alone gave a value on the closed side, which Di Valentino, Melchiorri and Silk (2020) read as a preference for a closed universe; with the baryon acoustic oscillations added, the value is flat (Aghanim and others 2020); and the second data release of DESI, the Dark Energy Spectroscopic Instrument, with the microwave background, gives a curvature parameter of 0.0023 ± 0.0011, on the open side (Abdul-Karim and others 2025, as discussed by Chen and Zaldarriaga 2025); that value lies about two standard deviations from flatness, short of the confirmed curvature that the rule of decision names. Wheeler's lasting gain stands beside all of this: by insisting on the mass a closed universe would need, he kept the missing mass before cosmology until measurement showed that most of the mass is dark.

IX. Summary

Wheeler saw the shape of the collection's ground from inside physics: the phenomenon closed only by an irreversible act, the answer as a bit, the observer as a participant, no tower of turtles, and a loop of three in which physics, observer-participancy and information give rise to one another. The collection holds each of these, on the ground of the act of comparison, and Wheeler's loop is the cycle of its second axiom, running in the same direction.

The collection completes Wheeler by counting the act of comparing as a third term beside the two things compared, and by giving every registered finding its structure, the six intrinsics of comparison. It parts from Wheeler on two main claims. Both the it and the bit come from the act, the it as the content met and the bit as the verdict on it, so the bit is not prior to the it; and in-

formation taken as a floor has the same two conjugate sides that quantum theory and general relativity had. And the arena is the context of physics, which quantization does not reach: the Wheeler–DeWitt equation puts the context into the quantum state, which is why its state has no time to evolve in. From these two follow its partings from "No continuum", "No laws", "mass without mass" and "No space, no time". The canonical program that the equation began stands as an achievement. Where the first two predictions part, the source lies in one premise: whether the geometry is a quantum variable at every scale or the arena of every finding; where the third parts, it lies in whether the total content of the universe fixes the curvature of space. Wheeler's estimate of the foam goes past the edge of its own formula. Superspace is a space of alternatives laid out, and not the context of physics: it lays out at once every geometry a slice of space could have, and it orders none of them before another. His closed universe and the collection's flat one differ only if space closes as a sphere does, and with the closed models of Friedmann comes the premise the collection denies, that the total content fixes the curvature; the curvature measured by DESI and Euclid will decide between them. Wheeler asked how the world could come from acts of observer-participancy. The collection's answer is that the act of comparison is where both the world as found and the record of the finding begin. Wheeler made the bit primary and found the canonical equation without time; Julian Barbour, in the next chapter, answered him that things come first, and took from the same timeless equation the conclusion that time does not exist.

Key Concepts

- Wheeler's "irreversible act of amplification" is the click of a measurement, which makes actual a before and after, a here and there, and one outcome among the possible ones.
- One comparison is one bit: Wheeler's yes-or-no answer is the verdict of any comparison.
- Wheeler's loop of physics, observer-participancy and information is the cycle of the second axiom, transcendent to immanent to omniscient and back, in the same direction.
- The collection completes Wheeler by counting the act of comparing as a third term and by giving every registered finding the structure of the six intrinsics.
- Both the it and the bit come from the act of comparison, and neither is prior to the other.
- The continuum belongs to one of the two pairings the theorem leaves standing, continuity with asymmetry, and cannot be built from bits; laws exist as the structure laid out from acts.
- The Wheeler–DeWitt equation puts the arena into the quantum state; the arena is not quantized.
- Where the predictions part: Wheeler's foam goes past the edge of the description of small waves on a further premise; the canonical program and the collection rest on opposite premises about the geometry; and a closed universe differs from a flat one only if space closes as a sphere does, and then at whether the total content of the universe fixes the curvature of space.

Terms

Category error. Applying to the context of physics, the arena, the treatment that belongs to content, as quantizing the geometry does.

Content and context. In every comparison, what is found and the arena it is found in; in physics, quantum matter and the geometry of general relativity.

Delayed-choice experiment. Wheeler's experiment in which the choice of what to measure on a photon is made after it has entered the apparatus.

Geon. Wheeler's model of a mass made of electromagnetic or gravitational waves held together by their own gravity.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

It from bit. Wheeler's program of deriving every physical thing from the answers to yes-or-no questions.

Mach's principle. The principle that the inertia of a body is set by the matter of the universe; Wheeler took it to require a closed universe.

Modalities. The three roles of comparison: the immanent (held in the act), the omniscient (held as structure laid out), the transcendent (implicit, held in the stance).

Root Tautology. Comparison, interaction and relation are one act under three names.

Six intrinsics. The parts of every comparison, in three pairs: same and different, content and context, the subjective and the objective.

Spacetime foam. Wheeler's picture of the geometry at the Planck length, where quantum fluctuations would be as large as the geometry itself and its topology would change from place to place.

Superspace. Wheeler's name for the space of all the geometries a slice of space can have, over which the canonical program lays out the quantum dynamics of the geometry.

Wheeler–DeWitt equation. The equation of canonical quantum gravity, in which the quantum state of the geometry of space satisfies the Hamiltonian constraint and contains no time.

References

Abdul-Karim, M. and others (DESI Collaboration) (2025). "DESI DR2 Results II: Measurements of Baryon Acoustic Oscillations and Cosmological Constraints". *Physical Review D* 112, 083515. arXiv:2503.14738.

Aghanim, N. and others (Planck Collaboration) (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6.

Arnowitt, R., Deser, S. and Misner, C. W. (1959). "Dynamical structure and definition of energy in general relativity". *Physical Review* 116, 1322–1330.

Barbour, J. (2015). "Bit from It". In A. Aguirre, B. Foster and Z. Merali (eds.), *It From Bit or Bit From It? On Physics and Information*, 197–211. Cham: Springer. DOI 10.1007/978-3-319-12946-4_17.

Bohr, N. and Wheeler, J. A. (1939). "The mechanism of nuclear fission". *Physical Review* 56, 426–450.

Cao, Z. and others (LHAASO Collaboration) (2024). "Stringent tests of Lorentz invariance violation from LHAASO observations of GRB 221009A". *Physical Review Letters* 133, 071501.

Carlip, S. (2022). "Spacetime foam: a review". arXiv:2209.14282. Published in *Reports on Progress in Physics* 86 (2023), 066001.

Chen, S.-F. and Zaldarriaga, M. (2025). "It's All Ok: Curvature in Light of BAO from DESI DR2". arXiv:2505.00659.

de Swart, J. (2019). "Closing in on the Cosmos: Cosmology's Rebirth and the Rise of the Dark Matter Problem". arXiv:1903.05281.

DeWitt, B. S. (1967). "Quantum theory of gravity. I. The canonical theory". *Physical Review* 160, 1113–1148.

Di Valentino, E., Melchiorri, A. and Silk, J. (2020). "Planck evidence for a closed Universe and a possible crisis for cosmology". *Nature Astronomy* 4, 196–203.

Dirac, P. A. M. (1958). "The theory of gravitation in Hamiltonian form". *Proceedings of the Royal Society of London A* 246, 333–343.

Giulini, D. (2009). "The Superspace of Geometrodynamics". *General Relativity and Gravitation* 41(4), 785–815. DOI 10.1007/s10714-009-0771-4. arXiv: 0902.3923.

Isham, C. J. (1993). "Canonical quantum gravity and the problem of time". In L. A. Ibort and M. A. Rodríguez (eds.), *Integrable Systems, Quantum Groups, and Quantum Field Theories*, NATO Science Series C 409, 157–287. Dordrecht: Kluwer. arXiv:gr-qc/9210011.

Jacques, V., Wu, E., Grosshans, F., Treussart, F., Grangier, P., Aspect, A. and Roch, J.-F. (2007). "Experimental realization of Wheeler's delayed-choice gedanken experiment". *Science* 315, 966–968.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications. DOI https://doi.org/10.67291/RQQS3025.

Mashhoon, B. and Wesson, P. S. (2011). "Mach, the Universe, and Foundations of Mechanics". arXiv:1108.3059.

Misner, C. W., Thorne, K. S. and Wheeler, J. A. (1973). *Gravitation*. San Francisco: W. H. Freeman.

Misner, C. W. and Wheeler, J. A. (1957). "Classical physics as geometry". *Annals of Physics* 2, 525–603.

Perlman, E. S., Rappaport, S. A., Christiansen, W. A., Ng, Y. J., DeVore, J. and Pooley, D. (2015). "New constraints on quantum gravity from X-ray and gamma-ray observations". *The Astrophysical Journal* 805, 10.

Weinberg, S. (1964). "Photons and gravitons in S-matrix theory: derivation of charge conservation and equality of gravitational and inertial mass". *Physical Review* 135, B1049.

Wheeler, J. A. (1955). "Geons". *Physical Review* 97, 511–536.

Wheeler, J. A. (1957). "On the nature of quantum geometrodynamics". *Annals of Physics* 2, 604–614.

Wheeler, J. A. (1962). “The universe in the light of general relativity”. *The Monist* 47(1), 40–76.

Wheeler, J. A. (1968). “Superspace and the nature of quantum geometrodynamics”. In C. M. DeWitt and J. A. Wheeler (eds.), *Battelle Rencontres: 1967 Lectures in Mathematics and Physics*, 242–307. New York: W. A. Benjamin.

Wheeler, J. A. (1974). “Superspace”. *Harper’s Magazine*, July 1974, 9. Quoted as given in the epigraph of Giulini (2009).

Wheeler, J. A. (1978). “The ‘past’ and the ‘delayed-choice’ double-slit experiment”. In A. R. Marlow (ed.), *Mathematical Foundations of Quantum Theory*, 9–48. New York: Academic Press.

Wheeler, J. A. (1990). “Information, physics, quantum: the search for links”. In W. H. Zurek (ed.), *Complexity, Entropy and the Physics of Information*. Redwood City, California: Addison-Wesley. (First given at the 3rd International Symposium on Foundations of Quantum Mechanics, Tokyo, 1989.)

Wheeler, J. A. and Ford, K. (1998). *Geons, Black Holes, and Quantum Foam: A Life in Physics*. New York: W. W. Norton.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Julian Barbour

Janus and the Turn

Julian Barbour, the Arrow of Time and Physics from Comparison

Abstract

Julian Barbour has built his physics on Mach's principle: motion, inertia and time itself are relations among the things of the world, and nothing stands behind them. He showed with Bruno Bertotti that dynamics can be derived from the comparison of configurations alone. In *The End of Time* (1999) he argued that the world is a collection of instants and that time, as something flowing, does not exist. In *The Janus Point* (2020) he showed that a law which treats past and future alike can still give every observer an arrow of time, pointing away from a central point of least structure, with no special condition placed at a beginning. The physics collection of the Immanent Metaphysics stands with Barbour on more than it parts from him. It holds that inertia is a comparison and supplies Mach's principle from the principle that a difference no comparison can register is no difference; that the direction of time is present in every act of comparison, with no need of a low-entropy beginning; that every record is a record of the past; and that there must be something for a comparison to be about. It parts from him on one question: whether time is real. The collection distinguishes what exists, laid out as structure, from what is real, given in an actual act of comparison, and holds that both are needed; Barbour keeps the first and calls the second an illusion. The timeless equation of quantum gravity from which Barbour drew support is, in the collection's account, the product of putting the arena into the quantum state. The essay sets Barbour's Janus point beside the collection's turn, the passage from one epoch to the next, and shows where the two pictures meet and why the collection's arrow runs one way through every turn. A last section takes the one place where the two accounts predict different results: whether the geometry of space carries quantum degrees of freedom of its own. Both arguments are valid, and they part at one premise: whether removing absolute space makes the geometry one more configuration of the world, or leaves the geometry the context in which configurations are compared.

I. Barbour's Program

Barbour begins from Ernst Mach. Mach held that position, rest and rotation have meaning only relative to other bodies, and that time is something we abstract from change itself, not a container in which change happens. Barbour took that as a program for physics: to build dynamics from relations alone, with no absolute space and no absolute time standing behind the relations.

The first result was *best matching*, developed with Bruno Bertotti and published in 1982. Two configurations of a universe of bodies are compared by moving one against the other, shifting and turning it, until the difference between them is as small as it can be made. What is left after that matching is the physical difference between the configurations, and dynamics is built from such differences. Barbour and Bertotti showed that the formal structure of Einstein's general relativity fits this pattern of dynamics, without a background grid of space and time, given the thin-sandwich conjecture, that two nearby geometries of space fix the history between them (Barbour and Bertotti 1982). Later, with Brendan Foster and Niall Ó Murchadha, Barbour derived general relativity from a starting point of the same relational kind, an action on the geometries of space whose only symmetry is the relabeling of their points (Barbour, Foster and Ó Murchadha 2002). In later work by Henrique Gomes, Sean Gryb and Tim Koslowski, building on Barbour's program, the program became *shape dynamics*, a reformulation of general relativity in which only the shapes of configurations, and not their overall size, carry physical meaning.

The second result was Barbour's account of time in *The End of Time* (1999). The universe, he argued, is a collection of instants, each a complete configuration of everything, and the space of all possible configurations he named Platonia, after Plato's world of eternal forms. No instant flows into another. Our sense of a flowing time, he holds, comes from configurations that contain what he calls time capsules: structures, such as brains and fossils and tracks in a cloud chamber, that encode a coherent history and so present a past. Barbour found support in the Wheeler–DeWitt equation, the central equation of the canonical quantization of general relativity, which contains no time at all.

The third result is the one that matters most for the arrow of time. In 2014 Barbour, Koslowski and Flavio Mercati studied the Newtonian problem of many bodies under gravity, with zero total energy and zero total angular momentum, as a model of a closed universe. They found that typical solutions pass through a single point at which the configuration is least structured, and that a measure of the complexity of its shape grows away from that point in both directions. Structures that store information about the dynamics, which they call records, form as complexity grows, and an observer inside either half sees the records of that half alone and infers one past and one future. In *The Janus Point* (2020) Barbour named that point after the Roman god with two faces and built a theory of time on it (Barbour 2020; reviewed by Perkowitz 2022). The law treats past and future alike, no special condition is placed at any beginning, and still every observer has an arrow, pointing away from the Janus point. Barbour also argues that the thermodynamic idea of entropy, built for steam engines and gases in boxes, is the wrong tool for an expanding universe that has no box around it.

Barbour has also answered John Archibald Wheeler's claim that every physical thing derives from information, "it from bit". He holds the reverse: things are primary, and "Probabilities without things are pure nothings".

Barbour has established three things the collection credits plainly. Mach's principle can be made the foundation of a working dynamics, one that recovers general relativity. A law symmetric in time can give every observer inside it an arrow of time, with no special initial condition. And the felt past is carried by records, structures that encode a history.

II. Where the Collection Stands With Him

Inertia is a comparison

The collection holds Mach's principle, and gives it a ground. At the Edge of Reality, Chapter 8, states it: "To be at rest, to move uniformly or to rotate is always to do so relative to something. Inertia, the tendency of a body to keep its state of motion, is therefore a comparison: a state of motion is a content, and what it is measured against is its context". The equations of general relativity allow worlds empty of matter in which inertial frames are still fixed, with

nothing for them to be compared against, so general relativity does not impose Mach's principle. The collection supplies what general relativity leaves open, from the principle that "a difference that no comparison can register is no difference": "frames are frames only through the comparable content that fixes them. Where content is there to compare against, there is a frame. Where nothing is, no comparison can tell one frame from another" (At the Edge of Reality, Chapter 8; the same step stands in The Gravitational Passage, Chapter 18, Section IV).

Barbour's best matching puts the same principle to work: a difference that no comparison can register is no difference. To match two configurations is to compare them. The matching removes every difference that depends only on where the observer stands or which way the observer faces, and so treats as no difference anything that a comparison of the two configurations themselves cannot register. What survives the matching is what a comparison of the two configurations can find. Barbour built from Mach a method; the collection finds in the method the structure of comparison it begins from.

Time from change

Mach and Barbour hold that time is abstracted from change. The collection holds that "Time is the context of the order in which findings are found" (Measurement, Chapter 12, Section I). Both take time from the happenings, and neither treats it as a container given before them. Measurement, Chapter 12, Section II, says of the order of findings: "Findings define the order of event time; they do not occur within a time given before them". Here the collection and Barbour stand together against the picture of a time that would tick on in an empty world.

The arrow needs no special beginning

Barbour's central result in *The Janus Point* is that a law symmetric in time gives an arrow of time with no special condition placed at a beginning. The collection holds the same, on a different ground. Its structural arrow is "the structural precedence of Axiom II applied to the physical domain. The direction of time is the direction in which comparison proceeds" (Incommensuration, Chapter 8, Section X). In every comparison there is first a stance and a

range of what could be found, then the act in which one finding is made, then the record of it. That order "needs no large number of parts and no special beginning of the world: it is present in one comparison, made once" (Physics Is Not Math, Chapter 8, Section II). Essay 11 of The Basis of Physics gives the second route, through the Incommensuration Theorem, and names what the route needs none of: "Perfect time-reversal is therefore precluded, and the preclusion depends on no entropy, no boundary condition, no Past Hypothesis, and no particular formalism".

The Past Hypothesis, the condition that the universe began in a state of extraordinarily low entropy (the name is David Albert's; Albert 2000), is for Barbour unnecessary, and for the collection it is "neither an axiom nor a brute law added to physics" (The Compactification, Chapter 3, Section VIII). The structural arrow gives the direction of time without the Past Hypothesis, so the hypothesis is not needed as the source of that direction. As a statement about the beginning, the Past Hypothesis splits into two parts: the entropy of the matter was high, as observed, and the low entropy of gravity follows from the even beginning of each epoch.

Records

Barbour's arrow is read from records, and so is the collection's. "The observation that bears on it is that every record ever found is a record of the past. No instrument holds a finding before the interaction that makes it" (Measurement, Chapter 12, Section I). The collection also says how the two arrows of physics, the structural one and the growth of entropy, are joined: "A record is itself an irreversible change, a darkened grain of emulsion or a registered count, and making it raises the entropy of the instrument that holds it. So each act of recording joins the two arrows in one event" (Measurement, Chapter 12, Section VII).

Things before information

On Barbour's answer to Wheeler, Objections from Physics, Answered takes his side. Every comparison is on something: "A comparison yields a verdict, same or different: two intrinsics. The verdict is on something, in some respect that is not the thing judged: two more". So "a comparison with nothing to be

about is no comparison, and the books hold the point Barbour presses against Wheeler". The books also stand with Barbour against the digital view his argument opposes, the view that the world is made of bits: the arena is continuous, and content is discrete, each in its own character.

Entropy needs a context

Barbour argues that entropy, a concept built for bounded systems, is the wrong tool for a universe with no box around it. The collection says why. "An entropy is a count: the number of states of a system that the comparisons available from some context cannot tell apart. The count is made relative to that context" (The Compactification, Chapter 3, Section V). The box around a gas is the context relative to which its states are counted. A count for the whole universe needs a context for the whole, and the universe has none outside itself. Barbour's doubt about the entropy of the universe and the collection's principle that every count has a context are one point, reached from two sides.

III. What Time Is in the Collection

The collection's account of time begins from the single stance of the one comparing. "Findings are found by a comparing, and the comparing is a single stance. From one stance, any two findings stand in one relation of order: one is earlier and the other later. So time has one dimension" (Measurement, Chapter 12, Section I). The order has a direction, and the direction is the order of the second axiom: the range of what could be found comes first, then the act, then the record, and the record shapes the next range.

Physics uses the word time for three objects, and the collection holds them as one triple (Measurement, Chapter 12, Section III). *Geometric time* is time laid out as one structure: the proper time along paths and the order of cause carried by the metric of space and time. *Event time* is the order of findings: a discrete sequence of outcomes, each the label of one registered result. *Evolution time* is the parameter of the smooth evolution of a quantum state over the range of what could be found. Comparison has three roles, the *modalities*: the immanent, held in the act itself, now; the omniscient, held as structure laid out, every case in view at once; and the transcendent, implicit, held in the

stance from which an act proceeds. Applied to time, geometric time takes the omniscient role, event time the immanent, and evolution time the transcendent, and the three are distinct, inseparable and not interchangeable. Each needs the other two. A finding needs a state whose range it selects among, and a place in the order of cause where its record lies; geometric time is known only through findings; and evolution time needs a preparation, which is a finding, and a clock by which its parameter is read.

Two words carry the rest. "To say that something exists is to say that it stands as structure: timeless, the same in every instance, like the pattern of a law, or the state of a system at an instant. To say that something is real is to say that it is given in an actual act of comparison: temporal, occurring now, with the future still open to possibilities not yet settled. A law exists; a measurement is real" (Comparison; The Necessary Basis, Chapter 10, Section II). Geometric time exists; event time is real. The ground of the whole account is the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The theorem forbids symmetry and continuity perfected together, and faithful reversal of a process would need exactly that pairing: its law perfected in symmetry and its state given without a gap. So time has a direction that no law of motion can undo, whatever symmetry the law has. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

IV. Where the Roads Part: Is Time Real?

Barbour's instants are configurations, each complete and none flowing into the next. In the collection's terms, a configuration is a state of a system at an instant, the very example Comparison; The Necessary Basis gives of what exists: structure, timeless, laid out. Platonia, the space of all configurations, is

the omniscient: everything laid out at once, every case in view. Barbour keeps what exists, and holds that what is real, the act given now, is an illusion of the mind.

The collection keeps both, because each needs the other. A configuration is known as a configuration only through findings: every measured position is a comparison of a body with a standard, and leaves a record. Barbour holds that a time capsule is a structure within one instant, made by no earlier act; the collection holds that a record is the result of the act it records, a finding laid out by an act. This is the collection's premise, and one Barbour denies. On the collection's premise, the instants Barbour keeps are themselves laid out from acts of comparison, and removing the acts would remove the means by which any instant is known. The Basis of Physics, Essay 11, says of the block universe, the view that past, present and future are equally real and laid out once: "The block universe takes geometric time for the whole, and drops event time". Barbour's Platonia drops event time in the same way, and with it the third member, evolution time, whose range of what could be found is what each act selects from.

Barbour drew support for timelessness from the Wheeler–DeWitt equation, which contains no time. The collection places that equation exactly. The Unquantized Arena, Chapter 6, Section VI: "The equation contains no time parameter. The quantum state, which in every other quantum theory evolves in the time of an arena, has nothing in which to evolve. That is the problem of time (Isham 1993). I read it as the category error in its plainest form. The context in which things happen has been put into the quantum state, instead of serving as the arena in which the state evolves". The timelessness of the equation is a feature of a description in which the arena of physics has been quantized, and the collection holds that gravitation is not quantized. What Barbour took for a discovery about the world is a property of that description. Essay 12 of The Basis of Physics, in its Section IX, names what the problem of time is, in the terms of the three times. The time of general relativity is geometric, and the time of quantum mechanics is the parameter of evolution; "The problem of time is what one gets by asking the two conjugate times to be one time without going through the third", the third being the time of the act of measurement, where the two meet.

The same distinction answers Barbour's time capsules. A time capsule, for Barbour, encodes a history without being the result of a chain of causes running back through earlier instants. The collection holds that "Causation is established, and determinism never" (Measurement, Chapter 12, Section IV). A causal connection is a connection without a break along the order of findings, continuity with asymmetry, and that pairing is one of the two the theorem allows. A record is the result of the act it records, and that is why every record ever found is a record of the past.

V. The Janus Point and the Turn

The collection's *turn* is the passage from the end of one epoch to the beginning of the next. In the collection's cosmology, set out in *The Compactification* and *At the Edge of Reality*, space has six further dimensions besides its three, held compact and too small to see, and the end of every black-hole interior is the start of a new epoch of the universe. At the end of every black-hole interior, the conditions that hold the six internal dimensions compact fail, the ten-dimensional geometry restores a context, and the collection identifies that restoration with the Big Bang of the next epoch. No comparison registers the turn as an event, and the cycle of epochs has no first turn (The Compactification, Chapter 1, Section V). Barbour's Janus point and the turn have the same place in their accounts: each is where an arrow of time starts, and each is a state of least structure from which structure grows. Barbour's Janus point is the configuration of least complexity; the collection's new epoch begins even, with no clumping of its geometry carried from before, up to the small departures the theorem requires (The Compactification, Chapter 3, Section VI). In both, the low order of the beginning follows from what the beginning is, and is not a condition added by hand.

Mach's principle appears in both, and in the collection it is the hinge of the turn. At the end of an interior, "there is no comparable distribution of mass and energy against which a standard of rest could be defined. The Mach principle then fixes no frame. Time goes with it" (At the Edge of Reality, Chapter 13). What goes is time's large-scale direction, the direction set by the growth of entropy, the expansion and the reference of distant matter. The order inside each act stays: "The one-way order inside each act of comparison, from the

stance through the finding to what is laid out (Chapter 4), is not reversed; at the end of an interior there is no content that can be compared with, and so nothing for that order to arrange". Barbour's Machian universe and the collection's turn meet here: where nothing is left to compare against, no frame is fixed, and the large-scale measure of time has nothing to rest on.

The two part in three ways. The first is where the starting point lies. Barbour's Janus point is a point within one solution of one law, a configuration through which the history passes. The collection's turn lies outside every history: no comparison of the old epoch registers it, and the context of the new epoch re-forms with no prior identity. The second is how many ways the arrow points. Barbour's arrow points away from the Janus point in both directions, so that the observers on the far side have their past toward the same point as ours. No record reaches the far side of either, so no observer tells the two pictures apart by a finding (Appendix C, "The Janus point and the turn"); they differ in what the arrow is, which the third difference sets out. The collection's arrow points one way through every turn, because it is the order of the second axiom, renewed in every act of comparison, in every epoch, and is inherited from no point. The cycle of epochs runs in one sequence, and each epoch's large-scale arrow points away from its own turn toward its own end. The third is where the arrow comes from. Barbour's arrow is a property of typical solutions of a particular dynamics, the gravitational problem of many bodies, and an observer infers it from records. The collection's arrow is present in a single comparison and needs no dynamics, no large number of parts and no particular solution.

Barbour's own explanation of why an observer infers one direction uses the collection's arrow. His observers infer a past from records, and a record is by its nature later than what it records: it is a finding laid out by an act. The direction from act to record is the order of the second axiom. So the arrow Barbour's observers read off their records is the structural arrow, met in the records. Barbour's dynamical arrow, the growth of complexity away from the Janus point, belongs with the collection's second arrow: like the growth of entropy, it is found in systems of very many parts and needs a state of least

structure to grow from. The collection holds both arrows and says how they are joined, in every act of recording. Barbour found the dynamical arrow and read it through the structural arrow without naming the structural arrow.

VI. Where the Predictions Part, and Why

Most of what divides Barbour from the collection is a difference of kind, and Section IV set it out: whether time is real. One difference is a difference of prediction; the dated register of 4 November 2026 that sets Barbour's predictions beside the collection's finds no other. That register is Appendix C of this volume, a record of its own, dated three days after the sealed record of 1 November 2026, from which it quotes each prediction. This section takes the argument of the book on which the sealed prediction rests, sets it beside Barbour's own reasoning, and finds the step at which the two part.

Whether the geometry of space carries quantum degrees of freedom of its own

The sealed prediction. "No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter. A description of the small waves of the geometry by quanta holds below the Planck curvature, and its quanta are quanta of that description, never quanta of the arena". It was registered on 1 November 2026 as Prediction 3 of *The Registered Predictions of Physics from Comparison*, which names The Unquantized Arena as the book where it is argued.

The argument of the book. The Unquantized Arena, Chapter 6, Section II, sets out the chain step by step and then states it in seven sentences. It begins from the Incommensuration Theorem: "any comparison perfected at its foundation is either continuously asymmetric or discontinuously symmetric". It takes two laws: "Content is governed by symmetry and context by continuity". It makes one identification, that gravity is the context of physics, which the book numbers P18 and checks against four markers in Chapter 5: "the matter and forces of particle physics are content, and gravity is the context of physics, its arena". Quantization is the passage of a description of content from one of its two forms to the other, which the book calls the mode exchange, and Proposition 6.1 holds that the arena admits no mode exchange. Its second strand turns on the role of the arena: "The mode exchange of a con-

tent is a passage between two descriptions of that content, and the two descriptions are compared within one arena that stays as it is", and "A mode exchange of the arena would need a further setting in which its two descriptions could be compared, and that further setting would then be the context of physics in the arena's place". Proposition 6.3 then fixes what "not quantized" means, and its second part is the prediction's ground: "(ii) Nothing is a quantum of the arena itself, at any scale". The words "beyond those tied to the alternatives of the matter" come from Chapter 7, which gives each alternative of the matter its own classical geometry; its Section VII says of the free waves of the geometry: "I reason that the free curvature of the arena, the Weyl part of Section III, belongs to the context of the content that produced it, and carries that content's alternatives". So on the book's account every superposition the geometry shows is the superposition of the matter whose context the geometry is, and the geometry has no alternatives of its own.

Barbour's argument. Barbour begins, as Section I set out, from Mach: only the relative configurations of the universe are physical, and nothing stands behind them. For a universe governed by Einstein's theory, the configurations are of the matter and of the geometry of space together, and best matching applies to the geometry as to the matter: two geometries of space are compared by shifting the one against the other until their difference is least (Barbour and Bertotti 1982), and in shape dynamics by changes of scale as well (Gomes, Gryb and Koslowski 2011). Barbour then applies quantum theory to the universe as a whole. The abstract of his paper "The timelessness of quantum gravity: II. The appearance of dynamics in static configurations" begins: "A strategy for quantization of general relativity is considered" (Barbour 1994). The state of the universe is a wave function on Platonia, the space of all its configurations, governed by an equation of the kind of the Wheeler–DeWitt equation, and its instants "are not embedded in any kind of external or internal time" (Barbour 1994). Each step follows from the one before. If the geometry of space is one part of the configuration, and the configuration is the variable of a quantum state, then the geometry of space carries amplitudes of its own, as every variable of a quantum state does, including amplitudes for geometries that no superposition of the matter produces.

Where they part. Both start from Mach, and they part over what Mach's principle removes. For the collection, removing absolute space makes the frame depend on the content that fixes it, and leaves the geometry the context in which every configuration of the content is compared and laid out: "frames are frames only through the comparable content that fixes them", as Section II quoted. For Barbour, removing absolute space makes the geometry of space one more part of the configuration of the universe, of the same kind as the matter, compared with other configurations by best matching.

Whose step, and what decides it. Both arguments are valid: in each, every step follows from the premises before it, and the two differ in one premise. Stated as one sentence, the premise in dispute is this: when absolute space is removed, the geometry of space is one more configuration of the universe, and not the context in which the configurations of the universe are compared. Barbour affirms it; the book denies it, in its identification of gravity as the context of physics (P18). It is a premise about what a thing is, an identification, and no derivation inside either account settles it.

Barbour's own construction shows where the context goes when the premise is affirmed. Best matching compares two configurations under a measure of difference defined on the space of configurations, and a history is a path in that space (Barbour and Bertotti 1982; Barbour, Koslowski and Mercati 2014). Once the geometry of space is a configuration, Platonia and its measure of difference are the setting in which every configuration, the geometry included, is compared. Platonia with its measure of difference is then the further setting which the second strand of Proposition 6.1 says a quantum arena would need, standing as the context of physics in the arena's place. The book draws the consequence for the canonical equation: once the arena is itself the state, "the formalism has no context left, and its evolution has no parameter" (The Unquantized Arena, Chapter 6, Section VI). Barbour draws the same consequence and reads it as a discovery, that time does not exist, and Section IV took up that reading. So each account carries its premise through to the consequence that the other foresees, and no step of either contradicts a step of the other.

The two readings of Mach also differ in what a measurement could find. On the book's account every superposition of geometries is carried by the matter, since the geometry has no alternatives of its own. On Barbour's account the geometry of space has amplitudes of its own, so the wave function of the universe can hold a superposition of geometries that no superposition of the matter produces. The Unquantized Arena, Chapter 19, Section III, names the two kinds of observation that decide between them: "the cross-section for the scattering of small waves of the geometry, computed in their description by quanta, at energies where the corrections of the effective theory are large", and "every search for an effect in which the geometry carries quantum degrees of freedom of its own, for example a superposition of macroscopically different geometries that no superposition of the matter sources and that is not a state of free small waves in their description by quanta". The sealed record names no coming measurement of either kind, and it states that "Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed". The entanglement of two masses through gravitation leaves the two accounts undecided, since the collection predicts it and a quantized geometry "gives the same phase", in the sealed record's words.

What the comparison teaches runs both ways. For the collection, Barbour's program is a worked case of Proposition 6.1: a careful relational program that puts the geometry into the quantum state still has a context: it moves the context into the space of configurations, and loses its time there, as the book foresees. For Barbour, the collection shows that a relational starting point is consistent with a geometry that is not quantized: the collection is Machian about the frame and keeps the geometry as context, with no alternatives of its own. On this point the collection carries Mach's principle further than Barbour does, since in it the geometry has no superposition that the matter does not give it; on time, Barbour carries Mach's principle further than the collection, since he removes time along with absolute space.

VII. Summary

Barbour and the collection agree on more than either agrees with the usual account of time in physics. Inertia is a comparison, and a frame is a frame only through content there to compare against. Time is taken from the happenings, and is not a container given before them. The arrow of time is present with no special condition placed at a beginning, and the Past Hypothesis is not a law of nature. Every record is a record of the past. A comparison must be about something. And entropy, a count, needs a context, which the universe as a whole does not have.

They part on whether time is real. Barbour keeps the instants, what exists laid out as structure, and calls the flow of time an illusion. The collection holds time as a triple of geometric, event and evolution time, and holds that what exists and what is real each need the other: every instant is known through acts of comparison, and the act given now is real. The timeless equation Barbour drew on is the product of quantizing the arena, and the collection holds that the arena is not quantized. Barbour's Janus point and the collection's turn are each the start of an arrow in a state of least structure, and Mach's principle fixes no frame at either. The Janus point lies within one history, with an arrow running both ways from it; the turn is registered by no comparison, and the arrow runs one way through every epoch, because the arrow is renewed in every act.

The one difference of prediction is whether the geometry of space carries quantum degrees of freedom of its own. Barbour's argument and the book's are each valid, and they part at one premise: for Barbour, removing absolute space makes the geometry one more configuration of the universe; for the collection, it leaves the geometry the context in which configurations are compared. Barbour's program, carried through, moves the context into the space of configurations and loses time there, which is the consequence The Unquantized Arena foresees for a quantized arena. An observation of a superposition of geometries that the matter does not carry would decide between the two. Barbour removes time along with absolute space; Lee Smolin, in the next chapter, holds that time is real and fundamental, and that the laws themselves change within it.

Key Concepts

- Best matching is a comparison of two configurations that counts as no difference what no comparison of them can register; the collection's principle of difference grounds Mach's principle.
- Time is the context of the order in which findings are found; it is not a container given before them.
- The structural arrow is the order of the second axiom, present in one comparison; it needs no Past Hypothesis.
- Geometric time exists; event time is real; evolution time carries the range of what could be found; the three are one triple.
- The timelessness of the Wheeler–DeWitt equation comes from putting the arena into the quantum state.
- Barbour's records presuppose the structural arrow; his growth of complexity belongs with the second, statistical arrow.
- The Janus point and the turn each start an arrow in a state of least structure; the turn is registered by no comparison, and the arrow runs one way through it.
- Barbour and the collection part on one premise in prediction: whether the geometry of space is one more configuration of the universe or the context in which configurations are compared; affirmed, it moves the context into Platonia and loses time there.

Terms

Best matching. Barbour and Bertotti's method of comparing two configurations by shifting and turning one against the other until their difference is least, and building dynamics from what remains.

Event time. The order of findings: a discrete sequence of registered outcomes.

Evolution time. The parameter of the smooth evolution of a quantum state over the range of what could be found.

Exist and real. To exist is to stand as structure, timeless and laid out; to be real is to be given in an actual act of comparison, now.

Geometric time. Time laid out as one structure: proper time and the order of cause carried by the metric.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Janus point. In Barbour's account, the point of least complexity in a typical solution of the gravitational problem of many bodies, from which complexity grows in both directions.

Mach's principle. Inertial frames are fixed by the distribution of mass and energy in the universe.

Modalities. The three roles of comparison: the immanent (held in the act itself, now), the omniscient (held as structure laid out, every case in view at once) and the transcendent (implicit, held in the stance from which an act proceeds).

Mode exchange. In The Unquantized Arena, the passage of a description of content between its two forms; quantization is the mode exchange, and the book holds that the arena admits none.

Past Hypothesis. The condition that the universe began in a state of extraordinarily low entropy.

Platonia. Barbour's name for the space of all possible configurations of the universe, after Plato's world of eternal forms.

Structural arrow. The direction of time as the direction in which comparison proceeds: from the range of what could be found, to the act, to the record.

Turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

References

Albert, D. Z. (2000). *Time and Chance*. Cambridge, Massachusetts: Harvard University Press.

Barbour, J. B. (1994). "The timelessness of quantum gravity: II. The appearance of dynamics in static configurations". *Classical and Quantum Gravity* 11(12), 2875–2897. DOI 10.1088/0264-9381/11/12/006.

Barbour, J. (1999). *The End of Time: The Next Revolution in Our Understanding of the Universe*. London: Weidenfeld and Nicolson; Oxford: Oxford University Press.

Barbour, J. (2015). "Bit from It". In A. Aguirre, B. Foster and Z. Merali (eds.), *It From Bit or Bit From It? On Physics and Information*, 197–211. Cham: Springer. DOI 10.1007/978-3-319-12946-4_17.

Barbour, J. (2020). *The Janus Point: A New Theory of Time*. New York: Basic Books; London: The Bodley Head.

Barbour, J. and Bertotti, B. (1982). "Mach's principle and the structure of dynamical theories". *Proceedings of the Royal Society of London A* 382, 295–306.

Barbour, J., Foster, B. Z. and Ó Murchadha, N. (2002). "Relativity without relativity". *Classical and Quantum Gravity* 19, 3217. DOI 10.1088/0264-9381/19/12/308. arXiv:gr-qc/0012089.

Barbour, J., Koslowski, T. and Mercati, F. (2014). "Identification of a gravitational arrow of time". *Physical Review Letters* 113, 181101. arXiv:1409.0917.

DeWitt, B. S. (1967). "Quantum theory of gravity. I. The canonical theory". *Physical Review* 160, 1113–1148.

Gomes, H., Gryb, S. and Koslowski, T. (2011). "Einstein gravity as a 3D conformally invariant theory". *Classical and Quantum Gravity* 28, 045005.

Isham, C. J. (1993). "Canonical quantum gravity and the problem of time". In L. A. Ibort and M. A. Rodríguez (eds.), *Integrable Systems, Quantum Groups, and Quantum Field Theories*, NATO Science Series C 409, 157–287. Dordrecht: Kluwer. arXiv:gr-qc/9210011.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Perkowitz, S. (2022). "How entropy might increase backwards in time, as well as forwards" (review of *The Janus Point*). *Physics World*, 25 January 2022.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.



Lee Smolin

Time Is Real

Lee Smolin and Physics from Comparison

Abstract

If time is real, must the laws of physics change? Lee Smolin has argued for forty years, from inside theoretical physics, that time is real, that the universe is one and has a history, that the laws of physics are not a timeless mathematical object standing outside the world, and that physics must be built from relations. The physics collection of the Immanent Metaphysics holds each of these, on its own ground, and it shares two of Smolin's specific moves: a principle by which what no comparison can tell apart is one, and a new epoch of the universe that begins where the interiors of black holes end. The two part on what keeps time real. Smolin keeps the future open by letting the laws themselves change, and by letting the constants of each new universe vary from those of its parent. The collection keeps the future open with laws that stay the same: the Incommensuration Theorem forbids any law to be perfected together with continuity, and so determinism cannot be had. The collection fixes the structure of physics by the axioms in every epoch, in a single sequence of epochs in which no epoch inherits anything from a parent. The two also part on gravity and on quantum theory. Smolin helped found loop quantum gravity, in which areas and volumes come in discrete steps; the collection holds that the arena of physics is continuous, with no least step, and is not quantized. Smolin seeks a realist completion of quantum mechanics; the collection derives quantum mechanics and finds it complete in its scope. The essay sets out his program at full strength, what the collection shares with it, and where and why they part. For the four places where the registered predictions and his work say experiment will find different things, it sets the argument of each book beside his own and finds the premise or step where they part.

I. A Physicist Who Says Time Is Real

Lee Smolin, of the Perimeter Institute for Theoretical Physics, is one of the founders of loop quantum gravity, and with Carlo Rovelli he computed in 1995 that, in that program, the area of every surface and the volume of every region take separate, discrete values. In 1992 he proposed that each black hole gives rise to a new universe whose constants differ slightly from its parent's, so that over many generations the universes that make many black holes come to predominate. He called this *cosmological natural selection* and set it out at length in *The Life of the Cosmos* (1997). In *The Trouble with Physics* (2006) he argued that string theory had taken over the field without producing a test.

From *Time Reborn* (2013) onward his central claim has been about time. Time is real and fundamental, and the picture of the universe as a timeless block, in which past, present and future are equally real, is wrong. In *The Singular Universe and the Reality of Time* (2014), written with the philosopher Roberto Mangabeira Unger, he adds that there is one universe, and only one, and that the laws of nature are not immutable. The method of physics states timeless laws for a small system set in a larger world and then supplies its starting conditions; stretched to the whole universe, he argues, the method fails, because nothing lies outside the whole to supply those conditions or to serve as a clock. With Marina Cortês he has built models in which the universe is a process of unique events, each event distinguished from every other by its relations, so that "any two events must have non-isomorphic causal pasts", a form of Leibniz's principle that things alike in every respect are the same thing. In 2012 he proposed a *principle of precedence*: that "the outcome of a measurement on a quantum system is selected randomly from the ensemble of outcomes of previous instances of the same measurement on the same quantum system", so that the laws of quantum physics act like habits that nature has formed, and a situation with no precedent is free to produce something new. And in *Einstein's Unfinished Revolution* (2019) he argues that quantum mechanics is incomplete, and that a realist completion of it is still to be found.

Smolin's work is a sustained argument that physics went wrong when it took its timeless mathematics for the world. The collection reaches that conclusion too, and Section II sets out how much of the rest it shares.

II. What the Collection Shares

Time runs one way in every act

The collection finds the direction of time in the structure of comparison itself. Incommensuration, Chapter 8, Section X, states it: "The non-entropic arrow of time is the structural precedence of Axiom II applied to the physical domain. The direction of time is the direction in which comparison proceeds". Every comparison proceeds in one order: first the stance (the side from which a comparison is made, which belongs to every comparison, human or not), with everything that might be found; then the act; then the record, which can never not have been made; and what is laid down shapes the next stance (Home in the World, Records That Are Never Un-laid). This structural arrow is present in every single comparison and needs no low-entropy beginning; the entropic arrow of systems of many parts is real too, and points the same way, because making a record raises the entropy of the instrument that holds it (Why Time Travel Is Not a Concept). Time is real, on this account, because comparison runs one way, and every finding of physics is a comparison.

The universe, likewise, is a process, and not a static container. The Last Turtle, Chapter 5, Section VII, calls it "a process whose structure is the precondition for the emergence of beings who can ask what the universe is", and holds that creation "has no time and no source; it is an aspect of every event". Smolin's universe of unique events, each made new, and the collection's universe as process, with creation an aspect of every event, are the same picture drawn from two sides.

No view from outside

Smolin's objection to stretching the method of physics to the whole universe is an objection to the view from outside. The collection holds the same. Every comparison has two sides, the side from which it is made and the side about which it is made, and the two are inseparable, so every description is made from somewhere (Physics Is Not Math, Chapter 3, Section II). The view that seems to stand nowhere, the objective standpoint at its limit, "is real, and it is one of the great achievements of knowing. The laws of physics are stated in it" (Chapter 3, Section VI). The error is to take that view for everything,

which the same chapter calls taking the frame of mathematics for everything (Section VIII). The collection's order of depth puts mathematics last, after metaphysics, physics and computation, because every proof is checked by a run, every run is a physical process, and every finding of physics is a comparison made from inside the world (Physics Is Not Math, Chapter 5). Smolin's rejection of the universe as a timeless mathematical object is the same rejection, and the collection gives it a ground: the order of what each thing presupposes.

Relations first, and the identity of what cannot be told apart

Smolin is a relationalist: a thing is what its relations make it. The collection starts from relation as such. Its one premise, the Root Tautology, is that comparison, interaction and relation are one act under three names, and The Last Turtle, Chapter 1, Section VI, takes the relationship as "more fundamental than either of the two things related".

The two also share Leibniz's principle, in a precise form. Cortês and Smolin distinguish every event from every other by its causal past. The collection states its principle as "a difference that no comparison can register is no difference", and states it exactly: two things are one when, for every possible comparison and for every thing whatever, the comparison of the first with that thing gives the same verdict as the comparison of the second (At the Edge of Reality, Chapter 11). Two identical coins, one in each hand, are two: compare each with your left hand, and one is in it and the other is not. On this principle the collection joins the ends of all black-hole interiors into one, and leaves the interiors themselves distinct. Smolin uses the principle to make every event unique; the collection uses it, stated as a fact about comparison, to say exactly which things are one.

One universe, and its beginning inside a black hole

Smolin and Unger argue for one universe and against a population of universes that no one could observe. The collection's universe is one sequence of epochs, each following the last, with "a single sequence of epochs, and a structure fixed in every epoch by the axioms" (At the Edge of Reality, Notes to Chapter 20). And the collection shares the identification Smolin made in

1992, that the interior of a black hole is the origin of a universe: The Gravitational Companion names him among those whose proposals it shares, and The Gravitational Passage, Chapter 18, Section XII, cites him as a precedent. On the collection's account space has, beside its three large directions, six compact internal dimensions, a complex projective plane and a sphere, also called the six dimensions of possibility. At the end of every black-hole interior, the conditions that hold the six internal dimensions compact fail, and the ten-dimensional geometry restores a context, which the collection identifies with the Big Bang of the next epoch; it calls the passage the *turn* (The Compactification, Chapter 1, Section V).

The string theory critique

Smolin argued in 2006 that string theory had not earned its place. The collection agrees that the route of string theory is the wrong one, and it reaches ten dimensions without strings: one of time, three of space and six of possibility, each count found from the structure of comparison (Measurement, Chapter 4).

III. Two Kinds of Precedence

Smolin's principle of precedence and the collection's second axiom share a word, and much of what the word means. In both, what has happened shapes what can happen next, and the order cannot be reversed. The Last Turtle, Chapter 3, Section VI, states the axiom's order: "The order Axiom II states is one of precedence, not of clock time", and it runs from many to one, three times over: "Many existing patterns converge into one creative act. Many creative potentials converge into one actual event. Many actual events converge into one knowable structure".

The two differ in where the precedence is held. Smolin's precedence is a memory of instances: nature draws the outcome of a measurement from the outcomes of earlier measurements of the same kind, and a law is the habit those outcomes have formed. That raises a question the principle must answer: how nature has access to its own past instances, and what counts as the same measurement. The collection's precedence is the structure of each single comparison. Every comparison proceeds from a stance that already contains

what has been laid down, and its record becomes part of the stance the next comparison proceeds from; so no ensemble of earlier instances is consulted, and none is needed. The past shapes the present by being part of what each act starts from, not by being looked up. And a law, on the collection's account, is a finding (and not a habit): "A law of physics states what stays the same when the circumstances of a measurement change", a sameness of content across a difference of context, which is symmetry (Measurement, Chapter 2, Section V). What Smolin's principle reaches for, a world in which the past constrains the present without a timeless rulebook standing outside it, the collection has in the order of every act.

IV. Laws That Stay the Same, and a Future That Stays Open

The deepest difference concerns the laws. Smolin lets the laws change because he sees no other way to keep time real: if the laws are timeless and fix every state from the one before, then the future is already contained in the present, and time adds nothing. The collection keeps what he fears to lose, a future not contained in the present, and keeps it with laws that stay the same.

The ground is the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. A law is symmetry: the same rule, everywhere and at every time. Determinism needs that symmetry made perfect and, at once, every state specified at every point with no gap, which is continuity made perfect. Causality Without Determinism, Chapter 1, Section VIII, quotes Incommensuration: determinism "is an assertion of total symmetry and total continuity", and "since symmetry and continuity cannot both be perfected, total specification (continuity) of lawful structure (symmetry) is structurally precluded". So a law can hold everywhere and always, and the future still is not contained in the present. Causes are real, and determinism cannot be had; su-

perdeterminism is excluded with it (Chapter 3, Section VIII). The openness Smolin protects by letting the laws evolve is already secured by the theorem, with no change in the laws required.

What the axioms fix, and what they leave to measurement, is stated plainly in the collection. They fix structure: the gauge group of the forces (The Kinds of Particle, Chapter 4), the kinds of particle and their charges, the three generations, the dimensions of time, space and possibility. That structure is the same in every epoch. They do not fix sizes: "The axioms are structural and carry no units, so they fix roles and not sizes", and what experiment finds are dimensionless ratios (Measurement, Chapter 7, Section VIII). Every one of the twenty-six numbers of the Standard Model carries a stated standing, derived or measured (The Spectral Chain, Chapter 1, Section VII).

V. Cosmological Natural Selection and the Turn

Smolin's cosmological natural selection and the collection's turn begin from the same identification, a universe born at the end of a black hole's interior, and from there they diverge on three points.

The first is the number of universes. Cosmological natural selection needs a population: every black hole of every universe begins a universe of its own, and the universes that make the most black holes leave the most descendants. In the collection the ends of all interiors are one. No comparison of the epoch in which a hole forms registers the end of its interior, and the context of the new epoch re-forms with no prior identity, keeping no trace of which old region it came from: "Every possible comparison therefore gives the end of one interior the same verdicts as the end of another, and the ends are one" (At the Edge of Reality, Chapter 11). There is one next epoch, not one per black hole. This holds for holes that form at any time in the old epoch, early or late: the end of an interior is registered by no comparison of that epoch, so no clock of that epoch dates it. One next epoch is the singular universe that Smolin and Unger argue for, held exactly.

The second is inheritance. Selection needs heredity: the constants of a new universe must be those of its parent, changed by a small amount. In the collection, every distinction of the old epoch ends at the turn: none crosses it as a

distinction. Nothing that told one thing from another in the old epoch, no value, no record and no identity of a region, is carried into the new one. The book says of the new epoch's context: "I take that context to register no distinction that the old outside world drew, so no comparison of the new epoch registers from which interior any part of its content came" (At the Edge of Reality, Chapter 11), and every count has a context, so no count reckoned in the old epoch is carried across (The Compactification, Chapter 3, Section V). With no parent registered, there is no lineage for selection to act on.

The third is the constants. In cosmological natural selection the constants are what varies and what is selected. In the collection the structure is fixed in every epoch by the axioms, and does not vary at all. For the measured ratios, the collection's own results hold whether or not the ratios repeat from epoch to epoch: its rule for the amount of dark matter, The Weight of Possibility, Chapter 3, Section I, notes, "does not depend on whether the ratios of the content repeat, since the identity concerns what the present measurement registers".

Smolin's proposal deserves its credit. It took the black-hole origin of a universe and made it explain something, the values of the constants, and it made claims a measurement could bear on. The collection takes the same origin and explains the structure instead, by a route that needs neither a population nor a lineage.

VI. Loop Quantum Gravity and the Arena

The objection from loop quantum gravity is one the collection states at full strength. The Unquantized Arena, Chapter 4, Section III: "That program finds discrete spectra for the operators of area and volume (Rovelli and Smolin 1995; Ashtekar and Lewandowski 1997), and its proponents read those spectra as a discreteness of geometry itself". Rovelli and Smolin call the spectra predictions for hypothetical measurements of the geometry of space at the Planck scale.

The collection answers it where it rests. "The spectra are spectra of operators defined after the arena has been quantized". That the operators are finite, independent of any background and unchanged under every change of co-

ordinates makes them well defined; the question is what they are operators on, and they are operators on a quantized arena. The collection holds that the arena is not quantized, and it says exactly what that means: "(i) The arena has no least step: no least length, area or duration. (ii) Nothing is a quantum of the arena itself, at any scale" (The Unquantized Arena, Proposition 6.3). The ground is the theorem: gravity is the context of every finding, continuous and uneven, and to describe the context in the character of content, discrete and governed by symmetry, is to pair what the theorem forbids to pair: one description of space and time would carry both the continuity and unevenness of the geometry and the discrete sameness of quanta.

The measurements so far agree. Many models of a granular arena make light of different energies travel at slightly different speeds, so that photons of different energies from a distant burst arrive at different times. None has been seen. The Fermi telescope's photon of 31 GeV from the burst GRB 090510 puts the energy at which a first-order effect would appear above 1.2 times the Planck energy (Abdo and colleagues 2009). The LHAASO observatory's observations of GRB 221009A put it above ten times the Planck energy (Cao and colleagues 2024), as The Unquantized Arena, Chapter 19, sets out. The collection predicts no such spread at any energy, because the arena has no least step, and, by Proposition 5.3 of The Unquantized Arena, on no other route either, as Section IX sets out. Smolin himself wrote in 2001 of how far the programs of quantum gravity remained from what they were meant to reach (Smolin 2001, as the collection's book What Cannot Be reports); the collection holds that the reason is the same in every program, the attempt to give the arena the character of its content, that is, to treat space and time as made of quanta, as matter is.

VII. Quantum Theory, Complete in Its Scope

Smolin and the collection agree that the postulates of quantum mechanics, as usually taught, explain nothing about where they come from. Smolin concludes that the theory is incomplete and that a realist theory beneath it must be found. The collection derives the postulates instead. The Quantum Passage obtains the algebra of quantum observables, the Hilbert space of states and the Born rule from the structure of comparison, and finds that the measure-

ment problem comes from treating an update of the shared record as a physical process: "the state update upon measurement is not a physical process. It is not an additional dynamical law". The correlations of quantum mechanics exceed the bound that any shared origin of definite values obeys, so a hidden layer of such values beneath the quantum description cannot produce them (The Basis of Physics, Why Hidden Variables Cannot Help). Smolin's realism and the collection's agree that the world is real and is not made by being observed; they part on whether quantum mechanics is missing something. On the collection's account quantum mechanics is complete in its scope: it is the theory of content, as general relativity is the theory of context.

VIII. Time and Space Both Counted

In his later work Smolin takes time as fundamental and space as something that emerges from relations among events. The collection counts both from one source. Measurement, Chapter 4, Section VIII, gives the second of its two roads. The second axiom orders the three roles of comparison in a cycle with three transitions: from the stance to the act, from the act to the laid-out finding, and from the laid-out finding to a new stance. Each transition is identified with an independent direction of extension, three directions of space, and the cycle has one direction, the order of its return, identified with the one direction of time. Time and space are both what the structure of comparison gives when it is counted, so time is not prior to space, and space does not emerge from time. Time is real for the same reason space is: comparison has that structure.

IX. Where the Predictions Part, and Why

In four places the registered predictions of 1 November 2026 (the sealed record, *The Registered Predictions of Physics from Comparison*, reproduced whole in Volume One as its Appendix B) and Smolin's own work say that experiment will find different things. For each, this section sets the argument of the book the sealed prediction rests on beside Smolin's own reasoning, and finds the first premise or step at which the two part. Where both sides follow from

different premises, the section names the premise in dispute and what would settle it; where a step on either side does not follow, the section names the step.

Discrete area and volume

The sealed prediction. "No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else", registered on 1 November 2026 as the second sentence of Prediction 5.

The argument of the book. The Unquantized Arena, Chapter 6, Section II, sets out the chain with what each step rests on. The law of continuity governs context, and gravity is the context of physics, its arena. So the findings of the arena, perfected at their foundation, "take smooth values with no gaps" (Proposition 4.2). To quantize the arena would give one description of it the continuity and asymmetry of the context together with the discontinuous symmetry of a quantized finding, and so "it would carry at least one of the two forbidden pairings" (Proposition 6.1). And so, for area and volume: "A least step of the arena would be a discontinuity in its findings, and by the law of continuity and Proposition 4.2 the findings of the arena have none at their foundation" (Proposition 6.3).

His argument. Rovelli and Smolin (1995) start from general relativity written in Ashtekar's variables (a rewriting of the theory, due to Abhay Ashtekar, in which the geometry is carried by a field of the kind that carries the other forces), and quantize it with no background, as any field with dynamics of its own is quantized. The states of the quantized geometry are spin networks (graphs whose edges and nodes carry labels of spin). The operators for the area of a surface and the volume of a region, defined on those states, have discrete spectra, and Rovelli and Smolin read those spectra as the geometry of space at the Planck scale.

Where they part. They part at the first premise. For Smolin, the geometry is a field with dynamics, like the others, and so it has quantum states of its own. For the collection, the geometry is the context in which every finding is made, and the law of continuity governs it.

Whose step, and what decides it. Each chain follows from its own premises, so the difference is a premise, and it can be stated in one sentence: the geometry of space and time is the context of every finding, and not one more content found within it. The premise is a claim about what a thing is. The sealed record names what reaches it, "every observation of the spectrum of area or volume", and it states that "Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed"; so a measurement of geometry at the Planck scale is what would separate the two. One step inside loop quantum gravity is open on the program's own ground, apart from anything the collection says. The operators whose spectra are discrete do not commute with the quantum constraints, and Bianca Dittrich and Thomas Thiemann (2009) showed, in simpler models, that "kinematical discreteness of the spectrum does not necessarily survive at the gauge invariant level"; Rovelli (2007) replied that their counter-example "illustrates a pathology which does not seem to be present in gravity". So the step from the computed spectra to a discreteness that a measurement would find has not been completed inside the program either. On the collection's side, The Unquantized Arena already places the spectra exactly: they "belong to the step whose coherence Chapter 6 examines" (Chapter 4, Section III). The two rest on different premises, and no fault is found on either side.

The speed of light at every energy

The sealed prediction. "The speed of light in vacuum does not depend on the energy of the light through any step of spacetime", registered on 1 November 2026 as the first sentence of Prediction 5.

The argument of the book. The Unquantized Arena, Chapter 19, Section V, gives the route by which a dependence would come: "A step of spacetime would generally change the relation between energy and momentum of light at high energy". The arena has no step (Proposition 6.3), so that route is closed, and "the account says that the arrival times will show no such dependence". The same section adds that "A discreteness that keeps Lorentz in-

variance, as in causal sets (Bombelli, Henson and Sorkin 2009), predicts no such dispersion", and that the step these observations test "is the category error of Chapter 6: that the arena is not quantized and has no least step".

The same section closes every other route by a ground that uses no step at all: "Light of every energy follows the light cone of the one geometry, and the account's ground for that uses no step of spacetime" (The Unquantized Arena, Chapter 19, Section V). The ground is Proposition 5.3: "the coupling of every content to the arena equals its inertia, and the ratio is the same for every content", so "the free path of a content through a geometry is set by the geometry and not by the mass or the energy of the content". For light that free path is the light cone, "and within one geometry the light cone is the same in every frame" (Chapter 7, Section IV, in the argument of Proposition 7.2). So "A speed of light that depended on the energy of the light would give light of each energy its own free path through one geometry, set by a property of the content, and the equal ratio of Proposition 5.3 excludes that, whether the dependence came from a step of spacetime or from some other source". The book names Smolin's route as one such source, "a deformed symmetry of special relativity that keeps, beside the speed of light, a second quantity the same for every observer, an energy of the order of the Planck energy, set into the symmetry itself and not into a step of spacetime (Magueijo and Smolin 2002)", and it excludes the versions of that symmetry in which the speed of light depends on its energy "on the ground just given".

His argument. Smolin's route is a different one. With João Magueijo he proposed that "a physical energy, which may be the Planck energy, joins the speed of light as an invariant", through "a non-linear modification of the action of the Lorentz group on momentum space" (Magueijo and Smolin 2002). With Giovanni Amelino-Camelia he then set out how the photons of gamma-ray bursts can bound or measure a dispersion of light that comes "from breaking or deforming of Poincare invariance" (Amelino-Camelia and Smolin 2009). On this route an energy dependence comes from a deformed symmetry of the arena, and no least step is needed for it.

Where they part. For the collection, the free path of light through a geometry is set by the geometry alone, because the coupling of every content to the arena equals its inertia, so light of every energy follows the one light cone.

For Smolin, the symmetry of the arena can be deformed so that it keeps an energy invariant, and the speed of light can then depend on its energy with no least step.

Whose step, and what decides it. Both chains follow from their premises, and the premise in dispute can be stated in one sentence: light of every energy moves on the light cone of the one geometry, so no symmetry of the arena, kept or deformed, makes its speed depend on its energy. The collection holds it on the ground of Proposition 5.3, which reaches the step of spacetime that the sealed sentence names and a deformed symmetry alike. Smolin's route has its own difficulty, on its own ground, and The Unquantized Arena credits the work that shows it. Sabine Hossenfelder (2010) showed that a speed of light that depends on energy the same way for every observer has non-local effects, and that keeping them within known particle physics allows her to "rule out a modification to first order in energy over the Planck mass". She later named a second difficulty: "The most pressing problem in these models is the treatment of multi-particle states, known as the 'soccer-ball problem'" (Hossenfelder 2014). "The timing bounds of Table 19.2 test a deformed symmetry and a step of spacetime alike", as the same section of The Unquantized Arena states. And measurement has reached the scale Smolin's route names. As Section VI reported in part, for a dependence of the first order, the energy at which it would appear lies above 1.2 times the Planck energy from one photon of the burst GRB 090510 (Abdo and others 2009), above 7.6 times from several bursts (Vasileiou and others 2013), and above ten times from GRB 221009A (Cao and others 2024), as The Unquantized Arena sets out. All three are of one kind, the timing of photons from bursts, and the rule of decision (a result counts when it is established at five standard deviations by at least two independent kinds of measurement) asks for two independent kinds, so the three together count as one kind of evidence toward a decision. A dependence of the second order is bounded only at energies far below the Planck energy, and no measurement yet reaches it at the Planck energy. The neutrinos from bursts that Amelino-Camelia and Smolin proposed would give the second, independent kind of measurement.

The sealed prediction. "Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights", registered on 1 November 2026 as Prediction 25.

The argument of the book. The Quantum Passage, Chapter 7, derives the weights in three layers. The Incommensuration Theorem makes the outcome a residual, what is left of a finding once every law has been applied, which no law fixes, and "the state before the measurement, known as fully as the theory allows, gives the weight of each outcome, and the outcome found is not contained in it". A probability is "the stable relative frequency of an outcome over repetitions of one comparison" (Section IV). And "The single weight of a finding follows from the law of symmetry" (Section VI), after which Gleason's theorem (the theorem that, on a space of states of three or more dimensions, every consistent assignment of weights to outcomes takes the form of the Born rule) leaves the Born rule as the only measure. A law, in the collection, states what stays the same when the circumstances of a measurement change (Section III above), and how many times the measurement has been made before is one of those circumstances. The weight of an outcome is fixed by the law of symmetry alone (The Quantum Passage, Chapter 7, Section VI), so it is the content of a law, and the content of a law is the same across every change of circumstance, the count of earlier instances included. So the weight the state gives an outcome holds at the first finding as at the millionth.

His argument. Smolin (2012b) proposes that "the outcome of the present measurement is determined by picking randomly from the ensemble of precedents of that measurement". Where there are no precedents, nothing has formed the habit: "The first several iterations of a novel state are not determined by any law". His real ensemble formulation (Smolin 2012a) likewise implies departures from quantum mechanics for states expected to have few copies in the universe.

Where they part. They part on what holds the weight of a first finding. For the collection, the present state of the system holds it, whether or not the measurement has been made before. For Smolin, the record of earlier instances holds it, and a first instance has none.

Whose step, and what decides it. Each step follows from its premises; the difference is the premise about what holds the weight of a first finding. Two findings come out of setting the arguments side by side. On Smolin's side, the principle gives no rule for which earlier instances count as the same measurement; Smolin writes that it "takes the notion of copy, or similar preparation or measurement, as a primitive" (Section 4). The principle predicts a departure for a named experiment only once that rule is given, because a new entangled state of parts that have each been prepared countless times can be counted either as new or as old. On the collection's side, the sealed sentence speaks of what repeated measurements "settle to", and Smolin's principle allows the same long-run weights once precedents have formed. So the two part in the first outcomes, which The Quantum Passage addresses in its words that the state "gives the weight of each outcome", and which the sealed sentence leaves aside. What follows from the two statements is the measurement that would decide: the first outcomes of many distinct states, each prepared for the first time and measured once, pooled against the weights each state gives. That design is not in the sealed record. The nearest measurement made is the sampling of random circuits on a superconducting processor (Arute and others 2019): each circuit was new, each was sampled between half a million and two and a half million times, and the authors report that their "system fidelity is well predicted by a simple model" built from the errors of single gates and measurements. That sampling reaches the long-run weights of states without precedent, and not their first outcomes.

Galaxies at low acceleration

The sealed prediction. "A galaxy falling freely in the field of a larger one feels that field only through its tide; the external field effect that modified Newtonian dynamics predicts will not be found", registered on 1 November 2026 as Prediction 24.

The argument of the book. The Weight of Possibility, Chapter 5, Section V, takes up the measured acceleration scale of the galaxies and asks whether the cosmological constant sets it. "The field equations hold Newton's constant and the cosmological constant, and no constant of acceleration". The pull with which the cosmological constant draws two free bodies apart comes to "about 1.0×10^{-15} meters per second per second across ten kiloparsecs, the size of a galaxy, which is less than a hundred-thousandth of the scale". So "With the field equations exact throughout the domain of the smooth description, below the Planck curvature, as the Passage derives them, a galaxy falling freely in the field of a larger one feels that field only through its tide, as general relativity requires". Beneath that lies the equality of gravitational and inertial mass, which the collection derives. The Unquantized Arena, Proposition 5.3: "For a context-modal phenomenon, the coupling of every content to it equals that content's inertia" (a context-modal phenomenon is one that belongs to the context, the arena, and not to the content found in it), because "for the context there is only the one relation, so the coupling and the inertia have nothing to differ by". The Weight of Possibility applies Proposition 5.3 to gravitation, which "is a distortion of a context", and draws the consequence: "That holds at every acceleration and in every environment, so the ratio of gravitational to inertial mass is one everywhere, and no temperature of the horizon enters inertia apart from weight". With that sentence the section answers "the second route by which the horizon has been proposed to set the scale", the route through the de Sitter temperature that Smolin (2017) proposed.

The same section accounts for the tightness of the relation between the visible matter and the motions of galaxies, which is where the scale is measured: "The tightness of that relation follows from galaxy formation under general relativity with a cold component that acts only through gravity, and the account inherits it because the gyrations are such a component". The gyrations are the collection's dark matter: conserved excitations of the six held internal dimensions (kept at the same size and shape at every point), each of about the Planck mass. "Simulations of galaxy formation with such a component reproduce the relation and its small scatter (Keller and Wadsley 2017; Ludlow and others 2017; Dutton and others 2019)", and the section traces the

origin of the relation to "the self-similar profiles of cold halos, in the narrow range of halo mass in which disc galaxies form, and in the slow relaxation of the dark component around the gathering ordinary matter (Navarro and others 2017; Paranjape and Sheth 2021)". So "The acceleration at which the relation turns is therefore set by formation and not by a constant of the field equations, and the clusters of galaxies show it: there the same form turns at (2.02 $\pm$ 0.11) $\times$ 10^{-9} meters per second per second, about seventeen times the galactic value (Tian and others 2020; Tian and others 2024)".

His argument. Smolin (2017) builds on Verlinde's hypothesis that gravity is entropic, and takes inertia to arise from how well a particle can be localized. An accelerated body in a world with a positive cosmological constant sees a temperature, and the cosmic horizon has an irreducible temperature of its own, the de Sitter temperature. Taking the response to acceleration from the excess of the one temperature over the other makes the ratio of inertial to gravitational mass equal to the acceleration divided by the de Sitter scale of acceleration, wherever the acceleration falls below that scale. The de Sitter scale of acceleration is the speed of light squared times the square root of the cosmological constant, and in the limit Smolin takes, that ratio gives Milgrom's law. Free fall stays the same for every body at one place, but the ratio of the two masses "can depend on global or environmental parameters". He presents it as a tentative proposal (Smolin 2017, Section 6).

Where they part. For the collection, a body's inertia and its weight are one relation of the body to its context, found twice, so their ratio is one at every acceleration. For Smolin, inertia is a thermal response that also depends on the temperature of the cosmic horizon, so the ratio falls below one under the de Sitter scale. Both keep free fall the same for every body at one place, so the measurements of the universality of free fall, which compare bodies of different composition, do not separate them.

Whose step, and what decides it. Both chains follow from their premises; the premise in dispute is this: a body's inertia is the same relation to its context as its weight, at every acceleration, with nothing added from the temperature of the cosmic horizon. The premise is a claim about what inertia is, and motions at low acceleration reach it. The wide binary stars measured by the Gaia satellite preferred Newtonian dynamics over the modified dynamics "at

19σ confidence", that is, at nineteen standard deviations (Banik and others 2024); Kyu-Hyun Chae reported an anomaly in the binaries he selected (Chae 2024), and later, with colleagues, in a sample of 36 wide binaries (Chae and others 2026); a reanalysis of those 36 binaries that models their orbits in three dimensions found them consistent with Newtonian gravity (Saad and Ting 2026). In galaxies, a sample analyzed with the external field separated from the surroundings in which each galaxy formed would give the second kind of measurement; the 2020 report of an external field effect (Chae and others 2020) estimated each galaxy's external field from its neighbors and did not separate the external field from the surroundings in which each galaxy formed. The sealed record names no measurement that decides Prediction 24; this paragraph names two.

X. Summary

Lee Smolin holds that time is real, that the universe is one, that the laws of physics are not a timeless mathematical object outside the world, that physics is built from relations, and that a universe can begin inside a black hole. The physics collection holds all of this, from the structure of comparison: time is the direction in which comparison proceeds; the universe is a process, one sequence of epochs; no view stands outside it; relation is the one premise; and the end of each black-hole interior is the turn to the next epoch. The two share Leibniz's principle, which the collection states as a fact about comparison: a difference that no comparison can register is no difference.

They part on four points of principle. Smolin lets the laws change to keep the future open; the collection keeps the future open with laws that stay the same, because the theorem forbids any law to be perfected together with continuity. Smolin's universes form a population that inherits and varies its constants; in the collection the ends of all black-hole interiors are one, nothing crosses the turn as a distinction, and the structure of physics is fixed in every epoch by the axioms. Smolin's arena comes in discrete steps of area and volume; the collection's arena has no least step, and the measurements of light from distant bursts so far find no sign of one. Smolin seeks what is miss-

ing beneath quantum mechanics; the collection derives quantum mechanics and finds it complete in its scope. In each case Smolin found the right question and the collection answers it from the structure of comparison.

Set side by side, the arguments behind the four differing predictions part at premises, not at faulty steps: whether the geometry is the context of every finding, whether light of every energy follows the one light cone, what holds the weight of a first finding, and whether inertia is the one relation of a body to its context. The collection's ground for the second and the fourth is one proposition, that the coupling of every content to the arena equals its inertia: it excludes an energy-dependent speed of light whether the dependence comes from a least step or from a deformed symmetry, and it excludes any temperature of the horizon entering inertia apart from weight. Galaxy formation with a cold component accounts for the tightness of the relation between the visible matter and the motions of galaxies, and for the acceleration at which that relation turns. Time is real, on both accounts; the collection finds it real in every act of comparison, with laws that need not change to keep it so. Smolin holds that physics went wrong when it took its timeless mathematics for the world; Max Tegmark, in the next chapter, holds that the world is a mathematical structure, and he reaches that claim from a premise both accounts share.

Key Concepts

- Time is real because comparison runs one way: from stance, to act, to record, with the record shaping the next stance.
- The view from nowhere is real, and the laws are stated in it; the error is to take it for everything.
- Leibniz's principle, stated for comparison: a difference that no comparison can register is no difference.
- Smolin's precedence is a memory of instances; the collection's precedence is the order of every single comparison.
- Laws are statements of what stays the same; determinism cannot be had, so laws that stay the same leave the future open.
- The turn: one next epoch, not a population; nothing crosses it as a distinction; the structure is fixed by the axioms in every epoch.
- The arena is not quantized: no least length, area or duration, and nothing is a quantum of the arena at any scale.
- Where the predictions differ, the two accounts part at premises: the geometry as context, light of every energy on the one light cone, the present state as what holds a weight, and inertia and weight as one relation.

Terms

Content and context. In every comparison, what is found and the arena it is found in; in physics, quantum matter and the geometry of general relativity.

Cosmological natural selection. Smolin's proposal that each black hole begins a new universe whose constants differ slightly from its parent's, so that universes that make many black holes predominate.

De Sitter temperature. The temperature that the horizon of a universe with a positive cosmological constant has, the least temperature an observer in it can see.

Deformed special relativity. A proposal, made by Magueijo and Smolin and by Amelino-Camelia, that an energy, perhaps the Planck energy, is the same for every observer as the speed of light is, with the symmetry of the arena changed at high energy to keep it so.

External field effect. The prediction of the modified Newtonian dynamics that a system falling freely in the field of a larger one moves differently because of that field, beyond its tide.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Inertia. A body's resistance to a change in its state of motion; in the collection, the same relation of the body to its context as its weight, found a second time.

Loop quantum gravity. A program that quantizes the geometry of space without a fixed background, in which areas and volumes take discrete values.

Principle of precedence. Smolin's proposal that the outcome of a quantum measurement is drawn from the outcomes of earlier instances of the same measurement.

Root Tautology. Comparison, interaction and relation are one act under three names.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Second axiom. The directed cycle of the three roles of comparison, an order of precedence and not of clock time, converging from many to one at each step.

Stance. The side from which a comparison is made; it belongs to every comparison, human or not.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

References

Abdo, A. A. and others (Fermi LAT and GBM Collaborations) (2009). "A limit on the variation of the speed of light arising from quantum gravity effects". *Nature* 462, 331–334.

Amelino-Camelia, G. and Smolin, L. (2009). "Prospects for constraining quantum gravity dispersion with near term observations". *Physical Review D* 80, 084017. arXiv:0906.3731.

Arute, F. and others (2019). "Quantum supremacy using a programmable superconducting processor". *Nature* 574, 505–510.

Banik, I., Pittordis, C., Sutherland, W., Famaey, B., Ibata, R., Mieske, S. and Zhao, H. (2024). "Strong constraints on the gravitational law from Gaia DR3 wide binaries". *Monthly Notices of the Royal Astronomical Society* 527, 4573–4615. arXiv:2311.03436.

Cao, Z. and others (LHAASO Collaboration) (2024). "Stringent tests of Lorentz invariance violation from LHAASO observations of GRB 221009A". *Physical Review Letters* 133, 071501.

Chae, K.-H. (2024). "Breakdown of the Newton–Einstein standard gravity at low acceleration in internal dynamics of wide binary stars". *The Astrophysical Journal* 960, 114.

Chae, K.-H., Lelli, F., Desmond, H., McGaugh, S. S., Li, P. and Schombert, J. M. (2020). "Testing the strong equivalence principle: detection of the external field effect in rotationally supported galaxies". *The Astrophysical Journal* 904(1), 51. DOI 10.3847/1538-4357/abbb96. arXiv:2009.11525.

Chae, K.-H., Lee, B.-C., Hernandez, X., Orlov, V. G., Lim, D., Turnshek, D. A. and Lee, Y.-W. (2026). "Detection of gravitational anomaly at low acceleration from a highest-quality sample of 36 wide binaries with accurate 3D velocities". arXiv:2601.21728.

Cortês, M. and Smolin, L. (2014). "The universe as a process of unique events". *Physical Review D* 90, 084007. arXiv:1307.6167.

Dittrich, B. and Thiemann, T. (2009). "Are the spectra of geometrical operators in loop quantum gravity really discrete?". *Journal of Mathematical Physics* 50, 012503. arXiv:0708.1721.

Dutton, A. A., Macciò, A. V., Obreja, A. and Buck, T. (2019). "NIHAO XVIII: Origin of the MOND phenomenology of galactic rotation curves in a LCDM universe". *Monthly Notices of the Royal Astronomical Society* 485(2), 1886–1899. arXiv:1902.06751. doi:10.1093/mnras/stz531.

Hossenfelder, S. (2010). "Bounds on an energy-dependent and observer-independent speed of light from violations of locality". *Physical Review Letters* 104, 140402. arXiv:1004.0418.

Hossenfelder, S. (2014). "The soccer-ball problem". *Symmetry, Integrability and Geometry: Methods and Applications* 10, 074. arXiv:1403.2080.

Keller, B. W. and Wadsley, J. W. (2017). "ΛCDM is Consistent with SPARC Radial Acceleration Relation". *The Astrophysical Journal Letters* 835(1), L17. DOI 10.3847/2041-8213/835/1/L17. arXiv:1610.06183.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Ludlow, A. D., Benítez-Llambay, A., Schaller, M., Theuns, T., Frenk, C. S., Bower, R., Schaye, J., Crain, R. A., Navarro, J. F., Fattahi, A. and Oman, K. A. (2017). "The Mass-Discrepancy Acceleration Relation: a Natural Outcome of Galaxy Formation in Cold Dark Matter halos". *Physical Review Letters* 118(16), 161103. DOI 10.1103/PhysRevLett.118.161103. arXiv: 1610.07663.

Magueijo, J. and Smolin, L. (2002). "Lorentz invariance with an invariant energy scale". *Physical Review Letters* 88(19), 190403. DOI 10.1103/PhysRevLett.88.190403. arXiv:hep-th/0112090.

Navarro, J. F., Benítez-Llambay, A., Fattahi, A., Frenk, C. S., Ludlow, A. D., Oman, K. A., Schaller, M. and Theuns, T. (2017). "The origin of the mass discrepancy-acceleration relation in ΛCDM". *Monthly Notices of the Royal Astronomical Society* 471(2), 1841–1848. arXiv:1612.06329. doi:10.1093/mnras/stx1705.

Paranjape, A. and Sheth, R. K. (2021). "The radial acceleration relation in a ΛCDM universe". *Monthly Notices of the Royal Astronomical Society* 507, 632–650. arXiv:2102.13116. doi:10.1093/mnras/stab2141.

Rovelli, C. (2007). “Comment on ‘Are the spectra of geometrical operators in loop quantum gravity really discrete?’”. arXiv:0708.2481.

Rovelli, C. and Smolin, L. (1995). “Discreteness of area and volume in quantum gravity”. *Nuclear Physics B* 442, 593–619.

Saad, S. M. and Ting, Y.-S. (2026). “No gravitational anomaly in wide binaries from forward modeling of 3D orbits”. arXiv:2603.11015, version 2, 9 September 2026; version 1 (March 2026) was titled “Gravitational anomaly measurement in wide binaries is sensitive to orbital modeling”. doi: 10.33232/001c.170182.

Smolin, L. (1992). “Did the universe evolve?”. *Classical and Quantum Gravity* 9, 173–191.

Smolin, L. (1997). *The Life of the Cosmos*. New York: Oxford University Press.

Smolin, L. (2001). *Three Roads to Quantum Gravity*. New York: Basic Books.

Smolin, L. (2006). *The Trouble with Physics*. Boston: Houghton Mifflin.

Smolin, L. (2012a). “A real ensemble interpretation of quantum mechanics”. *Foundations of Physics* 42, 1239–1261. arXiv:1104.2822.

Smolin, L. (2012b). “Precedence and freedom in quantum physics”. arXiv: 1205.3707.

Smolin, L. (2013). *Time Reborn*. Boston: Houghton Mifflin Harcourt.

Smolin, L. (2017). “MOND as a regime of quantum gravity”. *Physical Review D* 96, 083523. arXiv:1704.00780.

Smolin, L. (2019). *Einstein’s Unfinished Revolution*. New York: Penguin Press.

Tian, Y., Umetsu, K., Ko, C.-M., Donahue, M. and Chiu, I-N. (2020). “The Radial Acceleration Relation in CLASH Galaxy Clusters”. *The Astrophysical Journal* 896, 70. arXiv:2001.08340. doi:10.3847/1538-4357/ab8e3d.

Tian, Y., Ko, C.-M., Li, P., McGaugh, S. and Poblete, S. L. (2024). “A Distinct Radial Acceleration Relation across the Brightest Cluster Galaxies and Galaxy Clusters”. *Astronomy and Astrophysics* 684, A180. arXiv:2402.12016. doi:10.1051/0004-6361/202347868.

Unger, R. M. and Smolin, L. (2014). *The Singular Universe and the Reality of Time*. Cambridge: Cambridge University Press.

Vasileiou, V., Jacholkowska, A., Piron, F., Bolmont, J., Couturier, C., Granot, J., Stecker, F. W., Cohen-Tanugi, J. and Longo, F. (2013). “Constraints on Lorentz invariance violation from Fermi-Large Area Telescope observations of gamma-ray bursts”. *Physical Review D* 87, 122001. arXiv:1305.3463.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Max Tegmark

The Structure and the Act

Max Tegmark's Mathematical Universe and Physics from Comparison

Abstract

If the world does not depend on us, must it be mathematics? Max Tegmark holds that the physical world is a mathematical structure. He reaches the claim from a premise the physics collection of the Immanent Metaphysics shares: that there is an external physical reality completely independent of us humans. Two of his results stand inside the collection's own arguments. His estimate of decoherence in the brain is cited by the collection against the hypothesis that consciousness rests on sustained quantum coherence in neurons, and his analysis of the dimensions of spacetime is cited in support of the count of one direction of time. The collection parts from Tegmark at the step from an independent world to a mathematical one. A mathematical structure exists, laid out and the same in every instance; a finding is real, given in an actual act of comparison; and the frame of mathematics is the frame that has set aside the stance from which every comparison is made: mathematics describes what is found as if no one stood anywhere to find it. To take the world for a mathematical structure is to take that frame for everything. The essay sets out Tegmark's position at its full strength, the ground the two share, the step at which they part and why, his restriction to computable structures beside the collection's three grounds against a computed world, his four levels of multiverse level by level, and his account of consciousness as a state of matter beside the collection's bound triple, the arrow of time, hard randomness and the subjective, distinct and inseparable, taken as one act. Where the two accounts predict different results, on the primordial waves of the metric, a long phase of inflation and the nature of the dark matter, the essay sets the argument of each book behind the sealed prediction beside Tegmark's own reasoning and finds the premise at which they part.

I. Tegmark's Position

Max Tegmark, a cosmologist at the Massachusetts Institute of Technology, set out his central hypothesis in "The Mathematical Universe" (2008) and at book length in *Our Mathematical Universe* (2014). His argument starts from what he calls the External Reality Hypothesis: there exists an external physical reality completely independent of us humans. He then argues that a complete description of such a reality must be free of every human notion, every word and concept that only humans use, and that a description with all such notions removed is a purely abstract structure. In his words, "with a sufficiently broad definition of mathematics", the External Reality Hypothesis implies the Mathematical Universe Hypothesis: that our physical world is an abstract mathematical structure. On this view the world is mathematics (as distinct from a world that obeys mathematics), and the observers inside it are parts of the structure.

Three further claims follow in his work. He adds the hypothesis that only computable and decidable structures exist, in Gödel's sense of decidable, a restriction he offers to ease the problem of how to weigh infinitely many possibilities and to explain why the laws of physics look simple. He arranges parallel universes in four levels: Level I, regions of our own space beyond our cosmic horizon, with the same laws; Level II, other regions left by inflation, where the constants and even the effective laws differ; Level III, the branches of quantum mechanics on Hugh Everett's many-worlds account; and Level IV, every other mathematical structure, each as real as ours. And in "Consciousness as a State of Matter" (2015) he proposes that consciousness is a state of matter, which he calls perceptronium, marked by its abilities to process information and characterized by five principles: information, integration, independence, dynamics and utility.

Two earlier results of Tegmark's are cited in the collection on their own merits. In "On the Dimensionality of Spacetime" (1997) he showed that with two or more directions of time the wave equation becomes ultrahyperbolic, and that its initial value problem is then ill posed for data given on a surface that contains no direction of time. In "The Importance of Quantum Decoherence in Brain Processes" (2000) he estimated that quantum superpositions in the brain lose their coherence in times of the order of 10^{-13} to 10^{-20} seconds,

much shorter than the times on which neurons act, and concluded that the degrees of freedom of the brain that bear on thinking should be treated as classical.

II. The Ground the Two Share

The collection agrees with the first half of Tegmark's argument, the External Reality Hypothesis, read plainly: the world does not depend on human beings. Objections from Physics, Answered, in its entry on Tegmark, states that agreement first, and grounds it in the collection's own terms. An observer, in the collection, is a comparer, "a position inside the world, and it never names a mind"; and "Events before any observer were related as they are now". Every interaction is a comparison, so the world was comparing itself, in every collision of particles, long before anything human looked at it. Tegmark's External Reality Hypothesis is a claim the collection holds on a ground of its own.

The collection also takes up both of Tegmark's earlier results, each at its own scope. His analysis of 1997 supports, from the field equations, the count of one direction of time, which the collection draws from the directed order of its second axiom: "Analyses of the field equations support the same count". The books cite it as a support from the field equations, beside their own ground. His estimate of 2000 is the standard objection to the hypothesis of Stuart Hameroff and Roger Penrose, which places consciousness in sustained quantum coherence in the microtubules of nerve cells. The collection accepts the estimate and states where it bears: The Basis of Physics, Essay 19, distinguishes its own account from that hypothesis, which "meets the standard objection that entanglement in warm neural tissue decoheres far too quickly to bear on neural events (Tegmark, 2000)", and adds that the Immanent Metaphysics "does not depend on any specific biological mechanism, and it needs no sustained entanglement in the brain". Objections from Physics, Answered, puts the consequence in one sentence: "the decoherence times bear on the hypothesis of Hameroff and Penrose, and not on the step". The channel the collection names for the indeterminacy of a choice is sensitive dependence near

criticality, where small disturbances cascade (The Basis of Physics, Essay 19, Section V), and not sustained coherence; Tegmark's estimate leaves that channel untouched.

III. The Step at Which They Part

The collection denies the second half of Tegmark's argument, the Mathematical Universe Hypothesis that the world is a mathematical structure, and it denies it on the ground of a distinction it draws exactly. Comparison, Chapter 10, Section II:

> "To say that something exists is to say that it stands as structure: timeless, the same in every instance, like the pattern of a law, or the state of a system at an instant. To say that something is real is to say that it is given in an actual act of comparison: temporal, occurring now, with the future still open to possibilities not yet settled. A law exists; a measurement is real".

Every physical theory has both: its mathematics, which exists, and its findings, which are real. Tegmark's hypothesis takes the first for the whole. The Basis of Physics, Essay 3, Section IV, names the step:

> "To take the structure that exists for the act that is real is to take mathematics for physics. Mathematics is, and cannot not be, founded on patterns of relation laid out as structure. Physics is, and cannot not be, founded on patterns of interaction. Structures model interactions; they do not become them".

The reason a structure cannot become the act lies in the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. Every finding of physics is a comparison, made at some moment, after one moment and before anoth-

er, so every finding falls under it. Mathematics, taken as objects that simply are, has no one comparing in it, and so, in the words of Physics Is Not Math, Chapter 3, Section VII, quoting Incommensuration, it has "no comparison in it and no time":

> "In a domain from which temporal comparison is removed, symmetry and continuity can be written down together. Such a domain is not a real world, precisely because the real world has a temporal element and that domain does not".

A mathematical structure can be smooth and perfectly symmetric at once, like the circle of geometry; no comparison ever finds a thing that is both. Every mathematical structure, taken as a whole, is laid out at once and is the same in every instance, so as a whole it holds the perfect sameness and the gapless completeness that no single act of comparison can hold together, whatever its parts look like; the circle shows it, and a structure that is discrete and irregular in its parts is no exception. So the world that comparisons find, the only world physics has, is not a mathematical structure, and a mathematical description of it, however exact, is never complete. Measurement, Chapter 14, Section XI, names Tegmark's ordering among the three orderings of physics, logic and computation that are often proposed, "mathematical Platonism takes logic as fundamental, and physics as an instance of a mathematical structure", and answers it: "None reduces to another. Physics does not reduce to logic: a purely symmetric description of a continuous process would perfect both characters, and the theorem forbids it; the mathematical description of physics is very powerful and never complete".

Physics Is Not Math gives the same result as an order of depth, an order of what each thing presupposes: metaphysics, then physics, then computation, then mathematics (Chapter 5). Mathematics stands after computation, because every proof is checked by a run (Chapter 7); computation stands after physics, because every run is a physical process; and physics stands after the act of comparison, because every finding of physics is a comparison made from inside the world. Tegmark's hypothesis reverses the whole order, placing mathematics at the bottom and physics, with everything in it, inside mathematics. The collection's order keeps every power mathematics has. As Comparison, Chapter 10, Section IX, puts it: "Mathematics keeps everything it

has. Its necessity is real necessity; its validity is exact ... None of this lowers mathematics". What it changes is where mathematics stands: last, as the finest instrument there is for what is laid out as structure.

IV. Why a Description Free of Humans Still Has a Stance

Tegmark's step from the External Reality Hypothesis to the Mathematical Universe Hypothesis has one hinge. A description of a reality independent of humans must contain nothing human; a description with nothing human in it is pure structure; so the reality is pure structure. The collection accepts the first premise and denies the second, and the reason is the distinction between a human and a stance.

Every comparison is made from somewhere. Physics Is Not Math, Chapter 3, Section VI, sets out what the view from nowhere is: the objective standpoint at its limit, "a view that holds the same from every place, so that no place needs naming". The view is real, and the laws of physics are stated in it. But "the stance has not vanished: the law was found by comparisons made from stances, and it is read, every time it is read, by someone. The stance has been left unnamed, because the content is the same from every stance". The stance is the side from which any comparison is made, and a collision of two particles has one as surely as a laboratory does. A stance is not a human. Removing every human notion from a description removes nothing of the stance, because the stance was never human. So a description of a world independent of humans is still a description of a world in which comparisons are made from stances, and the structure that a third-person description lays out is one side of each such comparison, never the whole of it.

Physics Is Not Math, Chapter 3, Section VIII, names the generalization that Tegmark's hinge makes:

> "Mathematics assumes only the objective, and no subjective. That is right for mathematics. The assumption becomes a mistake when it is generalized, because it is not true everywhere. Generalized, the assumption says that the deepest truth about the world would be a truth with no stance in it".

And it says why the generalized assumption fails: "the generalized assumption asks of the world what no comparison in the world can give, and it calls the absence of an answer the deepest truth". The Mathematical Universe Hypothesis is that generalization taken to its end. Its vantage, from which the whole world is one structure, is the vantage Measurement, Chapter 2, Section II, rules out: "a description of the whole world from a vantage outside it has no comparison behind it, because the whole has no outside to compare it with".

V. The Computable Universe

Tegmark's restriction to computable and decidable structures brings his hypothesis into contact with a second claim the collection excludes: that the world is a computation. Physics Is Not Math excludes it on three independent grounds, each turning on what a computation is (Chapter 8, Section VII).

The first ground is determinism. A computation applies the same rule at every step, which is symmetry perfected, and fixes each state completely by the one before, which is continuity perfected; a whole world fixed completely in that way perfects symmetry and continuity together, the first pairing the Incommensuration Theorem forbids. So no world is purely and completely deterministic, and what every world has instead is causation, a connection without a break along the order in which findings are made. The second ground is the two levels of every exact description: a description and what it describes always take the two characters one each, so that a continuous description describes symmetric findings and a symmetric description describes continuous findings, and the description reaches what it describes as closely as one wishes without ever containing it. A computation has one character at both levels. The third ground is the bound triple, the arrow of time, hard randomness and the subjective, which are distinct, inseparable and not interchangeable: a computed world has no hard randomness of its own, so it has no arrow of its own and no stance of its own.

Which of computation and physics depends on the other is plain. Physics Is Not Math, Chapter 8, Section VI: "every computation that is carried out is a physical process, and physics, both the world it studies and the findings it makes, needs no computation". "Chapter 7 found that every proof waits on a

run; here the run waits on the world". A computable structure is a structure some run could produce, and every run is a process in the world, so restricting the mathematical universe to computable structures restricts it to what the world can do, and cannot make the world one of them.

Tegmark invokes Gödel's sense of decidability to draw his line. The collection gives Gödel's theorem its place as one instance of the Incommensuration Theorem's limit: a system both perfectly consistent and perfectly complete would perfect symmetry and continuity together, which is the first forbidden pairing. Every rendering of a structure leaves something it does not contain, and Gödel found that limit inside arithmetic (Physics Is Not Math, Chapter 21, Section V).

VI. The Four Levels, Level by Level

Level I: regions beyond our horizon. The collection has one arena, and every observer's comparable world is bounded by a horizon. In an accelerating universe every observer has a cosmological event horizon, a boundary beyond which no event can ever send a signal to that observer (At the Edge of Reality, Chapter 12). Regions beyond it are parts of the one arena, related to their own neighbors as our region is to ours. The collection's principle of existence fixes their standing: "Existence without any interaction whatsoever is indistinguishable from non-existence, and therefore is non-existence" (Objections from Physics, Answered, quoting Incommensuration, Chapter 9, Section I). Regions beyond a horizon interact with what is near them, so they exist; they are further parts of one world, and not another universe. On Level I the two accounts agree in substance, since Tegmark's Level I is the same space, with the same laws, beyond our horizon; they differ only in whether those regions are called another universe.

Level II: other regions left by inflation, with other constants. The collection excludes this level by three routes. It needs no inflationary phase and excludes a long one, so there is no eternal inflation to make the regions. Its internal space is one space and not a choice among many: "That the internal space is one space, and not a choice among many, has two grounds, reached by routes that use different premises" (The Compactification, Chapter 2, Section IX), so there is no landscape of vacua among which constants could vary. And the

cosmological constant, the value most often explained by selection among regions, is given by the collection without selection: The View from Inside sets out the strategy of accepting the landscape, in which the value "becomes an accident of location in a vast and unknowable multiverse", and gives a different answer from the structure of comparison.

Level III: the branches of many worlds. The collection reads every interpretation of quantum mechanics by which of the three roles of comparison it keeps and which it removes. In The Quantum Passage, Chapter 9, Section VIII, the many-worlds account "eliminates measurement time entirely": "In IM [Immanent Metaphysics] terms, this abolishes the immanent modality, violating Axiom III [the third axiom, which makes the three modalities distinct, inseparable and not interchangeable]". The immanent is the role of the act itself, the comparing as it happens. The book names the consequence: the inability of many-worlds to derive the Born rule from within its formalism "is the structural consequence of dropping the immanent modality. The Born rule is the bridge from the formalism to the findings, and the findings are given in the immanent act; remove the modality, lose the bridge". Physics Is Not Math adds the second ground: the many-worlds account describes a whole world as completely deterministic, and "A whole world completely fixed by a law perfects symmetry and continuity together, whichever account describes it, and the theorem forbids that pairing".

Level IV: every mathematical structure. This level is the Mathematical Universe Hypothesis applied to all structures at once, and it falls with the hypothesis. A mathematical structure exists; a world is real, given in acts of comparison made from stances inside it. Structures that no comparison could ever find are not further worlds. Mathematics, as Physics Is Not Math says, "can lay out structures that no comparison could ever find"; that is a power of mathematics, and it is exactly the power that marks its objects as laid out and not found.

VII. Perceptronium and the Bound Triple

Tegmark treats consciousness as a state of matter, as a physicist treats solids, liquids and gases, and asks what distinguishes conscious matter by how it processes information. The collection agrees that the question belongs to the

study of what matter does, and it gives consciousness a definition of its own. Causality Without Determinism, Chapter 5, Summary: "Consciousness is the bound triple taken as one act: the arrow of time, hard randomness and the subjective, distinct, inseparable and non-interchangeable; the Incommensuration Theorem binds the three, and physics confirms the binding".

Tegmark's five principles (information, integration, independence, dynamics and utility) describe how conscious matter behaves as seen from outside, by any observer, in the third person. The collection's account says what is left out of every such description. Incommensuration, as quoted in Physics Is Not Math, Chapter 3, Section VI, states it: "No third-person description of a system contains a privileged now or a privileged here". The subjective is the continuously asymmetric character, the stance that sets this place, this moment and this outcome apart; a description from outside, made symmetric so that anyone can check it, has no place for the subjective. Perceptronium is therefore a description of the outside of conscious matter, and it can be exact as such. What makes the matter conscious is the bound triple, held in the act, which a description of information processing does not contain.

The collection's argument that a computation cannot be what consciousness is applies to every account of mind as information processing, perceptronium included in so far as its principles are principles of processing. Causality Without Determinism, Chapter 5, Section VI: "classical computation, however intricately organized, cannot be what consciousness is". A computation is one rule applied the same way at every step, symmetry perfected; by the theorem, what is absolutely symmetric is intrinsically discontinuous, and a continuity cannot be composed of such steps; so a computation lacks the arrow of time in the first person, and, being deterministic, lacks hard randomness, and by the binding lacks the subjective. The Basis of Physics, Essay 19, Section V, states the conclusion: "computation cannot replicate any system in which the three are present, which is to say any system that is real in the full sense". The book adds the point most often missed: "From the outside, a conscious choice is indistinguishable from a random event". That is why no third-person criterion, however refined, finds the subjective: from outside, its mark is an outcome that nothing before it fixed.

VIII. Where the Predictions Part, and Why

In three areas, carried by five of the collection's registered predictions of 1 November 2026 (Predictions 10, 13, 16, 30 and 34, in the sealed record, *The Registered Predictions of Physics from Comparison*, reproduced whole in Volume One as its Appendix B), Tegmark's account gives a different result. For each, this section sets the argument of the book that the sealed prediction rests on beside Tegmark's own reasoning, and finds the step at which the two part. Each finding is a place where one account or the other learns something, whichever way the measurement falls.

Primordial gravitational waves

The sealed prediction. "The primordial departures of the metric are scalar, sourced by departures of density, and waves of the metric arise from them only at second order: the ratio of tensor to scalar power is far below 10^{-6}. The Simons Observatory and LiteBIRD will find no primordial tensor signal". It was registered on 1 November 2026 as Prediction 10.

The argument of the book. The Gravitational Passage, Chapter 18, Section IX, carries the prediction in three steps; the turn, in them, is the passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior. First, what the departures are: "I identify the departures with the form of the content carried from one side of the turn to the other (Section XIII), the old distinctions averaged". Second, the new epoch adds almost nothing of its own on the lengths we observe: "The vacuum of the new epoch adds almost nothing to them: a scale observed today lay, near the turn in the reconstructed history, some 10^{27} times beyond the new horizon, and the vacuum of a wave so far beyond the horizon carries a power below 10^{-51}, against the observed 2×10^{-9}". Third, what content sources in the metric: "A departure of density sources a scalar departure of the metric. A wave of the metric needs an anisotropic stress, which content close to equilibrium does not have at first order, so the primordial departures of the metric are scalar, and waves arise from them only at second order". The step from the second premise to the third is the step the sealed record names as the one that would fail: the scalar character of the departures. The step to scalar departures holds in the general theory of small departures as well: at first order

a departure of the scalar kind and a wave of the metric are independent of each other, so a scalar source drives no wave (Bardeen 1980). A wave could then come only from a wave already present, and the book's second premise leaves none on the observed lengths. The Compactification, Chapter 6, Section V, Chapter 7, Section VI, and Chapter 8, Section XI, and At the Edge of Reality, Chapter 19 and Appendix B, carry the same conclusion.

Tegmark's argument. In "What Does Inflation Really Predict?" (2005) Tegmark took the departures to be made during inflation, as fluctuations of the vacuum of that phase, the metric's own among them. On that premise every inflationary phase makes waves of the metric at first order, with a strength fixed by how fast the phase ends; and he computed the strength for potentials with many minima, as in the landscape of string theory. In its limit of high energy his calculation gives a ratio of about 0.15, and "the arguably best-motivated single-field models" favor "the detectable level" of about 0.03. In 2014 he read the signal then reported by BICEP2 in the same way, as "quantum fluctuations not in any old quantum field, but in the gravitational field" (Tegmark 2014).

Where they part. Tegmark: the primordial departures of the metric include the vacuum fluctuations of the metric itself, made during inflation and stretched to the observed lengths. The collection: the primordial departures of the metric are only those the content's departures source, since nothing of the new epoch's vacuum reaches the observed lengths and nothing of the old metric passes the turn.

Whose step, and what decides it. Both steps follow from their premises. Given inflation, waves at first order follow, and Tegmark's numbers follow from his potentials and his measure; given the collection's identification, scalar departures alone follow, by the step quoted above and by the independence of the two kinds at first order. The two rest on different premises, and the premise in dispute is one sentence: the departures on the observed lengths were made by the vacuum of an inflationary phase. Part of Tegmark's range is already decided by measurement: the ratio is below 0.032 (Tristram and others 2022), below the 0.15 of his limit of high energy. His best-motivated value of about 0.03 lies just inside the bound, and LiteBIRD, aiming at about one part in a thousand (Ghigna and others 2024), and the Simons Observatory, at

about three parts in a thousand (Ade and others 2019), decide it. A detection at his level refutes Prediction 10 and the identification behind it; if they find no signal, the models he called best motivated are excluded. One further point keeps the two disputes apart. A detection would not show gravitation quantized, on the collection's account: Prediction 3 holds that "A description of the small waves of the geometry by quanta holds below the Planck curvature, and its quanta are quanta of that description, never quanta of the arena", and an inflationary wave is computed in exactly that description. So the measurement decides whether inflation made the departures, and leaves the question Tegmark attached to it in 2014, whether gravitation is quantized, to Prediction 3 and the measurements that bear on it.

A long inflationary phase

The sealed prediction. "No inflationary phase long enough to stretch the lengths observed today from within the early horizon to beyond it occurred. The horizon and flatness problems are answered by the turn from the previous epoch, with no inflation". It was registered on 1 November 2026 as Prediction 13.

The argument of the book. The Compactification, Chapter 6, Section VIII, gives two steps, and says what kind each is. The first step answers the horizon and flatness problems without inflation: the one domain from which the new epoch comes answers the sameness of the sky, and the lengths that remain answer the flatness of space, so "the account needs no inflationary phase for the horizon and flatness problems". The one domain is the premise of The Gravitational Passage, Chapter 18, Section II, and Chapter 18, Section IX, draws the consequence: "The interiors are one at their end (Section II): no comparison of the new epoch registers from which interior any part of its content came", so the form that passes "is correlated across the whole new exterior, and it is one form for every component of the content". The second step is the exclusion: "A phase long enough to stretch the lengths observed today from within the early horizon to beyond it would make the departures on those lengths the departures of the inflationary vacuum". The book states the kind of this step plainly: "The kind of this step is *must*, relative to the identification: if the identification of Section II holds, a long phase cannot have oc-

curred". The Compactification, Chapter 1, Section VIII, adds a second ground, from the dark matter, quoting The Weight of Possibility, Chapter 4, Section VI: "in an epoch whose observed departures were made by inflation, the bound on primordial gravitational waves would keep the temperature far below the limit above, and dark matter of this mass could not be made after that inflation in the measured amount".

Tegmark's argument. Regions that no signal of our epoch has connected are alike because, on the inflationary account, they were once in contact and were then stretched apart. From the dynamics of typical potentials Tegmark holds that "inflation is generically eternal, in the sense that that's what typical inflation models predict", and that where the fundamental theory has several solutions "inflation will create volumes realizing each of these solutions" (Tegmark 2014); his Level II multiverse is that consequence. He added in the same exchange that if the fundamental theory has only one such solution, the measurable parameters are the same everywhere.

Where they part. The two accounts part at the first question the horizon problem asks: what makes regions alike that no signal of our epoch has connected. Tegmark: an earlier contact, within this epoch, before inflation stretched them apart. The collection: one domain, the common end of the interiors of the previous epoch, from which the form of the new epoch comes, with no contact in the new epoch required.

Whose step, and what decides it. Both steps follow, and the books say so of their own step: the exclusion is *must* relative to the identification, and so it is exactly as strong as the identification. The premise in dispute is one sentence: the correlation of the departures across the whole sky was set by causal contact within our epoch. The measurements of Predictions 9 to 12 decide it together, and of these only the waves of the metric separate the two accounts, as the subsection above found; flatness, the adiabatic character and the one pattern are predicted by both. The comparison also teaches the collection something, and the lesson belongs here plainly. Tegmark's calculation of 2005 gives a spectral index of about 0.96 in its limit of high energy, and the measured index is 0.965 ± 0.004 (Aghanim and others 2020). The Gravitational Passage, Chapter 18, Section IX, reads the tilt as "a weak reference of the departures to a length of the new epoch" (the strength of the departures

changes slightly with their length, in a way tied to some length of the new epoch), names the two lengths it might refer to, and concludes "This section therefore does not fix the sign of the tilt"; the collection does not derive the index. Every step of the collection holds there, and the sealed record lists the amplitude and the tilt among what it does not predict. The inflationary account computed a value the collection does not derive, and the question this puts to the collection is a real one: which length of the new epoch do the departures refer to, and how do they depend on it? On Level II the two accounts part a second time, even granting inflation: Tegmark's own condition, many solutions of the fundamental theory, is the premise the collection denies, since its internal space is one space (The Compactification, Chapter 2, Section IX), and by his own words one solution gives the same parameters everywhere.

What the dark matter is

The sealed predictions. "No further kind of particle will be found", the list naming among others "no axion, no species of dark matter", registered on 1 November 2026 as Prediction 30; and "The ratio of the density of the dark matter to the density of the ordinary matter is $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$, the same at every time since helium formed", registered as Prediction 16. Prediction 34 adds that "the structure calls on no axion to cancel the measured angle θ", the angle by which the strong force could break the symmetry of reversal, which is measured to be near zero.

The argument of the books. The list of kinds is closed by the structure that carries them: The Kinds of Particle, Chapter 6, Section I, takes the kinds from the algebra of the finite geometry and the labels its parts carry, sixteen states in each generation, and Section IV draws the consequence: "No further kinds exist: no fourth generation, no supersymmetric partner, no X or Y boson, no graviton, no dark-matter particle of any type". The structure calls on no axion in particular, because the angle the axion was proposed to cancel has no source of its own: The Branches of the Kinds, Chapter 3, Section V, finds that color breaks no reversal by its form, so its own angle is zero, and "the structure calls on no axion to cancel it". The ratio is a count: The Weight of Possibility, Chapter 3, Section V, "The dark residue is the count of six classes less the share of the curvature of $\mathbb{C}P^2$; the ordinary residue is the one class of

the open". Here $\mathbb{C}P^2$, the complex projective plane, is the four-dimensional part of the six internal dimensions, which are a complex projective plane and a sphere. Which curvature reduces the count is the step the sealed record names as the one that would fail, and The Weight of Possibility, Chapter 3, Section IV, settles that step by one principle: "a count that includes a factor's Euler number is not reduced again by that factor's curvature". The Euler number of a closed space is a whole number fixed by its shape, three for the complex projective plane and two for the sphere; the share of a factor's curvature that does reduce a count, the book calls its abiding share. The same section reports the readings it sets aside, each with the value it would give: read from the accelerations, "the ratio would be $6 - 3/\pi = 5.045$, which the data exclude".

Tegmark's argument. In "Dimensionless Constants, Cosmology and Other Dark Matters" (2006), Tegmark, with Anthony Aguirre, Martin Rees and Frank Wilczek, took axion dark matter as a case study, on a stated condition: "If a Peccei-Quinn phase transition occurred before or during inflation" (the breaking of symmetry that gives rise to the axion), then "the axion dark matter density will vary from place to place with a probability distribution", and that distribution, "computed at stable solar systems, is arguably peaked near the observed dark matter density". On this scenario the ratio is a value of our region, chosen by the conditions under which observers can arise, and the dark matter is a kind of particle.

Where they part. Tegmark and his colleagues: the dark matter is a species of particle whose density was set by an initial value that differs from region to region. The collection: the dark matter is a conserved excitation of the six held internal dimensions (kept at the same size and shape at every point), not a kind of particle, and its ratio to the ordinary matter is a count fixed by the structure, the same everywhere.

Whose step, and what decides it. Both steps follow from their premises. The scenario's step is conditional and says so; it rests on three premises the collection denies, an axion, a phase of inflation, and many regions with different values. The collection's step rests on the principle of Section IV of The Weight of Possibility, which is a principle of bookkeeping with a reason given for it, the theorem of Gauss and Bonnet (the theorem that the total curvature

of a closed space fixes its Euler number); the data are used there to set aside two other readings, and the principle, not the data, selects the reading kept. The premise in dispute is one sentence: the dark matter is a kind of particle. The searches decide it: an axion found as the dark matter refutes Predictions 30 and 34 and confirms the kind of the scenario. A measurement of the ratio tests the count, and it cannot test the scenario: a second, independent kind of measurement at the precision of the microwave background, which the Simons Observatory with Planck would give at about 0.6 percent (the sealed record, Prediction 16), tests $6 - 2/\pi$ directly, while the scenario sets no single value for a measurement to meet or miss.

IX. Summary

Max Tegmark and the physics collection begin from the same premise: there is a world, and it does not depend on us. Two of Tegmark's results stand in the collection at their own scope: his analysis of the dimensions of spacetime, which supports the count of one direction of time, and his estimate of decoherence in the brain, which the collection accepts and which bears on the hypothesis of Hameroff and Penrose and not on its own account.

The two accounts part at one step. Tegmark reasons that a world free of humans must be described by pure structure, and so is pure structure. The collection holds that removing the human removes nothing of the stance, because every comparison is made from somewhere and the stance was never human. A mathematical structure exists, laid out and the same in every instance; a world is real, given in acts of comparison; and the Incommensuration Theorem shows that no structure written without the stance can be the world that comparisons find, because such a structure can hold symmetry and continuity together and no finding can. The order of depth places mathematics last, with all its powers, as the instrument for what is laid out. On that ground the collection excludes the world as a computation, on three independent grounds; treats Level I as further parts of one world; excludes Level II by its one internal space and its exclusion of long inflation; reads Level III as an account that removes the act of comparison and so loses the Born rule; and finds Level IV to be the mathematical universe applied to

every structure, which falls with it. Tegmark's perceptronium is an exact description of conscious matter from outside; consciousness itself is the bound triple taken as one act.

Where the two accounts predict different results, each argument follows from its own premises; for the early universe the premises part at one question, whether an inflationary phase made the departures, and for the dark matter at a second, whether it is a kind of particle. Measurements of the polarization of the microwave background decide that question; the search for the axion and a second measurement of the ratio of dark to ordinary matter decide what the dark matter is. On the tilt of the departures Tegmark's inflationary calculation gave a value the collection does not derive, and this puts a real question to the collection: which length of the new epoch do the departures refer to? Tegmark restricts the mathematical universe to computable structures; Stephen Wolfram, in the next chapter, holds that the universe is, at its foundation, a computation, a simple rule rewriting a network of discrete elements.

Key Concepts

- The shared premise: an external world independent of humans; the collection's observer is a comparer, a position inside the world that never names a mind.
- Exists and real: a structure exists, laid out and the same in every instance; a finding is real, given in an act of comparison.
- Taking the frame of mathematics for everything: the step from an independent world to a mathematical one.
- A stance is not a human: removing human notions from a description removes nothing of the side from which every comparison is made.
- The world is not a computation: excluded on three grounds, determinism, the two levels of description, and the bound triple.
- The four levels: Level I is one world, Level II is excluded by one internal space and no long inflation, Level III removes the act of comparison, Level IV falls with the hypothesis.
- Consciousness is the bound triple taken as one act; perceptronium describes conscious matter from outside.
- Where the predictions part: whether inflation made the early departures; the polarization of the microwave background decides it, and the axion search and the ratio of dark to ordinary matter decide what the dark matter is.

Terms

Abiding. In The Weight of Possibility, the share of a factor's curvature that holds fast in a registration as a term of its own, and by which it reduces a count of classes.

Axion. A proposed particle that would cancel the angle by which the strong force could break the symmetry of reversal; a candidate for the dark matter.

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable.

Exists, real. To exist is to stand as structure, timeless and the same in every instance; to be real is to be given in an actual act of comparison.

External Reality Hypothesis. Tegmark's premise that there exists an external physical reality completely independent of us humans.

Immanent. The role of the act of comparison itself, as it happens; one of the three modalities, with the omniscient (what is laid out as structure) and the transcendent (the stance and the range of what could be found).

Inflation. A proposed early phase of accelerated expansion that would stretch a region once in contact to beyond the present horizon, its vacuum fluctuations becoming the departures from uniformity.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Mathematical Universe Hypothesis. Tegmark's claim that our physical world is an abstract mathematical structure.

Order of depth. Metaphysics, physics, computation, mathematics, ordered by what each presupposes.

Perceptronium. Tegmark's name for consciousness considered as a state of matter with distinctive abilities to process information.

Ratio of tensor to scalar power. The strength of the primordial waves of the metric relative to the primordial departures of density.

Spectral index. The measure of how the strength of the primordial departures changes with length; an index of one is the same strength at every length, and the tilt is its departure from one.

Stance. The side from which a comparison is made; it belongs to every comparison, human or not.

Turn. On the collection's account, the passage from the previous epoch to this one, through which the form of the content is carried.

References

Ade, P. and others (Simons Observatory Collaboration) (2019). "The Simons Observatory: science goals and forecasts". *Journal of Cosmology and Astroparticle Physics* 2019(02), 056. arXiv:1808.07445.

Aghanim, N. and others, Planck Collaboration (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6. DOI 10.1051/0004-6361/201833910. arXiv:1807.06209.

Bardeen, J. M. (1980). "Gauge-invariant cosmological perturbations". *Physical Review D* 22(8), 1882–1905. DOI 10.1103/PhysRevD.22.1882.

Everett, H. (1957). "'Relative state' formulation of quantum mechanics". *Reviews of Modern Physics* 29, 454–462.

Ghigna, T. and others (LiteBIRD Collaboration) (2024). "The LiteBIRD mission to explore cosmic inflation". arXiv:2406.02724.

Hameroff, S. and Penrose, R. (1996). "Orchestrated reduction of quantum coherence in brain microtubules: a model for consciousness". *Mathematics and Computers in Simulation* 40, 453–480.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Tegmark, M. (1997). "On the dimensionality of spacetime". *Classical and Quantum Gravity* 14, L69–L75.

Tegmark, M. (2000). "Importance of quantum decoherence in brain processes". *Physical Review E* 61, 4194–4206.

Tegmark, M. (2005). "What does inflation really predict?". *Journal of Cosmology and Astroparticle Physics* 2005(04), 001. arXiv:astro-ph/0410281.

Tegmark, M., Aguirre, A., Rees, M. J. and Wilczek, F. (2006). "Dimensionless constants, cosmology and other dark matters". *Physical Review D* 73, 023505. arXiv:astro-ph/0511774.

Tegmark, M. (2008). "The mathematical universe". *Foundations of Physics* 38, 101–150. arXiv:0704.0646.

Tegmark, M. (2014). *Our Mathematical Universe; My Quest for the Ultimate Nature of Reality*. New York: Knopf.

Tegmark, M. (2014). "Guest post: Max Tegmark on cosmic inflation", with his replies to comments. *Preposterous Universe*, 21 April 2014. preposterousuniverse.com

Tegmark, M. (2015). "Consciousness as a state of matter". *Chaos, Solitons and Fractals* 76, 238–270. arXiv:1401.1219.

Tristram, M., Banday, A. J., Górski, K. M., Keskitalo, R., Lawrence, C. R., Andersen, K. J., Barreiro, R. B., Borrill, J., Colombo, L. P. L., Eriksen, H. K., Fernandez-Cobos, R., Kisner, T. S., Martínez-González, E., Partridge, B., Scott, D., Svalheim, T. L. and Wehus, I. K. (2022). "Improved limits on the tensor-to-scalar ratio using BICEP and Planck data". *Physical Review D* 105(8), 083524. DOI 10.1103/PhysRevD.105.083524. arXiv:2112.07961. The combined analysis of Planck, BICEP/Keck 2018 and baryon acoustic oscillation data gives a ratio of tensor to scalar power below 0.032 at 95 percent confidence.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Stephen Wolfram

The Rule and the World

Stephen Wolfram and Physics from Comparison

Abstract

Stephen Wolfram holds that the universe is, at its foundation, a computation: a simple rule rewriting a network of discrete elements, from which space, time, gravity and quantum mechanics emerge for observers like us. He has established a real result on the way, computational irreducibility: in general, the only way to know what a computation will do is to run it. The physics collection of the Immanent Metaphysics holds the same result, proves it in its own form, and agrees with Wolfram on two further points: that equations are not the foundation of physics, and that the observer cannot be removed from it. The two accounts part on what comes before mathematics. Wolfram puts computation there. The collection puts physics there, and the act of comparison before physics: every computation that is carried out is a physical process, and every measure of computation is a measure of time. On that order, the collection excludes a world that is a computation at its foundation on three independent grounds: a whole world fixed by one rule is the determinism the Incommensuration Theorem forbids; a world whose description and findings have one character is a character compared with itself; and every actual world has hard randomness, an arrow and a stance, while a computation has none of the three of its own. The essay sets out Wolfram's program at its full strength, credits what it establishes, shows where the collection's account parts from it and why, and places his ruliad, his bounded observer and his discrete space in the collection's terms. A closing section takes the four places that the dated record of 4 November 2026 compares, opens the book on which each sealed prediction rests, and finds the step where the arguments part: three premises in dispute, and one difference of words, where on Wolfram's own definitions the two accounts agree.

I. Wolfram's Program

In *A New Kind of Science* (2002), Stephen Wolfram asked whether "underneath all the complex phenomena we see in physics there lies some simple program", which would be "a complete and precise representation of the actual operation of the universe" (page 465). The book's evidence was a long study of simple programs, cellular automata above all, which showed that rules of a few lines can produce behavior of unbounded complexity.

In 2020 he launched the Wolfram Physics Project to carry the question through (Wolfram 2020). Its model begins with space itself made of discrete elements, linked into a network (a hypergraph), and a rule that rewrites the network again and again. Time is the progress of the rewriting. Because the rule can be applied at many places in many orders, the possible histories branch and merge into a *multiway system*. Where the order of updates does not change the final relations among events, a property Wolfram calls causal invariance, the model shows the invariance of special relativity. In a continuum limit the project reports deriving the equations of general relativity. The branching of histories is the project's account of quantum mechanics. Beyond any one rule stands the *ruliad*, in Wolfram's words "the deeply abstract but unique object that is the entangled limit of all possible computational processes". Observers are part of it, and they are computationally bounded: "we're computationally bounded", and "It's because we're observers like us that we perceive the laws of physics we do", laws which, he writes, "turn out to be precisely the three key theories of 20th-century physics", general relativity, quantum mechanics and statistical mechanics. His conclusion is stated plainly: "it's computational. So computation isn't just a possible formalization; it's the ultimate one for our universe" (Wolfram 2023).

The program reaches for the whole of physics, and Wolfram has carried it out with great energy and a large body of worked results. The collection engages it at length in The Last Turtle, Chapter 32 ("The Incompressible Residue; Wolfram's Physics and the Limits of Any Omniscient Theory"), The Last Turtle, Chapter 33 ("Against Computationalism"), and The Basis of Physics, Essay 19. Objections from Physics, Answered, Chapter 53 ("Computation, Simulation and the Residual"), states at full strength the objection that the world is, at its foundation, a computation, and answers it.

II. What Wolfram Establishes

Wolfram's central technical idea is *computational irreducibility*: for most computations there is no shortcut, and "the passage of time corresponds to an irreducible computation that we have to run to know how it will turn out". The idea is a real result, and the collection holds it. Physics Is Not Math, Chapter 7, Section IV, gives it in the form logicians proved it: Henry Gordon Rice's theorem of 1953 says that no general procedure decides any non-trivial property of what a program does, and so "In general, there is no way to know what a program will do except by running it". The chapter adds what the result rests on: "Its content, like the halting problem's, comes from the sequence. ... Take the sequence away, and there is no 'in advance' and no 'running' for the theorem to be about". Wolfram saw, and made vivid with a great many examples, that irreducibility holds for ordinary simple rules and not only for contrived ones.

Wolfram establishes a second thing, and here too the collection stands with him. He took the foundation of physics away from equations. On his view, an explanation in physics is found in a rule that is run, and not in the differential equations of physics. The collection also holds that the foundation of physics lies deeper than mathematics. Its order of depth, set out in Physics Is Not Math, Chapter 5, places mathematics last: metaphysics, physics, computation, mathematics, each presupposing the ones before it. Wolfram moved the foundation one step deeper than mathematics, to computation.

And Wolfram establishes a third thing: the observer cannot be taken out of physics. On his account the laws we find are the laws that observers like us perceive. The collection holds that every finding of physics is a comparison made from inside the world, and every comparison is made from a stance. Both hold that every finding is made from somewhere inside the world.

III. The Order of Depth

The two accounts part on the step Wolfram took. He moved the foundation from mathematics to computation, and stopped there. The collection holds that computation itself presupposes physics, and physics presupposes the act of comparison. Physics Is Not Math, Chapter 8, Section VI, states it:

> "Physics is deeper than computation ... every computation that is carried out is a physical process, and physics, both the world it studies and the findings it makes, needs no computation".

A rule computes only when it is run. Running a rule is an interaction in the world: current in a circuit, a bead pushed along a wire, graphite left on a page. And physics needs no computation: "Rain falls, tides rise and stars burn whether or not anything anywhere is computed".

Computational irreducibility, Wolfram's own result, shows the order from his side. Physics Is Not Math, Chapter 7, Section V, observes that the measures of computation are counts of steps, and "a count of steps is a measure of time: the time a computation must take". Irreducibility says a computation must be run to be known, and running takes time. Wolfram reads the tie between irreducibility and time as showing that the passage of time is a computation. The collection reads the tie the other way: computation has measures of time because every run is a physical process in a world that already has time. Both accounts read the same result, and they reverse which depends on which: for Wolfram, time depends on computation; for the collection, computation depends on time, and that direction is what the order of depth asserts.

The deepest member of the order is the act of comparison, and it carries the result on which the collection's exclusion of a computed world rests. The Incommensuration Theorem states that symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. Every measurement is a comparison, so the theorem holds wherever anything is measured, including the running of a computation.

IV. Three Grounds

On the ground of the theorem the collection excludes the thesis that the world is, at its foundation, a computation. It names the thesis computational reductionism, and Physics Is Not Math, Chapter 8, Section VII, excludes it "on three independent grounds, and each of them turns on what a computation is" (also The Last Turtle, Chapter 33, Section VI).

Determinism

A world computed at its foundation is deterministic: given its state and its rule, every later state is fixed. Complete determinism needs the same law carrying every state into its successor everywhere and always, which is symmetry perfected, together with every state specified at every point with nothing left unfixed, which is continuity perfected. That is the first pairing the theorem forbids. The continuity perfected here is the completeness of the specification, every state fixed at every point with nothing left unfixed; it is a different respect from the smoothness of what is specified, and in that second respect a computation's states and steps are discrete, as the next ground takes up. "So no world is purely and completely deterministic". Every world has causation instead: a connection without a break along the order in which findings are made, running one way.

The ground of determinism reaches Wolfram's multiway system too. The multiway system replaces one history with all the histories a rule allows, and as a whole it is fixed by the rule and the starting state just as a single history is. Physics Is Not Math, Chapter 8, Section VII, says of accounts that describe a whole world as completely deterministic and place the randomness of an outcome in which branch of the world an observer finds itself, as Hugh Everett's many-worlds account does: "A whole world completely fixed by a law perfects symmetry and continuity together, whichever account describes it, and the theorem forbids that pairing". The multiway system is such an account.

One character at both levels

Every exact theory has two levels: its formalism, the mathematics written down as structure, and its findings, made by comparison. The two levels always take the two characters the theorem allows, one each. Quantum theory describes stepwise findings with smooth equations; general relativity describes a smooth arena with laws that are the same for every observer. This is the cross-modal principle of Measurement, Chapter 8, Section VIII, and that section names exactly the kind of theory it excludes at the foundation of physics:

> "A cellular automaton on a lattice is the form such a theory would take: discrete states, a discrete rule that is the same at every site and every step, and no continuous parameter anywhere in its formalism. What it finds and how it describes would both be discontinuously symmetric. The principle excludes it because one mode at both levels is self-application".

A character compared with itself finds only what it already held. A network of discrete elements rewritten by one rule has one character at both levels at its foundation, whatever its large-scale behavior looks like. The same section grants the large-scale picture its place: "an automaton whose large-scale behavior approximates smooth physics, as a lattice used to compute a fluid does, is a formalism of computation and not a foundation, and the principle says nothing against it". So the collection accepts Wolfram's continuum limits as calculations. It excludes the step from a calculation that approximates the world to the claim that the world is that calculation.

The bound triple

The third ground is the one the collection develops at greatest length. Physics Is Not Math, Chapter 8, Section III, finds three things bound together: the arrow of time, *hard randomness* (an outcome that no prior specification fixes, however complete), and the stance from which every comparison is made. Each requires the next. The arrow requires hard randomness, because a direction needs each next moment to hold something the present did not. Hard randomness requires a stance, because from outside, in a description in the third person, an outcome no prior state fixed and an outcome fixed but un-

known look exactly alike; the difference is in the finding, and a finding needs a finder. And a stance requires the arrow, because to perceive, to remember and to anticipate each run one way. These three together are the *bound triple*.

A computation has none of the three of its own. It is deterministic, so it has no hard randomness; its random numbers are produced by a fixed rule from a starting number. An outcome that a bounded observer inside such a computation cannot predict is still fixed by the rule and the starting state, so it is unknown to that observer, and it is not hard randomness. It therefore has no arrow: "An order of dependence in which nothing new happens is a sequence without a direction of its own" (Physics Is Not Math, Chapter 8, Section IV). Every computation can be run in reverse by keeping a record of each step (Bennett 1973), and where a real computer has a direction, it is because it erases information, which is a thermodynamic act of the machine (Landauer 1961). "The direction of a running computation is the arrow of the world that runs it, and never the arrow of its algorithm" (The Last Turtle, Chapter 33, Section IV). And a computation is laid out wholly in the third person, so it has no stance. A world that was a computation at its foundation would have an indexing of states and no arrow, and by the bound triple, no subjects in it.

The strongest reply is to let the computation draw true randomness from somewhere. The collection answers it directly: randomness read from a physical source "enters the computation as input from outside it", and "the randomness such a system has is the world's randomness, carried through the computation" (The Basis of Physics, Essay 19, Section III). A quantum computer is the same case: between preparation and readout its operations are a reversible rule, and its readout is a measurement made in the world. Computation that is not deterministic is computation with the world inside it.

V. The Rule, the Residue and the Ruliad

The Last Turtle, Chapter 32, asks what any program of Wolfram's kind can achieve, and answers through information. The output of a rule run on starting conditions carries no more information than the rule and the starting conditions together. In words: the information in the generated state is at most the information in the rule plus the information in the starting conditions, where the information of a thing is the length of its shortest description. De-

duction conserves information, and that conservation is what makes a theory useful: a phenomenon that matches a generated state is compressed into a much smaller rule and starting state. Three questions follow for any such program (Chapter 32, Sections III and IV): how closely must a generated state match a phenomenon before the phenomenon is taken to be produced by the rule and not merely to resemble its output; on what basis is a match, among the endless choices of rule and start, held to be anything other than selected after the fact; and where does the information in the rule itself come from?

The third question is the deep one. Every theory laid out wholly as structure takes some information as given and cannot produce it, because deduction conserves information. It can move that information, from the phenomena into the rule, but not make it from nothing, and "However many iterations of theory building are attempted, there remains an incompressible residue, something no theory predicts". That residue is hard randomness: since by the theorem no world is completely fixed by any rule, what every rule leaves unfixed includes outcomes that no prior specification fixes, and those are the residue that no iteration of theory building compresses. The theorem names the same residue from the side of comparison: it forbids both perfected determinism and its opposite pole, pure randomness, so that every actual world holds causation together with a residue no theory compresses. Chapter 32, Section VI, draws the conclusion: the entrance of that residue is inseparable from the moment it enters and from the first-person standpoint from which it is observed, so the bound triple "is forever beyond what such a theory can know".

Set beside the third question, Wolfram's ruliad shows where the residue goes. The ruliad contains every rule, so no particular rule needs to be chosen, and the information that a chosen rule would carry seems to vanish. That information has moved, and Wolfram's own account shows where. In Wolfram's account, which laws an observer finds depends on where the observer is in the ruliad and how it samples it. The information that a single rule would have carried has moved into the observer's place and manner of sampling. That is exactly where the collection locates the residue: in the stance from which each comparison is made, with its hard randomness and its arrow. The ruliad, taken as one whole, has a further difficulty that the col-

lection names in Measurement, Chapter 2, Section II: "a description of the whole world from a vantage outside it has no comparison behind it, because the whole has no outside to compare it with". The ruliad is described from just such a vantage, as the limit of all possible computations, held in view at once.

VI. The Observer

Wolfram's observer is the most interesting part of his program for the collection, because there he comes closest to the collection's account. He holds that the laws of physics are what observers like us find, and that what we find depends on our being bounded. The collection holds that every finding is a comparison made from a stance inside the world. Both put the observer at the foundation of what is found.

The two accounts part on what the observer is. For Wolfram, the observer is itself a computational process inside the ruliad, bounded in what it can compute. For the collection, the observer is anything that makes a comparison, and every comparison has a stance, a direction and an outcome no prior state fixed. A computational process has none of the three of its own (Section IV). So a computationally bounded observer, taken as a computation, is a description of an observer from outside, laid out in the third person, and the stance from which it observes is not in that description. The collection's argument in Causality Without Determinism, Chapter 5, Section VI, applies to it directly: "classical computation, however intricately organized, cannot be what consciousness is", since a classical computation is symmetry perfected, and "the first-person perspective is continuously asymmetric, a computation is discontinuously symmetric, and the one cannot be composed of the other". Wolfram brought the observer in and then described it as the one kind of thing the collection shows an observer cannot be.

The collection's result also says exactly what it allows. A computation can be built to behave, from outside, as a person behaves, to any degree of fidelity; "Artificial intelligence is possible, and computation is enormously powerful" (The Last Turtle, Chapter 33, Section VII). The boundary lies between processing and experience, not between what machines can and cannot do.

VII. Discrete Space and the Arena

Wolfram's model begins with space made of discrete elements, and the smooth space of general relativity appears only in a limit. The collection holds that gravitation is not quantized, and The Unquantized Arena, Proposition 6.3, says exactly what that means: "(i) The arena has no least step: no least length, area or duration. (ii) Nothing is a quantum of the arena itself, at any scale". The arena is the context of every finding, continuous and uneven, and it is described by general relativity; a network of discrete elements as its foundation is a description of the context in the character of content, which the theorem excludes.

The collection's exclusion is structural, and it stands on its own ground: "Three routes on different premises reach one conclusion, and they confirm one another. None of them depends on what experiments can presently detect" (The Basis of Physics, Essay 19, Section VII). It also makes a prediction about the world, and a discrete foundation would have consequences that could show. The Unquantized Arena, Prediction 19.4: "The arena has no least length, area or duration. The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed". Every search for a least step of spacetime is a search the collection says will find none.

The multiway account of quantum mechanics meets the bound triple in the same way that many-worlds does. In it every branch the rule allows is realized, and an observer's definite outcome is a matter of how a bounded observer samples the branches. The Basis of Physics, Essay 19, Section IV, records how the many-worlds account stands to the triple: it "drops all three at once, since it has no fact of which branch a comparer is in, no outcome that is not fixed, and a fundamental equation symmetric in time". The collection's account of the single outcome is that it is hard randomness, an outcome no prior specification fixes, found from a stance; The Quantum Passage, Chapter 9, Section IV, describes the update after a measurement as an update of the shared record, not a physical process and not a choice among branches.

VIII. Where the Predictions Part, and Why

The dated record *The Registered Predictions Beside Stephen Wolfram* (4 November 2026) names four places where the collection and Wolfram expect different results. For each, this section opens the book on which the sealed prediction rests, sets that argument beside Wolfram's own, and finds the first step at which the two part. The aim is to learn where a fault lies, on either side, and to say plainly what would settle it.

A least length of space

The sealed prediction. Under the heading "The arena has no least length, area or duration", the sealed record states: "The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else". It was registered on 1 November 2026 as Prediction 5.

The argument of the book. The prediction rests on The Unquantized Arena, Chapter 6, Section IV, Proposition 6.3: "That the arena is not quantized means exactly two things. (i) The arena has no least step: no least length, area or duration. (ii) Nothing is a quantum of the arena itself, at any scale". The argument for Proposition 6.3 is short: "A least step of the arena would be a discontinuity in its findings, and by the law of continuity and Proposition 4.2 the findings of the arena have none at their foundation". Behind it stands the chain the chapter sets out before it (Chapter 6, Section II, with Proposition 6.1). By the Incommensuration Theorem, a comparison perfected at its foundation is continuously asymmetric or discontinuously symmetric, and never continuous with symmetry or asymmetric with discontinuity. The law of symmetry governs content, and the law of continuity governs context (*An Immanent Metaphysics*, aphorism 1.83-5). And "gravity is the context of physics, its arena", an identification the book makes in Chapter 5 with the observations that bear on it. So the findings of the arena are continuous at the foundation, and a least step would be a discontinuity among them.

Wolfram's argument. Wolfram begins from the thesis that beneath physics lies a simple program (Wolfram 2002, page 465), and a program acts on discrete elements. So space is made of discrete elements, the nodes of a hyper-

graph, and the smooth space of general relativity appears only in a limit, where causal invariance gives the symmetry of relativity (Gorard 2020a). The technical introduction of the project gives an elementary length that "is considerably smaller than the Planck length" (Wolfram 2020b).

Where they part. For the collection, the foundation of space is context, and context is continuous at its foundation. For Wolfram, the foundation of space is a network of discrete elements rewritten by one rule, and its continuity belongs to the large-scale limit. In the collection's terms, Wolfram's model describes the context of physics in the character of content: discrete elements, and the same rule at every place and every step. That is the passage Proposition 6.1 says the arena cannot take: "The arena admits no mode exchange".

Whose step, and what decides it. Each side's steps follow from its premises. The two rest on different premises about what space is at its foundation, and the premise in dispute can be put in one sentence: is the arena the context of every finding, continuous at its foundation, or a discrete structure whose continuity is an appearance at large scale? The collection's premise rests on more than the identification of gravity: the order of depth (Section III) and the cross-modal principle (Section IV) each bear on Wolfram's starting thesis independently, so the dispute traces back to the step from mathematics to computation, which Wolfram took and which the collection carries further, to physics and the act of comparison.

The two predictions are also of different kinds, and the difference shapes what a measurement can do. The collection's is universal: no least step, at any scale. Every search for a step can refute it. Wolfram's is that a least step exists, at a scale not yet fixed, below the Planck length, with the symmetry of relativity kept in the limit. The timing of photons from distant bursts, the bound the sealed record reports (any energy dependence of the first order lies above about ten times the Planck energy), tests the discrete pictures that predict a dispersion, and a discreteness of Wolfram's kind lies outside its reach, as The Unquantized Arena, Chapter 19, Section V, says: "These timing bounds test the discrete pictures that predict a dispersion. A discreteness that keeps Lorentz invariance, as in causal sets (Bombelli, Henson and Sorkin 2009), predicts no such dispersion and is tested by its own signatures". So the collection carries the side that a measurement can refute now, and Wolfram's side be-

comes refutable when the project fixes the scale and the signature of its rule. The sealed record names what decides the difference: the timing of photons of different energies, told apart from effects at the source by its growth with distance, and every observation of the spectrum of area or volume. Whatever signature the project fixes for its rule will decide the difference as well.

One discrete rule beneath every finding

The sealed prediction. "For any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement, reaching below the rule's least step, tells the rule's statistics from the world's". It was registered on 1 November 2026 as Prediction 29.

The argument of the book. The prediction rests on the cross-modal principle, The Unquantized Arena, Chapter 3, Section II, Proposition 3.1: "Framework and content are always in conjugate modes. A symmetric framework probes continuous content; a continuous framework probes symmetric content". The reason the book gives for Proposition 3.1 is that "A framework in the same mode as its content would apply that mode to itself, which the criterion of no self-application excludes". Quantum theory meets the principle: what a measurement finds is one count among discrete alternatives, and the evolution between findings is continuous. The Basis of Physics, Essay 18, Section VII, draws the consequence for a rule: "A discrete rule can be chosen to reproduce the statistics of that evolution to any finite precision named in advance; what no discrete rule can be is the continuous evolution itself, which has no least step at any precision". And so, "If the evolution were in fact discrete, if the wavefunction were an approximation to some one underlying finite rule, that rule would have a least step, and with enough trials and enough sensitivity reaching below that step, its statistics would be found to differ". The Unquantized Arena, Chapter 3, Section VI, and Measurement, Chapter 8, Section VIII, state the same exclusion.

Wolfram's argument. Beneath the established findings lies a simple program, "a complete and precise representation of the actual operation of the universe" (Wolfram 2002, page 465). The quantum statistics are the branching of the histories the rule allows, and Gorard (2020b) reports that the geometry

of those branches converges, in the continuum limit, to that of complex projective Hilbert space. The rule itself is not yet named: "We don't (yet) know an actual rule that represents our universe" (Wolfram 2020a).

Where they part. For the collection, the evolution between findings is continuous at every precision, so any discrete rule is an approximation that shows its step below some precision. For Wolfram, the evolution between findings is a discrete rule, and the continuous evolution of quantum theory is its limit, so at a fine enough precision the world's statistics are the rule's.

Whose step, and what decides it. Both steps follow, and the two rest on different premises about the evolution between findings. The collection's step holds on a case of the same form with nothing at stake, the book's own case: a lattice used to compute the flow of a fluid matches the fluid to any precision chosen in advance, and below its spacing the computed flow and the fluid part. A real fluid is itself made of molecules, and the case does not turn on that: below the lattice spacing the computed flow parts from whatever it computes, a smooth fluid or a fluid of molecules alike. The step holds for any rule with no continuous parameter in it, and Wolfram's rule is of that kind: a rewriting of discrete elements. Both accounts expect a fine enough measurement to show something, and they disagree on what it shows: the collection, the statistics of quantum theory unchanged; Wolfram, the statistics of the rule, departing from quantum theory below the rule's step. The statistics below a rule's step are therefore the most decidable of the four differences, once the project names its rule and with it the precision at which the rule's step would show. The strongest reply open to Wolfram is that observers, being bounded and made of the rule, never reach below its step. Then the rule and the continuous evolution would agree in every finding any comparer could make, and by the principle that a difference no comparison can register is no difference (Measurement, Chapter 11, Section IV), the two would name no difference a measurement could find; the dispute would then be settled by structure, as the three grounds of Section IV settle it, and not by measurement. Wolfram's program expects its rule to have consequences that show, such as changes in the dimension of space, the next difference, and so it does not take that reply.

The collection's statement. The sealed record numbers no prediction on the count. Measurement, Chapter 11, Section VI, derives the count and concludes: "So the dimension of space is three". The dated record of 4 November draws from that derivation that no region and no epoch will show another count, and files that statement among the predictions outside the sealed record. For the waves of the geometry, the sealed record carries Prediction 6: "Gravitational waves carry the two polarizations of a massless field of spin two, and travel at the speed of light; no further polarization and no other speed will be found".

The argument of the book. This argument is the most technical in the essay, and the paragraphs that follow it state its conclusion in plain words. Measurement, Chapter 11, Section II, sets the count at the level of the ground: "a context has no feature but its form of difference, the number of its independent ways", and the numbers the structure of comparison supplies are one, two, three, four and six. Section VI then argues in steps. Space is not one, since space and time are distinct and one way would give them the same form of difference. Space is not two, by the doubling (every difference is placed twice, in a context and by a comparing) and the placing rule ("the distinction between two ways of a context is placed in that context when, and only when, the context has a way that is not composed from those two"). In a context of two ways, the distinction between those two ways could be placed only by a third way not composed from them, which a context of two ways does not have, and the doubling requires that every difference be placed. Three, four and six all meet the doubling: "The doubling bounds the dimension of space from below, at three". The minimality principle makes the choice among three, four and six: "Of the numbers comparison supplies, three, four and six remain, and by the minimality principle a context takes the least". Chapter 11, Section IV, gives the minimality principle its reason: the principle that "a difference that no comparison can register is no difference", whose "scope is every possible comparison: every comparison that any comparer could make, in any domain, at any place and at any time". Section IV applies that reason to the count in one step: "A way of a context is registered as distinct only through the work it does in the structure of comparison: placing a distinction,

meeting a requirement. In a context of three ways every distinction is placed exactly once, each by the way not composed from the two it divides, and every requirement on space is met. A fourth way would place only distinctions already placed, and it would meet no requirement not already met; so nothing in the structure of comparison would mark it as a way of its own, apart from the other three, and by the principle it is none". Section IV then shows why the work a way does in the structure of comparison is the only thing that registers the way at the level of the ground: "The work a way does in the structure of comparison is also the only thing that can register it at this level, because any finding that registers a way presupposes that way". Every finding is placed in a context, and the ways in which it can differ are the ways of that context, so "a finding laid out along a way is found in that way as its context: the way is the respect in which the finding is made, and the difference found is its content, and the content and the context of a comparison cannot be one respect". "A finding therefore cannot supply a way to the context in which it is found; it finds differences along the ways the context already has". "Whether a context has a given way is settled where its form is settled, and the count of its ways is made at the level of the ground", "where nothing is yet found". "What registers a way at that level is the structure of comparison, which every finding presupposes and which presupposes no finding". "A fourth way of space would do no work in that structure, so nothing at the ground registers it, and by the principle it is not a way of the form of space". "It is then no way along which any finding could be laid out". A measurement of how the pull of a mass weakens with distance "would show a fourth way of space if space had one; it is a comparison made in a space whose form the ground has already fixed, and every measurement of the large world finds three directions of extension". Section IV closes on an image: "the rules of a board fix its ranks, and no move can establish a rank the rules do not supply, since a move along a rank already presupposes the rank".

Wolfram's argument. In the model, the dimension of space is a property of how the network is connected at large scale, and it can change. The technical introduction states that "dimension is in effect a dynamical variable", and that changes of dimension may produce effects that "mimic the presence of mass" (Wolfram 2020b). Wolfram writes that it is quite possible, according to

the models, that "there are at least local deviations" from three dimensions, and that "most likely there were actually large deviations in the early universe" (Wolfram 2020a).

Where they part. For the collection, the count belongs to the form of the context, fixed at the level of the ground by the structure of comparison, which every finding presupposes; so it is the same wherever a finding is made. For Wolfram, the count is a statistic of the network, and it can differ from place to place and from epoch to epoch.

Whose step, and what decides it. Both steps follow from their premises, and the premises differ. As the argument above showed, and stated now as one sentence, the premise in dispute is whether the number of ways of space belongs to the form of the context, settled at the level of the ground before any finding is laid out along it, or is a property of how a discrete network is connected at large scale, which emerges from the rule and can vary. The collection's count has two parts, and both follow from its premises. The floor of three follows from the doubling and the placing rule. The choice of three over four and six follows from the minimality principle and its reason: at the level of the ground a way is registered only by the work it does in the structure of comparison, since any finding that registers a way presupposes that way; a fourth way would do no such work, and so it is no way of the form of space. On Wolfram's premise the rewriting of the network makes the space, so the form of space comes with the findings made in it and not before them; its dimension is read from how the network grows, and a region or an epoch can show another count.

What rests on the choice of three over four and six, and what does not, can be said exactly. What rests on it is that space has three dimensions by necessity, and with it the statement against Wolfram that no region and no epoch shows another count, which the sealed record does not carry. What does not rest on it: the floor of three; the counts of time and of possibility, which Chapter 11, Section V, and Chapter 11, Section VII, reach by other arguments; the count found by measurement, three wherever the large world has been measured, and from the gravitational waves of GW170817, $4.02\ (+0.07, -0.10)$ dimensions of spacetime with the distance ladder's value of the Hubble constant and $3.98\ (+0.07, -0.09)$ with the microwave background's

(Pardo, Fishbach, Holz and Spergel 2018); and every numbered prediction of the sealed record, Prediction 6 included, which is stated for the arena as measured. Wolfram's expectation is decidable by measurement: a dimension of space other than three found in some region or epoch, or a wave of the geometry with a polarization beyond the two of Prediction 6.

Travel faster than light

The sealed prediction. "A finding changes no geometry, here or anywhere, and news of a distant finding enters a record only at an event on or within the future light cone of the finding. ... No signal crosses the boundary of comparison, and no body arrives somewhere that is not in its cone. ... Travel within the cone is not excluded, nor the recession of distant galaxies faster than light, which is a growth of the arena between them and not a signal across it". It was registered on 1 November 2026 as Prediction 27.

The argument of the book. The Unquantized Arena, Chapter 7, Section IV, Proposition 7.2, argues from the geometry of each alternative: "What a distant finding changes for a comparer here is that comparer's record, and the record changes only when a signal carrying the finding arrives, which is no earlier than light from the finding could arrive". The Basis of Physics, Essay 10, Section VIII, marks the edge of the claim: "Travel within the cone, however slow relative to popular aspiration, remains structurally permitted, and the essay takes no position at all on its technological feasibility. A body can go anywhere its forward cone reaches, and its forward cone, given time, reaches a great deal. What it cannot do is arrive somewhere that is not in the cone, and that is not a limitation on the body but a description of where "somewhere" is".

Wolfram's argument. Wolfram holds that "going faster than light is not a physical impossibility", and that doing it may be "an irreducibly hard engineering problem" (Wolfram 2020c). His route is the space tunnel, a structure in the network that gives "an alternative path from one part of space to another", of which "there's at least a special case of them that can be defined even in standard general relativity: wormholes". Through such a structure, "effects propagate, say through space tunnels, faster than light to places that seem distant in space". And in the same essay he keeps every effect within the or-

der of causes: “One event can affect another through a single connection in the causal graph”, and the events affected “have to be “subsequent events” with respect to the partial ordering defined by the causal graph”.

Where they part. Read with Wolfram’s own definitions, the two accounts agree at this place, and the dated record files it as an agreement. Wolfram’s faster than light is faster than the large-scale distance between two places allows, through a shortcut in the structure of space; every effect still runs along the order of causes. The collection’s prediction excludes arrival outside the cone of the geometry a body travels in. A shortcut is a feature of that geometry, as a wormhole is a solution of Einstein’s equations, so a body that takes it arrives within the cone of the geometry that has it. Neither account allows an effect outside the order of causes of the structure it travels in.

Whose step, and what decides it. Both sides’ steps hold. The apparent disagreement comes from two meanings of “faster than light”: outside the order of causes, which both accounts exclude, and faster than the large-scale distance allows, which is a question about the geometry. On the second meaning the collection makes no claim either way, and the sealed record says so: “No technological feasibility of travel within the light cone is claimed either way (The Basis of Physics, Essay 10, Section VIII)”. What would refute Prediction 27 is a signal or a body arriving outside the cone of the geometry it travels in, and Wolfram’s model forbids that too. What would bear on Wolfram’s expectation is whether a geometry with a shortcut can exist or be made. In general relativity the wormhole case calls for what Wolfram himself names, “a large-scale wormhole-like structure presumably requires negative mass”, and the collection, whose arena is the arena of general relativity with one geometry for each alternative, carries the same requirement and states nothing about whether such matter exists. On Wolfram’s own definitions the two accounts agree here: what first appears as a difference is agreement about the order of causes and a question of feasibility on which the collection takes no side.

IX. Summary

Stephen Wolfram and the physics collection agree on three things that most of physics does not hold: equations are not the foundation of physics; the observer cannot be removed from it; and computation is irreducible, so that in general the only way to know what a rule will do is to run it. They part on what comes before mathematics. Wolfram puts computation there. The collection puts physics there, because every run is a physical process and every measure of computation is a measure of time, and it puts the act of comparison before physics.

On that order, a world that is a computation at its foundation is excluded on three independent grounds: a whole world fixed by one rule, whether as one history or as all the histories of a multiway system, is the determinism the Incommensuration Theorem forbids; a world whose description and findings share one character compares a character with itself; and every actual world has hard randomness, an arrow and a stance, while a computation has none of the three of its own. The residue that every theory laid out as structure must take as given is hard randomness, and Wolfram's ruliad moves it into the place and sampling of the observer, which is where the collection says it lives. His bounded observer, described as a computation, is a description of an observer and not a stance. His discrete space is a calculation that can approximate the arena and cannot be it, and the collection predicts that no least step of spacetime will be found. Wolfram's program stands, in the collection's account, as the most thorough exploration there is of what computation can describe, and, in its bounded observer, as an exact picture of where description stops: at the stance from which every description is made.

Set beside the books they rest on, three of the four places compared rest on premises in dispute, and at the fourth the two accounts agree, and differ only in words. Whether space has a least length, and what a fine enough measurement of quantum statistics will show, rest on premises in dispute, and the collection carries the side a measurement can refute now. The count of three dimensions rests on the third premise in dispute: for the collection, whether a context has a way is settled at the level of the ground, where the structure of comparison, which every finding presupposes, registers a way only by the work it does, so a fourth way is none; for Wolfram, the dimension

of space is a property of how a network is connected, and it can vary. And Wolfram's travel faster than light keeps every effect within the order of causes, as Prediction 27 requires, so the two differ there only on a question of feasibility that the collection leaves open. Wolfram would compute the world from one rule; Arthur Eddington, in the next chapter, which opens Part Four, would deduce its numbers from the conditions of knowing, and his program is remembered as the warning case for every derivation of a constant of nature.

Key Concepts

- Computational irreducibility is a real result, held by the collection in the form of Rice's theorem: in general a program's behavior is known only by running it.
- The order of depth: metaphysics, physics, computation, mathematics; Wolfram moved the foundation from mathematics to computation, and the collection places it two steps further, in physics and the act of comparison.
- Three grounds exclude a world that is a computation at its foundation: determinism, one character at both levels, and the bound triple.
- A multiway system, taken whole, is as fixed by its rule as a single history.
- The incompressible residue of every structural theory is hard randomness; the ruliad moves it into the observer's place and sampling.
- A computationally bounded observer, taken as a computation, is a description of an observer, without the stance from which observing is done.
- The arena has no least length, area or duration; a discrete network can approximate it as a calculation and cannot be its foundation.
- Where the predictions part: a least length and the statistics below a rule's step rest on premises in dispute; the count of three dimensions rests on a premise in dispute, that the form of space is settled at the level of the ground, where a fourth way would do no work and so is none; and Wolfram's travel faster than light keeps to the order of causes that Prediction 27 protects, so there the two accounts agree.

Terms

Bound triple. The arrow of time, hard randomness and the stance from which a comparison is made: distinct, inseparable and not interchangeable.

Causal invariance. Wolfram's name for the property of a rewriting rule whose final relations among events do not depend on the order in which updates are applied.

Computational irreducibility. Wolfram's name for the fact that, for most computations, there is no shorter way to find the outcome than to run the computation.

Doubling. Every difference is placed twice: it is found in a context, and it is found by a comparing.

Cross-modal principle. A description and what it describes always take the two characters the Incommensuration Theorem allows, one each.

Hard randomness. An outcome that no prior specification fixes, however complete.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Minimality principle. Of the numbers the structure of comparison supplies, a context takes the least that meets every requirement comparison places on it.

Mode exchange. The Unquantized Arena's name for quantization: the passage of a description of content from one of the two characters the Incommensuration Theorem allows to the other.

Multiway system. In Wolfram's model, the structure of all the histories that a rule allows, branching and merging.

Order of depth. Metaphysics, physics, computation, mathematics, ordered by what each presupposes.

Placing rule. The distinction between two ways of a context is placed in that context when, and only when, the context has a way that is not composed from those two.

Ruliad. In Wolfram's words, "the entangled limit of all possible computational processes".

Space tunnel. In Wolfram's model, a structure in the network that gives an alternative path from one part of space to another; a wormhole of general relativity is a special case.

References

Bennett, C. H. (1973). "Logical reversibility of computation". *IBM Journal of Research and Development* 17, 525–532.

Bombelli, L., Henson, J. and Sorkin, R. D. (2009). "Discreteness without symmetry breaking: a theorem". *Modern Physics Letters A* 24, 2579–2587.

Gorard, J. (2020a). "Some Relativistic and Gravitational Properties of the Wolfram Model". *Complex Systems* 29(2), 599. arXiv:2004.14810.

Gorard, J. (2020b). "Some Quantum Mechanical Properties of the Wolfram Model". *Complex Systems* 29(2), 537–598.

Landauer, R. (1961). "Irreversibility and heat generation in the computing process". *IBM Journal of Research and Development* 5, 183–191.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Pardo, K., Fishbach, M., Holz, D. E. and Spergel, D. N. (2018). "Limits on the number of spacetime dimensions from GW170817". *Journal of Cosmology and Astroparticle Physics* 2018(07), 048. arXiv:1801.08160.

Rice, H. G. (1953). "Classes of recursively enumerable sets and their decision problems". *Transactions of the American Mathematical Society* 74, 358–366.

Wolfram, S. (2002). *A New Kind of Science*. Champaign, Illinois: Wolfram Media.

Wolfram, S. (2020). *A Project to Find the Fundamental Theory of Physics*. Champaign, Illinois: Wolfram Media.

Wolfram, S. (2020a). “Finally We May Have a Path to the Fundamental Theory of Physics… and It’s Beautiful”. Stephen Wolfram Writings, April 2020. writings.stephenwolfram.com

Wolfram, S. (2020b). *A Class of Models with the Potential to Represent Fundamental Physics*. Technical introduction, Wolfram Physics Project; sections “Units and Scales” and “Cosmology, Expansion and Singularities”. wolframphysics.org

Wolfram, S. (2020c). “Faster than Light in Our Model of Physics: Some Preliminary Thoughts”. Stephen Wolfram Writings, 2 October 2020. writings.stephenwolfram.com

Wolfram, S. (2023). “How to Think Computationally about AI, the Universe and Everything”. Stephen Wolfram Writings, October 2023. https://writings.stephenwolfram.com/2023/10/how-to-think-computationally-about-ai-the-universe-and-everything/

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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PART FOUR

The Cosmos and the Dark Component

These are the models of the cosmos and its dark component: Arthur Eddington, George Ellis, Mordehai Milgrom and Stacy McGaugh, and Erik Verlinde.

Arthur Eddington

The Net and the Measure

Arthur Eddington and Physics from Comparison

Abstract

Arthur Eddington saw, earlier and more clearly than any physicist of his time, that the form of what physics finds is shaped by the means of finding it. His image of a fishing net whose meshes decide the smallest fish ever caught is used in the physics collection of the Immanent Metaphysics, and it is his. From that insight he built, between 1929 and his death in 1944, a program to deduce the laws and constants of nature from the conditions of knowing, and he gave numbers: 136, then 137, for the inverse of the fine-structure constant; 1847.6 for the ratio of the proton's mass to the electron's; 136 times two to the power 256 for the number of protons in the universe. The program is remembered as the warning case for every attempt to derive constants from first principles, and readers will compare the collection with it. The comparison shows the collection standing apart from Eddington at each point where his program failed, and, where one of its own derivations shares the form of his step from 136 to 137, it names the shared form and the test that separates the two cases. On the fine-structure constant, the number Eddington is remembered for, the collection gives the opposite verdict: it argues that no argument from the structure of comparison can fix that number, so the number stays measured. It derives no constant with units, gives every number a stated standing, holds every result to measurement at five standard deviations by at least two independent kinds of measurement, and treats a value that fits before its reason is known as a question, never as a proof. Eddington put the net in the mind of the knower. The collection puts it in the act of comparison, which every interaction is, so that the form it finds is the form of the world's own interactions and not a projection of the knower. A closing section sets each of Eddington's four settled predictions beside the argument of the book on which the collection's statement rests, finds the step where each failed, and asks the same question of the collection's own derived values.

I. Eddington's Program

Arthur Stanley Eddington was among the most accomplished astronomers of the twentieth century. He led the expedition whose photographs of the eclipse of 29 May 1919 showed starlight bent by the Sun by the amount general relativity requires (Dyson, Eddington and Davidson 1920), a result the collection cites in Two Theories, One World and Measurement. His *The Internal Constitution of the Stars* (1926) founded the physics of stellar interiors. In 1930 he showed that Einstein's static universe is unstable, a result The View from Inside cites.

From 1929 until his death in 1944 he worked on a theory meant to cover everything from the electron to the universe, set out in *Relativity Theory of Protons and Electrons* (1936) and in *Fundamental Theory*, which appeared in 1946, after his death, in a manuscript edited and titled by Edmund Whittaker. He described the theory as "purely deductive, being based on epistemological principles and not on physical hypotheses", and he held that its resources were "sufficient and our methods powerful enough to calculate the constants exactly" (as quoted in Kragh 2015). Its philosophical ground he called *selective subjectivism*: the mind determines the nature and extent of what is called the external world, so that "what we comprehend about the universe is precisely that which we put into the universe to make it comprehensible" (as quoted in Kragh 2015).

II. The Numbers

The constants of nature were the center of the program. In his 1929 paper "The charge of an electron", Eddington derived the inverse of the fine-structure constant, the pure number that measures the strength with which light acts on charge, as sixteen, plus one half of sixteen times fifteen: 136. Measurement kept returning a value near 137. At first he wrote, "I cannot persuade myself that the fault lies with the theory". He then concluded that the inverse is exactly 137, the extra unit coming from the exclusion principle's implication that all elementary particles are indistinguishable, and by 1932 he described 137 as "obtained by pure deduction, employing only hypotheses already accepted as fundamental in wave mechanics" (Kragh 2015).

For the ratio of the proton's mass to the electron's, he took the ratio of the two roots of a quadratic equation whose coefficients, in units of a standard mass, are ten, one hundred thirty-six and one, and obtained 1847.6 (Kragh 2015). Measured, the ratio is 1836.152673426, with uncertainty 32 in the last two digits (CODATA 2022; The Matter We Know, Volume One, gives the earlier value of CODATA 2018, 1836.15267343). In his Tarner Lectures at Trinity College, Cambridge, in 1938, he gave the number of protons in the universe as 136 times two to the power 256, about 1.57×10^{79}, and wrote it out to the last digit; with as many electrons, the number of particles is about 3.15×10^{79}. In 1923 he had called that number "presumably decided by pure accident"; in the program, he held that it could not have been different (Kragh 2015).

When observation disagreed with his calculations, Eddington usually blamed the observation. In 1935 he wrote that one should not put "overmuch confidence in the observational results" until they "have been confirmed by theory" (as quoted in Kragh 2015). His contemporaries rejected the program. Wolfgang Pauli, in a letter of 1929, called it "romantic poetry, not physics", objecting specifically to the identification of the fine-structure constant with one over 136. Herbert Dingle attacked the "pseudo-science of invertebrate cosmythology" in the cosmologies of Eddington and Edward Milne; Max Born, in letters to Einstein in 1944, called the approach "rubbish"; and the historian Helge Kragh describes the cosmophysics of the 1930s, the program of Eddington and Milne as a whole, as "a full-blown rationalism where experimental tests were of no more significance than in mathematical proofs" (Kragh 2011, Sections 4 and 5, from which all three quotations come; as Objections from Physics, Answered, quotes them). Kragh calls the program "a grand failure in so far that it was rejected by the large majority of physicists".

III. What Eddington Saw

Eddington saw something real behind his failed numbers, and the collection takes it from him by name. In *The Philosophy of Physical Science* (1939), Chapter II, he told of a scientist who studies the life of the sea by casting a net whose meshes are two inches wide. Everything the net brings up is more than

two inches across, and the scientist concludes that no creature of the sea is smaller. The Story of the Particles, Level 6, Section II, states the lesson in its own words:

> "The fish are real; the form in which he finds them, nothing smaller than two inches, is the form of his net. The form of what can be found is the form of the instrument of finding".

Eddington saw three things that the collection holds. Physics rests on what measurement can be, and a law found by measurement carries the form of the measuring. Some features of the world's description are fixed before any particular observation, by what observing is. And a number fixed in that way is fixed exactly, as the ratio of a circle's circumference to its diameter is fixed exactly by what a circle is. Each of these is correct, and each appears in the collection. Eddington went wrong in where he placed the net, and in which numbers he asked it to fix.

IV. The Net Made Exact

Eddington placed the net in the mind. Selective subjectivism holds that what we comprehend is what we put in; the form of law is the knower's contribution. On that ground the laws describe the knower more than the known, and a critic can reply that a theory of the knower has no authority over the stars.

The collection places the net in the act of comparison, and the passage that uses Eddington's image states the one difference that makes the image exact: "Re-projection is this, with one difference that makes it exact: the instrument of comparison is comparison itself. So whatever comparison finds inside the proton has the form of comparison, the six intrinsics, and nothing else could be its form" (The Story of the Particles, Level 6, Section II; also The Spectral Chain, Chapter 4, Section III). Re-projection is that book's name for what Eddington's image describes, the form of the instrument of finding returning as the form of what is found; the six intrinsics are the parts of every comparison, in three pairs: same and different, content and context, the subjective and the objective. Every interaction is a comparison, and a knower comparing is one case among all the others. The *Root Tautology*, the premise of the whole collection, is that comparison, interaction and relation are one act under three

names, and Comparison, Chapter 3, Section V, draws the consequence: "The Root Tautology binds the world, and not only what we know of the world. ... By the Root Tautology, every interaction is a comparison. What every comparison requires is therefore required of every interaction, between two particles as much as between a particle and a detector".

So the form the collection finds is the form of the world's own interactions, the same in a particle meeting a particle as in an instrument meeting a particle. It is neither a projection of the knower nor a structure standing apart from every knower: the collection is neither idealism nor physicalism (The Last Turtle, Chapter 1, Section V). Objectivity, on this account, is built from many comparisons made from many places, which agree (Physics Is Not Math, Chapter 3, Section V). Eddington's insight survives with its ground corrected: the net is real, it is everywhere, and the knower is one instance of it.

V. The Fine-Structure Constant: The Opposite Verdict

The number for which Eddington is remembered is the one on which the collection's verdict is the opposite of his. First, measurement. The Strengths of the Kinds, Chapter 1, Section V, states it: "Measured, the strength of light is $1/\alpha_{em} = 137.035999177$, with uncertainty 21 in the last two digits (2022 recommended values). Eddington's whole number 137 is excluded, because $1/\alpha_{em}$ is not a whole number". Five routes determine the value, and the book keeps them side by side.

Second, and more important, the collection argues that no argument of Eddington's kind can fix this number at all. The Strengths of the Kinds, Chapter 1, Section VI, "Why the Strength of Light Stays Measured", gives the argument in steps. Light acts by turning the phase of charged things, and the turns of a phase form a circle; for such a group of turns, the symmetry leaves exactly one positive number undetermined, the strength of the coupling. Everything the symmetry fixes, the whole-number charges, the conservation of charge and every symmetry of the laws, is the same at every value of that strength. On a finite lattice the strength enters the weight of each arrangement only through a bounded quantity, so the arrangements that are possible, impossible and certain are the same at every value. The kinds of finding, which contents recur across contexts, and the possible verdicts, the whole of what

the book calls the comparison structure of a world, therefore do not change when the strength of light changes. A valid argument keeps its verdict wherever its premises hold, and premises drawn from the comparison structure hold at every value, so "no argument from the comparison structure, of any length, fixes αem".

The book closes the argument with a rule taken from the circle, the case Eddington's hope rested on. A value is fixed by concepts alone only when one form supplies all the terms the value relates: the concept of a circle in a flat plane supplies both the circumference and the diameter, so it fixes their ratio, and a figure with another ratio is not a circle. The strength of light relates terms that no single form among the parts of comparison supplies together, and the concept of it stays whole under a different value. So the fine-structure constant is a value of this world that the structure of comparison does not fix, and it stays measured. Beyond replacing Eddington's number with the measured one, the collection shows why the search he made could not succeed for that number, and it says how a constant that comparison does fix would show itself: as the one value at which a world has the structure the constant's concept requires, as π is the one ratio at which a figure in the flat plane is a circle. Why These Numbers retells the argument in plain words.

VI. Every Number with Its Standing

Eddington called every one of his numbers a deduction, and gave no number any other standing. The collection gives every number one of six standings, named where the number is stated (The Spectral Chain, Chapter 1, Section V): a measured input, taken from measurement as a premise; a structural value, fixed by the structure of comparison; derived, following from stated premises; derived given one named premise or identification; a measured agreement, a value the account reaches that measurement finds, which "carries the question of why it lands"; and a fork, two routes carried side by side until a named measurement decides. A result taken from the physics literature is reported, with its primary citation. The Spectral Chain, Chapter 1, Section VII, then sorts its own steps: the theorem is a theorem, its match to the

two theories of physics is an identification, the gauge group and the number of generations are derived, and every value the form of the theory leaves open carries its standing in a table.

Three of Eddington's numbers show what the standings do. Objections from Physics, Answered, puts the first difference in one sentence: "Eddington claimed to deduce constants of nature with units by theory alone, and the books deduce no constant with units". Of Newton's constant, Two Theories, One World, Chapter 8, says: "It is measured, by weighing the pull between masses in the laboratory, and nothing in this book derives it. The ground of comparison fixes what role the arena plays, and not how large any quantity in it is: its axioms are structural, and they carry no units".

Of the ratio of the proton's mass to the electron's, The Strengths of the Kinds, Chapter 6, Section V, derives the order of the two inertias, the proton's the greater, and states that "the amount is a value of the instance (a value of this world that the structure of comparison does not fix) and is not derived". Where Eddington gave 1847.6 as a deduction, the collection gives the measured value as measured, and says which part of the question its argument reaches.

Of the number of particles in the universe, the collection says it is not a structural number at all. The Coming of the Kinds, Chapter 1, Section VI, "The Amounts Are History", draws the line: the structure of comparison fixes which kinds of particle there are, and not how many of each the universe holds; the excess of matter "belongs to the initial conditions, to the history of the universe". Eddington's first judgment of 1923, that the number of particles was decided by accident, stood nearer to the collection than his later deduction of it.

The standard by which the collection counts a result as confirmed is a standard of the kind Dingle demanded and Eddington set aside, that theory answer to observation, made exact: "confirmed means established at five standard deviations by at least two independent kinds of measurement" (The Gravitational Passage, Chapter 20, Questions). And the books say exactly what their derivation from comparison reaches: "It does not say that metaphysics tells physics what it will find. It says that metaphysics describes the structure of finding" (The Basis of Physics, Essay 17, Section IV).

VII. A Dial Turned and a Value That Lands

The step from 136 to 137 is the exact case Physics Is Not Math, Chapter 13, Section IV, describes when it gives the one fair use of the word "fitted": "A value is fitted when it was chosen to match: a dial turned until the needle points where it should". Eddington turned the dial by one unit when measurement moved, and then supplied a reason for the new setting. The collection's rule runs the other way. A value that agrees with measurement before its reason is known is written as a question, "why does it land?", with every clue to the reason kept beside it, and the question stays open until the reason is found. Even a value that was fitted keeps its question: why does the world need the dial at that setting?

The objection that follows from Eddington's history is stated at full strength in Objections from Physics, Answered, in its makers' words: attempts to derive the laws of nature by reason alone have a long record of failure, physicists judged them pseudo-science, and short expressions in small numbers match measured constants by chance more often than intuition expects (Amir, Lemeshko and Tokieda 2016). The collection answers the objection on the points the objection names. Eddington held experiment to be of no more account than in a proof; the collection places every law and every number it reaches under measurement. Eddington gave every number one standing, deduced, whatever its premises; the collection states each number's standing and, for each value that lands, gives the reason with the value or writes the question. And the verdict that physicists judged such programs pseudo-science is a fact about how those programs were received, which is a matter of agreement among people. Physics Is Not Math, Chapter 19, Section IV, names the three ways a claim is validated: measurement, in the first person; agreement, in the second; and proof, in the third. Only measurement and proof validate truth. Eddington's program failed where its numbers met measurement, which is the first of those ways, and the collection states its numbers so that measurement can meet them.

The ground beneath the collection is a theorem, and the collection says why no measurement can overturn it. The Incommensuration Theorem, that symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison, and neither can asymmetry and discon-

tinuity, is proved from the parts of comparison alone, by enumerating ten cases. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. Every measurement is a comparison and so an instance of it. What comes after the theorem comes by steps of three marked kinds: the theorem itself; established physics, cited to its literature; and identifications, each made in the first person beside the observation that tests it. Eddington's program had one kind of step, deduction, and gave it authority over measurement. The collection has three kinds, marks each, and gives measurement the last word wherever a number meets the world.

VIII. Where the Predictions Part, and Why

Four times Eddington stated a number or an outcome that differs from what the collection states, and measurement has settled all four. For each, this section sets the argument of the book on which the collection's statement rests beside Eddington's own reasoning, and finds the step where the two part. The outcomes are known, so the question is which step failed, and what the failure teaches. The section ends by asking the same question of the collection's own derived values.

The strength of light

The collection's statement. The sealed record of 1 November 2026 makes no prediction of this value. Its list of what the account does not predict states: "The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (The Gravitational Passage, Chapter 13; The Strengths of the Kinds, Chapter 1, Section VI; The Measures of the Kinds, Chapter 13, Section X)".

The argument of the book. The Strengths of the Kinds, Chapter 1, Section VI, reaches that standing in five steps of argument, which Section V of this essay set out in words. The step the book names as the one that carries the load is the third: "The kinds, the symmetries and the possible verdicts are the

same at every value of α_{em}; varying α_{em} leaves the comparison structure the same". The fourth follows from it: "A valid argument keeps its verdicts wherever its premises hold, and premises drawn from the comparison structure hold at every value of α_{em} (Step 3); so no argument from the comparison structure, of any length, ends at one value of α_{em}".

Eddington's argument. In "The charge of an electron" (1929) he worked from his own version of Dirac's equation, whose matrices generate an algebra of sixteen elements, and from his own reading of the exclusion principle. From them he counted sixteen, plus one half of sixteen times fifteen, which is 136, the number of independent entries of a symmetric array of sixteen rows and sixteen columns, and he set the inverse of the fine-structure constant equal to that count (Eddington 1929; Kragh 2015, Section 3). When measurement held near 137, he added one unit and traced it to the exclusion principle, read as making any two elementary particles indistinguishable, as Section II told.

Where they part. For Eddington, the strength with which light acts on charge is a count taken from the structure of the wave equation. For the book, that structure, like every part of the comparison structure, is the same at every value of the strength.

Whose step, and what decides it. The step that fails is Eddington's, and it fails as a step, before any measurement is consulted. His premises are the algebra of sixteen elements and the exclusion principle, and neither contains the coupling of light to charge: Dirac's matrices and the exclusion principle are the same in a world whose inverse coupling is 100 as in ours. Premises that hold at every value cannot end at one value, so the count of 136, or of 137, says nothing about the coupling. Our own world is the case in which his premises hold and his conclusion fails: the measured inverse is 137.035999177, about 1.7 million of its standard uncertainties from 137 (computed from the uncertainty of 21 in the last two digits). The lesson is the circle's rule of Section V: a count fixes a value only when one form supplies every term the value relates, and the algebra of the wave equation does not supply the strength with which light acts.

The ratio of the proton's mass to the electron's

The collection's statement. The sealed record carries no prediction of this amount. The Strengths of the Kinds, Chapter 6, Section V, states what the collection holds: "The argument from comparison gives the order of the two inertias, the proton's the greater; the amount is a value of the instance (a value of this world that the structure of comparison does not fix) and is not derived".

The argument of the book. The same section gives the reason the amount is left to measurement: "Its form is argued (Section II): m_p/m_e is the exponential of an inverse strength of color, times numbers fixed by structure. Its value is measured; a law fixes that value, and this book does not state that law". And the section draws the consequence: "Since color's strength and m_p/m_e are one value, a law for the proton's place is a law for color's strength, and the converse". The ratio of the masses therefore stands where the strength of color stands, and of the strengths Chapter 1, Section VI, says that "the structure gives no computation of the values of the strengths".

Eddington's argument. He took the two masses as the two roots of a quadratic equation whose coefficients, in units of a standard mass, are ten, one hundred thirty-six and one, and took their ratio: 1847.6, which he judged "nearly the same as the experimental value" (Kragh 2015, Section 4). The arithmetic holds: one hundred thirty-six plus the square root of 18,456, divided by one hundred thirty-six less that root, is 1847.6 (computed).

Where they part. For Eddington, the ratio of the masses is fixed by numbers drawn from his counting. For the book, the ratio is the exponential of an inverse strength of color, and so it is as free of the structure as that strength is.

Whose step, and what decides it. The failed step is Eddington's, and it is the step of the strength of light again: an amount that his structure does not supply is set equal to a value computed from counts whose premises do not contain the strength of color. The measured ratio, 1836.152673426 (CODATA 2022), is the case in which his premises hold and his conclusion fails; his value lies 0.62 percent above it, about 360 million times its uncertainty (computed). The episode teaches a second thing. A short expression in small

whole numbers lands within a percent of a measured ratio more often than intuition expects (Amir, Lemeshko and Tokieda 2016), so a landing of that closeness, by itself, was no evidence for the counting that produced it.

The rate at which the galaxies recede

The sealed prediction. "Matter makes up a fraction $\Omega_m = 0.311 \pm 0.001$ of the energy of a spatially flat universe at the present epoch, and the cosmological constant carries $\Omega_\Lambda = 0.689$". Its identity is such that "the Hubble constant and the Planck mass cancel from it, so it fixes a pure number", and a rate is reached only through one more measured quantity: "with the matter density in physical units that the microwave background measures, $\Omega_m h^2 = 0.1430 \pm 0.0011$, a Hubble constant of 67.8 ± 0.3 kilometers per second per megaparsec". This was registered on 1 November 2026 as Prediction 7.

The argument of the book. The Gravitational Passage, Chapter 13, Section II, identifies the cosmological constant with the share of the vacuum energy that an observer inside the horizon can reach: three degrees of freedom, one for each channel of measurement, among the degrees of freedom the particle horizon counts. Chapter 13, Section III, sets that share equal to the vacuum energy that the Friedmann equation requires; the two must describe one expansion history, and in the equation that results the Hubble constant and the Planck mass cancel, leaving one equation in one unknown, the matter fraction. The book says what the identity reaches and what it leaves to measurement: "The identity fixes the dimensionless split of the energy, not the Hubble constant, which cancels from it".

Eddington's argument. In 1931 he expressed the cosmological constant through the constant of gravitation and the masses and charge of the proton and the electron, as 9.8×10^{-55} per square centimeter, and from it computed a recession rate of 528 kilometers per second per megaparsec, which matched the generally accepted observational value; he counted the match as evidence for his theory (Kragh 2015, Section 4). The accepted value rested on Hubble's estimate of 1929, about 500 (MacCallum 2015).

Where they part. For Eddington, a rate carrying units follows from the constants of the atom. For the book, the structure fixes only a pure number, and any rate is reached through a measured density.

Whose step, and what decides it. Two things failed on Eddington's side. The deduction is the step of the first two cases, a value of this world set equal to an expression in other values of this world that do not supply it; the collection derives no constant with units, as Section VI said. And the measurement he counted as confirmation was itself in error. The variable stars by which Hubble set his distances were confused with fainter stars of another kind, and Baade's recognition of two populations of stars doubled the distances. Sandage then found that what had been taken for the brightest stars of other galaxies were regions of glowing gas, and in 1958 put the rate between 50 and 100, an increase of the distance scale by a factor of five to ten (MacCallum 2015; Tammann and Reindl 2013). Eddington's 528 is more than seven times the collection's 67.8 (computed). The lesson is the collection's rule of decision: agreement with one kind of measurement, at one time, carried Eddington's confidence, and the collection asks for five standard deviations from two independent kinds. The same question bears on the collection today. The microwave background's fit, 67.4 ± 0.5, lies 0.8 standard deviations from 67.8, and the distance ladder of Cepheid variables, 73.04 ± 1.04, lies 5.0 away, each counted in units of the measurement's own uncertainty (0.7 and 4.8 with the prediction's uncertainty added in quadrature; the sealed record, quoting the dated record of The Gravitational Passage, gives 4.9); the sealed record states in advance that a Hubble constant settled near 73, with the microwave background's matter density standing, would refute Prediction 7. Eddington's history shows that a ladder of distances can carry an error of calibration for decades; it does not show which of today's two kinds carries one, and the sealed record leaves that to the measurements it names.

The fate of a star above the greatest mass

The collection's statement. The sealed record carries no numbered prediction for this. The Gravitational Passage, Chapter 18, Section III, states where every path of a star ends: "bound structures end in black holes".

The argument of the book. The Matter We Know, Volume Two, Chapter 13, Section IV, reports the established argument in outline, in its Box 13.2. The electrons that hold up a white dwarf fill their states from the bottom, by the exclusion principle; an electron at the top moving near the speed of light car-

ries energy in proportion to its momentum, which falls off with the size of the star exactly as the star's gravitational energy does. When gravity is the larger of the two, the energy "falls without end as R [the star's radius] shrinks: by (4), no radius holds the star", and the result is: "A star held up by electrons moving near c [the speed of light] has a greatest mass, the Chandrasekhar mass, about 1.4 times the Sun's mass for matter of two nucleons to each electron".

Eddington's argument. At the meeting of the Royal Astronomical Society of 11 January 1935, following Chandrasekhar's paper, he spoke on "Relativistic Degeneracy" and objected to Chandrasekhar's use of relativity together with the quantum statistics of the electrons; he set out his own case in a separate paper, "On 'Relativistic Degeneracy'" (Eddington 1935b; the article "Chandrasekhar–Eddington dispute"). He said that "there is no such thing as relativistic degeneracy", called the result "a reductio ad absurdum of the relativistic degeneracy formula" (as quoted in Indian Institute of Astrophysics, The Legacy of S. Chandrasekhar), and in his reply at the meeting, printed in The Observatory, gave his reason in one sentence: "Various accidents may intervene to save the star, but I want more protection than that. I think there should be a law of Nature to prevent a star from behaving in this absurd way!" (Eddington 1935a, as Harwit 2013 cites it; also reported by Sutter 2026).

Where they part. For Eddington, a conclusion that a star collapses without end is absurd, so the formula that leads to it must be wrong. For the book, the formula follows from two premises of established physics, the exclusion principle and the energy of a fast particle, and the conclusion stands with them.

Whose step, and what decides it. The failed step is Eddington's. A reduction to absurdity needs a contradiction with a premise, and "absurd" here named a conclusion he found unacceptable, not one that contradicts anything the argument assumed. The case in which the premises hold and his conclusion fails is the world. Peierls proved in 1936 a relation of pressure to volume for a relativistic gas that went against Eddington's theory, and in 1941 Peierls, Dirac and Pryce set out his misunderstandings of relativity combined with quantum theory (the article "Chandrasekhar–Eddington dispute"). Every

white dwarf weighed lies below the greatest mass; Cygnus X-1, identified in 1972, was the first black hole detected; and the first gravitational wave detected came from the merger of two black holes (Abbott and others 2016), so two independent kinds of measurement find the remnants he held impossible. Pulsars, observed since 1967, are neutron stars, remnants of stellar cores that passed the greatest mass of a white dwarf and are held up by the pressure of neutrons; that pressure holds some remnants that electrons cannot, and above its own greatest mass no pressure holds. The lesson is the one Section VII drew from the three ways of validation: a valid step is not undone by the strangeness of where it leads, and only measurement and proof decide.

The same question, asked of the collection

Three of Eddington's failures share one step: a value his structure does not supply was set equal to a number computed from that structure, and the number was trusted because it landed near a measurement. The collection's two most exact derived values must answer the same question. The matter fraction, 0.311, comes from an identity between two expressions for the energy of the vacuum, one from the count of the particle horizon and one from the Friedmann equation, and what remains when the Hubble constant and the Planck mass cancel is one equation in one unknown (The Gravitational Passage, Chapter 13, Section III). One equation in one unknown is the form Section V gave for a constant fixed by comparison, the one value at which a world has the structure its concept requires; Eddington's count had no such equation, since the algebra he counted is the same at every value of the coupling. The identity rests, however, on identifications the book names as such, three channels and one degree of freedom for each, counted in nats (units of information on the natural logarithm, as bits are on the logarithm to base two, so that S below is the horizon's count in nats), and the book states what the neighbors give: "in bits the same horizon counts S/ln 2, and one bit for each channel would give $\Omega_m = 0.407$ in place of 0.311" (Chapter 13, Section II), and with the ground-state part of the vacuum energy alone the solution is 0.280. The ratio of the dark matter to the ordinary matter, $6 - 2/\pi$, was chosen within a published family of forms, and The Weight of Possibility, Chapter 5, Section VIII, says how: "The rule was selected from a small family of expres-

sions of one form, and twelve expressions were examined in all". The ratio's count of classes rests on principles the book calls the account's own (The Weight of Possibility, Chapter 3, Section II). Eddington's step from 136 to 137 was also a choice among near forms made with the measurement in view. Three things separate the collection's choice from his, and each is a matter of record. The family examined is published, in the same section of The Weight of Possibility, with each member's distance from the measurement, so a reader can weigh the selection. The choice of which curvature abides is stated with its ground in the theorem of Gauss and Bonnet (The Weight of Possibility, Chapter 3, Section IV). And the two values share one coefficient, the curvature of the internal dimensions (k, in Planck units, which Prediction 17 sets at 1), which two independent observables must both meet (Prediction 17), a test that no setting chosen to match one of them can pass by being chosen. The sealed record reports where that test stands, quoting the dated record of The Weight of Possibility: "the dated record gives 0.989 ± 0.075 from the ratio and 1.13 ± 0.21 from the matter fraction (Planck 2018), and, within the analyses that add DESI, 1.26 ± 0.06 and 0.68 ± 0.11". Within the Planck analysis the two observables agree; within the analyses that add DESI (the Dark Energy Spectroscopic Instrument) they part, from one kind of measurement, short of the rule of decision. The same question bears more sharply on the simple values that The Strengths of the Kinds carries into the laws of its closures, in the chapter this essay cites for the proton's mass: color's slot of five halvings, the electroweak level 169/4 and the ratio 21/4. Of the level the book says plainly, "The level is read from measurement; no law of this book fixes it" (The Strengths of the Kinds, Chapter 3, Section V), and the book holds each of these values as a value that lands. Until the circle's rule is shown met for each, each keeps the question Eddington never asked of 137: why does it land? What Eddington's history teaches the collection is where to look first: wherever a count is set equal to an amount, the book must show that one form supplies both terms, and the shared coefficient of Prediction 17 is the measurement that will say whether the collection has done so for its two exact values.

IX. Summary

Eddington saw that the form of what physics finds is the form of the means of finding, and the collection uses his image of the net to say so. He placed the net in the knower's mind, deduced from it numbers with and without units, adjusted the fine-structure constant from 136 to 137 when measurement moved, and held measurement answerable to his theory. His program failed where its numbers met measurement, and it is remembered as the warning case for deriving constants.

The collection keeps the insight and differs at every point of the failure, and where one of its own derivations shares the form of his step from 136 to 137, it names the shared form and the test that separates the two cases. It places the net in the act of comparison, which every interaction is, so the form it finds is the world's own. On the fine-structure constant, Eddington's own number, it argues that no argument from the structure of comparison can fix the value, so the value stays measured. It derives no constant with units, sorts every number into one of six stated standings, treats the amounts of matter as history, holds its results to five standard deviations by at least two independent kinds of measurement, and writes a value that lands as a question rather than a proof. A reader who sets the collection beside Eddington finds the comparison in the collection's favor at exactly the places where Eddington is remembered as having gone wrong.

Set beside the books, Eddington's four settled predictions fail at two steps: three set a value that his structure does not supply equal to a number computed from that structure, and the fourth took the strangeness of a valid conclusion for a refutation of its premises. Asked of the collection, the same question finds the matter fraction resting on an identity with one solution, and the ratio of the dark matter to the ordinary matter chosen from a published family of near forms; the curvature coefficient that the two values share, which two independent observables must both meet, is the measurement that separates the collection's case from Eddington's. Eddington held measurement answerable to his theory; George Ellis, in the next chapter, has argued longest, from inside physics, that a theory must face the world to count as physics, and that the future is not yet.

Key Concepts

- Eddington's net: the form of what can be found is the form of the instrument of finding.
- Selective subjectivism places the net in the knower; the collection places it in the act of comparison, which every interaction is.
- The fine-structure constant stays measured: the structure of comparison is the same at every value of it, so no argument from that structure fixes it.
- The circle's rule: a value is fixed by concepts alone only when one form supplies every term the value relates.
- Six standings for every number; no constant with units derived; the amounts of matter are history.
- A value fitted is a dial turned; a value that lands is a question, "why does it land?".
- Eddington's settled failures part from the books at two steps, a count set equal to a value the structure does not supply and an unwelcome conclusion taken for a refutation; the collection's ratio $6 - 2/\pi$ was chosen from a published family of near forms, and the coefficient it shares with the matter fraction is the test that separates its case from his.

Terms

Abiding. In The Weight of Possibility, the share of a factor's curvature that holds fast in a registration as a term of its own, and by which it reduces a count of classes.

Chandrasekhar mass. The greatest mass of a star held up by electrons moving near the speed of light, about 1.4 times the Sun's mass for matter of two nucleons to each electron.

Circle's rule. A value is fixed by concepts alone only when one form supplies all the terms that the value relates.

Comparison structure. The kinds of finding a world has, which contents recur across contexts, and the possible verdicts of its comparisons.

Fine-structure constant. The pure number that measures the strength with which light acts on charge; its inverse is measured as 137.035999177.

Fitted. Said of a value chosen to match a measurement, as a dial is turned until the needle points where it should.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Particle horizon. The bound of what has reached an observer over the whole expansion; its radius is the distance light has traveled since the expansion began.

Relativistic degeneracy. The state of electrons packed so densely, by the exclusion principle, that those at the top move near the speed of light.

Root Tautology. Comparison, interaction and relation are one act under three names.

Selective subjectivism. Eddington's view that the mind determines the nature and extent of what is called the external world.

Standing. The kind of number a value is: measured input, structural value, derived, derived given a named premise or identification, measured agreement, or fork.

Value that lands. A value the account reaches that measurement finds, before its reason is known; it is written as a question, "why does it land?", with every clue to the reason kept beside it.

References

Abbott, B. P. and others, LIGO Scientific Collaboration and Virgo Collaboration (2016). "Observation of gravitational waves from a binary black hole merger". *Physical Review Letters* 116(6), 061102. DOI 10.1103/PhysRevLett.116.061102.

Amir, A., Lemeshko, M. and Tokieda, T. (2016). "Surprises in numerical expressions of physical constants". arXiv:1603.00299.

Chandrasekhar, S. (1931). "The maximum mass of ideal white dwarfs". *Astrophysical Journal* 74, 81–82. DOI 10.1086/143324.

Dyson, F. W., Eddington, A. S. and Davidson, C. (1920). "A determination of the deflection of light by the Sun's gravitational field, from observations made at the total eclipse of May 29, 1919". *Philosophical Transactions of the Royal Society of London A* 220, 291–333.

Eddington, A. S. (1926). *The Internal Constitution of the Stars*. Cambridge: Cambridge University Press.

Eddington, A. S. (1929). "The charge of an electron". *Proceedings of the Royal Society of London A* 122, 358–369.

Eddington, A. S. (1930). "On the instability of Einstein's spherical world". *Monthly Notices of the Royal Astronomical Society* 90, 668–678.

Eddington, A. S. (1935a). Reply to Chandrasekhar at the meeting of the Royal Astronomical Society of Friday 11 January 1935, printed in the report of the meeting, *The Observatory* 58, 37–39; cited by Harwit (2013) as "Response to Chandrasekhar". The sentence "I think there should be a law of Nature to prevent a star from behaving in this absurd way!" is given here in the wording of the accounts cited; one account, by Kameshwar Wali, gives "absurd manner".

Eddington, A. S. (1935b). "On 'Relativistic Degeneracy'". *Monthly Notices of the Royal Astronomical Society* 95, 194–206. A separate paper from the report of the meeting; the "law of Nature" sentence is not in it.

Eddington, A. S. (1936). *Relativity Theory of Protons and Electrons*. Cambridge: Cambridge University Press.

Eddington, A. S. (1939). *The Philosophy of Physical Science*. Cambridge: Cambridge University Press.

Eddington, A. S. (1946). *Fundamental Theory*. Edited by E. T. Whittaker. Cambridge: Cambridge University Press.

Harwit, M. (2013). *In Search of the True Universe; The Tools, Shaping, and Cost of Cosmological Thought*. Cambridge: Cambridge University Press. Chapter 5, "Conclusions Based on Calculations", pages 76–96, and its reference list.

Hubble, E. (1929). “A relation between distance and radial velocity among extra-galactic nebulae”. *Proceedings of the National Academy of Sciences* 15(3), 168–173. DOI 10.1073/pnas.15.3.168.

Indian Institute of Astrophysics. “The Legacy of S. Chandrasekhar (1910 to 1995)”. iiap.res.in, accessed 4 November 2026.

Kragh, H. (2011). “Visions of revolutions: microphysics and cosmophysics in the 1930s”. arXiv:1111.6163.

Kragh, H. (2015). “On Arthur Eddington’s theory of everything”. arXiv: 1510.04046.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications. https://doi.org/10.67291/RQQS3025.

MacCallum, M. A. H. (2015). “Milestones of general relativity: Hubble’s law (1929) and the expansion of the universe”. arXiv:1504.03606.

Sutter, P. (2026). “Chandrasekhar and the Limits of Physics, Part 2: Humiliation”. *Universe Today*, 21 July 2026.

Tammann, G. A. and Reindl, B. (2013). “Allan Sandage and the distance scale”. arXiv:1211.4655.

Wikipedia contributors. “Chandrasekhar–Eddington dispute”. *Wikipedia*, accessed 4 November 2026, for the meeting of 11 January 1935, the work of Peierls, Dirac and Pryce, and Cygnus X-1.

Wikipedia contributors. “Eddington number”. *Wikipedia*, accessed 4 November 2026, for the value 136 times two to the power 256 and the Tarner Lectures of 1938.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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George Ellis

The Open Future

George Ellis, Time, Causation and Physics from Comparison

Abstract

George Ellis is the cosmologist who has argued longest, from inside physics, that the future is not yet, that causes act from higher levels of structure as well as from lower ones, and that a theory must face the world to count as physics. The physics collection of the Immanent Metaphysics holds all three, and on time and causation Ellis is its nearest ally among working cosmologists. His evolving block universe keeps a fixed past and an open future; the collection excludes determinism by the Incommensuration Theorem and so finds the same open future, and it drops the frozen block for the reason he gives: the future is not yet decided. The two part on where the present is and what makes it advance. For Ellis the present is a surface across the whole universe, advanced by quantum reduction as a physical process, with its direction imposed by the expansion of the cosmos. For the collection the present is the act of comparison itself, the arrow of time is in every act and needs no low-entropy beginning, and reduction is an update of the record, not a process. His top-down causation is the role of context in every comparison, which the collection writes into its definition of causality. The collection accepts his demand that physics be testable for every claim of the kind a test can reach, and meets it with dated predictions. Its foundation is a claim of another kind: every test is itself an act of comparison, the act the foundation describes, and the foundation answers Popper's criterion, which Ellis invokes, on Popper's own ground. On the multiverse the collection reaches Ellis's verdict from a further ground: its structure has one vacuum and no landscape to select from. A closing section sets the argument of each book that a registered prediction rests on beside Ellis's own reasoning, at the four places where the predictions differ. At all four the two accounts part on premises, and measurements that the sealed record already names will settle each. The section also states the collection's argument for the flatness of space, which builds a radius of curvature only from what the state that begins the

epoch holds, and the second of the two steps on which the collection's prediction for the energy of the vacuum rests: the result of Green and Wald, which Ellis has disputed in print.

I. A Cosmologist Who Defends the Present

Ellis's place in physics is secure on its own terms. With Stephen Hawking he wrote *The Large Scale Structure of Space-Time* (1973), which the collection names as "the standard account" of the causal structure of space and time (What Cannot Be). With Malcolm MacCallum he showed in 1969 that in an expansion the same at every place, with flat slices of space and no stress pulling differently in different directions, the shear of the expansion falls as the inverse cube of the scale of distances. The collection uses that result as its second, independent route to the even beginning of an epoch: "Standard physics gives a second route to the same result, from other premises" (The Gravitational Companion, Comparisons at Single Steps, Section IX; What the Beginning Left Behind). In the collection's cosmology an epoch is one cycle of the universe. It begins at the turn, the passage from the end of one epoch to the beginning of the next, at the end of every black-hole interior, where the interiors of the old epoch are one at their end and the open space of the new epoch re-forms from that one domain; the books call that re-forming the restoration (The Gravitational Passage, Chapter 18). An even beginning is one with no shear, an expansion that starts the same in every direction.

Over the last two decades Ellis has used that standing to argue three positions that most physicists do not hold. The future does not yet exist, and the block universe, in which past, present and future are all equally there, is a mistake. Causes act from higher levels of structure down to lower ones, and not only upward from particles. And theories that cannot face experiment, the multiverse first among them, should not be awarded the name of science. The collection holds all three, each on its own ground, and the sections below take them in turn.

II. The Evolving Block Universe

Ellis's account of time, which he set out in 2006 and later developed with Barbara Drossel, is the *evolving block universe* (Ellis 2006b; Ellis and Drossel 2020). Space and time form a block whose past boundary is fixed at the start of the universe and whose future boundary keeps advancing. Each later block contains the earlier ones, and the direction of time is the direction of that inclusion. The past exists, because its events lie in the causal past of the present and have acted on it. The future does not yet exist, because what will happen is not yet decided: conservation laws constrain it, but they do not fix which outcome will occur. The present is the advancing boundary, defined by the proper time along the worldlines that the motion of matter picks out, with no need for a synchronization across the whole universe at once. Ellis places the advance of the boundary in quantum reduction: the step in which a superposition becomes one definite outcome is, on his account, where the indefinite future becomes the definite past, and it is irreversible because information about the earlier state is lost. He ties the direction of time to the cosmos: the expansion of the universe imposes a direction from the top down, and the local arrows of time (thermodynamic, electromagnetic and biological) line up with it.

The collection reaches the same open future, and it drops the frozen block for the reason Ellis gives: the future is not yet decided. The Basis of Physics, Essay 11, names the view and its partner: "The block universe view holds that past, present, and future are equally real, that time is a static dimension rather than a directed process, and that the felt direction of time is a feature of us and not of the world. This view is the natural companion of determinism". The Incommensuration Theorem excludes determinism. The theorem is a structural fact about the nature of knowing: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. Determinism is the conjunction of perfected symmetry with perfected continuity, and so it cannot be had (Causality Without Determinism, Chapter 1, Section VIII). Faithful reversal of time needs the same conjunction, and is excluded with it. Essay 11 draws the consequence in words Ellis could have written: "If determinism is precluded, the future does not exist in the sense the past does: there is a genu-

ine residual, an openness that is not merely our ignorance. If faithful reversal is precluded, the two temporal directions are not equivalent: there is a structural distinction between forward and backward that is not a convention" (The Basis of Physics, Essay 11, Section VI). Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

Even Ellis's word for the advance of the present is in the collection. With Tony Rothman he calls his picture the crystallizing block universe, in which the indefinite future crystallizes into the definite past (Ellis and Rothman 2010). Incommensuration, Chapter 9, Section II, describes the present from the first person: "The plurality of potentialities converges to the singularity of what actually happens. ... Out of the field of possibilities, one actuality crystallizes in the here and now". The same chapter names the error both Ellis and the collection oppose: to take the third-person view as exhaustive "and thereby eliminate choice and creation from the picture of reality". Ellis reached the open future from physics, by way of quantum indeterminism and the irreversibility of measurement; to reach it there, against a strong current in his field, is a real achievement. The collection reaches the open future from the structure of comparison, which every measurement Ellis relies on already has.

III. Where the Present Is

The two accounts part on three things: where the present is, what makes it advance, and where its direction comes from.

For Ellis the present is a surface across the universe, a boundary in a block, fixed by the flow of matter. For the collection the present is the act of comparison itself. The Basis of Physics puts it in one sentence: comparison "is made only in the present, and the present is not one point on a line but the site of the interaction itself". Time is a triple, in the collection's account: geometric time, the dimension, which exists; event time, the order of findings, which is real; and evolution time, the time over which the range of possible outcomes develops. "The block universe takes geometric time for the whole,

and drops event time" (Essay 11, Section VI). Event time is defined in The Unquantized Arena, Chapter 10: "the order of findings for a comparer: each finding is one outcome selected from a discrete set of possible outcomes and laid down as a record", and its order "is a precedence and not a clock reading, and it cannot be reversed" (quoted in Why Time Travel Is Not a Concept). A comparer is whatever makes a comparison: an instrument, a detector, an interaction. So the collection needs no boundary across the universe to carry the present forward. Each act is a present, and the order of acts is the order of time; the evolving block Ellis draws is what those acts leave behind, read from outside.

For Ellis the present advances by quantum reduction, a physical process that turns a superposition into one outcome. For the collection reduction is an update of the record, and not a process at all. The Quantum Passage, Chapter 9, Section IV: "the state update upon measurement is not a physical process. It is not an additional dynamical law. It is an epistemic update: the comparison has occurred, and the result is now part of the omniscient content". Epistemic here means concerning knowing, and the book says exactly what changes: the omniscient content, which is the laid-out record, shared and the same for everyone who has the outcome. Ellis and the collection agree that something one-way happens when a measurement is made, and that this one-way step is where the open becomes the settled. The collection says what the step is: a comparison, whose outcome is one selection from the range of possible outcomes. No added dynamical law is needed to make the present advance, because the advance is what a comparison is.

For Ellis the direction of time comes from the top down: the expansion of the cosmos, together with a low-entropy beginning, sets a direction that local processes inherit. The collection finds two arrows. The first is structural, and Essay 11 states what it does not need: "Perfect time-reversal is therefore precluded, and the preclusion depends on no entropy, no boundary condition, no Past Hypothesis, and no particular formalism" (The Basis of Physics, Essay 11, Abstract). It is "the direction in which comparison proceeds": the range of what is possible comes first, then the act, then the record, and the record shapes the next range. The second is the entropic arrow, a statistical arrow of systems of very many parts, which does need a low-entropy begin-

ning; and the two point the same way wherever both are found, because making a record raises the entropy of the instrument that holds it (Why Time Travel Is Not a Concept, The Two Arrows of Time). The cosmic alignment Ellis describes is real, and it belongs to the second arrow. The first arrow is in every comparison already, at every scale, and needs nothing from the cosmos to point.

Ellis also holds that something random is needed to break the symmetry of the laws in time, or the direction of the second law would be arbitrary. The collection agrees and binds the two: hard randomness, the arrow of time and the subjective are one bound triple, distinct, inseparable and not interchangeable, so that where one is present the others are too (Incommensuration, Chapter 8, Section X). The randomness that Ellis adds to break the symmetry of the laws in time is, in the collection, one face of the same structure as the arrow of time itself.

IV. Causation from Above and from Below

Ellis's second position is that causes run downward as well as upward. In his 2012 paper on mechanisms he identifies five kinds: algorithmic top-down causation; control by information that does not adapt; selection that adapts; control by information that adapts; and the intelligent kind, the effect of a mind on the physical world. His one-line statement of the idea is that "Top-down causation takes place owing to the crucial role of context in determining the outcomes of lower level causation", and its mark is that the same higher-level state leads to the same higher-level outcome whichever lower-level states realize it. *How Can Physics Underlie the Mind?* (2016) carries the argument to the human brain and to the effect of thought on the world.

The collection writes Ellis's insight into its definition of causality. "As defined in An Immanent Metaphysics, causality is 'the subjective perception (context) of a consistency between two objective contents'" (Causality Without Determinism, Chapter 1, Section III). Context is part of what a causal relation is, and not an added influence on it. Every comparison has a content and a context, distinct and inseparable, and no outcome is fixed by the con-

tent alone. Ellis's "crucial role of context" is, in the collection's terms, a structural feature of every act of comparison, and so of every causal relation at every level.

The collection also says where each level of description belongs. "Causality, determinism and teleology ... are not competing descriptions of the same level of reality. They belong to different scales". Causality belongs to the scale of observers, where antecedent and consequent can both be held in view; teleology, the coherence of a whole, belongs to the scale of the cosmos; and determinism, if it could hold, would have to be made good all the way down to the scale of exactly zero (Chapter 1, Section V). It keeps two words apart: "Causality is causation perceived; causation is what causality perceives, wherever it holds", and causation is the one-way, unbroken order at each event that physics finds at every scale (Section VI). Ellis's levels and the collection's scales are close kin: both refuse to let the bottom level speak for the whole.

Where Ellis speaks of top-down and bottom-up as two directions of causation in a hierarchy, the collection speaks of interdependence. "There is neither absolute dependence nor absolute independence; there is only interdependence (interaction)", in the words of An Immanent Metaphysics that Causality Without Determinism quotes; and "To be real is to be interdependent" (Chapter 2, Section VIII). On this account, causation from above and causation from below are the two directions of one interdependence of levels, neither prior, and a hierarchy whose top or bottom fixed the rest would be a case of absolute dependence, which the quoted line excludes. The *non-polarization principle* states the consequence: "All worlds are to some non-zero and positive degree causal. No world is purely and completely deterministic, and no world is purely and completely logical" (Chapter 1, Section IX). Ellis looks to the indeterminism of the lowest level, combined with selection, for the slack that lets higher levels act. The collection finds the slack at every scale, because no deterministic description, at any scale, can be complete.

Ellis's fifth kind, the effect of a mind on the world, is where the collection goes furthest. It holds that choice is real and conjugate to causality: "Choice and causality are conjugate: each can be held more fully only as the other is held less fully, and neither comes before the other" (Chapter 1, Section VI).

Choice is the partner of causation in the triple of the real (choice, change and causality), present to some degree in every world, and not a higher level acting on a lower one. Ellis argues that physics must leave room for minds to act; the collection shows why the room is always there.

V. The Integrity of Physics

In 2014 Ellis and Joseph Silk wrote in *Nature*, under the title "Scientific method: Defend the integrity of physics", that "Attempts to exempt speculative theories of the Universe from experimental verification undermine science", and that "The imprimatur of science should be awarded only to a theory that is testable". They rejected the view that a sufficiently elegant and explanatory theory need not be tested, and they set against the non-empirical confirmation that Richard Dawid had described the question every theorist should answer: what observational or experimental evidence would persuade you that the theory is wrong. The collection's book of objections states the objection at full strength and in their words, and applies it to the collection itself (Objections from Physics, Answered).

The collection accepts the demand where it applies, and it says where the demand applies. A test is a comparison of outcomes, and it can settle something only when its outcome can be compared by others, at other times, along other routes: "So a test applies exactly where the outcome of a comparison can be objective, and nowhere else" (Physics Is Not Math, Chapter 19, Section III). Every claim the collection makes about the world is of that kind, and each is stated beside the measurement that bears on it. The Case for Measurement, Chapter 5, gives the rule for any charge of unfalsifiability: "identify what type of claim is being assessed. If it is empirical, the charge may be legitimate. If it is formal or contextual, the charge is almost certainly a method mismatch". Falsifiability there is a method suited to one kind of claim, and the merit of a body of work is read as a profile across many measures, not from that one method. The book of objections answers Ellis and Silk directly: "So the account meets the standard of Ellis and Silk where the standard applies, in its consequences" (Objections from Physics, Answered, the cross-modal reach), and it lists those consequences: entanglement through gravity at the Newtonian phase; no effect in which the geometry carries quantum de-

grees of freedom of its own; an equivalence principle without exception; a speed of light with no dependence on energy from any step of space and time. These are dated predictions on the record, each held to a stated standard: "confirmed means established at five standard deviations by at least two independent kinds of measurement" (The Gravitational Passage, Chapter 20).

The collection also agrees with Ellis and Silk on what confirms a theory. Of the three ways anything can be validated, measurement in the first person, agreement in the second and proof in the third, "only the first and the third validate truth. Agreement among people validates nothing by itself" (Physics Is Not Math, Chapter 19, Section IV). The non-empirical confirmation Ellis and Silk warn against is confirmation by the agreement and the sense of fit of a community, and the collection counts none of its physical claims confirmed by fit (Objections from Physics, Answered, on non-empirical confirmation).

The collection's foundation is a claim of another kind, and the books name its kind. The Incommensuration Theorem is proved from the meanings of the parts of comparison, and "a test of it is a comparison, within its scope before the test begins". The Ground of Objection, the collection's book on where prior philosophy meets the Immanent Metaphysics, takes up Popper's criterion in its entry T1.10, and meets the criterion, which Ellis and Silk invoke, on Popper's own ground. The criterion is one of demarcation and expressly not of meaning, and Popper held metaphysical statements to be not nonsense and possibly fruitful; so "A system placed outside empirical science by his criterion has not been convicted of anything by him". The foundation states, in its author's words, what a counterexample to it would have to be: "A genuinely dyadic foundational structure, one that could not be decomposed into or derived from three mutually essential terms, would refute it. An arbitrary tripartition, three terms that could be interchanged without structural consequence, would refute it. And the challenge put to anyone who doubts the foundation: produce an interaction that is not a comparison, a comparison that is not an interaction, or a relation that is neither". Every experiment already performs the act of comparison that the foundation describes, and so no experiment can stand outside the foundation to refute it. Ellis and Silk

asked that physics not exempt itself from the world; the collection exempts nothing a test can reach, and it places its ground where no test can go, because every test is itself an act of comparison.

VI. The Multiverse

Ellis's sharpest target is the multiverse: a vast ensemble of universes with different constants, among which ours is selected because observers can live in it. He holds that it cannot be tested, and so should not be called physics.

The collection reaches his verdict on a further ground: it has nothing to select from. Its action is the geometry alone, with no form field and no flux integers, so "the account has no flux sectors, and the landscape of flux vacua has no counterpart in it" (The Compactification, Chapter 2, Section VI). There is one internal space and one vacuum, and the split between matter and the cosmological constant is derived as a pure number, a matter fraction of 0.311, against the measured 0.315 ± 0.007, with no measured value among its inputs; the rule of counting it shares with the ratio of Prediction 16 is the one rule of its family that the measured ratio admits (as the Milgrom and McGaugh chapter, Section VIII, quotes The Weight of Possibility), and the coefficient the two numbers share is the test of that rule (Prediction 17). The View from Inside states what selection gives up: "If Λ is an environmental variable selected by our existence, then it cannot be predicted. It cannot be derived from first principles. It is not a consequence of the laws of nature but an accident of location". There Λ is the cosmological constant. And The Gravitational Passage, Chapter 13, gives the reason selection cannot even pick out a present: a selection stated from outside "can give a distribution of the epochs at which comparers stand. It cannot single out one of them as real, since that would take the presents of all epochs as given together". The collection distinguishes its own result from the anthropic argument it could be mistaken for: "The anthropic principle is a selection effect. The self-descriptive closure is a uniqueness theorem applied to the structure of comparison itself" (The Geometric Route, Chapter 32, Section IV).

So the collection and Ellis stand together against the multiverse, and the collection adds a reason that does not wait on whether a test can be built: the structure of comparison yields one world, with its constants fixed, and an ensemble of others would have to be laid out from a vantage no comparison can occupy.

VII. Where the Predictions Part, and Why

At four places the collection's registered predictions and Ellis's account expect different results. For each, this section sets the argument of the book the sealed prediction rests on beside Ellis's own reasoning, and looks for the first step at which the two part. Where both arguments follow from their premises, the difference is a premise, and the section names it and the measurement that settles it. At all four places the difference is a premise. The section also states in full the collection's argument for the flatness of space, and both steps on which its prediction for the energy of the vacuum rests.

The curvature of space

The sealed prediction. "The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}", registered on 1 November 2026 as Prediction 9. The sealed record adds that "A curvature confirmed at the level of 10^{-3} refutes it".

The argument of the book. The Gravitational Passage, Chapter 18, Section IX, argues the flatness from what the state that begins the epoch holds, and The Compactification, Chapter 6, Section VI, repeats the argument. "A radius of spatial curvature is a length". "In the equation of the expansion the curvature carries a constant that the law of the geometry does not fix: it is a constant of integration, set once by the state from which the history begins and carried unchanged thereafter" (the book cites Misner, Thorne and Wheeler 1973, Chapter 27). "So the radius of curvature belongs to the state that the restoration sets, and it can be built only from what that state holds". "The metric has no prior identity, and no total of the old content passes, since no comparison of the new epoch registers the mass of the old interiors". "No

length of the old epoch passes the turn, and no count passes it either". "The cosmological constant belongs to the law of the geometry, fixed once as its constant term", "and at the turn it acts as nothing at all". So the state holds "the length of the turn, of the order of the Planck length", "the pure numbers of its structure, of order one", "and the size of the departures, about 10^{-5}". "A radius built from the length of the turn and the de Sitter radius together, such as the length halfway between them in powers of ten, is the length of the turn multiplied by a pure number near 10^{30}". "It would need the de Sitter radius in the state, where the constant does not act, or a pure number near 10^{30} in the state, where the only numbers that large are counts, and no count passes the turn". "So the radius is of the order of the length of the turn, or there is none". A radius of the Planck length "would close the new epoch within a few Planck times or leave it dominated by curvature, and neither epoch produces the structure that the cycle requires", since "the restoration is one process, recurring at every turn, and an epoch without structure makes no black holes from which a next epoch could come". "The homogeneous model of the new epoch is therefore spatially flat, and the geometry found is curved only by its departures, at their own size, about 10^{-5}". "The argument uses nothing of the cosmological constant, neither its value nor its sign". The essay Why the New Epoch Is Flat sets out the same argument step by step.

Ellis's argument. Ellis's closed models carry a length of their own from before the hot history. The emergent universe of Ellis and Roy Maartens begins as an Einstein static universe, a closed space at rest whose radius is an initial condition of the model; positive curvature is what lets such a start exist, and with that radius above the Planck length the model needs no era of quantum gravity (Ellis and Maartens 2004). An inflationary phase then drives the curvature down without changing its sign, and Uzan, Kirchner and Ellis found the limit that positive curvature places on the length of that phase (Uzan, Kirchner and Ellis 2003). In 2006 Ellis read the combined evidence then available, taken at face value, as pointing to positive curvature (Ellis 2006, Section 2.8). Each step follows from his premises: his models are solutions of Einstein's equations, with the initial radius and the length of the inflation chosen as inputs of each model.

Where they part. They part at the step that says what the state that begins the epoch holds. For Ellis, the epoch inherits a length from before its hot history: the radius of the static space it starts from. For the collection, no length and no count passes the turn, so the state holds the length of the turn and pure numbers of order one, and the cycle excludes a radius of that length.

Whose step, and what decides it. Both arguments follow from their premises, and the premise in dispute is one sentence: the new epoch inherits no length from what came before it. The collection draws that premise from the identity of the interiors at their end (The Gravitational Passage, Chapter 18, Section II); Ellis's models put a length in as an initial condition. The measured curvature share, 0.001 ± 0.002 (Aghanim and others 2020), allows both. A positive curvature confirmed at the level of 10^{-3} by the Dark Energy Spectroscopic Instrument (DESI) and the Euclid satellite would agree with Ellis's closed models and refute Prediction 9.

Ellis's emergent universe shows the premise at work. Its radius is a length of the state from which its history begins, set before the hot history as an initial condition; on his premises the state holds such a length, and on the collection's it holds no length but the length of the turn. The argument of the book settles every other length the state could supply. As the argument of the book showed, a radius built from the length of the turn and the de Sitter radius together would need the de Sitter radius in the state, where the cosmological constant does not act, or a pure number near 10^{30} in the state, and the only numbers that large are counts, which do not pass the turn. So the flatness rests on what the state holds, and on nothing of the cosmological constant.

Other results of the collection rest on the flatness, and the books state the order in which they rest on it. The identity for the cosmological constant uses the flatness and gives the matter fraction of 0.311, and the book states the order between the identity and the flatness: "Chapter 13, Section III, uses this flatness, and the flatness takes nothing from the constant that the identity there fixes". So the identity rests on the flatness, and the flatness does not rest on the identity. The collection's use of Ellis's own result with MacCallum rests on the flatness too, since "The route needs the slices to be flat" (The Gravitational Companion, Chapter 3, Section IX).

An inflationary phase and its gravitational waves

The sealed prediction. "No inflationary phase long enough to stretch the lengths observed today from within the early horizon to beyond it occurred", registered on 1 November 2026 as Prediction 13; and "the ratio of tensor to scalar power is far below 10^{-6}", with "The Simons Observatory and LiteBIRD will find no primordial tensor signal", registered the same day as Prediction 10.

The argument of the book. The Gravitational Passage, Chapter 18, Questions, takes the two problems inflation was proposed for. On the sameness of the sky: "The interiors are one at their end", the new exterior re-forms from that one domain, and "Regions that no signal within the new epoch has connected are alike because they come from one domain, not because a signal passed between them". On flatness: "no length and no count of the old epoch passes the turn, so the state that the restoration sets holds the length of the turn and only pure numbers of order one, and the cycle excludes a radius of that length, which leaves a flat homogeneous model", the argument of the previous subsection. On the departures: they are the form of the content carried through the turn, "to which the vacuum of the new epoch adds almost nothing". Section IX gives the size: a length observed today lay near the turn "some 10^{27} times beyond the new horizon", where the vacuum of such a wave "carries a power below 10^{-51}, against the observed 2×10^{-9}" (Chapter 18, Section IX). A long inflation would make the departures on those lengths the departures of its own vacuum: "in such a phase the departures on those scales would be those of the inflationary vacuum". So the identification excludes a long inflation, and The Compactification, Chapter 6, Section VIII, states the strength of the step: "The kind of this step is must, relative to the identification". A shorter phase "is neither required nor excluded by the account". The absence of primordial waves follows from the same identification: "A departure of density sources a scalar departure of the metric. A wave of the metric needs an anisotropic stress, which content close to equilibrium does not have at first order, so the primordial departures of the metric are scalar, and waves arise from them only at second order" (Chapter 18, Section IX).

Ellis's argument. The emergent universe answers the horizon problem by its static past: before it expands, the static space has had time for its regions to come into causal contact (Ellis and Maartens 2004). It then inflates, and reheats into the hot big bang. As in every inflationary model, its departures from uniformity are the fluctuations of the vacuum of the inflationary phase, carried to large lengths, and such a phase also makes primordial gravitational waves, at a size set by its energy. Ellis has stated plainly what standing he gives inflation: most cosmologists regard it as the "best proposal available for the era prior to the Hot Big Bang", it is a "generic proposal for what happened" rather than a specific physical theory, and detecting its primordial gravitational waves would be an "important test of inflation" (Ellis 2006, Section 2.6).

Where they part. They part on the source of the departures. In Ellis's models they are the vacuum of an inflationary phase, stretched; in the collection they are the form of the content carried through the turn. On the sameness of the sky the two are closer than they look: both answer it by a state before the hot history, Ellis by a static past long enough for signals to cross it, the collection by one domain from which every region comes, with no signal needed.

Whose step, and what decides it. Both arguments follow from their premises; once the identification is granted, the collection's exclusion of a long inflation follows with no further premise, and it is exactly as strong as the identification. The premise in dispute: the departures from uniformity are the form of the content carried through the turn, and not the vacuum of an inflationary phase. The measurement that decides the premise is sharper in one direction than the other. A primordial tensor signal confirmed at any size the Simons Observatory and LiteBIRD reach refutes Prediction 10, undoes the identification, and passes the test of inflation that Ellis named. No signal at their reach leaves Prediction 10 standing and bounds the energy of Ellis's inflationary phase; it does not refute inflation as such, since a phase of low enough energy makes waves too weak to find. The sealed record names the measurements of Predictions 9 to 12 together as what decides Prediction 13: the flatness of space (Prediction 9), the ratio of tensor to scalar power (Prediction 10), the adiabatic character of the departures, every component depart-

ing from uniformity together (Prediction 11), and their one pattern across the whole sky (Prediction 12). The collection ties one more thing to this premise: in an epoch whose departures were made by inflation, "dark matter of this mass could not be made after that inflation in the measured amount" (The Weight of Possibility, Chapter 4, Section VI), so a tensor signal would bear on its account of the dark matter as well.

A small universe

The sealed prediction. "No closed path that goes around the universe, and so cannot be shrunk to a point, is shorter than the diameter of the horizon, at any location", registered on 1 November 2026 as Prediction 23, which adds that a region with such a path "would count at least two classes, and the ratio of Prediction 16 would then be $6 - 1/\pi = 5.682$ or larger".

The argument of the book. The Weight of Possibility, Chapter 3, Section II, argues the prediction from what a registration counts. "A registration counts kinds, not holders of energy", and what it counts are independent classes. The ordinary matter is registered in the open space within the horizon: "The region a registration holds is the region within its horizon, which is a ball, and a ball has one class". "Within the limit of comparison, that ball cannot be told apart by any comparison from a ball of an infinite flat space", so "the open space counts as one, whatever it is beyond the horizon". The region is a ball unless a closed path through our location that cannot be shrunk to a point is shorter than the horizon's diameter. "The identity fixes the ratio for every registration, wherever it is made", so the count of one holds for every registration, and no short loop exists anywhere. A short loop would make the count at least two, and the ratio of the dark matter to the ordinary matter 5.682 in place of 5.3634.

Ellis's argument. Einstein's equations are local: they fix the curvature at each place, and not the shape of space as a whole. On that ground Ellis's account leaves the question of a small universe undecided, a matter for observation. Among the readings of the low power of the microwave background on the largest angles, Ellis lists our living in a small, spatially closed universe (Ellis 2006, Section 2.3.7), and he points out that only in a universe whose spatial sections are small enough for light to have crossed them does the visual hori-

zon not hide most of the universe from us (Section 2.4). He leaves the size of the universe to observation, and names a small universe as observable; he does not predict that the universe is small.

Where they part. They part on what fixes the shape of space as a whole. For Ellis, the initial conditions fix it, and observation reads them. For the collection, what every registration counts fixes it: the ratio is the same for every registration, and it counts one class.

Whose step, and what decides it. Both arguments follow from their premises. The premise in dispute: the ratio of the dark matter to the ordinary matter is the same for every registration, and it counts the classes of the region within the horizon. At our own location the measurements have gone the collection's way. The searches of the microwave background find that "every closed path through our location that goes around the universe is longer than 98.5 percent of the diameter of the last scattering surface" (Petersen and others 2023, as The Weight of Possibility reports it), and that excludes, for loops through our location, the small universe Ellis named as observable. The measured ratio, 5.370 ± 0.048 (Camphuis and others 2026, as the sealed record reports it), lies well below the 5.682 that a short loop would give; it is one kind of measurement, and Prediction 16 asks for a second. A short loop that does not pass through our location lies beyond what the searches can reach: the same paper finds that, in all but the simplest shapes of space, "the shortest non-contractible loop in the space can avoid us, and be shorter than the diameter of the last scattering surface by a factor ranging from 2 to at least 6" (Petersen and others 2023). The collection excludes such a loop, and Ellis's account allows it.

The acceleration of the expansion: a constant, or an effect of the lumps

The sealed prediction. "The energy of the vacuum has an equation of state of exactly -1, at every epoch"; "No dynamical field, no quintessence and no evolving scalar drives the acceleration"; and "The reported departure from -1 will not be confirmed": registered on 1 November 2026 as Prediction 8.

The argument of the book. The Gravitational Passage, Chapter 13, Section V, fixes the cosmological constant once, "from the information content of the horizon of the measurement, now", and the reconstructed history "is one geo-

metry, whose field equations carry Λ as the constant term of Lovelock's theorem". Section VI shows that such a term cannot vary: "If Λ varied from place to place or from epoch to epoch, the divergence of the left side would be the gradient of Λ, and the equations would set that gradient to zero. So within one geometry Λ does not vary". That step is a theorem of the geometry, and nothing in Ellis's account disputes it: a constant term is constant. The same section states the second step the prediction needs: "That the measured acceleration of the expansion is this constant term rests also on a result about averages: the small-scale inhomogeneities of the universe, averaged, do not act as a constant term". It credits the result to Green and Wald (2011), who showed, assuming the weak energy condition, that such inhomogeneities supply only an effective stress-energy that is traceless and has positive energy density, so that they "cannot mimic the effects of dark energy". It names the dispute over that result and the answer to it: "Buchert and others (2015) dispute that the result proves backreaction irrelevant in cosmology, and Green and Wald (2015) answer them". The Quantum Bridge, Chapter 8, relies on the same result in Section IV. The homogeneous geometry "leaves out the effect of the inhomogeneities it carries"; the metric perturbation of the observed universe is about 2.7×10^{-5}; and "Green and Wald (2011) showed that, where the metric perturbation is small, though the density contrast may be large, the effect of small-scale inhomogeneities on the large-scale geometry cannot mimic a cosmological constant". "So the fixed-background error of a Friedmann computation is small, and it is not a source of the accelerated expansion".

Ellis's argument. Ellis treats the sameness of the universe on the largest scales as a hypothesis to test, and not a principle to assume. He has argued that averaging over the lumps of the universe can feed back on the expansion of the average, and that a universe lumpy on the scale of the Hubble radius, against the Copernican principle, might account for some or all of the apparent acceleration with no dark energy at all (Ellis 2011). In 2015 he and ten colleagues answered Green and Wald directly: their scheme, they argued, involves no averaging and so misses effects that are not local, and it has not proved that the lumps leave the expansion alone (Buchert and others 2015); Green and Wald replied in a preprint (Green and Wald 2015). With Jean-Philippe Uzan and Chris Clarkson he proposed a test that uses the expansion

alone: in every homogeneous universe, whatever its content, the drift of redshifts over time and the distances of the same sources obey one relation, and a departure from it would show lumpiness on the largest scales (Uzan, Clarkson and Ellis 2008).

Where they part. On both accounts a constant term is constant, so they do not part at the theorem. They part at the step that makes the measured acceleration that constant. The collection holds, through Green and Wald, that the expansion that measurements average over is the expansion of the one homogeneous geometry; Ellis holds that this premise has not been shown.

Whose step, and what decides it. Both arguments follow from their premises, and the premise in dispute is one sentence: the expansion that measurements of distance and redshift average over is the expansion of the one homogeneous geometry, to within the size of its metric perturbation. The prediction rests on two steps, and The Gravitational Passage, Chapter 13, Section VI, states both: the constant term of one geometry, which cannot vary, and this premise, with the result of Green and Wald that supports it. For Prediction 8 the sealed record names the first as the step that would fail: "Λ fixed once, as the constant term of one geometry". The comparison with Ellis turns on the second. Ellis is a party to the dispute over that premise, on the other side from the books, and this section names the paper of Buchert and others in which he took that side. One form of his alternative has already met a measurement: the limits on the kinetic Sunyaev Zel'dovich effect rule out the adiabatic void model, in which we sit near the center of a large region of low density, as an alternative to dark energy (Zhang and Stebbins 2011). The form that rests on averaging has not yet met a measurement that decides it. The expansion history and the growth of structure measured by Euclid, the Vera C. Rubin Observatory and the Nancy Grace Roman Space Telescope decide Prediction 8, as the sealed record names; the drift of redshifts set beside distances, the test Ellis proposed, bears on the premise directly, and it has not yet been measured.

VIII. Summary

George Ellis and the physics collection stand together on the three positions Ellis has defended against the main current of his field. The future is not yet: Ellis's evolving block universe and the collection's exclusion of determinism by the Incommensuration Theorem reach the same open future and drop the frozen block for the same reason: the future is not yet decided. Causes act from every level: Ellis's top-down causation is the role of context in every comparison, which the collection writes into its definition of causality and extends, through interdependence and the non-polarization principle, to every scale. Physics must face the world: the collection accepts the demand of Ellis and Silk for every claim a test can reach, meets it with dated predictions held to a stated standard, and agrees that agreement and fit confirm nothing.

The collection goes further in three places. The present is the act of comparison itself, not a surface across the universe, so no global boundary is needed to carry it forward. Reduction is an update of the record, not a physical process, so no added law is needed to make the present advance. The arrow of time is in every act and needs no cosmic beginning to point, while the alignment Ellis finds with the expansion of the cosmos belongs to the second, entropic arrow. And the multiverse is excluded twice: by Ellis, because it cannot be tested, and by the collection, because the structure of comparison yields one vacuum and nothing to select from.

At the four places where the registered predictions differ from Ellis's account, the two part on premises, and a measurement the sealed record already names settles each. On the curvature of space, the premise is whether the new epoch inherits a length from before its hot history; on inflation, what made the departures from uniformity; on a small universe, whether what a registration counts fixes the shape of space; on the acceleration, whether averaging over the lumps of the universe leaves the expansion of the one geometry unchanged. As Section VII sets out, the collection's argument for flatness builds a radius of curvature only from what the state that begins the epoch holds: the length of the turn and pure numbers of order one. The cycle excludes a radius of the length of the turn; a radius formed from the length of the turn and the de Sitter radius together would need the de Sitter radius or a number near 10^{30} in that state, and the state holds neither, so the argument

uses nothing of the cosmological constant. And The Gravitational Passage, Chapter 13, Section VI, states both steps on which Prediction 8 rests, the constant term of one geometry and the premise from Green and Wald, together with the dispute over that premise in which Ellis has taken part. Ellis asks whether the lumps of the universe can stand in for a constant of the geometry; Mordehai Milgrom and Stacy McGaugh, in the next chapter, ask whether the regularity of the galaxies is a law of gravity or a history of how they formed.

Key Concepts

- Evolving block universe (Ellis): a fixed past and an advancing future boundary; the future does not yet exist.
- The collection reaches the same open future: determinism and faithful reversal are excluded by the Incommensuration Theorem, and the block universe "takes geometric time for the whole, and drops event time".
- The present is the site of the act of comparison, not a surface across the universe; event time is the order of findings for a comparer.
- Reduction is an update of the shared record, not a physical process.
- Two arrows: the structural arrow, in every comparison, needing no Past Hypothesis; and the entropic arrow, to which cosmic alignment belongs.
- Top-down causation is the role of context in every comparison; causality is defined as the subjective perception (context) of a consistency between two objective contents.
- Interdependence: causation from above and from below are two directions of one interdependence of levels.
- Testability applies where the outcome of a comparison can be objective; the collection's physical claims meet it with dated predictions; its foundation is outside a test's reach, because every test is itself an act of comparison.
- The multiverse is excluded by the collection on a structural ground: one internal space, one vacuum, no landscape.
- Where the predictions part: on whether the new epoch inherits a length, on what made the departures, on what fixes the shape of space, and on whether averaging over the lumps of the universe can mimic a constant; the collection's argument for flatness builds a radius of curvature only from what the state that begins the epoch holds, which leaves no radius but the one the cycle excludes.

Terms

Event time. The order of findings for a comparer: each finding one outcome selected from the possible outcomes and laid down as a record.

Evolving block universe. Ellis's account of space and time as a block with a fixed past boundary and an advancing future boundary.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Interdependence. The condition in which each term of a relation is what it is only in and through the relation, without being reducible to it; neither absolute dependence nor absolute independence.

Non-polarization principle. Every world is to some positive degree causal; no world is purely deterministic or purely logical.

Top-down causation. Ellis's term for the effect of a higher level of structure on the outcomes of lower-level causes, owing to the role of context.

Structural arrow of time. The direction in which comparison proceeds: the range of the possible, then the act, then the record.

Three ways of validation. Measurement (first person), agreement (second person) and proof (third person); only measurement and proof validate truth.

Backreaction. The effect of the lumps of the universe on the expansion of its average, which a homogeneous model leaves out.

Curvature share. The curvature of space expressed as a share of the critical density; zero for flat space; in the usual convention it is negative for a closed space, whose curvature is positive.

Emergent universe. The model of Ellis and Maartens that begins as a closed Einstein static universe, then inflates and reheats into the hot big bang.

Redshift drift. The slow change over time of the redshift of a distant source; set beside distances, it tests whether the universe is the same everywhere on the largest scales.

Short loop. A closed path that goes around the universe, cannot be shrunk to a point, and is shorter than the diameter of the horizon.

Epoch. One cycle of the universe in the collection's cosmology, from one turn to the next; each begins even, with no shear.

Restoration. The re-forming, at the turn, of the open space of the new epoch from the one domain that the interiors of the old epoch are at their end.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

References

Aghanim, N. and others (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6. doi: 10.1051/0004-6361/201833910. arXiv:1807.06209.

Buchert, T., Carfora, M., Ellis, G. F. R., Kolb, E. W., MacCallum, M. A. H., Ostrowski, J. J., Räsänen, S., Roukema, B. F., Andersson, L., Coley, A. A. and Wiltshire, D. L. (2015). "Is there proof that backreaction of inhomogeneities is irrelevant in cosmology?". *Classical and Quantum Gravity* 32 (21), 215021. doi:10.1088/0264-9381/32/21/215021. arXiv:1505.07800.

Camphuis, E. and others (2026). Cited as the sealed record of 1 November 2026 cites it.

Drossel, B. and Ellis, G. F. R. (2018). "Contextual wavefunction collapse: an integrated theory of quantum measurement". arXiv:1807.08171.

Ellis, G. F. R. (2006). "Issues in the philosophy of cosmology". arXiv:astro-ph/0602280.

Ellis, G. F. R. (2006b). "Physics in the real universe: time and spacetime". *General Relativity and Gravitation* 38, 1797–1824. arXiv:gr-qc/0605049.

Ellis, G. F. R. (2011). "Inhomogeneity effects in cosmology". arXiv:1103.2335.

Ellis, G. F. R. (2012). "Top-down causation and emergence: some comments on mechanisms". *Interface Focus* 2, 126–140.

Ellis, G. F. R. (2013). "The arrow of time and the nature of spacetime". arXiv:1302.7291.

Ellis, G. F. R. (2016). *How Can Physics Underlie the Mind? Top-Down Causation in the Human Context*. Berlin: Springer.

Ellis, G. F. R. and Drossel, B. (2020). "Emergence of time". arXiv:1911.04772.

Ellis, G. F. R. and Maartens, R. (2004). "The emergent universe: inflationary cosmology with no singularity". *Classical and Quantum Gravity*, doi: 10.1088/0264-9381/21/1/015. arXiv:gr-qc/0211082.

Ellis, G. F. R. and MacCallum, M. A. H. (1969). "A class of homogeneous cosmological models". *Communications in Mathematical Physics* 12, 108–141.

Ellis, G. F. R. and Rothman, T. (2010). "Time and spacetime: the crystallizing block universe". *International Journal of Theoretical Physics* 49, 988–1003. doi: 10.1007/s10773-010-0278-5. arXiv:0912.0808.

Ellis, G. F. R. and Silk, J. (2014). "Scientific method: Defend the integrity of physics". *Nature* 516, 321–323.

Green, S. R. and Wald, R. M. (2011). "New framework for analyzing the effects of small scale inhomogeneities in cosmology". *Physical Review D* 83 (8), 084020. doi:10.1103/PhysRevD.83.084020. arXiv:1011.4920.

Green, S. R. and Wald, R. M. (2015). "Comments on Backreaction". arXiv: 1506.06452 (preprint; no journal publication found).

Hawking, S. W. and Ellis, G. F. R. (1973). *The Large Scale Structure of Space-Time*. Cambridge: Cambridge University Press.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications. DOI https://doi.org/10.67291/RQQS3025.

Misner, C. W., Thorne, K. S. and Wheeler, J. A. (1973). *Gravitation*. San Francisco: W. H. Freeman.

Petersen, P. and others (2023). "Cosmic topology. Part I. Limits on orientable Euclidean manifolds from circle searches". *Journal of Cosmology and Astroparticle Physics* 2023 (01), 030.

Popper, K. (1963). *Conjectures and Refutations*. London: Routledge and Kegan Paul.

Uzan, J.-P., Clarkson, C. and Ellis, G. F. R. (2008). "Time drift of cosmological redshifts as a test of the Copernican principle". *Physical Review Letters* 100, 191303. arXiv:0801.0068.

Uzan, J.-P., Kirchner, U. and Ellis, G. F. R. (2003). "WMAP data and the curvature of space". *Monthly Notices of the Royal Astronomical Society*, doi: 10.1046/j.1365-8711.2003.07043.x. arXiv:astro-ph/0302597.

Zhang, P. and Stebbins, A. (2011). "Confirmation of the Copernican principle at Gpc radial scale and above from the kinetic Sunyaev Zel'dovich effect power spectrum". *Physical Review Letters* 107, 041301. arXiv:1009.3967.

The books of the physics collection, and The Ground of Objection, are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Mordehai Milgrom and Stacy McGaugh

The Law and the History

Mordehai Milgrom, Stacy McGaugh and the Weight of Possibility

Abstract

Mordehai Milgrom and Stacy McGaugh have shown, more clearly than anyone, how tightly the motions of galaxies follow their visible matter. Below an acceleration of about 1.2×10^{-10} meters per second per second, galaxies move as if gravity were stronger than Newton's law gives, and at each radius of 153 disc galaxies the pull found from the rotation is one function of the pull the visible stars and gas alone would give. Milgrom's modified Newtonian dynamics writes that regularity into the law of gravity. The physics collection of the Immanent Metaphysics keeps the law of gravity exactly as general relativity gives it, and places the regularity in the history of how galaxies formed, around a dark matter that is a conserved excitation of the six internal dimensions. The two accounts agree on what the galaxies show. They part on whether what the galaxies show is a law or a history. The essay credits the regularities first, sets out the collection's dark matter and its reasons for keeping the field equations, answers the modified dynamics where the books answer it, sets out how the books derive the tightness of the relation from the formation of galaxies under general relativity, asks why the scale of the relation lands where it does, and reports the measurements that bear on the parting. A final section sets each of the six differences of prediction beside the argument of the book that the registered prediction rests on, and finds that they come down to two premises (whether the gravitational field is the metric alone, and whether galaxies hold an unseen component) and to the collection's own rules of counting, on which its number for the ratio rests.

I. What the Galaxies Show

The outer parts of a spiral galaxy turn about as fast as its inner parts. Vera Rubin and Kent Ford found it for the Andromeda galaxy in 1970, and it has been found since in every disc galaxy measured well: the rotation speed rises and

then stays flat, far beyond the radius where the visible stars and gas thin out (The Weight of Possibility, Chapter 1, Section I). By Newton's law, a speed that stays flat where the visible mass has stopped growing means mass that is not seen.

In 1983 Mordehai Milgrom proposed reading the same fact another way. Where the acceleration of a star or a cloud of gas is large, Newton's law holds; where it falls to about 1.2×10^{-10} meters per second per second and below, the dynamics departs from Newton's law in one fixed way. That one rule, with one constant of acceleration, gives flat rotation curves from the visible matter alone. It also gave something more demanding: predictions made before the measurements. Galaxies of low surface brightness, faint and spread out, whose matter sits almost entirely at low acceleration, were predicted to show large departures from Newton's law throughout, and they do (Famaey and McGaugh 2012).

Stacy McGaugh and his colleagues turned the pattern into measured relations. The first is the baryonic Tully–Fisher relation: the mass of the stars and gas of a galaxy goes as the fourth power of its flat rotation speed, with little scatter, across galaxies of very different size (McGaugh, Schombert, Bothun and de Blok 2000). The second is the radial acceleration relation, measured with Federico Lelli and James Schombert in the SPARC sample (Spitzer Photometry and Accurate Rotation Curves) of 175 galaxies. In their words:

> "We report a correlation between the radial acceleration traced by rotation curves and that predicted by the observed distribution of baryons. The same relation is followed by 2693 points in 153 galaxies with very different morphologies, masses, sizes, and gas fractions. The correlation persists even when dark matter dominates. Consequently, the dark matter contribution is fully specified by that of the baryons. The observed scatter is small and largely dominated by observational uncertainties. This radial acceleration relation is tantamount to a natural law for rotating galaxies" (McGaugh, Lelli and Schombert 2016).

The scatter is about 0.13 dex, a factor of about 1.35, and errors of measurement account for most of it (The Concept Branches, entry F-035, the entry in which the collection quotes and places the relation). In 2017 Lelli, McGaugh, Schombert and Marcel Pawlowski extended the relation to 240 galaxies,

adding elliptical, lenticular and dwarf spheroidal galaxies to the discs, and found all of them on the same relation (Lelli, McGaugh, Schombert and Pawlowski 2017). In 2024 Tobias Mistele, McGaugh and colleagues extended the rotation curves of isolated galaxies by weak gravitational lensing, the slight distortion of the images of more distant galaxies: the circular speeds they infer stay flat for hundreds of kiloparsecs, with no clear decline out to a megaparsec, and they follow the baryonic Tully–Fisher relation found from the motions of gas.

These are among the most exact regularities in astronomy. They were found by people who asked what the galaxies themselves were doing before asking what dark matter should do, and the collection's books take the radial acceleration relation as a measured input, quoted and placed.

II. What the Modified Dynamics Proposes

The modified Newtonian dynamics proposes that the regularity is a law. There is no unseen mass in galaxies; there is a law of gravity that holds a constant of acceleration, and below that constant the law departs from Newton's. A law of that kind has a consequence general relativity does not have. Because the modified law is not linear, a galaxy falling freely in the field of a larger one feels that larger field in its own internal motions, and not only through the tide that the field's variation across the galaxy produces. This is the *external field effect*, and it breaks the strong equivalence principle, which holds in general relativity: a body falling freely carries its own physics with it, whatever field it falls in.

A law of gravity must also say what happens to light and to the universe as a whole, so the modified dynamics has been built into relativistic theories. Jacob Bekenstein's tensor, vector and scalar theory of 2004 was the first. Constantinos Skordis and Tom Złośnik published in 2021 a theory that agrees with the measured microwave background and the measured spectrum of matter on large scales while keeping Milgrom's law in galaxies. Its added fields contribute to the expansion of the universe as an effective fluid that approximates dust, matter without pressure, more and more closely at late times (Rosa and Złośnik 2023).

III. The Collection's Dark Matter

The collection's account of the unseen mass is stated in The Weight of Possibility, Chapter 1, Section IV:

> "The dark matter is a conserved excitation of the six dimensions of possibility, made at the turn, with no exit afterward".

The turn is the passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior. The book says plainly that this is an identification and gives its argument. The six internal dimensions are held: each stands at the modal boundary, the Planck curvature, which is the same throughout the exterior, so the internal space has the same size and the same shape at every point (The Gravitational Passage, Chapter 11, Section II). An excitation of that space is a distortion of a context, and not an item of content. It has energy, so it gravitates; it is not content, so nothing that registers content registers it. Every exit is closed. It cannot turn into content, since the geometry of possibility is re-formed only at the turn. It cannot pass its energy to waves of the open geometry, since the lightest excitation that changes sign under the map of the sphere to its opposite points is kept by that symmetry of the action (Chapter 4, Section V, The Lightest Odd Level). And it cannot evaporate, since at the Planck scale it has no lower level of its kind.

The account, which is that of The Weight of Possibility within the collection, fits what is observed of the dark matter, item by item (Chapter 1, Section I). It acts only through gravity. It is perfectly cold and collisionless, so it clusters as standard cold dark matter does. In the colliding cluster 1E 0657-56, the Bullet Cluster, the mass mapped by lensing lies with the galaxies, apart from the hot gas that holds most of the ordinary matter, and the collision bounds the scattering of the dark component on itself below about one square centimeter per gram; the account's gyrations (its name for single excitations of the six internal dimensions) scatter at least forty-five orders of magnitude below that bound. It does not decay, and the expansion history bounds any decay into unseen products to lifetimes beyond about 160 billion years.

The account also gives the amount. The ratio of dark matter to ordinary matter is fixed by an identity of the present measurement, a count of the classes that a registration made now counts in each factor of the internal space (Section VIII sets out the count), as the cosmological constant is fixed in The Gravitational Passage, at $6 - 2/\pi = 5.3634$ (Chapter 3, Section V). The Planck satellite alone gives 5.364 ± 0.065, and the combination of the South Pole Telescope, Planck and the Atacama Cosmology Telescope gives 5.370 ± 0.048 (Chapter 5, Section I). So the collection has, for the dark component of the universe, what the modified dynamics was built not to need: a kind, a reason it persists, and a number.

IV. Why the Law of Gravity Is Kept

The collection keeps the law of gravity because it derives it. The Gravitational Passage, Chapter 12, obtains the Einstein field equations from the structure of comparison, and its Section VII closes the question of their form with Lovelock's theorem: in four dimensions, the most general symmetric, divergence-free tensor built from the metric and its first and second derivatives is a combination of the Einstein tensor and the metric, and "within the theorem's conditions there is no other equation". The equations hold two constants, Newton's constant and the cosmological constant. They hold no constant of acceleration. The Weight of Possibility, Chapter 5, Section V, draws the consequence: "The field equations hold Newton's constant and the cosmological constant, and no constant of acceleration". A law of gravity with a constant of acceleration in it is a different equation from the one the collection derives, and the collection's equation holds exactly throughout the domain of the smooth description, below the Planck curvature.

The collection's account of the three things that bend the arena gives the parting its exact place. There are three contexts of measurement, space, time and possibility, and three distortions of them: "Gravitation distorts space", "The cosmological constant distorts time", and "The dark matter distorts possibility" (The Weight of Possibility, Chapter 2, Section II). In physical terms, the distortion of possibility is the excitation of the six internal dimensions set out in Section III: it carries energy, so it gravitates, and it is no item of content, so nothing that registers content registers it. The dark matter, a distortion of

possibility, "registers only as a distortion of space, by gravitating", and the book adds that the two "meet in exactly that one way, which is the one way the dark matter is observed" (Chapter 2, Section VI). The modified dynamics takes that one way of registering for all that the unseen component is. It sees a distortion that appears in space, and it changes the law of the distortion of space to produce it. On the collection's account, the effect appears in space because that is the only place a distortion of possibility can register, and its source lies in the third context, which no change to the law of space can reach.

The book grounds that pairing in the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. With the cosmological constant as the clear immanent member of the triple, the first axiom makes gravitation and the dark matter its conjugate pair, standing where the horizon and the Planck scale stand, "as the limits of perfected symmetry and of perfected continuity" (The Weight of Possibility, Chapter 2, Section VI). Gravitation distorts the context in which pattern is laid out, and what it does is itself laid out: the bending of light maps it. The dark matter distorts the context of what could occur, and what it does is laid out nowhere except through gravitation. A single law of space asked to produce both is a single framework asked to carry both members of a conjugate pair, and that is what the theorem excludes. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

V. Where the Two Accounts Part

The books name three places where the modified dynamics meets measured difficulty, and they hold the account against it on each (The Weight of Possibility, Chapter 5, Section V; The Concept Branches, entry F-035).

Clusters of galaxies. “Changing the law of gravity instead, as the modified dynamics (modified Newtonian dynamics, MOND) does, still leaves clusters of galaxies short of mass” (Sanders 2003; Famaey, Pizzuti and Saltas 2025). In clusters the modified law still needs unseen mass, which is the thing it was proposed to remove.

The microwave background. “Without dark matter it predicts a third peak of the microwave background lower than the one measured” (McGaugh 2004; Aghanim and others 2020). The measured peak is set by a component that takes no part in the sound of the early plasma, its acoustic oscillations, and gravitates, and the collection’s dark matter is that component. The relativistic theory of Skordis and Złośnik answers the microwave background, and it answers with a component of its own. Its added fields act on the expansion as an effective fluid that approximates dust: on the scale of the universe, a component that gravitates and does not take part in the sound. The cosmological role of a dark component returns, carried by a field of the modified theory. So the agreement of that theory with the microwave background is an agreement that such a component is there; the two accounts then differ on what it is and on what it does in galaxies.

The external field. “With the field equations exact throughout the domain of the smooth description, below the Planck curvature, as the Passage derives them, a galaxy falling freely in the field of a larger one feels that field only through its tide, as general relativity requires, and not through the external field effect that the modified dynamics predicts”. There is no external field effect. The collection’s field equations hold the strong equivalence principle: a body falling freely carries its own physics with it, whatever field it falls in, and the only trace of the larger field inside it is the tide. The modified law breaks that principle, and the external field effect is the form its breaking takes. The external field effect marks the sharpest difference between the two accounts, because it concerns no quantity of dark matter at all.

VI. The Tightness of the Relation

The books derive the tightness of the radial acceleration relation from the formation of galaxies: “The tightness of that relation follows from galaxy formation under general relativity with a cold component that acts only

through gravity, and the account inherits it because the gyrations are such a component: they couple to the content through gravity alone (Chapter 4, Section II), and they are cold whatever speed the turn gives them, so that on the scales of galaxies they cluster exactly as standard cold dark matter does (Section VI)" (The Weight of Possibility, Chapter 5, Section V). On the account, the scale and the tightness both belong to how the galaxies formed. The gas of ordinary matter radiates as it falls inward, loses energy, sinks and breaks up into stars; the dark component radiates nothing, keeps its motion and stays spread out (Chapter 1, Section I). Galaxies are what that difference makes, under one law of gravity, and the relation between where the visible matter ends up and how the whole galaxy pulls is a record of that difference. The account states the tightness as a consequence of that history, and the questions that follow ask how the history writes it.

Questions that would answer it. Does galaxy formation with a perfectly cold, collisionless component and gas that radiates reproduce a relation of this form, with this small scatter, across galaxies of very different histories? The book answers from the simulations: "Simulations of galaxy formation with such a component reproduce the relation and its small scatter (Keller and Wadsley 2017; Ludlow and others 2017; Dutton and others 2019)". What sets the scatter as small as the measured one? The book places the origin of the relation "in the self-similar profiles of cold halos, in the narrow range of halo mass in which disc galaxies form, and in the slow relaxation of the dark component around the gathering ordinary matter (Navarro and others 2017; Paranjape and Sheth 2021)". Which feature of the formation (the cooling of the gas, the feedback of stars, or the coupling of the two components through gravity alone) fixes the acceleration at which the relation turns? The book holds that formation sets that acceleration, and that the clusters of galaxies show it: "there the same form turns at $(2.02 \pm 0.11) \times 10^{-9}$ meters per second per second, about seventeen times the galactic value (Tian and others 2020; Tian and others 2024)". Read under Milgrom's law, the higher turning point of the clusters asks for unseen mass left over in them, the mass the law was proposed to remove and that its own analysts find there (Section VIII); on the

account no leftover is needed, since the clusters hold the same dark component as the galaxies, and a turning point that differs from one kind of structure to another is what a scale set by formation gives.

Questions that check the question. Is the relation a law of gravity or a regularity of formation? The two give different answers in places where no galaxy formed: a law with a constant of acceleration acts on two stars orbiting each other at low acceleration, far from any galaxy's history, and a regularity of formation does not. And they give different answers where a galaxy falls in a larger field: a law with a constant of acceleration predicts the external field effect, and general relativity predicts only the tide. These two measurements decide which kind of thing the relation is.

Questions that collect the clues. The acceleration scale lies close to the speed of light times the Hubble constant divided by 2π, which is 1.05×10^{-10} meters per second per second at the Passage's Hubble constant. Why does it land there? The book answers the first form of the question: the cosmological constant, which sets the present expansion, draws two free bodies apart across ten kiloparsecs, the size of a galaxy, at about 1.0×10^{-15} meters per second per second, "less than a hundred-thousandth of the scale", so "the field equations give the scale no value at any place in a galaxy" (Chapter 5, Section V). The near-equality is then a relation between how galaxies formed and the epoch in which they formed, and the clue to its reason lies in the history of formation. The baryon fractions McGaugh and his colleagues measure, falling from clusters to dwarf galaxies, are a further clue of the same kind: on the account they are "fractions within formed structures" (Objections from Physics, Answered). The flat curves of weak lensing out to a megaparsec are a third: Antonino Del Popolo and Man Ho Chan argue that standard cold dark matter halos, with their virial radii estimated anew, match those flat curves (Del Popolo and Chan 2025). A fourth bears on law or history directly, since a law holds one constant of acceleration for every galaxy: Davi Rodrigues and his colleagues fitted the scale to each of 193 disc galaxies separately and found the values incompatible with one common scale at more than ten standard deviations (Rodrigues and others 2018). McGaugh and his

colleagues, and Pavel Kroupa and his colleagues, disputed that finding, Kroupa and his colleagues arguing that it rests on poorly measured galaxies (McGaugh and others 2018; Kroupa and others 2018).

VII. What the Measurements Say

The account predicts that two stars in a wide orbit, at accelerations below Milgrom's scale, move by Newton's law, since the field equations hold no constant of acceleration. The wide binaries measured by the Gaia satellite bear on exactly that. Indranil Banik and his colleagues found in 2024 that Newtonian dynamics is preferred over the modified dynamics at 19 standard deviations. Kyu-Hyun Chae has reported an anomaly in samples of binaries he selected (Chae 2024); Serat Saad and Yuan-Sen Ting reanalyzed in 2026 the 36 binaries of a later sample of Chae and his colleagues (Chae and others 2026), which had given a strengthening of gravity of about 1.6 times Newton's, and, modeling the orbit of each pair in three dimensions, found a factor of 1.00 $(+0.24/-0.19)$, consistent with Newtonian gravity; with the separation estimated as Chae and his colleagues estimated it, they recover the anomaly (Saad and Ting 2026). The wide binaries stand with the account.

The account predicts that a galaxy falling freely in a larger field feels it only through its tide. Chae, Lelli, Desmond, McGaugh, Li and Schombert reported in 2020 a detection of the external field effect in the SPARC galaxies: at 8 to 11 standard deviations in a few galaxies under exceptionally strong external fields, statistically at more than 4 standard deviations across 153 galaxies, and as a downward trend at the weak end of the radial acceleration relation. They argue that tides from neighboring galaxies are too weak to produce it. The account predicts that this detection will not stand: there is no external field effect, and a measurement that finds one has found something else. The account also says what that something is. The external field of each galaxy is estimated from the galaxies around it, and not measured directly, so a galaxy assigned a strong external field is a galaxy that formed in a crowded place. A trend that follows the estimated field follows the crowding, and crowding shapes how a galaxy forms: how its gas is stripped, heated and gathered, and so where its visible matter ends up relative to its whole pull. On the account the radial acceleration relation is the record of that history, so a trend in the

relation with crowding is what the account expects, and it is a trend of history, not of the law of gravity. The wide binaries have already shown the same pattern on a smaller scale: the reported anomaly appears under one way of modeling the orbits and disappears when the orbits are modeled independently. The prediction is definite, and the measurements that will settle it are definite too: a sample of galaxies selected and analyzed independently, with the external field separated from the environment of formation, will find the tide and nothing more.

These measurements bear on one question: whether the field equations hold without modification at the accelerations of galaxies. They do not bear on the identification of the dark matter, on its ratio to the ordinary matter, or on the argument that no process can carry ordinary matter into dark matter. Those rest on other ground: that each of the six internal dimensions is held at the Planck curvature, so that the internal space has one size and one shape everywhere; that the excitation can neither turn into ordinary matter, nor pass its energy to waves of the geometry, nor evaporate; and the identity of the present measurement that fixes the ratio, which the microwave background measures at 5.370 ± 0.048 against the predicted 5.3634. They do bear on the predicted matter fraction, which The Gravitational Passage ties to the premise that the gravitational field is the metric alone (Section VIII quotes it), and through that fraction on the amplitude of clustering of Prediction 18. Whatever the galaxies show about the external field, the dark component of the universe is measured in the microwave background, where the modified dynamics also needs a component that gravitates and takes no part in the sound.

VIII. Where the Predictions Part, and Why

The dated record *The Registered Predictions Beside Mordehai Milgrom and Stacy McGaugh*, of 4 November 2026, printed as Appendix I of this volume, which quotes each prediction in the words sealed on 1 November 2026, sets out six places where the two accounts predict different results. For each, this section sets the argument of the book that the registered prediction rests on beside the reasoning of Milgrom and McGaugh, and finds the first step at which the

two part. Where a step does not follow from its premises, the section names it. Where both steps follow, from different premises, it names the premise in dispute and what settles it. The aim is to learn where a fault lies, on either side.

1. The external field effect

The sealed prediction. "A galaxy falling freely in the field of a larger one feels that field only through its tide; the external field effect that modified Newtonian dynamics predicts will not be found". It was registered on 1 November 2026 as Prediction 24.

The argument of the book. The argument runs through The Gravitational Passage in four steps. First, the premise of the action: "the gravitational action is built from the metric alone" (The Gravitational Passage, Chapter 11, Section I). Second, covariance: the Passage identifies invariance under every change of coordinates with the omniscient modality (the role of what is held as structure laid out), and notes that covariance restricts nothing by itself; "What Lovelock's theorem uses is covariance together with an action built from the metric alone, with no field fixed in advance" (Chapter 11, Questions). Third, the second-order condition: equations of higher order "carry extra degrees of freedom, and these generically include states of negative energy (Ostrogradsky 1850)". Fourth, Lovelock's theorem: in four dimensions the most general symmetric, divergence-free tensor built from the metric and its first and second derivatives is a combination of the Einstein tensor and the metric, and "Within the theorem's conditions there is no other equation" (Chapter 12, Section VII). The equations so obtained hold Newton's constant and the cosmological constant and no constant of acceleration, and general relativity holds the strong equivalence principle; so a galaxy falling freely feels the larger field only through its tide (The Weight of Possibility, Chapter 5, Section V).

Their argument. Milgrom read the regularity of the galaxies as a law with one constant of acceleration (Milgrom 1983). Jacob Bekenstein and Milgrom wrote that law as a field equation for the potential, and the equation is not linear (Bekenstein and Milgrom 1984). In an equation that is not linear, a uniform field from outside does not drop out of the motions inside: the external field effect follows from the law as a theorem of it. The relativistic forms keep

that limit in galaxies by adding fields beside the metric: Bekenstein's theory a vector and a scalar (Bekenstein 2004), and the theory of Skordis and Złośnik, the Aether Scalar Tensor theory, a vector and a scalar as its name says (Skordis and Złośnik 2021). The strongest ground of the argument is prediction made before measurement. McGaugh used the external field effect to predict the velocity dispersion of the faint satellite Crater II, 2.1 $(+0.9/-0.6)$ kilometers per second (McGaugh 2016), and the measured value is 2.7 ± 0.3 (Caldwell and others 2017).

Where they part. The collection: the gravitational field is the metric alone. Milgrom and McGaugh, in the relativistic forms of their law: the gravitational field holds, beside the metric, further fields whose dynamics hold a constant of acceleration.

Whose step, and what decides it. On both sides every step after the first premise follows. Lovelock's theorem is a theorem, and given its conditions the equations of the collection hold no constant of acceleration; the external field effect is a theorem of any law of Milgrom's kind. The two accounts rest on different premises, and the difference is one sentence: whether the gravitational field consists of the metric alone, or of the metric together with further fields that carry a constant of acceleration. On the collection's side, the Passage states the premise of the metric alone in Chapter 11, Section I; it does not derive the premise from comparison there. It supports the premise by what a further field would cost. For one such field, the connection of a spin-c structure on the internal factor (a field that spinning fields would need on the internal space, which does not admit them without one), it writes: "With a field of its own, the action would no longer be built from the metric alone; the field's classical energy would enter the external value of Chapter 13, Section II, beside the bare curvature term, and so change the predicted matter fraction; and its coupling would be a second constant beside GN. This book takes no such field" (The Gravitational Passage, Chapter 12, Questions). A constant of acceleration is exactly a second constant beside Newton's, and Section IV of this essay gives the further ground in the Incommensuration Theorem: one law of space asked to carry both members of a conjugate pair. So Prediction 24 tests the premise of the metric alone directly. What rests on that premise: the absence of any constant of acceleration, Prediction 24 itself, and, as the

Passage states for the field it names, the predicted matter fraction. What does not rest on it: the identification of the dark matter, the closed exits that keep it, and the count that fixes its ratio. On the side of Milgrom and McGaugh, the step from the regularity to a law does not follow by itself: simulations of galaxy formation under general relativity with a cold component reproduce the relation and its small scatter (Keller and Wadsley 2017; Ludlow and others 2017; Dutton and others 2019), so the regularity holds there with no constant of acceleration in the law. Their ground for the law is the predictions made before the measurements, and the prediction for Crater II used the external field effect itself. Within cold dark matter, the tides of the Milky Way lower the dispersion of Crater II to the measured value but also shrink the galaxy below its measured size (Borukhovetskaya and others 2022), so Crater II is at this date a measurement of interest on both sides. What decides it is the measurement the sealed record names: internal motions measured against the field each body falls in, with the external field established by more than one kind of measurement, at five standard deviations by at least two independent kinds. Section VII of this essay gives the measurements made so far.

2. The mass of clusters of galaxies

The sealed prediction. "The ratio of the density of the dark matter to the density of the ordinary matter is $\Omega c/\Omega b = 6 - 2/\pi = 5.3634$, the same at every time since helium formed". It was registered on 1 November 2026 as Prediction 16. In a cluster of galaxies, on this account, the unseen mass is the same dark matter, and the share of the ordinary matter in all the matter, with the lightest neutrinos, is 0.15644 (What the Beginning Left Behind).

The argument of the book. The number comes from the count of Chapter 3 of The Weight of Possibility, taken up under the next heading. For clusters the book reports two measurements: the gas of galaxy clusters gives 0.156 ± 0.034 for the share of the ordinary matter (Mantz and others 2022, as cited in Chapter 5, Section II), and in the colliding cluster 1E 0657-56 the mass mapped by lensing lies with the galaxies, apart from the hot gas (Chapter 1, Section I).

Their argument. The modified law, applied to the gas and galaxies of a cluster, reduces the missing mass without removing it. Robert Sanders found that "the typical mass discrepancy is three to four times smaller than with Newtonian dynamics", and that "while MOND significantly reduces the mass of the dark component in clusters it does not remove it completely"; the mass still missing in the central regions is "one to two times that in the gas" (Sanders 2003). Benoit Famaey, Lorenzo Pizzuti and Ippocratis Saltas find from gravitational lensing that the missing mass in clusters remains under the modified law (Famaey, Pizzuti and Saltas 2025).

Where they part. The collection: an unseen component is present in clusters, and it is the dark matter of the account. Milgrom and McGaugh: the unseen mass of galaxies is a misreading of the law; with the law corrected, there is no unseen component.

Whose step, and what decides it. The premise of the modified dynamics that no unseen component exists is contradicted in clusters by the measurements already made, read under the modified law itself, and its own analysts say so. The contradiction is a fault of premise on the side of the modified dynamics, at the scale of clusters. The question then moves to what the remaining component is, and there the two accounts differ on its kind, with both holding that it is there. On the collection's side the measurement of clusters agrees and tests little: the share in the gas of clusters, 0.156 ± 0.034, is about thirty times less precise than the microwave background (The Weight of Possibility, Chapter 5, Section II), so it does not reach the difference between $6 - 2/\pi$ and its neighbors. What decides the number is the measurement of the ratio by the microwave background, taken up under the next heading.

3. The ratio that the microwave background measures

The sealed prediction. The same Prediction 16: the ratio of the dark matter to the ordinary matter is $6 - 2/\pi = 5.3634$, fixed by the account with no parameter to fit.

The argument of the book. The next steps count classes on the internal space, and they show how the number $6 - 2/\pi$ is reached; a reader who takes the count on trust can pass to the argument of Milgrom and McGaugh below. Chapter 3 of The Weight of Possibility gives the number in five steps. The ra-

tio is an identity of the present measurement, fixed as the Passage fixes the cosmological constant, and the reconstructed history carries it back to the forming of helium (Chapter 3, Section I). A registration counts kinds by classes, and the book names this as a principle of its own: "That a registration counts the residues it registers by classes too, as the Passage counts its channels, is the account's principle". The dark residue ranges over both factors of the internal space, so it counts "the three classes of $\mathbb{C}P^2$ times the two classes of S^2, $3 \times 2 = 6$"; the ordinary residue fills the region within the horizon, which is a ball, so "the open space counts as one" (Section II). Here $\mathbb{C}P^2$ is the complex projective plane, a curved space of four real dimensions, and S^2 the ordinary sphere of two dimensions; together they make the six internal dimensions. A class is one of the independent cycles of a space; $\mathbb{C}P^2$ has three and S^2 two, and that number is each space's Euler number. A curved factor reduces the count by the share of its curvature, two over π for $\mathbb{C}P^2$ (Section III). Which curvature reduces the count is fixed by one principle: "a count that includes a factor's Euler number is not reduced again by that factor's curvature"; the count of six includes the Euler number of S^2, so only the curvature of $\mathbb{C}P^2$ reduces it (Section IV). The result is $6 - 2/\pi$ (Section V).

Their argument. In 1999, before the measurements, McGaugh named the test that separates a universe with cold dark matter from one without it, the ratio of the first two peaks of the microwave background (McGaugh 1999), and he read the first measurements of the second peak as consistent with a universe whose matter is all ordinary (McGaugh 2000). Without dark matter, the modified dynamics predicts a third peak lower than the one measured (McGaugh 2004; Aghanim and others 2020). The Aether Scalar Tensor theory agrees with the measured microwave background through its added fields, which act on the expansion as dust, and of the amount of that dust its authors write: "the density $\bar{\rho}$ is not (classically) predicted" (Skordis and Złośnik 2021).

Where they part. Against the first form of the modified dynamics the parting is the one of clusters: whether a component that gravitates and takes no part in the sound of the early plasma exists at all, and the measured third peak says it does, as McGaugh's own analysis found. Against the Aether Scalar Tensor theory the parting is a premise: the collection holds that the amount

of that component, relative to the ordinary matter, is fixed by structure at registration; the theory holds that it is set by an initial condition, and it makes no contrary prediction of the number.

Whose step, and what decides it. The steps of the book follow from its premises, and the arithmetic is exact. The place to look for a fault on the collection's side is in the premises, and the book names them as its own. Counting by classes is "the account's principle". The rule for which curvature reduces the count "is a principle of bookkeeping, and it is the account's". The use of each factor's own Einstein trace (the trace of the Einstein tensor taken over that factor alone, a measure of its curvature), and not the accelerations of its motion, is a further choice the book states with its alternative: "Read from the accelerations, the abiding in the dark residue would be $3/\pi$, and the ratio would be $6 - 3/\pi = 5.045$, which the data exclude". And the book states plainly how the form within its family was settled: of the four choices of which curvature reduces the count, "Of these four, the measurement admits one" (Section VII). So the measured ratio alone cannot confirm these principles, since it was among the grounds on which the form was settled. The book supplies a second check from the same principles: the rule for which curvature reduces a count also decides the Passage's identity for the cosmological constant, where the count does not include the Euler number of S^2, so its curvature reduces that count too; "Exempting S^2 in the Passage's identity too would give the matter fraction 0.300 in place of 0.311. One statement gives both numbers" (Section IV). The matter fraction and the ratio also share one coefficient, the curvature of the internal dimensions in Planck units, which the ratio measures at 0.99 ± 0.08 (Chapter 5, Section III). The ratio and the matter fraction both rest on the principle of which curvature reduces the count, and they move together with it; the identification of the dark matter, its persistence and its kind rest on other ground. Two measurements decide the principle. The analyses that add the baryon acoustic oscillations of the Dark Energy Spectroscopic Instrument (DESI) give 5.199 ± 0.035, 4.7 standard deviations from the rule, from one kind of measurement (Chapter 5, Section I); and a second, independent kind of measurement of the two densities, at the

precision of the microwave background, is the test the sealed record names, with the Simons Observatory and Planck expected to reach the ratio to about 0.6 percent (Chapter 5, Section IV).

4. How early massive galaxies formed

The sealed prediction. "With the matter fraction of Prediction 7, the ratio of Prediction 16, and the primordial amplitude and tilt of Planck 2018, the amplitude of clustering today is S8 = 0.823 ± 0.006 (0.827 ± 0.007 with h = 0.678). The gyrations cluster exactly as standard cold dark matter does". It was registered on 1 November 2026 as Prediction 18. Prediction 7, which it names, is the matter fraction: matter makes up 0.311 of the energy of a spatially flat universe at the present epoch.

The argument of the book. The ordinary matter departed from evenness by about three parts in a hundred thousand when the light went free, and once matter rules the expansion a small excess grows in proportion to the distances between things, which have grown about 1,090 times since; "so ordinary matter alone would have formed no galaxy" (Chapter 1, Section I). The dark component takes no part in the sound, so its departures grew earlier, and structure forms in its wells. The gyrations are cold whatever speed the turn gives them, so "on these scales the gyrations cluster exactly as standard cold dark matter does" (Chapter 5, Section VI).

Their argument. Under the modified law, the pull at low acceleration is stronger than Newton's, so ordinary matter alone assembles faster than cold dark matter allows: massive galaxies form at redshifts of about ten and above, and clusters of galaxies and the reionization of the universe also come early (McGaugh, Schombert, Lelli and Franck 2024). They state the choice the observations of the James Webb Space Telescope leave: an extremely efficient conversion of ordinary matter into stars at early times within cold dark matter, or an assembly faster than cold dark matter allows. The prediction of early massive galaxies, made before those observations, is theirs.

Where they part. The collection: departures from evenness grow at the rate general relativity gives, and the wells they grow in are those of a cold component. Milgrom and McGaugh: at low acceleration the departures of the ordinary matter grow under a law that is not linear and is stronger than Newton's.

Whose step, and what decides it. The book's step that ordinary matter alone would have formed no galaxy follows under general relativity; the growth in proportion to the distances is the growth general relativity gives, so the step is not an argument against the modified dynamics separate from the external field effect. The step reduces to the premise of the metric alone. A second point lies on the collection's side. The registered number, the amplitude of clustering today, is not what the early galaxies measure. What the account fixes for them is the abundance of the wells at each epoch, the abundance of standard cold dark matter at the account's matter fraction and ratio; how efficiently gas in those wells turns into stars is a matter of content, and the books do not fix it. So the count of bright galaxies at early times does not by itself reach the collection's prediction; the masses of the wells do. What decides the difference: the masses of galaxies above redshift ten found from their motions or from the bending of light, and not from their starlight, set beside the abundance of cold dark matter at the account's parameters; and the amplitude of clustering by independent kinds of measurement at the rule of decision, five standard deviations by at least two independent kinds of measurement.

5. Dark clumps that hold no stars

The sealed prediction. "The dark matter has no cut-off in its structure on small scales from its own motion; it clumps on every small scale". It was registered on 1 November 2026 as Prediction 21.

The argument of the book. A perfectly cold, collisionless component has no scale below which its departures are erased; the account's gyrations are cold for every speed the turn can give them, and the present bounds from the faintest satellites and from strong lensing place any cut-off below about ten million solar masses (Chapter 5, Section V; Section VI). So clumps too small to hold stars exist around galaxies, and the bending of light weighs them.

Their argument. The modified dynamics places no unseen mass in galaxies (Milgrom 1983; Famaey and McGaugh 2012), so it holds no dark clump around a galaxy. In its relativistic forms light is bent by the same strengthened field that moves the stars (Famaey and McGaugh 2012), so a small object with little light bends light more than Newton's law gives for its visible mass.

Where they part. They part on the same premise as for clusters: whether an unseen component exists in and around galaxies.

Whose step, and what decides it. Both steps follow from their premises. One lens has found a satellite of $1.9 \pm 0.1 \times 10^8$ solar masses that gives off no light (Vegetti and others 2012); on the strongest reading of the modified dynamics, such a perturber is a faint object whose bending is strengthened by the law, so a single detection does not decide between them. What decides the premise is the number of such masses, found by the bending of light alone, at the small scales the prediction names, together with the counts of the faintest satellites, at the rule of decision. A cut-off found in those counts would bear against Prediction 21.

6. What the dark component is made of

The sealed prediction. "The dark matter comes in gyrations whose mass is of the order of the Planck mass: the lightest odd state is about 0.6 Planck masses at first order and $\sqrt{2}$ Planck masses, about 1.7×10^{19} GeV, at the classical level, so that there is about one gyration for every 1.5 to 3.4×10^{18} baryons". It was registered on 1 November 2026 as Prediction 22.

The argument of the book. The internal space is held, with "the same size and the same shape at every point of the exterior"; its lowest level that holds states odd under the map of the sphere to its opposite points is the first harmonic of the sphere, with a squared mass of two in Planck units at the classical level, lowered at first order by the term that holds the space to about 0.6 Planck masses; "The lightest of them is the one that persists" (Chapter 4, Section V). The book states the conditions on these masses: that the higher Lovelock terms do not alter the operators, and that the term holding the space acts as an ordinary source; and it names three candidates for the lightest state.

Their argument. In galaxies there is no dark component to be made of anything (Milgrom 1983). In the Aether Scalar Tensor theory, the dust that the cosmological measurements require is the energy of the added fields (Skordis and Złośnik 2021).

Where they part. The collection: the component that gravitates and takes no part in the sound is a population of conserved excitations of a held internal space. The Aether Scalar Tensor theory: it is the energy of fields added to the gravitational field beside the metric.

Whose step, and what decides it. Both follow from their premises, and the premise in dispute is the one of the external field effect: whether the gravitational field is the metric alone. The added fields of the Aether Scalar Tensor theory are exactly what the Passage's premise excludes. The external field effect and the ratio that the microwave background measures bear on the composition first; no measurement reaches the composition itself at this date, and the sealed record names none. A detected effect would show that fields beside the metric exist, which removes the Passage's ground for excluding the Aether Scalar Tensor account of the dust; it would not show that the dark matter is other than gyrations.

What the six come to

The six differences come down to two premises and one set of principles. The first premise is whether the gravitational field is the metric alone: the external field effect, the growth of the early galaxies, and the composition of the dark component turn on it. The collection states that premise in the Passage and supports it by its costs and by the Incommensuration Theorem, and the external field effect is its direct test. The second premise is whether an unseen component exists in and around galaxies: clusters, the third peak and the starless clumps turn on it. In clusters and in the third peak, the first form of the modified dynamics is contradicted by measurements read under its own law, as its own analysts report, and the question that remains between the accounts there is the kind of the component, since both hold that it is present. The principles are the collection's own rules of counting, on which the number $6 - 2/\pi$ rests; the book names them as its own, says that the measurement settled the form within its family, and gives the matter fraction as a second

number from the same principle. A second, independent kind of measurement of the ratio is what tests those principles, and the analyses that add the oscillations measured by DESI press on them now.

IX. Summary

Milgrom and McGaugh found that the motions of galaxies follow their visible matter by one rule, turning at one acceleration, with a scatter set mostly by the errors of measurement. The collection takes that rule as measured and credits it as one of the most exact regularities in astronomy. The modified dynamics writes the rule into the law of gravity. The collection keeps the law of gravity as it derives it, with Newton's constant and the cosmological constant and no constant of acceleration, and identifies the unseen component as a conserved excitation of the six internal dimensions, a distortion of possibility that registers only as a distortion of space, with its amount fixed at $6 - 2/\pi$ times the ordinary matter. On this account the rule is the history of how galaxies formed under one law, and its tightness follows from that history, with a cold component that acts only through gravity. The two accounts part on whether the rule is a law or a history, and two measurements decide which. The first is orbits far from any galaxy's history, where the wide binaries so far stand with the account. The second is galaxies falling in larger fields, where the account predicts the tide and nothing more: there is no external field effect, and the trend reported in 2020 is, on the account, a trend of formation in crowded places. Neither measurement reaches the identification of the dark matter, its ratio, or the argument that rests on that identification. Both bear on the predicted matter fraction, which the Passage ties to the premise of the metric alone, and through it on the amplitude of clustering of Prediction 18. Set beside the books, the six differences of prediction come down to two premises. The first is whether the gravitational field is the metric alone, which the Passage states and the external field effect tests. The second is whether galaxies hold an unseen component, which measurements of clusters and of the third peak, read under the modified law itself, show they do. The collection's own number, $6 - 2/\pi$, rests on rules of counting the book names as its own; a second, independent kind of measurement of the ratio tests them. The nearness of the turning acceleration to the speed of light times

the Hubble constant divided by 2π, which the account places in the history of formation, is where Erik Verlinde, in the next chapter, begins: he reads gravity from the thermodynamics of information at a boundary, and derives a scale of that size from the rate of the cosmic expansion.

Key Concepts

- The radial acceleration relation: at each radius of a disc galaxy, the pull found from the rotation is one function of the pull of the visible matter alone, turning at about 1.2×10^{-10} meters per second per second.
- The modified Newtonian dynamics writes that relation into the law of gravity, with a constant of acceleration, and so predicts the external field effect.
- The collection's field equations hold Newton's constant and the cosmological constant and no constant of acceleration; a galaxy falling freely feels a larger field only through its tide.
- The collection's dark matter is a conserved excitation of the six internal dimensions, a distortion of possibility that registers only as a distortion of space.
- Law or history: the relation is, on the account, a record of how galaxies formed; wide binaries and the external field decide which.
- The identification of the dark matter and its ratio, $6 - 2/\pi$, rest on the hold of the six and the identity of the present measurement, not on galactic dynamics.
- Where the predictions part: the external field effect tests the premise that the gravitational field is the metric alone; clusters and the third peak show an unseen component under either law; the ratio tests the collection's own rules of counting.

Terms

Abiding. In The Weight of Possibility, the share of a curved factor's curvature that holds fast in a registration as a term of its own and reduces a count of classes: two over π for $\mathbb{C}P^2$.

Aether Scalar Tensor theory. The relativistic theory of the modified dynamics of Skordis and Złośnik, with a vector field and a scalar field beside the metric.

Baryonic Tully–Fisher relation. The mass of a galaxy's stars and gas goes as the fourth power of its flat rotation speed.

Dark matter (on the collection's account). A conserved excitation of the six held internal dimensions, made at the turn, with every exit closed; its unit is called a gyration.

External field effect. In the modified dynamics, the change in a galaxy's internal motions produced by the uniform field of a larger body it falls in; general relativity has no such effect, only the tide.

Lovelock's theorem. In four dimensions, the most general symmetric, divergence-free tensor built from the metric and its first and second derivatives is a combination of the Einstein tensor and the metric; so an action of the metric alone, generally covariant and of second order, gives the Einstein equations with a cosmological constant and no other.

Modal boundary. The Planck curvature, at which the descriptions of content and context exchange dominance; each of the six internal dimensions stands at it, the same throughout the exterior.

Radial acceleration relation. See Key Concepts.

Strong equivalence principle. A body falling freely carries its own physics with it, whatever field it falls in, its own gravity included.

Tide. The part of a field that varies across a body, stretching it; the only way a uniform fall is felt in general relativity.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

References

Aghanim, N. and others (Planck Collaboration) (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6. doi: 10.1051/0004-6361/201833910. arXiv:1807.06209.

Banik, I., Pittordis, C., Sutherland, W., Famaey, B., Ibata, R., Mieske, S. and Zhao, H. (2024). "Strong constraints on the gravitational law from Gaia DR3 wide binaries". *Monthly Notices of the Royal Astronomical Society* 527, 4573–4615.

Bekenstein, J. and Milgrom, M. (1984). "Does the missing mass problem signal the breakdown of Newtonian gravity?". *The Astrophysical Journal* 286, 7. doi:10.1086/162570.

Bekenstein, J. D. (2004). "Relativistic gravitation theory for the modified Newtonian dynamics paradigm". *Physical Review D* 70, 083509.

Borukhovetskaya, A., Navarro, J. F., Errani, R. and Fattahi, A. (2022). "Galactic tides and the Crater II dwarf spheroidal: a challenge to LCDM?". *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stac653. arXiv:2112.01540.

Caldwell, N. and others (2017). "Crater 2: an extremely cold dark matter halo". *The Astrophysical Journal* 839, 20. doi:10.3847/1538-4357/aa688e.

Chae, K.-H. (2024). "Breakdown of the Newton–Einstein standard gravity at low acceleration in internal dynamics of wide binary stars". *The Astrophysical Journal* 960, 114.

Chae, K.-H., Lee, B.-C., Hernandez, X., Orlov, V. G., Lim, D., Turnshek, D. A. and Lee, Y.-W. (2026). "Detection of gravitational anomaly at low acceleration from a highest-quality sample of 36 wide binaries with accurate 3D velocities". arXiv:2601.21728.

Chae, K.-H., Lelli, F., Desmond, H., McGaugh, S. S., Li, P. and Schombert, J. M. (2020). "Testing the strong equivalence principle: detection of the external field effect in rotationally supported galaxies". *The Astrophysical Journal* 904 (1), 51. doi:10.3847/1538-4357/abbb96. arXiv:2009.11525.

Clowe, D., Bradač, M., Gonzalez, A. H., Markevitch, M., Randall, S. W., Jones, C. and Zaritsky, D. (2006). "A direct empirical proof of the existence of dark matter". *The Astrophysical Journal* 648, L109–L113.

Del Popolo, A. and Chan, M. H. (2025). "Flat circular velocities on a megaparsec scale from the ΛCDM model". arXiv:2504.12662.

Dutton, A. A., Macciò, A. V., Obreja, A. and Buck, T. (2019). "NIHAO XVIII. Origin of the MOND phenomenology of galactic rotation curves in a ΛCDM universe". *Monthly Notices of the Royal Astronomical Society* 485 (2), 1886–1899. doi:10.1093/mnras/stz531. arXiv:1902.06751.

Famaey, B. and McGaugh, S. S. (2012). "Modified Newtonian dynamics (MOND): observational phenomenology and relativistic extensions". *Living Reviews in Relativity* 15, 10.

Famaey, B., Pizzuti, L. and Saltas, I. D. (2025). "Nature of the missing mass of galaxy clusters in MOND: the view from gravitational lensing". *Physical Review D* 111, 123042.

Keller, B. W. and Wadsley, J. W. (2017). "ΛCDM is consistent with SPARC radial acceleration relation". *The Astrophysical Journal Letters* 835 (1), L17. doi:10.3847/2041-8213/835/1/L17. arXiv:1610.06183.

Kroupa, P., Banik, I., Haghi, H., Zonoozi, A. H., Dabringhausen, J., Javanmardi, B., Müller, O., Wu, X., Zhao, H. and others (2018). "A common Milgromian acceleration scale in nature". *Nature Astronomy* 2, 925–926. doi:10.1038/s41550-018-0622-x.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Lelli, F., McGaugh, S. S. and Schombert, J. M. (2016). "SPARC: mass models for 175 disk galaxies with Spitzer photometry and accurate rotation curves". *The Astronomical Journal* 152, 157.

Lelli, F., McGaugh, S. S., Schombert, J. M. and Pawlowski, M. S. (2017). "One law to rule them all: the radial acceleration relation of galaxies". *The Astrophysical Journal* 836 (2), 152. doi:10.3847/1538-4357/836/2/152. arXiv:1610.08981.

Ludlow, A. D., Benítez-Llambay, A., Schaller, M., Theuns, T., Frenk, C. S., Bower, R., Schaye, J., Crain, R. A., Navarro, J. F., Fattahi, A. and Oman, K. A. (2017). "Mass-discrepancy acceleration relation: a natural outcome of galaxy formation in cold dark matter halos". *Physical Review Letters* 118 (16), 161103. doi:10.1103/PhysRevLett.118.161103.

Mantz, A. B. and others (2022), as cited in The Weight of Possibility, Chapter 5, Section II, and its bibliography.

McGaugh, S. S. (1999). "Distinguishing between cold dark matter and modified Newtonian dynamics: predictions for the microwave background". *The Astrophysical Journal Letters* 523 (2), L99–L102. doi:10.1086/312274. arXiv:astro-ph/9907409.

McGaugh, S. S. (2000). "BOOMERanG data suggest a purely baryonic universe". arXiv:astro-ph/0008188.

McGaugh, S. S. (2004). "Confrontation of modified Newtonian dynamics predictions with Wilkinson Microwave Anisotropy Probe first year data". *The Astrophysical Journal* 611, 26–39.

McGaugh, S. S. (2016). "MOND prediction for the velocity dispersion of the 'feeble giant' Crater II". *The Astrophysical Journal Letters* 832, L8. doi: 10.3847/2041-8205/832/1/L8. arXiv:1610.06189.

McGaugh, S. S., Lelli, F. and Schombert, J. M. (2016). "Radial acceleration relation in rotationally supported galaxies". *Physical Review Letters* 117, 201101. doi:10.1103/PhysRevLett.117.201101. arXiv:1609.05917.

McGaugh, S. S., Li, P., Lelli, F. and Schombert, J. M. (2018). "Presence of a fundamental acceleration scale in galaxies". *Nature Astronomy* 2, 924. doi: 10.1038/s41550-018-0615-9.

McGaugh, S. S., Schombert, J. M., Bothun, G. D. and de Blok, W. J. G. (2000). "The baryonic Tully–Fisher relation". *The Astrophysical Journal* 533, L99–L102.

McGaugh, S. S., Schombert, J. M., Lelli, F. and Franck, J. (2024). "Accelerated structure formation: the early emergence of massive galaxies and clusters of galaxies". arXiv:2406.17930.

Milgrom, M. (1983). “A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis”. *The Astrophysical Journal* 270, 365–370.

Mistele, T., McGaugh, S., Lelli, F., Schombert, J. and Li, P. (2024). “Indefinitely flat circular velocities and the baryonic Tully–Fisher relation from weak lensing”. *The Astrophysical Journal Letters*. doi:10.3847/2041-8213/ad54b0. arXiv:2406.09685.

Navarro, J. F., Benítez-Llambay, A., Fattahi, A., Frenk, C. S., Ludlow, A. D., Oman, K. A., Schaller, M. and Theuns, T. (2017). “The origin of the mass discrepancy-acceleration relation in ΛCDM”. *Monthly Notices of the Royal Astronomical Society* 471 (2), 1841–1848. doi:10.1093/mnras/stx1705. arXiv:1612.06329.

Paranjape, A. and Sheth, R. K. (2021). “The radial acceleration relation in a ΛCDM universe”. *Monthly Notices of the Royal Astronomical Society* 507, 632–650. doi:10.1093/mnras/stab2141. arXiv:2102.13116.

Poulin, V., Serpico, P. D. and Lesgourgues, J. (2016). “A fresh look at linear cosmological constraints on a decaying dark matter component”. *Journal of Cosmology and Astroparticle Physics* 2016 (08), 036.

Rodrigues, D. C., Marra, V., del Popolo, A. and Davari, Z. (2018). “Absence of a fundamental acceleration scale in galaxies”. *Nature Astronomy* 2 (8), 668–672. doi:10.1038/s41550-018-0498-9. arXiv:1806.06803.

Rosa, J. L. and Złośnik, T. (2023). “Dynamical system analysis of cosmological evolution in the Aether scalar tensor theory”. arXiv:2309.06232.

Rubin, V. C. and Ford, W. K. (1970). “Rotation of the Andromeda Nebula from a spectroscopic survey of emission regions”. *The Astrophysical Journal* 159, 379–403.

Saad, S. M. and Ting, Y.-S. (2026). “No gravitational anomaly in wide binaries from forward modeling of 3D orbits”. arXiv:2603.11015, version 2, 9 September 2026; version 1 (March 2026) was titled “Gravitational anomaly measurement in wide binaries is sensitive to orbital modeling”. doi:10.33232/001c.170182.

Sanders, R. H. (2003). “Clusters of galaxies with modified Newtonian dynamics”. *Monthly Notices of the Royal Astronomical Society* 342, 901–908.

Skordis, C. and Złośnik, T. (2021). “New relativistic theory for modified Newtonian dynamics”. *Physical Review Letters* 127, 161302.

Tian, Y., Umetsu, K., Ko, C.-M., Donahue, M. and Chiu, I-N. (2020). “The radial acceleration relation in CLASH galaxy clusters”. *The Astrophysical Journal* 896, 70. doi:10.3847/1538-4357/ab8e3d. arXiv:2001.08340.

Tian, Y., Ko, C.-M., Li, P., McGaugh, S. and Poblete, S. L. (2024). “A distinct radial acceleration relation across brightest cluster galaxies and galaxy clusters”. *Astronomy and Astrophysics* 684, A180. doi: 10.1051/0004-6361/202347868. arXiv:2402.12016.

Vegetti, S., Lagattuta, D. J., McKean, J. P., Auger, M. W., Fassnacht, C. D. and Koopmans, L. V. E. (2012). “Gravitational detection of a low-mass dark satellite galaxy at cosmological distance”. *Nature* 481 (7381), 341–343. doi: 10.1038/nature10669. arXiv:1201.3643.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Erik Verlinde

Where the Dark Sector Lives

Erik Verlinde, Emergent Gravity and Physics from Comparison

Abstract

Erik Verlinde showed in 2010 that Newton's law of gravitation can be obtained as an entropic force, a force that arises from changes in the information associated with the positions of bodies, and in 2016 he proposed that the effects now attributed to dark matter are an extra gravitational force of the same origin, set by the ordinary matter and the rate of the cosmic expansion. The physics collection of the Immanent Metaphysics arrives, on its own ground, at four claims that he takes as starting points: gravity is tied to a count of what can be found; gravity is not a field to be quantized; the energy of empty space is decided at a horizon; and the dark sector belongs to the setting of physics, not to its ordinary matter. The two part on what the setting is. For Verlinde, space and gravity emerge from the entanglement of microscopic degrees of freedom. For the collection, gravity is the arena, the context of every finding, and the Incommensuration Theorem excludes composing that continuous arena from discrete constituents. The collection's dark matter is a conserved excitation of the six held internal dimensions (the internal space $\mathbb{C}P^2 \times S^2$, a complex projective plane and a sphere, kept at the same size and shape at every point), a real component with energy that gravitates, which carries the signatures the measurements show for a component: it passes through colliding clusters with the galaxies, it set the third peak of the microwave background, and its amount has not changed since the background was released. Verlinde found the right kind of thing, a response of a held part of the context, and placed it in the large arena, which is not held; the collection finds it in the six internal dimensions, which are held. Where the two accounts predict different results, the essay sets the argument of each book beside Verlinde's reasoning and finds the step at which they part. In the ratio of the dark matter to the ordinary matter the step that fails is Verlinde's setting of the radius of his formula equal to the Hubble radius, which he himself said his derivation may not reach. In the scale of the relation between visible matter and

the motions of galaxies the two accounts rest on different premises: the collection sets the scale by how the galaxies formed, and Verlinde sets it at the horizon.

I. Gravity from Information

In January 2010 Erik Verlinde posted a paper whose abstract stated its thesis in seven words: "Gravity is explained as an entropic force". On his account, space is emergent, through a holographic scenario in which the information about a region is held on screens that bound it, and gravity is the force that arises when the information associated with the positions of bodies changes. From that starting point he obtained Newton's law of gravitation, and, extended to relativity, Einstein's field equations. He argued further that inertia itself has an entropic origin, so that the equivalence principle, the equality of the mass that gravitates with the mass that resists acceleration, becomes a consequence of the same account. The paper was published in 2011 in the *Journal of High Energy Physics*.

Verlinde's work stands in a line that began with Ted Jacobson in 1995. Jacobson derived Einstein's equation from two premises, that entropy is proportional to the area of a horizon and that heat, entropy and temperature are related as thermodynamics says, and concluded that the Einstein equation is an equation of state, which it may be no more appropriate to quantize than the equation for sound in air. Thanu Padmanabhan developed the same reading further. The Gravitational Companion, "Verlinde (2011) and Padmanabhan (2010; 2015)", records what Verlinde's program obtains and what it takes as input: it derives Newton's law "as an entropic force on holographic screens", its relativistic extension "recovers the Einstein equations by an argument parallel to Jacobson's", and it assumes the holographic principle, the Bekenstein bound on the entropy a region can hold, and the Unruh effect, by which an accelerated observer finds the vacuum warm.

Verlinde's achievement is real: he showed that the form of gravity (the law of attraction and the equations that carry it) can be read from the thermodynamics of information at a boundary. He made the face of gravity that faces

thermodynamics visible in its simplest setting, Newton's law, and he tied the place where the vacuum's information is held, the horizon, to the largest scale of the universe.

II. Emergent Gravity and the Dark Universe

Is the dark matter a substance, or a sign that the law of gravity is not what it seems? In November 2016 Verlinde carried the program to the dark sector, with an answer of the second kind, in a paper published in 2017 in *SciPost Physics* as "Emergent Gravity and the Dark Universe". There, as he puts it, "spacetime and gravity emerge together from the entanglement structure of an underlying microscopic theory". In a universe with positive dark energy, the entropy of the microscopic states acquires, besides the part that grows with the area of a boundary, a thermal part that grows with volume, and at the scale of the cosmological horizon that volume part overtakes the area part. Matter then displaces some of that entropy, and the response of the dark energy medium to the displacement, which Verlinde describes as an elastic response, produces an extra gravitational force. He estimates its strength from the ordinary matter alone, Newton's constant and the acceleration scale set by the Hubble rate, and proposes that this extra force accounts for the effects attributed to dark matter in galaxies and clusters.

The proposal was tested at once. Margot Brouwer and her colleagues measured, by weak gravitational lensing in the Kilo-Degree Survey, the average mass profiles around 33,613 isolated galaxies and compared them with the profiles Verlinde's account predicts from each galaxy's ordinary mass. They found the prediction, "despite requiring no free parameters", in good agreement with the measured profiles in four bins of stellar mass, while noting that the account had no description yet of lensing and cosmology of its own and that the study was "only a first step". Federico Lelli, Stacy McGaugh and James Schombert compared it in 2017 with the radial acceleration relation of rotating galaxies: the account matches the relation only if the ratios of stellar mass to light are lowered well below other astronomical estimates, and it predicts that the scatter about the relation should correlate with radius, which is not observed. ZuHone and Sims found in 2019 that it does not reproduce

the observed characteristics of massive, relaxed clusters of galaxies. In its 2016 form the account had no description of its own of gravitational lensing or of cosmology, as Brouwer and her colleagues noted.

III. What the Collection Shares

The collection's account of gravity starts from the structure of comparison, not from thermodynamics, and on that ground it arrives at four claims that Verlinde takes as starting points.

Gravity follows the count of what can be found

Verlinde ties gravity to the information associated with the positions of bodies. The collection ties the bending of the arena to the number of findings that can be made, a finding being an interaction that registers which alternative is the case. Measurement, Chapter 3, Section VI, gives the reason. Every act of comparing connects what it finds without a break, and what is found must hold together as one consistent world, the same for every comparer. The Incommensuration Theorem, that symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison, and neither can asymmetry and discontinuity, says no one character can perfect both demands, so the strain falls on the third term, the context:

> "I identify where the arena curves, and how much. It curves where findings can be made, and in proportion to how many can be made there. Laid out everywhere at once, that curving is the gravitational field".

On this ground, the collection and Verlinde agree that gravity is fixed by how much can be found where; Verlinde measures it as information on a screen, and the collection measures it as findings that can be made. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

Gravity is not a field to be quantized

The thermodynamic line of Jacobson and Verlinde treats gravity as the large-scale behavior of something else, so that quantizing the Einstein equation would be quantizing an equation of state. The collection holds that gravitation is not quantized, and it counts this line as physics reaching the same place by another road. The Basis of Physics, Essay 12, says so: to look for a particle of gravity at all is to treat a context as a content, and "Physics has its own versions of this thought, in Jacobson's reading of the field equations as an equation of state and in Verlinde's reading of gravity as entropic, and I take those as evidence that the reading is not foreign to physics". Two Theories, One World places emergent gravity among the three programs that leave the arena unquantized.

The energy of empty space is decided at a horizon

Verlinde's dark energy carries a volume part of the entropy that overtakes the area part at the cosmological horizon. The collection also decides the energy of empty space at a horizon. The View from Inside, Chapter 11, identifies the cosmological constant with "the share of the vacuum's energy that is open to an observer inside the vacuum, and not with the total", and counts that share against the degrees of freedom listed on a horizon: three tiles out of about 10^{123}. Both accounts put the largest scale of the universe and the energy of empty space at the same place: the edge of what an observer inside can reach.

The dark sector belongs to the context

Verlinde's apparent dark matter is a response of the medium of spacetime itself, and not a new kind of particle. The collection's dark matter is likewise an excitation of the context, and not a new kind of particle. The Weight of Possibility, Chapter 1, Section IV, states the identification plainly:

> "The dark matter is a conserved excitation of the six dimensions of possibility, made at the turn, with no exit afterward".

and adds: "An excitation of the internal space is a distortion of a context, not an item of content". The turn is the passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior;

no comparison registers it as an event. A gyration, the book's name for one such excitation, has energy, so it gravitates; it is not content, so nothing that registers content registers it, and that is the observed signature: gravitation, and nothing else. Both accounts therefore place the dark sector in the setting of physics and not among its ordinary kinds of matter.

IV. What the Arena Is

The two accounts part on one question: what the setting is that gravity belongs to.

For Verlinde, space is emergent. Spacetime and gravity arise together from the entanglement of an underlying microscopic theory, and gravity is the statistical behavior of microscopic degrees of freedom that compose space. For the collection, gravity is the arena: the context of every finding, which couples to everything, which nothing shields, and in which the mass that couples and the mass that resists are one (Measurement, Chapter 3, Section VII). The arena is not made of anything more basic that is found in it. The Unquantized Arena, Proposition 6.3, states what that means exactly: "(i) The arena has no least step: no least length, area or duration. (ii) Nothing is a quantum of the arena itself, at any scale".

The ground is the theorem itself. Content is discrete and governed by symmetry; context is continuous and uneven; and the theorem says one cannot be built from the other. Causality Without Determinism, Chapter 5, Section VI, quotes Incommensuration on exactly this point: "One cannot compose a continuity out of purely symmetric components, any more than one can abstract a symmetry out of a pure continuity given alone". Microscopic degrees of freedom that compose space would be constituents of the arena with the character of content, discrete states counted and entangled, and the continuous arena would then be composed from them. The theorem excludes exactly that composition. The two characters are conjugate, and neither emerges from the other.

The collection's own route to Einstein's equations needs no entropic derivation. The Gravitational Companion, "What the Passage Obtains That Jacobson Assumes", sets the two routes side by side: Jacobson's runs through the

thermodynamic relation of heat and entropy on local horizons; that of *The Gravitational Passage* (the Passage) runs through the reduction of a ten-dimensional geometry and Lovelock's theorem, which fixes Einstein's equations, with the cosmological term, as the only field equations of their kind in four dimensions. The published objections to the entropic derivation of Newton's law, from the quantum states of neutrons held in the Earth's field (Kobakhidze 2011) and from the conservative character of gravity (Visser 2011), bear on Verlinde's derivation; as The Unquantized Arena and Two Theories, One World both state, Jacobson's equation of state stands, and the collection's reasons for an unquantized arena rest on neither entropic derivation.

The philosophy of physics has drawn the same line from the other side. Dennis Dieks, Jeroen van Dongen and Sebastian de Haro compared three holographic schemes in 2015 and found that only Verlinde's entropic scheme straightforwardly makes gravity emerge (The Unquantized Arena). His account is the clearest statement of the emergence the collection excludes, and for that reason the most useful one to set beside it.

V. A Held Medium, and Where It Is

Verlinde's dark force comes from the elastic response of a medium: the dark energy, displaced by matter, pushes back. An elastic response belongs to a held structure, one with a shape it returns to, as a crystal keeps its lattice. The collection has such a structure, and it is not the large arena. Verlinde's medium is the dark energy of the four-dimensional universe, spread through space and time; on the collection's reading that makes it a property of the large arena, and the large arena returns to no shape.

The large arena, the four dimensions of space and time, is not held: it bends smoothly and without limit, and nothing returns it to a shape. The six internal dimensions are held. The Weight of Possibility, Chapter 1, Section IV:

> "The comparison with a lattice holds because the internal space is held: each of its directions stands at the modal boundary, so it keeps the same size and the same shape at every point of the exterior (the Passage, Chapter 11, Section II), as a crystal keeps its lattice, and so each of its modes of vibration has a definite energy".

The modal boundary is the Planck curvature, at which the descriptions of content and context exchange dominance. The vibrations of that held space are the collection's dark matter, and "The open dimensions, the arena, are not held in that way, and gravitation, the distortion of space, is not quantized". So the collection has a held part of the context whose response is the dark sector, as Verlinde proposed. Verlinde placed it in the large arena, where the collection finds nothing held; the collection places it in the six, where the hold is.

The difference decides what the dark sector is. In Verlinde's account it is a force tied, place by place, to the ordinary matter that displaces the medium. In the collection it is a component in its own right, made at the turn and conserved, with energy that gravitates wherever the gyrations are, whether or not ordinary matter is there.

VI. What the Measurements Show

The measurements of the dark component show the signatures of a component. The Weight of Possibility, Chapter 1, Section I, gathers them. In the colliding cluster 1E 0657-56, the Bullet Cluster, the mass mapped by gravitational lensing lies with the galaxies, apart from the hot gas that holds most of the ordinary matter (Clowe and others 2006). The amount of the dark component has not changed since the microwave background was released: a component that decayed into anything unseen would have changed the expansion, and the measurements bound such a decay to lifetimes beyond about 160 billion years. By mass it is about 5.4 times the ordinary matter, and that ratio is the same everywhere the microwave background can measure it. Changing the law of gravity instead still leaves clusters of galaxies short of mass, and, without dark matter, predicts a third peak of the microwave background lower than the one measured (The Weight of Possibility, Chapter 5, Section V). The collection's dark matter is a conserved component that gravitates and does nothing else, and it carries each of these signatures.

The tightness of the relation between the visible matter and the motions of galaxies, measured at 2693 points in 153 disc galaxies, is where Verlinde's account began. The collection places it in how the galaxies formed. The acceleration scale of that relation, about 1.2×10^{-10} meters per second per second,

lies close to the speed of light times the Hubble constant divided by 2π, which is 1.05×10^{-10} meters per second per second at the Passage's Hubble constant. The collection does not derive that value; why the scale lands near it is taken up in Section VIII. *The Weight of Possibility* asks the question a reader asks, whether the cosmological constant sets the scale in the galaxies, and answers it: the acceleration with which the cosmological constant draws two free bodies apart across ten kiloparsecs, the size of a galaxy, is about 1.0×10^{-15} meters per second per second, less than a hundred-thousandth of the scale, and the field equations hold Newton's constant and the cosmological constant and no constant of acceleration. "So on this account the scale belongs, with the tightness of the relation, to how the galaxies formed under general relativity; the field equations give the scale no value at any place in a galaxy" (The Weight of Possibility, Chapter 5, Section V). Verlinde's account ties the scale to the Hubble rate through the response of the medium; the collection, having no medium in the large arena, ties it to the history of the galaxies.

VII. Which Horizon

Both accounts decide the energy of empty space at a horizon, and they choose different horizons. Verlinde's volume part of the entropy belongs to de Sitter space and overtakes the area part at the cosmological horizon, the horizon of a universe that holds dark energy alone. The View from Inside, Chapter 12, gives the collection's choice and its reason:

> "The count uses the particle horizon, and the reason is the reason this whole account rests on. A measurement is made here and now, from one place, in the first person. The particle horizon is the edge of everything that has actually reached the observer: everything that has, by now, been compared".

The event horizon is drawn by what could reach us in the future, and no present measurement contains the future; the de Sitter radius is drawn by an idealized universe, not by what has arrived. The collection counts at the edge of what has been compared, because a measurement made from inside holds that edge and no other. In a universe that holds matter and light as well as the

energy of empty space, the Hubble radius and the event horizon reach the de Sitter radius, the scale Verlinde's account uses, only in the infinitely far future (The View from Inside, Chapter 12).

VIII. Where the Predictions Part, and Why

The dated record *The Registered Predictions Beside Erik Verlinde*, of 4 November 2026, finds six places where the collection and Verlinde's account say different things about what will be measured. For each, this section sets the argument of the book the collection's statement rests on beside Verlinde's own reasoning, and finds the first step at which the two part. Two of the six trace straight back to the parting set out in Section IV of this essay: whether the arena is composed of microscopic constituents. Three turn on whether the dark sector is a component with a place of its own or a response tied to the ordinary matter. In one of these three, the ratio of the dark matter to the ordinary matter, Verlinde's step fails on his own premises. In the sixth, the scale of the relation between visible matter and the motions of galaxies, the two accounts rest on different premises.

The dark mass in colliding clusters

The collection's statement. This statement is argued in the books and is not among the numbered predictions of the sealed record, whose fifth section states the identification it rests on: "The account identifies the dark matter as a conserved excitation of the six held internal dimensions: its units are gyrations, made at the turn and kept from decaying by the antipodal parity of the sphere S^2".

The argument of the book. The Weight of Possibility, Chapter 1, Section IV, gives three steps. A gyration has energy, so it gravitates where it is. "It is not content, so nothing that registers content registers it", so it does not collide with the gas. And "With the exits closed, the excitation is made only at the turn, where the context of possibility re-forms, and it keeps its energy wherever it moves afterward". So in a collision of clusters the dark mass travels with what passes through without colliding, the galaxies, and is left apart from the gas, which collides. Chapter 1, Section I, sets this beside the measurement in the Bullet Cluster, where the lensing mass lies with the

galaxies and not the gas (Section VI of this essay), and the same collision bounds the scattering of the dark component on itself below about one square centimeter per gram (Markevitch and others 2004).

Verlinde's argument. His main formula gives the apparent dark mass within a radius from the ordinary mass within it, for "(approximately) spherically symmetric and isolated astronomical systems in non-dynamical situations" (Verlinde 2017, Section 7.2). Of collisions he writes: "Dynamical situations as those that occur in the Bullet cluster are not described by these same equations".

Where they part. For the collection, the dark mass is a component, with a place and a motion of its own. For Verlinde, the apparent dark mass of a system is fixed by where its ordinary matter is.

Whose step, and what decides it. For a collision, Verlinde's account has no step to examine: by his own statement it has no equations there, and the absence of equations is a gap in the account, not a fault in a step. For the static clusters that his formula does cover, a measurement already bears on the formula: ZuHone and Sims (2019) found its mass profiles and fractions of ordinary matter discrepant with the observations of massive, relaxed clusters, and Milgrom and Sanders (2016) note its conflict with the mass found in the cores of clusters. The premise in dispute is this one: the apparent dark mass of a cluster is fixed by where its ordinary matter is now. In the Bullet Cluster most of the ordinary matter is in the gas, and the lensing mass is not with the gas, so any dynamical form of Verlinde's equations must let the dark mass leave the gas behind. That requires a response with a place and a motion of its own, which is what the collection's component has. Every lensing map of a collision of clusters decides between the two, once Verlinde's account states equations for one.

The ratio of the dark matter to the ordinary matter

The sealed prediction. "The ratio of the density of the dark matter to the density of the ordinary matter is $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$, the same at every time since helium formed". It was registered on 1 November 2026 as

Prediction 16. Here Ω_c and Ω_b are the density parameters of the dark matter and of the ordinary matter, each a density written as a fraction of the density that makes space flat.

The argument of the book. The Weight of Possibility, Chapter 3, Section I, fixes the ratio as the Passage fixes the cosmological constant, by an identity of what a measurement registers: "The rule is an identity of the present measurement, $\Omega c/\Omega b = 6 - 2/\pi$, and the reconstructed history carries that value at every time since helium formed". Section II counts the two residues by classes: the dark residue ranges over both factors of the internal space and counts "the three classes of $\mathbb{C}P^2$ times the two classes of S^2, $3 \times 2 = 6$" ($\mathbb{C}P^2$, the complex projective plane, and S^2, the two-sphere, are the two factors of the six internal dimensions; the classes counted are the independent closed cycles of each factor, of dimension zero, two and four in $\mathbb{C}P^2$ and of dimension zero and two in S^2, and their numbers, three and two, are the Euler numbers of the two factors); the ordinary residue is registered in the region within the horizon, "which is a ball, and a ball has one class". Section IV reduces the count of six by one share of curvature, that of $\mathbb{C}P^2$, $2/\pi$, on the principle that "a count that includes a factor's Euler number is not reduced again by that factor's curvature". Section V gives the result, $6 - 2/\pi$. Each step follows from the one before. Two of the premises the book names as the account's own principles: that a registration counts kinds by classes, and that the dark residue ranges over both classes of S^2. And Chapter 5, Section VIII, says plainly that the rule "was selected from a small family of expressions of one form, and twelve expressions were examined in all".

Verlinde's argument. Applying his density formula to a region of constant density, Verlinde writes: "we take the radius to be equal to the Hubble radius, i.e. we put r = L" (r is the radius of the region, L the Hubble radius). With the critical density written in terms of the Hubble radius, that gives his Equation 7.51: the square of the density parameter of the apparent dark matter equals four thirds of the density parameter of the ordinary matter. He reports that it "holds remarkably well for the values of ΩD and ΩB [his density parameters of the apparent dark matter and of the ordinary matter] obtained by the WMAP and Planck collaborations", and adds his own caution: "We ask the reader not to read too much in this striking and somewhat surprising

fact", "Because it is far from clear that our derivation of the density formula (7.47) would be applicable to the entire universe". On his relation the ratio of the two densities is the square root of the quotient of four thirds by the density parameter of the ordinary matter, so it moves with the amount of ordinary matter.

Where they part. For the collection, the ratio is fixed by structure, and it is the same whatever the density of the ordinary matter. For Verlinde, the dark density is a response to the ordinary density, and the ratio moves with it.

Whose step, and what decides it. The step that fails is Verlinde's, at the setting of the radius equal to the Hubble radius. His derivation took the radius far smaller than the de Sitter radius and dropped the term of the metric that grows as the square of their ratio (Verlinde 2017, Section 4.1), and, as he writes, "We have worked exclusively in a static situation near the center of the static patch of a dark energy dominated universe". For a galaxy those premises hold. At the Hubble radius the dropped term is as large as the terms kept, and the universe is neither static nor isolated, so his Equation 7.51 is not a consequence of the premises from which his density formula was derived. Verlinde says as much himself. Measurement bears on the relation as well. At the collection's density of ordinary matter, 0.0486 (the books' matter fraction, with the lightest neutrinos taken out, divided in the ratio $6 - 2/\pi$), his relation gives a ratio of 5.24: four thirds of 0.0486 is 0.0648, whose square root is 0.2546, and 0.2546 divided by 0.0486 is 5.24. At the density Planck measures (a baryon density times the square of the reduced Hubble constant of 0.02237, with a Hubble constant of 67.36 kilometers per second per megaparsec, both from Table 2 of Aghanim and others 2020, in its baseline column for the temperature and polarization spectra with lensing, labeled TT,TE,EE+lowE+lensing), the density of ordinary matter is 0.0493, and his relation gives 5.20. The same Planck analysis measures the ratio itself at 5.364 ± 0.065; Verlinde's 5.20 lies about two and a half of that measurement's standard deviations below it, and $6 - 2/\pi$ lies within 0.001 of it (The Weight of Possibility, Chapter 5, Section I). On the collection's side, the steps follow from the account's principles, and the weight of those principles rests, as the book says, on the form of the rule, the exclusion of its neighbors within that form, and the coefficient it shares with the identity for the cosmological constant. The analyses that add

the baryon acoustic oscillations measured by the Dark Energy Spectroscopic Instrument (DESI) give 5.199 $\pm$ 0.035 (Louis and others 2025), from one kind of measurement, close to what Verlinde's relation gives at Planck's density of ordinary matter. The two densities measured together by a second, independent kind of measurement decide between a ratio that stays at 5.3634 and one that moves with the ordinary matter.

The relation between visible matter and the motions of galaxies

The collection's statement. This statement is argued in the books and is not among the numbered predictions of the sealed record: "So on this account the scale belongs, with the tightness of the relation, to how the galaxies formed under general relativity; the field equations give the scale no value at any place in a galaxy" (The Weight of Possibility, Chapter 5, Section V).

The argument of the book. Section VI of this essay set out its steps: the field equations hold Newton's constant and the cosmological constant and no constant of acceleration; the acceleration with which the cosmological constant draws two free bodies apart across the size of a galaxy is less than a hundred-thousandth of the scale; so the field equations give the scale no value anywhere in a galaxy. The same section of the book derives the tightness of the relation and its scale from how the galaxies formed: "The tightness of that relation follows from galaxy formation under general relativity with a cold component that acts only through gravity, and the account inherits it because the gyrations are such a component: they couple to the content through gravity alone", and "they are cold whatever speed the turn gives them, so that on the scales of galaxies they cluster exactly as standard cold dark matter does". "Simulations of galaxy formation with such a component reproduce the relation and its small scatter (Keller and Wadsley 2017; Ludlow and others 2017; Dutton and others 2019)". "Its origin lies in the self-similar profiles of cold halos, in the narrow range of halo mass in which disc galaxies form, and in the slow relaxation of the dark component around the gathering ordinary matter (Navarro and others 2017; Paranjape and Sheth 2021)". "The acceleration at which the relation turns is therefore set by formation and not by a constant of the field equations, and the clusters of galaxies show it: there the

same form turns at $(2.02 \pm 0.11) \times 10^{-9}$ meters per second per second, about seventeen times the galactic value (Tian and others 2020; Tian and others 2024)".

Verlinde's argument. The acceleration scale of his account is the speed of light times the Hubble constant, set by the entropy of the de Sitter horizon, and the acceleration that appears in Milgrom's formula is one sixth of it (Verlinde 2017, Equation 1.7). At the Passage's Hubble constant of 67.8 kilometers per second per megaparsec that is 1.10×10^{-10} meters per second per second, close to the measured 1.2×10^{-10}. His formula is the same for every galaxy with the same distribution of ordinary matter.

Where they part. For the collection, the scale is in the history of each galaxy. For Verlinde, the scale is in the law, set at the horizon.

Whose step, and what decides it. The collection's steps follow from its premises, and they show two things: the cosmological constant does not set the scale through the field equations, and galaxy formation under general relativity, with a cold component that acts only through gravity, gives the relation, its small scatter and the acceleration at which it turns. Verlinde's steps follow from his premises, and his scale is set at the de Sitter horizon. *The Weight of Possibility* places the scale in how the galaxies formed, and the value at which formation sets it lands near the speed of light times the Hubble constant divided by 2π. Why does it land there? For the collection that question is a topic for another day, and Volume One, Part One, Section X, gathers the clues to it; Verlinde's account answers it with its own number, one sixth of the speed of light times the Hubble constant, set at the horizon. Each account says what sets the scale, from a different premise, which can be stated in one sentence: is the acceleration at which the relation turns a constant of the law, set at the horizon, or is it set by how each system formed? The clusters of galaxies bear on that premise: the book reads the turn of the same form there, at about seventeen times the galactic value, as showing that formation sets the scale, and Verlinde's formula, applied to the ordinary matter of a cluster, would have to give the turn measured in clusters. On Verlinde's side, measurement bears on the premise that the formula is the same for every galaxy. Lelli, McGaugh and Schombert (2017) found that it fits the relation of rotating galaxies only with ratios of stellar mass to light below other estimates, and

that it predicts a correlation of the scatter with radius that is not observed. Brouwer and colleagues (2021) found, by lensing, a difference of at least six standard deviations between the relations of early-type and late-type galaxies at the same stellar mass, which a law applied alike to every galaxy cannot give on its own unless the early-type galaxies alone hold halos of gas comparable in mass to their stars. Weak lensing of isolated galaxies (Brouwer and others 2017) and a study of dwarf galaxies (Yoon, Han and Hwang 2026, a preprint) found his formula in good agreement. What decides the premise is whether the relation, at the same ordinary mass, depends on how a galaxy formed, measured by a second, independent kind of measurement beside lensing, with the gas around each galaxy counted.

A decoherence from gravitation

The sealed prediction. "No mass, however large, no separation of two placements, however wide, and no length of time ends a superposition of its own accord; a superposition ends only through a finding, an interaction that registers which alternative is the case". It was registered on 1 November 2026 as Prediction 2.

The argument of the book. The Unquantized Arena, Proposition 7.1, gives each alternative of the matter its own classical geometry, with the relative phases kept. Chapter 7, Section V, draws the consequence: "Gravity-induced collapse adds a new process to quantum dynamics: a reduction of the state made by gravity. Per-alternative geometry adds none". The geometry is continuous and found without a least step, and a finding is discontinuous, "so the geometry of an alternative lays down no record of which alternative is the case". Section VI concludes: "Per-alternative geometry predicts no decoherence beyond the ordinary kind. Every decoherence it allows is a comparison made by some environment".

The argument of the entropic line. Verlinde's own papers state no rate of decoherence. Kobakhidze (2011) argued that the quantum states of ultracold neutrons bound in the Earth's gravitational field, which are observed, are inconsistent with an entropic origin of the force: a force that comes from the entropy of microscopic degrees of freedom couples each body to those degrees of freedom, and they act on it as an environment. Schimmoller, McCaul,

Abele and Bondar (2021) built an entropic master equation that the neutron measurements allow, and it predicts a rise of energy and a decoherence for large masses over long times.

Where they part. For the collection, the attraction of a mass is carried by a geometry that records nothing. For the entropic line, the attraction is carried by microscopic degrees of freedom that can register where the mass is.

Whose step, and what decides it. Each side's steps follow from its premises, and the two rest on different premises. The premise in dispute is the one Section IV of this essay found at the root of the two accounts: the arena is composed of microscopic degrees of freedom. The collection rejects that premise on the Incommensuration Theorem, through Proposition 6.3; the entropic line assumes it, and decoherence follows. The experiment of Prediction 1 bounds any extra channel of decoherence directly and reaches the regime of large masses and long times in which the entropic master equation predicts its decoherence; the ultracold neutrons of the qBounce experiment, which measures the quantum states of neutrons bouncing above a mirror in the Earth's field, already bound the free parameter of that equation. So this experiment tests, through one consequence, whether space is built from microscopic degrees of freedom, which is where Section IV found the two accounts part.

Entanglement through gravitation

The sealed prediction. "Two masses, each held in a superposition of two places and related only through gravitation, become entangled, with the phase of their Newtonian interaction". It was registered on 1 November 2026 as Prediction 1.

The argument of the book. The Unquantized Arena, Chapter 8, Section II, proves Proposition 8.1 in four steps: each joint alternative of the two masses carries its own classical geometry, with the phases kept (Proposition 7.1); the energy of each joint alternative contains the Newtonian interaction at that alternative's separation; the phase of each alternative advances at the rate its energy sets; and every term that belongs to one mass alone drops out. For the design of Bose and colleagues (2017) the entangling phase is 0.314 radians. In that design two small diamonds of 10^{-14} kilograms, each carrying a spin and

held by it in a superposition of two places 250 micrometers apart, with centers 450 micrometers apart, interact for 2.5 seconds through gravitation alone, and the entanglement is read from the two spins; Volume One, Part One, Section III, sets out the inputs and the arithmetic. Section IV gives the other side of the test: "A single geometry sourced by the expectation value acts on each diamond as a classical field fixed by the other diamond's average", and gives no entanglement.

Verlinde's argument. Verlinde's paper of 2011 precedes the proposal of 2017, and his paper of 2017 states no prediction for it.

Where they part. For the collection, each joint placement of the two masses has its own interaction energy, and the phases are kept. For an entropic force, what acts on a body is the gradient of an entropy, an average over microscopic states, and the account does not say whether that average is taken alternative by alternative.

Whose step, and what decides it. On both sides the steps given follow; Verlinde's account lacks one premise, which can be stated in one sentence: the entropic force between two bodies depends on each joint alternative of their placements separately, with the relative phases of the alternatives kept. If that premise holds, entropic gravity entangles the two masses with the same phase as the collection. If the force is an average over the alternatives, it acts as the single geometry of The Unquantized Arena, Chapter 8, Section IV, does, and entangles nothing. The microscopic theory of Verlinde's account is quantum, so the first reading is available to it; the coarse-graining of its derivation points to the second. The experiment of Prediction 1 decides between the two readings, for both accounts at once.

The external field effect

The sealed prediction. "A galaxy falling freely in the field of a larger one feels that field only through its tide; the external field effect that modified Newtonian dynamics predicts will not be found". It was registered on 1 November 2026 as Prediction 24.

The argument of the book. The Weight of Possibility, Chapter 5, Section V, gives it in one sentence: "With the field equations exact throughout the domain of the smooth description, below the Planck curvature, as the Passage

derives them, a galaxy falling freely in the field of a larger one feels that field only through its tide, as general relativity requires, and not through the external field effect that the modified dynamics predicts". The steps are three: the field equations are exact in that domain; the dark matter is a component that gravitates by those same equations; and in general relativity the internal motions of a body in free fall feel an outside field only through its tide.

Verlinde's argument. His formula makes the square of the apparent dark mass grow with the ordinary mass, so the apparent dark mass of a satellite and that of its host do not simply add. Milgrom and Sanders (2016) found his account silent on the effect: "The formula cannot be applied to the internal dynamics of a system embedded in an external field".

Where they part. For the collection, the dark part of a galaxy's field is the field of a component, and it adds to the field of the ordinary matter as any field of matter does. For Verlinde, the dark part is a response that does not grow in proportion to the ordinary matter, and in a law of that kind the field of a host can enter the internal motions of a satellite, which is how the modified dynamics obtains its effect.

Whose step, and what decides it. The collection's steps follow from its premises; Verlinde's account has no step here, by Milgrom and Sanders' reading and by his own scope. The premise in dispute is this one: the dark part of the field of a galaxy is the field of a component, adding to the field of its ordinary matter. Chae and colleagues (2020) reported a signal of the effect in the rotation of galaxies; a reanalysis by Sargent and colleagues (2025) offers an account of that signal through known correlations of the form, surroundings and motions of galaxies, without any departure from the equivalence principle. Every measurement of the internal motions of a galaxy that falls freely in the field of a larger one decides the premise.

What the six show

The two places that bear on gravitation and quantum superposition (decoherence and entanglement) trace back to one premise: that space is built from microscopic degrees of freedom. One experiment with two masses tests that premise for both. The three places that bear on the dark sector (clusters, the ratio and the external field) turn on whether the dark sector is a component

or a response; there the cluster maps and the external field so far side with a component; for the ratio, the Planck analysis lies at the collection's value and the analyses that add DESI lie near Verlinde's number, from one kind of measurement, and a second independent kind of measurement decides; and the one step that fails is Verlinde's setting of the radius equal to the Hubble radius, which his own premises do not license. In the relation between visible matter and the motions of galaxies, both accounts give the tightness and the scale, from different premises: Verlinde's from the horizon, through a law that is the same for every galaxy with the same ordinary matter; the collection's from galaxy formation under general relativity with a cold component that acts only through gravity, which also gives the clusters of galaxies a turn of their own, about seventeen times the galactic value. Whether the relation, at the same ordinary mass, depends on how a system formed decides between them.

IX. Summary

Erik Verlinde showed that gravity can be read from the thermodynamics of information at a boundary, and he proposed that the dark sector is a response of the medium of spacetime. The physics collection of the Immanent Metaphysics shares his starting points: the arena curves where findings can be made, in proportion to how many can be made there; gravitation is not a field to be quantized; the energy of empty space is decided at a horizon; and the dark sector belongs to the context, not to the ordinary kinds of matter.

The two part on what the context is. Verlinde composes space from microscopic degrees of freedom; the collection holds that the continuous arena is not composed of discrete constituents, because the Incommensuration Theorem excludes composing a continuity from symmetric parts, and so nothing is a quantum of the arena at any scale. His elastic medium has a place in the collection, in the six held internal dimensions, whose conserved vibrations are the dark matter; the large arena is not held, and nothing in it pushes back. The collection's dark matter is a component with energy, made at the turn and conserved, and it carries the signatures the measurements show: it moves with the galaxies through colliding clusters, it set the third peak of the microwave background, its amount has not changed, and its ratio to ordinary

matter is the same everywhere. The scale of the relation between visible matter and galactic motion belongs, on the collection's account, to how the galaxies formed under general relativity, and the horizon at which the energy of empty space is counted is the edge of what has been compared.

Where the predictions part, the parting has a place. Decoherence and entanglement through gravitation turn on whether the arena is composed of microscopic degrees of freedom, and one experiment with two masses tests both. The ratio of the dark matter to the ordinary matter turns on Verlinde's step of setting the radius of his formula equal to the Hubble radius, which the premises of his derivation do not license, and Planck's measured ratio lies at the collection's value, and the analyses that add DESI give 5.199 ± 0.035, from one kind of measurement, which a second independent kind decides. The tightness and the scale of the relation between visible matter and galactic motion follow, on the collection's account, from galaxy formation under general relativity with a cold component that acts only through gravity, and on Verlinde's from the horizon; whether the relation depends on how a system formed decides between them. Verlinde reads the order of the large universe from entropy at a horizon; Ilya Prigogine, in the next chapter, which opens Part Five, finds order made by irreversible processes, and asks where the direction of time comes from.

Key Concepts

- Entropic gravity: Newton's law and Einstein's equations obtained from the information associated with the positions of bodies on a boundary (Verlinde 2011).
- Emergent gravity and apparent dark matter: an extra force from the elastic response of the dark energy medium, set by ordinary matter and the Hubble rate (Verlinde 2017).
- Shared ground: gravity follows the count of what can be found; it is not quantized; the energy of empty space is decided at a horizon; the dark sector belongs to the context.
- The parting: the continuous arena is not composed of discrete constituents; nothing is a quantum of the arena at any scale.
- The held part of the context is the six internal dimensions; their conserved vibrations are the collection's dark matter.
- The horizon that counts is the particle horizon, the edge of what has been compared.
- Where the predictions part: composition of the arena (decoherence, entanglement); component or response (clusters, the ratio, the external field); Verlinde's relation for the ratio applies his formula at the Hubble radius, outside its premises; the scale of the galactic relation is set by formation on the collection's account and at the horizon on Verlinde's.

Terms

Apparent dark matter. In Verlinde's account, the extra gravitational force of the elastic response of the dark energy medium, written as the mass that would produce it.

Arena. The context of every finding: in physics, the geometry of space and time that general relativity describes.

Content and context. In every comparison, what is found and the setting it is found in.

Decoherence. The spreading of the relative phase of two alternatives into an environment that registers which alternative is the case, after which they no longer interfere in measurements on the system alone.

Entropic force. A force that arises from the tendency of a system to move toward states of greater entropy, without a field that carries it.

External field effect. In modified Newtonian dynamics, the dependence of a system's internal motions on the field of a larger system in which it falls freely, beyond the tide of that field.

Finding. An interaction that registers which alternative is the case.

Gyration. A conserved excitation of the six held internal dimensions; the collection's dark matter.

Held. Kept at the same size and shape at every point, as the six internal dimensions are, each standing at the modal boundary.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Modal boundary. The Planck curvature, at which the descriptions of content and context exchange dominance.

Particle horizon. The edge of everything that has reached an observer by now.

Per-alternative geometry. The configuration in which each alternative of the quantum matter carries its own classical geometry, sourced by its own stress-energy, with the relative phases of the alternatives kept (The Unquantized Arena, Proposition 7.1).

Radial acceleration relation. The measured relation between the acceleration found from a galaxy's rotation and the acceleration its visible stars and gas alone would produce.

Short names. "The Passage" is *The Gravitational Passage*; "the Companion" is *The Gravitational Companion*.

Six internal dimensions. The internal space $\mathbb{C}P^2 \times S^2$, a complex projective plane and a sphere, also called the six dimensions of possibility; held at the modal boundary, they are the range from which each finding is one selection, and nothing travels through them.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

References

Aghanim, N. and others, Planck Collaboration (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6. doi: 10.1051/0004-6361/201833910. arXiv:1807.06209. The values used here are from Table 2, column TT,TE,EE+lowE+lensing.

Bose, S., Mazumdar, A., Morley, G. W., Ulbricht, H., Toroš, M., Paternostro, M., Geraci, A. A., Barker, P. F., Kim, M. S. and Milburn, G. (2017). "Spin entanglement witness for quantum gravity". *Physical Review Letters* 119 (24), 240401. doi:10.1103/PhysRevLett.119.240401.

Brouwer, M. M., Visser, M. R., Dvornik, A., Hoekstra, H. and others (2017). "First test of Verlinde's theory of Emergent Gravity using Weak Gravitational Lensing measurements". *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stw3192. arXiv:1612.03034.

Brouwer, M. M., Oman, K. A., Valentijn, E. A., Bilicki, M., Heymans, C., Hoekstra, H., Napolitano, N. R., Roy, N., Tortora, C., Wright, A. H. and 15 others (2021). "The weak lensing radial acceleration relation: constraining modified gravity and cold dark matter theories with KiDS-1000". *Astronomy and Astrophysics* 650, A113. doi:10.1051/0004-6361/202040108.

Chae, K.-H., Lelli, F., Desmond, H., McGaugh, S. S., Li, P. and Schombert, J. M. (2020). "Testing the strong equivalence principle: detection of the external field effect in rotationally supported galaxies". *The Astrophysical Journal* 904 (1), 51. doi:10.3847/1538-4357/abbb96.

Clowe, D. and others (2006). "A direct empirical proof of the existence of dark matter". *The Astrophysical Journal* 648, L109–L113.

Dieks, D., van Dongen, J. and de Haro, S. (2015). "Emergence in holographic scenarios for gravity". *Studies in History and Philosophy of Modern Physics* 52, 203–216.

Dutton, A. A., Macciò, A. V., Obreja, A. and Buck, T. (2019). "NIHAO XVIII: Origin of the MOND phenomenology of galactic rotation curves in a LCDM universe". *Monthly Notices of the Royal Astronomical Society* 485 (2), 1886–1899. doi:10.1093/mnras/stz531. arXiv:1902.06751.

Jacobson, T. (1995). "Thermodynamics of spacetime: the Einstein equation of state". *Physical Review Letters* 75, 1260–1263.

Keller, B. W. and Wadsley, J. W. (2017). "ΛCDM is Consistent with SPARC Radial Acceleration Relation". *The Astrophysical Journal Letters* 835, L17. doi:10.3847/2041-8213/835/1/L17. arXiv:1610.06183.

Kobakhidze, A. (2011). "Gravity is not an entropic force". *Physical Review D* 83, 021502.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Lelli, F., McGaugh, S. S. and Schombert, J. M. (2017). "Testing Verlinde's emergent gravity with the radial acceleration relation". *Monthly Notices of the Royal Astronomical Society: Letters*. doi:10.1093/mnrasl/slx031. arXiv:1702.04355.

Louis, T. and others (2025). "The Atacama Cosmology Telescope: DR6 Power Spectra, Likelihoods and ΛCDM Parameters". arXiv:2503.14452.

Ludlow, A. D., Benítez-Llambay, A., Schaller, M., Theuns, T., Frenk, C. S., Bower, R., Schaye, J., Crain, R. A., Navarro, J. F., Fattahi, A. and Oman, K. A. (2017). "The Mass-Discrepancy Acceleration Relation: a Natural Outcome of Galaxy Formation in Cold Dark Matter halos". *Physical Review Letters* 118 (16), 161103. doi:10.1103/PhysRevLett.118.161103. arXiv:1610.07663.

Markevitch, M., Gonzalez, A. H., Clowe, D., Vikhlinin, A., Forman, W., Jones, C., Murray, S. and Tucker, W. (2004). "Direct constraints on the dark matter self-interaction cross section from the merging galaxy cluster 1E 0657-56". *The Astrophysical Journal* 606 (2), 819–824. doi:10.1086/383178.

McGaugh, S. S., Lelli, F. and Schombert, J. M. (2016). "Radial acceleration relation in rotationally supported galaxies". *Physical Review Letters* 117, 201101. doi:10.1103/PhysRevLett.117.201101. arXiv:1609.05917.

Milgrom, M. and Sanders, R. H. (2016). "Perspective on MOND emergence from Verlinde's "emergent gravity" and its recent test by weak lensing". arXiv:1612.09582.

Navarro, J. F., Benítez-Llambay, A., Fattahi, A., Frenk, C. S., Ludlow, A. D., Oman, K. A., Schaller, M. and Theuns, T. (2017). "The origin of the mass discrepancy-acceleration relation in ΛCDM". *Monthly Notices of the Royal Astronomical Society* 471 (2), 1841–1848. doi:10.1093/mnras/stx1705. arXiv:1612.06329.

Padmanabhan, T. (2010). "Thermodynamical aspects of gravity: new insights". *Reports on Progress in Physics* 73, 046901.

Paranjape, A. and Sheth, R. K. (2021). "The radial acceleration relation in a ΛCDM universe". *Monthly Notices of the Royal Astronomical Society* 507, 632–650. doi:10.1093/mnras/stab2141. arXiv:2102.13116.

Sargent, C., Clark, W., Seifert, A., Mand, A., Rogers, E., Lane, A., Deur, A. and Terzić, B. (2025). "On the evidence for violation of the equivalence principle in disk galaxies". arXiv:2511.03839.

Schimmoller, A. J., McCaul, G., Abele, H. and Bondar, D. I. (2021). "Decoherence-free entropic gravity: model and experimental tests". *Physical Review Research* 3 (3), 033065. doi:10.1103/PhysRevResearch.3.033065.

Tian, Y., Umetsu, K., Ko, C.-M., Donahue, M. and Chiu, I-N. (2020). "The Radial Acceleration Relation in CLASH Galaxy Clusters". *The Astrophysical Journal* 896, 70. doi:10.3847/1538-4357/ab8e3d. arXiv:2001.08340.

Tian, Y., Ko, C.-M., Li, P., McGaugh, S. and Poblete, S. L. (2024). "A Distinct Radial Acceleration Relation across Brightest Cluster Galaxies and Galaxy Clusters". *Astronomy and Astrophysics* 684, A180. doi: 10.1051/0004-6361/202347868. arXiv:2402.12016.

Verlinde, E. P. (2011). "On the origin of gravity and the laws of Newton". *Journal of High Energy Physics* 2011 (04), 029. arXiv:1001.0785.

Verlinde, E. P. (2017). "Emergent gravity and the dark universe". *SciPost Physics* 2, 016. arXiv:1611.02269.

Visser, M. (2011). "Conservative entropic forces". *Journal of High Energy Physics* 2011 (10), 140. arXiv:1108.5240.

Yoon, Y., Han, S. and Hwang, H. S. (2026). "Comparison of MOND and Verlinde's emergent gravity in dwarf spheroidals". arXiv:2601.01715 (preprint).

ZuHone, J. A. and Sims, J. (2019). "Testing emergent gravity with optical, X-ray, and weak lensing measurements in massive, relaxed galaxy clusters". *The Astrophysical Journal*. doi:10.3847/1538-4357/ab2b34. arXiv:1905.03832.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

The record *The Registered Predictions Beside Erik Verlinde; A Dated Record, 4 November 2026*, and the sealed record *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), state the predictions compared in Section VIII; measurements cited through the books have their full entries in the books' bibliographies.

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PART FIVE

Time, Life and Mind

These are the models of time's arrow, of life and of mind: Ilya Prigogine, Robert Rosen, Giulio Tononi and Karl Friston.

Ilya Prigogine

The Arrow Comes First

Ilya Prigogine, Irreversibility and Physics from Comparison

Abstract

Ilya Prigogine spent half a century arguing that the direction of time is real, that irreversible processes build order as well as destroy it, that probability cannot be removed from the description of unstable systems, and that determinism fails. The physics collection of the Immanent Metaphysics holds every one of these conclusions, and it holds them on a single ground: the Incommensuration Theorem, which forbids perfecting symmetry and continuity together. On chance, it holds that chance cannot be removed from the world, and parts from Prigogine on whether it lives in the law (Section V). Determinism asks for exactly that pairing, so no world is purely deterministic, whether its dynamics are stable or unstable. Prigogine reached his conclusions through a class of dynamical systems, the large Poincaré systems whose resonances defeat a description by trajectories, and he built irreversibility into the laws by choosing the evolution that runs toward equilibrium in the future. The collection finds the laws symmetric in time to an extraordinary degree and never perfectly, and it finds the arrow beneath the laws: symmetric laws guarantee that a reversed process is lawful, they never guarantee that the reversal is faithful, and faithful reversal needs the forbidden pairing. The essay sets out what Prigogine established, how the collection grounds it, where Prigogine and the collection differ about the place of irreversibility and chance, and how the collection's two arrows of time settle the long dispute between Prigogine and the heirs of Boltzmann.

I. A Chemist Against Determinism

Ilya Prigogine (1917 to 2003) received the Nobel Prize in Chemistry in 1977 "for his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures". A *dissipative structure* is an ordered pattern that exists only because energy and matter keep flowing through it, far from equilibrium: the hexagonal cells that appear in a fluid heated from below, or

the colored waves that travel through the Belousov–Zhabotinsky reaction. His Nobel lecture of 8 December 1977 was titled "Time, Structure and Fluctuations", and the title states his program. Irreversible processes, which classical thermodynamics treated as the road to disorder, can also be the source of order; and which order appears, at the point where a system far from equilibrium must choose among patterns, is decided by a fluctuation.

With Isabelle Stengers he carried the argument to a general audience in *Order Out of Chaos* (1984) and *The End of Certainty* (1997; French original 1996). The second book states its conclusion in a sentence: "The more we know about our universe, the more difficult it becomes to believe in determinism". Behind the books stood a technical program, pursued with Tomio Petrosky and the Brussels–Austin group. In *large Poincaré systems*, systems with a continuous set of resonances among their motions, the divergences the resonances produce can be removed only by passing to a new description. Petrosky and Prigogine (1993) put the result in these words: the removal of the resonance divergences "leads to complex irreducible spectral representations", and "irreducibility means that this representation is implementable only by statistical ensembles and not by trajectories". In their phrase, "Complex means that time symmetry is broken". The group set the evolution in an extended space (a rigged Hilbert space), where it splits into two semigroups, one approaching equilibrium toward the future and the other approaching equilibrium toward the past, and the group chose the first. On this account irreversibility is part of the dynamics and probability is part of the law; neither is any longer an artifact of approximation or of ignorance.

II. What Prigogine Established

Four of Prigogine's conclusions stand in the collection, each stated there in the collection's own words.

Determinism fails, and with it the future is open. Causality Without Determinism, Chapter 1, Section IX, states it as the non-polarization principle: "All worlds are to some non-zero and positive degree causal. No world is purely and completely deterministic". Measurement, Chapter 12, Section V, states the openness: what a description written from the third person leaves

out "is newness, and a description in mathematics, which is deterministic, cannot contain newness" (Section V of this essay explains why a stochastic description is no exception).

The arrow of time is real. Incommensuration, Chapter 8, Section X: "The structural arrow of time is the result that perfect time-reversal symmetry is impossible", and "The direction of time is the direction in which comparison proceeds".

Chance cannot be removed. The Basis of Physics, Essay 6, names what cannot be removed *hard randomness*, "a phenomenon that could not be predicted on the basis of any past knowledge, because no causal prediction capacity exists for it", and finds it at the edge of the domain of measurement, amplified upward through every process sensitive to small differences.

Irreversibility builds order. At a branching point far from equilibrium, which branch is taken is settled in the event itself, by no law laid out in advance, and the branch, once taken, is lawful in all that follows; Section VI sets out how the collection finds the order of a dissipative structure there.

Prigogine reached these conclusions as a physical chemist, from the laboratory and from the mathematics of unstable systems, against the settled view of his field, and he held them for fifty years. The four conclusions are correct, and the collection reaches every one of them.

III. Why Determinism Cannot Be Had

Prigogine's route to the failure of determinism ran through instability. A trajectory that diverges from its neighbors at an exponential rate cannot be followed by any finite specification, and in large Poincaré systems the resonances defeat the trajectory description altogether. The route is strong where it applies. It applies to a class of systems: those unstable enough, and with resonances dense enough, for the trajectory description to fail.

The collection's route applies to every world, stable or not, and it begins with what determinism asks for. The Basis of Physics, Essay 2, Section III, says plainly what determinism asks for. Determinism claims a specification that "is everywhere continuous: no gaps, no missing values", and that "is everywhere symmetric: the same laws hold in every context". "Determinism is

therefore the assertion of total symmetry and total continuity, applied simultaneously and without remainder. That is the first forbidden conjunction of the theorem, named without alteration". The theorem is the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. So "no world is purely and completely deterministic", and, Essay 2 adds, "The conclusion does not depend on the results of any experiment". The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. Causality Without Determinism, Chapter 1, Section VIII, puts the same result in the picture of Laplace's demon, which, in that book's words, "asks for the forbidden top row": the pairing the theorem forbids first, of total specification, which is continuity, with lawful structure, which is symmetry.

The failure of determinism leaves causation, not nothing. Measurement, Chapter 12, Section IV: "The failure of determinism leaves causation and not nothing, because the pairing that causation has is never forbidden: continuity with asymmetry, a connection without a break along an order that runs one way". The formalisms that physics uses can stay deterministic at their own level: the same chapter reads the deterministic evolution of the quantum state as "the symmetry of the law at its own level", with the findings causal and not determined. Prigogine's demand, that the future be open, is met by the collection's argument for every system, without waiting on a proof that each system is unstable. His instability arguments then take a different place: they show where, inside the domain, the openness becomes visible at the scale of everyday things (Section V).

IV. Lawful Reversal and Faithful Reversal

The deepest of Prigogine's questions concerned the arrow of time. The fundamental equations of mechanics are symmetric in time: run any solution backward and it is still a solution. Where, then, does the one-way character of the

world come from? Prigogine's answer was to change the dynamics: in the extended description of large Poincaré systems, the evolution splits into two semigroups, and the one that runs toward equilibrium in the future is selected. Robert Bishop, in a careful account of the program, records that the selection appeals in part to the observed asymmetry of time, so that the arrow is put in by the choice it was meant to explain.

The collection leaves the dynamics as physics has them, and it finds the laws symmetric in time to a very high degree and never perfectly. The Basis of Physics, Essay 11, Section VII, states the degree: "The laws exhibit time-reversal symmetry to an extraordinary degree, and the argument does not say otherwise. It says the symmetry cannot be perfect". The residual asymmetry is already measured, and that section of The Basis of Physics cites the three measurements. The weak interaction violates the combined symmetry of charge and parity (Christenson, Cronin, Fitch and Turlay, 1964). By the CPT theorem, that violation entails a violation of time reversal, and the violation of time reversal has since been observed directly (CPLEAR, 1998; BaBar, 2012). Essay 11 reads the measured violation as "a place where the impossibility of perfecting temporal symmetry has become visible to instruments", and it is exact about the strength of that reading: "The argument says that some asymmetry must exist. It does not say how large, in which interaction, or through what mechanism". The sealed record of predictions registers the requirement as Prediction 28: "Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible". The collection finds the arrow itself beneath the laws. The measured violations are not that arrow; they are places where the asymmetry it requires shows in the laws. The Basis of Physics, Essay 11, Section III, draws the distinction on which the answer turns. There are two claims about reversal, "and they are not the same claim". "The first is that the laws are symmetric: if a process is lawful, its time-reverse is lawful. The second is that the reversal is faithful: the time-reversed process traces back through exactly the states the original process traversed, and arrives at exactly the original condition". "Symmetry of the laws guarantees lawful reversal. It does not guarantee faithful reversal". Faithful reversal needs every aspect of the state captured with no gap, and a symmetric law acting on a state specified with no gap is the conjunction the theorem forbids.

The abstract of Essay 11 draws the consequence: “Perfect time-reversal is therefore precluded, and the preclusion depends on no entropy, no boundary condition, no Past Hypothesis, and no particular formalism”.

The arrow beneath the laws is the direction in which comparison proceeds. Every comparison runs from the range of what is possible, through the act, to the record, and the record shapes the next range; that order is the precedence of the second axiom of the Immanent Metaphysics, read in physics as the direction of time (Incommensuration, Chapter 8, Section X). The second axiom, stated in aphorism 1.3-1 of *An Immanent Metaphysics*, is the directed cycle of the three roles of comparison: an order of precedence, not of clock time, converging from many to one at each step. Every act of comparison carries the direction, so no evolution has to be selected by hand. Prigogine looked for the arrow in the laws because the laws were where physics kept its foundations; the collection finds it in the act every law is learned through.

The collection also keeps the second arrow, the one Boltzmann explained. Measurement, Chapter 12, Section VII, sets the two side by side. The structural arrow “is present in every single comparison” and “needs no large number of parts and no particular beginning of the world”. The entropic arrow “is a statistical arrow: it is found in systems of very many parts, and it needs a beginning of low entropy from which the growth proceeds”. “The two arrows point the same way wherever both are found”, because “a record is itself an irreversible change”, and “each act of recording joins the two arrows in one event”. The Matter We Know, Volume Two, Chapter 2, Section VI, follows the joining down to particles: “the arrow of the count is the order in which every trace follows the act that makes it, counted over very many particles”.

The two arrows settle a dispute that ran through the last decades of Prigogine’s life. His critics, Jean Bricmont among the clearest (1996), held with Boltzmann that the irreversibility of large systems is explained by counting states, together with a beginning of low entropy, with no change to the dynamics. Prigogine held that irreversibility is more than statistics and must be found at the level of the fundamental description. Each side was right about one arrow. The entropic arrow is statistical and needs its low-entropy beginning, as Boltzmann’s heirs say. Beneath the entropic arrow lies an arrow that

holds in a single comparison and needs no special beginning, as Prigogine said there must be. That arrow lies in the impossibility of faithful reversal, which holds for one particle as for many, and it needs no modified law.

V. Instability, Amplification and Hard Randomness

Prigogine's technical work showed that in unstable systems the trajectory description cannot be carried forward, and that ensembles, distributions of probability, carry what trajectories cannot. The collection agrees about the systems and places the source of the openness differently.

Measurement, Chapter 12, Section VI, names the mechanism *microstate amplification*: "the process by which small differences at a fine-grained level of a system are propagated and magnified into differences at the level that matters for the system's behavior". The section separates the complex from the merely complicated. "A clockwork is complicated: it has many parts, and a small error in one gear stays a small error in the time it shows. The weather is complex". "So a complex system carries, at the level of its behavior, the asymmetry of its finest differences, and no symmetric description of finite resolution contains it". That is Prigogine's finding about unstable systems, stated without his formalism.

Where do the finest differences come from? The Basis of Physics, Essay 6, Section VI, follows the amplification downward, through the three-body problem and the weather. The differences that decide the outcome "fall below the limits of measurement, below the microscopic limit, where differences inside one cell of the space of states are not distinct states. At that point the microstate of the system cannot be known, not because our instruments are poor but because there is no instrument for it. And yet the system still produces an outcome". What produces the outcome is "whatever is happening at the scale below the boundary of measurement", and that, in the words of Essay 6, "from the standpoint of anything inside the domain, is hard random". So the picture is "of a world in which the incompressible residue is not confined to the laboratory but seeps upward through every process that amplifies what it cannot resolve".

Here Prigogine and the collection differ about where chance lives. Prigogine placed it in the law: the dynamics of a large Poincaré system has an irreducible representation by ensembles, so probability is part of the fundamental description. The collection places it at the edge of the domain of comparison, which is the domain of measurement, below the action Planck's constant marks, where no measurement can be made (The Basis of Physics, Essay 6, Section VII), and lets amplification carry it upward. The difference matters for a reason Measurement, Chapter 12, Section V, states exactly: "A stochastic model does not escape this: a mathematical description exists as structure, laid out whole, and any randomness in it is a distribution laid out in advance; the one outcome that occurs is a finding, and no structure laid out in advance contains it". A law of probabilities, however irreducible, is still a law: structure laid out, the same from every standpoint. Prigogine's laws "of possibilities" therefore stop one step short of what he wanted. The newness he looked for is in the outcome, and the outcome is a finding, made in an act of comparison; the distribution, laid out in advance, cannot contain it. Bishop's observation, that the trajectories remain valid locally even where the ensembles are needed globally, fits the same account: determinate structure is present to some degree in every world and complete in none, which is the non-polarization principle again (Causality Without Determinism, Chapter 1, Section IX).

VI. Order Out of Chaos

Prigogine's dissipative structures show order built by irreversibility. Near equilibrium, order is the kind The Matter We Know, Volume Two, Chapter 2, Section XIV, sets out: a system held at a fixed temperature "settles where its energy, less its temperature times its entropy, is least", and bonded, aligned or packed arrangements win when it is cold. Far from equilibrium, a flow of energy can hold a pattern that equilibrium never would, and at the point where several patterns become possible the system takes one of them. Prigogine called the process order through fluctuations: which pattern appears is decided by a fluctuation too small to be seen.

The collection supplies what decides the fluctuation. At such a branching point the system is complex in exactly the sense of Section V: its outcome depends on differences that, followed downward, pass below the microscopic

limit, where the outcome is hard random. So the pattern that appears is new in the full sense: which branch is taken is settled in the event itself, by no law laid out in advance, and the branch, once taken, is lawful in all that follows.

The collection describes every event in three aspects, change, causality and choice, and these say in what order the new pattern arrives. Causality Without Determinism, Chapter 6, Section II, after An Immanent Metaphysics, names the three as change, causality and choice: change the immanent, "the continuity of content and asymmetry of context"; causality the omniscient, which "registers what is conserved"; and choice the transcendent, "what introduces the new into the domain". The three names are the modalities of *An Immanent Metaphysics*, the three roles of comparison: the immanent, held in the act; the omniscient, held as structure laid out; and the transcendent, implicit, held in the stance. In the terms of physics, change is what continues, causality is what is conserved and can be traced, and choice is what enters new. In a cell of heated fluid the three aspects read this way: the new pattern enters at the branching point as choice, unfolds as change, and is read afterward, by anyone who studies it, as a causal history. Prigogine wrote of the creativity of nature. The collection places the new in every act, at every scale, in a proportion that varies with the scale (Causality Without Determinism, Chapter 6, Section IV), and the branching points of a system far from equilibrium are where that newness is amplified to a size anyone can watch.

The register beside Prigogine, Appendix K, finds that the two accounts "agree on what the world will show about time and chance", and that no measurement named in this essay or in the books separates them. It records two agreements: that no world is deterministic and the arrow of time is real, registered together as Prediction 28, with which the measured violations of time reversal agree; and that the pattern a system takes at a branching point far from equilibrium is not fixed in advance, stated only in this essay and outside the sealed record, with which the experiments on the crystallization of sodium chlorate agree. So no measurement decides between Prigogine's account and the collection; they part, as Sections IV and V set out, on where the arrow and chance live.

VII. Summary

Ilya Prigogine established, against the settled view of his time, that the arrow of time is real, that irreversibility builds order, that chance cannot be removed from unstable systems, and that determinism fails. The physics collection holds each conclusion and gives it one ground. Determinism is the assertion of total symmetry and total continuity together, the first pairing the Incommensuration Theorem forbids, so no world is purely deterministic, stable or unstable. The arrow of time lies beneath the laws, with no modified law needed: symmetric laws guarantee lawful reversal and never faithful reversal, and the direction of time is the direction in which comparison proceeds. The statistical arrow of Boltzmann rides on that structural arrow and joins it in every record, so each side of the old dispute keeps the arrow it was right about. Chance lives at the edge of the domain of measurement and is amplified upward by every complex process; a law of probabilities remains a law, and the newness is in the finding. Prigogine's order through fluctuations is that newness made large. His program sought, in the mathematics of unstable systems, what the collection finds in the structure of the act through which every law is known. Order made by flows of energy raises the next question, what makes a living system more than a structure far from equilibrium, which is Robert Rosen's.

Key Concepts

- Determinism is total symmetry with total continuity, the first pairing the Incommensuration Theorem forbids; no world is purely deterministic, whether its dynamics are stable or not.
- The failure of determinism leaves causation: continuity with asymmetry, a pairing the theorem keeps.
- Lawful reversal and faithful reversal: symmetric laws guarantee the first and never the second.
- Two arrows of time: the structural arrow, present in every comparison, and the entropic arrow, statistical and needing a low-entropy beginning; they join in every record.
- Microstate amplification carries hard randomness from below the edge of measurement into behavior at every scale.
- A law of probabilities is still structure laid out; the newness is in the outcome, which is a finding.
- Order through fluctuations is newness amplified at a branching point.

Terms

Dissipative structure. An ordered pattern maintained by a continuing flow of energy and matter far from equilibrium.

Faithful reversal. A reversal that retraces exactly the states the original process passed through and arrives at exactly the original condition.

Hard randomness. An outcome that no prior specification fixes, however complete; no capacity for causal prediction exists for it.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Large Poincaré system. In Prigogine's program, a dynamical system with a continuous set of resonances among its motions.

Lawful reversal. The time reverse of a lawful process being itself lawful.

Microstate amplification. The magnification of small differences at a fine-grained level into differences in a system's behavior.

Modalities. The three roles of comparison: the immanent (held in the act), the omniscient (held as structure laid out), the transcendent (implicit, held in the stance).

Non-polarization principle. Every world is to some degree causal, and no world is purely deterministic.

Second axiom. The directed cycle of the three roles of comparison, an order of precedence and not of clock time, converging from many to one at each step (*An Immanent Metaphysics*, aphorism 1.3-1).

Structural arrow of time. The direction in which comparison proceeds: from the range of what is possible, through the act, to the record.

References

Angelopoulos, A., and others (CPLEAR Collaboration) (1998). "First direct observation of time-reversal non-invariance in the neutral-kaon system". *Physics Letters B* 444, 43.

Bishop, R. C. (2003). "Brussels-Austin nonequilibrium statistical mechanics in the later years: large Poincaré systems and rigged Hilbert space". arXiv:physics/0304020.

Bricmont, J. (1996). "Science of chaos or chaos in science?". arXiv:chao-dyn/9603009.

Christenson, J. H., Cronin, J. W., Fitch, V. L. and Turlay, R. (1964). "Evidence for the 2π decay of the K_2^0 meson". *Physical Review Letters* 13, 138.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications. DOI https://doi.org/10.67291/RQQS3025.

Lees, J. P., and others (BaBar Collaboration) (2012). "Observation of time-reversal violation in the B^0 meson system". *Physical Review Letters* 109, 211801.

Petrosky, T. and Prigogine, I. (1993). "Poincaré resonances and the limits of trajectory dynamics". *Proceedings of the National Academy of Sciences of the United States of America* 90, 9393–9397.

Prigogine, I. (1977). "Time, Structure and Fluctuations". Nobel Lecture, 8 December 1977.

Prigogine, I. and Stengers, I. (1984). *Order Out of Chaos: Man's New Dialogue with Nature*. New York: Bantam.

Prigogine, I., with Stengers, I. (1997). *The End of Certainty: Time, Chaos, and the New Laws of Nature*. New York: The Free Press.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.



Robert Rosen

No Largest Model

Robert Rosen, Relational Biology and Physics from Comparison

Abstract

Robert Rosen (1934 to 1998) built a science of life on relation rather than on matter. He set out the modeling relation between a natural system and a formal system, defined a mechanism as a system all of whose models can be simulated, and argued in *Life Itself* (1991) that an organism is a material system closed to efficient causation, whose models therefore cannot all be simulated by any machine. The physics collection of the Immanent Metaphysics stands closer to Rosen than to almost any other scientist: it takes the relationship as more fundamental than the things related; it holds that a model, however well it fits, is not the thing it describes; and it holds that a computation cannot be what a self is. The collection gives each of these a ground in the structure of comparison, and from that ground it reaches two results that go beyond Rosen. First, every comparison leaves a remainder that no rendering contains, so no natural system has a largest model; "mechanism", in Rosen's strict sense, names a property of descriptions and not of anything in nature. Second, what makes a living being different in kind is choice gathered into a self (brought together from many acts of comparison into one persisting stance) and known from inside, a difference no description from outside can draw. Rosen's closure to efficient causation, like the autopoiesis of Maturana and Varela, is organization in the transcendent role, the condition from which a living being's activity proceeds, and his diagram of it is a model that cannot contain it. The essay also shows where the long debate over Rosen's proof of non-computability stands: the collection reaches the conclusion that a living being is not a mechanism on two grounds of its own, and neither ground uses the step that the debate concerns.

I. Relation Before Matter

Rosen trained under Nicolas Rashevsky at the University of Chicago, in the program Rashevsky called relational biology. Its starting point was that what makes a thing alive is how its parts are organized, and not the stuff it is made of: the same organization, realized in other stuff, would be the same kind of living thing. In 1958 Rosen gave that idea its first exact form, the metabolism-repair systems, written (M,R) systems: abstract diagrams of components that make one another, in which the parts that carry out metabolism are themselves replaced by repair processes that the system's own metabolism supplies. For the next forty years he developed the program in category theory (a branch of mathematics that describes structures by the maps between them) and in a series of books, of which *Anticipatory Systems* (1985), *Life Itself* (1991) and the posthumous *Essays on Life Itself* (2000) carry its main results.

Rosen's achievement is real, and it came early. Rosen saw, before most of the life sciences, that a living system is a closed web of relations and not a list of parts, and he gave that web an exact mathematical description. He saw that the question "what is life?" is a question about organization that physics, as practiced, had no way to ask. And he saw that the habits of modeling that serve physics so well, taking a system apart into components and rebuilding it as a machine, lose exactly what makes a living thing alive. His question, whether a natural system can be captured whole by a model, is a question about every natural system, and so it belongs in a book of models of the universe: the collection answers it for physics as well as for life.

The collection begins at the same place, from a different side. The Last Turtle, Chapter 1, Section VI, states the starting point:

> "we take the relationship between context and content as more fundamental than the context or the content, and we define each of them in terms of that relationship".

That sentence is the ground of the first axiom: the immanent, the act of relating as it happens, is more fundamental than the omniscient (what is laid out as structure) and the transcendent (the stance and the range of possibility an act proceeds from). The collection's single premise, the *Root Tautology*, says that comparison, interaction and relation are one act under three names (The

Grand Synthesis, Chapter 1). Rosen put relation before matter in biology. The collection puts relation, the act of comparing, before everything, matter included, and finds Rosen's priority of relation in biology to be one case of that ordering. Rosen's nearest predecessor in putting relation first is Peirce, who, as Peirce and the Immanent Metaphysics, Chapter 1, puts it, "held a version of the first axiom, in his insistence that relation is irreducible".

A science built on relation must meet the oldest objection to relation: F. H. Bradley's regress, which holds that a relation joining two terms needs a further relation to join it to each of them, and so on without end. The collection's answer, in The Ground of Objection, T1.1a, gives relational biology the ground it lacked:

> "a comparison is not an object standing between its terms. It is the boundary at which they are told apart, and a boundary has no interior. Its entire being is the distinguishing it performs".

The relation is the relating, not a thing that relates. Rosen needed that answer and did not state it: the organization of an organism is the parts relating to one another, and not one more part standing beside them.

II. The Modeling Relation

Rosen's best-known device is the modeling relation. A natural system has its own causal order: one state of it brings about the next. A formal system, a piece of mathematics, has its own order of inference: one statement entails the next. To model the natural system is to encode its states as statements, let the formal system run, and decode the result back into a prediction about the world. The model succeeds when the two routes agree: when encoding, inferring and decoding gives the same state as letting nature run. Rosen insisted that the encoding and the decoding belong to neither system. The encoding and the decoding are a third thing, a relation made by someone, and nothing in the formal system can supply them.

The collection describes the same relation and names its two ends exactly. Causality Without Determinism, Chapter 4, Section I: "Compatibility between a model and a body of measurements is not equivalence: many models may be compatible with the same data, and no amount of compatibility can estab-

lish that the model is the reality it describes". Incommensuration puts the difference in one sentence: "A law exists; a measurement is real" (Incommensuration, Chapter 3). The step Rosen called encoding and decoding, the collection calls an *identification*, made in the first person and in the open. Measurement, Chapter 6, Section III:

> "An identification is the place where an argument meets the world, and so it is the place where soundness is decided. Within a structure fixed by definition, a deduction is valid, and it is certain. Its passage to the world carries a reading, because the structure and the world are two domains".

Rosen's commuting diagram (the modeling relation drawn as two routes, nature's and the model's, that must arrive at the same state) and the collection's identification describe one step: the place where a formal structure is joined to the world by someone who makes the join. The collection adds the reason the join can never be absorbed into the formalism. Mathematics deals in claims held as structure laid out, and the act of joining that structure to a world is held in the act itself (Physics Is Not Math, Chapter 9, Section III). The order of depth (metaphysics, then physics, then computation, then mathematics) places the formal system after the act that encodes into it (Physics Is Not Math, Chapter 5). Rosen's encoding and decoding stand outside the formal system because they come before it.

III. Mechanisms, and Why Nothing Has a Largest Model

In *Life Itself* Rosen drew the line between machines and organisms with the modeling relation. A natural system is a *mechanism* when every one of its models can be simulated, that is, computed by a machine that follows a fixed procedure. For a mechanism the models can be gathered into one largest model, from which every other follows, and taking the system apart into components loses nothing: the analysis and the rebuilding agree. Rosen called a system that is not a mechanism *complex*. His central claim is that an organism is complex. An organism, in his definition, is a material system closed to efficient causation: every process that makes some part of it (every efficient cause, in Aristotle's term) is itself made by some other process within the sys-

tem. Such closure folds the system back on itself, so that its description must refer to itself, and Rosen argued that this self-reference cannot be captured in any model that a machine can simulate.

The collection reaches Rosen's distinction from the structure of comparison, and finds that the distinction reaches further than he drew it. Causality Without Determinism, Chapter 5, Section II, defines what it is to be classical in terms Rosen would recognize:

> "A classical system is one that can be virtualized, and that is the single defining feature of being classical: classical things are modelable. If a model of a thing can be built that behaves identically to the original for all purposes one cares about, then that thing is classical".

The same section says why a model works at all: "Any form of modeling inherently depends on symmetry: to model a thing is to treat some of its aspects as irrelevant to the behavior of interest, and to factor them out as not important". A model holds the differences of context it leaves out to be differences that make no difference. Treating them so is a choice of purpose, and the definition of classical carries that choice in its words "for all purposes one cares about".

Rosen's mechanism is the collection's definition of classical with the purposes removed: a system with a model that serves every purpose at once. A model from which every other model of a system follows must leave out no difference that any purpose could need, and so must contain the whole of what it models. The collection shows that no natural system has a model that serves every purpose at once. The ground is the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. A model is laid-out structure, invariant from copy to copy: symmetry perfected. A model that contained the whole of what it models would also be in unbroken contact with all of it: continuity perfec-

ted. Such a model would pair perfected symmetry with perfected continuity, the first forbidden pairing; so, in the words of Physics Is Not Math, Chapter 21, Section V, every rendering "leaves a remainder", "the part of what is rendered that a rendering approaches as closely as one wishes and does not contain". The Last Turtle, Chapter 3, Section XIII, gives the same result in the terms of the roles: "the omniscient cannot contain the transcendent".

Every interaction is a comparison, by the Root Tautology, and every comparison leaves a remainder: an outcome that nothing prior fixes, which the collection calls hard randomness (Causality Without Determinism, Chapter 5, Section IV). The two remainders are one: what no rendering of a comparison contains is exactly the outcome that nothing before the comparison fixes. So no natural system, organism or stone, has a largest model. The Ground of Objection, T2.18, states the consequence in so many words: "A description is a comparison; therefore no description of any actual thing is complete, and this is a theorem the system derives and builds on rather than a limitation it concedes". What Rosen called a mechanism is a property of a description: a system described for a purpose for which what the description leaves out makes no difference. A clock is a mechanism for the purpose of telling time and not for the purpose of predicting each collision of its atoms. Living things have mechanisms, and the collection affirms that they do. The Ground of Objection, T2.24, holds that the collection's deepest claim entails them: an organism telling two things apart is interacting, "so the system's deepest claim entails that there are comparings going on inside an organism that compares, that they are made of something, and that what they are made of can be described". A description of those mechanisms is a description within a domain, and neither it nor the account of comparison displaces the other. What fails is only the step from "this organism has mechanisms that can be described" to "this organism is a mechanism", the step to a largest model. Rosen drew the line between mechanism and organism inside nature. The collection draws the line of mechanism between the description and the thing described, and then finds a different line inside nature, the gathering of choice into a self, which Section VI sets out.

IV. The Debate over the Proof

Rosen's claim that closure to efficient causation forbids simulable models rests on a proof in the mathematics of categories, and the proof has been disputed. In 2006 Dominique Chu and Weng Kin Ho reviewed it in *Artificial Life*, argued that some of its central notions are not well defined, and concluded that the proof does not hold. Aloisius Louie, Rosen's student and the chief interpreter of his work, replied in the same journal in 2007 that a living system must have models that cannot be computed, and Chu and Ho answered him in turn. In 2009 Matteo Mossio, Giuseppe Longo and John Stewart gave an expression of closure to efficient causation in the lambda calculus, a formalism of computation, and argued that closure to efficient causation does not by itself rule out computable models.

The collection reaches its conclusion on grounds of its own, and the debate concerns a step those grounds do not use. The collection reaches Rosen's conclusion, that a living being is not a mechanism, and more, on two grounds already set out, each with its own conclusion: every natural system leaves a remainder that no model contains (Section III), so no natural system, the living included, has a largest model, and none is a mechanism; and a computation lacks the bound triple of arrow, hard randomness and the subjective, which a self has (Section VI), so no computation is a self, and no simulation of a living being is what that being is. Neither ground uses Rosen's categorical proof. So the debate, however it is settled, leaves the collection's conclusion where it is. The debate bears on one formal route to Rosen's conclusion, and the collection reaches that conclusion by another.

The collection also says what kind of question the debate is. Whether closure to efficient causation, written as a formal property of a diagram, forces a non-computable model is a question of mathematics, settled by proof. Whether a living being is a mechanism is a question about the world, and the formal property is a rendering of it. By the order of depth a rendering cannot set the scope of what it renders. Mossio, Longo and Stewart's computable expression shows that one rendering of closure can be computed. What the expression shows stops at the rendering: that rendering, like every other, leaves its remainder, so the expression does not show that the organism so rendered can be computed.

V. Closure, and the Foundation That Describes Itself

The feature Rosen found at the heart of life is a loop: a system whose making refers back to itself, so that its description is impredicative, defined in terms of a whole to which it belongs. Rosen took such loops to mark the living off from the mechanical, and he saw that mathematics built from the bottom up, element before set, has trouble holding them.

The collection finds closure of that kind at its own foundation, and finds it in every act, not only in organisms. The Root Tautology is a loop: every interaction is a comparison, every comparison a relation, and every relation an interaction, and none is first. The second axiom orders the three roles in a cycle with no first member. And the axioms, taken as their own subject matter, describe themselves. The Last Turtle, Chapter 3, Section IX:

> "the axioms describing themselves is itself a process, an instance of the general class of process, and Axiom II is the axiom of process. So the axioms describe not only themselves but the process of describing themselves. That is full closure over the reification of the foundation".

The Grand Synthesis, Chapter 4, Section VI, states the same closure as a property of the whole framework: the axioms, turned on themselves, describe their own structure with perfect fidelity.

The same closure answers the fear that self-reference must regress without end. The Ground of Objection, T1.1a, grants Bradley's regress and shows its shape: each step treats a relation as a term, and "three such levels (relation, domain, identity) form a closed cycle: each becomes the next, and the third returns to the first. The ascent Bradley describes is real, and it is periodic rather than infinite". A loop of exactly three steps, through which the question passes and returns, is impredicative in Rosen's sense and stable at once. The Ground of Objection, T2.18, says what kind of closure the foundation claims: "The closure claimed is a closure of the descriptive apparatus and not of the inquiry". Rosen's organism is closed in the same way: closed in its making, open in its encounter with everything it meets.

Rosen found closure to efficient causation in the living cell. The collection finds closure of the same form in the act of comparison itself, beneath every domain, and so it can say why closure appears in the living: in a living being,

the closure present in every act of comparison is taken up by one self, which keeps making itself from what it has done. Rosen's impredicative loops are the foundation showing through, and not an anomaly that biology adds to physics.

VI. What Makes a Living Thing Different

Rosen's line between organism and mechanism is drawn by a property of organization, visible in a relational diagram: closure to efficient causation. The collection agrees that a living being is different in kind from a stone, and it draws the difference where no diagram can reach it. Home in the World, "A Village That Is Alive", sets the difference out. Every part of every world has some degree of choice, however small, and the degree runs on without a break from the stone to the person.

> "The difference in kind lies elsewhere: in whether choice is gathered, held together and carried forward as one's own, and known from inside. A self is that gathering".

The same passage says why no description from outside can draw the line: "a true choice, seen from outside, looks exactly like chance, so no description from outside can draw the line".

The collection's account of why a computation is not a self supplies the rest. A classical computation is one rule applied the same way at every step, which is symmetry perfected; by the theorem it is intrinsically discontinuous, and the arrow of time in the first person, continuity with asymmetry, cannot be composed of its steps. So a computation lacks the arrow, lacks hard randomness, and, because the three are bound together, lacks the subjective: "classical computation, however intricately organized, cannot be what consciousness is" (Causality Without Determinism, Chapter 5, Section VI; the bound triple in Section III). The same chapter extends the result to simulation of a whole world: a deterministic simulation can match the statistics of the world's outcomes to any chosen precision and still cannot be what the world is, because its outcomes are fixed by its program (Section VIII).

Rosen's closure has a near twin in the autopoiesis of Humberto Maturana and Francisco Varela: a network of processes of production that continuously regenerates the very network that produced it. The Immanent Metaphysics and the Modern Engagement, Chapter 9, which takes up Evan Thompson's enactive account built on autopoiesis, assigns its triple to the modalities: "Thompson's autopoietic organization maps to the transcendent modality, his embodied living activity to the immanent, and his sense-making to the omniscient". Autopoietic organization is the transcendent there because it is the condition of the living system, "the network of relations that defines what the system is prior to any particular instance". Rosen's closure to efficient causation is organization of the same kind, and it takes the same role: the organization of the organism is the transcendent, the condition from which its living proceeds; the organism living in its surroundings, making and remaking itself, is the immanent; and Rosen's relational diagram of that organization is a model, laid out as structure, which is the omniscient.

That assignment says exactly why Rosen's criterion picks out the living so well and why it cannot by itself make the difference in kind. A being that gathers choice and carries it forward as its own must make and remake itself from within: what it is depends on what it has done, and what it does depends on what it is. Its organization, seen from outside and drawn as a diagram, is a system whose every making is made within the system, which is closure to efficient causation. The diagram is a laid-out structure, and the omniscient cannot contain the transcendent: no diagram of closure contains the organization it renders, and still less the self that gathers within it.

The same chapter of The Immanent Metaphysics and the Modern Engagement names the one place where the collection differs from enactivism, and the collection differs from Rosen at the same place: "the question of whether the modalities extend to non-living systems, which Thompson's framework does not affirm and the Immanent Metaphysics requires". The Ground of Objection, T4.6, gives the collection's side plainly: "There is no non-conscious interaction, and every interaction has a subjective aspect". Rosen and the enactivists draw a line between the living and the non-living by organization; the collection finds the relating, and some degree of choice, on both sides of that line, and finds the difference in kind in the gathering of choice into a self.

VII. Anticipation

In *Anticipatory Systems* Rosen described a kind of system that contains a predictive model of itself or of its surroundings and changes its present state according to what the model predicts for a later time. He held that anticipation of this kind is everywhere in living things and that physics, whose causes run only from the past, had no room for it.

The collection gives anticipation its place in the cycle of every comparison. The second axiom orders the three roles in a cycle, as Measurement, Chapter 4, Section VIII, sets it out: from the stance to the act, from the act to the laid-out finding, and from the laid-out finding to a new stance. The record of what has been found shapes the range from which the next act proceeds. A model is a record laid out as structure, and an anticipatory system is one in which that step, from the laid-out finding to the new stance, is carried by a model the system holds of itself. The model is present, and it acts by shaping the range of the present act; no cause runs backward from the future. Rosen was right that the step from the laid-out finding to the new stance is everywhere in the living, and the collection adds that the step is in every comparison; in a self, it is carried by a model the self holds of itself, and taken up as its own.

The register beside Rosen, Appendix L, finds that the sealed record "carries no prediction on which the two accounts give different results, and the relation essay states none". It records one agreement: an anticipatory system acts on a model it holds in the present and needs no signal from a later time, which the sealed record registers, for every process, as Prediction 27. The collection's claim that no natural system has a largest model reaches a measurement once, in Prediction 29, for a discrete rule offered as the foundation of physics, and Rosen's account neither states that nor denies it. The remaining differences are claims of logical form, descriptions of what a thing is, or claims about the act of knowing, and no measurement decides them.

VIII. Summary

Robert Rosen and the physics collection stand together on three things: relation comes before the things related; a model, however well it fits, is not the thing it models, and the join between them is made by someone and belongs

to neither; and a living being is not a mechanism. Rosen reached these as a biologist, with the modeling relation and the mathematics of categories. The collection reaches them from the structure of comparison, and its ground carries each further. Relation comes first because comparison, interaction and relation are one act. The model is not the thing because every rendering leaves a remainder, and so no natural system, living or not, has a largest model; Rosen's mechanism is a property of descriptions. A living being is different in kind because choice is gathered in it into a self and known from inside, which no description from outside contains. Rosen's closure to efficient causation, like autopoiesis, is the organization from which that gathering proceeds, and his diagram of the organization is a model that cannot contain it. Where Rosen and the enactivists draw the line of life by organization, the collection finds the relating, and some degree of choice, on both sides of the line. The dispute over Rosen's proof concerns one formal route to his conclusion, and the collection's conclusion stands on other ground. Rosen saw the closure at the heart of life. The collection finds the same closure at the foundation of every act, and life as the place where it is gathered. Rosen asked what makes a living thing more than a mechanism; Giulio Tononi, in the next chapter, asks what makes a physical system conscious, and answers with a quantity computed from the structure of its causes.

Key Concepts

- Rosen's modeling relation and the collection's identification describe one step: a formal structure joined to the world by someone who makes the join.
- Classical means modelable for the purposes one cares about; no natural system is modelable for every purpose at once, because every rendering leaves a remainder.
- Rosen's mechanism is a property of descriptions, not of anything in nature.
- The collection's conclusion that a living being is not a mechanism rests on two grounds of its own (every rendering leaves a remainder; a computation lacks the bound triple) and uses none of Rosen's categorical proof, which is disputed.
- Closure to efficient causation appears at the foundation of every act (the Root Tautology; the axioms describing themselves); life is where it is gathered.
- The difference in kind between the living and a stone is choice gathered into a self and known from inside; every interaction has a subjective aspect, so the modalities reach the non-living too.
- Rosen's closure, like autopoiesis, is organization in the transcendent role; living activity is the immanent; a model of the organization is the omniscient.
- A relation is the relating, not a further thing that relates; Bradley's regress is periodic, a closed cycle of three, not infinite.
- Anticipation is the step from the laid-out finding to the new stance, carried by a model the system holds of itself.

Terms

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable; consciousness is the bound triple taken as one act.

Gathered. Said of choice: brought together from many acts of comparison into one persisting stance.

Autopoiesis. Maturana and Varela's term for a network of processes of production that continuously regenerates the network that produced it.

Closure to efficient causation. Rosen's defining property of an organism: every process that makes some part of the system is itself made within the system.

Complex system. In Rosen's usage, a natural system with at least one model that cannot be simulated.

Hard randomness. An outcome that no prior specification fixes, however complete; the remainder every comparison leaves.

Identification. A stated step from the structure of comparison to a physical quantity, made in the first person, with the observation that bears on it.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Mechanism. In Rosen's usage, a natural system all of whose models can be simulated, so that they have a largest model.

Modalities. The three roles of comparison: the immanent (held in the act), the omniscient (held as structure laid out), the transcendent (the stance and the range of possibility).

Modeling relation. Rosen's account of a model: states of a natural system encoded into a formal system, inference run, and the result decoded into a prediction.

Remainder. The part of what is rendered that a rendering approaches as closely as one wishes and does not contain.

Root Tautology. Comparison, interaction and relation are one act under three names.

References

Chu, D. and Ho, W. K. (2006). "A category theoretical argument against the possibility of artificial life: Robert Rosen's central proof revisited". *Artificial Life* 12(1), 117–135. doi:10.1162/106454606775186392.

Chu, D. and Ho, W. K. (2007). "The localization hypothesis and machines". *Artificial Life* 13(3), 299–302.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest (2026). *Peirce and the Immanent Metaphysics; The Nearest Kin*. Wytheville, Virginia: UVSM Publications.

Landry, Forrest (2026). *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications.

Landry, Forrest (2026). *The Immanent Metaphysics and the Modern Engagement; From Husserl to Wilber*. Wytheville, Virginia: UVSM Publications.

Louie, A. H. (2007). "A living system must have noncomputable models". *Artificial Life* 13(3), 293–297.

Maturana, H. R. and Varela, F. J. (1980). *Autopoiesis and Cognition: The Realization of the Living*. Dordrecht: D. Reidel.

Mossio, M., Longo, G. and Stewart, J. (2009). "A computable expression of closure to efficient causation". *Journal of Theoretical Biology* 257(3), 489–498. doi:10.1016/j.jtbi.2008.12.012.

Rosen, R. (1958). "A relational theory of biological systems". *Bulletin of Mathematical Biophysics* 20, 245–260.

Rosen, R. (1985). *Anticipatory Systems: Philosophical, Mathematical and Methodological Foundations*. Oxford: Pergamon Press.

Rosen, R. (1991). *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

Rosen, R. (2000). *Essays on Life Itself*. New York: Columbia University Press.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Giulio Tononi

The Measure of an Inside

Giulio Tononi's Integrated Information and Physics from Comparison

Abstract

Giulio Tononi's Integrated Information Theory begins where few scientific theories of consciousness begin: with experience itself, stated as axioms that the theory holds to be true of every experience. From those axioms it derives requirements on any physical system that has experience, and it concludes that a system's experience is its intrinsic cause-effect structure, whose amount is a quantity it calls integrated information. The theory has two consequences that it shares with the physics collection of the Immanent Metaphysics: a system that only passes signals forward, and a conventional digital computer running any program whatever, has little or no consciousness, because what counts is the physical system's causal power upon itself and not the computation it carries out. The collection reaches that conclusion on its own ground, the Incommensuration Theorem, through the bound triple of the arrow of time, hard randomness and the subjective. The theory stands between the two poles the collection has already treated: with David Chalmers it takes experience as a real datum that function does not explain, and with Daniel Dennett it ends by giving experience a complete third-person description. The two accounts part at one step. Integrated Information Theory takes its axioms, which are claims held in the act of experiencing, and identifies experience with a quantity computed from a system's structure, which is a claim held from outside. The collection holds that consciousness is the bound triple taken as one act, and that no quantity laid out from outside can be that act, since the subjective and the objective are the two characters the theorem keeps apart. The essay credits what the theory establishes, including a candidate answer to a question the collection asks, what measure of the richness and structure of a system's interactions tracks its degree of consciousness; sets out where the two accounts agree; shows exactly where and why they part; and answers the 2023 charge that the theory is pseudoscience on the ground of Popper's own criterion, as The Ground of Objection reads that criterion.

I. A Theory That Starts From Experience

Most scientific approaches to consciousness start from the brain and ask which of its activities go with reports of experience. Tononi started from the other end. In 2004 he proposed that consciousness is integrated information, and over the next two decades, with Christof Koch, Larissa Albantakis and many colleagues, he built the proposal into a theory whose current form, Integrated Information Theory 4.0, was published in 2023. Tononi and Koch state the method plainly: "start from consciousness itself, by identifying its essential properties", and only then ask what physical mechanisms could account for them. The theory belongs in a book of models of the universe because it places consciousness in a physical system's causal power upon itself, and so makes a claim about what physical systems are.

The theory states its starting points as axioms of experience. The 2023 statement gives a zeroth axiom, existence, and five further axioms: existence ("Experience exists: there is something"); intrinsicality ("Experience is intrinsic: it exists for itself"); information ("Experience is specific: it is the way it is"); integration ("Experience is unitary: it is a whole, irreducible to separate experiences"); exclusion ("Experience is definite: it is this whole"); and composition ("Experience is structured: it is composed of distinctions and the relations that bind them together"). Each axiom is translated into a postulate about the physical system that has the experience, and the first of these sets the terms of all the rest: "The substrate of consciousness must have cause–effect power". A system's *integrated information* is then a measure of how far its cause-effect power upon itself is irreducible to that of its parts, and the theory identifies a system's experience with the full structure of causes and effects that its maximally irreducible core specifies.

The comparison here is built from what the collection's books say about consciousness, computation, measurement and the subjective, since the books do not discuss Tononi by name; from the chapters on David Chalmers and Daniel Dennett in *The Immanent Metaphysics and the Modern Engagement*, the two thinkers between whom Integrated Information Theory stands; and from *The Ground of Objection*. The comparison finds more agreement than either side's vocabulary would suggest.

II. What the Collection Credits

The first axiom is a claim of the kind the collection holds deepest. Physics Is Not Math, Chapter 9, Section III, distinguishes three ways a claim can be held. A claim is *performed* when it is established by what happens in the act of engaging it, including the act of trying to deny it: "To doubt that one is doubting is to doubt". It is *surveyed* when it is established from a vantage that holds many cases in view at once, by counting or proving. It is *implied* when it is held without being stated, in the stance from which a practice proceeds. "Experience exists: there is something" is a performed claim. Anyone who denies it has the experience of denying it. Tononi's decision to begin a science of consciousness from a performed claim, and not from a correlation surveyed in brain scans, is the decision the collection makes for every science. Tononi deserves full credit for making that decision inside neuroscience, where it runs against the habit of the field.

The second axiom, intrinsicality, names the subjective. "It exists for itself" is the theory's way of saying that experience is had from a side: the side from which experience occurs. The collection calls that side the subjective, the stance of the one to whom things happen (Causality Without Determinism, Chapter 5, Section III).

The theory's most quoted consequence is also the collection's. On Integrated Information Theory, a network that only passes signals forward has no cause-effect power upon itself and so no integrated information; Tononi and Koch call such networks "zombies, carrying out tasks unconsciously", and they hold that a feedforward system matching a human brain's behavior exactly would be a perfect zombie. A simulation of a brain on a digital computer fares no better: "the brain is real, but a simulation of a brain is virtual", and what counts is the causal power of the physical system, not the program it runs. They reject, for the same reason, any behavioral test for consciousness. Causality Without Determinism, Chapter 5, Section VII, reaches the same verdict in nearly the same terms: "Whether a system has the bound triple depends on whether it is a physical process making comparisons in the world, with an inside; it never depends on which program it runs". On behavior, Section IX of the same chapter answers the question how anyone could tell a

perfect imitation from a person: "Not by watching the behavior, and the argument does not ask anyone to. It concerns what a computation is ... and that is known from how the computation is built, not from how it behaves".

Both accounts draw the line about zombies in the same place. Chalmers' zombie is a being physically identical to a person, in every atom, with no experience; on Integrated Information Theory it cannot exist, because the same physical causal structure has the same integrated information. The Modern Engagement, Chapter 8, gives the collection's reason: "The zombie scenario is a request to separate the objective pole of comparison from the subjective pole, which Axiom III forbids", so that "the conception fails at a level deeper than physical law"; Axiom III, the third axiom of the Immanent Metaphysics, holds the three roles of every comparison to be distinct, inseparable and not interchangeable. Both accounts allow the other kind of duplicate, a different physical system that matches a person's behavior: the theory's perfect feedforward zombie, and the collection's program that "may be capable of much else, including behavior that looks, from a third-person vantage, indistinguishable from conscious behavior" and still not be what consciousness is (Causality Without Determinism, Chapter 5, Section VI).

The agreement reaches further than the conclusion. Integrated Information Theory locates consciousness in a system's causal power upon itself. The collection's Root Tautology holds that interaction, comparison and relation are one act under three names, so a system's causal power upon itself is the comparisons the system makes within itself. Both accounts therefore put consciousness in the physical process, in what the system does with itself, and neither puts it in a description of that process. Among scientific theories of consciousness, Integrated Information Theory comes nearest to the collection's account, and it was reached from experience, as the collection's account was.

III. The Collection's Account

The collection's account of consciousness rests on the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the

nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. Because symmetry and continuity cannot both be perfected, every comparison leaves a remainder, an outcome that no prior specification fixes, however complete: *hard randomness*. Every comparison is made from a side, the subjective, and proceeds in one direction, from the act to its record: the arrow of time. Causality Without Determinism, Chapter 5, Section IV, quoting Incommensuration, Chapter 8, Section X: "These three are bound together as three aspects of the same structural act: comparison proceeding in a direction, registered by a perspective, with an outcome not fully determined. No one of the three can be present without the other two". The three, so bound, are the *bound triple*, and "taken that way, the bound triple can be identified directly as consciousness, and it is immanent": held in the act, as the act happens (Section III). The Modern Engagement, Chapter 7, Section V, states the same identification from the side of the act: "Consciousness is interaction. Not produced by interaction, not correlated with interaction, not supervening on interaction. Consciousness is the immanent modality, and the immanent modality is what interaction means". In the triple of the perceiver, the perceived and perception, the perceiver is transcendent, the perceived omniscient, and perception, consciousness itself, immanent.

A classical computation lacks all three. It is "one rule applied the same way at every step", which is symmetry perfected; by the theorem, what is absolutely symmetric is intrinsically discontinuous, and "one cannot compose a continuity out of purely symmetric components". So a computation has an indexing of its states and no arrow; being fixed by its rule, it has no hard randomness of its own; and lacking two members of the triple, it lacks the third. "Classical computation, however intricately organized, cannot be what consciousness is" (Section VI). Hard randomness, described from the position of the one engaged, is choice: "From outside, randomness; from inside, choice; one event, two descriptions, both correct, neither complete" (Section V). Causality Without Determinism, Chapter 2, Section IX, puts the definition of

An Immanent Metaphysics in plain words: consciousness "is everything one perceives, taken together; it is where one's choices gather; and it is made of interacting and creating, not of a thing that exists apart".

IV. Where the Two Part

The two accounts part at one step: the step from the axioms to the measure. Integrated Information Theory's axioms are performed claims, held in the act of experiencing. Its postulates restate them as properties of a physical system described from outside: its states, its transition probabilities (the probability of each next state given each present state), the causes and effects each part specifies. Integrated information is computed from that description, and the theory identifies the experience with the cause-effect structure the computation returns. The claim that a system has a given amount of integrated information is a surveyed claim: it is established from a vantage that holds all of the system's states in view at once, and establishing such claims is what mathematics does best. So the theory passes from the first kind of claim to the second, and then says that the second is the first.

The passage from performed axioms to a surveyed quantity puts the theory between the two poles the collection has already examined. Chalmers held that a complete functional account of the brain would leave something unexplained, and the collection agrees: "Chalmers' philosophical intuition and the theorem's structural result converge on the same claim" (The Modern Engagement, Chapter 7, Section IX). Integrated Information Theory starts on Chalmers' side: experience is the datum, and function does not capture it. Dennett held that third-person description is complete, and the collection names his position "a one-modality metaphysics operating in a three-modality world", the error it calls omniscient modal bias (The Modern Engagement, Chapter 8). Integrated Information Theory ends on Dennett's side: it replaces his functional description with a description of causal structure, but the description it offers is still third-person, and it says that the description is the experience. The theory is the nearest of the scientific theories to the collection because it begins where Chalmers began, and it parts from the collection because it ends where Dennett ended.

The collection holds that the theorem forbids this passage, whichever of the two kinds of claim it starts from. The Last Turtle, Chapter 2, Section VIII, sets out the two characters the theorem allows: "Objectivity has its basis in symmetry, and subjectivity has its basis in continuity", and "The subjective, the side from which every comparison is made, is continuous and asymmetric: the stance persists without a break, and what it meets never exactly repeats". A quantity computed from a system's structure belongs to the objective character: exact, repeatable, the same for every observer who computes it. The subjective is the other character. A description that captured the subjective completely in objective terms would perfect symmetry and continuity together, which is the first pairing the theorem forbids. The Modern Engagement, Chapter 7, Section VII, applies the theorem to consciousness in these terms: knowing is third-person and has the nature of symmetry, understanding is first-person and has the nature of continuity, and "No amount of omniscient-modal description will ever produce immanent-modal understanding, for the same reason that no amount of symmetry will ever produce continuity". Integrated information can therefore describe, exactly and usefully, the structure within which a system's acts of comparison occur. Integrated information cannot be the act.

The collection already draws this distinction, between the act and the physical circumstance under which the act occurs, for one physical quantity, and integrated information falls on the same side of it as that quantity. Asked whether the brain's poise between order and disorder is consciousness, Causality Without Determinism, Chapter 5, Section IX, answers: "The brain's poise between order and disorder, which physicists call criticality, is the physical circumstance under which the bound triple is expressed in us; it is not the bound triple itself". Integrated information stands where criticality stands. High integration of a system's causes and effects upon itself is a physical circumstance under which acts of comparison gather into one stance, and a system lacking it has no single place where its choices gather. That is, when a system's parts act strongly and irreducibly on one another, its many acts of comparison can be made from one side, by one self. Integrated information is the measure of the circumstance, and not the inside the circumstance supports.

The second point of parting follows from the first. Integrated information is computed from a system's transition probabilities, and nothing in its definition requires that any outcome be left unfixed by the system's prior state. A network of logic gates whose every next state follows from its present state by rule can have high integrated information, and the theory then assigns it experience. The computer scientist Scott Aaronson pressed this point in 2014 with large networks of simple logic gates wired as expander graphs, which on the theory are conscious though they do nothing a person would call experiencing; Tononi, in reply, accepted the consequence and extended it to a plain two-dimensional grid of such gates. The collection rejects the consequence, for the following reason. A system whose every step is fixed by a rule has no hard randomness of its own; with no hard randomness, its order of states is an indexing and not an arrow; and with neither, it has no subjective. A physical grid of gates is a physical system interacting with itself and its surroundings, and on the collection's account the grid has whatever its interactions have: something real and simple, as a thermostat's interaction with temperature is real and simple. The grid's rule, from which the integrated information is computed, supplies none of what its interactions have. On this point the collection is stricter than the theory: integrated information computed from a rule with no hard randomness is integration of a determinism, and a determinism, as a rule, has no inside.

V. Grades of Experience and Choice in Every Degree

Integrated Information Theory holds that consciousness is graded and that it reaches down to very simple systems; Tononi and Koch suggest that a single photodiode linked to a one-bit memory "can have a modicum of experience". This consequence is often counted against the theory. The collection holds something close to that consequence. Hard randomness and choice are one event described from two positions, and the collection applies the two descriptions to the simplest physical system it treats: the undetermined response of a particle in the free will theorem is, "described from outside, hard randomness; described from the position of the process from which it came, the same event is choice" (Causality Without Determinism, Chapter 5, Section V). Choice, on the collection's account, is present in every degree, wherever

an outcome is not fixed in advance. The Modern Engagement, Chapter 7, Section V, draws the consequence for consciousness: "Wherever interaction occurs, some form of consciousness is present", and this "is structurally different from panpsychism", since consciousness is a property of interaction and not of matter, so the account "does not begin from micro-experiences that must somehow be combined". Integrated Information Theory also avoids the problem of combining small experiences into one, by its exclusion postulate: only the maximally irreducible whole is a subject.

The collection states what its degrees correlate with. The Ground of Objection, entry T3.19: "consciousness is a property of interaction whose degree and kind correlate with the richness and structure of the interaction. A thermostat's interaction with temperature is real and simple. A brain's interaction with a world is real and enormously complex". The same entry states what the collection asserts and what it asks for: "The correlation between richness of interaction and degree of consciousness is asserted and is not derived, and the system does not supply a measure of richness or a function from one to the other". The question it asks is what measure of the richness and structure of an interaction tracks its degree of consciousness. Integrated information is a measure of exactly that kind: a measure of how richly and irreducibly a system's parts act upon one another. Read in the collection's terms, it is a candidate for the measure of the structure of a system's interactions, the omniscient signature of the degree of consciousness, as predictive utility is, in the collection's treatment of Dennett, "a real feature of belief, its omniscient-modal signature". The collection rejects the theory's further step, that the measure is the experience. As a measure of the richness of interaction, integrated information would be computed over a system's physical interactions, hard randomness included, and not over the rule that describes them; computed from the rule of the grid of Section IV, it is high, while the grid's interactions are simple.

The two accounts differ in what the grades are grades of. For Tononi, they are amounts of one quantity, integrated information, and the quantity is the experience. For the collection, they are degrees of the interaction itself, and in the richest of them the choices made are held together by one self that persists. Causality Without Determinism, Chapter 6, Section VI: "The self, as An

Immanent Metaphysics defines it, is the appearance of the aggregation of that aspect of interaction which is choice. Self is an intrinsic of choice". A photodiode's single undetermined click is choice at its least gathered; a living person is choice gathered across every channel of perception into one persisting stance. The theory's exclusion axiom, "Experience is definite: it is this whole", points at the same gathering: one stance, one whole, at a time. The collection adds what makes the gathering a self and not only a structure: that the stance persists without a break while what it meets changes, which are the first two of the four theorems of being, "Subjective context is continuous: the persistence of self-identity. Subjective content is discontinuous: the diversity of thoughts and perceptions" (Chapter 6, Section VII).

VI. Distinctions, Relations and the Act of Comparing

The composition axiom says that experience is "composed of distinctions and the relations that bind them together". The composition axiom's description is close to the collection's own description of what any finding contains. A comparison returns a verdict of same or different, in some respect, and every finding is built from such verdicts and from the relations among them; perception, on the collection's account, is a comparison considered from the side of the self (Causality Without Determinism, Chapter 4, Section IX). The structure Integrated Information Theory computes, its structure of distinctions and relations, is then the structure of the verdicts a system's comparisons return.

The collection keeps the verdicts and the act that returns them apart, since the act is held in the first person and the verdicts, once returned, can be laid out and surveyed. A structure of distinctions and relations, held in view as a whole, is a record: the laid-out side of the act. The theory's identification of experience with that structure takes the record of experiencing for the experiencing. The collection says the same of the qualities of experience in its treatment of Dennett: qualia "have the nature of non-local context and are characterized by continuity. They cannot be picked out by any procedure that works by distinguishing content, because they are not content" (The Modern Engagement, Chapter 8, Section IX). Computing a structure of distinctions is a procedure that works by distinguishing content. Integrated Information Theory holds that the structure fully specifies the quality of an experience; the

collection holds that the axioms of the Immanent Metaphysics "predict the structure of consciousness, not the content of any particular experience, so that qualia are not derived from them" (The Modern Engagement, Chapter 7, Section XV). The structure is real, and computing it gives real knowledge about a system; the structure is the omniscient side of something whose own character is immanent, held in the act as it happens.

VII. The Charge of Pseudoscience, and What a Measurement Can Reach

In 2023 more than a hundred researchers signed an open letter, posted on PsyArXiv, calling Integrated Information Theory pseudoscience. Its central complaint was that although some aspects of the theory had been tested, "the theory as a whole has not", so that there was "little experimental support" for its "bold and counter-intuitive implications". Other researchers called the letter "poorly reasoned and disproportionate", and in 2025, in *Nature Neuroscience*, answering a later commentary by the letter's authors, Tononi and colleagues wrote that it had "much fervor and little fact". In April 2025 the adversarial collaboration between proponents of Integrated Information Theory and of global neuronal workspace theory published its results in *Nature*: each theory's predictions about where and when the brain's activity tracks conscious perception came out partly right and partly wrong, and one of its leading authors, Oscar Ferrante, summarized: "Both theories are incomplete".

The dispute mixes two kinds of claim, and the collection's distinction between them settles what each side can ask. "A test applies where the outcome of a comparison can be objective: comparable by many, consistent across them, and able to surprise" (Physics Is Not Math, Chapter 19, Summary). Claims of Integrated Information Theory about which regions of the brain carry the activity that goes with reported perception are of that kind, and the adversarial collaboration tested them properly. The theory's central claim, that an experience is its system's cause-effect structure, is of another kind. Experience is held in the act of experiencing, a performed claim, and no third-person measurement takes another's first-person act as its content. So the central identity is a metaphysical claim, which no experiment reaches in either direction.

The Ground of Objection, entry T1.10, sets out what follows, on Popper's own ground. Popper's criterion "is a criterion of demarcation and expressly not of meaning", and on his account metaphysical statements "are not nonsense ... may be fruitful, and are simply not scientific"; so "a system placed outside empirical science by his criterion has not been convicted of anything by him". The collection accepts the demarcation for itself and places its own foundational claims outside empirical science "without embarrassment", while its physical predictions are offered to measurement. The collection's own claim that a computation cannot be what consciousness is belongs with the foundational claims: it concerns what a computation is, and it is checked by its structure, step by step, as a logical claim is checked. The open letter was right that the theory's central identity has not been tested by experiment, and wrong to treat the absence of a test as a conviction: Popper's criterion places the identity outside empirical science and convicts it of nothing. The theory made the charge possible by presenting its identity inside a scientific theory without marking where the empirical claims end and the metaphysical one begins, a line the collection draws for itself. Judged by its argument, which is how a claim of its kind is judged, the identity fails at one step: the step that sets a surveyed quantity equal to a performed act.

The register beside Tononi, Appendix M, finds that "no measurement made or proposed separates the two accounts": the collection makes no statement about which regions of the brain, or which patterns of their activity, go with conscious perception, and Integrated Information Theory makes no prediction about gravitation, cosmology or the kinds of particle, which is what the sealed record holds. One statement of the books bears on the brain and can be measured, that the brain operates near criticality; the sealed record does not carry it, and the measurements so far agree with it. The true differences, on what experience is, on whether a wholly determined system can have it, on what fixes the quality of an experience and on what its grades are grades of, are of a kind that no experiment reaches.

VIII. Summary

Integrated Information Theory is the scientific theory of consciousness nearest to the collection's account. It begins from experience itself, with a first axiom that is a performed claim, and it names the subjective in its axiom of intrinsicality. It places consciousness in a physical system's causal power upon itself, which the collection's Root Tautology reads as the comparisons a system makes within itself. It denies consciousness to feedforward networks and to simulations on digital computers, for the reason the collection gives: what counts is the physical process, never the program it runs.

The two accounts part where the theory passes from its axioms to its measure. Integrated information is a surveyed quantity, computed from a system's structure as laid out from outside. Consciousness, on the collection's account, is the bound triple of the arrow of time, hard randomness and the subjective, taken as one act, and it is held in the act. The Incommensuration Theorem keeps the objective and subjective characters apart, so no objective quantity can be the subjective act. Integrated information measures the circumstance under which acts of comparison gather into one stance, as criticality does, and the structure of distinctions and relations that the theory computes is the laid-out record of the verdicts those acts return. Because the measure makes no requirement that any outcome be unfixed, the theory grants experience to wholly determined systems that the collection holds have no inside. The theory stands between Chalmers and Dennett: it begins with Chalmers' datum and ends with a third-person description of the kind Dennett offered. Both accounts find something of mind at every scale: for the theory, an amount of integration; for the collection, interaction, whose degree correlates with its richness and structure, and choice, gathered into a self where interaction is richest. The collection asks what measure of that richness and structure tracks the degree of consciousness, and integrated information is a candidate for that measure; it is not the experience it measures. The charge of pseudoscience fails on Popper's own criterion: the theory's central identity is a metaphysical claim, to be judged by its argument. Tononi measures the structure of a system's causes upon itself; Karl Friston, in the next chapter, describes every thing that persists by the boundary across which it meets its world, and reads perception and action as inference.

Key Concepts

- Integrated Information Theory starts from axioms of experience; its first axiom, "Experience exists", is a performed claim, held in the act.
- Both accounts deny consciousness to feedforward networks and to programs as such: what counts is the physical process, never the program.
- Causal power upon itself, in the theory, is the comparisons a system makes within itself, in the collection's terms.
- Integrated information is a surveyed quantity; consciousness is the bound triple taken as one act; the theorem keeps the objective and subjective characters apart.
- Integrated information measures a circumstance, as criticality does, and is not the inside that circumstance supports.
- A wholly determined system has no hard randomness, so no arrow and no subjective, whatever its integrated information.
- The theory begins with Chalmers' datum (experience is real and not captured by function) and ends with a third-person description of the kind Dennett offered.
- Both accounts deny the physical-duplicate zombie and allow the behavioral duplicate with no inside.
- Grades of experience in the theory are amounts of integration; in the collection they are degrees of interaction, correlated with its richness and structure; integrated information is a candidate measure of that structure, not the experience.
- The theory's identity of experience with structure is judged by its argument, not by experiment; it fails where it sets a surveyed quantity equal to a performed act.

Terms

Bound triple. The arrow of time, hard randomness and the subjective: distinct, inseparable and not interchangeable; taken as one act, consciousness.

Cause-effect power. In Integrated Information Theory, what a system's parts in their present state specify about the system's past and future states.

Feedforward network. A network whose signals pass only from input toward output, with no part acting back on another.

Hard randomness. An outcome that no prior specification fixes, however complete; described from inside, choice.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Integrated information. In Integrated Information Theory, the measure of how far a system's cause-effect power upon itself cannot be reduced to that of its parts.

Performed, surveyed, implied. The three ways a claim can be held: by what happens in the act of engaging it; from a vantage with many cases in view; in the stance a practice proceeds from.

Root Tautology. Comparison, interaction and relation are one act under three names.

Self. In the collection, the appearance of the aggregation of choice.

References

Aaronson, S. (2014). "Why I am not an integrated information theorist (or, the unconscious expander)". *Shtetl-Optimized* (blog), 21 May 2014.

Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A. M., Marshall, W., Mayner, W. G. P., Zaeemzadeh, A., Boly, M., Juel, B. E., Sasai, S., Fujii, K., David, I., Hendren, J., Lang, J. P. and Tononi, G. (2023). "Integrated information theory (IIT) 4.0: Formulating the properties of phenomenal existence in physical terms". *PLOS Computational Biology* 19, e1011465.

Cogitate Consortium, Ferrante, O. and others (2025). "Adversarial testing of global neuronal workspace and integrated information theories of consciousness". *Nature*, published 30 April 2025. DOI: 10.1038/s41586-025-08888-1.

Fleming, S. M. and others (2023). “The integrated information theory of consciousness as pseudoscience”. PsyArXiv, zsr78.

Goff, P. (2023). “Consciousness: why a leading theory has been branded ‘pseudoscience’”. *The Conversation*, 2 October 2023.

Landry, Forrest. *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Immanent Metaphysics and the Modern Engagement; From Husserl to Wilber*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Oizumi, M., Albantakis, L. and Tononi, G. (2014). “From the phenomenology to the mechanisms of consciousness: Integrated Information Theory 3.0”. *PLOS Computational Biology* 10, e1003588.

Tononi, G. (2004). “An information integration theory of consciousness”. *BMC Neuroscience* 5, 42.

Tononi, G. and Koch, C. (2015). “Consciousness: here, there and everywhere?”. *Philosophical Transactions of the Royal Society B* 370, 20140167.

Tononi, G. (2014). “Why Scott should stare at a blank wall and reconsider (or, the conscious grid)”. Posted on *Shtetl-Optimized* (blog), 30 May 2014, in S. Aaronson, “Giulio Tononi and Me: A Phi-nal Exchange”.

Zimmer, C. (2025). Report on the adversarial collaboration. *The New York Times*, 30 April 2025.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Karl Friston

The Boundary and the Act

Karl Friston's Free Energy Principle and Physics from Comparison

Abstract

Karl Friston's free energy principle holds that anything which persists as a thing, set apart from its surroundings by a boundary of sensory and active states, behaves as if it were inferring the causes of its sensations and acting to keep those sensations within the range its own existence requires. Perception is then inference, action is inference carried into the world, and a living system is one that gathers evidence for its own continued existence. The physics collection of the Immanent Metaphysics shares more of this picture than its vocabulary suggests: a thing is set apart from its world by a boundary across which it interacts, never wholly cut off and never wholly merged; perception is comparison; and the question Friston asks, "if things exist, what must they do?", has the form of the collection's own question, what an act of comparison cannot fail to contain. Friston also says plainly that his principle is not a falsifiable theory but a mathematical statement, and the collection agrees on exactly where a test applies and where it does not. The two accounts part on what comes first. Friston begins from probability densities over states and a statistical partition of them, and reads a self, a perception and a choice off that mathematics. The collection begins from the act of comparison, derives probability from it, and holds that a description laid out from outside, however exact, leaves out the stance from which a self perceives and chooses. The essay sets out the principle at full strength, credits what it establishes, and shows where and why the collection parts from it: on the boundary of a self, on the difference between a model of inference and the act of comparing, on choice, and on the order of mathematics and physics.

I. The Principle

Karl Friston, a neuroscientist at University College London, set out the free energy principle in 2006, with James Kilner and Lee Harrison, as an account of the brain, and in 2010 offered it as a candidate for a unified theory of brain function. Its later statements extend it from brains to every system that persists, and in a monograph of 2019 to physics itself. In its own words, that monograph "attempts a theory of every 'thing' that can be distinguished from other things in a statistical sense".

The principle has three parts. The first is the boundary. A thing is picked out by a *Markov blanket*: a set of states, the sensory states and the active states, that separates the thing's internal states from the external states of its world, so that the internal states depend on the external ones only through the blanket. Sensory states are influenced by the world and influence the inside; active states are influenced by the inside and influence the world.

The second is the quantity. Given such a boundary, the internal states can be read as encoding a probabilistic model of the external causes of the sensations. The *surprise* of a sensation is how improbable it is under that model. The system can compute a quantity called *variational free energy*, which is never less than surprise; surprise itself the system cannot compute directly. A thing that persists, Friston argues, is one whose internal and active states change so as to keep its free energy low, and so to keep its sensations within the range of states compatible with its continued existence.

The third is the reading. Changing internal states to lower free energy is perception, read as inference: the internal states come to encode the most probable causes of what is sensed. Changing active states to lower free energy is action, which Friston calls *active inference*: the thing changes the world so that what it senses fits what it expects. The system chooses among courses of action by expected free energy, a quantity that weighs both the value of reaching preferred states and the value of the information an action would gather. A system that persists in this way is *self-evidencing*: by acting, it gathers evidence for the model that its own existence embodies.

Friston and his colleagues are exact about what kind of claim the principle is. In the Physics Reports paper of 2023, "The free energy principle made simpler but not too simple", they compare it to Hamilton's principle of least ac-

tion (the principle that a system moves along the path for which a quantity called the action is stationary, from which the equations of motion of classical mechanics follow) and write that "it is not a falsifiable theory about the way 'things' behave", and that "the FEP [the free energy principle] is not falsifiable as a mathematical statement, but it may as well be falsifiable to the extent that its postulates refer to a specific class of empirical phenomena that the principle aims to describe". They put its central question in a turned form, "if things exist, what must they do?", in place of asking what things do.

The principle has met a serious objection on its central term. Jelle Bruineberg, Krzysztof Dołęga, Joe Dewhurst and Manuel Baltieri, in "The Emperor's New Markov Blankets" (2022), traced the Markov blanket from its origin in Judea Pearl's work on Bayesian networks (diagrams of the probabilistic dependence among variables), where it is a tool of inference within a model, to its use by Friston to mark the real boundary between an agent and its world. They proposed "to distinguish between 'Pearl blankets' to refer to the original epistemic use of Markov blankets and 'Friston blankets' to refer to the new metaphysical construct", and argued that inference with a model must be told apart from inference within a model, and that only the second can do metaphysical work, and then only with further premises.

II. What the Principle Establishes

The free energy principle reaches, from the mathematics of probability, four things the collection reaches from the structure of comparison.

First, a thing is a thing by a boundary across which it interacts. Friston's blanket makes the inside depend on the outside only through the boundary, and it keeps the inside and the outside coupled through the boundary. The thing is never sealed off and never dissolved into its surroundings. The collection says the same of the self, in Causality Without Determinism, Chapter 6, Section VI: the self "participates in interaction: it perceives, it chooses, it is embedded in a domain. The degree of its interaction is never zero (it is always engaged with something) and never infinite (it is never identical with the totality of what it interacts with)". An interaction never zero and never infinite is the collection's principle of non-polarization, applied to the subject, and the Markov blanket is a mathematical form of that principle.

The collection has already set out its relation to two traditions that bear on active inference, and both meet Friston at the boundary. Of Gregory Bateson's cybernetics, it holds that "mind is the immanent aspect of self, the boundary and the dynamics between internal subjective quality and external objective form", and that both accounts "deny that mind is a substance and affirm that mind is a process" (The Immanent Metaphysics and the Modern Engagement, Chapter 12, Section V). Of the enactivism of Francisco Varela and Evan Thompson, it takes as the unit of comparison "the living organism in its environment, taken as a single relational whole": cognition "happens at the boundary, in the interaction, in the structural coupling of organism and world", and the chapter calls enactivism "the closest contemporary scientific parallel" to the collection's account of perception (The Immanent Metaphysics and the Modern Engagement, Chapter 9). Friston places the inside, the outside and the coupling between them in one formal object. The collection places mind at that same boundary, as the dynamics across it.

Second, perception is what a living system does with what arrives at its boundary, and it is the same act as the measurement an instrument makes. Causality Without Determinism, Chapter 4, Section II: "Measurement is a comparison; so is perception, and so is every interaction", and "The comparer is a structural role, the role of relating, and a mind, an instrument or a thermostat can fill it". Friston's principle applies to a cell, a brain and a thermostat-like controller alike, for the same reason: the principle concerns what anything bounded does at its boundary, not what material it is made of.

Third, the engine of Friston's account is a comparison. A prediction error is the verdict, same or different and by how much, on what is sensed set beside what is expected. In the collection's terms the content is what is sensed (a brightness, a pressure, a sound) and the context is the expectation it is judged against; every comparison has both, and "the content and the context cannot be one respect" (Comparison; The Necessary Basis, Chapter 4, Section I). The collection describes the recognition of a face as three comparisons in order: something near enough to register, then like something held in memory, then taken in as one's own (Comparison, Chapter 8, Section VI). Friston's hierarchy of predictions, each level comparing what arrives from below with what it expects, is that sequence written as mathematics. A predic-

tion error is also what Bateson called a difference which makes a difference, and the collection says exactly what that difference is: it is "the epistemic face of difference", "the difference of content in a sameness of context", one face of one of the six parts of every comparison (The Immanent Metaphysics and the Modern Engagement, Chapter 12, Section VI).

On scope, Friston stands with the collection. His principle applies to every thing that can be set apart from its surroundings, living or not. Thompson's continuity of life and mind has a lower bound at life, and below it he does not commit to anything that could be called sense-making. The collection holds that the three modalities "are not features of living systems alone. They are features of reality as such", and that they "do not emerge at some threshold of biological complexity" (The Immanent Metaphysics and the Modern Engagement, Chapter 9, Section VII). Friston's extension of the principle from brains to every particle-like thing is the same refusal to draw a line where the structure draws none.

Fourth, the two accounts ask the same form of question. "If things exist, what must they do?" asks what must hold of anything at all, given only that it is a thing. The collection asks what an act of comparison cannot fail to contain, given only that it is an act of comparison, and from the answer (six parts in three pairs: same and different, content and context, the subjective and the objective) it proves the Incommensuration Theorem. Both reason from what anything of a kind must be, and not from a survey of cases. Reasoning from what anything of a kind must be is the right form of question for a foundation, and Friston asks it of living things and of every other thing that persists.

The principle also gives novelty its weight. Expected free energy weighs the information an action would gather, so a system governed by it seeks out what it does not yet know as well as what it prefers. The collection makes novelty one of the three conditions of objectivity, beside comparability by many and consistency across them: a thing is known as separate from oneself only if it can surprise, "to show what no one expected or could have fixed in advance; what does only what one expects is not known as separate from oneself" (Physics Is Not Math, Chapter 19, Section III). A self that took in only what it expected would lose its world as a world. Friston's epistemic term keeps the world in view, and on this the two accounts stand together.

III. Where a Test Applies

The collection reads Friston's statement, that his principle is not falsifiable, as a correct account of what kind of claim the principle is. A reader who expects every claim to be tested may see a weakness in that statement, and the collection's account of where a test applies shows why it is none. A test, in Physics Is Not Math, Chapter 19, Section III, "is a comparison of outcomes, and it can settle something only when its outcome can be compared: by another person, at another time, along another route", and so "a test applies exactly where the outcome of a comparison can be objective, and nowhere else". A mathematical statement is not such an outcome. It is a surveyed claim, in the collection's terms, established "from a vantage that holds many cases in view at once, by counting the cases or by proving, from fixed premises, what holds in every case they cover" (Physics Is Not Math, Chapter 9, Section III), and it is checked by proof.

The free energy principle, so stated, is checked the way Hamilton's principle is checked: by whether its conclusions follow from its premises. A test can reach every claim that applies the principle to a particular system. That a given population of neurons encodes a given prediction, that a given cell's membrane is the boundary across which its states are coupled in the way the principle requires, that a given behavior lowers a given quantity: each is a claim about the world, its outcome can be compared by many, and tests reach it. Friston's own program draws the same line between the principle and the process theories (predictive coding among them) that realize it in particular systems; in the words of the paper of 2023, the principle "may as well be falsifiable to the extent that its postulates refer to a specific class of empirical phenomena that the principle aims to describe". The collection's division and his agree. The collection also leaves to the sciences of each domain the question of which mechanisms there are. The Ground of Objection, entry T2.24, holds that "the system entails that comparison has implementations": neurons firing and signals crossing are interactions and therefore comparisons, and a description of the mechanisms that implement comparing "is a description within a domain" that neither displaces the collection's account nor is displaced by it. Predictive coding, as a description of how a brain implements its comparisons, is such a description.

Both accounts also place their foundations outside empirical science, and both do so openly. The Ground of Objection, entry T1.10, accepts Popper's criterion as a demarcation of empirical science, and places the collection's foundation outside it "without embarrassment": "a system placed outside empirical science by his criterion has not been convicted of anything by him". Friston's statement about his principle and the collection's statement about its ground are statements of the same kind.

The collection adds one distinction Friston's framing leaves out. The free energy principle is a surveyed claim: it holds of every model that meets its conditions. The Incommensuration Theorem is a performed claim: it is "established by what happens in the act of engaging it, including the act of trying to deny it" (Physics Is Not Math, Chapter 9, Section III). The Incommensuration Theorem is a structural fact about the nature of knowing: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The theorem is proved from the meanings of the parts of comparison, as Section II says, and it is also performed: any attempt to deny it is itself a comparison; proved and performed are two ways the one theorem is held. Every inference the free energy principle describes, and every check of the principle itself, is an act of comparison, and so the theorem holds in each of them before the principle is applied. The principle is outside the reach of a test because it is mathematics; the theorem is outside the reach of a test because every test is an instance of it. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

IV. The Boundary of a Self

The objection of Bruineberg and his colleagues marks the place where Friston's account and the collection part. A Markov blanket in a model is a fact about a probability distribution: given the blanket states, the internal and external variables are independent. Read as a Pearl blanket, it says something

about the model. Read as a Friston blanket, it is meant to say what the boundary of a living thing is. The step from the first to the second is the step the objection says needs further premises.

The collection names that step. Causality Without Determinism, Chapter 4, Section I: "Compatibility between a model and a body of measurements is not equivalence: many models may be compatible with the same data, and no amount of compatibility can establish that the model is the reality it describes", and, in one sentence from Incommensuration, "A law exists; a measurement is real". A statistical partition of a model exists, in the collection's sense: it is structure laid out, the same for every reader. The boundary of a cell or a self is real: it is where interactions happen, one at a time, from a side. The gap between Pearl blankets and Friston blankets is the gap between what exists and what is real, and no further premise of statistics can close it, because the premise needed is not statistical. The premise needed is that the partition of the model marks a place where comparisons are made. That premise is true of living things, and, since every interaction is a comparison, of every bounded thing; what sets the boundary of a self apart is that the comparisons made across it are made from one side, by one self that carries them forward as its own. The collection supplies the premise's ground: the boundary of a self is where the self compares, perceives and chooses. The Markov blanket can describe such a boundary exactly. The Markov blanket cannot be what makes the boundary, because a partition laid out in a model is held from outside, and the boundary of a self is held from the side of the self.

The same structure appears in a family of theories of perception that the collection answers in The Basis of Physics, Essay 4, Section VI: theories in which "everything we perceive comes to us through an interface", while a hidden reality lies behind it. Essay 4 asks of the translation from the hidden level to the interface whether it is real, and finds that if it is real it is an interaction, and so is privileged in exactly the sense the theory denied. In Friston's account the external states are hidden behind the blanket and known only by inference. The collection holds the blanket itself to be the place where the world is met: the sensory states are the comparisons in which the world is found, and not a veil between the self and its world.

The collection's account of representation says where Friston's generative model belongs. With the enactive tradition, it holds that "all of one's experiences are direct experiences" and that "there is no such process as direct perception; there is only direct experience"; representation "is a legitimate tool within the omniscient modality. But it is not the ground of knowing" (The Immanent Metaphysics and the Modern Engagement, Chapter 9). Friston's generative model is that legitimate tool, held exactly. The old question that the generative model seems to reopen, whether what a self has is its world or only a model of it, is answered in The Ground of Objection, entry T2.12, by a change in the kind of answer: objectivity "is not an attribute of any single perception"; it is a measure computed over many acts, by the three rings of verification (intensity, consistency and novelty), and "a single perception is simply real and has no degree of objectivity, any more than a single measurement has a variance". Each perception is an act in the world, and no perception is a proxy for the world; the world becomes known as objective across many such acts.

V. Inference and the Act

The free energy principle describes a self from outside, as a dynamical system whose internal and active states flow down a gradient of free energy, with random fluctuations added. That description can be exact, and the collection holds that the description leaves something out, for a reason the collection states precisely.

A description of this kind can be run. A simulated agent governed by active inference is a program: in Causality Without Determinism, Chapter 5, Section II, "a step-by-step procedure whose next state follows necessarily from its current state by a fixed rule". The chapter's argument then applies directly to such an agent. Consciousness is the bound triple taken as one act: the arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable (Section III). A classical computation is symmetry perfected, one rule applied the same way at every step; it lacks the arrow, lacks hard randomness of its own, and, since the three are bound, lacks the subjective (Section VI). So "classical computation, however intricately organized, cannot be what consciousness is", and an artificial agent that minimizes free energy,

however faithfully, is no exception. The chapter allows that such a system may behave, from a third-person vantage, in a way that cannot be told apart from conscious behavior. The argument concerns what the act is, not what outputs can be matched. The enactive tradition reaches the same conclusion on its own ground, that a computational system "does not enact a world; it manipulates symbols" (The Immanent Metaphysics and the Modern Engagement, Chapter 9).

The random fluctuations of the principle's equations take their place in the same account. In the model they are a term with a fixed distribution, set beside the deterministic flow. Causality Without Determinism, Chapter 5, Section V, distinguishes two things called random. Pure randomness, an outcome with no relation to anything, is an idealization the theorem forbids as an absolute, as it forbids determinism. Hard randomness is real: "the remainder that no completeness of prior specification closes off". Hard randomness and choice "are one event described from two positions": from the position of law, a gap in the specification; from the position of the one engaged, a choice. The fluctuation term of the free energy principle is the description from the position of law. That description is correct, and it describes from outside what, from inside, is the agent choosing.

VI. Decision and Choice

Active inference selects a course of action by comparing the expected free energy of each course in a set and favoring the lowest. The collection has an exact name for that operation: decision, as distinct from choice. Causality Without Determinism, Chapter 6, Section III: "A decision is a selection from a set of possibilities already defined, made by cutting away the others; if it involves trade-offs, it is a decision. A choice may realize a possibility that was open but not in the set. Decision engages causality: it weighs what is known to follow from what. Choice engages creation".

Policy selection by expected free energy is decision in this sense, and decision in this sense covers a great part of what living things do: a habit, a reflex, a weighing of known outcomes. The collection's account of the real places decision and choice in one structure. In the triple of the real, change is immanent, causality omniscient and choice transcendent, and the three run in

one order, from choice to change to causality and back to choice (Causality Without Determinism, Chapter 6, Section II). A model in which every action is the outcome of minimizing a quantity over a set reads that cycle from causality first, and the chapter warns that reading the cycle that way "leaves choice out of the cycle and reduces it to an effect of what came before". The free energy principle describes the causal side of a living thing completely enough to be useful in every laboratory that uses it. The collection finds choice in what the principle describes as fluctuation, and in any course of action that falls outside the set of courses the principle ranks.

VII. Probability and the Order of Depth

The deepest parting is in the order of the account. Friston's monograph of 2019 begins from probability densities over states and the conditional independences among them, and from that statistical structure it reads off things, their boundaries, their beliefs and, it proposes, the forms of quantum, statistical and classical mechanics. Mathematics comes first, and physics and mind are read from it.

The collection orders the four the other way: metaphysics, physics, computation, mathematics, each presupposing the one before. Mathematics, in Physics Is Not Math, Chapter 3, Section VII, "works as if only the objective existed, and as if there were no subjective side at all", and "What mathematics states leaves the stance out; how mathematics is done keeps the stance in". The collection derives probability itself, and does not assume it. The Quantum Passage, Chapter 7, derives the Born rule (the rule that gives the probability of each outcome of a quantum measurement) from the structure of comparison, and Chapter 11, Section V of the same book differs from the reading of quantum probabilities as an agent's degrees of belief (the reading called QBism). What a measurement changes is the laid-out record, "shared and the same for everyone who has the outcome", and not a personal degree of belief (Chapter 9, Section IV). Friston's internal states encode beliefs in a model; the collection's record of a comparison is a fact shared by every comparer who has it.

The order of depth is where the earlier sections meet. The boundary is real before any distribution is written over it. The comparison is made before any probability is assigned to its outcome. The choice is made before any fluctuation term describes it. In each case the free energy principle writes, from outside and exactly, the structure that an act of comparison lays out, and in each case the act comes first.

The register beside Friston, Appendix N, records one agreement: Prediction 25 of the sealed record, that the statistics of quantum theory hold, which Friston's account shares, since his monograph of 2019 presents its Bayesian mechanics as compatible with quantum mechanics and names no departure; the measurements so far agree with both. "No measurement named in the relation essay or in the books separates the two accounts", and the tests of predictive coding and the other process theories bear on those theories, because the collection makes no claim about which mechanisms carry out comparing.

VIII. Summary

The free energy principle and the physics collection describe the same living thing from opposite ends. Both hold that a thing is set apart by a boundary across which it interacts, never sealed and never dissolved, and that perception is the comparison of what arrives with what is held. Both hold that a living system must seek what it does not yet know, and that the right foundational question asks what anything of a kind must do or contain. Both agree on where a test applies: the principle, as mathematics, is checked by proof, and its applications to particular systems are claims about the world that tests reach. The collection's accounts of Bateson's cybernetics and of the enactivism of Varela and Thompson, two traditions that bear on active inference, place mind at the same boundary Friston formalizes, as the dynamics across it.

The two accounts part on what comes first. Friston begins from probability densities and a statistical boundary and reads perception, action and the self from that mathematics. The collection begins from the act of comparison, derives probability from it, and holds the boundary of a self to be the place where comparisons are made, which a Markov blanket can describe and cannot constitute. A system governed by the principle and run as a computation lacks the bound triple of arrow, hard randomness and the subjective, and so is

not what consciousness is, however exactly it behaves. The selection of actions by expected free energy is decision, the weighing of what is known to follow from what; choice, which may realize a possibility outside the set, is what the principle describes from outside as fluctuation. The free energy principle is an exact third-person description of the causal side of living things, and the collection supplies the act that the principle describes. With Friston the accounts of this volume close; the appendices that follow give the Prediction Matrix of this volume, the dated registers that set each account beside the sealed record, and the essay *Why the New Epoch Is Flat*, which gives the argument behind Prediction 9.

Key Concepts

- The Markov blanket is a mathematical form of the collection's principle that a self's interaction with its world is never zero and never infinite; the collection places mind at that boundary, as the dynamics across it.
- Friston's generative model is representation, a legitimate tool, not the ground of knowing; a single perception is simply real, and objectivity is a measure over many acts.
- A prediction error is a comparison: a verdict on what is sensed (content) set against what is expected (context); it is Bateson's difference which makes a difference, the difference of content in a sameness of context.
- The free energy principle is a surveyed claim, checked by proof; the Incommensuration Theorem is a performed claim, held in every act of comparison, including every check of the principle.
- The gap between Pearl blankets and Friston blankets is the gap between what exists (a partition laid out in a model) and what is real (a boundary where comparisons are made).
- A simulated active-inference agent is a computation and lacks the bound triple of arrow, hard randomness and the subjective.
- The fluctuation term describes from outside what, from inside, is choice; selection by expected free energy is decision.
- Friston reads physics and mind from probability; the collection derives probability from comparison.

Terms

Active inference. In Friston's account, action that changes the world so that what is sensed fits what is expected.

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable; taken as one act, they are consciousness.

Content and context. In every comparison, what the verdict is on, and the respect in which the two things compared are two.

Decision and choice. A decision selects from a set of possibilities already defined; a choice may realize a possibility open but not in the set.

Expected free energy. The quantity by which active inference ranks courses of action, weighing preferred outcomes and the information an action would gather.

Hard randomness. An outcome that no prior specification fixes, however complete; from the position of the one engaged, the same event is choice.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Markov blanket. A set of states that separates internal from external states, so that each depends on the other only through it; Bruineberg and colleagues distinguish its use within a model (Pearl blanket) from its use as the boundary of a thing (Friston blanket).

Performed and surveyed claims. A performed claim is established by what happens in the act of engaging it; a surveyed claim from a vantage that holds many cases in view at once.

Self-evidencing. In Friston's account, acting so as to gather evidence for the model that one's own existence embodies.

Surprise and variational free energy. Surprise is how improbable a sensation is under a system's model; variational free energy is a quantity the system can compute that is never less than surprise.

References

Bateson, G. (1972). *Steps to an Ecology of Mind*. New York: Ballantine.

Bruineberg, J., Dołęga, K., Dewhurst, J. and Baltieri, M. (2022). "The Emperor's New Markov Blankets". *Behavioral and Brain Sciences* 45, e183. doi: 10.1017/S0140525X21002351.

Friston, K. (2010). "The free-energy principle: a unified brain theory?". *Nature Reviews Neuroscience* 11, 127–138.

Friston, K. (2019). “A free energy principle for a particular physics”. arXiv: 1906.10184.

Friston, K., Da Costa, L., Sajid, N., Heins, C., Ueltzhöffer, K., Pavliotis, G. A. and Parr, T. (2023). “The free energy principle made simpler but not too simple”. *Physics Reports* 1024, 1–29. arXiv:2201.06387.

Friston, K., Kilner, J. and Harrison, L. (2006). “A free energy principle for the brain”. *Journal of Physiology, Paris* 100, 70–87.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest (2026). *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications.

Landry, Forrest (2026). *The Immanent Metaphysics and the Modern Engagement; From Husserl to Wilber*. Wytheville, Virginia: UVSM Publications.

Maturana, H. R. and Varela, F. J. (1980). *Autopoiesis and Cognition: The Realization of the Living*. Dordrecht: Reidel.

Pearl, J. (1988). *Probabilistic Reasoning in Intelligent Systems*. San Mateo, California: Morgan Kaufmann.

Thompson, E. (2007). *Mind in Life: Biology, Phenomenology, and the Sciences of Mind*. Cambridge, Massachusetts: Harvard University Press.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Appendices

How to read the appendices. Each register in these appendices is reprinted whole, as it was fixed on 4 November 2026, and quotes in full each sealed prediction it compares, so the same sealed sentence recurs from register to register; a reader who knows the sealed record, reproduced whole in Volume One as its Appendix B can pass over those quotations.

In the register tables, "agrees" in the column of standing means that measurement agrees with the collection's prediction; it does not mean that the two accounts agree. Where a standing reads "agrees, for the collection; the difference is untested", the first part is the standing of the collection's prediction and the second the standing of the difference between the two accounts.

A prediction filed "outside the sealed record" is stated in a relation essay or in a register, and is not among the forty-two predictions sealed on 1 November 2026.

Terms of the sealed record. The "count route" and the "Koide route" of Prediction 38 are the two ways *The Measures of the Kinds* places the neutrino masses: the count route is placed from the measured mass of the tau alone and predicts both splittings, and the Koide route takes both splittings as inputs. The "carry family" and the "segment family" of Prediction 39 are the two families of lepton mixing in the same book, which put the lepton phase in the fourth and in the third quadrant. The "second closure" and the "carriers' law" of Prediction 42 are laws of *The Strengths of the Kinds* (Chapter 3, Section VI, and Chapter 5) that give the strength of color and the masses of the W and Z bosons. The letter k names two quantities: in Prediction 17 it is the curvature of the internal dimensions in Planck units, which both observables will find equal to 1; in Prediction 42 it is the second-order coefficient of the span from the electron to the reduced Planck mass, 3.7160.

Figures in the sealed text, as later published. The sealed text is not revised, and these figures are carried to the next dated report. Under Prediction 10, the published targets are about one part in a thousand for LiteBIRD and about three parts in a thousand for the Simons Observatory. Under Prediction 7, the distance of 73.04 ± 1.04 from 67.8 is 5.0 standard deviations in units of the measurement's own uncertainty and 4.8 with the prediction's added in quadrature. Under Prediction 17, the two values within the DESI analyses, 1.26 ± 0.06 and 0.68 ± 0.11, differ by 4.6 standard deviations.

Appendix A

The Prediction Matrix

The Registered Predictions of Physics from Comparison, Set Beside the Accounts of This Volume

This table takes the forty-two predictions registered on 1 November 2026 in *The Registered Predictions of Physics from Comparison* (reproduced whole in Volume One, Appendix B), in the order and under the short titles the sealed record gives them, and names the accounts of this volume that meet each one: John Archibald Wheeler, Julian Barbour, Lee Smolin, Max Tegmark, Stephen Wolfram, Arthur Eddington, George Ellis, Mordehai Milgrom with Stacy McGaugh, Erik Verlinde, Ilya Prigogine, Robert Rosen, Giulio Tononi and Karl Friston. A name under "Differs" means that the person's register files the entry where the two accounts differ: it sets the prediction against a different prediction of that person's own, or, as in Verlinde 1, 5 and 6, against an account that states no prediction where the collection states one; a name under "Agrees" means that the register records the two accounts predicting the same finding. The number after a name is the number of the entry in that person's register. "none" means that no account of this volume addresses the prediction. The table says only where the accounts meet; it does not say how measurement stands, and it leaves out the differences that no measurement decides. Each person's full register, with the statement of each entry, the measurements reported and what decides it, follows as its own appendix.

No.	Sealed prediction	Differs	Agrees
1	Gravitation entangles two masses	Verlinde 5	Wheeler 6
2	Gravitation alone ends no superposition	Verlinde 4	Wheeler 7; Barbour 4; Tegmark 6
3	Gravitation is not quantized	Wheeler 2; Barbour 1; Smolin 1	Verlinde 7
4	Free fall is universal and nothing shields gravity	none	Wheeler 4; Barbour 3; Verlinde 8
5	The arena has no least length, area or duration	Wheeler 1; Smolin 1, 2; Wolfram 1	none

No.	Sealed prediction	Differs	Agrees
6	Gravitational waves have two polarizations and travel at the speed of light	Wolfram 3	Wheeler 4; Barbour 2; Milgrom and McGaugh 7
7	The matter fraction is 0.311	Eddington 3	none
8	The equation of state of the vacuum energy is exactly -1	Ellis 4	Tegmark 4; Eddington 6; Milgrom and McGaugh 10
9	Space is flat to the size of the primordial departures	Wheeler 3; Ellis 1	Tegmark 5; Milgrom and McGaugh 10
10	No primordial gravitational waves	Tegmark 1; Ellis 2	none
11	The primordial departures are adiabatic	none	none
12	The departures are one pattern across the whole sky	none	none
13	No long inflationary phase	Tegmark 2; Ellis 2	none
14	The gravitational waves of an epoch, and their absence where others expect them	none	none
15	The excess of matter has one sign everywhere	none	none
16	The ratio of the dark matter to the ordinary matter is $6 - 2/\pi$	Tegmark 3; Milgrom and McGaugh 2, 3; Verlinde 2	none
17	The coefficient shared with the cosmological constant is 1	none	none
18	The amplitude of clustering is 0.823	Milgrom and McGaugh 4	none
19	The dark matter acts only through gravity	none	Milgrom and McGaugh 8; Verlinde 9
20	The dark matter does not decay	none	Milgrom and McGaugh 9
21	The dark matter is perfectly cold	Milgrom and McGaugh 5	none
22	The gyrations have about the Planck mass	Milgrom and McGaugh 6	none
23	No short loop exists anywhere in space	Ellis 3	none

No.	Sealed prediction	Differs	Agrees
24	A galaxy feels the field of a larger one only through its tide	Smolin 4; Milgrom and McGaugh 1; Verlinde 6	none
25	The statistics of quantum theory hold	Smolin 3	Wheeler 8; Tegmark 7; Wolfram 5; Ellis 6; Friston 1
26	What is found of color, charge and spin	none	none
27	No signal faster than light, and none backward in time	none	Wheeler 8; Wolfram 4[b], 6; Rosen 1
28	No world is perfectly deterministic, and no process is perfectly reversible	none	Smolin 5; Ellis 5; Prigogine 1
29	A discrete rule shows itself to a fine enough measurement	Smolin 1; Wolfram 2	none
30	No kind of particle beyond the closed list	Tegmark 3	none
31	Exactly three generations	none	none
32	The neutrinos are Dirac particles; no neutrinoless double beta decay	none	none
33	The proton does not decay	none	none
34	The strong force breaks no reversal; no axion	Tegmark 3	none
35	No new particle in any loop	none	none
36	The running of the couplings changes only at known masses	none	none
37	Ceilings and relations among the masses	none	none
38	The neutrino masses: two readings, decided by their sum	none	none
39	Lepton mixing: two families, decided by the quadrant of the lepton phase	none	none
40	The mass of the tau: two readings	none	none
41	The quark unitarity triangle has a right angle	none	none

No.	Sealed prediction	Differs	Agrees
42	The strength of color, the W and Z, the Higgs and the top	none	none

[b] Wolfram 4 (travel faster than light) is filed where the two accounts agree: in Wolfram's own account a jump through a tunnel of space keeps the causal order of events, so a body that takes one stays within its cone, and the two accounts differ only in words, as the register sets out.

Entries that rest on no sealed prediction

These entries of Volume Two rest on an argument of the books, or on a statement of the relation essay, and on no prediction of the sealed record; so they appear in no row of the table above.

- *Wheeler 5.* The exterior of a black hole has no hair. (Filed where the accounts agree; argued in the books as a theorem of general relativity; the sealed record does not number it.)
- *Wheeler 9.* No mass made of geometry alone. (Filed among the predictions outside the sealed record; stated only in the relation essay.)
- *Tegmark 8.* Three directions of space and one of time. (Filed where the accounts agree; argued in the books; a count already measured, which the sealed record does not number.)
- *Wolfram 3.* The number of dimensions of space. (Filed where the accounts predict differently; the count of three dimensions is argued in the books, and the sealed record does not number it; the entry's second part, the two polarizations of a wave of the geometry, is Prediction 6, under which the table shows it.)
- *Tegmark 9.* Decoherence in the brain. (Filed where the accounts agree; the collection makes no prediction of its own here and accepts Tegmark's estimate.)
- *Eddington 1.* The strength of light. (Filed where the accounts predict differently; the sealed record lists the strength of light as a measured input, not as a prediction.)
- *Eddington 2.* The ratio of the proton's mass to the electron's. (Filed where the accounts predict differently; the books argue the order of the two masses; the sealed record does not number it.)

- *Eddington 4.* The fate of a star above the greatest mass. (Filed where the accounts predict differently; argued in the books; the sealed record does not number it.)
- *Eddington 5.* Starlight bent by the Sun. (Filed where the accounts agree; argued in the books; the sealed record does not number it.)
- *Eddington 7.* A universe of evenly spread matter cannot stand still. (Filed where the accounts agree; argued in the books; the sealed record does not number it.)
- *Milgrom and McGaugh 11.* The measured relations of galaxies. (Filed where the accounts agree; both accounts take the relations as measured; the sealed record does not number them.)
- *Milgrom and McGaugh 12.* Wide binary stars move by Newton's law. (Filed among the predictions outside the sealed record; stated only in the relation essay.)
- *Milgrom and McGaugh 13.* The reported trend follows the surroundings in which a galaxy formed. (Filed among the predictions outside the sealed record; stated only in the relation essay; its outcome is that of Prediction 24, that a galaxy feels the field of a larger one only through its tide, and its reading of the trend is the essay's.)
- *Verlinde 1.* The dark mass in colliding clusters. (Filed where the accounts predict differently; argued in the books; the sealed record does not number it.)
- *Verlinde 3.* The relation between visible matter and the motions of galaxies. (Filed where the accounts predict differently; argued in the books; the sealed record does not number it.)
- *Prigogine 2.* The pattern taken at a branching point is not fixed in advance. (Filed among the predictions outside the sealed record; stated only in the relation essay.)
- *Tononi 1.* The brain operates near criticality. (Filed among the predictions outside the sealed record; argued in the books; the sealed record does not carry it.)
- *Tononi.* The statement of the relation essay. (Filed among the predictions outside the sealed record; stated only in the relation essay; the register says it is not a prediction and does not make it one.)

Appendix B

The Registered Predictions Beside John Archibald Wheeler

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of John Archibald Wheeler. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Participant and the Act; John Archibald Wheeler and Physics from Comparison*.

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Abstract

John Archibald Wheeler made general relativity a working science again, popularized the name black hole, proposed the delayed-choice experiment, and asked, more boldly than any physicist of his century, how the world could come from acts of observer-participancy. This record sets the predictions of physics from comparison beside his, as they stand on 4 November 2026. The two accounts agree on most of what experiment has reached: gravitation is the geometry of spacetime; free fall is universal; gravitational waves carry two polarizations and travel at the speed of light; the settled exterior of a black hole is fixed by its mass, charge and spin; and the delayed-choice experiment he proposed in 1978 came out in 2007 as quantum theory says, with nothing sent backward in time. They predict differently in three places that measurement could reach in principle: whether the arena keeps no least length or seethes as a foam at the Planck length; whether the geometry carries quantum degrees of freedom of its own; and whether space is flat to the size of the primordial departures or closed on itself, as Wheeler held. Measurements bear on the first and the third, and

each so far agrees with the collection; no experiment now proposed reaches the second. One further prediction, that no mass made of geometry alone will be found, is stated only in the relation essay and stands outside the sealed record. The deepest differences, whether the bit comes before the it, what an observer is, and what a law is, are claims about the act of knowing, which no experiment decides, and the record names them as such.

I. What This Record Is

This record sets side by side what physics from comparison predicts and what the work of John Archibald Wheeler predicts, wherever the two can be compared. Its source for the collection is *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*, called here the sealed record, which this record quotes word for word and leaves as it is. Its source for the comparison is the relation essay *The Participant and the Act*, together with Wheeler's own papers and books.

The rule of decision is the sealed record's:

> A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such.

Every prediction of the collection stated here is argued in a book named at chapter and section, and carries its number in the sealed record, with two exceptions, each marked where it stands: the exterior of a black hole (Wheeler 5), which a book of the collection takes as a theorem of general relativity and the sealed record does not number; and the absence of a mass made of geometry alone (Wheeler 9), which is stated only in the relation essay. Wheeler's predictions are stated from his own writing. Where a later program turned one of his ideas into a model with a measurable consequence, the record names that program and says so.

The two bodies of work have their own dates. Wheeler proposed geons in 1955, the quantum foam in 1957, the delayed-choice experiment in 1978 and the program of it from bit in 1989. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the

Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. The Incommensuration Theorem is a structural fact about the nature of knowing, and every prediction of the collection below comes from it and the three axioms, applied to physics through the structure of comparison.

II. Where the Two Accounts Predict Differently

Wheeler 1. The arena at the smallest scale

The collection predicts.

> The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else. Discreteness belongs to the content, the charges and the kinds of particle, and the account predicts it there.

Registered on 1 November 2026 as Prediction 5 of *The Registered Predictions of Physics from Comparison*.

Wheeler predicts. Wheeler asked what quantum theory does to the geometry of space at the smallest scale, and his picture of the answer became the standard view. He held that the quantized geometry fluctuates, and that at the Planck length the fluctuations grow as large as the geometry itself, so that space there has the structure of a foam whose very topology changes from place to place (Wheeler 1957; Wheeler and Ford 1998). In 1989 one of his four refusals was "No continuum" (Wheeler 1990). Wheeler's foam named no rate at which its effects grow with distance. Later programs built models of it that do: light crossing a seething geometry over cosmological distances would gather a spread of phase, which would blur the images of the most distant sources, and in some models its speed would depend on its energy.

Where argued. The Unquantized Arena, Chapter 19, Section V (Prediction 19.4), and Chapter 6, Section IV; Two Theories, One World, Chapter 27; Incommensuration, Chapter 5, Section III. Two Theories, One World, Chapter 15, under the heading "Not a Least Length", meets the foam directly: "The

standard view, as many physicists state it, adds that space and time dissolve there into a foam of quantum fluctuations". Its answer: "The Planck length is the bound of every comparison made from a place inside the world, and the arena in which those comparisons are made has no least length, area or duration".

Measured. The sealed record reports that "the arrival of high-energy photons from gamma-ray bursts places any energy dependence of the first order above about ten times the Planck energy (LHAASO, Cao and others 2024)". Two Theories, One World, Chapter 15, sets out the burst GRB 090510, in which a photon "carrying about 31 billion electronvolts arrived within about a second of the low-energy light of the burst". For the blurring of images, Perlman and colleagues (2015) found that X-ray images of distant quasars from the Chandra telescope rule out the random-walk model of the foam, and that detections of distant quasars at billions and trillions of electronvolts appear to rule out the holographic model, the two models of most physical interest. Each of these measurements agrees with the collection's prediction. They exclude the models later built on Wheeler's foam; they do not reach his foam in the form he gave it, which named no rate of growth.

What decides it. In the sealed record's words: "The timing of photons of different energies from many sources, told apart from effects at the source by its growth with distance; every observation of the spectrum of area or volume". To these the blurring of the images of the most distant sources adds a direct test of any model of the foam that states its rate.

Wheeler 2. Quanta of the geometry itself

The collection predicts.

> No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter. A description of the small waves of the geometry by quanta holds below the Planck curvature, and its quanta are quanta of that description, never quanta of the arena. No measured cross section for the scattering of those waves that departs from the effective theory will agree with a calculation in which the metric is quantized beyond it. A detector that registers a gravitational wave in single clicks agrees with the account and does not show gravitation quantized.

Registered on 1 November 2026 as Prediction 3 of *The Registered Predictions of Physics from Comparison*.

Wheeler predicts. Wheeler, with Bryce DeWitt, gave the canonical program of quantum gravity its quantum form: the Hamiltonian form of general relativity, due to Dirac (1958) and to Arnowitt, Deser and Misner (1959; Misner was Wheeler's student), becomes in their hands a wave functional on superspace (DeWitt 1967). In that program the geometry of space is itself the quantum variable. The quantum state is a wave functional of the geometries of a slice of space; it satisfies the Wheeler–DeWitt equation; and superspace, the space of all such geometries, is the arena of the quantum dynamics (DeWitt 1967; Misner, Thorne and Wheeler 1973, Chapter 43). On this account the geometry carries quantum degrees of freedom of its own.

Where argued. The Unquantized Arena, Chapter 19, Section III (Prediction 19.2), and Chapter 9, Section III; the arena has no quantum of its own, The Unquantized Arena, Proposition 6.3; the Wheeler–DeWitt equation read as the arena put into the quantum state, The Unquantized Arena, Chapter 6, Section VI: "I read it as the category error in its plainest form. The context in which things happen has been put into the quantum state, instead of serving as the arena in which the state evolves".

Measured. The sealed record reports: "The first gravitational wave detected matched the classical waveform of general relativity (Abbott and others 2016); no graviton has been detected".

What decides it. A measured departure from the effective field theory of gravity, in the scattering of gravitational waves at curvatures near the Planck curvature, set beside a calculation in which the metric is quantized beyond

that theory; the collection predicts that no such departure will agree with such a calculation. No experiment now proposed reaches that regime. The sealed record says so in its Section IX, quoted in Section VI below: below the Planck curvature the two accounts give the same result for every experiment now proposed. At this date the difference stands, and no measurement is near it.

Wheeler 3. A flat space or a closed one

The collection predicts.

> The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}.

Registered on 1 November 2026 as Prediction 9 of *The Registered Predictions of Physics from Comparison*.

Wheeler predicts. Wheeler kept the question of the total mass of the universe before cosmology through the years when the mass that could be seen fell far short of it, and in doing so he helped to frame the problem of the missing mass (de Swart 2019). He held, for reasons he drew from Mach's principle, that the universe is closed: finite in volume and without boundary. He described Mach's principle as "conceived as the requirement that the universe be closed" (Wheeler 1962, as quoted by de Swart 2019), and in 1974 he pressed the case for closure again (Wheeler 1974). A closed universe has positive spatial curvature, which the curvature parameter shows as a value below zero.

Where argued. The Gravitational Passage, Chapter 18, Section IX, and Section XIII; The Compactification, Chapter 6, Section VI; At the Edge of Reality, Chapter 19, and Appendix B.

Measured. The sealed record reports: "$\Omega K = 0.001 \pm 0.002$, from the microwave background with baryon acoustic oscillations (Aghanim and others 2020)". The microwave background alone, in the Planck analysis of 2018, gave a best value of -0.0438, on the closed side, which Di Valentino, Melchiorri and Silk (2020) read as a preference for a closed universe at more than 99 percent confidence; adding the baryon acoustic oscillations brings the value to 0.0008 ($+0.0038$, -0.0037 at 95 percent confidence), flat. The value from the

microwave background alone leans toward Wheeler's closure; for the collection's prediction it is a measurement of interest, from one kind of measurement, and the two kinds together do not show closure. The second data release of DESI, with the microwave background, gives 0.0023 ± 0.0011 (DESI 2025, as reported by Chen and Zaldarriaga 2025): on the open side, at about two standard deviations from zero. That is a measurement of interest for the collection's prediction, short of the rule of decision, and it lies on the side away from closure.

What decides it. In the sealed record's words: "DESI and Euclid, which measure the curvature of space with the matter fraction. A curvature confirmed at the level of 10^{-3} refutes it". A curvature confirmed on the closed side at that level would show Wheeler's closure and refute the collection's prediction. A curvature consistent with zero at the precision of those surveys agrees with the collection and leaves open a closure too slight for any survey to reach; below that precision the two accounts are not told apart by measurement.

III. Where the Two Accounts Agree

Wheeler 4. Gravitation is the geometry: free fall and gravitational waves

The collection predicts.

> The Eötvös parameter, the fractional difference in the free fall of two materials, is zero for every pair of materials at every precision. Antimatter falls with the acceleration of matter. No arrangement of matter shields gravity, and nothing will be found that gravity leaves untouched.
>
> Gravitational waves carry the two polarizations of a massless field of spin two, and travel at the speed of light; no further polarization and no other speed will be found.

Registered on 1 November 2026 as Predictions 4 and 6 of *The Registered Predictions of Physics from Comparison*.

Wheeler predicts the same. Wheeler's geometrodynamics is the strongest statement ever made that gravitation is the geometry of spacetime, which he summed up in two clauses: spacetime tells matter how to move; matter tells spacetime how to curve (Wheeler and Ford 1998). In it every body falls alike,

and gravitational waves carry two polarizations and travel at the speed of light (Misner, Thorne and Wheeler 1973, Part VIII). **Where argued.** The Unquantized Arena, Chapter 19, Section IV (Prediction 19.3); Two Theories, One World, Chapter 9; The Gravitational Passage, Chapter 12, Section VII, and Chapter 16, Section V; The Compactification, Chapter 7, Section II. The View from Inside, Chapter 8, takes Wheeler's two clauses as its head. **Measured.** As the sealed record reports: MICROSCOPE finds the Eötvös parameter for titanium and platinum to be $[-1.5 \pm 2.3\ \text{(statistical)} \pm 1.5\ \text{(systematic)}] \times 10^{-15}$ (Touboul and others 2022); antihydrogen falls at $(0.75 \pm 0.13 \pm 0.16)$ g (Anderson and others 2023); GW170814 favors purely tensor polarization, and GW170817 bounds the difference between the speed of gravitational waves and the speed of light to between -3×10^{-15} and $+7 \times 10^{-16}$ of the speed of light (Abbott and others 2017). The standing in the sealed record is "agrees" for both.

Wheeler 5. The exterior of a black hole has no hair

The collection holds. The Gravitational Passage, Chapter 18, Section II: "The second fact is the no-hair theorem. The settled exterior of a black hole is determined entirely by its mass, charge and spin. Nothing else about the collapse that produced it can be registered from outside". The book takes this as a theorem of general relativity, whose field equations it derives in Chapter 12; the sealed record gives it no number of its own.

Wheeler predicts the same. Wheeler popularized the name black hole in 1967 and, with Remo Ruffini, gave this property its name: a black hole has no hair (Ruffini and Wheeler 1971). **Measured.** The ringdown of GW250114, observed on 14 January 2025, matches the dominant quadrupolar mode of a Kerr black hole and its first overtone, as the theorem requires (LIGO Scientific, Virgo and KAGRA Collaborations 2025); in the analysis that left the tones free, the frequency of the fundamental tone was measured to about two percent and its decay time to about nine percent, both in agreement with general relativity. **Standing.** Agrees as far as tested.

Wheeler 6. Gravitation entangles two masses

The collection predicts.

Two masses, each held in a superposition of two places and related only through gravitation, become entangled, with the phase of their Newtonian interaction. For the experiment proposed by Bose and colleagues (2017), two masses of 10^{-14} kilograms, each held in two places 250 micrometers apart, with centers 450 micrometers apart, for 2.5 seconds, the entangling phase is 0.314 radians; on that state the concurrence is 0.156 and the entanglement witness of Chevalier, Paige and Kim is -0.22. For any other design, the phase is the one the Newtonian interaction gives for that design's masses, distances and time.

Registered on 1 November 2026 as Prediction 1 of *The Registered Predictions of Physics from Comparison*.

Wheeler's program predicts the same outcome. The quantized geometry of the program Wheeler began, taken for the weak fields of a laboratory, is linearized quantum gravity, and the sealed record states that "below the Planck scale it does not separate the account from linearized quantum gravity, which gives the same phase". The two accounts predict the same entanglement for different reasons: on the collection's account each alternative of the matter carries its own geometry, and on Wheeler's the geometry is itself in a quantum state. Only a measurement near the Planck curvature could tell the two apart, as Wheeler 2 says. **Where argued.** The Unquantized Arena, Chapter 8, Sections II and III, and Chapter 19, Section II (Prediction 19.1); The Gravitational Passage, Chapter 12, Section VI; The Compactification, Chapter 8, Section XIII. **Measured.** The sealed record reports that no experiment has yet reported entanglement through gravitation alone, or its absence at a sensitivity that reaches this phase. **Standing.** Untested.

Wheeler 7. A phenomenon is closed only by an act

The collection predicts.

No mass, however large, no separation of two placements, however wide, and no length of time ends a superposition of its own accord; a superposition ends only through a finding, an interaction that registers which alternative is the case. The account allows no decoherence beyond the ordinary kind, which is a comparison made by some environment. For the masses of Prediction 1, the gravity-driven collapse of Diósi and Penrose gives a lifetime of about 0.012 seconds, against the 2.5 seconds the entangling phase needs.

Registered on 1 November 2026 as Prediction 2 of *The Registered Predictions of Physics from Comparison*.

Wheeler predicts the same. Wheeler insisted that "no elementary quantum phenomenon is a phenomenon until, in Bohr's words, 'It has been brought to a close' by 'an irreversible act of amplification'" (Wheeler 1990). His account names that act as what closes a phenomenon, and proposes no ending of a superposition by gravitation alone. The collection gives the act its structure: "Before a stopwatch is clicked, the race has no measured time. After the click, there is a before and an after that the record fixes, and the record will never be unclicked" (Causality Without Determinism, Chapter 4, Section IV). **Where argued.** The Unquantized Arena, Chapter 7, Sections V and VI, and Chapter 8, Section IV. **Measured.** As the sealed record reports: an underground search for the radiation that collapse noise would make has ruled out the version of the Diósi and Penrose model with no free parameter (Donadi and others 2021); versions with a larger effective size remain under test. **Standing.** Agrees as far as tested.

Wheeler 8. The delayed choice

The collection predicts.

Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights. The interference among three paths has no term that the pairs of paths do not account for. Tests of the CHSH inequality reach $2\sqrt{2}$ and go no further, and stay at 2 or below whenever either party's two observables commute. Experiments with independent sources find the complex, not the real, composition of independent systems.

> A finding changes no geometry, here or anywhere, and news of a distant finding enters a record only at an event on or within the future light cone of the finding. Until such a signal arrives, every local statistic follows quantum theory unchanged, whatever measurement was chosen far away. No signal crosses the boundary of comparison, and no body arrives somewhere that is not in its cone. The probabilities of a preparation's outcomes do not depend on which test is chosen later, and no later finding comes to precede an earlier one. Travel within the cone is not excluded, nor the recession of distant galaxies faster than light, which is a growth of the arena between them and not a signal across it.

Registered on 1 November 2026 as Predictions 25 and 27 of *The Registered Predictions of Physics from Comparison*.

Wheeler predicts the same. Wheeler proposed the delayed-choice experiment in 1978 and said what it would show: a single photon let into an interferometer gives interference when the second beam splitter is inserted after the photon has entered, and which-path behavior when it is withheld, as quantum theory says (Wheeler 1978). The experiment was performed with single photons by Jacques and colleagues in 2007, and the result was the one he gave. Later realizations, including delayed choice with entangled photons, found the same (Ma, Kofler and Zeilinger 2016). The credit for the experiment is Wheeler's. The two accounts read the result differently, and the difference of reading is set out in Section V; the statistics they predict are the same, and neither sends any signal backward in time. **Where argued.** The Quantum Passage, Appendix B, and Chapter 8, Section III; The Unquantized Arena, Chapter 7, Section IV (Proposition 7.2); Measurement, Chapter 14, Section IV; Why Time Travel Is Not a Concept, Chapter 4. **Measured.** The sealed record reports that "three-slit experiments find the third term consistent with zero (Sinha and others 2010); network experiments in 2022 found the complex composition (Chen and others; Li and others)", with the standing "agrees"; the delayed-choice experiment of Jacques and colleagues (2007) found what both accounts predict. **Standing.** Agrees.

IV. Predictions Stated Only in the Relation Essay

Wheeler 9. No mass made of geometry alone

The relation essay states. "A mass made of context alone would be the context taking the character of content, which the theorem excludes; mass needs a content as much as it needs the context in which it is weighed" (The Participant and the Act, Section VI). As a prediction: no lasting body whose mass is made of gravitational or electromagnetic waves held together by their own gravity alone, no geon, will be found.

Wheeler predicts. Wheeler built geons in 1955 as a model of mass made of geometry alone, and with Charles Misner he wrote of "mass without mass" and "charge without charge" (Wheeler 1955; Misner and Wheeler 1957). The model opened the study of self-gravitating waves.

Where argued. The books argue that mass is one relation of a content to its context, met as pattern, as inertia and as weight (Objections from Physics, Answered); no book of the collection argues the exclusion of geons, and the sealed record does not carry it. Stated in the relation essay; not argued in the books and not in the sealed record.

Measured. No geon has been found, and no search is aimed at one. **What decides it.** No measurement now made or proposed looks for a geon; the entry stands outside the sealed record, and a later dated report may register it.

V. Where No Measurement Decides

The differences in this section concern what a finding is, what an observer is, what a law is, and what comes first in the act of knowing. Falsification applies to a claim about which finding an act of comparison will return. It does not apply to a claim about the form that every act of comparison has, because every experiment is itself such an act, and carries that form in whatever outcome it returns. These claims are judged by whether they hold their own ground and by what follows from them; the measurable consequences that do follow from them are entered in Sections II to IV.

It from bit, and the act

A claim about what comes first in the act of knowing. Wheeler held that every it, "every particle, every field of force, even the spacetime continuum itself", derives its existence "from the apparatus-elicited answers to yes or no questions, binary choices, bits" (Wheeler 1990). The collection holds the bit with him: one comparison is one bit (Comparison; The Necessary Basis, Chapter 1, Section IV). It puts neither the it nor the bit first: every comparison is on something, "so a comparison with nothing to be about is no comparison" (Objections from Physics, Answered), and "Existence without any interaction is therefore non-existence" (The Quantum Passage, Chapter 4, Section V). Both come from the act, the it as the content met and the bit as the verdict given. One registered prediction stands near this difference, Prediction 29:

> For any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement, reaching below the rule's least step, tells the rule's statistics from the world's. The established findings of physics are reproduced at the foundation only by a theory of the conjugate kind.

Registered on 1 November 2026 as Prediction 29 of *The Registered Predictions of Physics from Comparison*.

It bears on any one fixed discrete rule offered as the foundation of physics. Wheeler's program offered no such rule, so at this date no measurement separates the two accounts here.

What an observer is

A description of what a thing is. Wheeler called the observer a participant, and the world a participatory universe. The collection defines the observer as "a comparer, a position inside the world, which a mind may occupy but which is not defined as a mind" (Comparison; The Necessary Basis, Chapter 1). It keeps its account of the kinds of particle apart from Wheeler's: what measurement finds at the microscopic limit "is not the observer effect, not the participatory universe of Wheeler, and not the it-from-bit program" (The Kinds of Particle).

What the delayed choice shows

A claim about the act of knowing. Wheeler read his experiment as showing that a choice made now decides what may be said about the photon's past. The collection reads it as a choice of which comparison is made: one that registers the photon's path, or one that registers the relation between its two paths. Until a comparison registers one or the other, neither is a fact, and no record already made is changed. The statistics both accounts predict are entered as Wheeler 8.

Law without law

A description of what a law is. Wheeler's refusals included "No laws", and his aim was to "derive everything from nothing, all law from no law". The collection places laws where they are found: "A law exists; a measurement is real" (Comparison; The Necessary Basis, Chapter 10, Section II). A law is what stays the same across acts of comparison, laid out from the acts; it is derived from the structure of comparison, which is more than nothing. The values that the collection takes from measurement are listed in Section VI.

The problem of time

A claim of logical form. The Wheeler–DeWitt equation contains no time parameter. On the collection's account the equation has no time because it treats the geometry, which is the arena in which states change, as one more quantum variable; with the arena inside the state, nothing is left outside it to mark time (The Unquantized Arena, Chapter 6, Section VI); on the canonical program it is a problem to be solved within the quantized geometry. The measurable part of this difference is entered as Wheeler 2.

The loop of three, held in common

A claim of logical form, shared. Wheeler's loop, in which physics gives rise to observer-participancy, observer-participancy gives rise to information, and information gives rise to physics, runs the cycle of the collection's second axiom in the same direction: "from the stance to the act, from the act to the laid-out

finding, and from the laid-out finding to a new stance" (Measurement, Chapter 4, Section VIII). It is entered here because the two accounts hold it in common and no measurement bears on it.

VI. What the Collection Does Not Predict Here

Three items of the sealed record's Section IX bear on the comparison with Wheeler. The first bears on the program of deriving all law from no law, since the collection takes these values from measurement:

> The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (*The Gravitational Passage*, Chapter 13; *The Strengths of the Kinds*, Chapter 1, Section VI; *The Measures of the Kinds*, Chapter 13, Section X).

The second bears on Wheeler 2 and Wheeler 6:

> Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed (*The Unquantized Arena*, Chapter 6, Section IV); a detection of single gravitons, or of a primordial background, would not show gravitation quantized (Chapter 9, Section III; Chapter 18, Section VI).

The third bears on Wheeler 5:

> The account asserts neither the return of the information that falls into a black hole formed from a star to the outside world, nor its loss to it (*The Unquantized Arena*, Chapter 17, Section VII); on the account of *The Gravitational Passage* that information is not destroyed, and re-emerges in the initial conditions of the next epoch (Chapter 18, Section XIII).

VII. The Record at Its Date

Entry	The collection	Wheeler	Measured	Standing
Wheeler 1. Smallest scale (Prediction 5)	no least length; the speed of light does not depend on energy	a foam at the Planck length; "No continuum"	any first-order energy dependence placed above about ten Planck energies; random-walk foam excluded, holographic foam appears excluded	agrees, for the collection; the later models of the foam tested are excluded, and the difference is untested for the foam in the form Wheeler gave it
Wheeler 2. Quanta of the geometry (Prediction 3)	no quantum of the arena	the geometry quantized (Wheeler–DeWitt)	no graviton; classical waveforms	agrees, for the collection; the difference is untested, and no experiment now proposed reaches it
Wheeler 3. Curvature (Prediction 9)	flat to order 10^{-5}	closed	0.001 ± 0.002 (2020); 0.0023 ± 0.0011 (2025)	agrees, for the collection; the difference is untested at the rule of decision, and the 2025 value is a measurement of interest at about two standard deviations, on the open side
Wheeler 4. Free fall; gravitational waves (Predictions 4, 6)	universal free fall; two polarizations at the speed of light	the same	as the sealed record reports	agrees
Wheeler 5. No hair (no number)	exterior fixed by mass, charge and spin	the same	GW250114 ringdown matches a Kerr black hole	agrees as far as tested
Wheeler 6. Entanglement through gravitation (Prediction 1)	yes; 0.314 rad for the 2017 design	the same phase	no result	untested
Wheeler 7. Closed by an act (Prediction 2)	no collapse from gravitation alone	closed by an irreversible act	the Diósi and Penrose version with no free parameter ruled out	agrees as far as tested

Entry	The collection	Wheeler	Measured	Standing
Wheeler 8. Delayed choice (Predictions 25, 27)	quantum statistics; no backward signal	the quantum result	Jacques and others 2007, and later realizations	agrees
Wheeler 9. No geon (relation essay only)	no mass of geometry alone	geons; mass without mass	none found; none sought	untested; outside the sealed record

Summary

Wheeler and the collection agree on most of what experiment has reached. Gravitation is the geometry of spacetime, every body falls alike, gravitational waves carry two polarizations at the speed of light, a black hole has no hair, a phenomenon is closed only by an act, and the delayed choice he proposed came out as quantum theory says; each of these stands confirmed or agrees as far as tested. Both predict that two masses will become entangled through gravitation with the same phase, and the experiment that will test it does not separate them. They predict differently in three places. At the smallest scale, the collection holds that the arena keeps no least length, and Wheeler held that it seethes as a foam; the measurements so far agree with the collection and exclude the models later built on the foam. The collection holds that the geometry carries no quanta of its own, and Wheeler's program quantizes it; no experiment now proposed reaches that difference. The collection predicts a space flat to the size of the primordial departures, and Wheeler held space to be closed; the measurements so far find it flat, with one measurement of interest on the closed side from the microwave background alone and one on the open side from DESI. One prediction, that no mass made of geometry alone will be found, rests only on the relation essay and stands outside the sealed record. The differences that go deepest, whether the bit comes before the it, what an observer is, what a law is, and how the delayed choice is read, are claims about the act of knowing, and the loop of three that Wheeler drew is held by both.

Key Concepts

- Wheeler and the collection agree that gravitation is the geometry of spacetime, that every body falls alike, and that gravitational waves carry two polarizations at the speed of light.
- The delayed-choice experiment Wheeler proposed in 1978 came out in 2007 as quantum theory says, and neither account sends any signal backward in time.
- At the smallest scale the collection predicts no least length where Wheeler saw a foam, and the measurements so far agree with the collection and exclude the models later built on the foam.
- The collection holds that the geometry carries no quanta of its own, while Wheeler's program quantizes it, and no experiment now proposed separates the two.
- The collection predicts a space flat to the size of the primordial departures where Wheeler held it closed, and the measurements so far find it flat.
- The exclusion of a mass made of geometry alone is stated only in the relation essay and stands outside the sealed record.
- Whether the bit comes before the it, what an observer is and what a law is are claims about the act of knowing, which no experiment decides.

Terms

Arena. The context of physics, the geometry of space and time within which content is found; on this account, what gravitation is.

Baryon acoustic oscillations. A length imprinted in the distribution of galaxies by sound waves in the early universe, measured at many distances to trace the expansion.

Born rule. The rule that the probability of a finding is the square of the magnitude of its amplitude.

Canonical quantum gravity. The program that writes general relativity in the Hamiltonian form of Dirac and of Arnowitt, Deser and Misner, and, in the quantum form DeWitt and Wheeler gave it, quantizes the geometry of space directly.

CHSH inequality. The inequality of Clauser, Horne, Shimony and Holt, a sum of four correlations between two parties that is at most 2 for any local account of hidden variables.

Concurrence. A measure of the entanglement of two spins: zero for every unentangled state, and at most one.

Content and context. In every comparison, what is found and the arena it is found in; in physics, quantum matter and the geometry of general relativity.

Curvature parameter. The share of the expansion rate that the curvature of space accounts for; zero for a flat space, below zero for a closed space, above zero for an open one.

Delayed-choice experiment. Wheeler's experiment in which the choice of what to measure on a photon is made after it has entered the apparatus.

Effective field theory of gravity. The description of small waves of the geometry, about a smooth background, by quanta, valid below the Planck curvature.

Entanglement witness. A quantity whose value beyond a stated threshold is possible only for an entangled state.

Eötvös parameter. The fractional difference between the accelerations of two bodies of different composition in free fall.

Geon. Wheeler's model of a mass made of electromagnetic or gravitational waves held together by their own gravity.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

It from bit. Wheeler's program of deriving every physical thing from the answers to yes-or-no questions.

Linearized quantum gravity. The effective field theory of gravity taken for weak fields.

Light cone. The events that a signal at the speed of light can reach from a given event, or from which it can be reached.

Measurement of interest. A measurement that differs from a prediction by less than the rule of decision requires.

No-hair theorem. The theorem that the settled exterior of a black hole is fixed by its mass, charge and spin alone.

Planck length, Planck curvature. The scale at which an object's gravitational size equals its quantum size; on this account a bound on how sharply a comparison made from inside the world can place a body, not a least length.

Ringdown. The settling of a black hole formed in a merger, heard as a set of decaying tones whose frequencies and decay times its mass and spin fix.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Spacetime foam. Wheeler's picture of the quantized geometry at the Planck length, where fluctuations grow as large as the geometry and its topology changes.

Standard deviation. The measure of the uncertainty of a measurement; a difference of five standard deviations is the usual threshold for a discovery in physics.

Superdeterminism. A deterministic completion of quantum mechanics in which the settings of an experiment are fixed together with the states of what is measured, so that statistical independence fails; the settings and the systems measured share a common cause, so that the choice of what to measure is not free of what is measured.

Superspace. The space of all geometries of a slice of space, the arena of the dynamics in canonical quantum gravity.

Wheeler–DeWitt equation. The equation of canonical quantum gravity, in which the quantum state of the geometry of space satisfies the Hamiltonian constraint and contains no time.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Participant and the Act; John Archibald Wheeler and Physics from Comparison*. Relation essay, 2026; the chapter of that title in Volume Two of this book.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-075-6. DOI: https://doi.org/10.67291/FVTH8832.

Landry, Forrest. *Comparison; The Necessary Basis*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-062-6. DOI: https://doi.org/10.67291/MOAS1658.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *Incommensuration; The Theorem and the Three Axioms*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-063-3. DOI: https://doi.org/10.67291/ARTV2404.

Landry, Forrest. *The Kinds of Particle*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-060-2. DOI: https://doi.org/10.67291/CEUK-2585.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Objections from Physics, Answered; The Identifications of Physics from Comparison, Step by Step*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/UEEI5258.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The View from Inside*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-074-9. DOI: https://doi.org/10.67291/HGNK5132.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Arnowitt, R., Deser, S. and Misner, C. W. (1959). "Dynamical structure and definition of energy in general relativity". *Physical Review* 116, 1322–1330.

Chen, S.-F. and Zaldarriaga, M. (2025). "It's All Ok: Curvature in Light of BAO from DESI DR2". arXiv:2505.00659.

de Swart, J. (2019). "Closing in on the Cosmos: Cosmology's Rebirth and the Rise of the Dark Matter Problem". arXiv:1903.05281.

DESI Collaboration (2025). "DESI DR2 Results II: Measurements of Baryon Acoustic Oscillations and Cosmological Constraints". arXiv:2503.14738.

DeWitt, B. S. (1967). "Quantum theory of gravity. I. The canonical theory". *Physical Review* 160, 1113–1148.

Di Valentino, E., Melchiorri, A. and Silk, J. (2020). "Planck evidence for a closed Universe and a possible crisis for cosmology". *Nature Astronomy* 4, 196–203.

Dirac, P. A. M. (1958). "The theory of gravitation in Hamiltonian form". *Proceedings of the Royal Society of London A* 246, 333–343.

Jacques, V., Wu, E., Grosshans, F., Treussart, F., Grangier, P., Aspect, A. and Roch, J.-F. (2007). "Experimental realization of Wheeler's delayed-choice gedanken experiment". *Science* 315, 966–968.

LIGO Scientific, Virgo and KAGRA Collaborations (2025). "GW250114: Testing Hawking's Area Law and the Kerr Nature of Black Holes". *Physical Review Letters* 135, 111403.

Ma, X.-S., Kofler, J. and Zeilinger, A. (2016). "Delayed-choice gedanken experiments and their realizations". *Reviews of Modern Physics* 88, 015005.

Misner, C. W., Thorne, K. S. and Wheeler, J. A. (1973). *Gravitation*. San Francisco: W. H. Freeman.

Misner, C. W. and Wheeler, J. A. (1957). "Classical physics as geometry". *Annals of Physics* 2, 525–603.

Perlman, E. S., Rappaport, S. A., Christiansen, W. A., Ng, Y. J., DeVore, J. and Pooley, D. (2015). "New constraints on quantum gravity from X-ray and gamma-ray observations". *The Astrophysical Journal* 805, 10.

Ruffini, R. and Wheeler, J. A. (1971). "Introducing the black hole". *Physics Today* 24(1), 30–41.

Wheeler, J. A. (1955). “Geons”. *Physical Review* 97, 511–536.

Wheeler, J. A. (1957). “On the nature of quantum geometrodynamics”. *Annals of Physics* 2, 604–614.

Wheeler, J. A. (1962). “The universe in the light of general relativity”. *The Monist* 47(1), 40–76.

Wheeler, J. A. (1974). “The universe as home for man”. *American Scientist* 62(6).

Wheeler, J. A. (1978). “The ‘past’ and the ‘delayed-choice’ double-slit experiment”. In A. R. Marlow (ed.), *Mathematical Foundations of Quantum Theory*, 9–48. New York: Academic Press.

Wheeler, J. A. (1990). “Information, physics, quantum: the search for links”. In W. H. Zurek (ed.), *Complexity, Entropy and the Physics of Information*. Redwood City, California: Addison-Wesley. (First given at the 3rd International Symposium on Foundations of Quantum Mechanics, Tokyo, 1989.)

Wheeler, J. A. and Ford, K. (1998). *Geons, Black Holes, and Quantum Foam: A Life in Physics*. New York: W. W. Norton.

Measurements cited from the sealed record are cited as it cites them, by author and year; the full entries are in the bibliographies of the books it names.

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Appendix C

The Registered Predictions Beside Julian Barbour

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Julian Barbour. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *Janus and the Turn; Julian Barbour, the Arrow of Time and Physics from Comparison*.

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Abstract

Julian Barbour and the physics collection of the Immanent Metaphysics agree on more than either agrees with the usual account of time in physics, and most of what divides them is a matter of what time is, which no measurement reaches. This record sets out, with the date, where the two accounts make claims that measurement can test. Three of the collection's registered predictions are predictions Barbour's work also makes: gravitational waves travel at the speed of light, which Barbour and his colleagues derived from best matching in 2002; free fall is universal; and no superposition ends through gravitation alone. Each agrees with every measurement made. One registered prediction parts from Barbour's account: the collection holds that gravitation is not quantized, and Barbour's timeless quantum universe is a wave function over configurations that include the geometry of space. No experiment now proposed separates the two, and the record says so. Five further differences are differences of kind: whether time is real, how the timeless equation of quantum gravity is to be read, what the Janus point and the turn are, what the laws must contain for

time to have a direction, and what lies at the end of a black-hole interior. The record names each one and the kind of claim it is, and invents no test for any of them.

I. What This Record Is

This record sets the registered predictions of physics from comparison beside the claims of Julian Barbour's physics: the dynamics of best matching that he built with Bruno Bertotti (1982), his account of time in *The End of Time* (1999), the gravitational arrow of time that he found with Tim Koslowski and Flavio Mercati (2014), and its development in *The Janus Point* (2020). It takes the collection's predictions from the sealed record of 1 November 2026 and quotes each one in full, with its number there. It takes Barbour's claims from his own works, cited at each entry.

The sealed record fixes what counts as a result: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement". A measurement short of that is a measurement of interest. Every prediction of the collection stated here is argued in a book of the collection, named at its chapter and section; none is stated only in the relation essay.

This record belongs to a comparative and retrospective collection, and the dates of the work are part of the comparison. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. The Incommensuration Theorem is a structural fact about the nature of knowing. Barbour's best matching dates from 1982 and his account of timelessness from 1999, and the record credits each result to him at its date.

II. Where the Two Accounts Predict Differently

Barbour 1. Whether the geometry of space carries quantum degrees of freedom of its own

The collection predicts. "No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter. A description of the small waves of the geometry by quanta holds below the Planck curvature, and its quanta are quanta of that description, never quanta of the arena. No measured cross section for the scattering of those waves that departs from the effective theory will agree with a calculation in which the metric is quantized beyond it. A detector that registers a gravitational wave in single clicks agrees with the account and does not show gravitation quantized". Registered on 1 November 2026 as Prediction 3 of The Registered Predictions of Physics from Comparison.

Barbour predicts. The universe as a whole is quantum. In *The End of Time* (1999) its state is a wave function on Platonia, the space of all configurations of the universe, and for a universe governed by Einstein's theory those configurations include the geometry of space. The equation that governs the wave function is of the kind of the Wheeler–DeWitt equation of canonical quantum gravity, which has no time in it; Barbour writes that "quantum cosmology will have no dynamics. It will be timeless" (1999). On that account the geometry of space carries quantum degrees of freedom of its own, as every configuration variable of a quantum universe does.

Where argued. The Unquantized Arena, Chapter 19, Section III (Prediction 19.2), and Chapter 9, Section III; The Gravitational Passage, Chapter 12, Questions; The Branches of the Kinds, Chapter 4, Section III. The reading of the Wheeler–DeWitt equation as the arena put into the quantum state is in The Unquantized Arena, Chapter 6.

Measured. As the sealed record reports it: "The first gravitational wave detected matched the classical waveform of general relativity (Abbott and others 2016); no graviton has been detected".

What decides it. The sealed record names no coming measurement for this prediction. It states, in its Section IX, that below the Planck curvature the collection and the effective field theory of gravity give the same result for

every experiment now proposed, and that a detection of single gravitons would not show gravitation quantized. A finding that decides between the two accounts is one that shows the geometry carrying quantum degrees of freedom beyond those tied to the alternatives of the matter, which the collection predicts will never be made. The entanglement of two masses through gravitation (Prediction 1) does not decide it: the collection predicts that entanglement, and a quantized geometry predicts the same phase.

Barbour's recent work with Maria Lourenço and Francisco Lobo relates the clustering of bodies in the Newtonian problem of many bodies to the filaments of the cosmic web (Lourenço, Barbour and Lobo 2026; Barbour, Lobo and Lourenço 2026). The work states no measured quantity, so the record sets no entry beside the collection's predictions of the primordial departures and the amplitude of clustering (Predictions 12 and 18); a comparison of predictions needs a number, or a kind of finding, from each side.

III. Where the Two Accounts Agree

Barbour 2. Gravitational waves travel at the speed of light

The collection predicts. "Gravitational waves carry the two polarizations of a massless field of spin two, and travel at the speed of light; no further polarization and no other speed will be found". Registered on 1 November 2026 as Prediction 6 of The Registered Predictions of Physics from Comparison.

Barbour predicts. Barbour, Brendan Foster and Niall Ó Murchadha derived from best matching, in 2002, that every scalar and vector field it treats must share the characteristic speed of gravity: "Thus Einstein causality emerges". The result came from Barbour's program and is credited to it at its date. Their work fixes the speed; it does not take up the count of polarizations, so the agreement is on the speed.

Where argued. The Gravitational Passage, Chapter 12, Section VII, and Chapter 16, Section V; The Unquantized Arena, Chapter 19, Section V; The Compactification, Chapter 7, Section II.

Measured. As the sealed record reports it: "The three-detector event GW170814 favors purely tensor polarization; GW170817 with its gamma-ray burst bounds the difference between the speed of gravitational waves and the speed of light to between -3×10^{-15} and $+7 \times 10^{-16}$ of the speed of light (Abbott and others 2017)".

Barbour 3. Free fall is universal

The collection predicts. "The Eötvös parameter, the fractional difference in the free fall of two materials, is zero for every pair of materials at every precision. Antimatter falls with the acceleration of matter. No arrangement of matter shields gravity, and nothing will be found that gravity leaves untouched". Registered on 1 November 2026 as Prediction 4 of The Registered Predictions of Physics from Comparison.

Barbour predicts. General relativity fits the pattern of best matching, given the thin-sandwich conjecture (Barbour and Bertotti 1982), and was later derived from a relational starting point of the same kind (Barbour, Foster and Ó Murchadha 2002); in it free fall is universal and nothing shields gravity. Barbour, Foster and Ó Murchadha (2002) found that self-consistency requires of any field of the vector kind "Einstein causality, the equivalence principle" and the Gauss constraint.

Where argued. The Unquantized Arena, Chapter 19, Section IV (Prediction 19.3); Two Theories, One World, Chapter 9.

Measured. As the sealed record reports it: MICROSCOPE, titanium and platinum, $[-1.5 \pm 2.3$ (statistical) ± 1.5 (systematic)$] \times 10^{-15}$ (Touboul and others 2022); antihydrogen falls toward the Earth at $(0.75 \pm 0.13 \pm 0.16)$ g (ALPHA-g, Anderson and others 2023); no shielding, with an absorption coefficient of $(3 \pm 5) \times 10^{-23}\ \mathrm{cm}^2\ \mathrm{g}^{-1}$ (Williams, Turyshev and Boggs 2009).

Barbour 4. Gravitation alone ends no superposition

The collection predicts. "No mass, however large, no separation of two placements, however wide, and no length of time ends a superposition of its own accord; a superposition ends only through a finding, an interaction that registers which alternative is the case. The account allows no decoherence beyond the ordinary kind, which is a comparison made by some environment.

For the masses of Prediction 1, the gravity-driven collapse of Diósi and Penrose gives a lifetime of about 0.012 seconds, against the 2.5 seconds the entangling phase needs". Registered on 1 November 2026 as Prediction 2 of The Registered Predictions of Physics from Comparison.

Barbour predicts. Barbour's quantum universe has no collapse. *The End of Time* (1999) reads quantum theory in a way of the many-worlds kind, and draws on John Bell's "Quantum mechanics for cosmologists" (1981), which Barbour finds close to his own account in all but its view of time. Nothing in that account ends a superposition through gravitation. The two accounts part on whether a superposition ends at all, since in a reading of the many-worlds kind none does; the agreement is that gravitation alone ends none.

Where argued. The Unquantized Arena, Chapter 7, Sections V and VI, and Chapter 8, Section IV.

Measured. As the sealed record reports it: "An underground search for the radiation that collapse noise would make has ruled out the version of the Diósi and Penrose model with no free parameter (Donadi and others 2021); versions with a larger effective size remain under test".

The two accounts also agree on claims of kind that no measurement reaches, and Section V sets them beside the differences: inertia is a comparison, and a frame is a frame only through content there to compare against; time is not a container given before the happenings in it; the arrow of time does not wait on a special condition placed at a beginning; and every record is a record of the past.

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction that the books do not argue and the sealed record does not carry.

V. Where No Measurement Decides

The differences of this section concern what a thing is, what form a law must take, or what the act of knowing contains. A measurement is itself an act of comparison, and both accounts read every finding alike: the same positions, the same records, the same clocks. Where two accounts agree on every find-

ing and part on what findings are, or on what a law must hold, no finding chooses between them. Falsification applies to claims about what findings will be; it does not apply to these, and the record invents no test for them.

Whether time is real

This is a description of what a thing is. Barbour holds that the universe is a collection of instants, each a complete configuration, and that time as something flowing is an illusion carried by time capsules, the structures within an instant that encode a history (1999). The collection holds that "A law exists; a measurement is real", that what exists, laid out as structure, and what is real, given in an actual act of comparison, each need the other (Comparison, Chapter 10, Section II), and that time is one triple of geometric time, event time and evolution time (Measurement, Chapter 12, Section III). Any measurement that bears on the question is an act of comparison that leaves a record, and Barbour reads that record as a time capsule within one instant. No finding separates the two readings.

The timeless equation

This is a claim of logical form. Barbour took the absence of time from the Wheeler–DeWitt equation as support for a world without time. The collection reads that absence as the product of a category error: "The context in which things happen has been put into the quantum state, instead of serving as the arena in which the state evolves" (The Unquantized Arena, Chapter 6). The measurable side of this difference is Barbour 1; the reading of the equation is not measured.

The Janus point and the turn

This is a description of what a thing is. Barbour's Janus point is the configuration of least complexity within one solution of the gravitational problem of many bodies, from which complexity grows in both directions, so that observers on either side have their past toward it (Barbour, Koslowski and Mercati 2014; Barbour 2020). The collection's turn is the passage from the end of one epoch to the beginning of the next, at the end of the black-hole interiors; no comparison registers it as an event, and the cycle of epochs has no first

turn (The Compactification, Chapter 1, Section V). Each is the point from which an arrow of time runs, in a state of least structure: for Barbour the configuration of least complexity, and for the collection the passage between epochs, after which the new epoch begins even, with no clumping of its geometry carried from before, up to the small departures the theorem requires (The Compactification, Chapter 3, Section VI). No record reaches the far side of either: Barbour's observers see only the records of their own half, and the collection's new epoch carries no record of the last. Neither account computes a finding on the far side, and the sealed record states that the dynamics of the transition between epochs are not computed (Section VI below).

What the laws must contain for time to have a direction

This is a claim of logical form, about what a law must hold. Barbour's account needs no asymmetry of time in the laws: his model law treats past and future alike, and the arrow comes from the solution (Barbour, Koslowski and Mercati 2014). The collection holds that the arrow is present in a single comparison and that some asymmetry of time must exist in the laws. The sealed record states: "No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one". Registered on 1 November 2026 as Prediction 28 of The Registered Predictions of Physics from Comparison, argued in The Basis of Physics, Essays 9 and 11; Measurement, Chapter 14, Sections II and III; Why Time Travel Is Not a Concept, Chapter 5, Sections III to V. The sealed record reports the measurements that bear on the asymmetry: "Violations of CP (1964) and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry". Those violations are what the collection requires, and Barbour's model neither requires them nor is troubled by them, since it

asks only that a symmetric law be enough for an arrow. The two accounts part on what a law must hold, which no measured violation, and no measured absence of one, can settle.

The end of a black-hole interior

This is a description of what a thing is. In shape dynamics, the program Barbour founded and developed with Henrique Gomes, Sean Gryb and Tim Koslowski, the spherically symmetric solution corresponding to a black hole is a wormhole with no singularity, a case in which shape dynamics and general relativity part (Gomes 2014); in the same program the big bang of a simple cosmological model is a regular point of the relational evolution, which continues through it (Koslowski, Mercati and Sloan 2018). The collection holds that at the end of every black-hole interior the conditions that hold the six internal dimensions compact fail, and the ten-dimensional geometry restores a context, which is the Big Bang of the next epoch (The Compactification, Chapter 1, Section V; At the Edge of Reality, Chapter 13). Outside the horizon both agree with general relativity. Within it no finding returns to an observer outside.

VI. What the Collection Does Not Predict Here

Four items of the sealed record's Section IX bear on this comparison, and are quoted in full.

"The size of the asymmetry of time is not predicted, only that it exists (The Basis of Physics, Essay 11, Section VII)".

"The dynamics of the transition between epochs, and how the gyrations are made at the turn, are not computed (The Weight of Possibility, Chapter 6)".

"Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed (The Unquantized Arena, Chapter 6, Section IV); a detection of single gravitons, or of a primordial background, would not show gravitation quantized (Chapter 9, Section III; Chapter 18, Section VI)".

"The account asserts neither the return of the information that falls into a black hole formed from a star to the outside world, nor its loss to it (The Unquantized Arena, Chapter 17, Section VII); on the account of The Gravitational Passage that information is not destroyed, and re-emerges in the initial conditions of the next epoch (Chapter 18, Section XIII)".

The first bears on the arrow of time, where Barbour's account also gives no size for the asymmetry, since it sets none in the law. The second bears on the turn beside the Janus point. The third bears on Barbour 1. The fourth bears on the end of a black-hole interior.

VII. The Record at Its Date

Entry	The collection	Barbour	Measured	Standing
Barbour 1 (Prediction 3)	The geometry carries no quantum degrees of freedom of its own	A quantum universe; the geometry among the quantized configurations	Classical waveform; no graviton detected	Agrees, for the collection; the difference is untested, and no experiment now proposed reaches it
Barbour 2 (Prediction 6)	Two polarizations; speed of light	Speed of light (2002)	Tensor favored; speed within 10^{-15}	Agrees
Barbour 3 (Prediction 4)	Universal free fall; no shield	General relativity recovered; the equivalence principle required	$[-1.5 \pm 2.3 \pm 1.5] \times 10^{-15}$	Agrees

Entry	The collection	Barbour	Measured	Standing
Barbour 4 (Prediction 2)	No collapse or decoherence from gravity alone	No collapse	The version of the Diósi and Penrose model with no free parameter ruled out	Agrees as far as tested

Summary

Julian Barbour and the collection stand together on most of what can be measured where their accounts meet. Gravitational waves travel at the speed of light, which Barbour and his colleagues derived from best matching in 2002; free fall is universal; and no superposition ends through gravitation alone. Each of these is a registered prediction of the collection, and each agrees with every measurement made. They part, where measurement could in principle reach, on one registered prediction: the collection holds that the geometry carries no quantum degrees of freedom of its own, and Barbour's quantum universe is a wave function over configurations that include it. No experiment now proposed separates the two, and the sealed record says so. The rest of what divides them is a difference of kind: whether time is real, how the timeless equation is to be read, what the Janus point and the turn are, what the laws must hold for time to have a direction, and what ends a black-hole interior. For each the record names the kind of claim it is. The two accounts also share claims of kind: inertia is a comparison, the arrow of time does not wait on a special beginning, and every record is a record of the past.

Key Concepts

- The rule of decision: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.
- Three registered predictions, Predictions 2, 4 and 6, are shared with Barbour's account, and each agrees with every measurement made.
- One registered prediction, Prediction 3, parts from Barbour's quantum universe; no experiment now proposed separates them.
- Barbour and his colleagues derived the shared speed of gravity and light from best matching in 2002.
- Whether time is real, and what the Janus point and the turn are, are differences of kind; no finding chooses between them.
- The measured violations of time reversal are what the collection requires; Barbour's model asks only that a symmetric law be enough.

Terms

Arena. The context of physics, the geometry of space and time within which content is found; on the collection's account, what gravitation is.

Best matching. Barbour and Bertotti's method of comparing two configurations by shifting and turning one against the other until their difference is least, and building dynamics from what remains.

Canonical quantum gravity. The quantization of general relativity in which the geometry of space is the configuration variable; its central equation is the Wheeler–DeWitt equation.

Collapse. An ending of a superposition proposed as a new physical process, as in the model of Diósi and Penrose, in which gravity itself ends it.

Effective field theory of gravity. The description of small waves of the geometry by quanta, valid below the Planck curvature.

Equivalence principle. The principle that every body and every field responds to gravity in the same way, so that free fall is universal.

Eötvös parameter. The fractional difference between the accelerations of two bodies of different composition in free fall.

Event time, evolution time, geometric time. The order of findings; the parameter of the smooth evolution of a quantum state; time laid out as one structure in the metric. The collection holds the three as one triple.

Epoch. One stage in the cycle of the universe, from one turn to the next.

Exist and real. To exist is to stand as structure, timeless and laid out; to be real is to be given in an actual act of comparison, now.

Gyration. The unit of the dark matter on the collection's account: a conserved excitation of the six held internal dimensions, of about the Planck mass.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Janus point. In Barbour's account, the configuration of least complexity in a typical solution of the gravitational problem of many bodies, from which complexity grows in both directions.

Planck curvature. The curvature whose radius is the Planck length, the scale at which an object's gravitational size equals its quantum size; it is not a least length.

Platonia. Barbour's name for the space of all possible configurations of the universe.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Shape dynamics. A reformulation of general relativity, developed in Barbour's program, in which only the shapes of configurations carry physical meaning.

Six internal dimensions. The internal space $\mathbb{C}P^2 \times S^2$, a complex projective plane and a sphere, held compact; on the collection's account they are the range from which each finding is one selection, and nothing travels through them.

Superposition. A quantum state that is a sum of alternatives, each with a complex weight.

Time capsule. In Barbour's account, a structure within one instant, such as a fossil or a record, that encodes a coherent history.

Turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

Wheeler–DeWitt equation. The central equation of canonical quantum gravity; it contains no time parameter.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *Janus and the Turn; Julian Barbour, the Arrow of Time and Physics from Comparison*. Relation essay, 2026; the chapter of that title in Volume Two of this book.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *The Branches of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-077-0. DOI: https://doi.org/10.67291/DOYL4735.

Landry, Forrest. *Comparison; The Necessary Basis*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-062-6. DOI: https://doi.org/10.67291/MOAS1658.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Barbour, J. (1999). *The End of Time: The Next Revolution in Our Understanding of the Universe*. London: Weidenfeld and Nicolson; Oxford: Oxford University Press.

Barbour, J. (2020). *The Janus Point: A New Theory of Time*. New York: Basic Books; London: The Bodley Head.

Barbour, J. and Bertotti, B. (1982). "Mach's principle and the structure of dynamical theories". *Proceedings of the Royal Society of London A* 382, 295–306.

Barbour, J., Foster, B. Z. and Ó Murchadha, N. (2002). "Relativity without relativity". *Classical and Quantum Gravity* 19, 3217. DOI 10.1088/0264-9381/19/12/308. arXiv:gr-qc/0012089.

Barbour, J., Koslowski, T. and Mercati, F. (2014). "Identification of a gravitational arrow of time". *Physical Review Letters* 113, 181101. arXiv:1409.0917.

Barbour, J., Lobo, F. S. N. and Lourenço, M. I. R. (2026). "Structural morphology and the gravitational arrow of time". arXiv:2607.27526.

Bell, J. S. (1981). "Quantum mechanics for cosmologists". In C. J. Isham, R. Penrose and D. W. Sciama (eds.), *Quantum Gravity 2: A Second Oxford Symposium*. Oxford: Clarendon Press.

Gomes, H. (2014). "A Birkhoff theorem for shape dynamics". *Classical and Quantum Gravity* 31, 085008. DOI 10.1088/0264-9381/31/8/085008. arXiv: 1305.0310.

Koslowski, T. A., Mercati, F. and Sloan, D. (2018). "Through the big bang". *Physics Letters B* 778. DOI 10.1016/j.physletb.2018.01.055. arXiv:1607.02460.

Lourenço, M. I. R., Barbour, J. and Lobo, F. S. N. (2026). "Scale invariance, variety and central configurations". arXiv:2602.11225.

Perkowitz, S. (2022). "How entropy might increase backwards in time, as well as forwards" (review of *The Janus Point*). *Physics World*, 25 January 2022.

The measurements are cited as the sealed record cites them, by author and year: Abbott and others (2016; 2017); Anderson and others (ALPHA-g, 2023); CPLEAR (1998); BaBar (2012); Donadi and others (2021); Touboul and others (2022); Williams, Turyshev and Boggs (2009). Their full entries are in the bibliographies of the books named at each entry.

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Appendix D

The Registered Predictions Beside Lee Smolin

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Lee Smolin. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *Time Is Real; Lee Smolin and Physics from Comparison*.

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Abstract

Lee Smolin's work makes predictions that measurement could reach in principle on four fronts: the discrete values of area and volume in loop quantum gravity; a dependence of the speed of light on its energy at the Planck scale, which his work holds open and sets out how to find; departures from the statistics of quantum mechanics for states that have few copies in the universe or no precedent; and the motions of galaxies at low acceleration, read as a regime of quantum gravity. On each, the physics collection of the Immanent Metaphysics makes a prediction registered on 1 November 2026 that differs from his: the arena has no least length, area or duration, and light of every energy travels at one speed (Prediction 5); repeated measurements settle to the weights of the Born rule in every sector (Prediction 25); and a galaxy feels the field of a larger one only through its tide (Prediction 24). The timing of light from distant bursts stands with the collection above about ten times the Planck energy, and every test of the Born weights so far agrees with it; the other two are not yet decided by the rule of decision. The two accounts agree that some asymmetry of time is in the laws (Prediction 28). Their deepest differences, whether the laws change, whether universes form a population that inherits its constants, and whether time is prior to space, are differences of kind that no measurement reaches, and

the record names them as such. Smolin's prediction of a ceiling on the mass of neutron stars is one the collection does not make; the record states it, with the measurement that bears on it, and counts it neither for nor against the collection.

I. What This Record Is

This record sets two bodies of prediction side by side: the predictions of the books of physics from comparison, as the sealed record of 1 November 2026 states them, and the predictions of Lee Smolin's program, as his own papers and books state them. Where the two say different things about what a measurement will find, the record states both, the measurement made so far, and the measurement that decides. Where they agree, it says so. Where they differ in a way no measurement reaches, it names the kind of claim each is.

The rule of decision is the sealed record's: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such".

Every prediction of the collection stated here is argued in a book named at its chapter and section, and carried in the sealed record under its number; Section IV is kept for any prediction stated only in the relation essay, and there is none. The ground of the collection is the Incommensuration Theorem, with the three axioms that follow from it. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

II. Where the Two Accounts Predict Differently

Smolin 1. Discrete area and volume

The collection predicts. "The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else. Discreteness belongs to the content, the charges and the kinds of particle, and the account predicts it there". Registered on 1 November 2026 as Prediction 5 of *The Registered Predictions of Physics from Comparison*. The same step of the account carries two further predictions. "No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter. A description of the small waves of the geometry by quanta holds below the Planck curvature, and its quanta are quanta of that description, never quanta of the arena. No measured cross section for the scattering of those waves that departs from the effective theory will agree with a calculation in which the metric is quantized beyond it. A detector that registers a gravitational wave in single clicks agrees with the account and does not show gravitation quantized". Registered on 1 November 2026 as Prediction 3. "For any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement, reaching below the rule's least step, tells the rule's statistics from the world's. The established findings of physics are reproduced at the foundation only by a theory of the conjugate kind". Registered on 1 November 2026 as Prediction 29.

Smolin predicts. In loop quantum gravity, which Smolin helped to found, the area of every surface and the volume of every region take separate, discrete values, labeled by spin networks; Carlo Rovelli and Smolin computed these spectra in 1995 and call them predictions for hypothetical measurements of the geometry of space at the Planck scale (Rovelli and Smolin 1995). On that program the geometry carries quantum degrees of freedom of its own.

Where argued. The Unquantized Arena, Chapter 19, Section V (Prediction 19.4), and Chapter 6, Section IV (Proposition 6.3); Two Theories, One World, Chapter 27; Incommensuration, Chapter 5, Section III. For Prediction 3: The

Unquantized Arena, Chapter 19, Section III (Prediction 19.2), and Chapter 9, Section III; The Gravitational Passage, Chapter 12, Questions; The Branches of the Kinds, Chapter 4, Section III. For Prediction 29: The Unquantized Arena, Chapter 3, Sections II and VI; The Basis of Physics, Essay 18, Section VII; Measurement, Chapter 8, Section VIII. The Unquantized Arena answers the program where it rests, in Chapter 4, Section III: "The spectra are spectra of operators defined after the arena has been quantized".

Measured. The first gravitational wave detected matched the classical waveform of general relativity, and no graviton has been detected (Abbott and others 2016, as the sealed record reports). No observation of a discrete spectrum of area or volume has been reported.

What decides it. In the sealed record's words, "every observation of the spectrum of area or volume". The sealed record also states where the decision lies: "Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed". So the two accounts are separated by a measurement of geometry that reaches the Planck scale, and not by any experiment now proposed.

Smolin 2. The speed of light at every energy

The collection predicts. "The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else. Discreteness belongs to the content, the charges and the kinds of particle, and the account predicts it there". Registered on 1 November 2026 as Prediction 5 of *The Registered Predictions of Physics from Comparison*.

Smolin predicts. Smolin's work holds open a dependence of the speed of light on its energy at the Planck scale, arising from a broken or deformed symmetry of spacetime, and sets out how to find it. With Giovanni Amelino-Camelia he examined how the highest-energy photons that the Fermi telescope records from gamma-ray bursts can measure or bound such a dependence, proposed bounds that assume little about the sources, and proposed a search for photons and neutrinos of still higher energy from the bursts, whose arrival would be delayed or advanced by days to months (Amelino-Camelia

and Smolin 2009). Many models of a granular arena make light of different energies travel at different speeds; the collection's prediction is that none does.

Where argued. The Unquantized Arena, Chapter 19, Section V (Prediction 19.4), and Chapter 6, Section IV; Two Theories, One World, Chapter 27; Incommensuration, Chapter 5, Section III.

Measured. The Fermi telescope's photon of 31 GeV from the burst GRB 090510 put the energy at which a dependence of the first order would appear above 1.2 times the Planck energy (Abdo and others 2009). The arrival of high-energy photons from the gamma-ray burst GRB 221009A places any energy dependence of the first order above about ten times the Planck energy (the Large High Altitude Air Shower Observatory, LHAASO; Cao and others 2024). Both measurements are of one kind, the timing of photons from bursts; no dependence has been found.

What decides it. In the sealed record's words, "The timing of photons of different energies from many sources, told apart from effects at the source by its growth with distance". The high-energy neutrinos from bursts that Amelino-Camelia and Smolin proposed would give a second, independent kind of measurement.

Smolin 3. Quantum statistics for states without precedent

The collection predicts. "Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights. The interference among three paths has no term that the pairs of paths do not account for. Tests of the CHSH inequality reach $2\sqrt{2}$ and go no further, and stay at 2 or below whenever either party's two observables commute. Experiments with independent sources find the complex, not the real, composition of independent systems". Registered on 1 November 2026 as Prediction 25 of *The Registered Predictions of Physics from Comparison*.

Smolin predicts. Smolin seeks a realist completion of quantum mechanics, and two of his proposals say where its statistics would fail. In his real ensemble formulation, the ensemble that a quantum state describes is the set of

all systems in that state in the universe, and the formulation implies departures from quantum mechanics for systems in states that can be expected to have few copies in the universe (Smolin 2012a). On his principle of precedence, "the outcome of a measurement on a quantum system is selected randomly from the ensemble of outcomes of previous instances of the same measurement on the same quantum system"; a system with no precedent is not bound by any prior law, and Smolin names the test: to construct new entangled states and study their evolution (Smolin 2012b, Section 4).

Where argued. The Quantum Passage, Chapters 5, 7 and 8, and Appendix B; The Unquantized Arena, Chapter 13, Section VII.

Measured. As the sealed record reports, three-slit experiments find the third term consistent with zero (Sinha and others 2010), and network experiments in 2022 found the complex composition (Chen and others; Li and others). No experiment has reported a departure from the Born weights. The sources this record draws on report no experiment designed to compare states prepared for the first time with states prepared many times. The sampling of random circuits on a superconducting processor (Arute and others 2019) prepared states of many qubits that had never been prepared before, and sampled each of them many times; on Smolin's principle the repetitions of each new state become precedents for the later ones, so such sampling reaches the long-run weights of states without precedent and not their first outcomes, as the relation essay sets out (*Time Is Real*, Section IX).

What decides it. Repeated measurements on entangled states prepared for the first time, or held in few copies, at enough repetitions to resolve the Born weights. The collection predicts the Born weights there as everywhere; Smolin's proposals predict a departure. Neither names a size for the departure, so the test is whether any departure at all is established by the rule of decision: Smolin's proposals predict one, the collection predicts none.

Smolin 4. Galaxies at low acceleration

The collection predicts. "A galaxy falling freely in the field of a larger one feels that field only through its tide; the external field effect that modified Newtonian dynamics predicts will not be found". Registered on 1 November 2026 as Prediction 24 of *The Registered Predictions of Physics from Comparison*.

Smolin predicts. Smolin proposes that the modified Newtonian dynamics of Mordehai Milgrom describes a regime of quantum gravity, which holds when the cosmological constant is small and positive, at temperatures below the de Sitter temperature (the temperature of the horizon of a universe with a positive cosmological constant) or lengths beyond the horizon. In that regime the equivalence principle in its usual form fails, and in its place the ratio of gravitational to inertial mass depends on environmental and global parameters; in the limit in which quantum effects and the finite speed of light drop out, this reproduces the modified dynamics (Smolin 2017). A ratio that depends on the environment is where the two accounts part: on the collection's account, a galaxy feels its environment only through the tide.

Where argued. The Weight of Possibility, Chapter 5, Section V: "a galaxy falling freely in the field of a larger one feels that field only through its tide, as general relativity requires, and not through the external field effect that the modified dynamics predicts".

Measured. The wide binary stars measured by the Gaia satellite stand with the tide: Indranil Banik and his colleagues found Newtonian dynamics preferred over the modified dynamics at 19 standard deviations (Banik and others 2024). Kyu-Hyun Chae reported an anomaly in samples of binaries he selected (Chae 2024), and later, with colleagues, in a sample of 36 wide binaries with accurate velocities in three dimensions (Chae and others 2026); Serat Saad and Yuan-Sen Ting reanalyzed those 36 binaries, modeling their orbits in three dimensions, and found a boost of gravity of 1.00 $(+0.24, -0.19)$, consistent with Newtonian gravity; with the semi-major axis replaced by a deprojection of the observed separation, they recover a boost close to the one Chae and colleagues reported (Saad and Ting 2026). Chae, Lelli, Desmond, McGaugh, Li and Schombert reported in 2020 a detection of the external field effect in rotationally supported galaxies (Chae and others 2020); it rests on one kind of measurement, and the external field of each galaxy in it is estimated from the galaxies around it, not measured. The sealed record states no measurement for this prediction.

What decides it. The sealed record names none. The relation essay on the modified dynamics, *The Law and the History*, names it: "a sample of galaxies selected and analyzed independently, with the external field separated from

the environment of formation, will find the tide and nothing more". In the modified dynamics a wide binary falling in the field of the Milky Way feels the external field effect as a galaxy does, so a Newtonian result for wide binaries bears on the same prediction. Together with the wide binaries, that is two independent kinds of measurement.

III. Where the Two Accounts Agree

Smolin 5. An asymmetry of time in the laws

The collection predicts. "No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one". Registered on 1 November 2026 as Prediction 28 of *The Registered Predictions of Physics from Comparison*.

Smolin predicts. Time is real and fundamental, and the laws carry its direction. With Marina Cortês he builds models of spacetime from energetic causal sets, whose principles posit a fundamental irreversibility of time and whose dynamics is asymmetric in time; a behavior symmetric in time emerges only approximately (Cortês and Smolin 2014). On his principle of precedence, a measurement with no precedent is not fixed by any prior law (Smolin 2012b).

Where argued. The Basis of Physics, Essays 9 and 11; Measurement, Chapter 14, Sections II and III; Why Time Travel Is Not a Concept, Chapter 5, Sections III to V.

Measured. As the sealed record reports, violations of CP, the combined reversal of charge and of left and right (1964), and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry.

The agreement, exactly. Both accounts put an asymmetry of time in the laws, and both keep the future open. The energetic causal set models generate new events by a deterministic rule; the collection's exclusion of a perfectly de-

terministic world bears on any such rule taken as the whole of physics, and agrees with Smolin's principle of precedence, which leaves a measurement without precedent unfixed by any law. The sealed record states plainly that "the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one", so the measurement of Smolin 3 does not touch this agreement.

IV. Predictions Stated Only in the Relation Essay

Every prediction the relation essay states is argued in the books and carried in the sealed record, as Predictions 5, 25 and 28; it states none of its own.

V. Where No Measurement Decides

Falsification applies to a claim about what a measurement will find. The differences below are of another kind: claims about what a law is, about what the passage between epochs is, about the order of the act of knowing, and about the order in which time and space are counted. Every measurement is made within one epoch, under the laws it would test, by a comparison that already has the structure these claims describe; so no measurement can be set against them, and each is checked by its argument and by its fit with the rest of the account.

Laws that change, and laws that stay the same

A claim of logical form: what a law is. Smolin holds that the laws of nature are not immutable, and lets them change so that the future is not contained in the present (Unger and Smolin 2014). The collection holds that "A law of physics states what stays the same when the circumstances of a measurement change" (Measurement, Chapter 2, Section V), and keeps the future open with laws that stay the same: determinism "is an assertion of total symmetry and total continuity", and "since symmetry and continuity cannot both be perfected, total specification (continuity) of lawful structure (symmetry) is structurally precluded" (Causality Without Determinism, Chapter 1, Section VIII). Both accounts reach an open future; they part on what has to change to reach it.

A population of universes, and one next epoch

A description of what a thing is: the passage at the end of a black-hole interior. Smolin's cosmological natural selection takes each black hole to begin a universe whose constants differ slightly from its parent's, so that universes that make many black holes come to predominate (Smolin 1992; Smolin 1997). The collection shares the identification of the end of a black-hole interior with the beginning of a universe, and reads it otherwise: "Every possible comparison therefore gives the end of one interior the same verdicts as the end of another, and the ends are one" (At the Edge of Reality, Chapter 11), so there is one next epoch, and nothing of the old epoch's distinctions crosses the turn as a distinction. The structure of physics is fixed in every epoch by the axioms. No measurement decides between the two, because no comparison made in this epoch registers the end of an interior, or the epoch that came before.

Precedence held in instances, and precedence held in each act

A claim about the act of knowing. Smolin's precedence is a memory of instances: nature draws an outcome from the earlier outcomes of the same measurement (Smolin 2012b). The collection's precedence is the order of each single comparison: "The order Axiom II states is one of precedence, not of clock time" (The Last Turtle, Chapter 3, Section VI), and the record of each comparison becomes part of the stance the next proceeds from. Where the principle of precedence predicts a departure that a measurement can find, the record carries it as Smolin 3; what remains is a difference in where the past is held.

Time before space, and both counted together

A claim of logical form: the order in which the dimensions are found. In his later work Smolin takes time as fundamental and space as emerging from relations among events. The collection counts both from one source: the second axiom orders the three roles of comparison in a cycle with three transitions, identified with the three directions of space, and the cycle has one direction,

identified with the one direction of time (Measurement, Chapter 4, Section VIII). Time is not prior to space on this account, and space does not emerge from time.

Quantum mechanics incomplete, and complete in its scope

A description of what a thing is: the quantum description. Smolin holds that quantum mechanics is incomplete and that a realist completion is still to be found (Smolin 2019). The collection derives the postulates from the structure of comparison and finds the state update upon measurement "not a physical process" (The Quantum Passage, Chapter 9, Section IV). The part of this difference that a measurement reaches is Smolin 3; the rest concerns what the description is, and no measurement reaches it.

VI. What the Collection Does Not Predict Here

The sealed record's Section IX states what the books do not predict, so that no later measurement is counted for or against the account where it makes no claim. Five of its items bear on this record.

"The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (The Gravitational Passage, Chapter 13; The Strengths of the Kinds, Chapter 1, Section VI; The Measures of the Kinds, Chapter 13, Section X)".

"The dynamics of the transition between epochs, and how the gyrations are made at the turn, are not computed (The Weight of Possibility, Chapter 6)".

"The size of the asymmetry of time is not predicted, only that it exists (The Basis of Physics, Essay 11, Section VII)".

"Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed (The Unquantized Arena, Chapter 6, Section IV); a detection of single gravitons, or of a primordial background, would not show gravitation quantized (Chapter 9, Section III; Chapter 18, Section VI)".

"The account asserts neither the return of the information that falls into a black hole formed from a star to the outside world, nor its loss to it (The Unquantized Arena, Chapter 17, Section VII); on the account of The Gravitational Passage that information is not destroyed, and re-emerges in the initial conditions of the next epoch (Chapter 18, Section XIII)".

Two of Smolin's own tests fall outside the collection's predictions, and the record states them so that they are counted for neither. Cosmological natural selection predicts that "the upper mass limit of neutron stars is less than 1.6 solar masses", and names a well-measured neutron star of high enough mass as the observation that would refute it (Smolin 2004, Sections 6.3 and 7). The pulsar PSR J0740+6620 has a mass of 2.08 ± 0.07 solar masses (Fonseca and others 2021). The collection makes no prediction about the upper mass of neutron stars. Smolin's 2004 statement also names conditions on inflation under which cosmological natural selection would be refuted (Section 6.4); it does not assert that inflation occurred, so the record sets no entry against Prediction 13, which says that no long inflationary phase occurred.

VII. The Record at Its Date

Entry	The collection	Smolin	Measured	Standing
Smolin 1. Discrete area and volume	No least length, area or duration; no quantum of the arena (Predictions 5, 3, 29)	Discrete spectra of area and volume	No discrete spectrum observed; no graviton detected	Agrees, for the collection (Predictions 5 and 3); the difference is untested, and no experiment now proposed reaches it
Smolin 2. Speed of light	Independent of energy (Prediction 5)	A Planck-scale dependence held open	None above about ten times the Planck energy	Agrees, for the collection; the difference is not yet decided by the rule of decision (one kind of measurement)
Smolin 3. Quantum statistics	Born weights in every sector (Prediction 25)	Departures for states with few copies or no precedent	Three-slit and network tests agree; no test on states without precedent	Agrees as far as tested, for the collection; the difference is untested, since no test on the first outcomes of states without precedent has been made
Smolin 4. Low acceleration	Tide only; no external field effect (Prediction 24)	A regime of quantum gravity reproducing the modified dynamics, with a mass ratio set by the environment	Wide binaries Newtonian at 19 standard deviations; a 2020 detection in galaxies, one kind	Agrees with the wide binaries at 19 standard deviations (one kind); one 2020 report in galaxies against it (one kind); not decided by the rule of decision
Smolin 5. Asymmetry of time	Some asymmetry of time in the laws (Prediction 28)	Time fundamental and irreversible	CP and time-reversal violation	Agrees

Summary

Lee Smolin's program reaches measurement in four places, and in each the collection's registered prediction differs from his. On the speed of light the measurements so far stand with the collection, above about ten times the Planck energy, and the high-energy neutrinos that Amelino-Camelia and

Smolin proposed would add the second kind of measurement the rule of decision asks. On quantum statistics, every test so far agrees with the Born weights, and the test that would separate the two accounts, on states prepared for the first time, is the one Smolin himself named. On the discreteness of area and volume, the two accounts give the same result for every experiment now proposed, and only a measurement at the Planck scale separates them. On galaxies at low acceleration, the wide binaries stand with the tide, and an independent sample of galaxies, with the external field separated from where the galaxies formed, will decide. The two agree that some asymmetry of time is in the laws. Smolin's ceiling on the mass of neutron stars lies outside the collection's predictions and is counted for neither. Their deepest differences, over whether laws change, whether universes form a population that inherits its constants, where precedence is held, and whether time comes before space, are differences of kind, and no measurement reaches them. Both accounts reach an open future; they part on what has to change to reach it.

Key Concepts

- The timing of light from distant bursts finds no dependence of the speed of light on its energy above about ten times the Planck energy, as Prediction 5 states.
- Every test of the Born weights so far agrees with Prediction 25, and the test that separates the two accounts is the one Smolin named: new entangled states, studied as they are first prepared.
- Discrete spectra of area and volume and the collection's arena with no least step give the same result for every experiment now proposed; only a measurement at the Planck scale separates them.
- The wide binaries stand with the tide, and an independent sample of galaxies, with the external field separated from where the galaxies formed, decides Prediction 24.
- Both accounts put an asymmetry of time in the laws, and both keep the future open.
- Whether laws change, whether universes form a population that inherits its constants, and whether time comes before space are differences of kind that no measurement reaches.

Terms

Arena. The context of physics, the geometry of space and time within which content is found; on the collection's account, what gravitation is.

Born rule. The rule that the probability of a finding is the square of the magnitude of its amplitude.

Content. What is found within the arena: the particles, their charges and their fields.

Cosmological natural selection. Smolin's proposal that each black hole begins a new universe whose constants differ slightly from its parent's, so that universes that make many black holes predominate.

Energetic causal set. A model of Cortês and Smolin in which spacetime emerges from discrete events whose causal links carry energy and momentum.

Epoch. The span of the universe from one turn to the next; this epoch began at the Big Bang.

Equivalence principle. The principle that gravitational and inertial mass are equal, so that bodies fall alike and a body falling freely carries its own physics with it.

External field effect. In the modified dynamics, the change in a galaxy's internal motions produced by the uniform field of a larger body it falls in; general relativity has no such effect, only the tide.

Gyration. The unit of the dark matter on the collection's account: a conserved excitation of the six held internal dimensions, of about the Planck mass.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Loop quantum gravity. A program that quantizes the geometry of space without a fixed background, in which areas and volumes take discrete values.

Modified Newtonian dynamics. Milgrom's law of gravity, which departs from Newton's below a constant of acceleration.

Planck energy. The energy fixed by Newton's constant, the speed of light and the reduced Planck constant, about 1.22×10^{19} GeV.

Principle of precedence. Smolin's proposal that the outcome of a quantum measurement is drawn from the outcomes of earlier instances of the same measurement.

Real ensemble formulation. Smolin's proposal that the ensemble a quantum state describes is the set of all systems in that state in the universe.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Spin network. A graph whose edges and nodes carry labels of spin, used in loop quantum gravity to label the discrete values of area and volume.

Tide. The difference in the pull of a distant body across an extended one, which is all of that body's field that a freely falling system feels.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

Wide binary. A pair of stars in orbit at a separation so large that their mutual acceleration falls into the range where the modified dynamics departs from Newton's.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *Time Is Real; Lee Smolin and Physics from Comparison*. An essay on the physics collection of the Immanent Metaphysics, 2026.

Landry, Forrest. *The Law and the History; Mordehai Milgrom, Stacy McGaugh and the Weight of Possibility*. An essay on the physics collection of the Immanent Metaphysics, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *The Branches of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-077-0. DOI: https://doi.org/10.67291/DOYL4735.

Landry, Forrest. *Causality Without Determinism*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *Incommensuration; The Theorem and the Three Axioms*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-063-3. DOI: https://doi.org/10.67291/ARTV2404.

Landry, Forrest. *The Last Turtle*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Abdo, A. A. and others (Fermi LAT and GBM Collaborations) (2009). "A limit on the variation of the speed of light arising from quantum gravity effects". *Nature* 462, 331–334.

Amelino-Camelia, G. and Smolin, L. (2009). “Prospects for constraining quantum gravity dispersion with near term observations”. *Physical Review D* 80, 084017. arXiv:0906.3731.

Arute, F. and others (2019). “Quantum supremacy using a programmable superconducting processor”. *Nature* 574, 505–510.

Banik, I., Pittordis, C., Sutherland, W., Famaey, B., Ibata, R., Mieske, S. and Zhao, H. (2024). “Strong constraints on the gravitational law from Gaia DR3 wide binaries”. *Monthly Notices of the Royal Astronomical Society* 527, 4573–4615.

Cao, Z. and others (LHAASO Collaboration) (2024). “Stringent tests of Lorentz invariance violation from LHAASO observations of GRB 221009A”. *Physical Review Letters* 133, 071501.

Chae, K.-H. (2024). “Breakdown of the Newton–Einstein standard gravity at low acceleration in internal dynamics of wide binary stars”. *The Astrophysical Journal* 960, 114.

Chae, K.-H., Lelli, F., Desmond, H., McGaugh, S. S., Li, P. and Schombert, J. M. (2020). “Testing the strong equivalence principle: detection of the external field effect in rotationally supported galaxies”. *The Astrophysical Journal* 904, 51. arXiv:2009.11525.

Chae, K.-H., Lee, B.-C., Hernandez, X., Orlov, V. G., Lim, D., Turnshek, D. A. and Lee, Y.-W. (2026). “Detection of gravitational anomaly at low acceleration from a highest-quality sample of 36 wide binaries with accurate 3D velocities”. arXiv:2601.21728.

Cortês, M. and Smolin, L. (2014). “The universe as a process of unique events”. *Physical Review D* 90, 084007. arXiv:1307.6167.

Fonseca, E., Cromartie, H. T., Pennucci, T. T., Ray, P. S. and others (2021). “Refined mass and geometric measurements of the high-mass PSR J0740+6620”. *The Astrophysical Journal Letters* 915, L12. arXiv:2104.00880.

Rovelli, C. and Smolin, L. (1995). “Discreteness of area and volume in quantum gravity”. *Nuclear Physics B* 442, 593–619; erratum *Nuclear Physics B* 456, 734. arXiv:gr-qc/9411005.

Saad, S. M. and Ting, Y.-S. (2026). “No gravitational anomaly in wide binaries from forward modeling of 3D orbits”. arXiv:2603.11015, version 2, 9 September 2026; version 1 (March 2026) was titled “Gravitational anomaly measurement in wide binaries is sensitive to orbital modeling”. doi: 10.33232/001c.170182.

Smolin, L. (1992). “Did the universe evolve?”. *Classical and Quantum Gravity* 9, 173–191.

Smolin, L. (1997). *The Life of the Cosmos*. New York: Oxford University Press.

Smolin, L. (2004). “Scientific alternatives to the anthropic principle”. arXiv:hep-th/0407213.

Smolin, L. (2012a). “A real ensemble interpretation of quantum mechanics”. *Foundations of Physics* 42, 1239–1261. arXiv:1104.2822.

Smolin, L. (2012b). “Precedence and freedom in quantum physics”. arXiv: 1205.3707.

Smolin, L. (2017). “MOND as a regime of quantum gravity”. *Physical Review D* 96, 083523. arXiv:1704.00780.

Smolin, L. (2019). *Einstein’s Unfinished Revolution*. New York: Penguin Press.

Unger, R. M. and Smolin, L. (2014). *The Singular Universe and the Reality of Time*. Cambridge: Cambridge University Press.

The measurements that the sealed record reports by author and year (Abbott and others 2016; Sinha and others 2010; Chen and others 2022; Li and others 2022; CPLEAR 1998; BaBar 2012) are given in full in the bibliographies of the books it names.

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Appendix E

The Registered Predictions Beside Max Tegmark

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Max Tegmark. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Structure and the Act; Max Tegmark's Mathematical Universe and Physics from Comparison*.

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Abstract

Tegmark named a value where the two accounts can be measured apart. This record sets the predictions of physics from comparison beside those of Max Tegmark, as they stand on 4 November 2026. In 2005 he found that the best-motivated models of inflation give primordial gravitational waves with a ratio of tensor to scalar power of about 0.03, a level he expected the coming maps of the polarization of the microwave background to detect; the collection predicts a ratio far below one part in a million, and those maps will decide between the two. Two further differences reach measurement: whether a long inflationary phase occurred, and whether the dark matter is a kind of particle whose share varies from region to region, as in the axion scenario Tegmark worked through with Anthony Aguirre, Martin Rees and Frank Wilczek, or a fixed ratio to the ordinary matter, $6 - 2/\pi$, carried by no kind of particle. The two accounts agree on five measurable matters: an equation of state of exactly -1 for the energy of the vacuum, a space flat to the size of the primordial departures, no ending of a superposition beyond ordinary decoherence, the statistics of quantum theory, and three directions of space with one of time. The collection also accepts, at its own scope, Tegmark's estimate of how fast quantum coherence is lost in the brain.

Most of what divides the two accounts is a difference of kind that no measurement reaches: whether the world is a mathematical structure, whether only computable structures exist, the standing of regions beyond every horizon, the many worlds of quantum theory, and whether consciousness is a state of matter described from outside. The record states each difference in its kind.

I. What This Record Is

This record sets two accounts side by side, prediction by prediction. One is physics from comparison, whose predictions were registered on 1 November 2026 in *The Registered Predictions of Physics from Comparison*, called here the sealed record. The other is the work of Max Tegmark, cosmologist at the Massachusetts Institute of Technology: his Mathematical Universe Hypothesis (MUH) and his four levels of multiverse, his calculations of what inflation predicts, his reading of quantum theory as many worlds, and his earlier results on the dimensions of spacetime and on decoherence in the brain. The relation essay *The Structure and the Act* sets out how the two accounts meet and where they part; this record states what each account says a measurement will find.

The sealed record fixes what counts as a result, and this record uses its rule:

> A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such.

Every prediction of the collection stated here is quoted from the sealed record with its number, or is argued in a book of the collection named at chapter and section. A prediction stated only in the relation essay would be marked as such in Section IV; there is none. Every statement of Tegmark's account is cited to his own work.

The predictions come from one account: the Incommensuration Theorem and the three axioms that follow from it, applied to physics through the structure of comparison. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before

1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998, the years in which Tegmark published his papers on the dimensions of spacetime and on many worlds. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

II. Where the Two Accounts Predict Differently

Tegmark 1. Primordial gravitational waves

The collection predicts. The sealed record states:

> The primordial departures of the metric are scalar, sourced by departures of density, and waves of the metric arise from them only at second order: the ratio of tensor to scalar power is far below 10^{-6}. The Simons Observatory and LiteBIRD will find no primordial tensor signal.

Registered on 1 November 2026 as Prediction 10 of The Registered Predictions of Physics from Comparison.

Tegmark predicts. Tegmark named a value in advance of the measurement, which makes this the clearest measurable test between the two accounts. In "What Does Inflation Really Predict?" (2005) he computed what inflation predicts when its potential has many minima, as in the landscape of string theory, and found "the arguably best-motivated single-field models favoring the detectable level" of about 0.03 for the ratio of tensor to scalar power; in the limit of high energy his calculation gives a ratio of about 0.15. He concluded that the findings "bode well for detecting an inflationary gravitational wave signature with future CMB polarization experiments". In 2014 he read the signal then reported by BICEP2 as made by "quantum fluctuations not in any old quantum field, but in the gravitational field" (Tegmark 2014).

Where argued. The Gravitational Passage, Chapter 18, Sections IX and XIII; The Compactification, Chapter 6, Section V, Chapter 7, Section VI, and Chapter 8, Section XI; At the Edge of Reality, Chapter 19 and Appendix B.

Measured. The ratio of tensor to scalar power is below 0.032 (Tristram and others 2022), and no primordial tensor signal has been detected. The bound lies below the ratio of about 0.15 that Tegmark's calculation gives at high en-

ergy, and at the level of about 0.03 that he named for the best-motivated models. The signal reported by BICEP2 in 2014 was found, in the joint analysis with Planck, to be consistent with polarized dust in our galaxy (BICEP2/Keck and Planck Collaborations 2015).

What decides it. The polarization of the microwave background; the Simons Observatory will reach about one part in a thousand, and LiteBIRD below two parts in a thousand (the sealed record, Prediction 10). The published targets run the other way: about one part in a thousand for the satellite LiteBIRD (Ghigna and others 2024), and about three parts in a thousand for the Simons Observatory (Ade and others 2019); the figures of the sealed text are carried to the next dated report. A primordial tensor signal at the level Tegmark named lies well within the reach of both. A detection at that level refutes Prediction 10; if they find no signal at their sensitivity, the models Tegmark named best motivated are excluded.

Tegmark 2. A long inflationary phase

The collection predicts. The sealed record states:

> No inflationary phase long enough to stretch the lengths observed today from within the early horizon to beyond it occurred. The horizon and flatness problems are answered by the turn from the previous epoch, with no inflation.

Registered on 1 November 2026 as Prediction 13 of The Registered Predictions of Physics from Comparison. The exclusion covers only a phase long enough to carry the observed lengths beyond the early horizon: a shorter phase, which leaves the observed lengths outside the early horizon throughout, "is neither required nor excluded by the account" (The Compactification, Chapter 6, Section VIII).

Tegmark predicts. Tegmark's Level II multiverse rests on inflation. He holds that "inflation is generically eternal, in the sense that that's what typical inflation models predict", and that where the fundamental theory has many solutions, "inflation will create volumes realizing each of these solutions" (Tegmark 2014). On his account the departures from uniformity that the microwave background shows were made during inflation, and his predictions for them in 2005 are predictions of inflation (Tegmark 2005).

Where argued. The Gravitational Passage, Chapter 18, Questions; The Compactification, Chapter 1, Section VIII, and Chapter 6, Section VIII; At the Edge of Reality, Chapter 19. The Compactification, Chapter 6, Section VIII, ties the exclusion to the dark matter, quoting *The Weight of Possibility*, Chapter 4, Section VI: "In an epoch whose observed departures were made by inflation, the bound on primordial gravitational waves (BICEP/Keck Collaboration 2021) would keep the temperature far below this limit, and dark matter of this mass could not be made after that inflation in the measured amount".

Measured. The sealed record names no single measurement for this prediction. It is decided by the measurements of Predictions 9 to 12 together. Of these, the two accounts agree on the flatness of Prediction 9 (Tegmark 5, below), and they part on the tensor signal of Prediction 10 (Tegmark 1).

What decides it. The measurements of Predictions 9 to 12 together (the sealed record, Prediction 13), with the polarization measurements of Tegmark 1 carrying the separation between these two accounts.

Tegmark 3. What the dark matter is

The collection predicts. The sealed record states:

> No further kind of particle will be found: no fourth generation, no supersymmetric partner, no X or Y boson or leptoquark, no W′ or Z′, no second Higgs boson, no axion, no species of dark matter, no sterile neutrino beyond the right-handed component of each neutrino, no dark photon, no mirror particle and no hidden sector. The next collider will not find a new species. Heavier composites wait at higher energies; a new kind does not.

Registered on 1 November 2026 as Prediction 30 of The Registered Predictions of Physics from Comparison. The same record states:

> The ratio of the density of the dark matter to the density of the ordinary matter is $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$, the same at every time since helium formed. The same prediction gives the share of the ordinary matter in the cold matter, $1/(7 - 2/\pi) = 0.15715$, and in all the matter, with the lightest neutrinos, 0.15644; with the matter fraction of Prediction 7, the densities are $\Omega_b = 0.0486$ and $\Omega_c = 0.2608$.

Registered on 1 November 2026 as Prediction 16 of The Registered Predictions of Physics from Comparison. Here Ω_c and Ω_b are the densities of the dark matter and of the ordinary matter, each as a share of the critical density. The absence of the axion is stated again in Prediction 34. On the collection's account the dark matter is a conserved excitation of the six held internal dimensions, whose units are gyrations; it is not a kind of particle.

Tegmark predicts. In "Dimensionless Constants, Cosmology and Other Dark Matters" (2006), Tegmark, with Anthony Aguirre, Martin Rees and Frank Wilczek, took axion dark matter as a case study of how the constants of physics may be set by place. If the Peccei and Quinn transition, the breaking of symmetry that gives rise to the axion, occurred before or during inflation, the density of axion dark matter varies from region to region; weighed at the places where stable solar systems can form, its distribution most probably peaks near the observed density. They add that if dark matter in the form of weakly interacting massive particles is discovered, comparable densities of the two kinds are to be expected. On this scenario the ratio of the dark matter to the ordinary matter is a value of our region, and the dark matter is one or more kinds of particle.

Where argued. For the closed list: The Kinds of Particle, Chapter 6, Section IV; The Story of the Particles, Level 9, Section IV; The Branches of the Kinds, Chapters 2 and 4; The Alphabet of Particles, entries N1 to N12. For the axion: The Branches of the Kinds, Chapter 3, Section V. For the ratio: The Weight of Possibility, Chapter 3, Section V, and Chapter 5, Sections I, II and IX; The Compactification, Chapter 6, Section X.

Measured. No axion and no species of dark matter has been found (the sealed record, Predictions 30 and 34). For the ratio, the combination of the South Pole Telescope, Planck and the Atacama Cosmology Telescope gives 5.370 ± 0.048 (Camphuis and others 2026), 0.14 standard deviations from 5.3634; Planck alone gives 5.364 ± 0.065 (Aghanim and others 2020). Analyses that add the baryon acoustic oscillations of DESI (the Dark Energy Spectroscopic Instrument) give 5.199 ± 0.035 (Louis and others 2025), 4.7 standard deviations away, about 4.0 with a correlation of -0.4 between the two densities; that is a measurement of interest, from one kind of measurement. By the rule of decision a departure found by one kind of measurement, however

large, is a measurement of interest and not a result, so the standing of the ratio is "agrees" with the microwave background alone and "under pressure" with DESI, and a second, independent kind of measurement decides.

What decides it. Searches at colliders, in underground detectors and in astrophysics, and searches for the axion (the sealed record, Predictions 30 and 34): the finding of an axion that makes the dark matter refutes both predictions and confirms the kind of the scenario. For the ratio, a second, independent kind of measurement of the two densities, at the precision of the microwave background; the Simons Observatory with Planck would measure it to about 0.6 percent (Prediction 16). The scenario sets no single value for the ratio, so the measurement of the ratio decides Prediction 16 and bears on the scenario only through the distribution it computes.

III. Where the Two Accounts Agree

Tegmark 4. The energy of the vacuum is constant

The collection predicts.

> The energy of the vacuum has an equation of state of exactly -1, at every epoch: $w_0 = -1$ and $w_a = 0$. The cosmological constant is fixed once, by the horizon of the measurement, as the constant term of one geometry, and the field equations do not let such a term vary from place to place or from epoch to epoch. No dynamical field, no quintessence and no evolving scalar drives the acceleration. The reported departure from -1 will not be confirmed.

Registered on 1 November 2026 as Prediction 8 of The Registered Predictions of Physics from Comparison. Here w_0 is the present equation of state of the energy of the vacuum and w_a its rate of change.

Tegmark predicts. Among the predictions of inflation on a landscape, Tegmark (2005) obtains an equation of state of -1 for the energy of the vacuum.

Where argued. The Gravitational Passage, Chapter 13, Sections V and VI, and Chapter 18, Section XIII; The View from Inside, Chapter 15; At the Edge of Reality, Appendix B.

Measured. The microwave background with baryon acoustic oscillations and type Ia supernovae gives -1.03 ± 0.03 (Aghanim and others 2020). The final analysis of the Dark Energy Survey, combined with DESI and the microwave background, gives a present value of -0.82 ± 0.05 with a rate of change of -0.63 $(+0.21/-0.18)$, about three standard deviations from a cosmological constant (Abbott and others 2026), from one family of combined analyses; both accounts predict -1, so this departure, which has not reached the rule of decision, bears on both alike.

Tegmark 5. Space is flat to the size of the primordial departures

The collection predicts.

> The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}.

Registered on 1 November 2026 as Prediction 9 of The Registered Predictions of Physics from Comparison.

Tegmark predicts. Tegmark (2005) obtains a total density equal to the critical density to within about one part in 10^5, which is a spatial curvature of the same order. The two accounts reach the same number by different routes: inflation by stretching, the collection by the restoration of the exterior at the turn.

Where argued. The Gravitational Passage, Chapter 18, Sections IX and XIII; The Compactification, Chapter 6, Section VI; At the Edge of Reality, Chapter 19 and Appendix B.

Measured. A spatial curvature of 0.001 ± 0.002, from the microwave background with baryon acoustic oscillations (Aghanim and others 2020). The second data release of DESI, with the microwave background, gives 0.0023 ± 0.0011 (Abdul-Karim and others 2025), about two standard deviations from flat on the open side: a measurement of interest for both accounts, short of the rule of decision.

Tegmark 6. No superposition ends beyond ordinary decoherence

The collection predicts.

> No mass, however large, no separation of two placements, however wide, and no length of time ends a superposition of its own accord; a superposition ends only through a finding, an interaction that registers which alternative is the case. The account allows no decoherence beyond the ordinary kind, which is a comparison made by some environment. For the masses of Prediction 1, the gravity-driven collapse of Diósi and Penrose gives a lifetime of about 0.012 seconds, against the 2.5 seconds the entangling phase needs.

Registered on 1 November 2026 as Prediction 2 of The Registered Predictions of Physics from Comparison.

Tegmark predicts. On the many-worlds reading Tegmark defends, the quantum state evolves without collapse, and its predictions agree with those of the Copenhagen reading "when environment-induced decoherence is taken into account" (Tegmark 1998). No mass and no length of time ends a superposition on his account either, so the two accounts expect the same of every test for an extra channel of decoherence. They part on what a finding is, a difference no measurement reaches (Section V).

Where argued. The Unquantized Arena, Chapter 7, Sections V and VI, and Chapter 8, Section IV.

Measured. An underground search for the radiation that collapse noise would make has ruled out the version of the Diósi and Penrose model with no free parameter (Donadi and others 2021); versions with a larger effective size remain under test.

Tegmark 7. The statistics of quantum theory hold

The collection predicts.

> Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights. The interference among three paths has no term that the pairs of paths do not account for. Tests of the CHSH inequality reach $2\sqrt{2}$ and go no further, and stay at 2 or below whenever either party's two observables commute. Experiments with independent sources find the complex, not the real, composition of independent systems.

Registered on 1 November 2026 as Prediction 25 of The Registered Predictions of Physics from Comparison.

Tegmark predicts. Tegmark takes the statistics of quantum theory as they stand. With Anthony Aguirre he argues that an infinite space "renders the Born rule redundant", with outcomes found "with relative frequencies given by the square of the wave function amplitudes" (Aguirre and Tegmark 2011).

Where argued. The Quantum Passage, Chapters 5, 7 and 8, and Appendix B; The Unquantized Arena, Chapter 13, Section VII.

Measured. Three-slit experiments find the third term consistent with zero (Sinha and others 2010); network experiments in 2022 found the complex composition (Chen and others; Li and others).

Tegmark 8. Three directions of space and one of time

The collection predicts. The collection draws one direction of time from the directed order of comparison: "The signature therefore has exactly one negative sign" (The Gravitational Passage, Chapter 10, Section III). It draws three directions of space from the counts comparison supplies: "So the dimension of space is three" (Measurement, Chapter 11, Section VI). The Gravitational Passage cites Tegmark's analysis of 1997 as support from the field equations: with two or more directions of time the wave equation is ultrahyperbolic, and its initial value problem is ill posed. The sealed record does not carry this count; it is a count already measured.

Tegmark predicts. In "On the Dimensionality of Spacetime" (1997) Tegmark argues that "all but the 3+1-dimensional one might correspond to 'dead worlds', devoid of observers", as quoted in Objections from Physics, Answered. The two accounts give the same count on different grounds: Tegmark's by the presence of observers, the collection's by the structure of comparison.

Measured. Every measurement of the large world finds three directions of space and one of time.

Tegmark 9. Decoherence in the brain

The collection holds. The collection makes no prediction of its own about decoherence in the brain, and it accepts Tegmark's estimate at its own scope. The Basis of Physics, Essay 19, sets its account apart from the hypothesis of Hameroff and Penrose, which "meets the standard objection that entanglement in warm neural tissue decoheres far too quickly to bear on neural events (Tegmark, 2000)", and states that the Immanent Metaphysics "does not depend on any specific biological mechanism, and it needs no sustained entanglement in the brain" (The Basis of Physics, Essay 19). Objections from Physics, Answered, states the consequence: "So the decoherence times bear on the hypothesis of Hameroff and Penrose, and not on the step".

Tegmark predicts. Quantum superpositions in the brain lose their coherence in times of the order of 10^{-13} to 10^{-20} seconds, much shorter than the times on which neurons act, so the degrees of freedom of the brain that bear on thinking are to be treated as classical (Tegmark 2000).

Measured. The collection's standing does not turn on these times: the channel it names for the indeterminacy of a choice is sensitive dependence near criticality, where small disturbances cascade (The Basis of Physics, Essay 19, Section V; the register beside Giulio Tononi, Tononi 1).

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction that the books of the collection do not argue; every measurable claim it makes is carried by the sealed record or by a book named above.

V. Where No Measurement Decides

The differences below are claims of logical form, descriptions of what a thing is, or claims about the act of knowing. Falsification applies to a claim that says what a measurement will find. These claims say what a finding is, or what a description can contain, or what lies where no comparison reaches; every

measurement, whatever it finds, is a finding of the kind they describe, so no measurement decides between them. They are settled by argument, and the relation essay gives the argument for each.

The world as a mathematical structure

A description of what a thing is. Tegmark holds that "our physical world is an abstract mathematical structure" (Tegmark 2008). The collection holds that a structure exists and a finding is real: "To say that something exists is to say that it stands as structure: timeless, the same in every instance, like the pattern of a law, or the state of a system at an instant. To say that something is real is to say that it is given in an actual act of comparison: temporal, occurring now, with the future still open to possibilities not yet settled. A law exists; a measurement is real" (Comparison, Chapter 10, Section II). The order of depth, metaphysics, then physics, then computation, then mathematics, places mathematics last, with every power it has (Physics Is Not Math, Chapter 5); Tegmark's hypothesis places it first.

Further mathematical regularities

A claim of logical form. Tegmark writes that "The MUH makes the testable prediction that further mathematical regularities remain to be uncovered in nature" (Tegmark 2008). The collection's own predictions include regularities of exactly this kind: the matter fraction of Prediction 7 and the ratio of Prediction 16 are pure numbers. The two accounts part on a further claim, that "the mathematical description of physics is very powerful and never complete" (Measurement, Chapter 14, Section XI). Every regularity found agrees with both readings, so no finding decides between a description that is complete and one that is never complete.

Only computable structures exist

A claim of logical form. Tegmark hypothesizes "that only computable and decidable (in Gödel's sense) structures exist" (Tegmark 2008). The collection excludes a computed world on three independent grounds: determinism, the two levels of every exact description, and the bound triple (Physics Is Not Math, Chapter 8, Section VII). The sealed record carries a measurable form of

the exclusion for any particular rule: "For any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement, reaching below the rule's least step, tells the rule's statistics from the world's" (Prediction 29, registered on 1 November 2026). Tegmark's hypothesis names a class of structures and offers no one rule, so Prediction 29 applies to Tegmark's hypothesis only once someone offers a particular rule.

Regions beyond every horizon: Levels I and II

A description of what a thing is, about regions no comparison of ours reaches. Both accounts hold that space continues beyond our horizon. The collection counts those regions as further parts of one world, on its principle of existence: "Existence without any interaction whatsoever is indistinguishable from non-existence, and therefore is non-existence" (Objections from Physics, Answered, quoting *Incommensuration*, Chapter 9, Section I). Tegmark's Level II adds regions with other constants and other effective laws. The collection has one internal space and no landscape of vacua among which constants could vary (The Compactification, Chapter 2, Section IX). The regions themselves lie beyond any measurement; the part of Level II that reaches measurement is the inflation that would make them, entered above as Tegmark 1 and Tegmark 2.

The energy of the vacuum shows the difference of kind most plainly. Tegmark (2005) obtains a distribution for it, with our value "in the observed ballpark but uncomfortably high". The collection fixes one value, a matter fraction of 0.311 ± 0.001 (Prediction 7). In a spatially flat universe the cosmological constant carries the rest, $\Omega_\Lambda = 0.689$ (Prediction 7), so the one value fixes the share of the energy of the vacuum as well. The measurement of the matter fraction decides Prediction 7; a distribution over regions is not decided by the value found in one region.

The many worlds of quantum theory: Level III

A claim of logical form, and a claim about the act of knowing. Tegmark states that the predictions of many worlds and of the Copenhagen reading are identical, except for "an experiment involving a Byzantine form of 'quantum suicide'" (Tegmark 1998). The collection reads many worlds as an account

that "eliminates measurement time entirely" and so loses the bridge from the formalism to the findings (The Quantum Passage, Chapter 9, Section VIII). Its exclusion of a perfectly deterministic world is registered in the sealed record with its own statement of kind:

> No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one.

Registered on 1 November 2026 as Prediction 28 of The Registered Predictions of Physics from Comparison. The measurable part of quantum theory, on which the two accounts agree, is entered above as Tegmark 6 and Tegmark 7.

Every mathematical structure: Level IV

A description of what a thing is. Level IV is the Mathematical Universe Hypothesis applied to every structure at once. On the collection's account a structure that no comparison could ever find is laid out and not found, and so is not a further world; the difference is the first difference of this section, applied to all structures.

Consciousness as a state of matter

A claim about the act of knowing. Tegmark proposes that consciousness is a state of matter, perceptronium, marked by five principles of information processing (Tegmark 2015). The collection holds that "Consciousness is the bound triple taken as one act: the arrow of time, hard randomness and the subjective, distinct, inseparable and non-interchangeable" (Causality Without Determinism, Chapter 5, Summary), and that "From the outside, a conscious choice is indistinguishable from a random event" (The Basis of Physics, Essay 19, Section V). A criterion stated in the third person describes conscious matter from outside, and can be exact as such; the subjective it leaves out is, by the collection's account, what no measurement made from outside registers.

VI. What the Collection Does Not Predict Here

The sealed record states what the books do not predict. Five of its items bear on the comparison with Tegmark, and are quoted in full.

> The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (*The Gravitational Passage*, Chapter 13; *The Strengths of the Kinds*, Chapter 1, Section VI; *The Measures of the Kinds*, Chapter 13, Section X).

Tegmark's Level II explains such values by place; the collection takes these four as measured, and explains none of them by selection among regions.

> The amplitude of the primordial departures and the sign of their tilt are not fixed; the running of the tilt is given only on a condition the books do not adopt (*The Gravitational Passage*, Chapter 18, Section IX; *The Compactification*, Chapter 6, Section VII).

Tegmark's calculation of 2005 gives a spectral index of about 0.96 in its limit of high energy, and the measured index is 0.965 ± 0.004 (Aghanim and others 2020); the credit for that number is his.

> The dynamics of the transition between epochs, and how the gyrations are made at the turn, are not computed (*The Weight of Possibility*, Chapter 6).

Inflation offers a dynamics for the early universe; the collection's account of the turn states what passes through it, and does not compute how.

> The size of the asymmetry of time is not predicted, only that it exists (*The Basis of Physics*, Essay 11, Section VII).

> Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed (*The Unquantized Arena*, Chapter 6, Section IV); a detection of single gravitons, or of a primordial background, would not show gravitation quantized (Chapter 9, Section III; Chapter 18, Section VI).

Tegmark read the signal reported by BICEP2 as quantum fluctuations in the gravitational field. On the collection's account a primordial tensor signal, if found, refutes Prediction 10, and leaves the claim that gravitation is not quantized where it stands.

VII. The Record at Its Date

Entry	The collection	Tegmark	Measured	Standing
Tegmark 1. Primordial gravitational waves	Ratio of tensor to scalar power far below 10^{-6} (Prediction 10)	About 0.03 for the best-motivated single-field models; about 0.15 at high energy	Below 0.032	Prediction 10 agrees; the bound lies at Tegmark's 0.03 and below his 0.15; the Simons Observatory and LiteBIRD decide
Tegmark 2. A long inflationary phase	None (Prediction 13)	Inflation, generically eternal	Decided by the measurements of Predictions 9 to 12 together	Untested
Tegmark 3. What the dark matter is	No axion and no species of dark matter; ratio $6 - 2/\pi = 5.3634$ (Predictions 30, 16, 34)	Axions, in the scenario of 2006, with a density that varies by region	No axion found; 5.370 ± 0.048; 5.199 ± 0.035	Closed list agrees; ratio agrees with the microwave background alone, under pressure with DESI (4.7 standard deviations, about 4.0 with correlation; one kind)
Tegmark 4. The energy of the vacuum	Equation of state exactly -1 (Prediction 8)	-1	-1.03 ± 0.03; present value -0.82 ± 0.05	Under pressure: about three standard deviations in one family of analyses, for both accounts
Tegmark 5. Flatness	Curvature of order 10^{-5} (Prediction 9)	Critical density to about one part in 10^5	0.001 ± 0.002; with DESI, 0.0023 ± 0.0011	Agrees; with DESI, a measurement of interest for both accounts (one kind)
Tegmark 6. No extra decoherence	None beyond the ordinary kind (Prediction 2)	No collapse; decoherence by the environment	Diósi and Penrose version with no free parameter ruled out	Agrees as far as tested
Tegmark 7. Quantum statistics	Born weights; $2\sqrt{2}$; no third term; complex composition (Prediction 25)	Born frequencies	As stated	Agrees

Entry	The collection	Tegmark	Measured	Standing
Tegmark 8. Dimensions	Three of space, one of time (books; not in the sealed record)	Three and one, by the presence of observers	Three and one	Agrees
Tegmark 9. Decoherence in the brain	No prediction; the estimate accepted at its scope	10^{-13} to 10^{-20} seconds	Not reported here	Accepted; the collection's account does not turn on it

Summary

Max Tegmark and physics from comparison agree on more of what measurement will find than their accounts of what the world is would suggest. Both predict an energy of the vacuum with an equation of state of exactly -1, and the one family of analyses that presses on that value bears on both alike; both predict a space flat to the size of the primordial departures; both expect no ending of a superposition beyond ordinary decoherence, and the statistics of quantum theory as they stand; both give three directions of space and one of time. The collection accepts Tegmark's estimate of decoherence in the brain; its account of choice needs no sustained coherence there.

Three differences reach measurement. The sharpest is the primordial gravitational waves: Tegmark named a ratio of about 0.03 for the best-motivated models of inflation, and the collection predicts a ratio far below one part in a million; the Simons Observatory and LiteBIRD will decide. With it goes the question whether a long inflationary phase occurred. The third is what the dark matter is: in the scenario Tegmark worked through, a kind of particle whose share is set by place; in the collection, no kind of particle, in a fixed ratio of $6 - 2/\pi$ to the ordinary matter. Every other difference between the two accounts is a difference of kind, about what a finding is, what a description can contain, or what lies beyond every horizon, and the relation essay argues each one.

Key Concepts

- The sealed record: the predictions of physics from comparison registered on 1 November 2026, quoted here with their numbers.
- The rule of decision: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.
- The clearest test: primordial gravitational waves, at about 0.03 on Tegmark's best-motivated models of inflation and far below 10^{-6} on the collection.
- Agreement on the measured: a constant energy of the vacuum, flat space, no extra decoherence, the quantum statistics, three and one dimensions.
- Differences of kind: the world as structure, computable structures only, regions beyond every horizon, many worlds, consciousness as a state of matter.

Terms

Axion. A hypothetical light particle proposed to cancel the strong force's own CP-violating angle and as a candidate for the dark matter.

Born rule. The rule that the probability of a finding is the square of the magnitude of its amplitude.

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable.

Decoherence. The spreading of the relative phase of two alternatives into an environment that registers which alternative is the case, after which they no longer interfere in measurements on the system alone; on the collection's account, a comparison made by that environment.

Equation of state. The ratio of the pressure of a component to its energy density; a cosmological constant has -1.

Eternal inflation. Inflation that, once begun, continues without end in some regions while it ends in others.

Exists, real. To exist is to stand as structure, timeless and the same in every instance; to be real is to be given in an actual act of comparison.

Gyration. The unit of the dark matter on the collection's account: a conserved excitation of the six held internal dimensions, of about the Planck mass.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Inflation. A proposed early phase of accelerated expansion that stretched a small region, once in causal contact, to beyond the present horizon.

Landscape. The many solutions of a fundamental theory, each with its own constants, among which regions of the universe could differ.

Levels I to IV. Tegmark's four levels of multiverse: regions beyond our horizon; regions left by inflation with other constants; the branches of many worlds; every other mathematical structure.

Mathematical Universe Hypothesis. Tegmark's claim that our physical world is an abstract mathematical structure.

Order of depth. Metaphysics, physics, computation, mathematics, ordered by what each presupposes.

Perceptronium. Tegmark's name for consciousness considered as a state of matter with distinctive abilities to process information.

Primordial departures. The departures from uniformity in the early universe, seen in the microwave background.

Spectral index. The measure of how the strength of the primordial departures changes with length; its departure from one is the tilt.

Ratio of tensor to scalar power. The strength of the primordial gravitational waves relative to the primordial departures of density.

The turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event. On the collection's account, the turn answers the horizon and flatness problems with no inflation.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Structure and the Act; Max Tegmark's Mathematical Universe and Physics from Comparison*. Relation essay, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *The Branches of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-077-0. DOI: https://doi.org/10.67291/DOYL4735.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-075-6. DOI: https://doi.org/10.67291/FVTH8832.

Landry, Forrest. *Comparison; The Necessary Basis*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-062-6. DOI: https://doi.org/10.67291/MOAS1658.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *The Kinds of Particle*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-060-2. DOI: https://doi.org/10.67291/CEUK-2585.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Objections from Physics, Answered; The Identifications of Physics from Comparison, Step by Step*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/UEEI5258.

Landry, Forrest. *Physics Is Not Math; Metaphysics, Physics, Computation and Mathematics, and Why Their Order Cannot Be Otherwise*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-070-1. DOI: https://doi.org/10.67291/LKMT1000.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *The Story of the Particles*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-053-4. DOI: https://doi.org/10.67291/TJQH1629.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The View from Inside*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-074-9. DOI: https://doi.org/10.67291/HGNK5132.

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Abdul-Karim, M. and others (DESI Collaboration) (2025). "DESI DR2 Results II: Measurements of Baryon Acoustic Oscillations and Cosmological Constraints". *Physical Review D* 112, 083515. arXiv:2503.14738.

Ade, P. and others (Simons Observatory Collaboration) (2019). "The Simons Observatory: science goals and forecasts". *Journal of Cosmology and Astroparticle Physics* 2019(02), 056. arXiv:1808.07445.

Aguirre, A. and Tegmark, M. (2011). "Born in an infinite universe: a cosmological interpretation of quantum mechanics". *Physical Review D* 84, 105002. arXiv:1008.1066.

BICEP2/Keck and Planck Collaborations (2015). "Joint analysis of BICEP2/Keck Array and Planck data". *Physical Review Letters* 114, 101301.

Ghigna, T. and others (LiteBIRD Collaboration) (2024). "The LiteBIRD mission to explore cosmic inflation". arXiv:2406.02724.

Tegmark, M. (1997). "On the dimensionality of spacetime". *Classical and Quantum Gravity* 14, L69–L75. arXiv:gr-qc/9702052.

Tegmark, M. (1998). "The interpretation of quantum mechanics: many worlds or many words?". *Fortschritte der Physik* 46, 855. arXiv:quant-ph/9709032.

Tegmark, M. (2000). "Importance of quantum decoherence in brain processes". *Physical Review E* 61, 4194–4206.

Tegmark, M. (2005). "What does inflation really predict?". *Journal of Cosmology and Astroparticle Physics* 2005(04), 001. arXiv:astro-ph/0410281.

Tegmark, M., Aguirre, A., Rees, M. J. and Wilczek, F. (2006). "Dimensionless constants, cosmology and other dark matters". *Physical Review D* 73, 023505. arXiv:astro-ph/0511774.

Tegmark, M. (2008). "The mathematical universe". *Foundations of Physics* 38, 101–150. arXiv:0704.0646.

Tegmark, M. (2014). "Guest post: Max Tegmark on cosmic inflation", with his replies to comments. *Preposterous Universe*, 21 April 2014. preposterousuniverse.com

Tegmark, M. (2015). "Consciousness as a state of matter". *Chaos, Solitons and Fractals* 76, 238–270. arXiv:1401.1219.

The measurements cited by author and year (Abbott and others 2026; Aghanim and others 2020; Camphuis and others 2026; Chen and others 2022; Donadi and others 2021; Li and others 2022; Louis and others 2025; Sinha and others 2010; Tristram and others 2022) are cited as the sealed record cites them; their full entries are in the bibliographies of the books it names.

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Appendix F

The Registered Predictions Beside Stephen Wolfram

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Stephen Wolfram. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Rule and the World; Stephen Wolfram and Physics from Comparison*.
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Abstract

Stephen Wolfram holds that the universe is, at its foundation, a simple rule rewriting a network of discrete elements, and the physics collection of the Immanent Metaphysics holds that the arena of physics has no least step and that no discrete rule is the foundation of physics. The two accounts agree that the statistics of quantum theory hold wherever they have been tested, and that nothing travels backward in time. They predict differently in three places that a measurement can reach. The collection predicts that no least length, area or duration of space will be found, where Wolfram's model has an elementary length far below the Planck length. It predicts that any one fixed discrete rule offered as the foundation of physics shows itself to a measurement fine enough to reach below its least step, where Wolfram's account holds that one rule underlies every finding. It holds that space has three dimensions, where Wolfram's model allows local departures from three and expects large ones in the early universe. And the two agree, read with Wolfram's own definitions, that no body arrives anywhere outside its light cone: Wolfram holds that travel faster than light is not ruled out and may be a problem of engineering, and his own account keeps every effect within the order of causes. Every measurement made to this date agrees with the collection, and none yet reaches the scale at which Wolfram's

discreteness would show. The deepest differences, over what computation is, whether a whole world can be fixed by one rule, and what an observer is, are of a kind no measurement reaches, and the record names them as such.

I. What This Record Is

This record sets the registered predictions of physics from comparison beside the predictions of Stephen Wolfram's program, the model of a hypergraph rewritten by a rule that he set out in *A New Kind of Science* (2002) and carried forward in the Wolfram Physics Project from 2020. Where the two accounts predict differently and a measurement can decide between them, Section II states both predictions, where the collection argues its own, what has been measured, and what will decide. Section III states where they agree. Section V states the differences that no measurement reaches, and Section VI quotes what the collection does not predict where it bears on Wolfram's account.

The rule of decision is the one the sealed record states: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement". A measurement that differs from a prediction by less is a measurement of interest.

Every prediction of the collection stated here is argued in a book named at chapter and section. Where the sealed record carries a prediction, the record quotes it in full and gives its number. One statement in Section II is argued in a book and is not carried by the sealed record as a numbered prediction; the entry says so, and files it among the predictions outside the sealed record. Wolfram's predictions are stated in plain words, each with a citation to his own work or to the work of the project.

II. Where the Two Accounts Predict Differently

Wolfram 1. A least length of space

The collection predicts.

> The speed of light in vacuum does not depend on the energy of the light through any step of spacetime. No discrete spectrum of area or volume will be observed, in the echoes of gravitational waves from merging black holes or anywhere else. Discreteness belongs to the content, the charges and the kinds of particle, and the account predicts it there.

Registered on 1 November 2026 as Prediction 5 of *The Registered Predictions of Physics from Comparison*, under the heading "The arena has no least length, area or duration".

Wolfram predicts. Space is made of discrete elements, the nodes of a hypergraph, and the smooth space of general relativity appears only in a limit. The technical introduction of the project gives an elementary length that "is considerably smaller than the Planck length" (Wolfram 2020b, "Units and Scales"). In the model, causal invariance gives discrete forms of special and general relativity, so that the symmetry of special relativity holds where the continuum limit holds (Gorard 2020a).

Where argued. The Unquantized Arena, Chapter 19, Section V (Prediction 19.4), and Chapter 6, Section IV (Proposition 6.3); *Two Theories, One World*, Chapter 27; *Incommensuration*, Chapter 5, Section III.

Measured. The sealed record reports: "The arrival of high-energy photons from gamma-ray bursts places any energy dependence of the first order above about ten times the Planck energy (LHAASO, Cao and others 2024)". The measurement agrees with the collection. It does not yet separate the two accounts, and *The Unquantized Arena* says why: the timing bounds "test the discrete pictures that predict a dispersion", while "A discreteness that keeps Lorentz invariance, as in causal sets (Bombelli, Henson and Sorkin 2009), predicts no such dispersion and is tested by its own signatures" (Chapter 19, Section V). Wolfram's model is built to keep that invariance in its limit, and its elementary length lies below the Planck length.

What decides it. The sealed record names "The timing of photons of different energies from many sources, told apart from effects at the source by its growth with distance; every observation of the spectrum of area or volume". *The Unquantized Arena* adds a third kind: "every experiment that looks for a least length, area or duration in the geometry; the account says that none will

find one" (Chapter 19, Section V). A least step found at any scale, by any of these, refutes the collection's prediction and supports Wolfram's model; the collection says that no such search will find one.

Wolfram 2. One discrete rule beneath every finding

The collection predicts.

> For any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement, reaching below the rule's least step, tells the rule's statistics from the world's. The established findings of physics are reproduced at the foundation only by a theory of the conjugate kind.

Registered on 1 November 2026 as Prediction 29 of *The Registered Predictions of Physics from Comparison*, under the heading "A discrete rule shows itself to a fine enough measurement". A theory of the conjugate kind is one whose description and findings take the two characters the Incommensuration Theorem allows, one each, as the cross-modal principle requires (Section V).

Wolfram predicts. Beneath the established findings lies a simple program, which would be "a complete and precise representation of the actual operation of the universe" (Wolfram 2002, page 465). The project's account of quantum mechanics is the branching of the histories that a rule allows; Gorard (2020b) reports that the geometry of those branches converges, in the continuum limit, to that of complex projective Hilbert space, and that the model is compatible with the violation of the CHSH inequality. The project has not yet named the rule of our universe: "We don't (yet) know an actual rule that represents our universe" (Wolfram 2020a).

Where argued. The Unquantized Arena, Chapter 3, Sections II and VI; *The Basis of Physics*, Essay 18, Section VII; *Measurement*, Chapter 8, Section VIII.

Measured. The sealed record reports no measurement under this prediction. The measurements it reports for the statistics of quantum theory find those statistics: "Three-slit experiments find the third term consistent with zero (Sinha and others 2010); network experiments in 2022 found the complex composition (Chen and others; Li and others)". No measurement to this date has found a departure from the statistics of quantum theory that a least step of a rule would make.

What decides it. A measurement of the statistics of a quantum process that reaches below the least step of the rule offered. *The Basis of Physics* states the connection: "each proposed rule fixes a precision beyond which it would show" (Essay 18, Section VII). The precision at which the two accounts part is fixed when the project names its rule; until then the prediction stands against every rule the project offers, one at a time.

Wolfram 3. The number of dimensions of space

The collection predicts. Measurement, Chapter 11, Section VI, counts the dimensions of space from the structure of comparison and concludes: "So the dimension of space is three". The six further dimensions the collection counts are dimensions of possibility, held and not traversed (Chapter 11, Sections VII and VIII), and are not dimensions of space. The sealed record carries no numbered prediction on the count; the statement that no region and no epoch will show another count is drawn here from the chapter's derivation, and is filed among the predictions outside the sealed record. For the waves of the geometry, the sealed record carries this:

> Gravitational waves carry the two polarizations of a massless field of spin two, and travel at the speed of light; no further polarization and no other speed will be found.

Registered on 1 November 2026 as Prediction 6 of *The Registered Predictions of Physics from Comparison*.

Wolfram predicts. In the model, the dimension of space is a property of the large-scale structure of the hypergraph and can change. Wolfram writes that it is quite possible, according to the models, that "there are at least local deviations" from three dimensions, and that "most likely there were actually large deviations in the early universe" (Wolfram 2020a). The technical introduction states that "dimension is in effect a dynamical variable", and that changes of dimension may produce effects that "mimic the presence of mass" (Wolfram 2020b, "Cosmology, Expansion and Singularities").

Where argued. Measurement, Chapter 11, Section VI, for the count; for Prediction 6, *The Gravitational Passage*, Chapter 12, Section VII, and Chapter 16, Section V; *The Unquantized Arena*, Chapter 19, Section V; *The Compactification*, Chapter 7, Section II.

Measured. For Prediction 6 the sealed record reports: "The three-detector event GW170814 favors purely tensor polarization; GW170817 with its gamma-ray burst bounds the difference between the speed of gravitational waves and the speed of light to between -3×10^{-15} and $+7 \times 10^{-16}$ of the speed of light (Abbott and others 2017)". From the same event, Pardo, Fishbach, Holz and Spergel (2018) measured the number of dimensions of spacetime through which the gravitational waves travel as 4.02 $(+0.07, -0.10)$ with the Hubble constant of the distance ladder, and 3.98 $(+0.07, -0.09)$ with the Hubble constant of Planck, in agreement with three dimensions of space and one of time. Both agree with the collection.

What decides it. A measurement that finds the dimension of space other than three in some region or at some epoch, or a wave of the geometry beyond the two polarizations of Prediction 6. The collection says that neither will be found; Wolfram's model allows both.

III. Where the Two Accounts Agree

Wolfram 4. Travel faster than light

The collection predicts.

> A finding changes no geometry, here or anywhere, and news of a distant finding enters a record only at an event on or within the future light cone of the finding. Until such a signal arrives, every local statistic follows quantum theory unchanged, whatever measurement was chosen far away. No signal crosses the boundary of comparison, and no body arrives somewhere that is not in its cone. The probabilities of a preparation's outcomes do not depend on which test is chosen later, and no later finding comes to precede an earlier one. Travel within the cone is not excluded, nor the recession of distant galaxies faster than light, which is a growth of the arena between them and not a signal across it.

Registered on 1 November 2026 as Prediction 27 of *The Registered Predictions of Physics from Comparison*, under the heading "No signal faster than light, and none backward in time".

Wolfram predicts. In "Faster than Light in Our Model of Physics: Some Preliminary Thoughts" (Wolfram 2020c), Wolfram holds that travel faster than light is not ruled out by the model. He describes it as "an engineering problem", one that "may well be an irreducibly hard engineering problem", and he names among its possible routes "space tunnels", "long-range threads" in the hypergraph that bring distant places close, including regions where the dimension of space differs. In the same essay he keeps every effect within the order of causes: the events affected "have to be 'subsequent events' with respect to the partial ordering defined by the causal graph". He states his conclusion as preliminary: "I don't know the full answer yet".

Where the two meet. Read with Wolfram's own definitions, the two accounts agree here. Wolfram's faster than light is faster than the large-scale distance between two places allows, through a shortcut in the structure of space, and every effect still runs along the order of causes. The collection's prediction excludes arrival outside the cone of the geometry a body travels in, and a shortcut is a feature of that geometry, as a wormhole is a solution of Einstein's equations, so a body that takes it arrives within the cone of the geometry that has it. The two differ only in words, and on a question of engineering on which the collection takes no side (Section VI).

Where argued. The Unquantized Arena, Chapter 7, Section IV (Proposition 7.2); *The Basis of Physics*, Essay 10; *Measurement*, Chapter 14, Section IV; *The Quantum Passage*, Chapter 8, Section III, and Chapter 11, Section III; *Why Time Travel Is Not a Concept*, Chapter 4, Section IV (Proposition 4.6).

Measured. The sealed record reports no measurement under this prediction. No body and no signal has been found to arrive anywhere outside its light cone.

What decides it. A body or a signal that arrives somewhere not in the cone of the geometry it travels in would refute the collection's prediction, and Wolfram's model forbids that too; the collection says that none will. Whether a geometry with a shortcut can exist or be made bears on Wolfram's expectation and not on Prediction 27. The collection makes no claim about what engineering can do within the cone, as Section VI quotes.

Wolfram 5. The statistics of quantum theory hold

The collection predicts.

> Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights. The interference among three paths has no term that the pairs of paths do not account for. Tests of the CHSH inequality reach $2\sqrt{2}$ and go no further, and stay at 2 or below whenever either party's two observables commute. Experiments with independent sources find the complex, not the real, composition of independent systems.

Registered on 1 November 2026 as Prediction 25 of *The Registered Predictions of Physics from Comparison*.

Wolfram predicts. The project's multiway account is built to reproduce quantum mechanics: the geometry of the branches converges to that of complex projective Hilbert space, the model gives the path integral and the Schrödinger equation in discrete form, and it is compatible with the violation of the CHSH inequality (Gorard 2020b). At every scale above the elementary length, the two accounts predict the same statistics; they part only below it, as Wolfram 2 states.

Where argued. The Quantum Passage, Chapters 5, 7 and 8, and Appendix B; *The Unquantized Arena*, Chapter 13, Section VII.

Measured. "Three-slit experiments find the third term consistent with zero (Sinha and others 2010); network experiments in 2022 found the complex composition (Chen and others; Li and others)". Standing: agrees.

Wolfram 6. Nothing travels backward in time

The collection predicts. Prediction 27, quoted in full under Wolfram 4, states: "The probabilities of a preparation's outcomes do not depend on which test is chosen later, and no later finding comes to precede an earlier one".

Wolfram predicts. Wolfram holds that even a jump faster than light in his model would not carry anything backward in time (Wolfram 2020c). The two accounts agree that no later finding comes before an earlier one, and, as Wolfram 4 sets out, read with Wolfram's own definitions they agree on travel faster than light as well.

Where argued. Why Time Travel Is Not a Concept, Chapter 4, Section IV (Proposition 4.6); *Measurement*, Chapter 14, Section IV.

Measured. The sealed record reports no measurement under this prediction.

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction that the books do not argue; the one prediction it states, that no least length, area or duration of the arena will be found, is argued in *The Unquantized Arena* and registered as Prediction 5.

V. Where No Measurement Decides

A measurement can find false a claim about what will be found. The differences below are of another kind: claims about what a computation is, about the logical form that every finding takes, and about what the act of knowing is. Every measurement already makes use of what such a claim describes, so no outcome of a measurement can be set against it, and falsification does not apply to it. Each is decided by argument, and the books give the argument at the place named.

The ground of each is the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

Which comes first, computation or physics

Kind of claim: a description of what a computation is. Wolfram holds that computation is the foundation: "So computation isn't just a possible formalization; it's the ultimate one for our universe" (Wolfram 2023b). The collection holds that "every computation that is carried out is a physical process, and physics, both the world it studies and the findings it makes, needs no computation" (*Physics Is Not Math*, Chapter 8, Section VI). Every measurement is itself a physical process, so no measurement chooses between the two orders.

A whole world fixed by one rule

Kind of claim: a claim of logical form. Wolfram's multiway system, taken whole, is fixed by its rule and its starting state. The collection excludes every world fixed whole by a law, and the sealed record carries the exclusion:

> No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one.

Registered on 1 November 2026 as Prediction 28 of *The Registered Predictions of Physics from Comparison*; argued in *The Basis of Physics*, Essays 9 and 11, and *Measurement*, Chapter 14, Sections II and III, and in the setting of Wolfram's program in *Physics Is Not Math*, Chapter 8, Section VII. The sealed record reports: "Violations of CP (1964) and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry".

One character at both levels

Kind of claim: a claim of logical form. The cross-modal principle holds that a description and what it describes take the two characters the theorem allows, one each, and *Measurement*, Chapter 8, Section VIII, names the theory it excludes at the foundation: "A cellular automaton on a lattice is the form such a

theory would take". A network of discrete elements rewritten by one rule is of this kind at its foundation. The principle itself is not a measured claim; its face toward measurement is Prediction 29, stated under Wolfram 2.

The observer

Kind of claim: a claim about the act of knowing. Wolfram describes the observer as a computationally bounded process inside the ruliad. The collection holds that every comparison has a stance, a direction and an outcome no prior state fixed, and that a computation has none of the three of its own: "the first-person perspective is continuously asymmetric, a computation is discontinuously symmetric, and the one cannot be composed of the other" (*Causality Without Determinism*, Chapter 5, Section VI). Every measurement is made from such a stance, so none decides what a stance is.

The ruliad and the residue

Kind of claim: a description of what a thing is. Wolfram's ruliad is "the entangled limit of all possible computational processes" (Wolfram 2023b). The collection holds that every theory laid out wholly as structure takes some information as given, an incompressible residue that is hard randomness (*The Last Turtle*, Chapter 32), and that "a description of the whole world from a vantage outside it has no comparison behind it, because the whole has no outside to compare it with" (*Measurement*, Chapter 2, Section II). A measurement is made from inside the world, so no measurement reaches the whole that the ruliad names.

A quantity with no measurement named

The technical introduction of the project gives an estimate of a maximum entanglement speed, a limit on how fast the branches of the multiway system can be explored, and says "one could imagine it being relevant for example in mergers of galactic black holes" (Wolfram 2020b, "Units and Scales"; Wolfram 2020c). The collection describes the update after a measurement as an update of the shared record, not a physical process (*The Quantum Passage*, Chapter 9, Section IV). Neither account names an observation at which the two would part on this quantity, and the record states no test for it.

Where the two agree without measurement

The two accounts agree on three claims of this kind, and the record credits Wolfram with each. Computation is irreducible: in general a program's behavior is known only by running it, which the collection holds in the form of Rice's theorem of 1953 (*Physics Is Not Math*, Chapter 7, Section IV); the theorem is about every program at once, that no general procedure decides any non-trivial property of what a program does, and Wolfram showed, with a great many examples, that irreducibility holds for ordinary simple rules. Equations are not the foundation of physics. And the observer cannot be removed from physics.

VI. What the Collection Does Not Predict Here

Three items of the sealed record's Section IX bear on Wolfram's account.

> Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed (The Unquantized Arena, Chapter 6, Section IV); a detection of single gravitons, or of a primordial background, would not show gravitation quantized (Chapter 9, Section III; Chapter 18, Section VI).

Wolfram's elementary length lies far below the Planck length, so the experiments now proposed do not reach the scale at which the two accounts part on the least step of space (Wolfram 1 and 2).

> No technological feasibility of travel within the light cone is claimed either way (The Basis of Physics, Essay 10, Section VIII).

Wolfram 4 concerns travel outside the light cone, which both accounts exclude on Wolfram's own definitions; on what engineering can do within the cone, the collection makes no claim.

> The size of the asymmetry of time is not predicted, only that it exists (The Basis of Physics, Essay 11, Section VII).

Wolfram derives the second law of thermodynamics from computational irreducibility (Wolfram 2023a); the collection predicts that an asymmetry of time exists in the laws and gives no size for it.

VII. The Record at Its Date

Entry	The collection	Wolfram	Measured	Standing
Wolfram 1. Least length (Prediction 5)	no least length, area or duration	elementary length far below the Planck length	any first-order energy dependence of the speed of light lies above about ten times the Planck energy	agrees with the collection; untested between the two accounts
Wolfram 2. One discrete rule (Prediction 29)	any one fixed rule shows itself below its least step	one rule underlies every finding; not yet named	quantum statistics found wherever tested	untested
Wolfram 3. Dimensions of space (Prediction 6; *Measurement*, Chapter 11)	three, everywhere and at every epoch; two polarizations only	local departures possible; large departures early	4.02 or 3.98 dimensions of spacetime from GW170817; tensor polarization favored	agrees as far as tested; the count filed outside the sealed record
Wolfram 4. Faster than light (Prediction 27)	no body arrives outside its cone	not ruled out; a problem of engineering; every effect within the order of causes	none reported in the sealed record	agree on Wolfram's own definitions; untested
Wolfram 5. Quantum statistics (Prediction 25)	Born weights; $2\sqrt{2}$; no third term; complex composition	reproduced by the multiway account	third term consistent with zero; complex composition found	agrees
Wolfram 6. Nothing backward in time (Prediction 27)	no later finding precedes an earlier one	no travel backward in time	none reported in the sealed record	untested

Summary

Stephen Wolfram and the physics collection agree that the statistics of quantum theory hold wherever they have been tested and that nothing travels backward in time, and they agree, beyond any measurement, that computation is irreducible, that equations are not the foundation of physics, and that the observer cannot be removed from it. They predict differently in three

places. The collection predicts no least length of space, and Wolfram's model has one far below the Planck length. The collection predicts that any one fixed discrete rule shows itself to a measurement reaching below its least step, and Wolfram holds that one rule underlies every finding. The collection holds that space has three dimensions everywhere, and Wolfram's model allows departures from three. On travel faster than light they agree, read with Wolfram's own definitions: the collection predicts that no body arrives outside its light cone, and Wolfram, who holds that travel faster than light is not ruled out, keeps every effect within the order of causes. Every measurement to this date agrees with the collection; none yet reaches the scale at which Wolfram's discreteness would show, and the precision that would decide between the two is fixed once the project names its rule. The deepest differences, over the order of computation and physics, a world fixed whole by a rule, the observer and the ruliad, are claims of a kind that no measurement reaches, and they are decided by the arguments the books give.

Key Concepts

- The collection predicts no least length, area or duration of space, and Wolfram's model has an elementary length far below the Planck length (Wolfram 1).
- Any one fixed discrete rule offered as the foundation of physics shows itself to a measurement that reaches below its least step, and the precision that decides is fixed once the project names its rule (Wolfram 2).
- The collection counts three dimensions of space, and Wolfram's model allows local departures from three; the count is filed among the predictions outside the sealed record (Wolfram 3).
- The collection predicts that no body arrives outside its light cone, and Wolfram's travel faster than light keeps every effect within the order of causes, so on his definitions the two agree (Wolfram 4).
- The two accounts agree that the statistics of quantum theory hold wherever tested and that nothing travels backward in time (Wolfram 5 and 6).
- The differences over the order of computation and physics, a world fixed whole by one rule, the observer and the ruliad are claims no measurement reaches, and the books decide them by argument.

Terms

Arena. The context of physics, the geometry of space and time within which content is found; on the collection's account, what gravitation is.

Causal invariance. Wolfram's name for the property of a rewriting rule whose final relations among events do not depend on the order in which updates are applied.

CHSH inequality. The inequality of Clauser, Horne, Shimony and Holt, a sum of four correlations between two parties that is at most 2 for any local account of hidden variables.

Computational irreducibility. Wolfram's name for the fact that, for most computations, there is no shorter way to find the outcome than to run the computation.

Cross-modal principle. A description and what it describes always take the two characters the Incommensuration Theorem allows, one each.

Elementary length. In Wolfram's model, the length of the smallest step of space.

Hard randomness. An outcome that no prior specification fixes, however complete.

Hypergraph. A network whose links may join any number of elements; in Wolfram's model, the structure of space.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Light cone. The set of events a signal from a given event can reach at or below the speed of light.

Maximum entanglement speed. In Wolfram's model, a limit on how fast the branches of the multiway system can be explored.

Multiway system. In Wolfram's model, the structure of all the histories that a rule allows, branching and merging.

Planck length. The length at which an object's gravitational size equals its quantum size, about 1.6×10^{-35} meters; on the collection's account, the scale where two descriptions meet and not a least length.

Polarization. One of the independent ways in which a wave of the geometry can stretch and squeeze space.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Ruliad. In Wolfram's words, "the entangled limit of all possible computational processes" (Wolfram 2023b).

Standard deviation. The measure of the uncertainty of a measurement.

Sources

Gorard, J. (2020a). "Some Relativistic and Gravitational Properties of the Wolfram Model". *Complex Systems* 29(2), 599. arXiv:2004.14810.

Gorard, J. (2020b). "Some Quantum Mechanical Properties of the Wolfram Model". *Complex Systems* 29(2), 537–598.

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Rule and the World; Stephen Wolfram and Physics from Comparison*. Relation essay, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Incommensuration; The Theorem and the Three Axioms*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-063-3. DOI: https://doi.org/10.67291/ARTV2404.

Landry, Forrest. *The Last Turtle; Essays from Comparison and the Incommensuration Theorem to Causation, the Arena and the Limits of Computation*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Physics Is Not Math; Metaphysics, Physics, Computation and Mathematics, and Why Their Order Cannot Be Otherwise*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Pardo, K., Fishbach, M., Holz, D. E. and Spergel, D. N. (2018). "Limits on the number of spacetime dimensions from GW170817". *Journal of Cosmology and Astroparticle Physics* 2018(07), 048. arXiv:1801.08160.

Wolfram, S. (2002). *A New Kind of Science*. Champaign, Illinois: Wolfram Media.

Wolfram, S. (2020a). "Finally We May Have a Path to the Fundamental Theory of Physics... and It's Beautiful". Stephen Wolfram Writings, April 2020. writings.stephenwolfram.com

Wolfram, S. (2020b). *A Class of Models with the Potential to Represent Fundamental Physics*. Technical introduction, Wolfram Physics Project; sections "Units and Scales" and "Cosmology, Expansion and Singularities". wolframphysics.org/technical-introduction

Wolfram, S. (2020c). "Faster than Light in Our Model of Physics: Some Preliminary Thoughts". Stephen Wolfram Writings, 2 October 2020. writings.stephenwolfram.com

Wolfram, S. (2023a). "Computational Foundations for the Second Law of Thermodynamics". Stephen Wolfram Writings, February 2023. writings.stephenwolfram.com

Wolfram, S. (2023b). “How to Think Computationally about AI, the Universe and Everything”. Stephen Wolfram Writings, October 2023. writings.stephenwolfram.com

Measurements are cited as the sealed record cites them, by author and year; the full entries are in the bibliographies of the books named there.

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Appendix G

The Registered Predictions Beside Arthur Eddington

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Arthur Eddington. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Net and the Measure; Arthur Eddington and Physics from Comparison*.

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Abstract

Arthur Eddington made predictions of two kinds. As an astronomer he tested general relativity at the eclipse of 29 May 1919 and found starlight bent by the Sun by about the amount the theory requires, and he held the cosmological constant to be a true constant of nature at a time when most specialists set it to zero. On both points the physics collection of the Immanent Metaphysics stands with him, and measurement has stood with him too. As the author of a program to deduce the constants of nature from the conditions of knowing, he gave numbers: 137 exactly for the inverse of the fine-structure constant, 1847.6 for the ratio of the proton's mass to the electron's, and, from his value of the cosmological constant, 528 kilometers per second per megaparsec for the rate at which the galaxies recede. He also held that a law of nature must stop a star from collapsing beyond the greatest mass that Subrahmanyan Chandrasekhar found. Measurement has decided each of these four against him. On each, the collection gives the answer measurement gave: the strength of light and the mass ratio stay measured, the rate of expansion follows from the registered matter frac-

tion, and stars above the greatest mass end as neutron stars or black holes. This record sets the two accounts side by side, entry by entry, with the measurement that decides each and its standing on 4 November 2026.

I. What This Record Is

This record sets what the books of physics from comparison predict beside what Arthur Eddington predicted, and says where measurement has decided between them. Eddington died in 1944, so his predictions are fixed in his published work, and most of them have already met measurement. The predictions of the collection are fixed in its books and, at 1 November 2026, in the sealed record named above, whose rule of decision this record keeps: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement". A measurement that differs from a prediction by less is a measurement of interest.

Every prediction of the collection stated here is argued in a book named at chapter and section, or is quoted from the sealed record with its number. Where an entry rests on established physics that the books report, such as the greatest mass of a white dwarf, the record says so. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1. The Incommensuration Theorem is a structural fact about the nature of knowing.

II. Where the Two Accounts Predict Differently

Eddington 1. The strength of light

The collection predicts. The collection makes no prediction of this value, and it argues that none can be made from the structure of comparison: "So no argument from the comparison structure, of any length, fixes α_{em}" (The Strengths of the Kinds, Chapter 1, Section VI). The sealed record lists the strength of light among the measured inputs (its Section IX, quoted in Section VI below). What the collection does state of the number is that it is not whole: "Meas-

ured, the strength of light is $1/\alpha_{em} = 137.035999177$, with uncertainty 21 in the last two digits (2022 recommended values). Eddington's whole number 137 is excluded, because $1/\alpha_{em}$ is not a whole number" (The Strengths of the Kinds, Chapter 1, Section V).

Eddington predicts. The inverse of the fine-structure constant is a whole number fixed by deduction: 136 in "The charge of an electron" (1929), then exactly 137, which by 1932 he described as "obtained by pure deduction, employing only hypotheses already accepted as fundamental in wave mechanics" (Kragh 2015).

Where argued. The Strengths of the Kinds, Chapter 1, Sections V and VI; Why These Numbers, in plain words.

Measured. The inverse strength of light is $137.035999177 \pm 0.000000021$ (2022 recommended values), determined by five routes that the book keeps side by side. Eddington's 137 lies about 1.7 million standard deviations from it (computed from the stated uncertainty).

What decides it. Decided. Independent kinds of measurement agree on a value that is not a whole number, well beyond the rule of decision. The measurement settles Eddington's value; it does not settle whether some deduction could fix the number, which Section V takes up.

Eddington 2. The ratio of the proton's mass to the electron's

The collection predicts. The order of the two masses is derived, the proton's the greater, and the amount is not: "The argument from comparison gives the order of the two inertias, the proton's the greater; the amount is a value of the instance (a value of this world that the structure of comparison does not fix) and is not derived" (The Strengths of the Kinds, Chapter 6, Section V). The same section returns the ratio from other measured couplings as a check of consistency, 1818 by light's way (1593 to 2074) and 1825.3 by the second closure of Chapter 3, and states that "a law fixes the ratio, and this book does not state that law".

Eddington predicts. 1847.6, the ratio of the two roots of a quadratic equation whose coefficients, in units of a standard mass, are ten, one hundred thirty-six and one (Kragh 2015).

Where argued. The Strengths of the Kinds, Chapter 6, Section V.

Measured. 1836.152673426, with uncertainty 32 in the last two digits (CODATA 2022; The Matter We Know, Volume One, gives the earlier value of CODATA 2018, 1836.15267343). Eddington's value lies 0.62 percent above it, about 360 million times that uncertainty (computed).

What decides it. Decided against the deduced value. The collection states no amount for measurement to contradict; its claim of order, the proton the heavier, agrees with measurement.

Eddington 3. The rate at which the galaxies recede

The collection predicts. "Matter makes up a fraction $\Omega_m = 0.311 \pm 0.001$ of the energy of a spatially flat universe at the present epoch, and the cosmological constant carries $\Omega_\Lambda = 0.689$. The number comes from an identity between the particle horizon and the vacuum energy, $I^2\Omega_\Lambda = 8 - 3/\pi$, where I is the radius of the particle horizon in units of the Hubble radius; the Hubble constant and the Planck mass cancel from it, so it fixes a pure number. The uncertainty of ± 0.001 is the spread that the measured density of radiation gives. The same prediction, stated through one more measured quantity each time, gives the age at which the constant is measured, 0.792 de Sitter times; with the matter density in physical units that the microwave background measures, $\Omega_m h^2 = 0.1430 \pm 0.0011$, a Hubble constant of 67.8 ± 0.3 kilometers per second per megaparsec; and with the measured radius of the particle horizon, a vacuum energy density of 2.56×10^{-47} GeV^4. These are one test, stated four ways". Registered on 1 November 2026 as Prediction 7 of *The Registered Predictions of Physics from Comparison*. In the quotation, h is the Hubble constant in units of 100 kilometers per second per megaparsec, and a de Sitter time is the inverse of the rate of expansion that the cosmological constant alone would give.

Eddington predicts. From his theory he took the cosmological constant as 9.8×10^{-55} per square centimeter (1931), and from it computed the recession constant as 528 kilometers per second per megaparsec, which agreed with the observational value accepted in his day and which he counted as evidence for his approach (Kragh 2015, Section 4).

Where argued. The Gravitational Passage, Chapter 13, Sections II to VII; *The Compactification*, Chapter 6, Section X; *The View from Inside*, Chapter 13 and Appendix B.

Measured. As the sealed record reports it: the microwave background's fit of the Hubble constant, 67.4 ± 0.5, lies 0.8 standard deviations from the collection's 67.8; the distance ladder of Cepheid variables gives 73.04 ± 1.04, which the sealed record places 4.9 standard deviations away (computed: 5.0 in units of the measurement's own uncertainty, and 4.8 with the prediction's uncertainty added in quadrature). Both kinds of measurement place the constant below a seventh of Eddington's 528 (computed).

What decides it. Against Eddington's value, decided by both kinds of measurement. For the collection, the sealed record names the decision: the coming measurements of the matter fraction by DESI, Euclid, the Vera C. Rubin Observatory and the Nancy Grace Roman Space Telescope; a Hubble constant settled near 73, with the microwave background's matter density standing, would refute Prediction 7.

Eddington 4. The fate of a star above the greatest mass

The collection predicts. A star held up by electrons has a greatest mass; above it, a remnant held up by the pressure of neutrons is a neutron star, and beyond what any pressure holds, matter ends in a black hole. The Matter We Know, Volume Two, Chapter 13, Section IV, reports the greatest mass from Chandrasekhar (1931): "A star held up by electrons moving near c has a greatest mass, the Chandrasekhar mass, about 1.4 times the Sun's mass for matter of two nucleons to each electron", and above it "no radius holds the star". The Gravitational Passage, Chapter 18, Section III, states where every such path ends: "Stars form, burn out and leave remnants; remnants accrete and merge; bound structures end in black holes". The horizon of a black hole, at the Schwarzschild radius, follows from the field equations that the same book derives (Chapter 16, Section III). The sealed record carries no numbered prediction for this; its Section IX speaks of "a black hole formed from a star".

Eddington predicts. At the meeting of the Royal Astronomical Society of 11 January 1935, in his talk "Relativistic Degeneracy", he rejected Chandrasekhar's greatest mass: "Various accidents may intervene to save the star, but I want more protection than that. I think there should be a law of

Nature to prevent a star from behaving in this absurd way!" (as reported by Sutter 2026; date and title of the talk from the article "Chandrasekhar–Eddington dispute").

Where argued. The Matter We Know, Volume Two, Chapter 13, Section IV, reporting established physics; The Gravitational Passage, Chapter 18, Section III, and Chapter 16, Section III.

Measured. Every white dwarf weighed lies below the greatest mass (standard accounts of white dwarfs, as The Matter We Know, Volume Two, reports them). Cygnus X-1, identified in 1972, was the first black hole detected (the article "Chandrasekhar–Eddington dispute"), and the first gravitational wave detected came from the merger of two black holes (Abbott and others 2016). Pulsars, observed since 1967, are neutron stars: remnants of stellar cores that passed the greatest mass of a white dwarf, held up by the pressure of neutrons.

What decides it. Decided. No law of the kind Eddington asked for has been found, and the remnants he held impossible are observed by light and by gravitational waves, two independent kinds of measurement.

III. Where the Two Accounts Agree

Eddington 5. Starlight bent by the Sun

Both predict. Light passing the Sun is bent by the amount general relativity requires. Eddington led the expedition whose photographs of the eclipse of 29 May 1919 found it so (Dyson, Eddington and Davidson 1920), a result the collection cites in Two Theories, One World and Measurement. The collection derives the field equations, and so the bending: "The classical tests of general relativity, the perihelion precession, the light deflection and the gravitational redshift, are therefore tests of the derived equations" (The Gravitational Passage, Chapter 16, Section III). The sealed record gives the bending no number of its own; its Prediction 6 names as its step that would fail the uniqueness of the Einstein form of the field equations, the same equations.

Measured. At the eclipse of 1919, by about the amount the theory predicts (as Two Theories, One World reports it). *Standing.* Agrees.

Eddington 6. The cosmological constant is a constant of nature

The collection predicts. "The energy of the vacuum has an equation of state of exactly -1, at every epoch: $w_0 = -1$ and $w_a = 0$. The cosmological constant is fixed once, by the horizon of the measurement, as the constant term of one geometry, and the field equations do not let such a term vary from place to place or from epoch to epoch. No dynamical field, no quintessence and no evolving scalar drives the acceleration. The reported departure from -1 will not be confirmed". Registered on 1 November 2026 as Prediction 8 of *The Registered Predictions of Physics from Comparison*.

Eddington predicts. The cosmological constant is indispensable and drives the expansion: "I would as soon think of reverting to Newtonian theory as of dropping the cosmical constant" (*The Expanding Universe*, 1933, page 24, as quoted in Kragh 2015). He held this when most specialists of the 1930s set the constant to zero (Kragh 2015, Section 4). His value of the constant differs from the collection's, as Eddington 3 records; on its being a true constant, the two accounts agree.

Where argued. The Gravitational Passage, Chapter 13, Sections V and VI, and Chapter 18, Section XIII; *The View from Inside*, Chapter 15.

Measured. The acceleration of the expansion was found in 1998 and 1999 from distant supernovae (Riess and others 1998; Perlmutter and others 1999), and Eddington's insistence on the constant was borne out. As the sealed record reports it: the microwave background with baryon acoustic oscillations and type Ia supernovae gives an equation of state of -1.03 ± 0.03; the final analysis of the Dark Energy Survey, combined with DESI and the microwave background, gives a present value of -0.82 ± 0.05, about three standard deviations from a cosmological constant, in one family of combined analyses, which has not reached the rule of decision. *Standing.* Agrees on the existence of the constant; under pressure on its exact constancy, about three standard deviations in one family of analyses. *What decides it.* The expansion history and growth of structure measured by Euclid, the Vera C. Rubin Observatory and the Nancy Grace Roman Space Telescope.

Eddington 7. A universe of evenly spread matter cannot stand still

Both predict. Eddington showed in 1930 that Einstein's static universe is unstable (Eddington 1930), and the collection takes the result from him by name: "So a universe whose matter is spread evenly, and held by nothing but gravity, cannot stand still: it is always growing or shrinking" (The View from Inside). The sealed record gives this no number of its own; its Predictions 7 and 8 describe a universe that expands.
Measured. The universe expands; the sealed record reports the rate as above.
Standing. Agrees.

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction that the books do not argue; every prediction it attributes to the collection is argued in a book cited above.

V. Where No Measurement Decides

The differences below are differences of kind. Each is a claim of logical form, a description of what a thing is, or a claim about the act of knowing, and falsification does not apply to such a claim: every measurement is itself a comparison, so a measurement presupposes the structure these claims describe and cannot stand outside it to test it. Each is decided by examining the argument, and the collection states its argument where named.

Where the net is

A claim about the act of knowing. Eddington placed the form of law in the mind of the knower, a view he called selective subjectivism: "what we comprehend about the universe is precisely that which we put into the universe to make it comprehensible" (as quoted in Kragh 2015). The collection places it in the act of comparison, which every interaction is, so the form found is the form of the world's own interactions (The Story of the Particles, Level 6, Section II; Comparison, Chapter 3, Section V).

Whether deduction can fix the strength of light

A claim of logical form. Measurement excluded Eddington's 137, but no measurement can show that no deduction will ever fix the number. The collection argues that point from the structure of comparison: the kinds, the symmetries and the possible verdicts are the same at every value of the strength of light, so no argument drawn from them ends at one value (The Strengths of the Kinds, Chapter 1, Section VI). Eddington held the opposite, that the resources of his theory were "sufficient and our methods powerful enough to calculate the constants exactly" (as quoted in Kragh 2015).

What kind of number the count of particles is

A description of what a thing is. Eddington gave the number of particles in the universe as twice 136 times two to the power 256, about 3.15×10^{79}, strictly fixed by theory, having called it in 1923 "a number presumably decided by pure accident" (Kragh 2015, Sections 2 and 4). The collection says the amounts are history: the structure of comparison fixes which kinds of particle there are, and not how many of each the universe holds (The Coming of the Kinds, Chapter 1, Section VI). On this point the collection stands with the Eddington of 1923.

Which way validates a number

A claim about the act of knowing. Eddington wrote in 1935 that one should not put "overmuch confidence in the observational results" until they "have been confirmed by theory" (as quoted in Kragh 2015). The collection names three ways a claim is validated, measurement, agreement and proof, and holds that only measurement and proof validate truth, with measurement deciding wherever a number meets the world (Physics Is Not Math, Chapter 19, Section IV); its numbers are stated so that measurement can meet them, under the rule of decision.

VI. What the Collection Does Not Predict Here

The sealed record's Section IX says what the books do not predict. These of its items bear on Eddington's numbers:

- "The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (*The Gravitational Passage*, Chapter 13; *The Strengths of the Kinds*, Chapter 1, Section VI; *The Measures of the Kinds*, Chapter 13, Section X)".
- "The Hubble constant is predicted only through the matter fraction, since it cancels from the identity of Prediction 7".
- "The size of the excess of matter over antimatter is a residue present from the start, which no process among the kinds makes; the kinds fix only the share of it held as baryons (*The Coming of the Kinds*, Chapter 5, Section IV; *The Story of the Particles*, Level 4, Section IV)".
- "The structural books fix the kinds and not their values; the masses, mixings and couplings are carried by *The Strengths of the Kinds* and *The Measures of the Kinds*, which state where measurement has not yet chosen between two readings (*The Story of the Particles*, Level 9, Section V; *The Measures of the Kinds*, Preface and Chapter 13, Section X; *The Strengths of the Kinds*, Chapter 3, Section VI)".

The first item answers Eddington's fine-structure constant; the second, his recession constant; the third, his count of particles; the fourth, his mass ratio.

VII. The Record at Its Date

Entry	The collection	Eddington	Measured	Standing
1. Strength of light	measured input; not a whole number	exactly 137 (earlier 136)	137.035999177 ± 0.000000021	decided against Eddington
2. Proton to electron mass ratio	proton the heavier; amount not derived	1847.6	1836.152673426 (CODATA 2022)	decided against Eddington; the collection's order agrees

Entry	The collection	Eddington	Measured	Standing
3. Rate of recession	67.8 ± 0.3 through Prediction 7	528	67.4 ± 0.5; 73.04 ± 1.04	decided against Eddington; Prediction 7 agrees with the microwave background at 0.8 standard deviations, and the distance ladder lies 4.9 away (one kind of measurement)
4. Star above the greatest mass	ends as a neutron star or a black hole	a law of nature prevents collapse	neutron stars seen as pulsars; black holes seen by light and by gravitational waves	decided against Eddington
5. Bending of starlight	as general relativity requires	as general relativity requires	1919 eclipse	agrees
6. Cosmological constant	a true constant, equation of state exactly -1 (Prediction 8)	indispensable	-1.03 ± 0.03; -0.82 ± 0.05	agrees on the constant; under pressure on exact constancy, about three standard deviations in one family of analyses
7. No still universe	evenly spread matter grows or shrinks	Einstein's static universe is unstable	the universe expands	agrees

Summary

Eddington's predictions as an astronomer and a relativist agree with the collection and with measurement; the numbers he deduced from the conditions of knowing were each decided against him, and the collection deduces none of them. The collection agrees with him that starlight bends by the amount general relativity requires, as his own expedition of 1919 found, that the cosmological constant is a true constant of nature, as the acceleration of the expansion bore out, and that a universe of evenly spread matter cannot stand still, as he showed in 1930. It differs from him on four numbers and claims that measurement has already settled: the strength of light, which is not the whole number 137 and which the collection keeps as a measured input; the

ratio of the proton's mass to the electron's, whose order the collection derives and whose amount it leaves to measurement; the rate of recession, which the collection reaches through its registered matter fraction at 67.8, against Eddington's 528; and the fate of a star above the greatest mass, which ends as a neutron star or a black hole and not by a law that saves it. The differences of kind, where the net of knowing lies, whether deduction can fix the strength of light, what kind of number the count of particles is, and which way validates a number, are argued in the books and are not matters for a measurement.

Key Concepts

- The rule of decision: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.
- Eddington's measured predictions, the bending of light and the cosmological constant, agree with the collection and with measurement.
- Eddington's deduced numbers, 137, 1847.6 and 528, are each decided against him; the collection deduces none of them.
- The strength of light stays measured, because the structure of comparison is the same at every value of it.
- The amounts of matter are history, not structure.
- Bound structures end in black holes; no law of nature saves a star above the greatest mass.

Terms

Chandrasekhar mass. The greatest mass a star held up by its electrons can have, about 1.4 times the Sun's mass.

Cosmological constant. The constant term in the field equations of gravitation, which drives the acceleration of the expansion.

Equation of state. The ratio of the pressure of a component to its energy density; a cosmological constant has the value -1.

Fine-structure constant. The pure number that measures the strength with which light acts on charge; the collection calls it the strength of light.

Hubble constant. The present rate of the expansion, in kilometers per second per megaparsec; Eddington's recession constant.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Matter fraction. The fraction of the energy density of a flat universe carried by matter at the present epoch.

Measured input. A number the account takes from measurement as a premise and does not derive.

Measurement of interest. A measurement that differs from a prediction by less than the rule of decision requires.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Schwarzschild radius. The radius of the horizon of a black hole of a given mass.

Selective subjectivism. Eddington's view that the mind determines the nature and extent of what is called the external world.

Standard deviation. The unit of the uncertainty of a measurement, in which the distance between a prediction and a measurement is counted.

White dwarf. The remnant of a star, held up against its gravity by the pressure of its electrons.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Net and the Measure; Arthur Eddington and Physics from Comparison*. Relation essay, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *The Coming of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-078-7. DOI: https://doi.org/10.67291/CIJI9065.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *The Strengths of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-115-9. DOI: https://doi.org/10.67291/DRP-C4419.

Landry, Forrest. *The Story of the Particles*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-053-4. DOI: https://doi.org/10.67291/TJQH1629.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *The View from Inside*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-074-9. DOI: https://doi.org/10.67291/HGNK5132.

Landry, Forrest. *Comparison, the Necessary Basis*; *Physics Is Not Math*; *The Matter We Know*, Volumes One and Two; *Why These Numbers*; *The Compactification*. Wytheville, Virginia: UVSM Publications, 2026.

Abbott, B. P. and others (2016). "Observation of gravitational waves from a binary black hole merger". *Physical Review Letters* 116, 061102.

Chandrasekhar, S. (1931). "The maximum mass of ideal white dwarfs". *The Astrophysical Journal* 74, 81–82.

Dyson, F. W., Eddington, A. S. and Davidson, C. (1920). “A determination of the deflection of light by the Sun’s gravitational field, from observations made at the total eclipse of May 29, 1919”. *Philosophical Transactions of the Royal Society of London A* 220, 291–333.

Eddington, A. S. (1929). “The charge of an electron”. *Proceedings of the Royal Society of London A* 122, 358–369.

Eddington, A. S. (1930). “On the instability of Einstein’s spherical world”. *Monthly Notices of the Royal Astronomical Society* 90, 668–678.

Eddington, A. S. (1933). *The Expanding Universe*. Cambridge: Cambridge University Press.

Kragh, H. (2015). “On Arthur Eddington’s theory of everything”. arXiv: 1510.04046.

Perlmutter, S. and others (1999). “Measurements of Ω and Λ from 42 high-redshift supernovae”. *The Astrophysical Journal* 517, 565–586.

Riess, A. G. and others (1998). “Observational evidence from supernovae for an accelerating universe and a cosmological constant”. *The Astronomical Journal* 116, 1009–1038.

Sutter, P. (2026). “Chandrasekhar and the limits of physics, part 2: humiliation”. *Universe Today*, 21 July 2026. universetoday.com.

Wikipedia contributors. “Chandrasekhar–Eddington dispute”. *Wikipedia*, accessed 4 November 2026, for the date of the meeting of 11 January 1935, the title of Eddington’s talk and the detection of Cygnus X-1 in 1972. en.wikipedia.org.

The measurements of the cosmological entries are cited as the sealed record cites them, with full entries in the bibliographies of the books named there.

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Appendix H

The Registered Predictions Beside George Ellis

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of George Ellis. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Open Future; George Ellis, Time, Causation and Physics from Comparison*.
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Abstract

George Ellis is the cosmologist who has asked most persistently what observation can and cannot settle about the universe as a whole, and the physics collection of the Immanent Metaphysics meets his standard of testability with predictions registered on 1 November 2026. This record sets those predictions beside his. Four differences can be decided by measurement. Ellis has long taken seriously a universe whose space is positively curved and closed, and the collection predicts space flat to the size of the primordial departures. Ellis's models of the early universe carry an inflationary phase, and the collection predicts no long inflationary phase and no primordial gravitational waves. Ellis has held open a spatially closed small universe, small enough that light has crossed it, and the collection predicts that no such short loop exists anywhere. Ellis has asked whether the acceleration of the expansion is an effect of inhomogeneity rather than a constant of the geometry, and proposed tests of homogeneity; the collection predicts a cosmological constant with an equation of state of exactly -1. On two further predictions the accounts agree: no world is perfectly deterministic, and the statistics of quantum theory hold, which the contextual collapse of Drossel and Ellis reproduces. Their deeper differences, where the present is, what reduction is, where the arrow of time comes from, and why the multiverse

is not physics, are of a kind no measurement reaches, and the record says which kind each is. At this date no deciding measurement has reached the rule of decision against either account; one, the equation of state of the vacuum energy, presses on the collection's Prediction 8 at about three standard deviations in one family of analyses.

I. What This Record Is

This record sets side by side what the physics collection predicts and what the work of George Ellis predicts, entry by entry, wherever a measurement, an observation, a search or an experiment can tell the two apart. It then states where the two agree, and where they part on questions no measurement can settle. Every prediction of the collection stated here is argued in a book named at its chapter and section, and is registered in the sealed record of 1 November 2026, whose words are quoted in full; a prediction stated only in the relation essay would be marked as such in Section IV, and there is none.

The rule of decision is the sealed record's own: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such".

The predictions come from one account. The Incommensuration Theorem is a structural fact about the nature of knowing: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

Ellis has argued that a theory earns the name of physics by facing the world. With Joseph Silk he wrote that "The imprimatur of science should be awarded only to a theory that is testable" (Ellis and Silk 2014), and the collection's book of objections answers that "the account meets the standard of Ellis and Silk where the standard applies, in its consequences" (Objections from Physics, Answered, the cross-modal reach). This record is that standard ap-

plied to the two accounts together. It also records a debt: the collection's second route to the even beginning of an epoch (an epoch is one cycle of the universe, from one turn to the next, and its even beginning is one with no shear) is Ellis's own result with Malcolm MacCallum, that in a homogeneous expansion with flat slices of space and no stress pulling differently in different directions the shear falls as the inverse cube of the scale of distances (The Gravitational Companion, Chapter 3, Section IX; Ellis and MacCallum 1969).

II. Where the Two Accounts Predict Differently

Ellis 1. The curvature of space

The collection predicts. "The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}". Registered on 1 November 2026 as Prediction 9 of The Registered Predictions of Physics from Comparison.

Ellis predicts. Ellis has kept a positively curved, spatially closed universe in view for decades, and his work treats the sign of the curvature as a question for observation. In 2003, with Jean-Philippe Uzan and Ulrich Kirchner, he took seriously the marginal indication of the WMAP data that space has positively curved, spherical sections, and worked out what it implies for the early universe (Uzan, Kirchner and Ellis 2003). In 2006 he wrote that the sign of the curvature was uncertain, but that the combined evidence of the observations then available, taken at face value, made it positive (Ellis 2006, Section 2.8). The emergent universe of Ellis and Roy Maartens depends on that sign: positive curvature is what allows it to begin as an Einstein static universe (Ellis and Maartens 2004). His closed models allow the curvature today to be very small, but its sign is positive.

Where argued. The restoration of the exterior at the turn (the re-forming of the open space of the new epoch, at the passage from one epoch to the next, from the one domain that the old interiors are at their end) fixes the curvature, since the only lengths the new epoch has to set one are the length of the turn and the de Sitter radius (The Gravitational Passage, Chapter 18, Section IX; The Compactification, Chapter 6, Section VI). Ellis's result with MacCallum, which the collection uses for the sameness of the expansion in

every direction, "needs the slices to be flat", and the collection's flat new epoch meets that condition (The Gravitational Companion, Chapter 3, Section IX).

Measured. The microwave background with the baryon acoustic oscillations gives a curvature share of 0.001 ± 0.002, as the sealed record reports (Aghanim and others 2020). The spectra of the Planck satellite taken alone prefer positive curvature at more than 99 percent confidence (Di Valentino, Melchiorri and Silk 2019); that preference comes from one kind of measurement, does not survive the addition of the baryon acoustic oscillations, and is a measurement of interest.

What decides it. The Dark Energy Spectroscopic Instrument (DESI) and the Euclid satellite, which measure the curvature of space with the matter fraction. "A curvature confirmed at the level of 10^{-3} refutes it", as the sealed record states for Prediction 9; a positive curvature confirmed at that level would agree with Ellis's closed models. A measurement that finds no curvature at finer precision leaves Ellis's closed models open only with a curvature driven very small, which in his models is the work of an inflationary phase (Uzan, Kirchner and Ellis 2003; Ellis and Maartens 2004), the subject of Ellis 2.

Ellis 2. An inflationary phase and its gravitational waves

The collection predicts. "No inflationary phase long enough to stretch the lengths observed today from within the early horizon to beyond it occurred. The horizon and flatness problems are answered by the turn from the previous epoch, with no inflation". Registered on 1 November 2026 as Prediction 13 of The Registered Predictions of Physics from Comparison. And: "The primordial departures of the metric are scalar, sourced by departures of density, and waves of the metric arise from them only at second order: the ratio of tensor to scalar power is far below 10^{-6}. The Simons Observatory and LiteBIRD will find no primordial tensor signal". Registered on 1 November 2026 as Prediction 10 of The Registered Predictions of Physics from Comparison.

Ellis predicts. Ellis's models of the early universe carry an inflationary phase. The emergent universe of Ellis and Maartens inflates after its static origin and then reheats into the hot big bang (Ellis and Maartens 2004), and

Uzan, Kirchner and Ellis found the limit that positive curvature places on the number of e-foldings (each a growth of the scale of distances by a factor of e, about 2.7) consistent with inflationary models that solve the usual cosmological problems (Uzan, Kirchner and Ellis 2003). Ellis has been careful about its standing: he wrote that most cosmologists regard inflation as the "best proposal available for the era prior to the Hot Big Bang", that it is a "generic proposal for what happened" rather than a specific physical theory, and that detecting its primordial gravitational waves would be an "important test of inflation" (Ellis 2006, Section 2.6). An inflationary phase that makes the observed departures from the fluctuations of its own vacuum also makes primordial gravitational waves, at a size set by the energy of the phase.

Where argued. The sameness of the sky is answered by the one domain carried through the turn, and the flatness by the lengths that remain; a long phase is excluded because the observed departures are the form of the content carried through the turn, while a shorter phase "is neither required nor excluded by the account" (The Compactification, Chapter 6, Section VIII; The Gravitational Passage, Chapter 18, Questions; The Compactification, Chapter 1, Section VIII). The exclusion bears on the dark matter as well: "In an epoch whose observed departures were made by inflation, the bound on primordial gravitational waves (BICEP/Keck Collaboration 2021) would keep the temperature far below this limit, and dark matter of this mass could not be made after that inflation in the measured amount" (The Weight of Possibility, Chapter 4, Section VI, quoted in The Compactification, Chapter 6, Section VIII). The scalar character of the departures is argued in The Gravitational Passage, Chapter 18, Section IX.

Measured. The ratio of tensor to scalar power is below 0.032 (Tristram and others 2022); no primordial tensor signal has been detected. The flatness, the adiabatic character of the departures and their one pattern across the sky, Predictions 9, 11 and 12, agree with the measurements the sealed record reports.

What decides it. The polarization of the microwave background: "the Simons Observatory will reach about one part in a thousand, and LiteBIRD below two parts in a thousand", in the sealed record's words. A primordial

tensor signal confirmed at any size those instruments reach refutes Prediction 10 and counts as the test of inflation Ellis named. The sealed record names the measurements of Predictions 9 to 12 together as what decides Prediction 13.

Ellis 3. A small universe

The collection predicts. "No closed path that goes around the universe, and so cannot be shrunk to a point, is shorter than the diameter of the horizon, at any location. A region with such a path would count at least two classes, and the ratio of Prediction 16 would then be $6 - 1/\pi = 5.682$ or larger". Registered on 1 November 2026 as Prediction 23 of The Registered Predictions of Physics from Comparison.

Ellis predicts. Among the readings of the low power of the microwave background on the largest angles, Ellis has listed our living in a "well-proportioned" small universe, spatially closed (Ellis 2006, Section 2.3.7), and he has pointed out that only in a universe whose spatial sections are small enough for light to have crossed them does the visual horizon not hide most of the universe from us (Section 2.4). He does not predict that the universe is small; his account allows it and names it as observable. The collection's account excludes it.

Where argued. The ratio of the dark matter to the ordinary matter, $6 - 2/\pi$, rests on a count of one class for the region within the horizon, which is a ball; a region with a closed path around the universe would count at least two classes, and the ratio would then be $6 - 1/\pi = 5.682$ or larger, as Prediction 23 states (The Weight of Possibility, Chapter 3, Section II; Chapter 5, Section IX).

Measured. "Searches of the microwave background find every such path through our location longer than 98.5 percent of the diameter of the last scattering surface (Petersen and others 2023)", as the sealed record reports. The measured ratio of the dark matter to the ordinary matter, 5.370 ± 0.048 (Camphuis and others 2026), lies well below the 5.682 that a short loop would give.

What decides it. Every finer search of the microwave background for a closed path around the universe, of the kind the sealed record reports; and the ratio of the dark matter to the ordinary matter, measured by a second in-

dependent kind of measurement as Prediction 16 requires. A short loop found anywhere would confirm the possibility Ellis kept open and refute Prediction 23.

Ellis 4. The acceleration of the expansion: a constant, or an effect of inhomogeneity

The collection predicts. "The energy of the vacuum has an equation of state of exactly -1, at every epoch: $w_0 = -1$ and $w_a = 0$. The cosmological constant is fixed once, by the horizon of the measurement, as the constant term of one geometry, and the field equations do not let such a term vary from place to place or from epoch to epoch. No dynamical field, no quintessence and no evolving scalar drives the acceleration. The reported departure from -1 will not be confirmed". Registered on 1 November 2026 as Prediction 8 of The Registered Predictions of Physics from Comparison.

Ellis predicts. Ellis treats the homogeneity of the universe on the largest scales as a hypothesis to be tested, and not a principle to be assumed. He has argued that averaging over inhomogeneities can feed back on the large-scale dynamics, and that a universe inhomogeneous on the scale of the Hubble radius, in violation of the Copernican principle, might account for some or all of the apparent acceleration with no dark energy at all (Ellis 2011). With Uzan and Chris Clarkson he proposed a test that uses only background observations: the drift of cosmological redshifts over time, set beside the distances of the same sources, obeys a consistency relation in every homogeneous universe whatever its content, and a departure from it would show inhomogeneity (Uzan, Clarkson and Ellis 2008). His account holds the source of the acceleration open; it does not fix the equation of state.

Where argued. The cosmological constant is one constant of one geometry, by the contracted Bianchi identity and the conservation of the content's energy (The Gravitational Passage, Chapter 13, Section V; Section VI; The View from Inside, Chapter 15). On inhomogeneity, The Quantum Bridge states: "Green and Wald (2011) showed that, where the metric perturbation is small, though the density contrast may be large, the effect of small-scale inhomogeneities on the large-scale geometry cannot mimic a cosmological constant", and the measured metric perturbation of the observed universe is about 3×10^{-5} (The Quantum Bridge, Chapter 8, Section IV).

Measured. As the sealed record reports: "The microwave background with baryon acoustic oscillations and type Ia supernovae gives $w = -1.03 \pm 0.03$ (Aghanim and others 2020). The final analysis of the Dark Energy Survey, combined with DESI and the microwave background, gives $w_0 = -0.82 \pm 0.05$ and $w_a = -0.63$ $(+0.21/-0.18)$, about three standard deviations from a cosmological constant, and 2.6 without its supernovae (Abbott and others 2026). That departure rests on one family of combined analyses, and it has not reached the rule of decision". On homogeneity, the upper limits on the kinetic Sunyaev Zel'dovich effect from the Atacama Cosmology Telescope and the South Pole Telescope rule out the adiabatic void model as an alternative to dark energy (Zhang and Stebbins 2011). The redshift drift Ellis proposed has not yet been measured.

What decides it. "The expansion history and growth of structure measured by Euclid, the Vera C. Rubin Observatory and the Nancy Grace Roman Space Telescope", as the sealed record names for Prediction 8. A departure from an equation of state of -1 confirmed by the rule of decision refutes Prediction 8; it would leave open, between a dynamical field and an effect of inhomogeneity, the question Ellis asked. The test of Uzan, Clarkson and Ellis, the drift of redshifts set beside distances, bears on homogeneity directly.

III. Where the Two Accounts Agree

Ellis 5. No world is perfectly deterministic

The collection predicts. "No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one". Registered on 1 November 2026 as Prediction 28 of The Registered Predictions of Physics from Comparison (The Basis of Physics, Essay 11; Causality Without Determinism, Chapter 1, Section IX).

Ellis predicts. The same. In the evolving block universe the future is not yet decided, conservation laws constrain it without fixing which outcome occurs, and measurement is irreversible (Ellis 2013; Ellis and Drossel 2020). Ellis reached the open future from inside physics, against a strong current in his field.

Measured. "Violations of CP (1964) and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry", as the sealed record reports.

Ellis 6. The statistics of quantum theory hold

The collection predicts. "Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights. The interference among three paths has no term that the pairs of paths do not account for. Tests of the CHSH inequality reach $2\sqrt{2}$ and go no further, and stay at 2 or below whenever either party's two observables commute. Experiments with independent sources find the complex, not the real, composition of independent systems". Registered on 1 November 2026 as Prediction 25 of The Registered Predictions of Physics from Comparison (The Quantum Passage, Chapter 7; Appendix B).

Ellis predicts. The contextual wavefunction collapse of Barbara Drossel and Ellis gives the weights of the Born rule: of their account of the double slit they write, "This is Born's rule for position measurements" (Drossel and Ellis 2018).

Measured. "Three-slit experiments find the third term consistent with zero (Sinha and others 2010); network experiments in 2022 found the complex composition (Chen and others; Li and others)", as the sealed record reports.

IV. Predictions Stated Only in the Relation Essay

There are none. Every prediction the relation essay names is argued in the books and registered in the sealed record: entanglement through gravitation (Prediction 1), no quantum of the arena (Prediction 3), universal free fall (Prediction 4), no dependence of the speed of light on its energy (Prediction 5), and the matter fraction of 0.311 (Prediction 7).

V. Where No Measurement Decides

The deepest differences between Ellis and the collection are not differences of prediction. A test is a comparison of outcomes, and it settles something only where the outcome of a comparison can be objective (Physics Is Not Math, Chapter 19, Section III). A claim of logical form, a description of what a thing is, or a claim about the act of knowing is not of that kind: every experiment already performs the act such a claim is about, and every outcome is read through it. Falsification applies to the claims of Sections II and III and does not apply to the claims below; to charge them with unfalsifiability is to fit a method to the wrong kind of claim (The Case for Measurement, Chapter 5). No test is proposed for them here.

Where the present is. For Ellis the present is the advancing boundary of an evolving block, defined by the proper time along the worldlines of matter. For the collection the present is the act of comparison itself, and event time is "the order of findings for a comparer" (The Unquantized Arena, Chapter 10; The Basis of Physics, Essay 11, Section VI). This is a description of what a thing is. Both accounts predict the same findings in every experiment, and both exclude the frozen block.

What reduction is. For Drossel and Ellis the collapse of the wavefunction is a physical process, stochastic and not unitary, arising in the heat bath of the detector. For the collection "the state update upon measurement is not a physical process. It is not an additional dynamical law. It is an epistemic update" (The Quantum Passage, Chapter 9, Section IV). This is a description of what a thing is. Both give the weights of the Born rule, so the measurements of Prediction 25 agree with both.

Where the arrow of time comes from. For Ellis the direction of time is imposed from the top down by the expansion of the cosmos together with a low-entropy beginning, and local arrows line up with it. For the collection there are two arrows: the structural arrow, in every comparison, which "depends on no entropy, no boundary condition, no Past Hypothesis, and no particular formalism", and the entropic arrow, to which the cosmic alignment Ellis describes belongs (The Basis of Physics, Essay 11, Abstract; The Compactification, Chapter 3, Section II; Why Time Travel Is Not a Concept, The Two Arrows of Time). The structural arrow is a claim of logical form, from the exclusion of faithful reversal. The size of the asymmetry is not predicted (Section VI).

Causation from above. Ellis's top-down causation acts "owing to the crucial role of context in determining the outcomes of lower level causation" (Ellis 2012). The collection writes context into the definition of causality, "the subjective perception (context) of a consistency between two objective contents", and holds causation from above and from below to be two directions of one interdependence (Causality Without Determinism, Chapter 1, Section III; Chapter 2, Section VIII). This is a description of what causation is, and the two accounts stand close on it.

The ground of a test. Ellis and Silk ask that every theory of the universe face experiment. The collection meets that demand for every claim a test can reach, and places its foundation, the Incommensuration Theorem, where no experiment can go, because "a test of it is a comparison, within its scope before the test begins"; the foundation states, in its author's words, what a counterexample to it would have to be (The Ground of Objection, entry T1.10, its entry on Popper's criterion). This is a claim about the act of knowing.

The multiverse. Ellis holds that an ensemble of universes cannot be tested and should not be called physics. The collection agrees, and adds a structural ground: its action is the geometry alone, so "the account has no flux sectors, and the landscape of flux vacua has no counterpart in it" (The Compactification, Chapter 2, Section VI). This is a claim of logical form. The two accounts reach the same verdict on different grounds.

VI. What the Collection Does Not Predict Here

Four items of the sealed record's Section IX bear on this comparison, and each is quoted in full.

> "The size of the asymmetry of time is not predicted, only that it exists (The Basis of Physics, Essay 11, Section VII)".

Ellis ties the size and direction of the arrow to the cosmos; the collection, as the item above states, claims its existence in every comparison and claims nothing about its size (The Basis of Physics, Essay 11, Section VII).

> "The amplitude of the primordial departures and the sign of their tilt are not fixed; the running of the tilt is given only on a condition the books do not adopt (The Gravitational Passage, Chapter 18, Section IX; The Compactification, Chapter 6, Section VII)".

An inflationary phase of the kind Ellis's models carry would set the amplitude and tilt from the field that drives it; the collection takes both as measured inputs (The Compactification, Chapter 6, Section VII).

> "The dynamics of the transition between epochs, and how the gyrations are made at the turn, are not computed (The Weight of Possibility, Chapter 6)".

The emergent universe of Ellis and Maartens gives a dynamics for the origin of the expansion, from an Einstein static state; the collection's turn has no computed dynamics (The Weight of Possibility, Chapter 6).

> "The account asserts neither the return of the information that falls into a black hole formed from a star to the outside world, nor its loss to it (The Unquantized Arena, Chapter 17, Section VII); on the account of The Gravitational Passage that information is not destroyed, and re-emerges in the initial conditions of the next epoch (Chapter 18, Section XIII)".

Ellis has argued that an astrophysical black hole, in a realistic cosmological setting, never evaporates away, and that the matter and information that fall in disappear into its singularity (Ellis 2013b). As the item above states, the collection holds that the information is not destroyed, and asserts neither its

return to the outside nor its loss to it (The Unquantized Arena, Chapter 17, Section VII; The Gravitational Passage, Chapter 18, Section XIII). No observation of a hole formed from a star reaches this difference.

VII. The Record at Its Date

Entry	The collection	Ellis	Measured	Standing
Ellis 1. Curvature of space (Prediction 9)	Flat; curvature of order 10^{-5}	Positive curvature taken seriously; closed models	0.001 ± 0.002; Planck alone prefers positive curvature (one kind)	agrees; the Planck preference is a measurement of interest
Ellis 2. Inflation and primordial waves (Predictions 10, 13)	No long inflationary phase; tensor ratio far below 10^{-6}	Models with an inflationary phase; its gravitational waves the test	Tensor ratio below 0.032	agrees as far as tested
Ellis 3. Small universe (Prediction 23)	No loop shorter than the horizon	A closed small universe kept open	None shorter than 98.5 percent	agrees as far as tested
Ellis 4. Source of the acceleration (Prediction 8)	A constant; equation of state exactly -1	Open; inhomogeneity may account for some or all of it	-1.03 ± 0.03; -0.82 ± 0.05 in one family of analyses; adiabatic void ruled out	under pressure: about three standard deviations in one family of analyses
Ellis 5. No perfect determinism (Prediction 28)	As stated	The same	CP and time-reversal violations	agrees
Ellis 6. Quantum statistics (Prediction 25)	Born weights; $2\sqrt{2}$; no third term	Born weights, from contextual collapse	As stated	agrees

Summary

George Ellis has asked more steadily than any other cosmologist what observation can settle about the universe as a whole, and the physics collection answers him with predictions registered at a date. Four of them part from his

account in ways a measurement will decide. On the curvature of space, Ellis has kept a closed universe in view and the collection predicts flatness to the size of the departures; the combined measurement agrees with flatness, and the preference of the Planck spectra alone for positive curvature is a measurement of interest. On inflation, Ellis's models carry an inflationary phase whose gravitational waves he named as its test, and the collection predicts no long phase and no primordial tensors; nothing has been found. On a small universe, Ellis kept open what the collection excludes; the searches find no short loop. On the acceleration, Ellis asked whether inhomogeneity could account for it and proposed the redshift drift to test homogeneity, and the collection predicts a constant with an equation of state of exactly -1; that prediction is under pressure at about three standard deviations in one family of analyses, short of the rule of decision.

The two accounts agree that no world is perfectly deterministic and that the statistics of quantum theory hold. They part, beyond any measurement, on where the present is, what reduction is, where the arrow of time comes from and how causes act from above, and they reach one verdict on the multiverse from two grounds. The collection owes its second route to the even beginning of an epoch to Ellis's own result with MacCallum.

Key Concepts

- The rule of decision: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.
- Four deciding measurements: the curvature of space; primordial gravitational waves; a short loop around the universe; the equation of state of the vacuum energy and the drift of redshifts.
- Agreement: no world is perfectly deterministic; the weights of the Born rule hold.
- Claims no measurement reaches: where the present is, what reduction is, the source of the arrow of time, causation from above, the ground of a test, the multiverse.
- A debt: the decay of shear in a flat homogeneous expansion (Ellis and MacCallum 1969) is the collection's second route to the even beginning.

Terms

Adiabatic void model. A universe in which we sit near the center of a large underdense region, so that the expansion seems to accelerate with no dark energy.

Backreaction. The effect of inhomogeneities, averaged, on the expansion of the universe as a whole.

Copernican principle. The assumption that we occupy no special place in the universe, from which, with isotropy, homogeneity follows.

Cosmological constant. The constant term of the geometry in the field equations, whose energy has an equation of state of exactly -1.

Curvature share. The share of the critical density carried by the curvature of space; positive curvature means closed, spherical sections.

De Sitter radius. The radius of the horizon of a universe of vacuum energy alone.

Emergent universe. The model of Ellis and Maartens that begins as an Einstein static universe, positively curved, and then inflates.

Equation of state. The ratio of the pressure of a component to its energy density.

Evolving block universe. Ellis's account of space and time as a block with a fixed past and an advancing future boundary.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Inflation. A proposed early phase of accelerated expansion that stretches a region once in causal contact to beyond the present horizon.

Kinetic Sunyaev Zel'dovich effect. The shift in the microwave background caused by its scattering off electrons moving relative to it.

Redshift drift. The slow change, over years, of the redshift of a distant source as the expansion proceeds.

Shear. The part of an expansion that changes the shape of a small region without changing its volume.

Short loop. A closed path that goes around the universe, so that it cannot be shrunk to a point, and is shorter than the diameter of the horizon.

Small universe. A spatially closed universe small enough that light has crossed it since the beginning.

Tensor to scalar ratio. The power of primordial gravitational waves relative to that of the primordial departures of density.

Turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; no comparison registers it as an event.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Open Future; George Ellis, Time, Causation and Physics from Comparison*. Relation essay, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-075-6.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *The Gravitational Companion; Extensions, Comparisons and Open Questions for The Gravitational Passage*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-057-2. DOI: https://doi.org/10.67291/LJOZ4364.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *The Quantum Bridge; Entanglement, Error Correction, and the Limits of Simulation*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-107-4. DOI: https://doi.org/10.67291/NHFX3629.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The View from Inside*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-074-9. DOI: https://doi.org/10.67291/HGNK5132.

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

The other books of the collection cited (Objections from Physics, Answered; Physics Is Not Math; The Case for Measurement; The Ground of Objection) are linked where cited and published by UVSM Publications, Wytheville, Virginia.

Aghanim, N. and others (Planck Collaboration) (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6.

Di Valentino, E., Melchiorri, A. and Silk, J. (2019). "Planck evidence for a closed Universe and a possible crisis for cosmology". *Nature Astronomy*. DOI 10.1038/s41550-019-0906-9. arXiv:1911.02087.

Drossel, B. and Ellis, G. F. R. (2018). "Contextual wavefunction collapse: an integrated theory of quantum measurement". *New Journal of Physics* 20, 113025. arXiv:1807.08171.

Ellis, G. F. R. (2006). "Issues in the Philosophy of Cosmology". arXiv:astro-ph/0602280.

Ellis, G. F. R. (2011). "Inhomogeneity effects in cosmology". *Classical and Quantum Gravity* 28, 164001. arXiv:1103.2335.

Ellis, G. F. R. (2012). "Top-down causation and emergence: some comments on mechanisms". *Interface Focus* 2, 126–140.

Ellis, G. F. R. (2013). "The arrow of time and the nature of spacetime". arXiv: 1302.7291.

Ellis, G. F. R. (2013b). "Astrophysical black holes may radiate, but they do not evaporate". arXiv:1310.4771.

Ellis, G. F. R. and Drossel, B. (2020). "Emergence of time". arXiv:1911.04772.

Ellis, G. F. R. and MacCallum, M. A. H. (1969). "A class of homogeneous cosmological models". *Communications in Mathematical Physics* 12, 108–141.

Ellis, G. F. R. and Maartens, R. (2004). "The emergent universe: inflationary cosmology with no singularity". *Classical and Quantum Gravity* 21. DOI 10.1088/0264-9381/21/1/015. arXiv:gr-qc/0211082.

Ellis, G. F. R. and Silk, J. (2014). "Scientific method: Defend the integrity of physics". *Nature* 516, 321–323.

Green, S. R. and Wald, R. M. (2011), as cited in The Quantum Bridge, Chapter 8, Section IV.

Uzan, J.-P., Clarkson, C. and Ellis, G. F. R. (2008). "Time drift of cosmological redshifts as a test of the Copernican principle". *Physical Review Letters* 100, 191303. arXiv:0801.0068.

Uzan, J.-P., Kirchner, U. and Ellis, G. F. R. (2003). "Wilkinson Microwave Anisotropy Probe data and the curvature of space". *Monthly Notices of the Royal Astronomical Society*. DOI 10.1046/j.1365-8711.2003.07043.x. arXiv:astro-ph/0302597.

Zhang, P. and Stebbins, A. (2011). "Confirmation of the Copernican principle at Gpc radial scale and above from the kinetic Sunyaev Zel'dovich effect power spectrum". *Physical Review Letters* 107, 041301. arXiv:1009.3967.

Measurements quoted from the sealed record (Tristram and others 2022; Petersen and others 2023; Camphuis and others 2026; Abbott and others 2026; Sinha and others 2010; Chen and others 2022; Li and others 2022; CPLEAR 1998; BaBar 2012) are cited there and in the bibliographies of the books it names.

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Appendix I

The Registered Predictions Beside Mordehai Milgrom and Stacy McGaugh

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Mordehai Milgrom and Stacy McGaugh. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Law and the History; Mordehai Milgrom, Stacy McGaugh and the Weight of Possibility*.

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Abstract

Mordehai Milgrom and Stacy McGaugh found that the motions of disc galaxies follow their visible matter by one rule, which turns at one acceleration, and the modified Newtonian dynamics writes that rule into the law of gravity. The physics collection of the Immanent Metaphysics keeps the law of gravity as general relativity gives it and places the rule in the history of how galaxies formed, around a dark matter that is a conserved excitation of the six internal dimensions. This record sets the two accounts side by side, prediction by prediction. The sharpest difference is the external field effect: the modified dynamics predicts it, and the collection predicts that a galaxy falling freely in a larger field feels that field only through its tide, so that there is no external field effect. The accounts also part on clusters of galaxies, on the ratio of dark to ordinary matter that the microwave background measures, on how early massive galaxies formed, and on whether dark clumps that hold no stars exist. They agree on the speed and polarizations of gravitational waves in the relativistic form of the modified dynamics now standing, on the outcome of every search for a dark

particle, and on the measured relations that Milgrom and McGaugh established, which the collection takes as measured input. Two predictions are stated in the relation essay and not in the books, and they are filed outside the sealed record.

I. What This Record Is

This record sets the registered predictions of physics from comparison beside what the modified Newtonian dynamics of Mordehai Milgrom, in the measured form that Stacy McGaugh and his colleagues have given it, says observation will find. It adds no prediction to the sealed record of 1 November 2026, and it changes none. Every prediction of the collection stated here is quoted from that record, or argued in a book named at chapter and section, or marked plainly as stated only in the relation essay.

The rule of decision is the one the sealed record states: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement". A measurement that differs from a prediction by less is a measurement of interest, and this record reports it as such.

This record belongs to a comparative and retrospective collection, so the dates of the account stand with it. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics* was published in 2001. Milgrom proposed the modified dynamics in 1983.

II. Where the Two Accounts Predict Differently

Milgrom and McGaugh 1. The external field effect

The collection predicts. "A galaxy falling freely in the field of a larger one feels that field only through its tide; the external field effect that modified Newtonian dynamics predicts will not be found". Registered on 1 November 2026 as Prediction 24 of *The Registered Predictions of Physics from Comparison*. There is no external field effect. The collection's field equations hold the

strong equivalence principle: a body falling freely carries its own physics with it, whatever field it falls in, and the only trace of the larger field inside it is the tide.

Milgrom and McGaugh predict. Because the modified law is not linear, the internal motions of a galaxy or a satellite falling freely in the field of a larger body depend on that field, and not only on its tide (Milgrom 1983; Famaey and McGaugh 2012). McGaugh used the effect to predict, before it was measured, the velocity dispersion of the faint satellite Crater II of the Milky Way: 2.1 ($+0.9/-0.6$) kilometers per second (McGaugh 2016). Kyu-Hyun Chae, Federico Lelli, Harry Desmond, McGaugh, Pengfei Li and James Schombert reported the effect in the rotation of the galaxies of the SPARC sample, Spitzer Photometry and Accurate Rotation Curves (Chae and others 2020).

Where argued. The Weight of Possibility, Chapter 5, Section V; The Concept Branches, entry F-035, the entry in which the collection quotes and places the radial acceleration relation; the form of the field equations, with Newton's constant and the cosmological constant and no constant of acceleration, in The Gravitational Passage, Chapter 12, Section VII.

Measured. The measured dispersion of Crater II is 2.7 ± 0.3 kilometers per second (Caldwell and others 2017), within McGaugh's prediction, which was made before the measurement; the credit for that is his. Within cold dark matter, the tides of the Milky Way lower the dispersion of Crater II to the measured value but also shrink the galaxy below its measured size (Borukhovetskaya and others 2022), a question on small scales that the collection inherits with cold dark matter, and a topic for another day (The Weight of Possibility, Chapter 5, Section V). Chae and colleagues reported the effect at 8 to 11 standard deviations in a few galaxies under exceptionally strong external fields, at more than 4 standard deviations statistically across 153 galaxies, and as a downward trend at the weak end of the radial acceleration relation (Chae and others 2020). That report rests on one kind of measurement, with each galaxy's external field estimated from the galaxies around it, and it has not reached the rule of decision; it is a measurement of interest. A reanalysis by Corey Sargent and colleagues accounts for the reported signal through known correlations of the form, surroundings and motions of galaxies,

without any violation of the equivalence principle, and concludes that the data do not permit a confident assessment of an external field effect (Sargent and others 2025).

What decides it. The internal motions of galaxies and satellites measured against the field each falls in, with the external field established by more than one kind of measurement, at the rule of decision. The collection predicts that every such measurement will find the tide and nothing more.

Milgrom and McGaugh 2. The mass of clusters of galaxies

The collection predicts. "The ratio of the density of the dark matter to the density of the ordinary matter is $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$, the same at every time since helium formed. The same prediction gives the share of the ordinary matter in the cold matter, $1/(7 - 2/\pi) = 0.15715$, and in all the matter, with the lightest neutrinos, 0.15644; with the matter fraction of Prediction 7, the densities are $\Omega_b = 0.0486$ and $\Omega_c = 0.2608$". Registered on 1 November 2026 as Prediction 16 of *The Registered Predictions of Physics from Comparison*. In a cluster of galaxies the unseen mass is the dark matter of the account, which passes through a collision without measurable scattering.

Milgrom and McGaugh predict. The modified law, applied to the visible matter of a cluster of galaxies, gives less mass than the cluster's gas and its lensing show, so the modified dynamics leaves a missing mass in clusters to some further component (Sanders 2003; Famaey, Pizzuti and Saltas 2025).

Where argued. The Weight of Possibility, Chapter 5, Section V, for clusters under the modified dynamics; Chapter 5, Section II, for the share measured in the gas of clusters; Chapter 1, Section I, for the colliding cluster; Chapter 3, Section V, for the ratio.

Measured. The gas of galaxy clusters gives 0.156 ± 0.034 for the share of the ordinary matter in all the matter (Mantz and others 2022), in agreement with 0.15644. In the colliding cluster 1E 0657-56, the Bullet Cluster, the mass mapped by gravitational lensing lies with the galaxies, apart from the hot gas that holds most of the ordinary matter (Clowe and others 2006).

What decides it. The share of the ordinary matter in clusters measured by their gas and by their lensing at higher precision, beside the sealed record's own test for the ratio: "A second, independent kind of measurement of the two densities, at the precision of the microwave background".

Milgrom and McGaugh 3. The ratio that the microwave background measures

The collection predicts. The ratio of Prediction 16, quoted in full under Milgrom and McGaugh 2: $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$, a number fixed by the account with no parameter to fit.

Milgrom and McGaugh predict. In 1999, before the measurements, McGaugh named the test that separates a universe with cold dark matter from one without it: the ratio of the amplitudes of the first two peaks of the microwave background (McGaugh 1999). He read the first measurements of the second peak, which came in low, as consistent with a universe whose matter is all ordinary (McGaugh 2000). Without dark matter, the modified dynamics predicts a third peak lower than the one measured (McGaugh 2004; Aghanim and others 2020). The relativistic theory of Constantinos Skordis and Tom Złośnik agrees with the measured microwave background through added fields that act on the expansion as dust, and the amount of that dust is set by an initial condition: in their words, "the density $\bar{\rho}$ is not (classically) predicted" (Skordis and Złośnik 2021).

Where argued. The Weight of Possibility, Chapter 3, Section V, and Chapter 5, Sections I, II and IX; The Compactification, Chapter 6, Section X.

Measured. As the sealed record reports it: "The combination of the South Pole Telescope, Planck and the Atacama Cosmology Telescope gives 5.370 ± 0.048 (Camphuis and others 2026), 0.14 standard deviations away; Planck alone gives 5.364 ± 0.065 (Aghanim and others 2020), 0.01 away". Analyses that add the baryon acoustic oscillations of the Dark Energy Spectroscopic Instrument (DESI) give 5.199 ± 0.035, 4.7 standard deviations away (about 4.0 with the correlation of the two densities), from one kind of measurement; the sealed record states that pressure in full.

What decides it. "A second, independent kind of measurement of the two densities, at the precision of the microwave background. The Simons Observatory with Planck would measure the ratio to about 0.6 percent". The differ-

ence between the accounts is that the collection gives the number before the measurement and the relativistic modified dynamics takes it from the measurement.

Milgrom and McGaugh 4. How early massive galaxies formed

The collection predicts. "With the matter fraction of Prediction 7, the ratio of Prediction 16, and the primordial amplitude and tilt of Planck 2018, the amplitude of clustering today is $S_8 = 0.823 \pm 0.006$ (0.827 ± 0.007 with $h = 0.678$). The gyrations cluster exactly as standard cold dark matter does". Registered on 1 November 2026 as Prediction 18 of *The Registered Predictions of Physics from Comparison*. The book adds the reason the dark component is needed for galaxies at all: held in the sound of the early plasma and growing under one law of gravity, ordinary matter alone would have formed no galaxy (The Weight of Possibility, Chapter 1, Section I). So the wells in which the massive galaxies above redshift ten formed are those of standard cold dark matter at the account's matter fraction and ratio, and how efficiently gas in those wells turned into stars is a matter the books do not fix (*The Law and the History*, Section VIII); of the two readings McGaugh and his colleagues state, the collection's is the first, an efficient conversion of ordinary matter into stars within cold dark matter.

Milgrom and McGaugh predict. Under the modified law, ordinary matter assembles faster than cold dark matter allows: massive galaxies form at redshifts of about ten and above and stop forming stars within about a billion years, and clusters of galaxies and the reionization of the universe also come early (McGaugh, Schombert, Lelli and Franck 2024).

Where argued. The Weight of Possibility, Chapter 5, Section VI, and Chapter 1, Section I; The Compactification, Chapter 6, Section X.

Measured. For the amplitude of clustering, as the sealed record reports it: the lensing of the microwave background, the complete Kilo-Degree Survey and the growth rate from the motions of galaxies agree with 0.823 within one standard deviation; the final clustering and lensing of the Dark Energy Survey lies 2.5 standard deviations below, and the clusters counted by eROSITA 3.2 above. For the early galaxies, McGaugh and his colleagues find in the observations of the James Webb Space Telescope massive galaxies that formed

early, and they state the choice the observations leave: either an extremely efficient conversion of ordinary matter into stars above redshift ten, within cold dark matter, or an assembly of ordinary matter faster than cold dark matter allows, as the modified dynamics predicted (McGaugh, Schombert, Lelli and Franck 2024). The credit for predicting early massive galaxies before those observations is theirs. At this date the observations are open between the two readings.

What decides it. The masses and numbers of galaxies above redshift ten, confirmed by their spectra, together with a measured account of how efficiently they turned gas into stars; and the amplitude of clustering measured by independent kinds of measurement at the rule of decision.

Milgrom and McGaugh 5. Dark clumps that hold no stars

The collection predicts. "The dark matter has no cut-off in its structure on small scales from its own motion; it clumps on every small scale". Registered on 1 November 2026 as Prediction 21 of *The Registered Predictions of Physics from Comparison*. Clumps of dark matter too small to hold stars exist around galaxies and are weighed by the bending of light.

Milgrom and McGaugh predict. The modified dynamics places no unseen mass in galaxies (Milgrom 1983; Famaey and McGaugh 2012), so it holds no dark clump without stars around a galaxy.

Where argued. The Weight of Possibility, Chapter 5, Sections V, VI and IX.

Measured. As the sealed record reports it: "The faintest satellite galaxies and the substructure seen by strong lensing place the half-mode mass of any cut-off below about ten million solar masses at 95 percent confidence (Nadler and others 2021)". Strong lensing has found a dark satellite of $1.9 \pm 0.1 \times 10^8$ solar masses, weighed by its bending of light and giving off none (Vegetti and others 2012), a measurement of interest from one kind of measurement.

What decides it. Further masses found by lensing alone, with no light of their own, at the small scales Prediction 21 names, and the counts of the faintest satellites, together at the rule of decision.

Milgrom and McGaugh 6. What the dark component is made of

The collection predicts. "The dark matter comes in gyrations whose mass is of the order of the Planck mass: the lightest odd state is about 0.6 Planck masses at first order and $\sqrt{2}$ Planck masses, about 1.7×10^{19} GeV, at the classical level, so that there is about one gyration for every 1.5 to 3.4×10^{18} baryons". Registered on 1 November 2026 as Prediction 22 of *The Registered Predictions of Physics from Comparison*. A gyration is the unit of the dark matter on the collection's account: a conserved excitation of the six held internal dimensions.

Milgrom and McGaugh predict. In galaxies there is no dark component to be made of anything (Milgrom 1983). In the relativistic theory of Skordis and Złośnik, the dust that the cosmological measurements require is the energy of added gravitational fields (Skordis and Złośnik 2021).

Where argued. The Weight of Possibility, Chapter 4, Sections V and VI, and Chapter 5, Section IX.

Measured. Untested at this date, as the sealed record states.

What decides it. The sealed record names no measurement for this prediction, and at this date none reaches it. The differences of Milgrom and McGaugh 1 to 5 bear on the two accounts before this one does.

III. Where the Two Accounts Agree

Milgrom and McGaugh 7. Gravitational waves

The collection predicts. "Gravitational waves carry the two polarizations of a massless field of spin two, and travel at the speed of light; no further polarization and no other speed will be found". Registered on 1 November 2026 as Prediction 6 of *The Registered Predictions of Physics from Comparison*. Where argued: The Gravitational Passage, Chapter 12, Section VII, and Chapter 16, Section V; The Unquantized Arena, Chapter 19, Section V; The Compactification, Chapter 7, Section II.

Milgrom and McGaugh's relativistic form predicts the same. The relativistic theory of Skordis and Złośnik was built to carry gravitational waves at the speed of light (Skordis and Złośnik 2021), and an analysis of its waves finds

two tensor polarizations, traveling at the speed of light (Tian, Hou, Cao and Zhu 2023). Bekenstein's earlier tensor, vector and scalar theory was excluded by the gravitational waves and gamma rays of GW170817 (Boran, Desai, Kahya and Woodard 2018), and the modified dynamics was rebuilt to meet that measurement; the credit for the rebuilding is its proponents'. Measured: the speed of gravitational waves equals the speed of light to within -3×10^{-15} and $+7 \times 10^{-16}$ of it, and the three-detector event GW170814 favors purely tensor polarization, as the sealed record reports.

Milgrom and McGaugh 8. Every search for a dark particle comes up empty

The collection predicts. "No search will detect the dark matter through any interaction but gravity, at any sensitivity: not by scattering in an underground detector, not by light or particles it gives off, and not by its production in a collider". Registered on 1 November 2026 as Prediction 19 of *The Registered Predictions of Physics from Comparison*. Where argued: The Weight of Possibility, Chapter 5, Sections VII and IX.

Milgrom and McGaugh's account gives the same outcome. The modified dynamics places no unseen mass in galaxies, so it places nothing in a galaxy's halo for a detector to register (Milgrom 1983; Famaey and McGaugh 2012). The two accounts agree on what the searches will find, and differ on why: on the collection's account the dark matter is there and is a distortion of context, which nothing that registers content registers. Measured: every such search has found nothing, as the sealed record reports.

Milgrom and McGaugh 9. The dark component does not decay

The collection predicts. "The dark component does not decay, so its density falls exactly as that of matter, and the ratio of Prediction 16 is the same when the microwave background was released and today. Each epoch's gyrations are made at its own turn, and none passes from one epoch into the next". Registered on 1 November 2026 as Prediction 20 of *The Registered Predictions of Physics from Comparison*. Where argued: The Weight of Possibility, Chapter 4, Section III, Chapter 5, Section IX, and Chapter 6, Section III.

The relativistic form agrees on the expansion. In the theory of Skordis and Złośnik the dust of the added fields thins exactly as matter does, with the expansion, by the cube of the scale of the universe (Skordis and Złośnik 2021). Measured: the expansion history bounds any decay of the dark component into unseen products to lifetimes beyond about 160 billion years (Poulin, Serpico and Lesgourgues 2016), as The Weight of Possibility, Chapter 1, Section I, reports.

Milgrom and McGaugh 10. Flat space and a constant vacuum energy

The collection predicts. "The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}". Registered on 1 November 2026 as Prediction 9 of *The Registered Predictions of Physics from Comparison*. And: "The energy of the vacuum has an equation of state of exactly -1, at every epoch: $w_0 = -1$ and $w_a = 0$". Registered on 1 November 2026 as Prediction 8. Where argued: The Gravitational Passage, Chapter 18, Sections IX and XIII, and Chapter 13, Sections V and VI.

The relativistic form works in the same frame. The cosmology of Skordis and Złośnik is built on a spatially flat expanding universe, and its cosmological constant "remains a freely specifiable parameter" (Skordis and Złośnik 2021), constant in time, with an equation of state of -1. The agreement is in kind: the relativistic modified dynamics assumes flatness and takes the constant from measurement, and the collection derives flatness and fixes the constant through the matter fraction of Prediction 7. Measured: $\Omega_K = 0.001 \pm 0.002$, and the equation of state as the sealed record reports it under Prediction 8, where a departure from -1 at about three standard deviations in one family of analyses stands as a measurement of interest.

Milgrom and McGaugh 11. The measured relations of galaxies

Both accounts take the relations as measured. The baryonic Tully–Fisher relation, in which the mass of a galaxy's stars and gas goes as the fourth power of its flat rotation speed (McGaugh, Schombert, Bothun and de Blok 2000), and the radial acceleration relation, followed by 2693 points in 153 galaxies of the SPARC sample with a scatter of about 0.13 dex (a factor of about 1.35)

that errors of measurement mostly account for (Lelli, McGaugh and Schombert 2016; McGaugh, Lelli and Schombert 2016), are among the most exact regularities in astronomy, and the credit for finding and measuring them is Milgrom's and McGaugh's. The modified dynamics predicted the large departures from Newton's law in galaxies of low surface brightness before they were measured (Famaey and McGaugh 2012). The collection takes the radial acceleration relation as a measured input, quoted and placed (The Weight of Possibility, Chapter 5, Section V; The Concept Branches, entry F-035). Weak lensing extends the flat rotation of isolated galaxies to hundreds of kiloparsecs, following the baryonic Tully–Fisher relation (Mistele, McGaugh, Lelli, Schombert and Li 2024). The accounts agree on what the galaxies show and part on whether it is a law or a history; Milgrom and McGaugh 1 and 12 are the measurements that separate the two readings.

IV. Predictions Stated Only in the Relation Essay

Milgrom and McGaugh 12. Wide binary stars move by Newton's law

Stated in the relation essay; not argued in the books and not in the sealed record.

The relation essay predicts. "The account predicts that two stars in a wide orbit, at accelerations below Milgrom's scale, move by Newton's law, since the field equations hold no constant of acceleration" (*The Law and the History*, Section VII). The premise is argued in the books: "The field equations hold Newton's constant and the cosmological constant, and no constant of acceleration" (The Weight of Possibility, Chapter 5, Section V); the books do not name wide binaries.

Milgrom and McGaugh predict. A law of gravity with a constant of acceleration acts on two stars orbiting each other at low acceleration, far from any galaxy's history, so wide binaries below the scale depart from Newton's law, modified by the external field of the Milky Way (Banik and others 2024).

Measured. Indranil Banik and colleagues found from the wide binaries of the Gaia satellite that Newtonian dynamics is preferred over the modified dynamics at 19 standard deviations (Banik and others 2024). Kyu-Hyun Chae reported an anomaly in samples of binaries he selected (Chae 2024), and he

and his colleagues a strengthening of gravity of about 1.6 times Newton's in a later sample of 36 binaries (Chae and others 2026); Serat Saad and Yuan-Sen Ting reanalyzed those 36 and, modeling the orbit of each pair in three dimensions, found a factor of 1.00 (+0.24/−0.19), consistent with Newtonian gravity (Saad and Ting 2026).

What decides it. Wide binaries measured at accelerations below the scale, by independent samples and methods of modeling the orbits, at the rule of decision.

Milgrom and McGaugh 13. The reported trend follows the surroundings in which a galaxy formed

Stated in the relation essay; not argued in the books and not in the sealed record.

The relation essay predicts. The external field of each galaxy is estimated from the galaxies around it, so a trend that follows the estimated field follows the crowding in which the galaxy formed, and "a sample of galaxies selected and analyzed independently, with the external field separated from the environment of formation, will find the tide and nothing more" (*The Law and the History*, Section VII). The outcome, the tide and nothing more, is Prediction 24 of the sealed record; the reading of the 2020 trend as a trend of formation, and the design that separates the field from the surroundings, are the essay's.

Milgrom and McGaugh predict. The trend is the external field effect itself, and tides from neighboring galaxies are too weak to produce it (Chae and others 2020).

Measured. The reanalysis of Sargent and colleagues accounts for the reported signal through correlations of the form, surroundings and motions of galaxies (Sargent and others 2025), which is the reading this entry states.

What decides it. A sample in which the external field of each galaxy is measured apart from the density of its surroundings, at the rule of decision.

V. Where No Measurement Decides

Some of the differences between the two accounts are differences of kind, which no experiment reaches. Falsification does not apply to such a claim, because a measurement registers content in the arena, and these claims concern what a thing is, the logical form of a law, or the act of knowing within which any measurement is made; each is held to the standard of its own kind, by the argument that states it.

What the dark matter is. On the collection's account the dark matter is "a conserved excitation of the six dimensions of possibility, made at the turn, with no exit afterward" (The Weight of Possibility, Chapter 1, Section IV), a distortion of possibility that registers only as a distortion of space, by gravitating. This is a description of what a thing is. The measurable consequences of it are in Section II and III; the identification itself is argued, not measured.

Why a single law of space cannot carry both. Gravitation distorts space and the dark matter distorts possibility, and the book places the two as a conjugate pair under the first axiom (The Weight of Possibility, Chapter 2, Section VI). The ground is the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity (*An Immanent Metaphysics*, aphorism 1.43-2). The Incommensuration Theorem is a structural fact about the nature of knowing. That a law of space asked to produce both members of a conjugate pair is excluded is a claim of logical form.

The form of the field equations. The collection derives the Einstein field equations from the structure of comparison, and closes their form with Lovelock's theorem: "within the theorem's conditions there is no other equation" (The Gravitational Passage, Chapter 12, Section VII). That the equations hold no constant of acceleration is a claim of logical form; its measurable consequences are Milgrom and McGaugh 1 and 12.

VI. What the Collection Does Not Predict Here

The sealed record's Section IX states what the books do not predict. These items bear on this record:

- "The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (*The Gravitational Passage*, Chapter 13; *The Strengths of the Kinds*, Chapter 1, Section VI; *The Measures of the Kinds*, Chapter 13, Section X)".
- "The Hubble constant is predicted only through the matter fraction, since it cancels from the identity of Prediction 7".
- "The amplitude of the primordial departures and the sign of their tilt are not fixed; the running of the tilt is given only on a condition the books do not adopt (*The Gravitational Passage*, Chapter 18, Section IX; *The Compactification*, Chapter 6, Section VII)".
- "The dynamics of the transition between epochs, and how the gyrations are made at the turn, are not computed (*The Weight of Possibility*, Chapter 6)".

The book states one more that bears here, which the sealed Section IX does not list: the collection does not predict the tightness of the radial acceleration relation or the acceleration at which it turns. "The account offers no explanation of that tightness beyond what galaxy formation under general relativity provides", and "the field equations give the scale no value at any place in a galaxy" (The Weight of Possibility, Chapter 5, Section V). The nearness of Milgrom's scale to the speed of light times the Hubble constant divided by 2π, 1.05×10^{-10} meters per second per second at the Passage's Hubble constant, is on the account a relation between how galaxies formed and the epoch in which they formed, and it is not predicted.

VII. The Record at Its Date

Entry	The collection	Milgrom and McGaugh	Measured	Standing
1. External field (Prediction 24)	tide only; no external field effect	external field effect	reported in 2020 from one kind of measurement; reanalysis finds no confident assessment; Crater II 2.7 ± 0.3 km/s	untested at the rule of decision
2. Clusters (Prediction 16)	dark matter at 5.3634 times the ordinary; ordinary share 0.15644	modified law leaves clusters short of mass	cluster gas 0.156 ± 0.034; Bullet Cluster mass with the galaxies	agrees as far as tested
3. Ratio (Prediction 16)	$6 - 2/\pi = 5.3634$, predicted	without dark matter, a low third peak; relativistic form fits the dust by an initial condition	5.370 ± 0.048; 5.364 ± 0.065; 5.199 ± 0.035 with DESI	agrees with the microwave background alone; under pressure with DESI (one kind)
4. Early galaxies (Prediction 18)	$S_8 = 0.823$; clusters as cold dark matter	massive galaxies at redshift about ten and above	surveys from -2.5 to $+3.2$ standard deviations on S_8; early massive galaxies observed	open between the two readings of the early galaxies
5. Dark clumps (Prediction 21)	clumps on every small scale	no dark clump without stars	half-mode mass below 10^7 solar masses; one dark satellite of 1.9×10^8	agrees as far as tested
6. Gyrations (Prediction 22)	about the Planck mass	no dark component in galaxies	untested	untested
7. Gravitational waves (Prediction 6)	two polarizations; speed of light	the same, in the relativistic form now standing	tensor favored; speed within 10^{-15}	agrees
8. Searches (Prediction 19)	nothing but gravity	nothing to detect	every search null	agrees
9. No decay (Prediction 20)	does not decay	dust of the added fields thins as matter	lifetime beyond about 160 billion years	agrees

Entry	The collection	Milgrom and McGaugh	Measured	Standing
10. Flatness, constant (Predictions 9 and 8)	derived	assumed; constant free	$\Omega_K = 0.001 \pm 0.002$; equation of state as in Prediction 8	agrees on flatness; Prediction 8 under pressure in one family of analyses
11. Measured relations	taken as measured input	found and measured	scatter about 0.13 dex	agrees
12. Wide binaries (essay only)	Newton's law	departure below the scale	Newtonian preferred at 19 standard deviations; reported anomaly consistent with Newton on reanalysis (factor 1.00 +0.24/−0.19)	agrees as far as tested
13. Trend of formation (essay only)	trend follows the surroundings of formation	trend is the external field effect	reanalysis attributes it to correlations of form, surroundings and motions	untested at the rule of decision

Summary

Milgrom and McGaugh established the relations by which the motions of galaxies follow their visible matter, and predicted, before the measurements, the departures in galaxies of low surface brightness and the velocity dispersion of Crater II; the collection takes their relations as measured and credits them. The two accounts part where the collection's field equations, with no constant of acceleration, meet the modified law. The sharpest place is the external field: the collection predicts, as registered on 1 November 2026, that a galaxy falling freely in a larger field feels it only through its tide, and that the external field effect will not be found; the report of 2020 is a measurement of interest from one kind of measurement, and a reanalysis finds no confident assessment of the effect. The accounts also part on the mass of clusters, on the ratio 5.3634 that the collection predicts and the relativistic modified dynamics takes from measurement, on how early massive galaxies formed, where the observations stand open between the two readings, and on dark clumps without stars. They agree on gravitational waves, on the outcome of every

search for a dark particle, on a dark component that does not decay, on flat space, and on the measured relations themselves. Two predictions, on wide binaries and on the reading of the 2020 trend as a trend of formation, are stated in the relation essay and stand outside the sealed record.

Key Concepts

- The rule of decision: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.
- There is no external field effect: a galaxy falling freely in a larger field feels it only through its tide (Prediction 24).
- The collection's field equations hold Newton's constant and the cosmological constant and no constant of acceleration.
- The ratio of dark to ordinary matter is $6 - 2/\pi = 5.3634$, a number the collection predicts and the relativistic modified dynamics takes from measurement.
- The radial acceleration relation and the baryonic Tully–Fisher relation are measured, and both accounts take them as given; they part on whether they are a law or a history.
- Differences of kind, such as what the dark matter is and why one law of space cannot carry a conjugate pair, are argued, not measured.

Terms

Baryonic Tully–Fisher relation. The mass of a galaxy's stars and gas goes as the fourth power of its flat rotation speed.

Dark matter (on the collection's account). A conserved excitation of the six held internal dimensions, made at the turn, with every exit closed; a distortion of possibility that registers only by gravitating.

External field effect. In the modified dynamics, the change in a galaxy's internal motions produced by the uniform field of a larger body it falls in; general relativity has no such effect, only the tide.

Gyration. The unit of the dark matter on the collection's account, of about the Planck mass.

Half-mode mass. The mass scale at which a cut-off in the structure of the dark matter would halve the amplitude of the primordial departures relative to cold dark matter.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Lovelock's theorem. In four dimensions, the most general symmetric, divergence-free tensor built from the metric and its first and second derivatives is a combination of the Einstein tensor and the metric.

Measurement of interest. A measurement that differs from a prediction by less than the rule of decision requires.

Modified Newtonian dynamics. Milgrom's proposal that below an acceleration of about 1.2×10^{-10} meters per second per second the dynamics departs from Newton's law in one fixed way.

Radial acceleration relation. At each radius of a disc galaxy, the acceleration found from the rotation is one function of the acceleration the visible stars and gas alone would produce.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Strong equivalence principle. A body falling freely carries its own physics with it, whatever field it falls in, its own gravity included.

Tide. The part of a field that varies across a body, stretching it; the only way a uniform fall is felt in general relativity.

Wide binary. Two stars orbiting each other at a separation so large that their mutual acceleration lies below Milgrom's scale.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Law and the History; Mordehai Milgrom, Stacy McGaugh and the Weight of Possibility*. Relation essay, 2026, printed as a chapter of this volume (The Law and the History).

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *The Concept Branches*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Aghanim, N. and others (Planck Collaboration) (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6.

Banik, I., Pittordis, C., Sutherland, W., Famaey, B., Ibata, R., Mieske, S. and Zhao, H. (2024). "Strong constraints on the gravitational law from Gaia DR3 wide binaries". *Monthly Notices of the Royal Astronomical Society* 527, 4573–4615.

Boran, S., Desai, S., Kahya, E. O. and Woodard, R. P. (2018). "GW170817 falsifies dark matter emulators". *Physical Review D* 97, 041501. arXiv:1710.06168.

Borukhovetskaya, A., Navarro, J. F., Errani, R. and Fattahi, A. (2022). "Galactic tides and the Crater II dwarf spheroidal: a challenge to LCDM?". *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stac653. arXiv:2112.01540.

Caldwell, N. and others (2017). "Crater 2: an extremely cold dark matter halo". *The Astrophysical Journal* 839, 20. doi:10.3847/1538-4357/aa688e.

Chae, K.-H. (2024). "Breakdown of the Newton–Einstein standard gravity at low acceleration in internal dynamics of wide binary stars". *The Astrophysical Journal* 960, 114.

Chae, K.-H., Lee, B.-C., Hernandez, X., Orlov, V. G., Lim, D., Turnshek, D. A. and Lee, Y.-W. (2026). "Detection of gravitational anomaly at low acceleration from a highest-quality sample of 36 wide binaries with accurate 3D velocities". arXiv:2601.21728.

Chae, K.-H., Lelli, F., Desmond, H., McGaugh, S. S., Li, P. and Schombert, J. M. (2020). "Testing the strong equivalence principle: detection of the external field effect in rotationally supported galaxies". *The Astrophysical Journal* 904, 51. arXiv:2009.11525.

Clowe, D., Bradač, M., Gonzalez, A. H., Markevitch, M., Randall, S. W., Jones, C. and Zaritsky, D. (2006). "A direct empirical proof of the existence of dark matter". *The Astrophysical Journal* 648, L109–L113.

Famaey, B. and McGaugh, S. S. (2012). "Modified Newtonian dynamics (MOND): observational phenomenology and relativistic extensions". *Living Reviews in Relativity* 15, 10.

Famaey, B., Pizzuti, L. and Saltas, I. D. (2025). "Nature of the missing mass of galaxy clusters in MOND: the view from gravitational lensing". *Physical Review D* 111, 123042.

Lelli, F., McGaugh, S. S. and Schombert, J. M. (2016). "SPARC: mass models for 175 disk galaxies with Spitzer photometry and accurate rotation curves". *The Astronomical Journal* 152, 157.

Mantz, A. B. and others (2022), as cited in *The Weight of Possibility*, Chapter 5, Section II, and its bibliography.

McGaugh, S. S. (1999). "Distinguishing between CDM and MOND: predictions for the microwave background". *The Astrophysical Journal Letters*. doi: 10.1086/312274. arXiv:astro-ph/9907409.

McGaugh, S. S. (2000). "BOOMERanG data suggest a purely baryonic universe". arXiv:astro-ph/0008188.

McGaugh, S. S. (2004). "Confrontation of modified Newtonian dynamics predictions with Wilkinson Microwave Anisotropy Probe first year data". *The Astrophysical Journal* 611, 26–39.

McGaugh, S. S. (2016). "MOND prediction for the velocity dispersion of the 'feeble giant' Crater II". *The Astrophysical Journal Letters* 832, L8. doi: 10.3847/2041-8205/832/1/L8. arXiv:1610.06189.

McGaugh, S. S., Lelli, F. and Schombert, J. M. (2016). "Radial acceleration relation in rotationally supported galaxies". *Physical Review Letters* 117, 201101.

McGaugh, S. S., Schombert, J. M., Bothun, G. D. and de Blok, W. J. G. (2000). "The baryonic Tully–Fisher relation". *The Astrophysical Journal* 533, L99–L102.

McGaugh, S. S., Schombert, J. M., Lelli, F. and Franck, J. (2024). "Accelerated structure formation: the early emergence of massive galaxies and clusters of galaxies". arXiv:2406.17930.

Milgrom, M. (1983). "A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis". *The Astrophysical Journal* 270, 365–370.

Mistele, T., McGaugh, S., Lelli, F., Schombert, J. and Li, P. (2024). "Indefinitely flat circular velocities and the baryonic Tully–Fisher relation from weak lensing". *The Astrophysical Journal Letters*. doi:10.3847/2041-8213/ad54b0. arXiv:2406.09685.

Nadler, E. O. and others (2021), as cited in the sealed record, Prediction 21.

Poulin, V., Serpico, P. D. and Lesgourgues, J. (2016). "A fresh look at linear cosmological constraints on a decaying dark matter component". *Journal of Cosmology and Astroparticle Physics* 2016 (08), 036.

Saad, S. M. and Ting, Y.-S. (2026). "No gravitational anomaly in wide binaries from forward modeling of 3D orbits". arXiv:2603.11015, version 2, 9 September 2026; version 1 (March 2026) was titled "Gravitational anomaly measurement in wide binaries is sensitive to orbital modeling". doi: 10.33232/001c.170182.

Sanders, R. H. (2003). "Clusters of galaxies with modified Newtonian dynamics". *Monthly Notices of the Royal Astronomical Society* 342, 901–908.

Sargent, C., Clark, W., Seifert, A., Mand, A., Rogers, E., Lane, A., Deur, A. and Terzić, B. (2025). "On the evidence for violation of the equivalence principle in disk galaxies". arXiv:2511.03839.

Skordis, C. and Złośnik, T. (2021). "New relativistic theory for modified Newtonian dynamics". *Physical Review Letters* 127, 161302. arXiv:2007.00082.

Tian, S., Hou, S., Cao, S. and Zhu, Z.-H. (2023). "Time evolution of the local gravitational parameters and gravitational wave polarizations in a relativistic MOND theory". arXiv:2302.13304.

Vegetti, S., Lagattuta, D. J., McKean, J. P., Auger, M. W., Fassnacht, C. D. and Koopmans, L. V. E. (2012). "Gravitational detection of a low-mass dark satellite galaxy at cosmological distance". *Nature*. doi:10.1038/nature10669. arXiv:1201.3643.

The measurements quoted from the sealed record carry their full citations in that record and in the books it names.

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Appendix J

The Registered Predictions Beside Erik Verlinde

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Erik Verlinde. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *Where the Dark Sector Lives; Erik Verlinde, Emergent Gravity and Physics from Comparison*.

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Abstract

Erik Verlinde reads gravity from the thermodynamics of information at a boundary, and he proposes that the effects attributed to dark matter are an extra gravitational force, set by the ordinary matter and the rate of the cosmic expansion. The physics collection of the Immanent Metaphysics reads gravity as the arena of physics, and it identifies the dark matter as a conserved excitation of the six held internal dimensions (kept at the same size and shape at every point), a component in its own right. This record sets the two accounts side by side, prediction by prediction. Three differences reach measurement: the ratio of the dark matter to the ordinary matter, which Verlinde's relation ties to the density of the ordinary matter and the collection fixes at $6 - 2/\pi$; whether the relation between visible matter and the motions of galaxies is one law or a product of how each galaxy formed; and whether gravitation adds a decoherence of its own. Three further statements of the collection, on the dark mass in colliding clusters, entanglement through gravitation and the absence of the external field effect, meet no stated prediction in Verlinde's account. The accounts agree that gravity is not a fundamental field to be quantized, that free fall is uni-

versal, and that the dark sector will show itself only through gravity. Four differences of kind lie beyond any measurement, and the record names each with the kind of claim it is.

I. What This Record Is

This record sets the predictions of physics from comparison beside the predictions of Erik Verlinde's emergent gravity: the entropic account of Newton's law of 2010, published in 2011, and the account of apparent dark matter of 2016, published in 2017. Each prediction of the collection stated here is printed in a book of the collection at the chapter and section named, and where the sealed record of 1 November 2026 carries it, the record quotes the sealed statement in full with its number. Where a statement is argued in a book and is not among the numbered predictions of the sealed record, the entry says so. Each prediction of Verlinde's account is cited to his own papers, or, where it belongs to a model built on his entropic gravity by others, to that model and its authors.

The books fix what counts as a result, and the sealed record quotes the rule: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement". A measurement short of that rule is a measurement of interest.

This record belongs to a comparative and retrospective collection, so it states the dates of the work it rests on. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

II. Where the Two Accounts Predict Differently

Verlinde 1. The dark mass in colliding clusters

The collection predicts. The dark matter is a component in its own right, made at the turn (the passage from one epoch of the universe to the next) and conserved, with energy that gravitates wherever the gyrations (its units,

the conserved excitations of the six internal dimensions) are, whether or not ordinary matter is there. When two clusters of galaxies collide, the dark component passes through with the galaxies, and the mass mapped by lensing lies with them, apart from the hot gas that holds most of the ordinary matter. Argued in the books; not among the numbered predictions of the sealed record, whose Section V states the identification on which it rests: "The account identifies the dark matter as a conserved excitation of the six held internal dimensions: its units are gyrations, made at the turn and kept from decaying by the antipodal parity of the sphere S^2". Here S^2 is the two-sphere, one factor of the internal space, and antipodal parity is whether a mode keeps or changes its sign when each point of the sphere is exchanged with the point opposite it.

Verlinde predicts. His formula gives the apparent dark matter from the distribution of the ordinary matter, for isolated, spherically symmetric and static systems. Of a collision he writes: "Dynamical situations as those that occur in the Bullet cluster are not described by these same equations" (Verlinde 2017, Section 7.2). His account states no prediction for a collision of clusters.

Where argued. *The Weight of Possibility*, Chapter 1, Section IV, for the identification; Chapter 1, Section I, for the signatures of a component.

Measured. In the colliding cluster 1E 0657-56, the Bullet Cluster, the mass mapped by gravitational lensing lies with the galaxies, apart from the hot gas (Clowe and others 2006). The same collision bounds the scattering of the dark component on itself below about one square centimeter per gram (Markevitch and others 2004). For massive, relaxed clusters, which are static, ZuHone and Sims (2019) found that Verlinde's formula does not reproduce the observed characteristics.

What decides it. Every lensing map of a collision of clusters bears on the collection's statement. For Verlinde's account, a dynamical extension of his equations, applied to a collision, would state a prediction that the same maps decide.

Verlinde 2. The ratio of the dark matter to the ordinary matter

The collection predicts. "The ratio of the density of the dark matter to the density of the ordinary matter is $\Omega c/\Omega b = 6 - 2/\pi = 5.3634$, the same at every time since helium formed. The same prediction gives the share of the

ordinary matter in the cold matter, $1/(7 - 2/\pi) = 0.15715$, and in all the matter, with the lightest neutrinos, 0.15644; with the matter fraction of Prediction 7, the densities are $\Omega b = 0.0486$ and $\Omega c = 0.2608$". Registered on 1 November 2026 as Prediction 16 of *The Registered Predictions of Physics from Comparison*.

Verlinde predicts. Verlinde credits his relation with a striking agreement: setting the size of the region in his formula for the apparent dark matter to the size of the observable universe, he obtains a relation between the cosmological density parameters, the square of the density parameter of the apparent dark matter equals four thirds of the density parameter of the baryons (Verlinde 2017, Section 7.2, Equation 7.51), and he reports that it "holds remarkably well for the values of ΩD and ΩB obtained by the WMAP and Planck collaborations". He adds a caution of his own: "We ask the reader not to read too much in this striking and somewhat surprising fact". On his relation the ratio of the two densities is the square root of the quotient of four thirds by the density parameter of the baryons, so it changes with the amount of ordinary matter. At the collection's baryon density of 0.0486, four thirds of it is 0.0648, whose square root, 0.2546, is the density of the apparent dark matter; the ratio is then 5.24, where the collection's is 5.3634. At the baryon density the microwave background measures, 0.0493 (Aghanim and others 2020), his relation gives 5.20, close to the 5.199 of the analyses that add DESI and about two and a half standard deviations below Planck's 5.364.

Where argued. *The Weight of Possibility*, Chapter 3, Section V, and Chapter 5, Sections I, II and IX; *The Compactification*, Chapter 6, Section X.

Measured. As the sealed record reports it: "The combination of the South Pole Telescope, Planck and the Atacama Cosmology Telescope gives 5.370 ± 0.048 (Camphuis and others 2026), 0.14 standard deviations away; Planck alone gives 5.364 ± 0.065 (Aghanim and others 2020), 0.01 away". Analyses that add the baryon acoustic oscillations of DESI, the Dark Energy Spectroscopic Instrument, give 5.199 ± 0.035 (Louis and others 2025), from one kind of measurement; the sealed record reports that measurement in full under Prediction 16.

What decides it. The two densities measured together, each at the precision of the microwave background, by a second, independent kind of measurement. The collection's ratio stays at 5.3634 whatever the density of the ba-

ryons; Verlinde's relation moves with it. The Simons Observatory with Planck would measure the ratio to about 0.6 percent (*The Weight of Possibility*, Chapter 5, Section IV).

Verlinde 3. The relation between visible matter and the motions of galaxies

The collection predicts. The field equations hold Newton's constant and the cosmological constant, and no constant of acceleration. "So on this account the scale belongs, with the tightness of the relation, to how the galaxies formed under general relativity; the field equations give the scale no value at any place in a galaxy" (*The Weight of Possibility*, Chapter 5, Section V). Argued in the books; not among the numbered predictions of the sealed record.

Verlinde predicts. One formula gives the apparent dark matter of a galaxy from its ordinary mass, Newton's constant and an acceleration scale set by the Hubble rate, the speed of light times the Hubble constant (Verlinde 2017). The acceleration scale that appears in Milgrom's fitting formula is, on his account, one sixth of that product (Verlinde 2017, Sections 1.4 and 7.2). The formula is the same for every galaxy with the same distribution of ordinary matter.

Where argued. *The Weight of Possibility*, Chapter 5, Section V.

Measured. Verlinde's formula has met measurement well in several places. Brouwer and colleagues (2017) found its prediction, with no free parameters, in good agreement with the mass profiles of 33,613 isolated galaxies measured by weak lensing in four bins of stellar mass. Yoon, Han and Hwang (2026, a preprint) applied it and the modified dynamics of Milgrom to 23 dwarf spheroidal galaxies and favor Verlinde's formula over the modified dynamics at 5.2 standard deviations. Lelli, McGaugh and Schombert (2017) found that it matches the radial acceleration relation of rotating galaxies only with ratios of stellar mass to light below other astronomical estimates, and that it predicts a correlation of the scatter with radius that is not observed. Brouwer and colleagues (2021), with the lensing of the Kilo-Degree Survey, found a difference of at least 6 standard deviations between the radial acceleration relations of early-type and late-type galaxies at the same stellar mass; they state that a modification of gravity applied alike to every galaxy cannot give that difference on its own, unless the early-type galaxies alone

hold halos of gas comparable in mass to their stars, and that models of cold dark matter in which the relation depends on a galaxy's history of formation can give it.

What decides it. Whether the relation between the visible matter and the acceleration depends, at the same ordinary mass, on how a galaxy formed, measured by a second, independent kind of measurement beside lensing, with the gas around each galaxy counted.

Verlinde 4. A decoherence from gravitation

The collection predicts. "No mass, however large, no separation of two placements, however wide, and no length of time ends a superposition of its own accord; a superposition ends only through a finding, an interaction that registers which alternative is the case. The account allows no decoherence beyond the ordinary kind, which is a comparison made by some environment. For the masses of Prediction 1, the gravity-driven collapse of Diósi and Penrose gives a lifetime of about 0.012 seconds, against the 2.5 seconds the entangling phase needs". Registered on 1 November 2026 as Prediction 2 of *The Registered Predictions of Physics from Comparison*.

The entropic line predicts. Verlinde's own papers state no rate of decoherence; the prediction below belongs to models built on his entropic gravity by others. Kobakhidze (2011) argued that gravity as an entropic force would destroy the coherence of the quantum states of neutrons held in the Earth's field, which are observed. Schimmoller, McCaul, Abele and Bondar (2021) answered with an entropic master equation compatible with the neutron measurements of the qBounce experiment, which predicts a rise of energy and a decoherence on long time scales and for large masses, open to tabletop experiments, and which they find incompatible with the model of Diósi and Penrose.

Where argued. *The Unquantized Arena*, Chapter 7, Sections V and VI, and Chapter 8, Section IV.

Measured. As the sealed record reports it: "An underground search for the radiation that collapse noise would make has ruled out the version of the Diósi and Penrose model with no free parameter (Donadi and others 2021);

versions with a larger effective size remain under test". The ultracold neutrons of qBounce bound the free parameter of the entropic master equation (Schimmoller and others 2021).

What decides it. As the sealed record states it: "The experiment of Prediction 1, which tests those versions in a new regime and bounds any extra channel of decoherence directly". The same experiment reaches the regime of large masses and long times in which the entropic master equation predicts its decoherence.

Verlinde 5. Entanglement through gravitation

The collection predicts. "Two masses, each held in a superposition of two places and related only through gravitation, become entangled, with the phase of their Newtonian interaction. For the experiment proposed by Bose and colleagues (2017), two masses of 10^{-14} kilograms, each held in two places 250 micrometers apart, with centers 450 micrometers apart, for 2.5 seconds, the entangling phase is 0.314 radians; on that state the concurrence is 0.156 and the entanglement witness of Chevalier, Paige and Kim is -0.22. For any other design, the phase is the one the Newtonian interaction gives for that design's masses, distances and time". Registered on 1 November 2026 as Prediction 1 of *The Registered Predictions of Physics from Comparison*. The concurrence is a measure of entanglement, zero for none and one for the most; an entanglement witness is a quantity whose negative value shows entanglement.

Verlinde predicts. Verlinde's paper of 2011 precedes the proposal of 2017, and his paper of 2017 states no prediction for it. His account states no prediction for this experiment.

Where argued. *The Unquantized Arena*, Chapter 8, Sections II and III, and Chapter 19, Section II; *The Gravitational Passage*, Chapter 12, Section VI; *The Compactification*, Chapter 8, Section XIII.

Measured. As the sealed record reports it: "No experiment has yet reported entanglement through gravitation alone, or its absence at a sensitivity that reaches this phase".

What decides it. As the sealed record states it: "An experiment with two such masses, isolated so that ordinary decoherence stays well below the entangling phase".

Verlinde 6. The external field effect

The collection predicts. "A galaxy falling freely in the field of a larger one feels that field only through its tide; the external field effect that modified Newtonian dynamics predicts will not be found". Registered on 1 November 2026 as Prediction 24 of *The Registered Predictions of Physics from Comparison*.

Verlinde predicts. Milgrom and Sanders (2016) found Verlinde's approach silent on the external field effect: his formula covers isolated, spherical and static systems, and it cannot be applied to the internal dynamics of a system that sits in an external field. His account states no prediction for the effect.

Where argued. *The Weight of Possibility*, Chapter 5, Section V.

Measured. The sealed record states the prediction with no measurement beside it.

What decides it. Every measurement of the internal motions of a galaxy that falls freely in the field of a larger one.

III. Where the Two Accounts Agree

Verlinde 7. Gravity is not a fundamental field to be quantized

The collection predicts. "No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter. A description of the small waves of the geometry by quanta holds below the Planck curvature, and its quanta are quanta of that description, never quanta of the arena. No measured cross section for the scattering of those waves that departs from the effective theory will agree with a calculation in which the metric is quantized beyond it. A detector that registers a gravitational wave in single clicks agrees with the account and does not show gravitation quantized". Registered on 1 November 2026 as Prediction 3 of *The Registered Predictions of Physics from Comparison*.

Verlinde predicts. Gravity is emergent: "spacetime and gravity emerge together from the entanglement structure of an underlying microscopic theory" (Verlinde 2017), and Newton's law is an entropic force (Verlinde 2011). The two accounts agree that the gravitational field is no fundamental field to be quantized. Verlinde's microscopic degrees of freedom are a difference of kind, set out in Section V.

Where argued. *The Unquantized Arena*, Chapter 19, Section III, and Chapter 9, Section III; *The Basis of Physics*, Essay 12, which names Verlinde's reading of gravity as entropic as physics reaching the same place.

Measured. "The first gravitational wave detected matched the classical waveform of general relativity (Abbott and others 2016); no graviton has been detected". Standing in the sealed record: agrees.

Verlinde 8. Free fall is universal

The collection predicts. "The Eötvös parameter, the fractional difference in the free fall of two materials, is zero for every pair of materials at every precision. Antimatter falls with the acceleration of matter. No arrangement of matter shields gravity, and nothing will be found that gravity leaves untouched". Registered on 1 November 2026 as Prediction 4 of *The Registered Predictions of Physics from Comparison*.

Verlinde predicts. Inertia has an entropic origin, so the mass that gravitates and the mass that resists acceleration are one, and the equivalence principle follows (Verlinde 2011).

Where argued. *The Unquantized Arena*, Chapter 19, Section IV; *Two Theories, One World*, Chapter 9; *Measurement*, Chapter 3, Section VII.

Measured. "MICROSCOPE, titanium and platinum: $[-1.5 \pm 2.3$ (statistical) $\pm$ 1.5 (systematic)$] \times 10^{-15}$ (Touboul and others 2022)". Standing in the sealed record: agrees.

Verlinde 9. The dark sector shows itself only through gravity

The collection predicts. "No search will detect the dark matter through any interaction but gravity, at any sensitivity: not by scattering in an underground detector, not by light or particles it gives off, and not by its production in a collider". Registered on 1 November 2026 as Prediction 19 of *The Registered Predictions of Physics from Comparison*.

Verlinde predicts. The effects attributed to dark matter in galaxies and clusters are an extra gravitational force, the response of the dark energy medium to the ordinary matter; no particle of dark matter is there to be found (Verlinde 2017).

Where argued. *The Weight of Possibility*, Chapter 5, Sections VII and IX.

Measured. "Every such search has found nothing; LZ excludes interaction rates down to about 2×10^{-48} cm^2 at 40 GeV (2024) (The Alphabet of Particles, entry N3)". Standing in the sealed record: agrees.

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction that the books do not argue; every statement of the collection in this record is argued in a book named at chapter and section.

V. Where No Measurement Decides

A measurement decides between two claims when the claims say that different things will be found. The four differences below are of another kind. In each, both accounts expect the same findings, and they differ in what a finding is, in the form of the argument that reaches it, or in where the knower stands. Every measurement returns the same result under both readings, so falsification, which decides by a finding, does not apply to these claims. Each is named with the kind of claim it is.

Whether space is composed

A claim of logical form. For Verlinde, space and gravity are composed: they emerge from the entanglement of microscopic degrees of freedom. For the collection, the arena is continuous and is composed of nothing more basic that is found in it. The Incommensuration Theorem is a structural fact about the nature of knowing: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison, and neither can asymmetry and discontinuity. Discrete constituents counted and entangled are content, governed by symmetry; the arena is context, continuous; and the theorem excludes composing the one from the other (*Causality Without Determinism*, Chapter 5, Section VI; *The Unquantized Arena*, Proposition 6.3). Below the Planck curvature both accounts give the results of general relativity for every experiment now proposed.

Two routes to the same field equations

A claim of logical form. Verlinde's route to Einstein's equations runs, as Jacobson's did, through the thermodynamics of information on a boundary. The collection's runs through the reduction of a ten-dimensional geometry and Lovelock's theorem, which fixes Einstein's equations, with the cosmological term, as the only field equations of their kind in four dimensions (*The Gravitational Companion*, "What the Passage Obtains That Jacobson Assumes"). Both routes arrive at the same equations, and every test of the equations tests both.

Where the held medium is

A description of what a thing is. Verlinde's dark force is the elastic response of a medium, the dark energy, displaced by matter; an elastic response belongs to a held structure, one with a shape it returns to. The collection finds such a structure in the six internal dimensions, which keep the same size and the same shape at every point, and finds the four dimensions of space and time unheld (*The Weight of Possibility*, Chapter 1, Section IV). The consequences of the placement reach measurement in Verlinde 1 to 3; the identification of the held medium itself is a description, and no measurement reaches it apart from those consequences.

Which horizon counts

A claim about the act of knowing. Verlinde's volume part of the entropy belongs to de Sitter space, the horizon of a universe that holds dark energy alone. The collection counts at the particle horizon, the edge of everything that has reached the observer by now, because a measurement is made here and now, from one place, and holds that edge and no other (*The View from Inside*, Chapter 12). The choice of the horizon is a claim about where the knower stands. On the collection's side it issues in a number that measurement decides, the matter fraction of 0.311 (sealed Prediction 7; *The Gravitational Passage*, Chapter 13), and Verlinde's account states no matter fraction to set beside it.

VI. What the Collection Does Not Predict Here

Four items of Section IX of the sealed record bear on the comparison, and they are quoted in full.

> "The value of Newton's constant, the strength of light, the strength of color and the vacuum value of the Higgs field are measured inputs (The Gravitational Passage, Chapter 13; The Strengths of the Kinds, Chapter 1, Section VI; The Measures of the Kinds, Chapter 13, Section X)".
>
> "The Hubble constant is predicted only through the matter fraction, since it cancels from the identity of Prediction 7".
>
> "The dynamics of the transition between epochs, and how the gyrations are made at the turn, are not computed (The Weight of Possibility, Chapter 6)".
>
> "Below the Planck curvature the account and the effective field theory of gravity give the same result for every experiment now proposed (The Unquantized Arena, Chapter 6, Section IV); a detection of single gravitons, or of a primordial background, would not show gravitation quantized (Chapter 9, Section III; Chapter 18, Section VI)".

Verlinde's account, like the collection, takes Newton's constant from measurement, and his acceleration scale takes the Hubble constant from measurement.

VII. The Record at Its Date

Entry	The collection	Verlinde	Measured	Standing
Verlinde 1. Colliding clusters	Dark mass passes through with the galaxies	No prediction for a collision	Lensing mass with the galaxies, apart from the gas (Clowe and others 2006)	Agrees as far as tested; Verlinde's account untested
Verlinde 2. Dark to ordinary ratio (Prediction 16)	$6 - 2/\pi = 5.3634$, fixed	Square of the dark density equals four thirds of the baryon density; 5.24 at a baryon density of 0.0486	5.370 ± 0.048; 5.364 ± 0.065; 5.199 ± 0.035 with DESI	Open between the two; the sealed standing of Prediction 16 holds
Verlinde 3. Visible matter and galactic motion	Scale and tightness from how galaxies formed	One formula from ordinary mass and the Hubble rate	Agreement in lensing (2017) and in dwarf spheroidals (2026); a difference by galaxy type of at least 6 standard deviations (2021)	Verlinde's formula agrees in isolated-galaxy lensing (2017) and dwarf spheroidals (2026); the split by galaxy type (2021, at least 6 standard deviations) agrees with the collection's reading; one kind of measurement each
Verlinde 4. Decoherence from gravitation (Prediction 2)	None beyond the ordinary kind	Entropic master equation: decoherence for large masses over long times	Diósi and Penrose version with no free parameter ruled out	Untested in the regime that separates them
Verlinde 5. Entanglement through gravitation (Prediction 1)	Yes; 0.314 rad for the 2017 design	No prediction stated	No result	Untested
Verlinde 6. External field effect (Prediction 24)	Not found; only the tide	No prediction stated	None stated in the sealed record	Untested

Entry	The collection	Verlinde	Measured	Standing
Verlinde 7. Gravity not a fundamental field to be quantized (Prediction 3)	No quantum of the arena	Gravity emergent	No graviton detected	Agrees
Verlinde 8. Universal free fall (Prediction 4)	Eötvös parameter zero	Equivalence principle from entropic inertia	$[-1.5 \pm 2.3 \pm 1.5] \times 10^{-15}$	Agrees
Verlinde 9. Gravity only (Prediction 19)	No detection but through gravity	No dark particle	Every search null	Agrees

Summary

Erik Verlinde and the physics collection share a great deal: gravity is fixed by how much can be found where, which Verlinde counts as information on a screen and the collection as findings that can be made; it is not a fundamental field to be quantized; free fall is universal, and the dark sector will show itself only through gravity. Verlinde's formula for apparent dark matter has met measurement well, in the lensing of isolated galaxies and in dwarf spheroidal galaxies, and his relation between the cosmological densities lands within a few percent of the measured ratio. The accounts part on what the dark sector is. For the collection it is a conserved component, the gyrations of the six held internal dimensions, with a ratio to the ordinary matter fixed at 5.3634; for Verlinde it is a force set by the ordinary matter, and his relation moves the ratio with the density of the baryons. Three differences reach measurement: the ratio, whether the galactic relation depends on how a galaxy formed, and a decoherence from gravitation. Three statements of the collection, on colliding clusters, entanglement through gravitation and the absence of the external field effect, meet no stated prediction in Verlinde's account. Four differences of kind lie beyond measurement: whether space is composed, the route to the field equations, where the held medium is, and which horizon counts.

Key Concepts

- The collection's dark matter is a conserved component, the gyrations of the six held internal dimensions; Verlinde's is a force set by the ordinary matter.
- The collection fixes the ratio of the dark matter to the ordinary matter at $6 - 2/\pi = 5.3634$; Verlinde's relation moves the ratio with the density of the baryons, and gives 5.24 at a baryon density of 0.0486.
- The collection places the acceleration scale of galaxies in how each galaxy formed; Verlinde gives it by one formula from the ordinary mass and the Hubble rate.
- Verlinde's account states no prediction for colliding clusters, for entanglement through gravitation, or for the external field effect.
- Both accounts hold that gravity is no fundamental field to be quantized, that free fall is universal, and that the dark sector shows itself only through gravity.
- Whether space is composed, the route to the field equations, where the held medium is, and which horizon counts are differences of kind that no measurement decides.

Terms

Apparent dark matter. On Verlinde's account, the extra gravitational force that the dark energy medium exerts in response to ordinary matter, read as if it were a dark component.

Arena. The context of every finding: in physics, the geometry of space and time that general relativity describes.

Bullet Cluster. The colliding cluster of galaxies 1E 0657-56, in which the mass mapped by lensing and the hot gas lie apart.

Content and context. In every comparison, what is found and the setting it is found in.

De Sitter space. A universe that holds the energy of empty space alone and expands at a steady rate; its horizon is fixed by that energy.

Decoherence. The spreading of the relative phase of two alternatives into an environment that registers which alternative is the case, after which they no longer interfere in measurements on the system alone.

Density parameter. The density of a component as a fraction of the density that makes space flat.

Entropic force. A force that arises from the tendency of a system to move toward states of greater entropy, without a field that carries it.

Entropic master equation. An equation for the evolution of a quantum system under gravity treated as an entropic force, with the decoherence that treatment brings.

Equivalence principle. The equality of the mass that gravitates and the mass that resists acceleration.

External field effect. On modified Newtonian dynamics, a change in the internal motions of a system caused by the uniform part of an external field.

Gyration. A conserved excitation of the six held internal dimensions, of about the Planck mass; the collection's unit of dark matter.

Held. Kept at the same size and shape at every point, as the six internal dimensions are.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Particle horizon. The edge of everything that has reached an observer by now.

Radial acceleration relation. The measured relation between the acceleration found from a galaxy's rotation and the acceleration its visible stars and gas alone would produce.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Standard deviation. The measure of the uncertainty of a measurement, used as the unit of the distance between a prediction and a measurement.

Superposition. A state in which a body holds more than one alternative, such as two places, with a definite relative phase.

Weak gravitational lensing. The slight, averaged distortion of the images of distant galaxies by the mass along the line of sight, which weighs that mass.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *Where the Dark Sector Lives; Erik Verlinde, Emergent Gravity and Physics from Comparison*. An essay on the physics collection of the Immanent Metaphysics, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *The Gravitational Companion*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The View from Inside*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-074-9. DOI: https://doi.org/10.67291/HGNK5132.

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Brouwer, M. M., Visser, M. R., Dvornik, A., Hoekstra, H. and others (2017). "First test of Verlinde's theory of Emergent Gravity using Weak Gravitational Lensing measurements". *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stw3192. arXiv:1612.03034.

Brouwer, M. M., Oman, K. A., Valentijn, E. A. and others (2021). "The weak lensing radial acceleration relation: Constraining modified gravity and cold dark matter theories with KiDS-1000". *Astronomy and Astrophysics* 650, A113. arXiv:2106.11677.

Clowe, D. and others (2006). "A direct empirical proof of the existence of dark matter". *The Astrophysical Journal* 648, L109 to L113.

Kobakhidze, A. (2011). "Gravity is not an entropic force". *Physical Review D* 83, 021502.

Lelli, F., McGaugh, S. S. and Schombert, J. M. (2017). "Testing Verlinde's emergent gravity with the radial acceleration relation". *Monthly Notices of the Royal Astronomical Society: Letters*. doi:10.1093/mnrasl/slx031. arXiv:1702.04355.

Markevitch, M., Gonzalez, A. H., Clowe, D. and others (2004). "Direct constraints on the dark matter self-interaction cross section from the merging galaxy cluster 1E 0657-56". *The Astrophysical Journal* 606, 819 to 824.

Milgrom, M. and Sanders, R. H. (2016). "Perspective on MOND emergence from Verlinde's 'emergent gravity' and its recent test by weak lensing". arXiv:1612.09582.

Schimmoller, A. J., McCaul, G., Abele, H. and Bondar, D. I. (2021). "Decoherence-free entropic gravity: Model and experimental tests". *Physical Review Research* 3, 033065.

Verlinde, E. P. (2011). "On the origin of gravity and the laws of Newton". *Journal of High Energy Physics* 2011 (04), 029. arXiv:1001.0785.

Verlinde, E. P. (2017). "Emergent gravity and the dark universe". *SciPost Physics* 2, 016. arXiv:1611.02269.

Yoon, Y., Han, S. and Hwang, H. S. (2026). "Comparison of MOND and Verlinde's emergent gravity in dwarf spheroidals". arXiv:2601.01715.

ZuHone, J. A. and Sims, J. (2019). "Testing emergent gravity with optical, X-ray, and weak lensing measurements in massive, relaxed galaxy clusters". *The Astrophysical Journal*. doi:10.3847/1538-4357/ab2b34. arXiv:1905.03832.

The measurements quoted from the sealed record are cited there by author and year, with full entries in the bibliographies of the books it names.

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Appendix K

The Registered Predictions Beside Ilya Prigogine

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Ilya Prigogine. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Arrow Comes First; Ilya Prigogine, Irreversibility and Physics from Comparison*.

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Abstract

Ilya Prigogine and the physics collection of the Immanent Metaphysics agree on what the world will show about time and chance. Both hold that the world is not deterministic, that the arrow of time is real and belongs to physics rather than to ignorance, and that the pattern a system takes at a branching point far from equilibrium is not fixed in advance. The first two are registered together as Prediction 28 of the sealed record of 1 November 2026, and the measured violations of time reversal agree with it. The third is stated in the relation essay, where the collection's account of amplified hard randomness is applied to Prigogine's dissipative structures, and it stands outside the sealed record; the experiments on the crystallization of sodium chlorate agree with it. No measurement named in the relation essay or in the books separates the two accounts. Where they part, they part on where irreversibility and chance live: Prigogine placed both in the dynamics of a class of unstable systems, and the collection places the arrow in the impossibility of faithful reversal and chance at the edge of the domain of measurement, for every world. Those differences are of a kind no experiment reaches, and the record names each with the kind of claim it is.

I. What This Record Is

This record sets two accounts side by side. One is the account of physics from comparison, whose predictions were gathered and sealed on 1 November 2026. The other is the account of Ilya Prigogine (1917 to 2003), who received the Nobel Prize in Chemistry in 1977 for the theory of dissipative structures and who argued, with Isabelle Stengers and with Tomio Petrosky and the Brussels–Austin group, that the arrow of time is real and that probability belongs to the laws of unstable systems.

The collection's account rests on the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

The rule of decision is the sealed record's: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such". Every prediction of the collection stated here is either quoted from the sealed record, with its number, and argued in the books named at chapter and section, or marked as stated only in the relation essay.

II. Where the Two Accounts Predict Differently

At this date the relation essay names no measurement on which the two accounts give different results, and the books name none. Prigogine's program changes the description of large Poincaré systems, and the collection keeps the established description and reads it differently; the essay sets out where each places irreversibility and chance, and those differences are recorded in Section V, where no measurement decides. This section therefore carries no entry.

III. Where the Two Accounts Agree

Prigogine 1. The world is not deterministic, and the arrow of time is real

The collection predicts. "No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one". Registered on 1 November 2026 as Prediction 28 of *The Registered Predictions of Physics from Comparison*.

Prigogine predicts. Determinism fails, and irreversibility is part of the dynamics and not an artifact of approximation or of ignorance. *The End of Certainty* (1997) states the conclusion in a sentence: "The more we know about our universe, the more difficult it becomes to believe in determinism". For large Poincaré systems, Petrosky and Prigogine (1993) found that the removal of the resonance divergences "leads to complex irreducible spectral representations", that "irreducibility means that this representation is implementable only by statistical ensembles and not by trajectories", and that "Complex means that time symmetry is broken". On his account no deterministic completion of the description of such systems is to be found, and time symmetry is broken in their laws.

Where argued. The Basis of Physics, Essay 9 and Essay 11; Measurement, Chapter 14, Section II and Section III; Why Time Travel Is Not a Concept, Chapter 5, Sections III to V. The relation essay also cites the non-polarization principle of Causality Without Determinism, Chapter 1, Section IX: "All worlds are to some non-zero and positive degree causal. No world is purely and completely deterministic".

Measured. As the sealed record reports it: "Violations of CP (1964) and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry". The Basis of Physics, Essay 11, Section VII, reads those violations as "a place where the impossibility of perfecting temporal symmetry has become visible to instruments".

What decides it. The sealed record states that these are exclusions the structure of comparison makes, and that a search for departures from the quantum predictions bears on Prediction 25 and not on Prediction 28. Each account says that no deterministic completion will be found; each further search that finds none agrees with both.

IV. Predictions Stated Only in the Relation Essay

Prigogine 2. The pattern taken at a branching point is not fixed in advance

The collection predicts, in the relation essay. Where a system far from equilibrium can take one of several patterns, its outcome depends on differences that, followed downward, pass below the microscopic limit, where the outcome is hard random; so "no law laid out in advance fixes which branch is taken, and the branch, once taken, is lawful in all that follows" (*The Arrow Comes First*, Section VI).

Prigogine predicts. Order through fluctuations: at the point where a system far from equilibrium must choose among patterns, which pattern appears is decided by a fluctuation (Prigogine 1977, "Time, Structure and Fluctuations").

Where argued. The books argue the general case and not this application. The Basis of Physics, Essay 6, Section VI, follows amplification downward through the three-body problem and the weather, to differences that "fall below the limits of measurement, below the microscopic limit", where what produces the outcome is, "from the standpoint of anything inside the domain, hard random". Measurement, Chapter 12, Section VI, names the mechanism microstate amplification. The relation essay applies the two to the branching points of dissipative structures.

Measured. Kondepudi, Kaufman and Singh (1990) crystallized sodium chlorate, whose crystals are optically active although its molecules are not chiral: from unstirred solution, left-handed and right-handed crystals appeared in roughly equal numbers, and from stirred solution about 99.7 percent of the crystals in a sample shared one handedness. Charles Day (2005),

reporting the later experiment of Cristobal Viedma, records that "Left-handed and right-handed crystals have the same chance of forming" and that in Viedma's runs "The dominant form was random".

What decides it. Repeated runs prepared as alike as instruments allow: on both accounts the pattern taken follows a distribution over runs, and no preparation fixes it.

Standing for registration. Stated in the relation essay; the books argue the general case and not this application, and the sealed record does not carry it; filed among the predictions outside the sealed record.

V. Where No Measurement Decides

Falsification applies to a claim that some outcome of a measurement could contradict. The differences below are of another kind. Each is a claim of logical form, which follows from the structure of comparison itself, or a description of what a thing is, such as a law, a probability or an arrow; every measurement is itself a comparison made within that structure, so no outcome of one bears on them. They are recorded so that no later measurement is counted for or against either account where neither makes a claim a measurement reaches.

Where the arrow of time lives

Prigogine built irreversibility into the laws: in the extended description of large Poincaré systems the evolution splits into two semigroups, and the one running toward equilibrium in the future is chosen. The collection finds the arrow beneath the laws. The Basis of Physics, Essay 11, Section III: "Symmetry of the laws guarantees lawful reversal. It does not guarantee faithful reversal". Faithful reversal needs a symmetric law acting on a state specified with no gap, which is the conjunction the theorem forbids, and the direction of time is "the direction in which comparison proceeds" (Incommensuration, Chapter 8, Section X). Essay 11, Section VII, adds that the laws exhibit time-reversal symmetry "to an extraordinary degree" and that the symmetry "can-

not be perfect". This is a claim of logical form: it follows from the Incommensuration Theorem and depends on no entropy, no boundary condition and no formalism.

Where chance lives

Prigogine placed probability in the law: the dynamics of a large Poincaré system has an irreducible representation by ensembles. The collection places chance at the edge of the domain of comparison, which is the domain of measurement named in the Abstract, where no measurement can be made (The Basis of Physics, Essay 6, Section VII), and reads a law of probabilities as structure laid out: "any randomness in it is a distribution laid out in advance; the one outcome that occurs is a finding, and no structure laid out in advance contains it" (Measurement, Chapter 12, Section V). This is a description of what a law and a finding are.

How far the failure of determinism reaches

Prigogine's route to the failure of determinism runs through instability and applies to systems unstable enough, with resonances dense enough, for the trajectory description to fail. The collection's route applies to every world, stable or not: determinism is "the assertion of total symmetry and total continuity, applied simultaneously and without remainder", the first conjunction the theorem forbids (The Basis of Physics, Essay 2, Section III), and "The conclusion does not depend on the results of any experiment". This is a claim of logical form.

The two arrows and the dispute with the heirs of Boltzmann

Prigogine held that irreversibility is more than statistics; his critics, Jean Bricmont among the clearest (1996), held with Boltzmann that counting states, together with a beginning of low entropy, explains it. Measurement, Chapter 12, Section VII, keeps two arrows: the structural arrow "is present in every single comparison" and "needs no large number of parts and no particular beginning of the world"; the entropic arrow "is a statistical arrow" that "needs a beginning of low entropy"; and "each act of recording joins the two

arrows in one event". Each side of the dispute is right about one arrow. This is a description of what each arrow is, and the two arrows point the same way wherever both are found, so no measurement separates the readings.

VI. What the Collection Does Not Predict Here

One item of Section IX of the sealed record bears on this comparison:

> "The size of the asymmetry of time is not predicted, only that it exists (The Basis of Physics, Essay 11, Section VII)".

The collection requires that some asymmetry of time exist in the laws; it does not say how large, in which interaction, or through what mechanism. A measurement of the size of a violation of time reversal therefore counts neither for nor against the collection. Prigogine's program, which places the arrow in the dynamics of large Poincaré systems, gives no value for the size of a violation of time reversal in any interaction either.

VII. The Record at Its Date

Entry	The collection	Prigogine	Measured	Standing
Prigogine 1 (Prediction 28)	no world purely deterministic; some asymmetry of time in the laws; no process perfectly reversible	determinism fails; time symmetry broken in the laws of unstable systems	CP violation (1964); time-reversal violation (CPLEAR 1998; BaBar 2012)	agrees as far as tested
Prigogine 2 (relation essay only)	the pattern at a branching point is not fixed in advance	order through fluctuations	sodium chlorate: equal chances; one handedness dominates when stirred	agrees as far as tested

Summary

Ilya Prigogine argued for half a century that determinism fails, that the arrow of time is real, and that the pattern a system takes far from equilibrium is decided by a fluctuation. The physics collection predicts each of these. The first two are registered together as Prediction 28, and the measured violations of CP and of time reversal agree with it. The third is stated in the relation essay,

applying the collection's account of amplified hard randomness to dissipative structures; the crystallization of sodium chlorate agrees with it, and it stands outside the sealed record. No measurement named in the essay or the books separates the two accounts. They part on where the arrow and chance live, and on how far the failure of determinism reaches: Prigogine found both in the dynamics of a class of unstable systems, and the collection finds the arrow in the impossibility of faithful reversal and chance at the edge of the domain of measurement, for every world. Those are claims of logical form and descriptions of what a law and an arrow are, and no outcome of a measurement bears on them. The size of the asymmetry of time is predicted by neither account.

Key Concepts

- Prediction 28 of the sealed record, that no world is purely deterministic and no process perfectly reversible, is one Prigogine shares.
- Lawful reversal and faithful reversal: symmetric laws guarantee the first and never the second.
- Prigogine placed the arrow and chance in the dynamics of large Poincaré systems; the collection places the arrow in comparison and chance at the edge of the domain of measurement.
- The pattern taken at a branching point is not fixed in advance; stated in the relation essay, outside the sealed record.
- The size of the asymmetry of time is not predicted, only that it exists.

Terms

CP violation. A difference between a process and its mirror image with particles exchanged for antiparticles; by the CPT theorem it entails a violation of time reversal.

Chiral symmetry breaking. The appearance, from conditions that favor neither, of a population dominated by one handedness.

Dissipative structure. An ordered pattern maintained by a continuing flow of energy and matter far from equilibrium.

Entropic arrow. The statistical arrow of time, found in systems of very many parts and needing a beginning of low entropy.

Faithful reversal. A reversal that retraces exactly the states the original process passed through and arrives at exactly the original condition.

Hard randomness. An outcome that no prior specification fixes, however complete; no capacity for causal prediction exists for it.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Large Poincaré system. In Prigogine's program, a dynamical system with a continuous set of resonances among its motions.

Lawful reversal. The time reverse of a lawful process being itself lawful.

Microstate amplification. The magnification of small differences at a fine-grained level into differences in a system's behavior.

Non-polarization principle. Every world is to some degree causal, and no world is purely deterministic.

Order through fluctuations. Prigogine's name for the selection, by a fluctuation, of one pattern among several at a branching point far from equilibrium.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Semigroup. In Prigogine's program, an evolution defined in one direction of time only; the extended description splits into two, and the one running toward equilibrium in the future is chosen.

Standard deviation. The measure of the uncertainty of a measurement; a difference of five standard deviations is the usual threshold for a discovery in physics.

Structural arrow of time. The direction in which comparison proceeds: from the range of what is possible, through the act, to the record.

Superdeterminism. A deterministic completion of quantum mechanics in which the settings of an experiment are fixed together with the states of what is measured, so that statistical independence fails; it is proposed, and the choices of measurement are correlated in advance with what is measured.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Arrow Comes First; Ilya Prigogine, Irreversibility and Physics from Comparison*. Relation essay, 2026.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-075-6.

Landry, Forrest. *Incommensuration; The Theorem and the Three Axioms*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-063-3. DOI: https://doi.org/10.67291/ARTV2404.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Angelopoulos, A., and others (CPLEAR Collaboration) (1998). "First direct observation of time-reversal non-invariance in the neutral-kaon system". *Physics Letters B* 444, 43.

Bricmont, J. (1996). "Science of chaos or chaos in science?". arXiv:chao-dyn/9603009.

Christenson, J. H., Cronin, J. W., Fitch, V. L. and Turlay, R. (1964). "Evidence for the 2π decay of the K_2^0 meson". *Physical Review Letters* 13, 138.

Day, C. (2005). "Crushing a solution of left-handed and right-handed crystals breaks its chiral symmetry". *Physics Today*, 1 April 2005.

Kondepudi, D. K., Kaufman, R. J. and Singh, N. (1990). "Chiral symmetry breaking in sodium chlorate crystallization". *Science* 250, 975–976. DOI: 10.1126/science.250.4983.975.

Lees, J. P., and others (BaBar Collaboration) (2012). "Observation of time-reversal violation in the B^0 meson system". *Physical Review Letters* 109, 211801.

Petrosky, T. and Prigogine, I. (1993). "Poincaré resonances and the limits of trajectory dynamics". *Proceedings of the National Academy of Sciences of the United States of America* 90, 9393–9397.

Prigogine, I. (1977). "Time, Structure and Fluctuations". Nobel Lecture, 8 December 1977.

Prigogine, I., with Stengers, I. (1997). *The End of Certainty: Time, Chaos, and the New Laws of Nature*. New York: The Free Press.



Appendix L

The Registered Predictions Beside Robert Rosen

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Robert Rosen. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *No Largest Model; Robert Rosen, Relational Biology and Physics from Comparison*.

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Abstract

Robert Rosen and the physics collection of the Immanent Metaphysics share three conclusions: relation comes before the things related; a model, however well it fits, is not the thing it models; and a living being is not a mechanism. Almost everything they share, and almost everything they dispute, lies where no measurement reaches. Rosen's claims concern organisms and their models, and the sealed record of 1 November 2026 holds predictions of physics; the two meet in three places. First, the two accounts agree that an anticipatory system acts on a model it holds in the present and needs no signal from a later time; the sealed record registers that, for every process, as Prediction 27. Second, the collection's claim that no natural system has a largest model reaches a measurement once, in Prediction 29: for any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement tells the rule's statistics from the world's. Rosen's account neither states that nor denies it. Third, the collection's ground for the remainder every model leaves is hard randomness, which carries the exclusion of Prediction 28, that no world is purely deterministic; Rosen's argument that an organism cannot be simulated runs through the self-reference of closure and not through chance. The sealed record carries no prediction on

which the two accounts give different results, and the relation essay states none. The remaining differences are claims of logical form, descriptions of what a thing is, or claims about the act of knowing, and the record names each with its kind. They concern where the line between mechanism and organism falls, whether a proof about a diagram settles a question about an organism, where the remainder of a model comes from, where the line between the living and the non-living falls, and where closure is found.

I. What This Record Is

This record sets two accounts side by side. One is the account of physics from comparison, whose predictions were gathered and sealed on 1 November 2026. The other is the account of Robert Rosen (1934 to 1998), who trained under Nicolas Rashevsky in relational biology, gave its first exact form in the metabolism-repair systems of 1958, and carried the program through *Anticipatory Systems* (1985), *Life Itself* (1991) and the posthumous *Essays on Life Itself* (2000). Rosen saw, before most of the life sciences, that a living system is a closed web of relations and not a list of parts, and he gave that web an exact mathematical description.

The collection's account rests on the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

The rule of decision is the sealed record's: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such". Every prediction of the collection stated here is quoted from the sealed record, with its number, and argued in the books named at chapter and section. Where either account

makes a claim of another kind than a prediction of measurement, the record says which kind, so that no later measurement or simulation is counted for or against either account where neither makes a claim a measurement reaches.

II. Where the Two Accounts Predict Differently

At this date the sealed record carries no prediction on which the two accounts give different results, and the relation essay names none. Rosen's claims about organisms that bear on observation are two: that living things act on predictive models they hold of themselves and their surroundings, and that their organization is closed to efficient causation. The collection agrees with the first (Section III) and reads the second as a description of organization, which it places in the transcendent role (Section V). Rosen's central claim of difference, that an organism has a model no machine can simulate, is a claim of mathematics about the models of a system; the relation essay places the debate over its proof as a question settled by proof (Section V). This section therefore carries no entry.

III. Where the Two Accounts Agree

Rosen 1. Anticipation needs no signal from a later time

The collection predicts. "A finding changes no geometry, here or anywhere, and news of a distant finding enters a record only at an event on or within the future light cone of the finding. Until such a signal arrives, every local statistic follows quantum theory unchanged, whatever measurement was chosen far away. No signal crosses the boundary of comparison, and no body arrives somewhere that is not in its cone. The probabilities of a preparation's outcomes do not depend on which test is chosen later, and no later finding comes to precede an earlier one. Travel within the cone is not excluded, nor the recession of distant galaxies faster than light, which is a growth of the arena between them and not a signal across it". Registered on 1 November 2026 as Prediction 27 of *The Registered Predictions of Physics from Comparison*.

Rosen predicts. An anticipatory system is "a system containing a predictive model of itself and/or its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a later instant" (Rosen 1985). The prediction that guides the change is a state of the model, and the model is part of the system at the instant it acts. Rosen held that anticipation of this kind is everywhere in living things, and on his account it runs on no signal from a later instant.

Where argued. The Unquantized Arena, Chapter 7, Section IV (Proposition 7.2); The Basis of Physics, Essay 10; Measurement, Chapter 14, Section IV; The Quantum Passage, Chapter 8, Section III, and Chapter 11, Section III; Why Time Travel Is Not a Concept, Chapter 4, Section IV (Proposition 4.6). The relation essay applies the prediction to anticipation through the cycle of the second axiom, which Measurement, Chapter 4, Section VIII, sets out: "The second axiom orders the three roles in a cycle with three transitions: from the stance to the act, from the act to the laid-out finding, and from the laid-out finding to a new stance". An anticipatory system is one in which the last of those transitions is carried by a model the system holds of itself; in the words of the essay, "No cause runs backward from the future: the model is present, and it acts by shaping the range of the present act" (*No Largest Model*, Section VII).

Measured. The sealed record reports no measurement under this prediction.

What decides it. Each account predicts that no anticipatory system needs a signal from a later time, so no measurement separates them. What Prediction 27 says will not be found, in any system, is a record in which a later finding comes to precede an earlier one.

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction of measurement that the books do not argue; each of its claims about Rosen's account is of a kind recorded in Section V and is argued in the books it cites.

V. Where No Measurement Decides

Falsification applies to a claim that some outcome of a measurement could contradict. The differences below are of other kinds: claims of logical form, which follow from the structure of comparison itself; descriptions of what a thing is, such as a model, a mechanism or a living being; and claims about the act of knowing, such as what a description from outside can contain. Every measurement is a comparison made within that structure, and every measurement is a description from outside, so no outcome of one bears on these claims. They are recorded so that no later measurement or simulation is counted for or against either account where neither makes a claim a measurement reaches. Three sealed predictions of the collection bear on the ground of these differences, and each is quoted in full where it bears.

Whether any natural system has a largest model

Rosen called a natural system a mechanism when every one of its models can be simulated, so that its models have a largest model from which every other follows; a system with a model that cannot be simulated he called complex, and he held that an organism is complex (Rosen 1991). He held complexity to be the general case, developing it, in Donald Mikulecky's words, "as a description of this more generic view promoted by biology", with the simple systems of physics as the special case. The collection finds that no natural system, organism or stone, has a largest model. A model works by symmetry, as Causality Without Determinism, Chapter 5, Section II, states: "Any form of modeling inherently depends on symmetry", and its definition of the classical carries a purpose: "If a model of a thing can be built that behaves identically to the original for all purposes one cares about, then that thing is classical". A model that served every purpose would leave no gap anywhere between itself and the original, and a rendering with no gap is continuity perfected. A model that served every purpose at once would be symmetry perfected and continuity perfected together, which is the first conjunction the theorem forbids; so every rendering "leaves a remainder", "the part of what is rendered that a rendering approaches as closely as one wishes and does not contain" (Physics Is Not Math, Chapter 21, Section V). The Ground of Objection, T2.18: "A description is a comparison; therefore no description of any actual thing is com-

plete, and this is a theorem the system derives and builds on rather than a limitation it concedes". Rosen's mechanism, on this reading, is a property of a description: a system described for a purpose for which what the description leaves out makes no difference. This is a claim of logical form, and a description of what a model and a mechanism are.

The claim reaches a measurement once, for the foundation of physics:

> "For any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement, reaching below the rule's least step, tells the rule's statistics from the world's. The established findings of physics are reproduced at the foundation only by a theory of the conjugate kind".

A theory of the conjugate kind is one whose formalism and findings are in conjugate modes, so that "the formalism is governed by the conjugate of the character that governs the findings" (*The Unquantized Arena*, Chapter 2); a cellular automaton, whose formalism and findings carry one character, is not of this kind. Registered on 1 November 2026 as Prediction 29 of *The Registered Predictions of Physics from Comparison*; argued in The Unquantized Arena, Chapter 3, Section II and Section VI, The Basis of Physics, Essay 18, Section VII, and Measurement, Chapter 8, Section VIII. The sealed record reports no measurement under it. Causality Without Determinism, Chapter 5, Section VIII, the section the relation essay cites on simulation, states both sides of what a model can do: "A deterministic simulation can reproduce the statistics of quantum outcomes to any precision chosen in advance", and "For any one fixed program, beyond its smallest step, a sensitive enough measurement eventually tells the program's statistics from the world's". Prediction 29 concerns a discrete rule offered as the foundation of physics. Rosen's account neither states it nor denies it, since his mechanism concerns which models of a system can be simulated and not what rule lies beneath physics. A simulation of an organism that meets its data to a precision chosen in advance is counted against neither account: the collection states that such a match can be made, and Rosen's claim concerns the existence of a model that no machine simulates, not the precision of any one simulation.

Whether a proof about a diagram settles a question about an organism

Rosen's claim that closure to efficient causation forbids simulable models rests on a proof in the mathematics of categories, and the proof has been disputed. Chu and Ho (2006) argued that some of its central notions are not well defined and that the proof does not hold; Louie (2007), Rosen's student, replied that a living system must have models that cannot be computed, and Chu and Ho (2007) answered him; Mossio, Longo and Stewart (2009) gave an expression of closure to efficient causation in the lambda calculus and argued that closure does not by itself rule out computable models. The relation essay places the debate: "Whether closure to efficient causation, written as a formal property of a diagram, forces a non-computable model is a question of mathematics, settled by proof. Whether a living being is a mechanism is a question about the world, and the formal property is a rendering of it" (*No Largest Model*, Section IV). By the order of depth, metaphysics, then physics, then computation, then mathematics (Physics Is Not Math, Chapter 5), a rendering cannot set the scope of what it renders. The collection's conclusion that a living being is not a mechanism stands on two grounds, the remainder every model leaves and the bound triple a computation lacks (Causality Without Determinism, Chapter 5, Section VI: "classical computation, however intricately organized, cannot be what consciousness is"), and passes through no step of Rosen's categorical proof. This is a claim of logical form; the debate itself is a question of mathematics, and no measurement settles either.

Where the remainder comes from

The collection's ground for the remainder is hard randomness: every interaction is a comparison, by the Root Tautology, and every comparison leaves an outcome that nothing prior fixes (Causality Without Determinism, Chapter 5, Section IV). That ground carries an exclusion the sealed record registers:

> "No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one".

Registered on 1 November 2026 as Prediction 28 of *The Registered Predictions of Physics from Comparison*; argued in The Basis of Physics, Essay 9 and Essay 11, Measurement, Chapter 14, Section II and Section III, and Why Time Travel Is Not a Concept, Chapter 5, Sections III to V. As the sealed record reports: "Violations of CP (1964) and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry". Rosen's argument that an organism cannot be simulated runs through a different ground: closure to efficient causation folds the system back on itself, so that its description must refer to itself, and Rosen argued that this self-reference cannot be captured in any model a machine can simulate. His argument rests on self-reference and not on chance, so the measurements reported under Prediction 28 agree with the collection and do not bear on that argument. The difference between the two grounds is a claim of logical form.

Where the line between the living and the non-living falls

Rosen drew the line between organism and mechanism by a property of organization, visible in a relational diagram: closure to efficient causation. The collection agrees that a living being is different in kind from a stone, and draws the difference where no diagram reaches. Home in the World, "A Village That Is Alive": "The difference in kind lies elsewhere: in whether choice is gathered, held together and carried forward as one's own, and known from inside. A self is that gathering". The same passage says why no measurement can draw the line: "a true choice, seen from outside, looks exactly like chance, so no description from outside can draw the line". The collection places Rosen's closure, like the autopoiesis of Maturana and Varela, in the transcendent role, the organization from which a living being's activity proceeds; the

organism living in its surroundings is the immanent; and Rosen's diagram of the organization is a model laid out as structure, the omniscient. The Last Turtle, Chapter 3, Section XIII: "the omniscient cannot contain the transcendent". Where Rosen and the enactivists draw the line of life by organization, the collection finds the relating, and some degree of choice, on both sides of it: The Ground of Objection, T4.6, "There is no non-conscious interaction, and every interaction has a subjective aspect"; and The Immanent Metaphysics and the Modern Engagement, Chapter 9, names that as the one place it parts from the enactive account, "the question of whether the modalities extend to non-living systems, which Thompson's framework does not affirm and the Immanent Metaphysics requires". This is a description of what a living being is, and a claim about the act of knowing: it says that a description from outside, which every measurement is, cannot draw the line.

Where closure is found

Rosen found closure to efficient causation in the living cell and took such impredicative loops to mark the living off from the mechanical. The collection finds closure of the same form at its own foundation, in every act. The Root Tautology is a loop: every interaction is a comparison, every comparison a relation, and every relation an interaction, and none is first. The Last Turtle, Chapter 3, Section IX: "the axioms describing themselves is itself a process, an instance of the general class of process, and Axiom II is the axiom of process. So the axioms describe not only themselves but the process of describing themselves. That is full closure over the reification of the foundation". The Ground of Objection, T2.18, says what kind of closure that is: "The closure claimed is a closure of the descriptive apparatus and not of the inquiry". On this account, in a living being the closure present in every act of comparison is taken up by one self, which keeps making itself from what it has done; and every comparison passes from a recorded finding to a new stance, and in a self that passage is carried by a model the self holds of itself, which is anticipation. This is a claim of logical form.

VI. What the Collection Does Not Predict Here

No item of Section IX of the sealed record bears on this comparison. That section names the quantities of physics that the account takes from measurement or leaves open: the constants that enter as measured inputs, the Hubble constant apart from the matter fraction, the amplitude and tilt of the primordial departures, the dynamics of the transition between epochs, the size of the excess of matter over antimatter, the values of the kinds, the size of the asymmetry of time, the agreement with the effective field theory of gravity below the Planck curvature, the fate of information that falls into a black hole, and the feasibility of travel within the light cone. Rosen's account makes no claim about any of them.

VII. The Record at Its Date

Entry	The collection	Rosen	Measured	Standing
Rosen 1 (Prediction 27)	no signal faster than light and none backward in time; no later finding comes to precede an earlier one	an anticipatory system acts on a predictive model it holds at the instant it acts	no measurement reported in the sealed record	untested in the sealed record; the two accounts agree

Predictions 28 and 29, quoted in Section V, bear on the ground of the collection's differences with Rosen and not on a measurement that separates the two accounts. The sealed record reports measurements consistent with Prediction 28 and none under Prediction 29.

Summary

Robert Rosen and the physics collection agree that relation comes before the things related, that a model is not the thing it models, and that a living being is not a mechanism. They agree as well that anticipation, which Rosen found everywhere in the living, needs no signal from a later time: the guiding model is present in the system, and Prediction 27 of the sealed record says that no later finding comes to precede an earlier one, in any system. No prediction of the sealed record, and none in the relation essay, separates the two accounts by measurement. Their differences are of other kinds. The collection finds that

no natural system has a largest model, and reads Rosen's mechanism as a property of a description; that claim reaches a measurement once, in Prediction 29, for a discrete rule offered as the foundation of physics, which Rosen's account neither states nor denies. The debate over Rosen's categorical proof is a question of mathematics, and the collection's conclusion passes through no step of it. The collection's ground for the remainder is hard randomness, which carries Prediction 28; Rosen's ground is the self-reference of closure. Rosen drew the line of life by organization; the collection draws it at choice gathered into a self and known from inside, which no description from outside can draw, and finds closure at the foundation of every act. Those are claims of logical form, descriptions of what a thing is, and claims about the act of knowing, and no outcome of a measurement bears on them.

Key Concepts

- No measurement registered or stated separates Rosen's account from the collection's; their differences are of kinds that falsification does not reach.
- Rosen's anticipation runs on a model present in the system, and Prediction 27 says no later finding comes to precede an earlier one; the two accounts agree.
- No natural system has a largest model, because every rendering leaves a remainder; Rosen's mechanism is a property of a description.
- Prediction 29: for any one fixed discrete rule offered as the foundation of physics, a sensitive enough measurement tells the rule's statistics from the world's.
- A simulation that meets its data to a precision chosen in advance counts against neither account.
- The debate over Rosen's proof is a question of mathematics; the collection's conclusion does not pass through it.
- The collection's remainder comes from hard randomness, which carries Prediction 28; Rosen's non-simulability comes from the self-reference of closure.
- The difference in kind between the living and a stone is choice gathered into a self and known from inside, which no description from outside can draw.

Terms

Anticipatory system. In Rosen's usage, a system containing a predictive model of itself or its surroundings, which changes its present state according to what the model predicts for a later instant.

Autopoiesis. Maturana and Varela's term for a network of processes of production that continuously regenerates the network that produced it.

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable; consciousness is the bound triple taken as one act.

Closure to efficient causation. Rosen's defining property of an organism: every process that makes some part of the system is itself made within the system.

Complex system. In Rosen's usage, a natural system with at least one model that cannot be simulated.

Conjugate kind. A theory whose formalism and findings are in conjugate modes, so that "the formalism is governed by the conjugate of the character that governs the findings" (*The Unquantized Arena*, Chapter 2); a cellular automaton, whose formalism and findings carry one character, is not of this kind.

CP violation. A difference between a process and its mirror image with particles exchanged for antiparticles; by the CPT theorem it entails a violation of time reversal.

Discrete rule. A rule acting on states that change in least steps, the same at every place and every step, such as a cellular automaton.

Hard randomness. An outcome that no prior specification fixes, however complete; the remainder every comparison leaves.

Impredicative. Defined in terms of a whole to which the thing defined belongs.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Largest model. In Rosen's usage, a model of a system from which every other model of it follows.

Light cone. The set of events that a signal at the speed of light, or slower, can reach from a given event (its future light cone) or could have come from (its past light cone).

Mechanism. In Rosen's usage, a natural system all of whose models can be simulated, so that they have a largest model.

Modalities. The three roles of comparison: the immanent (held in the act), the omniscient (held as structure laid out), the transcendent (the stance and the range of possibility).

Modeling relation. Rosen's account of a model: states of a natural system encoded into a formal system, inference run, and the result decoded into a prediction.

Order of depth. Metaphysics, then physics, then computation, then mathematics; each later member renders the earlier and cannot set its scope.

Remainder. The part of what is rendered that a rendering approaches as closely as one wishes and does not contain.

Root Tautology. Comparison, interaction and relation are one act under three names.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Simulation. A computation by a machine that follows a fixed procedure, offered as a model of a system.

Standard deviation. The measure of the uncertainty of a measurement; a difference of five standard deviations is the usual threshold for a discovery in physics.

Superdeterminism. A deterministic completion of quantum mechanics in which the settings of an experiment are fixed together with the states of what is measured, so that statistical independence fails; it is proposed, and the choices of measurement are correlated in advance with what is measured.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *No Largest Model; Robert Rosen, Relational Biology and Physics from Comparison*. Relation essay, 2026.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-075-6.

Landry, Forrest. *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-9896628-8-3.

Landry, Forrest. *Home in the World; The Immanent Metaphysics for Readers of Carlo Rovelli*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-069-5.

Landry, Forrest. *The Immanent Metaphysics and the Modern Engagement; From Husserl to Wilber*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-175-3.

Landry, Forrest. *The Last Turtle; Essays from Comparison and the Incommensuration Theorem to Causation, the Arena and the Limits of Computation*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-215-6.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Physics Is Not Math; Metaphysics, Physics, Computation and Mathematics, and Why Their Order Cannot Be Otherwise*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-070-1.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Chu, D. and Ho, W. K. (2006). "A category theoretical argument against the possibility of artificial life: Robert Rosen's central proof revisited". *Artificial Life* 12(1), 117 to 135. DOI: 10.1162/106454606775186392.

Chu, D. and Ho, W. K. (2007). "The localization hypothesis and machines". *Artificial Life* 13(3), 299 to 302.

Louie, A. H. (2007). "A living system must have noncomputable models". *Artificial Life* 13(3), 293 to 297.

Mikulecky, D. C. Review of *Essays on Life Itself* by Robert Rosen. Virginia Commonwealth University, undated. https://www.people.vcu.edu/~mikuleck/rosrev.html.

Mossio, M., Longo, G. and Stewart, J. (2009). "A computable expression of closure to efficient causation". *Journal of Theoretical Biology* 257(3), 489 to 498. DOI: 10.1016/j.jtbi.2008.12.012.

Rosen, R. (1958). "A relational theory of biological systems". *Bulletin of Mathematical Biophysics* 20, 245 to 260.

Rosen, R. (1985). *Anticipatory Systems: Philosophical, Mathematical and Methodological Foundations*. Oxford: Pergamon Press.

Rosen, R. (1991). *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

Rosen, R. (2000). *Essays on Life Itself*. New York: Columbia University Press.

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Appendix M

The Registered Predictions Beside Giulio Tononi

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Giulio Tononi. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Measure of an Inside; Giulio Tononi's Integrated Information and Physics from Comparison*.

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Abstract

Giulio Tononi's Integrated Information Theory has done what a theory of consciousness seldom does: it has stated in advance where in the brain, and in what pattern of activity, conscious perception will be found, and it has put those statements to a preregistered test against a rival theory. The physics collection of the Immanent Metaphysics makes no statement about which regions of the brain, or which patterns of their activity, go with conscious perception, and the sealed record of 1 November 2026 holds predictions of physics only. So no measurement made or proposed separates the two accounts, and this record says so plainly. One statement of the books bears on the brain and can be measured: that the brain operates near criticality, the poise between order and disorder in which small disturbances cascade. The books argue it as the physical circumstance under which consciousness is expressed in us, the sealed record does not carry it, and the measurements so far agree with it; Tononi's account places consciousness in integrated information and not in criticality as such. Where the two accounts truly part, on what experience is, on whether a wholly determined system can have it, on what fixes the quality of an experience and on what its grades are grades of, the claims are of a kind that no experiment reaches, and

the record names each and the kind of claim it is. The two agree, on claims of the same kind, that a network that only passes signals forward and a program as such have no consciousness, and that no test of behavior can show an inside.

I. What This Record Is

This record sets the predictions of physics from comparison beside those of Integrated Information Theory, the theory of consciousness that Tononi proposed in 2004 and that he and his colleagues stated in its current form, Integrated Information Theory 4.0, in 2023. It takes the collection's predictions from the sealed record and from the books it cites, and Tononi's from his own published work and from the tests made of it.

The sealed record fixes what counts as a result: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement". It goes on: "A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such". The rule was written for the measurements of physics; the measurements of the brain named below are reported as measurements of interest.

Every prediction of the collection stated here is either quoted from the sealed record with its number, or argued in a book named at chapter and section, or marked as stated only in the relation essay. Nothing here alters the sealed record, and this record adds no prediction to it.

II. Where the Two Accounts Predict Differently

No entry. The predictions of Integrated Information Theory that have been tested concern the brain. In 2016 Christof Koch, Marcello Massimini, Melanie Boly and Tononi wrote that the correlates of consciousness are "primarily localized to a posterior cortical hot zone that includes sensory areas", "rather than to a fronto-parietal network involved in task monitoring and reporting". In the adversarial collaboration published in *Nature* on 30 April 2025, the proponents of Integrated Information Theory and of global neuronal workspace theory, with a consortium neutral between them, preregistered "divergent predictions, expected outcomes and interpretation thereof" before 256 participants were measured by three methods. The consortium found information

about conscious content in visual, ventrotemporal and inferior frontal cortex, and reported: “For IIT, a lack of sustained synchronization within the posterior cortex contradicts the claim that network connectivity specifies consciousness”. Global neuronal workspace theory was challenged in its turn, by “the general lack of ignition at stimulus offset and limited representation of certain conscious dimensions in the prefrontal cortex”.

Tononi deserves full credit for this test. A theory that states beforehand what will be found, and accepts a result that goes against one of its predictions, has done exactly what this record is for. The collection makes no statement about which regions of the brain, or which patterns of their activity, go with conscious perception, so these results count neither for nor against it. Its own words on such work are plain: “Neuroscience studies the omniscient-modal aspect of consciousness, and that work is genuine, valuable, and necessary” (*The Immanent Metaphysics and the Modern Engagement*, Chapter 7, Section XV). On its side, Integrated Information Theory makes no prediction about gravitation, cosmology or the kinds of particle, which is what the sealed record holds; so no sealed prediction is one on which the two accounts differ.

III. Where the Two Accounts Agree

No entry. No prediction that a measurement can decide is made by both accounts. Their agreements are of the kind that no experiment reaches, and they are set out with the differences of that kind, under the heading “Where the two agree, on claims of the same kind”.

IV. Predictions Not in the Sealed Record

This section holds what bears on Tononi’s account and is not in the sealed record: one statement that the books argue and that no record has registered, and one that the relation essay states.

Tononi 1. The brain operates near criticality

The collection predicts. *The Basis of Physics*, Essay 19, Section V, marks the claim as the stronger of two: "The brain, on this account, operates near criticality, as the study of neuronal avalanches suggests (Beggs and Plenz, 2003), in a regime where small perturbations cascade, so that indeterminacy at the microscopic scale enters causal chains that reach the macroscopic and bear on choice". *Causality Without Determinism*, Chapter 5, Section IX, says what the claim is and what it is not: "The brain's poise between order and disorder, which physicists call criticality, is the physical circumstance under which the bound triple is expressed in us; it is not the bound triple itself". Argued in the books as the physical circumstance under which the bound triple is expressed in us, and stated there at the strength of its evidence; not in the sealed record.

Tononi predicts. His account ties consciousness to integrated information, the measure of how far a system's power to cause and to be caused upon itself cannot be reduced to that of its parts, and not to criticality as such (Albantakis and others, 2023). Work by others joins the two: in a model of the human brain network, Hyoungkyu Kim and UnCheol Lee found that "maximal criticality coincided with maximal" integrated information, as estimated by a surrogate measure, and in recordings of the brain "The conscious resting state showed the largest" of both (Kim and Lee, 2019).

Where argued. *The Basis of Physics*, Essay 19, Section V; *The Last Turtle*, Chapter 15, Section VIII; *Causality Without Determinism*, Chapter 5, Section IX; the objection to it, and the answer, in *Objections from Physics, Answered*, Chapter 52.

Measured. John Beggs and Dietmar Plenz found in 2003 that activity in cortical circuits comes in cascades, neuronal avalanches, whose sizes follow a power law, the signature of a critical regime. Jonathan Touboul and Alain Destexhe answered in 2010 that "power-law scaling may be a generic property of thresholded stochastic processes" and that it "does not constitute a proof of self-organized criticality". In 2022 Daniel Toker and colleagues reported, from recordings in people and animals, that "during conscious states, the electrodynamics of the cortex are poised near a critical point", and that unconsciousness under anesthesia and in generalized seizures goes with "a

transition of low-frequency cortical electric oscillations away from this critical point". These are measurements of interest, and they agree with the statement.

What decides it. *Objections from Physics, Answered*, Chapter 52, states what kind of question this is: "the regime in which the cortex operates is a question of measurement, and its answer leaves the triple as it is". Measurements that tell a critical regime apart from power laws made by noise with no criticality behind them, the distinction Touboul and Destexhe drew, decide it. The bound triple does not rest on the answer: the argument "needs no particular biological mechanism and no sustained entanglement in the brain" (*Causality Without Determinism*, Chapter 5, Section IX).

The statement of the relation essay

The relation essay places integrated information where the books place criticality: "Integrated information stands where criticality stands. High integration of a system's causes and effects upon itself is a physical circumstance under which acts of comparison gather into one stance, and a system lacking it has no single place where its choices gather". Stated in the relation essay; not argued in the books and not in the sealed record. The essay says that integrated information measures a condition under which a system can have one place where its choices gather, and that it does not measure the experience itself; the essay states this as a placing of the measure, and not as a prediction, and this record does not turn it into one. Its nearest measured counterpart is the perturbational complexity index of Adenauer Casali, Tononi, Massimini and colleagues, which in 2013 "reliably discriminated the level of consciousness in single individuals during wakefulness, sleep, and anesthesia". A reading of the essay's sentence as a statement about the sleeping or anesthetized brain would be a new step, and the books bear on it: *What Cannot Be*, Chapter 2, says that "the laws of a self are laws of persistence, like the law that the self who wakes is the self who fell asleep". This record does not make that reading.

V. Where No Measurement Decides

A test reaches a claim only where the outcome of a comparison can be objective. *Physics Is Not Math*, Chapter 19, Summary, states the condition: "A test applies where the outcome of a comparison can be objective: comparable by many, consistent across them, and able to surprise". The differences below concern the subjective, or what a rule is, and "What is subjective is defined by what cannot be compared, so no third-person observation reaches it" (*Objections from Physics, Answered*, Chapter 52). So falsification does not apply to them, and the books say so of their own claims of this kind: "That subjectivity is, at its foundation, continuity with asymmetry is a claim of the framework, not a result of any experiment" (*What Cannot Be*, Chapter 21). A claim of this kind is judged by its argument. On Popper's own criterion, as *The Ground of Objection*, entry T1.10, reads it, "A system placed outside empirical science by his criterion has not been convicted of anything by him".

What experience is

Tononi's account identifies an experience with the cause-effect structure that a system's maximally irreducible core specifies, and its amount with integrated information (Albantakis and others, 2023). The collection holds that consciousness is the bound triple of the arrow of time, hard randomness and the subjective, taken as one act and held in the act, and that a quantity computed from a system's structure, laid out from outside, belongs to the objective character, which the Incommensuration Theorem keeps apart from the subjective (*Causality Without Determinism*, Chapter 5, Section III; *The Modern Engagement*, Chapter 7, Sections V and VII). Kind of claim: a description of what a thing is, made by Tononi from outside and by the collection from within the act; the relation essay finds that the identity fails at the step where a number computed from the system's structure, as laid out from outside (a surveyed claim), is said to be the experience held in the act (a performed claim).

Experience in a wholly determined system

On Tononi's account a network of logic gates whose every next state follows from its present state by rule can have high integrated information, and so has experience; when Scott Aaronson pressed the case of large networks of gates

wired as expander graphs in 2014, Tononi accepted the consequence and extended it to a plain two-dimensional grid of such gates. The collection holds that a rule with no hard randomness has no arrow and no subjective, so that "Classical computation, however intricately organized, cannot be what consciousness is" (*Causality Without Determinism*, Chapter 5, Section VI). Kind of claim: a claim of logical form, about what a rule is, checked by its structure step by step. No measurement of a grid decides it, since "A third-person description of behavior is the one description that cannot show an inside, for a person or for a program" (Chapter 5, Section IX).

The physical side of the difference is registered. The sealed record carries it as Prediction 28:

> No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic. Some asymmetry of time must exist in the laws, and no process at any scale is perfectly reversible; a reversal of evolution, by an inverse in a formalism or by a pulse in a laboratory, does not remove a finding from the order of findings. These are exclusions that the structure of comparison makes; the outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on this one.

Registered on 1 November 2026 as Prediction 28 of The Registered Predictions of Physics from Comparison. Where argued, as the sealed record gives it: *The Basis of Physics*, Essays 9 and 11; *Measurement*, Chapter 14, Sections II and III; *Why Time Travel Is Not a Concept*, Chapter 5, Sections III to V. So a physical grid of gates is never perfectly deterministic, and the relation essay grants it what its interactions have, "something real and simple"; the difference concerns the rule from which integrated information is computed, and the rule, being fixed, has no inside. Integrated Information Theory makes no claim about whether the world is deterministic, so Prediction 28 is not a prediction on which the two accounts differ.

What fixes the quality of an experience

Tononi's account holds that the structure of distinctions and relations it computes fully specifies the quality of an experience. The collection holds that its axioms "predict the structure of consciousness, not the content of any particu-

lar experience, so that qualia are not derived from them" (*The Modern Engagement*, Chapter 7, Section XV), and that a structure of distinctions, held in view as a whole, is the laid-out record of the verdicts that acts of comparison return. Kind of claim: a description of what a thing is.

What the grades of experience are grades of

Both accounts find something of mind at every scale. For Tononi the grades are amounts of integrated information, and a photodiode linked to a one-bit memory "can have a modicum of experience" (Tononi and Koch, 2015). For the collection they are degrees of interaction, "whose degree and kind correlate with the richness and structure of the interaction", and in the richest of them the choices made are held together by one self that persists (*The Ground of Objection*, entry T3.19). The same entry says what the collection does not supply: "The correlation between richness of interaction and degree of consciousness is asserted and is not derived, and the system does not supply a measure of richness or a function from one to the other". The relation essay reads integrated information as a candidate for that measure, and not as the experience it measures. Kind of claim: a description of what a thing is.

Where the two agree, on claims of the same kind

The two accounts agree that a network which only passes signals forward has no consciousness, and that a program as such has none, since what counts is the physical process and never the program it runs (*Causality Without Determinism*, Chapter 5, Section VII). They agree that no test of behavior can show an inside, that a being physically identical to a person cannot lack experience, and that a different system matching a person's behavior can. They agree that a science of consciousness begins from experience itself, whose first axiom, "Experience exists: there is something", is a performed claim. These agreements are claims of the same kind as the differences above, and no measurement decides them either.

VI. What the Collection Does Not Predict Here

None of the items of the sealed record's Section IX, "What the Books Do Not Predict", bears on Tononi's account; they concern the measured inputs of physics, cosmology, the kinds of particle, the size of the asymmetry of time, gravitation below the Planck curvature, black holes and travel within the light cone. The books also make no statement about which regions of the brain, or which patterns of their activity, go with conscious perception.

VII. The Record at Its Date

Entry	The collection	Tononi	Measured	Standing
Section II	No statement about regions or patterns of brain activity	Posterior hot zone; sustained synchronization in posterior cortex	Adversarial collaboration, 2025: content in visual, ventrotemporal and inferior frontal cortex; no sustained synchronization within the posterior cortex	No entry: no measurement separates the accounts
Tononi 1. The brain operates near criticality	Near criticality, the circumstance under which the bound triple is expressed in us (books; not sealed)	Consciousness goes with integrated information, not criticality as such	Beggs and Plenz 2003; Touboul and Destexhe 2010; Toker and colleagues 2022	Measurements agree with the collection's statement as far as tested (measurements of interest); Tononi's account makes no prediction here
The statement of the relation essay	Integration is the circumstance under which acts of comparison gather into one stance (essay only)	The cause-effect structure is the experience; integrated information is its amount	Perturbational complexity index, 2013, as nearest counterpart	Not a prediction; outside the sealed record

Summary

Integrated Information Theory has stated in advance where in the brain conscious perception will be found, and it has put those statements to a preregistered test; the test of 2025 bore out some of them and went against its prediction of sustained synchronization in the posterior cortex. The collection makes no statement about regions or patterns of brain activity, and the sealed record holds predictions of physics, on which Integrated Information Theory makes none; so no measurement separates the two accounts, and Prediction 28, the one sealed prediction that touches the difference, is not one on which they differ. The one statement of the books that bears on the brain and can be measured, that the brain operates near criticality, is argued as the circumstance under which consciousness is expressed in us, is not in the sealed record, and agrees with the measurements so far. The true differences, on what experience is, on whether a wholly determined system has it, on what fixes its quality and on what its grades are grades of, are claims of a kind that no experiment reaches, and they are judged by their arguments; so are the agreements, on feedforward networks, programs, tests of behavior and the starting point of the science.

Key Concepts

- Tononi's theory states in advance where conscious perception will be found, and it was put to a preregistered test in 2025.
- The collection makes no statement about brain regions, and the sealed record holds predictions of physics only; no measurement separates the two accounts.
- The brain operates near criticality: argued in the books as the circumstance under which consciousness is expressed in us, not in the sealed record, and agreeing with the measurements so far.
- What experience is, whether a determined rule has an inside, what fixes quality, and what grades are grades of: claims that no experiment reaches, judged by their arguments.
- Prediction 28 registers that no world is perfectly deterministic; the difference over determined systems concerns the rule, not the physical grid.
- Both accounts deny consciousness to feedforward networks and to programs as such, and both hold that no test of behavior can show an inside.

Terms

Adversarial collaboration. A test in which the proponents of rival theories agree beforehand on the experiment, each theory's predictions and how the results will be read.

Bound triple. The arrow of time, hard randomness and the subjective: distinct, inseparable and not interchangeable; taken as one act, consciousness.

Criticality. The poise of a system between order and disorder, in which small disturbances can cascade to any size.

Feedforward network. A network whose signals pass only from input toward output, with no part acting back on another.

Hard randomness. An outcome that no prior specification fixes, however complete; described from inside, choice.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing.

Integrated information. In Integrated Information Theory, the measure of how far a system's power to cause and to be caused upon itself cannot be reduced to that of its parts.

Measurement of interest. In the sealed record, a measurement that differs from a prediction by less than the rule of decision requires.

Neuronal avalanche. A cascade of activity in a network of nerve cells; sizes that follow a power law are read as a sign of criticality.

Performed and surveyed claims. A performed claim is established by what happens in the act of engaging it; a surveyed claim from a vantage that holds many cases in view at once.

Perturbational complexity index. A measure of how complex the brain's response is to a pulse of magnetic stimulation, built from the ideas of Integrated Information Theory.

Posterior hot zone. The region of the back of the cortex, including sensory areas, where Koch, Massimini, Boly and Tononi placed the correlates of consciousness.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Sealed record. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*, fixed at its date and not revised.

Superdeterministic completion. A deterministic theory beneath quantum mechanics in which the settings chosen for a measurement are fixed together with what is measured.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Measure of an Inside; Giulio Tononi's Integrated Information and Physics from Comparison*. Relation essay. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Immanent Metaphysics and the Modern Engagement; From Husserl to Wilber*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Last Turtle; Essays from Comparison and the Incommensuration Theorem to Causation, the Arena and the Limits of Computation*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Objections from Physics, Answered; The Identifications of Physics from Comparison, Step by Step*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Physics Is Not Math; Metaphysics, Physics, Computation and Mathematics, and Why Their Order Cannot Be Otherwise*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *What Cannot Be; Signals Faster Than Light, Time Travel, Simulation and Determinism, in Plain Words*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Aaronson, S. (2014). "Why I am not an integrated information theorist (or, the unconscious expander)". Shtetl-Optimized (blog), 21 May 2014.

Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A. M., Marshall, W., Mayner, W. G. P., Zaeemzadeh, A., Boly, M., Juel, B. E., Sasai, S., Fujii, K., David, I., Hendren, J., Lang, J. P. and Tononi, G. (2023). "Integrated information theory (IIT) 4.0: Formulating the properties of phenomenal existence in physical terms". *PLOS Computational Biology* 19, e1011465.

Beggs, J. M. and Plenz, D. (2003). "Neuronal avalanches in neocortical circuits". *Journal of Neuroscience* 23, no. 35, 11167–11177.

Casali, A. G., Gosseries, O., Rosanova, M., Boly, M., Sarasso, S., Casali, K. R., Casarotto, S., Bruno, M.-A., Laureys, S., Tononi, G. and Massimini, M. (2013). "A theoretically based index of consciousness independent of sensory processing and behavior". *Science Translational Medicine* 5, 198ra105. DOI: 10.1126/scitranslmed.3006294.

Cogitate Consortium, Ferrante, O. and others (2025). "Adversarial testing of global neuronal workspace and integrated information theories of consciousness". *Nature*, published 30 April 2025. DOI: 10.1038/s41586-025-08888-1.

Kim, H. and Lee, U. (2019). "Criticality as a determinant of integrated information Φ in human brain networks". *Entropy* 21, no. 10, 981. DOI: 10.3390/e21100981.

Koch, C., Massimini, M., Boly, M. and Tononi, G. (2016). "Neural correlates of consciousness: progress and problems". *Nature Reviews Neuroscience* 17, 307–321. DOI: 10.1038/nrn.2016.22.

Tononi, G. (2004). "An information integration theory of consciousness". *BMC Neuroscience* 5, 42.

Tononi, G. (2014). "Why Scott should stare at a blank wall and reconsider (or, the conscious grid)". Posted on Shtetl-Optimized (blog), 30 May 2014, in S. Aaronson, "Giulio Tononi and Me: A Phi-nal Exchange".

Tononi, G. and Koch, C. (2015). “Consciousness: here, there and everywhere?”. *Philosophical Transactions of the Royal Society B* 370, 20140167.

Toker, D. and others (2022). “Consciousness is supported by near-critical slow cortical electrodynamics”. *Proceedings of the National Academy of Sciences* 119, no. 7, e2024455119. DOI: 10.1073/pnas.2024455119.

Touboul, J. and Destexhe, A. (2010). “Can power-law scaling and neuronal avalanches arise from stochastic dynamics?”. *PLoS ONE* 5, e8982. DOI: 10.1371/journal.pone.0008982. arXiv:0910.0805.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Appendix N

The Registered Predictions Beside Karl Friston

A Dated Record, 4 November 2026

Date of record: 4 November 2026. This record is fixed at its date and is not revised; a later report will carry its own date. It sets the predictions of physics from comparison beside those of Karl Friston. It draws on *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), which stands as it is, and on the relation essay *The Boundary and the Act; Karl Friston's Free Energy Principle and Physics from Comparison*.

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Abstract

Karl Friston's free energy principle and the physics collection of the Immanent Metaphysics agree on where a test applies. Friston and his colleagues state that the principle "is not falsifiable as a mathematical statement", and the collection's account of testing places it exactly there: a mathematical statement is checked by proof, and a test reaches every claim that applies the principle to a particular system. The sealed record of 1 November 2026 holds predictions of physics, and one of them meets Friston's account: Prediction 25, that the statistics of quantum theory hold. Friston's monograph of 2019 presents its Bayesian mechanics as compatible with quantum mechanics and names no departure from those statistics, so the two accounts agree there, and the measurements so far agree with both. No measurement named in the relation essay or in the books separates the two accounts, and the relation essay states no prediction of its own. The process theories that realize the principle in brains, predictive coding among them, make predictions that experiments in neuroscience test; the collection makes no claim about which mechanisms carry out comparing, so the outcomes of those experiments bear on the process theories and not on the collection. Where the accounts part, they part on what the boundary of a self is, on

whether a computation that minimizes free energy is the act it models, on decision and choice, and on whether probability or comparison comes first. Those are differences of kind that no experiment reaches, and the record names each with the kind of claim it is.

I. What This Record Is

This record sets two accounts side by side. One is the account of physics from comparison, whose predictions were gathered and sealed on 1 November 2026. The other is the account of Karl Friston, a neuroscientist at University College London, who set out the free energy principle in 2006 as an account of the brain, with James Kilner and Lee Harrison, offered it in 2010 as a candidate for a unified theory of brain function, and in a monograph of 2019 extended it to "every 'thing' that can be distinguished from other things in a statistical sense". In its statement of 2023, with Lancelot Da Costa and others, the principle is compared to Hamilton's principle of least action, and its authors write that "it is not a falsifiable theory about the way 'things' behave".

The collection's account rests on the Incommensuration Theorem: symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity. The Incommensuration Theorem is a structural fact about the nature of knowing. Forrest Landry formulated the first axiom in or before 1991, and the Incommensuration Theorem and the ethics of the Immanent Metaphysics in 1996; most of his physics work was done in 1997 and 1998. *An Immanent Metaphysics*, published in 2001, states the theorem in aphorism 1.43-2 and the three axioms in aphorism 1.3-1.

The rule of decision is the sealed record's: "A result counts when it is established at five standard deviations by at least two independent kinds of measurement. A measurement that differs from a prediction by less is a measurement of interest, and the record reports it as such". Every prediction of the collection stated here is quoted from the sealed record, with its number, and argued in the books named at chapter and section. The relation essay states no prediction that the books do not argue, so no entry here rests on the essay alone.

II. Where the Two Accounts Predict Differently

The two accounts share every measured outcome named in the relation essay and in the books, and at this date no measurement is named on which they give different results. There are three reasons, and each is stated by one account or the other.

The first is Friston's own. The free energy principle, as its authors state it, is a mathematical statement, and a mathematical statement is checked by whether its conclusions follow from its premises, not by an experiment. Its authors add, in the same sentence, that the principle "may as well be falsifiable to the extent that its postulates refer to a specific class of empirical phenomena that the principle aims to describe", which is the line the second reason draws.

The second is the collection's. What experiments reach is every claim that applies the principle to a particular system: that a population of neurons encodes a given prediction, that a given behavior lowers a given quantity. Friston's program draws the line between the principle and the process theories, predictive coding among them, that realize it in particular systems, and those process theories are tested in neuroscience. The collection makes no claim about which mechanisms there are. The Ground of Objection, entry T2.24: "The system entails that comparison has implementations", and "A description of neural mechanism is a description within a domain". So whatever a test of a process theory finds, it bears on that process theory and not on the collection, and it does not tell the two accounts apart.

The third concerns the one claim of the relation essay that might seem to invite a test: that a computation governed by the principle is not what consciousness is. Causality Without Determinism, Chapter 5, Section VI, states that such a computation "may be capable of much else, including behavior that looks, from a third-person vantage, indistinguishable from conscious behavior", and that "The argument is about what a computation is, and so it holds whatever the computation does". No measurement of behavior therefore bears on it, and the record places it in Section V.

This section has no entry, and the record adds no test.

III. Where the Two Accounts Agree

Friston 1. The statistics of quantum theory hold

The collection predicts. "Repeated measurements on identically prepared systems settle to the weights of the Born rule, in every sector and on the full space, including in the tests proposed for superdeterminism, which look for departures from those weights. The interference among three paths has no term that the pairs of paths do not account for. Tests of the CHSH inequality reach $2\sqrt{2}$ and go no further, and stay at 2 or below whenever either party's two observables commute. Experiments with independent sources find the complex, not the real, composition of independent systems". Registered on 1 November 2026 as Prediction 25 of *The Registered Predictions of Physics from Comparison*.

Friston predicts. No departure from these statistics. His monograph of 2019 recovers quantum mechanics "via the Schrodinger equation" as its description of small things, from the same statistical decomposition that picks out a thing, and states that "The ensuing Bayesian mechanics is compatible with quantum, statistical and classical mechanics" (Friston 2019, abstract). It names no measurement at which the weights of the Born rule would fail.

Where argued. The Quantum Passage, Chapters 5, 7 and 8, and Appendix B; The Unquantized Arena, Chapter 13, Section VII.

Measured. "Three-slit experiments find the third term consistent with zero (Sinha and others 2010); network experiments in 2022 found the complex composition (Chen and others; Li and others)". The sealed record gives the standing as "agrees". No later measurement bearing on it was found between 1 and 4 November 2026.

What decides it. A departure from the weights of the Born rule, a term of interference among three paths that the pairs do not account for, a value of the CHSH inequality above $2\sqrt{2}$, or a real composition of independent systems, established under the rule of decision. Any of these would bear on both accounts alike, so no outcome here separates them; the two accounts part only on how the statistics are reached, which Section V sets out.

IV. Predictions Stated Only in the Relation Essay

The relation essay states no prediction that the books do not argue and the sealed record does not carry, so this section has no entry.

V. Where No Measurement Decides

Falsification is a tool that applies where its object is the outcome of a comparison that others can repeat. Physics Is Not Math, Chapter 19, Section III: "A test is a comparison of outcomes, and it can settle something only when its outcome can be compared: by another person, at another time, along another route", and so "a test applies exactly where the outcome of a comparison can be objective, and nowhere else". Each difference below is a claim of logical form, a description of what a thing is, or a claim about the act of knowing. None of them is an outcome that another person reads off an instrument, so falsification does not apply to any of them; each is settled by proof, or by what happens in the act of engaging it. Friston places his own principle on the same side of that line, and the collection agrees with him that it belongs there.

What kind of claim each foundation is

A claim of logical form. Both accounts place their foundations outside the reach of a test, and both say so openly. They differ on why. The free energy principle is a surveyed claim: in the terms of Physics Is Not Math, Chapter 9, Section III, it is "established from a vantage that holds many cases in view at once", and it holds of every model that meets its conditions. The Incommensuration Theorem is a performed claim: it is "established by what happens in the act of engaging it, including the act of trying to deny it" (the same section). The Ground of Objection, entry T1.10, accepts Popper's criterion as a demarcation of empirical science and places the collection's foundation outside it "without embarrassment". The principle is outside the reach of a test because it is mathematics; the theorem is outside the reach of a test because every test is an instance of it.

What the boundary of a self is

A description of what a thing is. Both accounts hold that a thing is set apart from its world by a boundary across which it interacts, never sealed off and never dissolved; Causality Without Determinism, Chapter 6, Section VI, says of the self that "The degree of its interaction is never zero (it is always engaged with something) and never infinite". Friston picks out that boundary as a Markov blanket, a statistical partition of a model. Bruineberg, Dołęga, Dewhurst and Baltieri (2022) distinguish the blanket as a tool of inference within a model ("Pearl blankets") from the blanket read as the real boundary of a thing ("Friston blankets"), and argue that the step from the first to the second needs further premises. The collection names that step. Causality Without Determinism, Chapter 4, Section I: "Compatibility between a model and a body of measurements is not equivalence: many models may be compatible with the same data, and no amount of compatibility can establish that the model is the reality it describes". A partition laid out in a model exists; the boundary of a self is real, the place where the self compares, perceives and chooses. The blanket can describe that boundary exactly and cannot be what makes it. No measurement decides this, because every measurement of a living boundary is compatible with both readings.

Whether a computation that minimizes free energy is the act it models

A description of what a thing is. A simulated agent governed by active inference is a program, "a step-by-step procedure whose next state follows necessarily from its current state by a fixed rule" (Causality Without Determinism, Chapter 5, Section II). The collection holds that consciousness is the bound triple of the arrow of time, hard randomness and the subjective, taken as one act (Section III), and that a classical computation lacks all three, so that "classical computation, however intricately organized, cannot be what consciousness is" (Section VI). The same section allows that such a computation may behave, from a third-person vantage, in a way that cannot be told apart from conscious behavior. The claim concerns what the act is, and no outcome of a test of behavior bears on it.

Decision and choice

A claim about the act of knowing and choosing. Active inference selects a course of action by ranking a set of courses by expected free energy and favoring the lowest. Causality Without Determinism, Chapter 6, Section III: "A decision is a selection from a set of possibilities already defined, made by cutting away the others; if it involves trade-offs, it is a decision. A choice may realize a possibility that was open but not in the set". Selection by expected free energy is decision in this sense. The random fluctuations of the principle's equations are, in the collection's account, the description from outside of what, from inside, is choice: hard randomness is "the remainder that no completeness of prior specification closes off", and hard randomness and choice "are one event described from two positions" (Chapter 5, Section V). The collection's exclusion of a perfectly deterministic world is registered as Prediction 28: "No superdeterministic completion of quantum mechanics will be found, and no world is purely and completely deterministic". Friston's account makes no claim on that question either way, so Prediction 28 does not separate the two accounts; what divides them here is whether the fluctuation term is the whole of what happens at a choice, and that is a claim about the act.

Whether probability or comparison comes first

A claim of logical form. Friston's monograph of 2019 begins from probability densities over states and the conditional independences among them, and reads things, their boundaries and their beliefs from that structure. The collection orders the four the other way: metaphysics, physics, computation, mathematics, each presupposing the one before. Mathematics, in Physics Is Not Math, Chapter 3, Section VII, "works as if only the objective existed, and as if there were no subjective side at all", and "What mathematics states leaves the stance out; how mathematics is done keeps the stance in". The collection derives probability rather than assuming it: The Quantum Passage derives the Born rule from the structure of comparison, and holds that what a measurement changes is the laid-out record, "shared and the same for everyone who has the outcome" (Chapter 11, Section V), and not a personal degree of belief. Both accounts predict the same weights (Friston 1), so the difference is in the order of derivation, and no measurement of the weights reaches it.

VI. What the Collection Does Not Predict Here

None of the items of the sealed record's Section IX bears on Friston's account. They concern the measured inputs of physics, the Hubble constant, the primordial departures, the transition between epochs, the excess of matter over antimatter, the values of the particles, the size of the asymmetry of time, the regime below the Planck curvature, information in black holes, and travel within the light cone. Apart from that section, the books make no prediction about which mechanisms an organism uses to compare (The Ground of Objection, entry T2.24), and so no prediction about the findings of neuroscience that test the process theories of the free energy principle.

VII. The Record at Its Date

Entry	The collection	Friston	Measured	Standing
Friston 1 (Prediction 25)	Born weights in every sector; no third term; CHSH at most $2\sqrt{2}$; complex composition	compatible with quantum mechanics; no departure named	third term consistent with zero (Sinha and others 2010); complex composition (2022)	agrees

Summary

Karl Friston's free energy principle and the physics collection agree on where a test applies: the principle, as mathematics, is checked by proof, and its applications to particular systems are claims that experiments reach. They agree also on one registered prediction of physics. Prediction 25 of the sealed record, that the statistics of quantum theory hold, is one Friston's account shares, since his monograph of 2019 presents its Bayesian mechanics as compatible with quantum mechanics and names no departure; the measurements so far agree with both. No measurement named in the relation essay or in the books separates the two accounts, and the essay states no prediction of its own. The tests of predictive coding and the other process theories bear on those theories, because the collection makes no claim about which mechanisms carry out comparing. The accounts part on four questions: what kind of claim each foundation is, what the boundary of a self is, whether a computa-

tion that minimizes free energy is the act it models, and whether probability or comparison comes first; with these goes the difference between decision and choice. Each is a claim of logical form, a description of what a thing is, or a claim about the act of knowing, and no outcome of a measurement bears on any of them.

Key Concepts

- Friston states that the free energy principle "is not falsifiable as a mathematical statement"; the collection agrees that a test does not apply to it, and that a test does apply to each claim that applies the principle to a particular system.
- Prediction 25 of the sealed record, that the statistics of quantum theory hold, is shared: Friston presents his Bayesian mechanics as compatible with quantum mechanics.
- The collection makes no claim about which mechanisms carry out comparing, so the tests of predictive coding bear on the process theories and not on the collection.
- A Markov blanket describes the boundary of a self exactly and cannot be what makes it: a partition in a model exists, and the boundary where a self compares is real.
- A computation that minimizes free energy is not what consciousness is, whatever it does; no test of behavior bears on that claim.
- Selection by expected free energy is decision; choice may realize a possibility not in the set, and the fluctuation term is its description from outside.
- Friston reads physics and mind from probability; the collection derives probability from comparison.

Terms

Active inference. In Friston's account, action that changes the world so that what is sensed fits what is expected.

Born rule. The rule that gives the probability of each outcome of a quantum measurement from the state prepared.

Bound triple. The arrow of time, hard randomness and the subjective, distinct, inseparable and not interchangeable; taken as one act, they are consciousness.

CHSH inequality. A form of Bell's inequality for two parties with two settings each; no account with predetermined local answers exceeds 2, and quantum theory reaches $2\sqrt{2}$.

Decision and choice. A decision selects from a set of possibilities already defined; a choice may realize a possibility open but not in the set.

Expected free energy. The quantity by which active inference ranks courses of action, weighing preferred outcomes and the information an action would gather.

Free energy principle. Friston's statement that anything which persists, set apart by a Markov blanket, behaves as if it keeps its variational free energy low, and so can be read as inferring the causes of its sensations.

Hard randomness. An outcome that no prior specification fixes, however complete; from the position of the one engaged, the same event is choice.

Incommensuration Theorem. Symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison; and neither can asymmetry and discontinuity.

Markov blanket. A set of states that separates internal from external states, so that each depends on the other only through it; Bruineberg and colleagues distinguish its use within a model (Pearl blanket) from its use as the boundary of a thing (Friston blanket).

Measurement of interest. In the sealed record, a measurement that differs from a prediction by less than the rule of decision requires.

Performed and surveyed claims. A performed claim is established by what happens in the act of engaging it; a surveyed claim from a vantage that holds many cases in view at once.

Process theory. A theory, such as predictive coding, that realizes the free energy principle in a particular kind of system and makes claims that experiments test.

Rule of decision. The rule of the registered predictions: a result counts when it is established at five standard deviations by at least two independent kinds of measurement.

Superdeterminism. A deterministic completion of quantum mechanics in which the settings of an experiment are fixed together with the states of what is measured, so that statistical independence fails; the two are fixed together by a prior specification of the world.

Variational free energy. A quantity a system can compute that is never less than the surprise of a sensation, its improbability under the system's model.

Sources

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Boundary and the Act; Karl Friston's Free Energy Principle and Physics from Comparison*. Relation essay. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *Causality Without Determinism*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Physics Is Not Math; Metaphysics, Physics, Computation and Mathematics, and Why Their Order Cannot Be Otherwise*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Bruineberg, J., Dołęga, K., Dewhurst, J. and Baltieri, M. (2022). "The Emperor's New Markov Blankets". *Behavioral and Brain Sciences* 45, e183. doi: 10.1017/S0140525X21002351.

Friston, K. (2010). "The free-energy principle: a unified brain theory?". *Nature Reviews Neuroscience* 11, 127 to 138.

Friston, K. (2019). "A free energy principle for a particular physics". arXiv: 1906.10184. https://arxiv.org/abs/1906.10184.

Friston, K., Da Costa, L., Sajid, N., Heins, C., Ueltzhöffer, K., Pavliotis, G. A. and Parr, T. (2023). "The free energy principle made simpler but not too simple". *Physics Reports* 1024, 1 to 29. arXiv:2201.06387.

Friston, K., Kilner, J. and Harrison, L. (2006). "A free energy principle for the brain". *Journal of Physiology, Paris* 100, 70 to 87.

The measurements of Prediction 25 are cited as the sealed record cites them, by author and year (Sinha and others 2010; Chen and others 2022; Li and others 2022); the full entries are in the bibliography of *The Quantum Passage*.

The books of the physics collection cited are linked where cited; each is dated 2026 and published by UVSM Publications, Wytheville, Virginia.

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Appendix O

Why the New Epoch Is Flat

An Argument from the Restoration of Context

Abstract

Space on the largest scales is flat to within the present precision of measurement, and the physics collection of the Immanent Metaphysics predicts that it is flat to the size of the primordial departures from uniformity, about one part in a hundred thousand. Measurement can find a curvature larger than that, but it can never confirm a flatness finer than that, because the departures themselves set the floor of what any observer can measure. So the flatness of the epoch is settled by argument. This essay gives the argument whole. The state of the new epoch is set at the restoration of context, at the turn, and the spatial curvature, a constant of integration of general relativity, belongs to that state. The state holds one length, the length of the turn, and only pure numbers of order one, because no length and no count of the old epoch passes the turn, and because the cosmological constant and every other constant of the law belong to the law and not to the state, and the cosmological constant does not act at the turn. A radius of curvature built from the length of the turn and the de Sitter radius together therefore has nothing to be built from. A radius of the turn's own length is excluded by the cycle, since an epoch so curved builds no structure. What remains is no radius at all: the epoch is flat, and curved only by its departures, at their own size. The essay then sets out how one premise, that the new geometry has no prior identity, gives both the Weyl curvature hypothesis and spatial flatness; records Forrest Landry's observation that the turn and the flatness of the whole epoch are two global constraints in a reciprocal relation, measured by one residue; credits the different route, through the measure that Gibbons and Turok studied, by which Carroll and Tam reached the same conclusion; and lists the passages of the books that carry the argument.

I. What Measurement Can Settle

This appendix gives the argument behind Prediction 9 of the sealed record, under which the registers beside Wheeler, Tegmark, Ellis, and Milgrom and McGaugh file their entries on the curvature of space, and which Part One, Section VIII, in Volume One, and the chapter on George Ellis summarize. Prediction 9 stands as sealed; this essay restates the argument behind it.

The collection registered its prediction on 1 November 2026, as Prediction 9 of *The Registered Predictions of Physics from Comparison*:

> "The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}".

The measure of curvature used throughout is the *curvature share*: the part of the expansion of space that its curvature accounts for, stated as a share of the energy of a flat universe. A flat space has a curvature share of zero.

Measurement agrees with the prediction. The microwave background with the baryon acoustic oscillations gives a curvature share of 0.001 ± 0.002 (Aghanim and others 2020), as the sealed record reports. The second data release of DESI, with the microwave background, gives 0.0023 ± 0.0011 (Abdul-Karim and others 2025), about two standard deviations from flat on the open side, a measurement of interest from one kind of measurement, short of the rule of decision; Chen and Zaldarriaga (2025) discuss how that value arises. The sealed record names what would refute the prediction: "A curvature confirmed at the level of 10^{-3} refutes it".

Measurement also has a floor. Waterhouse and Zibin (2008) showed that an observer who sees a finite volume cannot measure the curvature share to arbitrary precision, because the departures from uniformity on scales beyond the horizon blur it: it "cannot be measured to better than about" 1.5×10^{-5}, at one standard deviation. That floor is the size of the departures, the same size the prediction gives for the curvature. So measurement can find a curvature of a part in a thousand and refute the prediction, as the sealed record says; in time it can reach a part in ten thousand, a level the sealed record does not name, where a curvature confirmed would on this essay's reading refute the

prediction too; it can never confirm a flatness finer than the departures. Whether the large-scale model of the epoch is exactly flat is a question that only an argument answers.

II. The Question the Argument Must Answer

The books argue flatness from the restoration of context. The Gravitational Passage, Chapter 18, Section IX, gives the argument in full:

> "The restoration also fixes the spatial curvature, which conformal flatness leaves free. A radius of spatial curvature is a length. The metric has no prior identity, and no total of the old content passes, since no comparison of the new epoch registers the mass of the old interiors (Section II). The lengths left are those of the turn, of the order of the Planck length, and the de Sitter radius that the reconstructed history carries. A radius of the Planck length would close the new epoch within a few Planck times or leave it dominated by curvature, and neither epoch produces the structure that the cycle requires (Section XII). A radius equal to the de Sitter radius leaves a curvature of about 10^{-64} today. The homogeneous model of the new epoch is therefore spatially flat, and the geometry found is curved only by its departures, at their own size, about 10^{-5}".

The argument tests each length alone. A radius can also be built from the two lengths together, and the size of the curvature it would leave shows why the matter needs the further step this essay supplies.

For one history of expansion, the curvature share today goes as the inverse square of the radius of curvature that the restoration sets, since every length of the epoch, the radius among them, is stretched by the same factor from the turn to the present. The book gives the figures needed. Near the turn, "a length observed today was some 10^{27} Planck lengths and some 10^{-34} of the de Sitter radius" (Chapter 18, Section IX), so the de Sitter radius is about 10^{61} times the length of the turn. A radius equal to the de Sitter radius leaves a curvature share of about 10^{-64}. The curvature share is the square of the ratio of the present horizon to the present radius, so 10^{-64} places the present horizon, traced back to the turn, at about 10^{-32} of the de Sitter radius, which is

about 10^{29} lengths of the turn. The present horizon is so about a hundred times the length of some 10^{27} Planck lengths in the quoted passage, which is a length observed today and not the horizon itself. The table gives the curvature share today for a radius set at the turn.

Radius of curvature at the turn	In lengths of the turn	Curvature share today
The length of the turn	1	10^{58}: curvature rules the epoch
The geometric mean of the two lengths	$10^{30.5}$	10^{-3}: at the edge of measurement
The de Sitter radius	10^{61}	10^{-64}: far below any measurement

Each entry is 10^{-64} multiplied by the square of the ratio of the de Sitter radius to the radius: for the length of the turn, $10^{-64} \times 10^{122} = 10^{58}$; for the geometric mean, $10^{-64} \times 10^{61} = 10^{-3}$. The present horizon, at the turn, sits 29 of the 61 powers of ten up from the length of the turn, about halfway between the two lengths, and so a radius halfway between them leaves a curvature at the level where the sealed record says Prediction 9 is refuted. That placing of the present horizon is the flatness problem of standard cosmology, written in the terms of this account. The question the argument must answer is therefore exact: what fixes the radius of curvature to the length of the turn, or to no length at all, and not to a length built from the length of the turn and the de Sitter radius together?

III. The Premises

Six premises carry the argument. Five are stated in the books, and one, a standard result of general relativity, is stated here explicitly. The fourth is stated in the books for the cosmological constant, and here, on the ground the books give for it, for every constant of the law.

The new geometry has no prior identity. The Gravitational Passage, Chapter 18, Section VIII: "A metric with no prior identity inherits no large-scale anisotropy or inhomogeneity from the old exterior, so on this account it

begins conformally flat up to the departures the Incommensuration Theorem requires: perfect isotropy would make symmetry and continuity both perfect, which the Incommensuration Theorem forbids".

No length of the old epoch passes the turn. The Gravitational Passage, Chapter 18, Questions: "The spatial flatness follows from the restoration: no length of the old epoch passes the turn, and the lengths that remain give a flat homogeneous model (Section IX)". The ground is the principle of Chapter 18, Section II: "a difference that no comparison can register is no difference", and no comparison of the new epoch registers the old interiors.

No count passes the turn. The Gravitational Passage, Chapter 18, Section VIII, answering Tolman: "Here no count is carried across the turn, for the matter or for the geometry, since each count is relative to the context that ends. Each epoch begins its own count, and the cycle has no first iteration".

The cosmological constant, and every other constant of the law, belongs to the law and not to the state, and the cosmological constant does not act at the turn. The Gravitational Passage, Chapter 13, Section VI: "So Λ is fixed once, by the present measurement, as the constant term of one geometry, and the reconstructed history carries that value at every epoch, before the present and after it". Chapter 18, Section XII: "Inside the common interior, where the exterior has dissolved, Λ does not act as a force resisting collapse. It acts as nothing at all, because the structural conditions for its definition are no longer met". The ground given for the constant, that it is fixed once as a term of the law and is not set by the state, holds for every constant of the law: the masses and strengths of the kinds of particle are fixed once by the law, as the cosmological constant is, so no constant of the law, and no ratio of such constants, is part of the state that the restoration sets.

The spatial curvature belongs to the state that the restoration sets. In general relativity the expansion of a homogeneous space obeys Friedmann's equation, in which the square of the rate of expansion is the sum of three terms: one from the density of the content, one from the cosmological constant, and one from the curvature of space. The first two terms come from the content and from the law. The third carries a constant that the law does not fix: it is a constant of integration, set once by the state from which the history begins, and carried unchanged thereafter (Misner, Thorne and Wheeler 1973,

Chapter 27). The book states the same of the restoration: "The restoration also fixes the spatial curvature, which conformal flatness leaves free" (Chapter 18, Section IX). So the radius of curvature is part of the state that the restoration sets, and it can be built only from what that state holds.

The restoration is one process, recurring at every turn. The Gravitational Passage, Chapter 18, Section XII: "Each epoch produces structure, structure produces black holes, the interiors of the black holes share one end, and at that end the internal space de-compactifies into a new epoch (Figure 4)". The concentration of content toward collapse and the restoration of context "alternate".

IV. The Argument

What the state holds. The state set at the restoration holds the lengths that the turn itself has, and no length of the old epoch. The length of the turn is of the order of the Planck length, and the radii of the six held internal dimensions are of the same order: "$R_T = l_{Pl}$ and $R_O = \sqrt{6}\, l_{Pl}$" (The Gravitational Passage, Chapter 11, Section IV), where R_T is the length of the turn, R_O the radius of the held internal dimensions, and l_{Pl} the Planck length. The pure numbers the state holds are the numbers of its structure, of order one, and the size of the departures from uniformity, about 10^{-5}. It holds no large count: the counts of the old epoch, the count of the old horizon among them, end with the context relative to which they were counts.

A radius built from both lengths has nothing to be built from. The geometric mean of the two lengths is the length of the turn multiplied by a pure number of about 10^{30}, and any length between the two lengths is the length of the turn multiplied by some large pure number. A radius of that kind needs one of two things in the state.

It could take the de Sitter radius as a second length. The de Sitter radius is the radius of the cosmological constant, and the constant belongs to the law of the geometry, fixed once as its constant term, and not to the state. At the turn it "acts as nothing at all, because the structural conditions for its definition are no longer met". As a check, its size agrees: the vacuum density is "about 10^{-123} of the Planck density" (Chapter 13, Section VI), and the square of the

ratio of the length of the turn to the de Sitter radius is $(10^{-61})^2 = 10^{-122}$, of the same order. The restoration happens at the length of the turn, where the constant's term is smaller than the terms of the turn by that factor, and the constant does not act there at all. So the de Sitter radius is not in the state.

It could take a pure number near 10^{30}. The numbers that large in the account are counts, such as the count of the present horizon, and ratios of the constants of the law, such as the Planck mass to the mass of a neutrino, about 1.4×10^{30} for the second neutrino of Prediction 38. No count passes the turn, and the constants of the law belong to the law and not to the state, as the cosmological constant does. The one small number the state holds, the size of the departures, enters the curvature as it enters everything else, at its own size, and that is the curvature the prediction gives. So no number near 10^{30} is in the state.

So the radius is of the order of the length of the turn, or there is none. With one length and only pure numbers of order one, a radius of curvature is either of the order of the length of the turn, or it is absent, and the homogeneous model has no curvature.

The cycle excludes a radius of the length of the turn. "A radius of the Planck length would close the new epoch within a few Planck times or leave it dominated by curvature, and neither epoch produces the structure that the cycle requires" (Chapter 18, Section IX). The restoration is one process, recurring at every turn, and an epoch that produces structure is how a turn comes about at all, since the turn is the common end of the interiors of the black holes that structure makes. A restoration that set a radius of the length of the turn would set it in every epoch, and no epoch would make the black holes from which the next one comes. So the restoration sets no radius of that length.

Therefore the new epoch is flat. The homogeneous model of the new epoch has no radius of curvature: it is spatially flat. The geometry found is curved only by its departures from uniformity, at their own size, about 10^{-5}, which is Prediction 9, and which sits at the floor that Waterhouse and Zibin found for any measurement.

What the argument no longer needs. The argument does not take the de Sitter radius as a length of the state, so it uses neither the value nor the sign of the cosmological constant; it uses only that the constant belongs to the law. The book's figure for a radius equal to the de Sitter radius, 10^{-64}, stays as a check: had that radius been available, it too would leave no curvature to measure. The identity of Chapter 13, Section III, which gives the matter fraction 0.311, takes the flatness, since its shares are summed "for a spatially flat universe, which the restoration of Chapter 18, Section IX, gives"; the flatness now takes nothing from the value of the constant, whose share of the energy the identity gives, so the two support each other with no circle between them.

A control. The same steps, run on the standard hot history that begins at the Planck time with no cycle and no reset, give the opposite result, and the difference shows where the conclusion comes from. There the state at the beginning holds the Planck length, so a radius of that order is the expected one, and nothing excludes it; that is the flatness problem, and inflation is its standard answer. In this account two premises change the outcome: the reset removes every large number from the state, and the cycle excludes the one length the state holds. The conclusion comes from those two premises, and the argument shows it.

V. One Step Carries the Result, and One Premise Gives Two Results

The result rests on the step that excludes a radius of the length of the turn, and that step rests on the cycle: the restoration is one process, recurring, and every epoch that leads to a turn produces structure. Every other step either follows from the premises that no length and no count pass the turn, or from the standard result that the curvature is a constant of integration of the state. The cycle is the account's identification of black hole collapse and cosmological origin as "one transition approached from its two sides" (Chapter 18, Section XII), and the flatness of the epoch is one of its consequences.

The same premise gives two results. That the new geometry has no prior identity gives conformal flatness: the new metric inherits no shape from the old exterior, so its Weyl curvature is zero up to the departures, which "is Pen-

rose's Weyl curvature hypothesis, reached here as a consequence of the restoration and not as a separate postulate" (Chapter 18, Section VIII). Conformal flatness leaves the spatial curvature free, because homogeneous spaces of every curvature are conformally flat; what decides between them is a length. The same premise, applied to length, gives spatial flatness: the new metric inherits no length from the old epoch, and the state holds no length from which a radius could be made. So the absence of a prior shape and the absence of a prior length are one premise, applied twice, and the Weyl curvature hypothesis and the flatness of space come from one source.

VI. The Turn and the Whole: A Meditation

This section records an observation of Forrest Landry's and the questions it raises. It states no new result.

The Incommensuration Theorem is a structural fact about the nature of knowing: symmetry and continuity are not both perfect in any comparison (An Immanent Metaphysics, aphorism 1.43-2). A perfected singularity at the turn would be such a perfection, and so would a perfected flatness of the epoch. The books already apply the theorem at the turn: "perfect isotropy would make symmetry and continuity both perfect, which the Incommensuration Theorem forbids. The old distinctions therefore survive the turn only as small departures from uniformity, averaged and not erased" (Chapter 18, Section VIII). And they give the epoch its curvature from the same departures: "curved only by its departures, at their own size" (Section IX). So the theorem forbids a perfected flatness as it forbids a perfected singularity, and the flatness it allows is indistinguishable in practice from a perfect one: it lies at the floor below which no measurement can go. The homogeneous model is flat exactly because it sets the departures aside; the epoch, departures included, is never perfectly flat.

Mr. Landry's observation is that the turn and the flatness of the whole epoch are two global constraints, and that they stand in a reciprocal relation. The books support one link between them. The turn is the greatest compression, and it falls short of a pure singularity by the least amount the theorem allows; what that shortfall leaves is the departures, the old distinctions averaged. The epoch, taken as a whole, falls short of a perfected flatness by its

curvature, and that curvature is the departures, at their own size. One residue measures both: the departures that survive the turn because it is not a perfect singularity are the same departures that are the only curvature the epoch has.

He adds a caution about the word "moment". The turn is not an event in time, and neither is the flatness of the epoch as a whole. The book says of the first: "The turn is a limit, and no comparison registers it as an event; the history of each epoch, reconstructed from inside, finds the turn as its Big Bang" (Chapter 18, Section XII, Figure 4). And the prediction speaks of the curvature "measured within one horizon", since no comparison takes in the whole epoch at once. In his words, each is "the concept or idea of a 'time' projected in a way in/with/for which we can conceptually sort of make it make sense, but which in any actual basis is inherently undefined and undefinable": both are transcendent concepts out of which the notion of time emerges, and "the basis of the thing is not the thing". That is, the turn and the epoch as a whole are ideas of a time that no comparison registers as an event.

The observation raises questions that the books do not yet take up.

- Is the size of the departures fixed by this reciprocal relation? The sealed record states that it is not fixed now: "The amplitude of the primordial departures and the sign of their tilt are not fixed". If the least shortfall of the turn from a pure singularity and the least shortfall of the epoch from a perfected flatness are one quantity, what sets its size?
- Do the two constraints meet as one quantity, or as a pair whose product the theorem bounds, the way it pairs symmetry and continuity?
- If both are transcendent concepts out of which time emerges, what is the "center" of the epoch, the opposite of the turn, in terms a comparison could reach? Is it where the reconstructed history comes nearest to the homogeneous model, at the greatest extent of the expansion that any comparison of the epoch registers?

VII. What Others Have Argued

Gibbons and Turok (2008) studied the natural measure on the space of homogeneous cosmologies, the measure of Gibbons, Hawking and Stewart. They traced a divergence of that measure at zero curvature to the "dilatation invariance of flat FRW universes", and removed it by identifying universes "so flat they cannot be observationally distinguished". Carroll and Tam (2010) drew the conclusion directly: "curved RW cosmologies are a set of measure zero", and so "the flatness problem, as conventionally understood, does not exist". Their route is a route of typicality: flat histories are almost all of them. It reaches the same conclusion as this essay by a different road, and it is credited here as convergent support.

McCoy (2017) disputes that route: the physicists who use it, he argues, misread what typicality means in that space of histories, and "no conclusion can be drawn at all about the flatness problem by using the canonical measure alone". The argument of this essay does not rest on the measure. It rests on what the state at the restoration holds, so McCoy's objection to the measure does not reach it, and the measure's support, where it holds, is added support.

VIII. Where the Books Carry the Argument

The passages that state flatness, with their present sentences, are these.

- The Gravitational Passage, Chapter 18, Section IX, "Spatial flatness": "The lengths left are those of the turn, of the order of the Planck length, and the de Sitter radius that the reconstructed history carries".
- The Gravitational Passage, Chapter 18, Questions: "no length of the old epoch passes the turn, and the lengths that remain give a flat homogeneous model (Section IX)".
- The Gravitational Passage, Chapter 13, Section III: "for a spatially flat universe, which the restoration of Chapter 18, Section IX, gives".
- The Compactification, Chapter 6, Section VI: "The lengths left to set a curvature are the two that the new epoch has of its own: the length of the turn, of the order of the Planck length, and the de Sitter radius that the reconstructed history carries, the radius of the horizon of a uni-

verse of vacuum energy alone". Its Chapter 1, Section VIII gives the short form: "space is flat because no length of the old epoch passes the turn".

- At the Edge of Reality, Chapter 19, "Why Space Is Flat": "So the only lengths left to set a curvature are the two of the new epoch: the length of the turn and the de Sitter radius".
- What the Beginning Left Behind, Chapter 12, "Flat Space": "The lengths left to set a curvature are the two that the new epoch has of its own". The same passage says "The argument for flatness uses only that the cosmological constant is positive, so that the new epoch has a de Sitter radius at all; it does not use the constant's value".

IX. Summary

The new epoch is flat because the state that the restoration sets holds nothing from which a radius of curvature could be made, except a length the cycle excludes. The curvature is a constant of integration, so it is set with the state. No length and no count of the old epoch pass the turn, the cosmological constant and every other constant of the law belong to the law and not to the state, and the cosmological constant does not act at the turn, so the state holds the length of the turn and only pure numbers of order one. A radius built from the length of the turn and the de Sitter radius together, which would leave a curvature of a part in a thousand, has neither the de Sitter radius nor a number near 10^{30} to be built from. A radius of the turn's own length would leave an epoch without structure, which the cycle excludes. So the homogeneous model is flat, and the epoch is curved only by its departures, at their own size, about one part in a hundred thousand, at the floor of what any measurement can reach. The argument uses neither the value nor the sign of the cosmological constant, only that the constant belongs to the law. One premise, that the new geometry has no prior identity, gives both the Weyl curvature hypothesis and the flatness of space. The departures that the turn leaves because it is not a perfect singularity are the same departures that are the epoch's only curvature, which is the reciprocal relation between the turn and the whole that Forrest Landry observed.

Key Concepts

- Exact flatness is settled by argument: the departures from uniformity set a floor of about 1.5×10^{-5} on any measurement of the curvature share.
- The spatial curvature is a constant of integration, part of the state that the restoration sets.
- The state holds one length, the length of the turn, and only pure numbers of order one: no length and no count of the old epoch pass the turn, the constants of the law belong to the law and not to the state, and the cosmological constant does not act there.
- A radius built from both lengths would leave a curvature of about 10^{-3}, and it has nothing in the state to be built from.
- The cycle excludes a radius of the length of the turn; the result rests on that step.
- One premise, no prior identity, gives the Weyl curvature hypothesis and spatial flatness.
- One residue, the departures, measures both how far the turn falls short of a pure singularity and how far the epoch falls short of a perfected flatness.

Terms

Constant of integration. A constant that a law leaves free and that the state from which a history begins sets once; in Friedmann's equation, the constant that carries the curvature of space.

Constant of the law. A constant that a law fixes once, such as the cosmological constant or the mass of a kind of particle; it belongs to the law and not to the state, and no constant of the law passes into the state at the turn.

Cosmological constant (Λ). The constant term of the law of the geometry, fixed once by the present measurement; it sets the energy of empty space and the de Sitter radius, and at the turn it acts as nothing at all.

Curvature share. The part of the expansion of space that its curvature accounts for, as a share of the energy of a flat universe; zero for a flat space.

Cycle. The account's identification of black hole collapse and cosmological origin as one transition approached from its two sides, so that each epoch's structure makes the black holes whose common end is the next turn.

De Sitter radius. The radius of the horizon of a universe that holds only the energy of empty space, set by the cosmological constant; about 10^{61} Planck lengths.

Departures from uniformity. The small differences of density from place to place in the early epoch, about one part in a hundred thousand, identified by the account with the old distinctions carried through the turn, averaged.

Friedmann's equation. The equation of general relativity for the expansion of a homogeneous space, in which the square of the rate of expansion is the sum of terms from the density of the content, the cosmological constant and the curvature of space.

Geometric mean. Of two lengths, the square root of their product; the length halfway between them in powers of ten.

Homogeneous model. The model of an epoch in which every place is like every other, with the departures set aside.

Incommensuration Theorem. The structural fact about the nature of knowing that symmetry and continuity are not both perfect in any comparison.

Length of the turn. The length at which the turn occurs, of the order of the Planck length.

No prior identity. The premise that the geometry of the new epoch inherits no shape, no length and no record from the old exterior.

Reset. The account's answer to Tolman: no count, of the matter or of the geometry, is carried across the turn, since each count is relative to the context that ends.

Restoration of context. The account's identification of the beginning of an epoch: at the common end of the interiors, the internal space de-compactifies and the exterior context re-forms.

Turn. The passage from the end of one epoch of the universe to the beginning of the next, at the end of every black-hole interior; it is a limit that no comparison registers as an event, the common end of the interiors of the black holes of one epoch and the beginning of the next.

Weyl curvature hypothesis. Penrose's proposal that the Weyl curvature, the part of the curvature that carries shape without volume, is zero at the beginning of the universe.

References

Abdul-Karim, M. and others (DESI Collaboration) (2025). "DESI DR2 Results II: Measurements of Baryon Acoustic Oscillations and Cosmological Constraints". Physical Review D 112, 083515. arXiv:2503.14738.

Aghanim, N. and others (Planck Collaboration) (2020). "Planck 2018 Results. VI. Cosmological Parameters". Astronomy and Astrophysics 641, A6. arXiv:1807.06209. doi:10.1051/0004-6361/201833910.

Carroll, S. M. and Tam, H. (2010). "Unitary Evolution and Cosmological Fine-Tuning". arXiv:1007.1417.

Chen, S.-F. and Zaldarriaga, M. (2025). "It's All Ok: Curvature in Light of BAO from DESI DR2". arXiv:2505.00659.

Gibbons, G. W. and Turok, N. (2008). "The Measure Problem in Cosmology". Physical Review D 77, 063516. arXiv:hep-th/0609095. doi:10.1103/PhysRevD.77.063516.

Landry, Forrest. An Immanent Metaphysics. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest (2026). At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions. Wytheville, Virginia: UVSM Publications. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest (2026). The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Background. Wytheville, Virginia: UVSM Publications. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest (2026). The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics. Wytheville, Virginia: UVSM Publications. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest (2026). The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026. Wytheville, Virginia: UVSM Publications. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest (2026). What the Beginning Left Behind. Wytheville, Virginia: UVSM Publications. DOI: https://doi.org/10.67291/DAQV7169.

McCoy, C. D. (2017). "Can Typicality Arguments Dissolve Cosmology's Flatness Problem?". Philosophy of Science 84(5).

Misner, C. W., Thorne, K. S. and Wheeler, J. A. (1973). Gravitation. San Francisco: W. H. Freeman.

Penrose, R. (1979). "Singularities and Time-Asymmetry". In General Relativity: An Einstein Centenary Survey, edited by S. W. Hawking and W. Israel, 581 to 638. Cambridge: Cambridge University Press.

Tolman, R. C. (1934). Relativity, Thermodynamics and Cosmology. Oxford: Clarendon Press.

Waterhouse, T. P. and Zibin, J. P. (2008). "The Cosmic Variance of Omega". arXiv:0804.1771.



Bibliography

Every work cited in the chapters and registers of this volume, listed once. The registers cite the chapters of the two volumes as relation essays; each chapter is found in the Contents of its volume, and a measurement that a register cites as the sealed record cites it is found in the sealed record.

Aaronson, S. (2014). "Why I am not an integrated information theorist (or, the unconscious expander)". *Shtetl-Optimized* (blog), 21 May 2014.

Abbott, B. P. and others, LIGO Scientific Collaboration and Virgo Collaboration (2016). "Observation of gravitational waves from a binary black hole merger". *Physical Review Letters* 116(6), 061102. DOI 10.1103/PhysRevLett.116.061102.

Abdo, A. A. and others (Fermi LAT and GBM Collaborations) (2009). "A limit on the variation of the speed of light arising from quantum gravity effects". *Nature* 462, 331–334.

Abdul-Karim, M. and others (DESI Collaboration) (2025). "DESI DR2 Results II: Measurements of Baryon Acoustic Oscillations and Cosmological Constraints". Physical Review D 112, 083515. arXiv:2503.14738.

Ade, P. and others (Simons Observatory Collaboration) (2019). "The Simons Observatory: science goals and forecasts". *Journal of Cosmology and Astroparticle Physics* 2019(02), 056. arXiv:1808.07445.

Aghanim, N. and others, Planck Collaboration (2020). "Planck 2018 results. VI. Cosmological parameters". *Astronomy and Astrophysics* 641, A6. doi: 10.1051/0004-6361/201833910. arXiv:1807.06209. The values used here are from Table 2, column TT,TE,EE+lowE+lensing.

Aguirre, A. and Tegmark, M. (2011). "Born in an infinite universe: a cosmological interpretation of quantum mechanics". *Physical Review D* 84, 105002. arXiv: 1008.1066.

Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A. M., Marshall, W., Mayner, W. G. P., Zaeemzadeh, A., Boly, M., Juel, B. E., Sasai, S., Fujii, K., David, I., Hendren, J., Lang, J. P. and Tononi, G. (2023). "Integrated information theory (IIT) 4.0: Formulating the properties of phenomenal existence in physical terms". *PLOS Computational Biology* 19, e1011465.

Albert, D. Z. (2000). *Time and Chance*. Cambridge, Massachusetts: Harvard University Press.

Amelino-Camelia, G. and Smolin, L. (2009). "Prospects for constraining quantum gravity dispersion with near term observations". *Physical Review D* 80, 084017. arXiv:0906.3731.

Amir, A., Lemeshko, M. and Tokieda, T. (2016). "Surprises in numerical expressions of physical constants". arXiv:1603.00299.

Angelopoulos, A., and others (CPLEAR Collaboration) (1998). "First direct observation of time-reversal non-invariance in the neutral-kaon system". *Physics Letters B* 444, 43.

Arnowitt, R., Deser, S. and Misner, C. W. (1959). "Dynamical structure and definition of energy in general relativity". *Physical Review* 116, 1322–1330.

Arute, F. and others (2019). "Quantum supremacy using a programmable superconducting processor". *Nature* 574, 505–510.

Banik, I., Pittordis, C., Sutherland, W., Famaey, B., Ibata, R., Mieske, S. and Zhao, H. (2024). "Strong constraints on the gravitational law from Gaia DR3 wide binaries". *Monthly Notices of the Royal Astronomical Society* 527, 4573–4615. arXiv: 2311.03436.

Barbour, J. (1999). *The End of Time: The Next Revolution in Our Understanding of the Universe*. London: Weidenfeld and Nicolson; Oxford: Oxford University Press.

Barbour, J. (2015). "Bit from It". In A. Aguirre, B. Foster and Z. Merali (eds.), *It From Bit or Bit From It? On Physics and Information*, 197–211. Cham: Springer. DOI 10.1007/978-3-319-12946-4_17.

Barbour, J. (2020). *The Janus Point: A New Theory of Time*. New York: Basic Books; London: The Bodley Head.

Barbour, J. and Bertotti, B. (1982). "Mach's principle and the structure of dynamical theories". *Proceedings of the Royal Society of London A* 382, 295–306.

Barbour, J. B. (1994). "The timelessness of quantum gravity: II. The appearance of dynamics in static configurations". *Classical and Quantum Gravity* 11(12), 2875–2897. DOI 10.1088/0264-9381/11/12/006.

Barbour, J., Foster, B. Z. and Ó Murchadha, N. (2002). "Relativity without relativity". *Classical and Quantum Gravity* 19, 3217. DOI 10.1088/0264-9381/19/12/308. arXiv:gr-qc/0012089.

Barbour, J., Koslowski, T. and Mercati, F. (2014). "Identification of a gravitational arrow of time". *Physical Review Letters* 113, 181101. arXiv:1409.0917.

Barbour, J., Lobo, F. S. N. and Lourenço, M. I. R. (2026). "Structural morphology and the gravitational arrow of time". arXiv:2607.27526.

Bardeen, J. M. (1980). "Gauge-invariant cosmological perturbations". *Physical Review D* 22(8), 1882–1905. DOI 10.1103/PhysRevD.22.1882.

Bateson, G. (1972). *Steps to an Ecology of Mind*. New York: Ballantine.

Beggs, J. M. and Plenz, D. (2003). "Neuronal avalanches in neocortical circuits". *Journal of Neuroscience* 23, no. 35, 11167–11177.

Bekenstein, J. and Milgrom, M. (1984). "Does the missing mass problem signal the breakdown of Newtonian gravity?". *The Astrophysical Journal* 286, 7. doi: 10.1086/162570.

Bekenstein, J. D. (2004). "Relativistic gravitation theory for the modified Newtonian dynamics paradigm". *Physical Review D* 70, 083509.

Bell, J. S. (1981). "Quantum mechanics for cosmologists". In C. J. Isham, R. Penrose and D. W. Sciama (eds.), *Quantum Gravity 2: A Second Oxford Symposium*. Oxford: Clarendon Press.

Bennett, C. H. (1973). "Logical reversibility of computation". *IBM Journal of Research and Development* 17, 525–532.

BICEP2/Keck and Planck Collaborations (2015). "Joint analysis of BICEP2/Keck Array and Planck data". *Physical Review Letters* 114, 101301.

Bishop, R. C. (2003). "Brussels-Austin nonequilibrium statistical mechanics in the later years: large Poincaré systems and rigged Hilbert space". arXiv:physics/0304020.

Bohr, N. and Wheeler, J. A. (1939). "The mechanism of nuclear fission". *Physical Review* 56, 426–450.

Bombelli, L., Henson, J. and Sorkin, R. D. (2009). "Discreteness without symmetry breaking: a theorem". *Modern Physics Letters A* 24, 2579–2587.

Boran, S., Desai, S., Kahya, E. O. and Woodard, R. P. (2018). “GW170817 falsifies dark matter emulators”. *Physical Review D* 97, 041501. arXiv:1710.06168.

Borukhovetskaya, A., Navarro, J. F., Errani, R. and Fattahi, A. (2022). “Galactic tides and the Crater II dwarf spheroidal: a challenge to LCDM?”. *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stac653. arXiv:2112.01540.

Bose, S., Mazumdar, A., Morley, G. W., Ulbricht, H., Toroš, M., Paternostro, M., Geraci, A. A., Barker, P. F., Kim, M. S. and Milburn, G. (2017). “Spin entanglement witness for quantum gravity”. *Physical Review Letters* 119 (24), 240401. doi:10.1103/PhysRevLett.119.240401.

Bricmont, J. (1996). “Science of chaos or chaos in science?”. arXiv:chao-dyn/9603009.

Brouwer, M. M., Oman, K. A., Valentijn, E. A., Bilicki, M., Heymans, C., Hoekstra, H., Napolitano, N. R., Roy, N., Tortora, C., Wright, A. H. and 15 others (2021). “The weak lensing radial acceleration relation: constraining modified gravity and cold dark matter theories with KiDS-1000”. *Astronomy and Astrophysics* 650, A113. doi:10.1051/0004-6361/202040108.

Brouwer, M. M., Visser, M. R., Dvornik, A., Hoekstra, H. and others (2017). “First test of Verlinde’s theory of Emergent Gravity using Weak Gravitational Lensing measurements”. *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stw3192. arXiv:1612.03034.

Bruineberg, J., Dołęga, K., Dewhurst, J. and Baltieri, M. (2022). “The Emperor’s New Markov Blankets”. *Behavioral and Brain Sciences* 45, e183. doi:10.1017/S0140525X21002351.

Buchert, T., Carfora, M., Ellis, G. F. R., Kolb, E. W., MacCallum, M. A. H., Ostrowski, J. J., Räsänen, S., Roukema, B. F., Andersson, L., Coley, A. A. and Wiltshire, D. L. (2015). “Is there proof that backreaction of inhomogeneities is irrelevant in cosmology?”. *Classical and Quantum Gravity* 32 (21), 215021. doi:10.1088/0264-9381/32/21/215021. arXiv:1505.07800.

Caldwell, N. and others (2017). “Crater 2: an extremely cold dark matter halo”. *The Astrophysical Journal* 839, 20. doi:10.3847/1538-4357/aa688e.

Camphuis, E. and others (2026). Cited as the sealed record of 1 November 2026 cites it.

Cao, Z. and others (LHAASO Collaboration) (2024). "Stringent tests of Lorentz invariance violation from LHAASO observations of GRB 221009A". *Physical Review Letters* 133, 071501.

Carlip, S. (2022). "Spacetime foam: a review". arXiv:2209.14282. Published in *Reports on Progress in Physics* 86 (2023), 066001.

Carroll, S. M. and Tam, H. (2010). "Unitary Evolution and Cosmological Fine-Tuning". arXiv:1007.1417.

Casali, A. G., Gosseries, O., Rosanova, M., Boly, M., Sarasso, S., Casali, K. R., Casarotto, S., Bruno, M.-A., Laureys, S., Tononi, G. and Massimini, M. (2013). "A theoretically based index of consciousness independent of sensory processing and behavior". *Science Translational Medicine* 5, 198ra105. DOI: 10.1126/scitranslmed.3006294.

Chae, K.-H. (2024). "Breakdown of the Newton–Einstein standard gravity at low acceleration in internal dynamics of wide binary stars". *The Astrophysical Journal* 960, 114.

Chae, K.-H., Lelli, F., Desmond, H., McGaugh, S. S., Li, P. and Schombert, J. M. (2020). "Testing the strong equivalence principle: detection of the external field effect in rotationally supported galaxies". *The Astrophysical Journal* 904(1), 51. DOI 10.3847/1538-4357/abbb96. arXiv:2009.11525.

Chae, K.-H., Lee, B.-C., Hernandez, X., Orlov, V. G., Lim, D., Turnshek, D. A. and Lee, Y.-W. (2026). "Detection of gravitational anomaly at low acceleration from a highest-quality sample of 36 wide binaries with accurate 3D velocities". arXiv: 2601.21728.

Chandrasekhar, S. (1931). "The maximum mass of ideal white dwarfs". *The Astrophysical Journal* 74, 81–82.

Chen, S.-F. and Zaldarriaga, M. (2025). "It's All Ok: Curvature in Light of BAO from DESI DR2". arXiv:2505.00659.

Christenson, J. H., Cronin, J. W., Fitch, V. L. and Turlay, R. (1964). "Evidence for the 2π decay of the K_2^0 meson". *Physical Review Letters* 13, 138.

Chu, D. and Ho, W. K. (2006). "A category theoretical argument against the possibility of artificial life: Robert Rosen's central proof revisited". *Artificial Life* 12(1), 117 to 135. DOI: 10.1162/106454606775186392.

Chu, D. and Ho, W. K. (2007). “The localization hypothesis and machines”. *Artificial Life* 13(3), 299 to 302.

Clowe, D., Bradač, M., Gonzalez, A. H., Markevitch, M., Randall, S. W., Jones, C. and Zaritsky, D. (2006). “A direct empirical proof of the existence of dark matter”. *The Astrophysical Journal* 648, L109–L113.

Cogitate Consortium, Ferrante, O. and others (2025). “Adversarial testing of global neuronal workspace and integrated information theories of consciousness”. *Nature*, published 30 April 2025. DOI: 10.1038/s41586-025-08888-1.

Cortês, M. and Smolin, L. (2014). “The universe as a process of unique events”. *Physical Review D* 90, 084007. arXiv:1307.6167.

Day, C. (2005). “Crushing a solution of left-handed and right-handed crystals breaks its chiral symmetry”. *Physics Today*, 1 April 2005.

de Swart, J. (2019). “Closing in on the Cosmos: Cosmology’s Rebirth and the Rise of the Dark Matter Problem”. arXiv:1903.05281.

Del Popolo, A. and Chan, M. H. (2025). “Flat circular velocities on a megaparsec scale from the ΛCDM model”. arXiv:2504.12662.

DESI Collaboration (2025). “DESI DR2 Results II: Measurements of Baryon Acoustic Oscillations and Cosmological Constraints”. arXiv:2503.14738.

DeWitt, B. S. (1967). “Quantum theory of gravity. I. The canonical theory”. *Physical Review* 160, 1113–1148.

Di Valentino, E., Melchiorri, A. and Silk, J. (2019). “Planck evidence for a closed Universe and a possible crisis for cosmology”. *Nature Astronomy*. DOI 10.1038/s41550-019-0906-9. arXiv:1911.02087.

Di Valentino, E., Melchiorri, A. and Silk, J. (2020). “Planck evidence for a closed Universe and a possible crisis for cosmology”. *Nature Astronomy* 4, 196–203.

Dieks, D., van Dongen, J. and de Haro, S. (2015). “Emergence in holographic scenarios for gravity”. *Studies in History and Philosophy of Modern Physics* 52, 203–216.

Dirac, P. A. M. (1958). “The theory of gravitation in Hamiltonian form”. *Proceedings of the Royal Society of London A* 246, 333–343.

Dittrich, B. and Thiemann, T. (2009). “Are the spectra of geometrical operators in loop quantum gravity really discrete?”. *Journal of Mathematical Physics* 50, 012503. arXiv:0708.1721.

Drossel, B. and Ellis, G. F. R. (2018). “Contextual wavefunction collapse: an integrated theory of quantum measurement”. *New Journal of Physics* 20, 113025. arXiv: 1807.08171.

Dutton, A. A., Macciò, A. V., Obreja, A. and Buck, T. (2019). “NIHAO XVIII. Origin of the MOND phenomenology of galactic rotation curves in a ΛCDM universe”. *Monthly Notices of the Royal Astronomical Society* 485 (2), 1886–1899. doi:10.1093/mnras/stz531. arXiv:1902.06751.

Dutton, A. A., Macciò, A. V., Obreja, A. and Buck, T. (2019). “NIHAO XVIII: Origin of the MOND phenomenology of galactic rotation curves in a LCDM universe”. *Monthly Notices of the Royal Astronomical Society* 485 (2), 1886–1899. doi:10.1093/mnras/stz531. arXiv:1902.06751.

Dyson, F. W., Eddington, A. S. and Davidson, C. (1920). “A determination of the deflection of light by the Sun’s gravitational field, from observations made at the total eclipse of May 29, 1919”. *Philosophical Transactions of the Royal Society of London A* 220, 291–333.

Eddington, A. S. (1926). *The Internal Constitution of the Stars*. Cambridge: Cambridge University Press.

Eddington, A. S. (1929). “The charge of an electron”. *Proceedings of the Royal Society of London A* 122, 358–369.

Eddington, A. S. (1930). “On the instability of Einstein’s spherical world”. *Monthly Notices of the Royal Astronomical Society* 90, 668–678.

Eddington, A. S. (1933). *The Expanding Universe*. Cambridge: Cambridge University Press.

Eddington, A. S. (1935a). Reply to Chandrasekhar at the meeting of the Royal Astronomical Society of Friday 11 January 1935, printed in the report of the meeting, *The Observatory* 58, 37–39; cited by Harwit (2013) as “Response to Chandrasekhar”. The sentence “I think there should be a law of Nature to prevent a star from behaving in this absurd way!” is given here in the wording of the accounts cited; one account, by Kameshwar Wali, gives “absurd manner”.

Eddington, A. S. (1935b). “On ‘Relativistic Degeneracy’”. *Monthly Notices of the Royal Astronomical Society* 95, 194–206. A separate paper from the report of the meeting; the “law of Nature” sentence is not in it.

Eddington, A. S. (1936). *Relativity Theory of Protons and Electrons*. Cambridge: Cambridge University Press.

Eddington, A. S. (1939). *The Philosophy of Physical Science*. Cambridge: Cambridge University Press.

Eddington, A. S. (1946). *Fundamental Theory*. Edited by E. T. Whittaker. Cambridge: Cambridge University Press.

Ellis, G. F. R. (2006). "Issues in the philosophy of cosmology". arXiv:astro-ph/0602280.

Ellis, G. F. R. (2006b). "Physics in the real universe: time and spacetime". *General Relativity and Gravitation* 38, 1797–1824. arXiv:gr-qc/0605049.

Ellis, G. F. R. (2011). "Inhomogeneity effects in cosmology". *Classical and Quantum Gravity* 28, 164001. arXiv:1103.2335.

Ellis, G. F. R. (2012). "Top-down causation and emergence: some comments on mechanisms". *Interface Focus* 2, 126–140.

Ellis, G. F. R. (2013). "The arrow of time and the nature of spacetime". arXiv:1302.7291.

Ellis, G. F. R. (2013b). "Astrophysical black holes may radiate, but they do not evaporate". arXiv:1310.4771.

Ellis, G. F. R. (2016). *How Can Physics Underlie the Mind? Top-Down Causation in the Human Context*. Berlin: Springer.

Ellis, G. F. R. and Drossel, B. (2020). "Emergence of time". arXiv:1911.04772.

Ellis, G. F. R. and Maartens, R. (2004). "The emergent universe: inflationary cosmology with no singularity". *Classical and Quantum Gravity* 21. DOI 10.1088/0264-9381/21/1/015. arXiv:gr-qc/0211082.

Ellis, G. F. R. and MacCallum, M. A. H. (1969). "A class of homogeneous cosmological models". *Communications in Mathematical Physics* 12, 108–141.

Ellis, G. F. R. and Rothman, T. (2010). "Time and spacetime: the crystallizing block universe". *International Journal of Theoretical Physics* 49, 988–1003. doi:10.1007/s10773-010-0278-5. arXiv:0912.0808.

Ellis, G. F. R. and Silk, J. (2014). "Scientific method: Defend the integrity of physics". *Nature* 516, 321–323.

Everett, H. (1957). "'Relative state' formulation of quantum mechanics". *Reviews of Modern Physics* 29, 454–462.

Famaey, B. and McGaugh, S. S. (2012). "Modified Newtonian dynamics (MOND): observational phenomenology and relativistic extensions". *Living Reviews in Relativity* 15, 10.

Famaey, B., Pizzuti, L. and Saltas, I. D. (2025). "Nature of the missing mass of galaxy clusters in MOND: the view from gravitational lensing". *Physical Review D* 111, 123042.

Fleming, S. M. and others (2023). "The integrated information theory of consciousness as pseudoscience". PsyArXiv, zsr78.

Fonseca, E., Cromartie, H. T., Pennucci, T. T., Ray, P. S. and others (2021). "Refined mass and geometric measurements of the high-mass PSR J0740+6620". *The Astrophysical Journal Letters* 915, L12. arXiv:2104.00880.

Friston, K. (2010). "The free-energy principle: a unified brain theory?". *Nature Reviews Neuroscience* 11, 127 to 138.

Friston, K. (2019). "A free energy principle for a particular physics". arXiv: 1906.10184. https://arxiv.org/abs/1906.10184.

Friston, K., Da Costa, L., Sajid, N., Heins, C., Ueltzhöffer, K., Pavliotis, G. A. and Parr, T. (2023). "The free energy principle made simpler but not too simple". *Physics Reports* 1024, 1 to 29. arXiv:2201.06387.

Friston, K., Kilner, J. and Harrison, L. (2006). "A free energy principle for the brain". *Journal of Physiology, Paris* 100, 70 to 87.

Ghigna, T. and others (LiteBIRD Collaboration) (2024). "The LiteBIRD mission to explore cosmic inflation". arXiv:2406.02724.

Gibbons, G. W. and Turok, N. (2008). "The Measure Problem in Cosmology". Physical Review D 77, 063516. arXiv:hep-th/0609095. doi:10.1103/PhysRevD.77.063516.

Giulini, D. (2009). "The Superspace of Geometrodynamics". *General Relativity and Gravitation* 41(4), 785–815. DOI 10.1007/s10714-009-0771-4. arXiv:0902.3923.

Goff, P. (2023). "Consciousness: why a leading theory has been branded 'pseudoscience'". *The Conversation*, 2 October 2023.

Gomes, H. (2014). "A Birkhoff theorem for shape dynamics". *Classical and Quantum Gravity* 31, 085008. DOI 10.1088/0264-9381/31/8/085008. arXiv:1305.0310.

Gomes, H., Gryb, S. and Koslowski, T. (2011). "Einstein gravity as a 3D conformally invariant theory". *Classical and Quantum Gravity* 28, 045005.

Gorard, J. (2020a). "Some Relativistic and Gravitational Properties of the Wolfram Model". *Complex Systems* 29(2), 599. arXiv:2004.14810.

Gorard, J. (2020b). "Some Quantum Mechanical Properties of the Wolfram Model". *Complex Systems* 29(2), 537–598.

Green, S. R. and Wald, R. M. (2011), as cited in The Quantum Bridge, Chapter 8, Section IV.

Green, S. R. and Wald, R. M. (2011). "New framework for analyzing the effects of small scale inhomogeneities in cosmology". *Physical Review D* 83 (8), 084020. doi: 10.1103/PhysRevD.83.084020. arXiv:1011.4920.

Green, S. R. and Wald, R. M. (2015). "Comments on Backreaction". arXiv:1506.06452 (preprint; no journal publication found).

Hameroff, S. and Penrose, R. (1996). "Orchestrated reduction of quantum coherence in brain microtubules: a model for consciousness". *Mathematics and Computers in Simulation* 40, 453–480.

Harwit, M. (2013). *In Search of the True Universe; The Tools, Shaping, and Cost of Cosmological Thought*. Cambridge: Cambridge University Press. Chapter 5, "Conclusions Based on Calculations", pages 76–96, and its reference list.

Hawking, S. W. and Ellis, G. F. R. (1973). *The Large Scale Structure of Space-Time*. Cambridge: Cambridge University Press.

Hossenfelder, S. (2010). "Bounds on an energy-dependent and observer-independent speed of light from violations of locality". *Physical Review Letters* 104, 140402. arXiv:1004.0418.

Hossenfelder, S. (2014). "The soccer-ball problem". *Symmetry, Integrability and Geometry: Methods and Applications* 10, 074. arXiv:1403.2080.

Hubble, E. (1929). "A relation between distance and radial velocity among extragalactic nebulae". *Proceedings of the National Academy of Sciences* 15(3), 168–173. DOI 10.1073/pnas.15.3.168.

Indian Institute of Astrophysics. "The Legacy of S. Chandrasekhar (1910 to 1995)". iiap.res.in, accessed 4 November 2026.

Isham, C. J. (1993). "Canonical quantum gravity and the problem of time". In L. A. Ibort and M. A. Rodríguez (eds.), *Integrable Systems, Quantum Groups, and Quantum Field Theories*, 157–287. Dordrecht: Kluwer.

Jacobson, T. (1995). "Thermodynamics of spacetime: the Einstein equation of state". *Physical Review Letters* 75, 1260–1263.

Jacques, V., Wu, E., Grosshans, F., Treussart, F., Grangier, P., Aspect, A. and Roch, J.-F. (2007). "Experimental realization of Wheeler's delayed-choice gedanken experiment". *Science* 315, 966–968.

Keller, B. W. and Wadsley, J. W. (2017). "ΛCDM is Consistent with SPARC Radial Acceleration Relation". *The Astrophysical Journal Letters* 835(1), L17. DOI 10.3847/2041-8213/835/1/L17. arXiv:1610.06183.

Kim, H. and Lee, U. (2019). "Criticality as a determinant of integrated information Φ in human brain networks". *Entropy* 21, no. 10, 981. DOI: 10.3390/e21100981.

Kobakhidze, A. (2011). "Gravity is not an entropic force". *Physical Review D* 83, 021502.

Koch, C., Massimini, M., Boly, M. and Tononi, G. (2016). "Neural correlates of consciousness: progress and problems". *Nature Reviews Neuroscience* 17, 307–321. DOI: 10.1038/nrn.2016.22.

Kondepudi, D. K., Kaufman, R. J. and Singh, N. (1990). "Chiral symmetry breaking in sodium chlorate crystallization". *Science* 250, 975–976. DOI: 10.1126/science.250.4983.975.

Koslowski, T. A., Mercati, F. and Sloan, D. (2018). "Through the big bang". *Physics Letters B* 778. DOI 10.1016/j.physletb.2018.01.055. arXiv:1607.02460.

Kragh, H. (2011). "Visions of revolutions: microphysics and cosmophysics in the 1930s". arXiv:1111.6163.

Kragh, H. (2015). "On Arthur Eddington's theory of everything". arXiv:1510.04046.

Kroupa, P., Banik, I., Haghi, H., Zonoozi, A. H., Dabringhausen, J., Javanmardi, B., Müller, O., Wu, X., Zhao, H. and others (2018). "A common Milgromian acceleration scale in nature". *Nature Astronomy* 2, 925–926. doi:10.1038/s41550-018-0622-x.

Landauer, R. (1961). "Irreversibility and heat generation in the computing process". *IBM Journal of Research and Development* 5, 183–191.

Landry, Forrest (2026). At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions. Wytheville, Virginia: UVSM Publications. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest (2026). *Peirce and the Immanent Metaphysics; The Nearest Kin*. Wytheville, Virginia: UVSM Publications.

Landry, Forrest (2026). The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Background. Wytheville, Virginia: UVSM Publications. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest (2026). The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics. Wytheville, Virginia: UVSM Publications. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest (2026). The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026. Wytheville, Virginia: UVSM Publications. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest (2026). What the Beginning Left Behind. Wytheville, Virginia: UVSM Publications. DOI: https://doi.org/10.67291/DAQV7169.

Landry, Forrest. *An Immanent Metaphysics*. First published 2001. Wytheville, Virginia: UVSM Publications. ISBN 979-8-9896628-4-5. Cited by aphorism number.

Landry, Forrest. *At the Edge of Reality; From Black Holes to the Big Bang in Ten Dimensions*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-058-9. DOI: https://doi.org/10.67291/BWNG7504.

Landry, Forrest. *Causality Without Determinism; Free Will, Measurement and Mind*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-075-6. DOI: https://doi.org/10.67291/FVTH8832.

Landry, Forrest. *Comparison, the Necessary Basis*; *Physics Is Not Math*; *The Matter We Know*, Volumes One and Two; *Why These Numbers*; *The Compactification*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Comparison; The Necessary Basis*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-062-6. DOI: https://doi.org/10.67291/MOAS1658.

Landry, Forrest. *Home in the World; The Immanent Metaphysics for Readers of Carlo Rovelli*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-069-5.

Landry, Forrest. *Incommensuration; The Theorem and the Three Axioms*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-063-3. DOI: https://doi.org/10.67291/ARTV2404.

Landry, Forrest. *Measurement; The Steps from Comparison to Physics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-064-0. DOI: https://doi.org/10.67291/VZSP1393.

Landry, Forrest. *Objections from Physics, Answered; The Identifications of Physics from Comparison, Step by Step*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/UEEI5258.

Landry, Forrest. *Physics Is Not Math; Metaphysics, Physics, Computation and Mathematics, and Why Their Order Cannot Be Otherwise*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-070-1. DOI: https://doi.org/10.67291/LKMT1000.

Landry, Forrest. *The Basis of Physics; Nineteen Essays on the Structural Limits of Physical Law*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-072-5. DOI: https://doi.org/10.67291/WHOM6253.

Landry, Forrest. *The Branches of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-077-0. DOI: https://doi.org/10.67291/DOYL4735.

Landry, Forrest. *The Coming of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-078-7. DOI: https://doi.org/10.67291/CIJI9065.

Landry, Forrest. *The Compactification; Initial Conditions, the Perturbation Spectrum, and the Gravitational Wave Signature*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-112-8. DOI: https://doi.org/10.67291/NSYP6219.

Landry, Forrest. *The Concept Branches*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Gravitational Companion; Extensions, Comparisons and Open Questions for The Gravitational Passage*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-057-2. DOI: https://doi.org/10.67291/LJOZ4364.

Landry, Forrest. *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-056-5. DOI: https://doi.org/10.67291/FPCR7748.

Landry, Forrest. *The Ground of Objection; Where Prior Philosophy Meets the Immanent Metaphysics*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-9896628-8-3.

Landry, Forrest. *The Immanent Metaphysics and the Modern Engagement; From Husserl to Wilber*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-175-3.

Landry, Forrest. *The Kinds of Particle*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-060-2. DOI: https://doi.org/10.67291/CEUK2585.

Landry, Forrest. *The Last Turtle; Essays from Comparison and the Incommensuration Theorem to Causation, the Arena and the Limits of Computation*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-215-6.

Landry, Forrest. *The Quantum Bridge; Entanglement, Error Correction, and the Limits of Simulation*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-107-4. DOI: https://doi.org/10.67291/NHFX3629.

Landry, Forrest. *The Quantum Passage; Quantum Mechanics from the Structure of Comparison*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-073-2. DOI: https://doi.org/10.67291/TKSP9901.

Landry, Forrest. *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. Wytheville, Virginia: UVSM Publications, 2026. DOI: https://doi.org/10.67291/RQQS3025.

Landry, Forrest. *The Story of the Particles*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-053-4. DOI: https://doi.org/10.67291/TJQH1629.

Landry, Forrest. *The Strengths of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-115-9. DOI: https://doi.org/10.67291/DRPC4419.

Landry, Forrest. *The Unquantized Arena; A Structural Diagnosis of Quantum Gravity and the Measurement Problem*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-067-1. DOI: https://doi.org/10.67291/OEIG2350.

Landry, Forrest. *The View from Inside*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-074-9. DOI: https://doi.org/10.67291/HGNK5132.

Landry, Forrest. *The Weight of Possibility; Dark Matter as a Vibration of Context*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-059-6. DOI: https://doi.org/10.67291/QFIN9517.

Landry, Forrest. *Two Theories, One World; Gravity, the Quantum and the Mistake Behind the Search for One Theory*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-068-8. DOI: https://doi.org/10.67291/VFIU1602.

Landry, Forrest. *What Cannot Be; Signals Faster Than Light, Time Travel, Simulation and Determinism, in Plain Words*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *Why Time Travel Is Not a Concept; A Meditation on the Three Times and the Cauchy Horizon*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-121-0. DOI: https://doi.org/10.67291/SNQF5135.

Lees, J. P., and others (BaBar Collaboration) (2012). "Observation of time-reversal violation in the B^0 meson system". *Physical Review Letters* 109, 211801.

Lelli, F., McGaugh, S. S. and Schombert, J. M. (2016). "SPARC: mass models for 175 disk galaxies with Spitzer photometry and accurate rotation curves". *The Astronomical Journal* 152, 157.

Lelli, F., McGaugh, S. S. and Schombert, J. M. (2017). "Testing Verlinde's emergent gravity with the radial acceleration relation". *Monthly Notices of the Royal Astronomical Society: Letters*. doi:10.1093/mnrasl/slx031. arXiv:1702.04355.

Lelli, F., McGaugh, S. S., Schombert, J. M. and Pawlowski, M. S. (2017). "One law to rule them all: the radial acceleration relation of galaxies". *The Astrophysical Journal* 836 (2), 152. doi:10.3847/1538-4357/836/2/152. arXiv:1610.08981.

LIGO Scientific, Virgo and KAGRA Collaborations (2025). "GW250114: Testing Hawking's Area Law and the Kerr Nature of Black Holes". *Physical Review Letters* 135, 111403.

Louie, A. H. (2007). "A living system must have noncomputable models". *Artificial Life* 13(3), 293 to 297.

Louis, T. and others (2025). "The Atacama Cosmology Telescope: DR6 Power Spectra, Likelihoods and ΛCDM Parameters". arXiv:2503.14452.

Lourenço, M. I. R., Barbour, J. and Lobo, F. S. N. (2026). "Scale invariance, variety and central configurations". arXiv:2602.11225.

Ludlow, A. D., Benítez-Llambay, A., Schaller, M., Theuns, T., Frenk, C. S., Bower, R., Schaye, J., Crain, R. A., Navarro, J. F., Fattahi, A. and Oman, K. A. (2017). "Mass-discrepancy acceleration relation: a natural outcome of galaxy formation in cold dark matter halos". *Physical Review Letters* 118 (16), 161103. doi:10.1103/PhysRevLett.118.161103.

Ludlow, A. D., Benítez-Llambay, A., Schaller, M., Theuns, T., Frenk, C. S., Bower, R., Schaye, J., Crain, R. A., Navarro, J. F., Fattahi, A. and Oman, K. A. (2017). "The Mass-Discrepancy Acceleration Relation: a Natural Outcome of Galaxy Formation in Cold Dark Matter halos". *Physical Review Letters* 118(16), 161103. DOI 10.1103/PhysRevLett.118.161103. arXiv:1610.07663.

Ma, X.-S., Kofler, J. and Zeilinger, A. (2016). "Delayed-choice gedanken experiments and their realizations". *Reviews of Modern Physics* 88, 015005.

MacCallum, M. A. H. (2015). "Milestones of general relativity: Hubble's law (1929) and the expansion of the universe". arXiv:1504.03606.

Magueijo, J. and Smolin, L. (2002). "Lorentz invariance with an invariant energy scale". *Physical Review Letters* 88(19), 190403. DOI 10.1103/PhysRevLett.88.190403. arXiv:hep-th/0112090.

Mantz, A. B. and others (2022), as cited in The Weight of Possibility, Chapter 5, Section II, and its bibliography.

Markevitch, M., Gonzalez, A. H., Clowe, D., Vikhlinin, A., Forman, W., Jones, C., Murray, S. and Tucker, W. (2004). "Direct constraints on the dark matter self-interaction cross section from the merging galaxy cluster 1E 0657-56". *The Astrophysical Journal* 606 (2), 819–824. doi:10.1086/383178.

Mashhoon, B. and Wesson, P. S. (2011). "Mach, the Universe, and Foundations of Mechanics". arXiv:1108.3059.

Maturana, H. R. and Varela, F. J. (1980). *Autopoiesis and Cognition: The Realization of the Living*. Dordrecht: D. Reidel.

McCoy, C. D. (2017). "Can Typicality Arguments Dissolve Cosmology's Flatness Problem?". Philosophy of Science 84(5).

McGaugh, S. S. (1999). "Distinguishing between CDM and MOND: predictions for the microwave background". *The Astrophysical Journal Letters*. doi:10.1086/312274. arXiv:astro-ph/9907409.

McGaugh, S. S. (1999). “Distinguishing between cold dark matter and modified Newtonian dynamics: predictions for the microwave background”. *The Astrophysical Journal Letters* 523 (2), L99–L102. doi:10.1086/312274. arXiv:astro-ph/9907409.

McGaugh, S. S. (2000). “BOOMERanG data suggest a purely baryonic universe”. arXiv:astro-ph/0008188.

McGaugh, S. S. (2004). “Confrontation of modified Newtonian dynamics predictions with Wilkinson Microwave Anisotropy Probe first year data”. *The Astrophysical Journal* 611, 26–39.

McGaugh, S. S. (2016). “MOND prediction for the velocity dispersion of the ‘feeble giant’ Crater II”. *The Astrophysical Journal Letters* 832, L8. doi: 10.3847/2041-8205/832/1/L8. arXiv:1610.06189.

McGaugh, S. S., Lelli, F. and Schombert, J. M. (2016). “Radial acceleration relation in rotationally supported galaxies”. *Physical Review Letters* 117, 201101. doi:10.1103/PhysRevLett.117.201101. arXiv:1609.05917.

McGaugh, S. S., Li, P., Lelli, F. and Schombert, J. M. (2018). “Presence of a fundamental acceleration scale in galaxies”. *Nature Astronomy* 2, 924. doi:10.1038/s41550-018-0615-9.

McGaugh, S. S., Schombert, J. M., Bothun, G. D. and de Blok, W. J. G. (2000). “The baryonic Tully–Fisher relation”. *The Astrophysical Journal* 533, L99–L102.

McGaugh, S. S., Schombert, J. M., Lelli, F. and Franck, J. (2024). “Accelerated structure formation: the early emergence of massive galaxies and clusters of galaxies”. arXiv:2406.17930.

Measurements are cited as the sealed record cites them, by author and year; the full entries are in the bibliographies of the books named there.

Measurements cited from the sealed record are cited as it cites them, by author and year; the full entries are in the bibliographies of the books it names.

Measurements quoted from the sealed record (Tristram and others 2022; Petersen and others 2023; Camphuis and others 2026; Abbott and others 2026; Sinha and others 2010; Chen and others 2022; Li and others 2022; CPLEAR 1998; BaBar 2012) are cited there and in the bibliographies of the books it names.

Mikulecky, D. C. Review of *Essays on Life Itself* by Robert Rosen. Virginia Commonwealth University, undated. https://www.people.vcu.edu/~mikuleck/rosrev.html.

Milgrom, M. (1983). "A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis". *The Astrophysical Journal* 270, 365–370.

Milgrom, M. and Sanders, R. H. (2016). "Perspective on MOND emergence from Verlinde's "emergent gravity" and its recent test by weak lensing". arXiv: 1612.09582.

Misner, C. W. and Wheeler, J. A. (1957). "Classical physics as geometry". *Annals of Physics* 2, 525–603.

Misner, C. W., Thorne, K. S. and Wheeler, J. A. (1973). *Gravitation*. San Francisco: W. H. Freeman.

Mistele, T., McGaugh, S., Lelli, F., Schombert, J. and Li, P. (2024). "Indefinitely flat circular velocities and the baryonic Tully–Fisher relation from weak lensing". *The Astrophysical Journal Letters*. doi:10.3847/2041-8213/ad54b0. arXiv:2406.09685.

Mossio, M., Longo, G. and Stewart, J. (2009). "A computable expression of closure to efficient causation". *Journal of Theoretical Biology* 257(3), 489 to 498. DOI: 10.1016/j.jtbi.2008.12.012.

Nadler, E. O. and others (2021), as cited in the sealed record, Prediction 21.

Navarro, J. F., Benítez-Llambay, A., Fattahi, A., Frenk, C. S., Ludlow, A. D., Oman, K. A., Schaller, M. and Theuns, T. (2017). "The origin of the mass discrepancy-acceleration relation in ΛCDM". *Monthly Notices of the Royal Astronomical Society* 471 (2), 1841–1848. doi:10.1093/mnras/stx1705. arXiv:1612.06329.

Oizumi, M., Albantakis, L. and Tononi, G. (2014). "From the phenomenology to the mechanisms of consciousness: Integrated Information Theory 3.0". *PLOS Computational Biology* 10, e1003588.

Padmanabhan, T. (2010). "Thermodynamical aspects of gravity: new insights". *Reports on Progress in Physics* 73, 046901.

Paranjape, A. and Sheth, R. K. (2021). "The radial acceleration relation in a ΛCDM universe". *Monthly Notices of the Royal Astronomical Society* 507, 632–650. arXiv: 2102.13116. doi:10.1093/mnras/stab2141.

Pardo, K., Fishbach, M., Holz, D. E. and Spergel, D. N. (2018). "Limits on the number of spacetime dimensions from GW170817". *Journal of Cosmology and Astroparticle Physics* 2018(07), 048. arXiv:1801.08160.

Pearl, J. (1988). *Probabilistic Reasoning in Intelligent Systems*. San Mateo, California: Morgan Kaufmann.

Penrose, R. (1979). "Singularities and Time-Asymmetry". In General Relativity: An Einstein Centenary Survey, edited by S. W. Hawking and W. Israel, 581 to 638. Cambridge: Cambridge University Press.

Perkowitz, S. (2022). "How entropy might increase backwards in time, as well as forwards" (review of *The Janus Point*). *Physics World*, 25 January 2022.

Perlman, E. S., Rappaport, S. A., Christiansen, W. A., Ng, Y. J., DeVore, J. and Pooley, D. (2015). "New constraints on quantum gravity from X-ray and gamma-ray observations". *The Astrophysical Journal* 805, 10.

Perlmutter, S. and others (1999). "Measurements of Ω and Λ from 42 high-redshift supernovae". *The Astrophysical Journal* 517, 565–586.

Petersen, P. and others (2023). "Cosmic topology. Part I. Limits on orientable Euclidean manifolds from circle searches". *Journal of Cosmology and Astroparticle Physics* 2023 (01), 030.

Petrosky, T. and Prigogine, I. (1993). "Poincaré resonances and the limits of trajectory dynamics". *Proceedings of the National Academy of Sciences of the United States of America* 90, 9393–9397.

Popper, K. (1963). *Conjectures and Refutations*. London: Routledge and Kegan Paul.

Poulin, V., Serpico, P. D. and Lesgourgues, J. (2016). "A fresh look at linear cosmological constraints on a decaying dark matter component". *Journal of Cosmology and Astroparticle Physics* 2016 (08), 036.

Prigogine, I. (1977). "Time, Structure and Fluctuations". Nobel Lecture, 8 December 1977.

Prigogine, I. and Stengers, I. (1984). *Order Out of Chaos: Man's New Dialogue with Nature*. New York: Bantam.

Prigogine, I., with Stengers, I. (1997). *The End of Certainty: Time, Chaos, and the New Laws of Nature*. New York: The Free Press.

Rice, H. G. (1953). “Classes of recursively enumerable sets and their decision problems”. *Transactions of the American Mathematical Society* 74, 358–366.

Riess, A. G. and others (1998). “Observational evidence from supernovae for an accelerating universe and a cosmological constant”. *The Astronomical Journal* 116, 1009–1038.

Rodrigues, D. C., Marra, V., del Popolo, A. and Davari, Z. (2018). “Absence of a fundamental acceleration scale in galaxies”. *Nature Astronomy* 2 (8), 668–672. doi: 10.1038/s41550-018-0498-9. arXiv:1806.06803.

Rosa, J. L. and Złośnik, T. (2023). “Dynamical system analysis of cosmological evolution in the Aether scalar tensor theory”. arXiv:2309.06232.

Rosen, R. (1958). “A relational theory of biological systems”. *Bulletin of Mathematical Biophysics* 20, 245 to 260.

Rosen, R. (1985). *Anticipatory Systems: Philosophical, Mathematical and Methodological Foundations*. Oxford: Pergamon Press.

Rosen, R. (1991). *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

Rosen, R. (2000). *Essays on Life Itself*. New York: Columbia University Press.

Rovelli, C. (2007). “Comment on ‘Are the spectra of geometrical operators in loop quantum gravity really discrete?’”. arXiv:0708.2481.

Rovelli, C. and Smolin, L. (1995). “Discreteness of area and volume in quantum gravity”. *Nuclear Physics B* 442, 593–619; erratum *Nuclear Physics B* 456, 734. arXiv:gr-qc/9411005.

Rubin, V. C. and Ford, W. K. (1970). “Rotation of the Andromeda Nebula from a spectroscopic survey of emission regions”. *The Astrophysical Journal* 159, 379–403.

Ruffini, R. and Wheeler, J. A. (1971). “Introducing the black hole”. *Physics Today* 24(1), 30–41.

Saad, S. M. and Ting, Y.-S. (2026). “No gravitational anomaly in wide binaries from forward modeling of 3D orbits”. arXiv:2603.11015, version 2, 9 September 2026; version 1 (March 2026) was titled “Gravitational anomaly measurement in wide binaries is sensitive to orbital modeling”. doi:10.33232/001c.170182.

Sanders, R. H. (2003). “Clusters of galaxies with modified Newtonian dynamics”. *Monthly Notices of the Royal Astronomical Society* 342, 901–908.

Sargent, C., Clark, W., Seifert, A., Mand, A., Rogers, E., Lane, A., Deur, A. and Terzić, B. (2025). "On the evidence for violation of the equivalence principle in disk galaxies". arXiv:2511.03839.

Schimmoller, A. J., McCaul, G., Abele, H. and Bondar, D. I. (2021). "Decoherence-free entropic gravity: model and experimental tests". *Physical Review Research* 3 (3), 033065. doi:10.1103/PhysRevResearch.3.033065.

Skordis, C. and Złośnik, T. (2021). "New relativistic theory for modified Newtonian dynamics". *Physical Review Letters* 127, 161302. arXiv:2007.00082.

Smolin, L. (1992). "Did the universe evolve?". *Classical and Quantum Gravity* 9, 173–191.

Smolin, L. (1997). *The Life of the Cosmos*. New York: Oxford University Press.

Smolin, L. (2001). *Three Roads to Quantum Gravity*. New York: Basic Books.

Smolin, L. (2004). "Scientific alternatives to the anthropic principle". arXiv:hep-th/0407213.

Smolin, L. (2006). *The Trouble with Physics*. Boston: Houghton Mifflin.

Smolin, L. (2012a). "A real ensemble interpretation of quantum mechanics". *Foundations of Physics* 42, 1239–1261. arXiv:1104.2822.

Smolin, L. (2012b). "Precedence and freedom in quantum physics". arXiv:1205.3707.

Smolin, L. (2013). *Time Reborn*. Boston: Houghton Mifflin Harcourt.

Smolin, L. (2017). "MOND as a regime of quantum gravity". *Physical Review D* 96, 083523. arXiv:1704.00780.

Smolin, L. (2019). *Einstein's Unfinished Revolution*. New York: Penguin Press.

Sutter, P. (2026). "Chandrasekhar and the limits of physics, part 2: humiliation". *Universe Today*, 21 July 2026. universetoday.com.

Tammann, G. A. and Reindl, B. (2013). "Allan Sandage and the distance scale". arXiv:1211.4655.

Tegmark, M. (1997). "On the dimensionality of spacetime". *Classical and Quantum Gravity* 14, L69–L75. arXiv:gr-qc/9702052.

Tegmark, M. (1998). "The interpretation of quantum mechanics: many worlds or many words?". *Fortschritte der Physik* 46, 855. arXiv:quant-ph/9709032.

Tegmark, M. (2000). “Importance of quantum decoherence in brain processes”. *Physical Review E* 61, 4194–4206.

Tegmark, M. (2005). “What does inflation really predict?”. *Journal of Cosmology and Astroparticle Physics* 2005(04), 001. arXiv:astro-ph/0410281.

Tegmark, M. (2008). “The mathematical universe”. *Foundations of Physics* 38, 101–150. arXiv:0704.0646.

Tegmark, M. (2014). “Guest post: Max Tegmark on cosmic inflation”, with his replies to comments. *Preposterous Universe*, 21 April 2014. preposterousuniverse.com

Tegmark, M. (2014). *Our Mathematical Universe; My Quest for the Ultimate Nature of Reality*. New York: Knopf.

Tegmark, M. (2015). “Consciousness as a state of matter”. *Chaos, Solitons and Fractals* 76, 238–270. arXiv:1401.1219.

Tegmark, M., Aguirre, A., Rees, M. J. and Wilczek, F. (2006). “Dimensionless constants, cosmology and other dark matters”. *Physical Review D* 73, 023505. arXiv:astro-ph/0511774.

The other books of the collection cited (Objections from Physics, Answered; Physics Is Not Math; The Case for Measurement; The Ground of Objection) are linked where cited and published by UVSM Publications, Wytheville, Virginia.

The record *The Registered Predictions Beside Erik Verlinde; A Dated Record, 4 November 2026*, and the sealed record *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026* (DOI https://doi.org/10.67291/RQQS3025), state the predictions compared in Section VIII; measurements cited through the books have their full entries in the books’ bibliographies.

Thompson, E. (2007). *Mind in Life: Biology, Phenomenology, and the Sciences of Mind*. Cambridge, Massachusetts: Harvard University Press.

Tian, S., Hou, S., Cao, S. and Zhu, Z.-H. (2023). “Time evolution of the local gravitational parameters and gravitational wave polarizations in a relativistic MOND theory”. arXiv:2302.13304.

Tian, Y., Ko, C.-M., Li, P., McGaugh, S. and Poblete, S. L. (2024). “A Distinct Radial Acceleration Relation across the Brightest Cluster Galaxies and Galaxy Clusters”. *Astronomy and Astrophysics* 684, A180. arXiv:2402.12016. doi: 10.1051/0004-6361/202347868.

Tian, Y., Umetsu, K., Ko, C.-M., Donahue, M. and Chiu, I-N. (2020). "The Radial Acceleration Relation in CLASH Galaxy Clusters". *The Astrophysical Journal* 896, 70. arXiv:2001.08340. doi:10.3847/1538-4357/ab8e3d.

Toker, D. and others (2022). "Consciousness is supported by near-critical slow cortical electrodynamics". *Proceedings of the National Academy of Sciences* 119, no. 7, e2024455119. DOI: 10.1073/pnas.2024455119.

Tolman, R. C. (1934). Relativity, Thermodynamics and Cosmology. Oxford: Clarendon Press.

Tononi, G. (2004). "An information integration theory of consciousness". *BMC Neuroscience* 5, 42.

Tononi, G. (2014). "Why Scott should stare at a blank wall and reconsider (or, the conscious grid)". Posted on *Shtetl-Optimized* (blog), 30 May 2014, in S. Aaronson, "Giulio Tononi and Me: A Phi-nal Exchange".

Tononi, G. and Koch, C. (2015). "Consciousness: here, there and everywhere?". *Philosophical Transactions of the Royal Society B* 370, 20140167.

Touboul, J. and Destexhe, A. (2010). "Can power-law scaling and neuronal avalanches arise from stochastic dynamics?". *PLoS ONE* 5, e8982. DOI: 10.1371/journal.pone.0008982. arXiv:0910.0805.

Tristram, M., Banday, A. J., Górski, K. M., Keskitalo, R., Lawrence, C. R., Andersen, K. J., Barreiro, R. B., Borrill, J., Colombo, L. P. L., Eriksen, H. K., Fernandez-Cobos, R., Kisner, T. S., Martínez-González, E., Partridge, B., Scott, D., Svalheim, T. L. and Wehus, I. K. (2022). "Improved limits on the tensor-to-scalar ratio using BICEP and Planck data". *Physical Review D* 105(8), 083524. DOI 10.1103/PhysRevD.105.083524. arXiv:2112.07961. The combined analysis of Planck, BICEP/Keck 2018 and baryon acoustic oscillation data gives a ratio of tensor to scalar power below 0.032 at 95 percent confidence.

Unger, R. M. and Smolin, L. (2014). *The Singular Universe and the Reality of Time*. Cambridge: Cambridge University Press.

Uzan, J.-P., Clarkson, C. and Ellis, G. F. R. (2008). "Time drift of cosmological redshifts as a test of the Copernican principle". *Physical Review Letters* 100, 191303. arXiv:0801.0068.

Uzan, J.-P., Kirchner, U. and Ellis, G. F. R. (2003). "Wilkinson Microwave Anisotropy Probe data and the curvature of space". *Monthly Notices of the Royal Astronomical Society*. DOI 10.1046/j.1365-8711.2003.07043.x. arXiv:astro-ph/0302597.

Uzan, J.-P., Kirchner, U. and Ellis, G. F. R. (2003). "WMAP data and the curvature of space". *Monthly Notices of the Royal Astronomical Society*, doi:10.1046/j.1365-8711.2003.07043.x. arXiv:astro-ph/0302597.

Vasileiou, V., Jacholkowska, A., Piron, F., Bolmont, J., Couturier, C., Granot, J., Stecker, F. W., Cohen-Tanugi, J. and Longo, F. (2013). "Constraints on Lorentz invariance violation from Fermi-Large Area Telescope observations of gamma-ray bursts". *Physical Review D* 87, 122001. arXiv:1305.3463.

Vegetti, S., Lagattuta, D. J., McKean, J. P., Auger, M. W., Fassnacht, C. D. and Koopmans, L. V. E. (2012). "Gravitational detection of a low-mass dark satellite galaxy at cosmological distance". *Nature* 481 (7381), 341–343. doi:10.1038/nature10669. arXiv:1201.3643.

Verlinde, E. P. (2011). "On the origin of gravity and the laws of Newton". *Journal of High Energy Physics* 2011 (04), 029. arXiv:1001.0785.

Verlinde, E. P. (2017). "Emergent gravity and the dark universe". *SciPost Physics* 2, 016. arXiv:1611.02269.

Visser, M. (2011). "Conservative entropic forces". *Journal of High Energy Physics* 2011 (10), 140. arXiv:1108.5240.

Waterhouse, T. P. and Zibin, J. P. (2008). "The Cosmic Variance of Omega". arXiv: 0804.1771.

Weinberg, S. (1964). "Photons and gravitons in S-matrix theory: derivation of charge conservation and equality of gravitational and inertial mass". *Physical Review* 135, B1049.

Wheeler, J. A. (1955). "Geons". *Physical Review* 97, 511–536.

Wheeler, J. A. (1957). "On the nature of quantum geometrodynamics". *Annals of Physics* 2, 604–614.

Wheeler, J. A. (1962). "The universe in the light of general relativity". *The Monist* 47(1), 40–76.

Wheeler, J. A. (1968). “Superspace and the nature of quantum geometrodynamics”. In C. M. DeWitt and J. A. Wheeler (eds.), *Battelle Rencontres: 1967 Lectures in Mathematics and Physics*, 242–307. New York: W. A. Benjamin.

Wheeler, J. A. (1974). “Superspace”. *Harper’s Magazine*, July 1974, 9. Quoted as given in the epigraph of Giulini (2009).

Wheeler, J. A. (1974). “The universe as home for man”. *American Scientist* 62(6).

Wheeler, J. A. (1978). “The ‘past’ and the ‘delayed-choice’ double-slit experiment”. In A. R. Marlow (ed.), *Mathematical Foundations of Quantum Theory*, 9–48. New York: Academic Press.

Wheeler, J. A. (1990). “Information, physics, quantum: the search for links”. In W. H. Zurek (ed.), *Complexity, Entropy and the Physics of Information*. Redwood City, California: Addison-Wesley. (First given at the 3rd International Symposium on Foundations of Quantum Mechanics, Tokyo, 1989.)

Wheeler, J. A. and Ford, K. (1998). *Geons, Black Holes, and Quantum Foam: A Life in Physics*. New York: W. W. Norton.

Wikipedia contributors. “Eddington number”. *Wikipedia*, accessed 4 November 2026, for the value 136 times two to the power 256 and the Tarner Lectures of 1938.

Wikipedia contributors. “Chandrasekhar–Eddington dispute”. *Wikipedia*, accessed 4 November 2026, for the date of the meeting of 11 January 1935, the title of Eddington’s talk and the detection of Cygnus X-1 in 1972. en.wikipedia.org.

Wolfram, S. (2002). *A New Kind of Science*. Champaign, Illinois: Wolfram Media.

Wolfram, S. (2020). *A Project to Find the Fundamental Theory of Physics*. Champaign, Illinois: Wolfram Media.

Wolfram, S. (2020a). “Finally We May Have a Path to the Fundamental Theory of Physics… and It’s Beautiful”. Stephen Wolfram Writings, April 2020. writings.stephenwolfram.com

Wolfram, S. (2020b). *A Class of Models with the Potential to Represent Fundamental Physics*. Technical introduction, Wolfram Physics Project; sections “Units and Scales” and “Cosmology, Expansion and Singularities”. wolframphysics.org/technical-introduction

Wolfram, S. (2020c). “Faster than Light in Our Model of Physics: Some Preliminary Thoughts”. Stephen Wolfram Writings, 2 October 2020. writings.stephenwolfram.com

Wolfram, S. (2023a). “Computational Foundations for the Second Law of Thermodynamics”. Stephen Wolfram Writings, February 2023. writings.stephenwolfram.com

Wolfram, S. (2023b). “How to Think Computationally about AI, the Universe and Everything”. Stephen Wolfram Writings, October 2023. writings.stephenwolfram.com

Yoon, Y., Han, S. and Hwang, H. S. (2026). “Comparison of MOND and Verlinde’s emergent gravity in dwarf spheroidals”. arXiv:2601.01715 (preprint).

Zhang, P. and Stebbins, A. (2011). “Confirmation of the Copernican principle at Gpc radial scale and above from the kinetic Sunyaev Zel’dovich effect power spectrum”. *Physical Review Letters* 107, 041301. arXiv:1009.3967.

Zimmer, C. (2025). Report on the adversarial collaboration. *The New York Times*, 30 April 2025.

ZuHone, J. A. and Sims, J. (2019). “Testing emergent gravity with optical, X-ray, and weak lensing measurements in massive, relaxed galaxy clusters”. *The Astrophysical Journal*. doi:10.3847/1538-4357/ab2b34. arXiv:1905.03832.

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