

Side by Side

Twenty-Four Models of the Universe

Volume One: The Questions and the Record

Forrest Landry

UVSM PUBLICATIONS
Wytheville, Virginia

© 2026 Forrest Landry. Some rights reserved.

Published by UVSM Publications LLC
965 Reed Creek Mill Rd
Wytheville, VA 24382-8287
USA

uvsmpublications.com
contact@uvsmpublications.com

ISBN 979-8-90710-081-7

DOI: https://doi.org/10.67291/ERWV7848

This is Volume One of six.

This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

You may share this work for non-commercial purposes with proper attribution, but you may not adapt, transform, or build upon it.

Full license text: https://creativecommons.org/licenses/by-nc-nd/4.0/

Links in the text name the book files of the physics collection of the Immanent Metaphysics and of the other volumes of this book, 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.

Author ORCID: 0009-0005-6275-0362

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise), except as permitted under the license above, without prior written permission of the publisher.

Contents

Terms of the Collection ..... **v**

Part One: Where the Accounts Part **1**

I. Twenty-Four Models, One Record 2

II. Is the Geometry Itself Quantized? 7

III. Does Gravity Entangle Two Masses? 10

IV. Does a Superposition End of Its Own Accord? 15

V. Is There a Least Length, or a Rule Beneath? 18

VI. Do the Quantum Statistics Hold Everywhere, and Is the World Determined? 22

VII. Did Inflation Happen? 27

VIII. Is Space Flat? 31

IX. What Is the Dark Matter? 35

X. Is There a Constant of Acceleration? 40

XI. Is the Energy of the Vacuum a Constant? 45

XII. How Many Dimensions Has Space? 49

XIII. Where Does the Arrow of Time Come From? 52

XIV. What Are Life and Mind to Physics? 56

XV. Can the Constants Be Derived? 60

XVI. Where Each Model Stands 64

XVII. Summary 73

Appendices **79**

A. The Prediction Matrix 81

B. The Sealed Record 91

Bibliography **132**

Index **139**

The six volumes of this book:

Volume One, The Questions and the Record (this volume): ISBN 979-8-90710-081-7, DOI https://doi.org/10.67291/ERWV7848.

Volume Two, Chance, Determinism and Measurement: ISBN 979-8-90710-082-4, DOI https://doi.org/10.67291/SCIA2359.

Volume Three, The Quantum and the Arena: ISBN 979-8-90710-450-1, DOI https://doi.org/10.67291/CWRY6534.

Volume Four, Discreteness and Computation: ISBN 979-8-90710-451-8, DOI https://doi.org/10.67291/NXFD7254.

Volume Five, The Cosmos and the Dark Component: ISBN 979-8-90710-452-5, DOI https://doi.org/10.67291/GPSA5264.

Volume Six, Time, Life and Mind: ISBN 979-8-90710-453-2, DOI https://doi.org/10.67291/DXRE6677.

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.

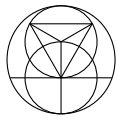
Three ways of validation. Measurement (first person), agreement (second person) and proof (third person); only measurement and proof validate truth.

PART ONE

WHERE THE ACCOUNTS PART

Abstract

Twenty-four models of the universe stand side by side in this book: physics from comparison, and twenty-three others put forward by the physicists and scientists who built them. Each is set against one record, the forty-two predictions sealed on 1 November 2026. This first part gives the questions on which the models part, fourteen of them, from whether the geometry of space is itself quantized to whether the constants of nature can be derived. For each question it states the answer of physics from comparison, the prediction that carries it and the book that argues it; it states where each other model stands and the premise on which it parts; and it names the measurement or the proof that decides. A table at the end shows where every model stands on every question. The chapters of Volumes Two to Six set out each model in full.



Section I

Twenty-Four Models, One Record

Every account of physics is a claim about what the universe is. Most accounts of physics make a claim about one part of the universe at a time: a theory of the quantum, of gravitation, of the dark matter or of the mind. The quantum is the world of atoms and particles that quantum mechanics describes. The dark matter is the matter that astronomers detect only through its gravity. I set twenty-four accounts of physics side by side and place every account beside one record of predictions. I call each of the twenty-four accounts a model.

The record is a register of forty-two predictions, The Registered Predictions of Physics from Comparison (DOI https://doi.org/10.67291/RQQS3025), sealed on 1 November 2026. To seal a prediction is to fix its wording at a stated date, before anyone makes the measurement that decides whether the prediction holds, so the record is fixed at its date and is not revised. The record 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, and whether any new kind of particle will be found. Two masses are "entangled" when what is found of one mass is tied to what is found of the other. The equation of state of the vacuum is the ratio of the pressure of empty space to the energy that empty space holds in each unit of volume, and the ratio is exactly -1 when the energy of the vacuum is a constant. For each prediction, the record also states the measurement that decides whether the prediction holds.

Physics from comparison is the first of the twenty-four models in this book. Physics from comparison is the physics of the Immanent Metaphysics. The Immanent Metaphysics is a philosophy built on the act of comparison, in which one thing is compared with another, and a person, an instrument or any physical system can make a comparison. Physics from comparison is founded on the Incommensuration Theorem. The Incommensuration Theorem states that symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison. In the Incommensuration Theorem, symmetry means sameness kept across a change, and continuity means smoothness that stays unbroken under division into ever finer parts. The Incommensuration Theorem is a structural fact about the nature of knowing. The Immanent Metaphysics has three axioms, the starting statements of its reasoning, and the first axiom was formulated in or before 1991. The Incommensuration Theorem was formulated in 1996, together with the ethics of the Immanent Metaphysics, and most of the physics of the Immanent Metaphysics was formulated in the years 1997 and 1998. The axioms are stated in the book *An Immanent Metaphysics*, published in 2001. I call the physics collection of the Immanent Metaphysics "the collection" for short: the name covers both the books that set out the physics of the Immanent Metaphysics and that physics itself. The predictions of physics from comparison are the forty-two predictions of the record, which this book calls the sealed record.

The other twenty-three models are the models of the physicists and scientists who built them. Two of the twenty-three models were built jointly, each by two people. The first joint model is an argument of the physicists Chiara Marletto and Vlatko Vedral: if gravity entangles two quantum systems, gravity cannot be classical (fully described by the physics before quantum theory). Marletto and Vedral base their argument on constructor theory, which states physical laws as rules about what can and cannot be done. The second joint model is modified Newtonian dynamics, as the physicist Mordehai Milgrom founded it and as the astronomer Stacy McGaugh has developed it. Modified Newtonian dynamics is a law of gravity with a constant of acceleration: below that acceleration, motions

depart from Newton's law. Some of the twenty-three models are models of the whole universe, while others describe something that the whole universe contains: the quantum, the cosmos (the universe on its largest scales), or life and mind. I credit each model plainly. Where a model reached a result first, or where measurement has confirmed a model, the chapter on that model says so. Some accounts appear in this book only in passing: the physicist Carlo Rovelli's relational quantum mechanics, Bohmian mechanics, QBism and the string program. In relational quantum mechanics a system has its properties only relative to another system. In Bohmian mechanics every particle always has a definite position, guided by a wave. In QBism the quantum description of a system expresses the degrees of belief of the person who uses the description. In the string program every particle is a tiny vibrating string. I leave one task for another day: setting the accounts named only in passing beside the collection.

I say that two models "part" at the place where they first disagree. Physics from comparison parts from each of the other twenty-three models at a step of reasoning, at a premise or at a measurement, and every place where two models part can be named in one sentence. The experiments now under way will settle several of the partings within years. The reader keeps the score: I set out each parting and what settles it, and the reader tallies how the partings come out. Each chapter of Parts Two to Six sets one model beside physics from comparison and states the step at which the two models part. At each parting, the chapter says which of three things holds. The first of the three things is that one side's step does not follow from that side's premises, and then I show a case where the step fails. The second of the three things is that both sides' steps follow and the two sides start from different premises. In that case I state the difference in premises as one sentence and say what settles the difference. The third of the three things is that a measurement already made contradicts a premise of one side. Each chapter has a register of its model's predictions set beside the sealed record, and the registers are the appendices of the volumes.

How the book is laid out

Part One, which you are reading, gives one short section to each question on which the models disagree. Part One then gives a table of every model's answer to every question. The later parts give each model a chapter of its own. The chapters are grouped into parts by the question that each model bears on most, and within each part the chapters come in the order in which the models were put forward; Part Six alone takes its three models of time first, and its models of life and of mind after them.

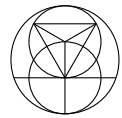
The book is printed in six volumes, and each part fills one volume. Volume One, The Questions and the Record, holds Part One and the sealed record. Volume Two, Chance, Determinism and Measurement, holds Part Two, with the models of the physicists Niels Bohr, Gerard 't Hooft, Nicolas Gisin, Anton Zeilinger and Sabine Hossenfelder. The models of Part Two are models of what a finding is, what the quantum state is, and whether the world is determined. A finding is an interaction that registers which alternative is the case. An instrument or an environment can make a finding, and no mind is needed to make one. The quantum state is the complete quantum description of a system.

Volume Three, The Quantum and the Arena, holds Part Three, with the models of the physicists Roger Penrose, Chiara Marletto and Vlatko Vedral, Sean Carroll, and Jonathan Oppenheim. The models of Part Three are models of what gravitation does to a superposition. A superposition is a quantum state that combines two or more alternatives, such as one small mass in two places at once. The arena of the volume's title is the geometry of space and time, taken as the setting in which every finding is made.

Volume Four, Discreteness and Computation, holds Part Four, with the models of the physicists John Archibald Wheeler, David Deutsch and Max Tegmark, and of the computer scientist Stephen Wolfram. Volume Five, The Cosmos and the Dark Component, holds Part Five, with the models of the astrophysicist Arthur Eddington, the cosmologist George Ellis, Mordehai Milgrom and Stacy McGaugh together, and the physicist Erik Verlinde. Volume Six, Time, Life and Mind, holds Part Six, with the mod-

els of the physicists Julian Barbour and Lee Smolin, the chemist Ilya Prigogine, the biologist Robert Rosen, and the neuroscientists Giulio Tononi and Karl Friston.

The appendices of Volume One open with the prediction matrix, which sets all twenty-three other models beside the sealed record. For each of the forty-two sealed predictions, the prediction matrix lists the models that agree and the models that differ. Volume One also holds the sealed record itself. The appendices of each later volume open with the prediction matrix of the models of that volume, and the register of each model of the volume then follows as an appendix of its own.



Section II

Is the Geometry Itself Quantized?

The question. The geometry of space and time is the arena in which every field of physics is found. Every other field of physics comes in quanta. The quanta of a field are the separate units in which the field is found, such as the photon, the quantum of light. Does the geometry come in quanta too?

Physics from comparison. No. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. The collection registered the answer no as Prediction 3 of its sealed record: "No effect will show the geometry carrying quantum degrees of freedom of its own, beyond those tied to the alternatives of the matter". The alternatives of the matter are the ways the matter could be found: for a mass in two places at once, the two places. On the collection's account, each alternative of the matter carries its own geometry. The degrees of freedom of a system are the independent quantities that must be given to describe the state of the system. So the prediction says that the geometry has no quantum degrees of freedom beyond the ones that come with the alternatives of the matter. The answer is no because the geometry is the context of every comparison: in physics, the content of a comparison is the quantum matter that is found, and the context is the geometry in which the matter is found. Quantization is a passage between two descriptions of a content, made within a context that stays as it is. For light, the two descriptions are light as a wave and light as a stream of photons. So quantization does not apply to the context itself. The small waves of the geometry can still be described by quanta, in the effective field theory

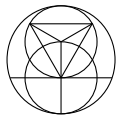
of gravity (in short, the effective theory). The effective theory holds below the Planck curvature, the curvature whose radius is the Planck length. The quanta of the effective theory are quanta of the description. None of them is ever a quantum of the arena. The collection argues for the answer no in its book *The Unquantized Arena*, in Chapter 6, Propositions 6.1 and 6.3. Proposition 6.1 argues that the arena, as the context of every comparison, cannot be quantized as a field of content is quantized, and so Proposition 6.3 states that nothing is a quantum of the arena itself, at any scale.

Who stands where. The physicist John Archibald Wheeler made the geometry a quantum variable at every scale: a quantity with quantum states of its own. Wheeler took as the law of the geometry the Wheeler and DeWitt equation, named for him and the physicist Bryce DeWitt. Wheeler and the collection part ways at the first premise of either account: whether the geometry is a variable with states of its own, or the context in which every variable takes its states. The physicist Julian Barbour makes the geometry one more configuration of the universe, of the same kind as the configuration of the matter. The physicist Sean Carroll makes the geometry part of what the quantum state describes. On Carroll's account, space emerges from the quantum state. The physicist David Deutsch holds that quantum theory applies to every physical system, and he counts the gravitational field as one more physical system, so on his account the gravitational field has quanta of its own. The physicist Lee Smolin gives area and volume discrete spectra: on Smolin's account, an area or a volume can take only certain separate values. Each of these five positions follows from the premise of the physicist who holds it: the positions of Wheeler, Barbour, Carroll, Deutsch and Smolin. The premise in dispute, stated in one sentence, is this: the gravitational field is one more physical system with states of its own, rather than the context within which the states of every physical system are laid out. The physicists Chiara Marletto and Vlatko Vedral call gravitation quantized when gravitation has two observables that cannot both be sharp at once. An observable, a quantity that can be measured, is sharp when it has a definite

value. The collection's geometry has two observables that cannot both be sharp, because it takes a different state in each alternative of the matter. So Marletto and Vedral and the collection part ways on what the word "quantized" names, and not on what the coming experiment will find: the test of Section III, whether two masses, each held in two places at once, become entangled through gravitation. The physicists Roger Penrose and Jonathan Oppenheim agree with the collection that the geometry is not quantized in the usual way, as the other fields are. Penrose and Oppenheim part ways with the collection on other questions, among them whether gravitation entangles two masses (Section III).

What decides it. No experiment now proposed decides the question, because below the Planck curvature the collection's account and the effective theory give the same result for every experiment now proposed. Two observations would decide the question, and *The Unquantized Arena* names both in Chapter 19, Section III. The first of the two observations is a cross section for the scattering of waves of the geometry, a cross section that departs from the effective theory. A cross section measures how likely a scattering is, and the cross section of the first observation would differ from what the effective theory predicts. The second of the two observations is a superposition of geometries that is sourced by no superposition of matter: the geometry in two or more shapes at once, with no matter in two or more places at once to produce the shapes.

Where each is set out. Every other model in this section has a chapter of its own that sets the model out in full. The chapters are those on Wheeler, Barbour, Carroll, Deutsch, Smolin, Marletto and Vedral, Penrose, and Oppenheim. The chapter on Wheeler is in Volume Four, and the chapters on Barbour and Smolin are in Volume Six.



Section III

Does Gravity Entangle Two Masses?

The question. Hold each of two small masses in two places at once, with the two masses close enough that only gravitation acts between the masses. A mass held in two places at once is in a superposition of the two places. Two masses are entangled when what is found of one mass is tied to what is found of the other. Do the two masses become entangled?

Physics from comparison. Yes. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. The collection registered the answer yes as Prediction 1 of the collection's sealed record, the forty-two predictions fixed on 1 November 2026. Prediction 1 reads: "Two masses, each held in a superposition of two places and related only through gravitation, become entangled, with the phase of their Newtonian interaction". A superposition combines two or more alternatives, and for a mass in two places, each place is one alternative. In quantum physics each alternative carries a phase, and the phase of an alternative advances like the hand of a clock, at a rate set by the energy of the alternative. The Newtonian interaction of the two masses is the pull of gravity between the masses, as Newton's law gives the pull. Of each mass's two places, the place closer to the other mass is the near place, and the other place is the far place. Two masses, each in two places, have four joint placements: both near, both far, and one near with the other far in either order. The energy of the pull depends on the distance between the masses, which is shortest in the joint placement of both near and longest in the joint placement of both far. The phase of each joint placement advances at a rate that depends on the energy of the

pull. The entangling phase is the sum of the phases of the two joint placements with both masses near or both far, less the sum of the phases of the other two. The two masses are entangled whenever the entangling phase is not a whole number of full turns.

Sougato Bose is a physicist. In 2017 Bose and his colleagues proposed an experiment with two masses of 10^{-14} kilograms. In the experiment each mass is held in two places 250 micrometers apart for 2.5 seconds. The two pairs of places have midpoints 450 micrometers apart. For the experiment of Bose and colleagues, the entangling phase is 0.314 radians, about a twentieth of a full turn. The concurrence is a measure of entanglement that is zero for every unentangled state and at most one. For the experiment of Bose and colleagues, the concurrence is 0.156. An entanglement witness is a quantity whose value beyond a stated threshold is possible only for an entangled state, and for the experiment of Bose and colleagues the entanglement witness of the physicists Chevalier, Paige and Kim is -0.22. The box near the end of this section derives the phase and the concurrence from the numbers of the design.

On the collection's account, gravitation is the arena: the geometry of space and time. The collection predicts entanglement for one reason: on the collection's account, each alternative of the matter carries its own geometry, and the relative phases of the alternatives, the differences between the phases, are kept. The collection's book *The Unquantized Arena* states the collection's account of the geometry as Proposition 7.1, in Chapter 7.

Who stands where. The physicist Roger Penrose predicts no entanglement in the design of Bose and colleagues. On Penrose's rule, when a mass is in two places, the superposition ends of its own accord, in a time set by how much the geometries of the two places disagree near the mass. For the masses of the design, Penrose's rule sets the lifetime of each superposition at about 0.012 seconds, against the 2.5 seconds the entangling phase needs, so each superposition ends before the entangling phase can build. The physicist Jonathan Oppenheim predicts no entanglement either. In Oppenheim's theory the geometry is classical, in the sense that

one configuration of the geometry serves every alternative of the matter, and so the geometry cannot entangle the two masses. Oppenheim proved that a theory with one classical geometry for every alternative has two further effects: the geometry wanders at random, and the matter undergoes decoherence, a loss of the interference between the alternatives of the matter.

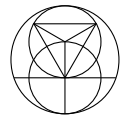
The physicist Erik Verlinde holds that gravitation is an entropic force. An entropic force is a force that arises from the tendency of a system of many parts to move toward the system's more numerous arrangements. Verlinde's account makes no prediction for the experiment of Bose and colleagues. If Verlinde's entropic force acts on each joint placement and keeps the phases, the two masses would become entangled on Verlinde's account at the phase the collection predicts. If the entropic force acts in any other way, the masses would not become entangled on Verlinde's account. The physicists Chiara Marletto and Vlatko Vedral predict entanglement, as the collection does. The physicists David Deutsch and Sean Carroll also predict entanglement. The physicist John Archibald Wheeler made the geometry itself quantized, and Wheeler's quantized geometry implies entanglement. The premise in dispute is a question about a mass in two places: is there one geometry for both places, or one geometry for each place with the phase kept? Oppenheim answers one geometry for both places, and the collection answers one geometry for each place, with the phase kept.

What decides it. The experiment of Bose and colleagues itself decides the question, because the outcome of the experiment separates two groups of accounts. The first group is every account with one geometry for all the alternatives of the matter, together with gravitational collapse, in which a superposition ends of its own accord through gravity, as on Penrose's rule. The second group is every account that has a geometry for each alternative of the matter. The first group predicts no entanglement, and the second group predicts entanglement. If the experiment finds entanglement, the result does not show that the geometry is quantized, because the collection's account predicts the entanglement with a classical

geometry for each alternative of the matter. The collection's geometry is classical in a different sense from Oppenheim's: the collection's geometry has no least step and no quanta of its own. The word "quantized" has two senses when the word is applied to gravity. A mediator is whatever carries an interaction from one mass to the other, and in the experiment the mediator is gravity. In the first sense, gravity is non-classical as a mediator: gravity has at least two observables that cannot both be sharp at once. An observable is a quantity that can be measured. An observable is sharp when it has a definite value. An entanglement found shows that gravity is non-classical in the first sense, and the collection predicts the entanglement. In the second sense, gravity is quantized as an arena: the geometry of space and time comes in quanta of its own. The experiment does not test the second sense, and the collection predicts that the geometry has no quanta of its own (Section II). I set out the two senses of "quantized" in full in the chapter on Marletto and Vedral.

The numbers of the design. The design of Bose and colleagues (2017) holds two masses of 10^{-14} kilograms each in two places 250 micrometers apart, with centers 450 micrometers apart, for 2.5 seconds. The phase that decides entanglement is Newton's constant times the square of the mass times the time, divided by the reduced Planck constant, multiplied by the sum of one over the near distance (200 micrometers) and one over the far distance (700 micrometers), less two over the distance between centers: 0.314 radians. The paper prints its two phase differences rounded, as about 0.7 and -0.2; its own inputs give 0.44 and -0.13, whose sum is 0.314. The concurrence is the sine of half the phase, 0.156. For a sphere of diamond (3,510 kilograms per cubic meter, radius about 0.88 micrometers), the self-energy of the difference of the two placements is about six fifths of Newton's constant times the square of the mass divided by the radius, and the reduced Planck constant divided by that energy is about 0.012 seconds, the lifetime on Penrose's rule.

Where each is set out. I set out the models of Penrose, Oppenheim, Verlinde, and Marletto and Vedral in full, each in a separate chapter. The chapter on Verlinde is in Volume Five.



Section IV

Does a Superposition End of Its Own Accord?

The question. Is there a mass, a separation or a length of time at which a superposition ends of its own accord, with nothing registering which alternative is the case? A superposition is a quantum state that combines two or more alternatives, such as one small mass held in two places at once. The question is whether enough mass, enough distance between the two places, or enough time ends the superposition by itself. To end by itself is to end with nothing registering the place of the mass.

Physics from comparison. No. Prediction 2 of the sealed record gives the answer of physics from comparison: "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". In Prediction 2, the words "the account" mean physics from comparison. Decoherence of the ordinary kind is the spreading of the difference between two alternatives into the surroundings of a system (the system's environment), as stray molecules or particles of light strike the system and register which alternative is the case. So ordinary decoherence is itself a finding, made by the environment, and Prediction 2 allows no other way for a superposition to end. I call physics from comparison "the collection" for short. The collection holds that gravity alone ends no superposition. The reason is that the geometry of space and time lays down no record of the alternative that is the case.

Who stands where. The physicist Roger Penrose holds that a superposition *does* end of its own accord: gravity ends the superposition. When one mass is held in two places, the mass shapes the geometry of space and time differently at each place, so the superposition carries two geometries, one for each place. On Penrose's rule, the superposition ends when the two geometries differ by enough self-energy. Penrose measures the difference between the two geometries by the gravitational self-energy of the difference between the two placements of the mass. A self-energy is the energy that a distribution of mass has from the gravitational pull of its parts on one another. Penrose compares the two geometries across all of space, in the Newtonian approximation. The Newtonian approximation describes gravity by Newton's law and takes the spaces of the two geometries to be approximately one space. The collection compares the two geometries only in the far region they share, the region far from the bodies, where the geometry of every alternative is flat and one measure of time serves every alternative. So Penrose and the collection part on where to compare the two geometries.

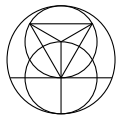
The physicist Nicolas Gisin holds that collapse is real, meaning that a superposition can end of its own accord, and that collapse belongs in the equation of evolution, the equation that says how a quantum state changes over time. The premise in dispute between Gisin and the collection is one sentence: an event that makes one alternative actual can occur where no interaction registers which alternative is the case. Gisin affirms the premise, and the collection denies the premise.

The physicist Jonathan Oppenheim makes the geometry classical (fully described by the physics before quantum theory), with one geometry serving every alternative of the matter, and in Oppenheim's model the classical geometry adds decoherence to the matter. The physicist Erik Verlinde describes gravity as an entropic force, a force that arises from entropy, which is a measure of how many ways the parts of a system can be arranged. Models built on Verlinde's entropic gravity add a gravitational decoherence of their own, a decoherence that gravity causes beyond the ordinary kind. Prediction 2 allows no decoherence beyond the ordinary

kind, so, on whether a superposition ends of its own accord, the collection parts from Oppenheim's model and from the models built on Verlinde's entropic gravity. Six physicists agree with the collection: Anton Zeilinger, David Deutsch, Sean Carroll, Julian Barbour, John Archibald Wheeler and Max Tegmark. The models of the six physicists contain no collapse.

What decides it. Three kinds of experiment decide the question. The first kind is the entanglement experiment of Prediction 1, set out in Section III, in which two small masses are each held in two places at once and only gravity acts between the two masses. An extra channel of decoherence is any way, beyond the ordinary kind, in which a superposition could end. The entanglement experiment bounds any extra channel of decoherence directly: the experiment sets a limit on how strong any extra channel can be. The experiment sets the limit directly because the experimenters must verify that each mass keeps its superposition for the whole run. The second kind is searches for the heating that collapse dynamics causes. A collapse dynamics is an equation of evolution under which superpositions end of their own accord at random, and the searches look for heating because the random part of a collapse dynamics heats matter. The third kind is interference with ever larger masses. A mass can show interference only while the mass is still in a superposition, held in more than one place at once. So each larger mass that shows interference narrows the rates a collapse may have. The collapse of Diósi and Penrose is the collapse driven by gravity that Lajos Diósi proposed in 1987 and Penrose proposed in 1996. Heating searches have already ruled out the Diósi and Penrose collapse in its form with no free parameter (Donadi and others 2021). In the form with no free parameter, theory alone fixes every number of the Diósi and Penrose collapse.

Where each is set out. Five chapters of this book set out the answers to the question of this section in full: the chapters on Penrose, Gisin, Oppenheim, Verlinde and Zeilinger. The chapter on Verlinde is in Volume Five.



Section V

Is There a Least Length, or a Rule Beneath?

The question. Picture a length cut in half, and each half cut in half again, and so on. Space and time are continuous all the way down if the cutting can go on forever, so that every piece of space and every piece of time can be cut again. Are space and time continuous all the way down? Or do space and time come in steps, with a least length, a least area or a least duration that cannot be cut? A discrete rule is one fixed rule that updates separate states step by step, as in a vast grid of cells. Or do space and time run on a discrete rule beneath everything we measure?

Physics from comparison. Space and time are continuous all the way down, on the account of physics from comparison. In this book, "the collection" is the physics collection of the Immanent Metaphysics. The physics of the collection is physics from comparison. Every comparison has a content, which is what is found, and a context, which is the arena in which the content is found. In physics the content is quantum matter. The context is the geometry of space and time, which this book calls the arena. Discreteness is the coming of a quantity in separate steps. On the collection's account, discreteness belongs to the content, that is, to the charges and the kinds of particle, and not to the arena. The collection fixed its answer to the question of this section in its sealed record, a register of forty-two predictions sealed on 1 November 2026, before anyone makes the measurements that decide whether the predictions hold. The answer is Prediction 5 of the sealed record: "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". The first sentence of

Prediction 5 says that no step of spacetime makes the speed of light depend on the energy of the light. A step of spacetime would be a least length, and a least length could make light of different energies travel at different speeds, because light of higher energy has a shorter wavelength, nearer to the least length. The spectrum of a quantity is the set of values the quantity can take, and a spectrum is discrete when the values are separate, with gaps between the values, like the heights of the steps of a staircase. The second sentence of Prediction 5 says that no observation will find an area or a volume that can take only separate values.

The collection also sealed 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". Statistics are counts of how often each outcome turns up over many repeated measurements, whether the outcomes come from a rule or from the world. When someone offers one fixed discrete rule as the foundation of physics, Prediction 29 says that a measurement fine enough to resolve sizes below the least step of the rule will show that the statistics of the rule differ from the statistics of the world.

The collection argues for Prediction 5 in its book *The Unquantized Arena*, Chapter 19, Section V. The section shows that every route to a speed of light that depends on energy fails, the route through a deformed symmetry included. The symmetry of special relativity is the sameness of the laws of physics for every observer in steady motion. A deformed symmetry keeps a principle of relativity for all observers, but adds a scale of energy. In many proposals of a deformed symmetry, the speed of light depends on energy. Chapter 19, Section V, states its conclusion in one sentence: "Light of every energy follows the light cone of the one geometry". The light cone of an event is every event that a signal from the event can reach without exceeding the speed of light. Because a light cone is set by the speed of light, the quoted sentence says that light of every energy travels at one speed, along the light cone of the one geometry of space and time.

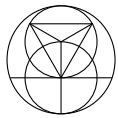
Who stands where. The physicist Lee Smolin gives area and volume discrete spectra: on Smolin's account, an area or a volume can take only separate values. Smolin also lets the speed of light depend on energy, through a deformed symmetry. The physicist John Archibald Wheeler held that at the Planck length the geometry of space and time froths as a foam. The Planck length is the length at which an object's gravitational size equals the object's quantum size. On the collection's account the Planck length is not a least length. The foam is Wheeler's image for a plain claim: at the Planck length the geometry changes shape at random from place to place, so strongly that the geometry is no longer smooth. The computer scientist Stephen Wolfram builds space from a discrete network: a set of separate points joined by links. One rule rewrites the network step by step. Wolfram puts the least step of the network below the Planck length. The physicist Gerard 't Hooft builds quantum mechanics on a deterministic cellular automaton, a kind of discrete rule. A cellular automaton is a vast grid of cells, each in one of a few states. One rule, the same for every cell, updates every cell at every step. The automaton of 't Hooft is deterministic. The state of the automaton at one step fixes the state of the automaton at every other step. Each of the four positions follows from its own premise: the positions of Smolin, Wheeler, Wolfram and 't Hooft. The premise in dispute is what space is at its foundation: the context of every finding (every interaction that registers which alternative is the case), or a structure of steps. Of the four positions of Smolin, Wheeler, Wolfram and 't Hooft, exactly one step does not follow from the premises of the person who takes the step: Wheeler's estimate of the foam. Wheeler's estimate applies the formula for a small fluctuation of the geometry where the fluctuation is no longer small, so the estimate marks only the place where the formula stops holding, and shows nothing about the geometry beyond that place.

The physicist Sabine Hossenfelder derived a bound from locality. Locality is the rule that every influence takes some time to cross a distance. The Planck energy is the energy fixed by Newton's constant, the speed of light and the reduced Planck constant. A dependence of the first order is a

change in the speed of light in direct proportion to the energy of the light divided by the Planck energy. Hossenfelder showed in 2010 that a speed of light that depends on energy in the same way for every observer produces effects that break locality, so, at first order, the dependence is ruled out by the locality of known particle physics. Hossenfelder's bound and the collection agree in ruling out a speed of light that depends on energy in the same way for every observer. Her bound applies only to a dependence that is the same for every observer, while Prediction 5 applies to every dependence of the speed of light on energy.

What decides it. Three kinds of measurement decide whether space and time are continuous all the way down. The first kind is the timing of light from distant bursts, such as gamma-ray bursts, brief flashes of very high-energy light. If the speed of light depended on the energy of the light, light of different energies that left one burst together would arrive at different times, and the gap would grow with the distance of the burst. The growth with distance tells the gap apart from effects at the burst itself. The timing of light from bursts has reached the Planck energy for a dependence of the first order, and finds no dependence. 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). The second kind is every observation of the spectrum of area and volume: for example, in the echoes of gravitational waves (ripples in the geometry of space and time) from merging black holes. The third kind applies to any one named rule. The third kind is a measurement fine enough to resolve sizes below the least step of the named rule, because Prediction 29 says that the measurement will tell the statistics of the named rule from the statistics of the world.

Where each is set out. Each model named in this section has a chapter of its own that sets the model out in full. The chapters are on Smolin, Wheeler, Wolfram, 't Hooft and Hossenfelder. The chapter on Smolin is in Volume Six, and the chapters on Wheeler and Wolfram are in Volume Four.



Section VI

Do the Quantum Statistics Hold Everywhere, and Is the World Determined?

The question. Quantum theory has a rule for probabilities, the Born rule. The Born rule states that the probability of an outcome of a measurement is the square of the magnitude of the outcome's amplitude: a number that the quantum state of the measured system has for the outcome. Physicists call the probabilities of the Born rule its weights. A world is deterministic when a complete specification of the world at one time fixes every outcome at every later time. Do repeated measurements in every experiment settle to the weights of the Born rule? Or does a deterministic world lie beneath the weights and fix the outcomes that the weights leave open?

Physics from comparison. The answer of physics from comparison has two parts. First, repeated measurements settle to the weights of the Born rule everywhere, in every experiment. Second, no world is perfectly determined. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. The collection registered the first part of the answer as Prediction 25 of the collection's sealed record: "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". Systems are identically prepared when every system is prepared by one method and starts in one quantum state. In Prediction 25, a sector is one part of the space of possible states of a quantum system, while the full space is the whole space of possible states, however many particles the

system has. Superdeterminism is 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. A completion of quantum mechanics is a deeper theory that adds a further state beneath the quantum state. Statistical independence is the assumption that the settings of the measuring devices are independent of the hidden state of the systems measured. The tests proposed for superdeterminism are experiments that look for departures from the weights of the Born rule.

The collection registered the second part of the answer 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". An asymmetry of time in the laws is a difference between the laws for time running forward and for time running backward. A process would be perfectly reversible if the process could be run backward so that every trace of the process was undone.

The collection gives two grounds for the answer, in the collection's book *The Quantum Passage*, Chapters 7 and 9. Each ground is about one kind of further state. A further state is a state of the measured system that lies beneath the quantum state and is not part of the quantum state. The first ground is the Incommensuration Theorem. The Incommensuration Theorem states that symmetry and continuity cannot both be applied, simultaneously and fundamentally, to any event or comparison. The Incommensuration Theorem is a structural fact about the nature of knowing. Suppose a further state settled every outcome. Then the world would have a description that fixes every finding: the description that includes the further state. A finding is an interaction that registers which alternative is the case, for example the click of a detector. A description that fixes every finding applies symmetry and continuity together, because the description needs one law that carries every state into the next, which is symmetry, and every state specified with no gap, which is continuity. So, by the Incommensuration Theorem, no further state settles the outcome.

The second ground is what the weight of an outcome is. In the collection, a measurement is a comparison: an act that sets one thing beside another. The context of a comparison is the arena in which the outcome is found, the geometry of space and time: for a measurement in a laboratory, the context includes the setting of the apparatus. The weight of an outcome is the stable frequency of the same comparison on the same state in the same context: repeat one comparison many times, on one state and in one context, and the outcome recurs with one stable frequency. A further state that shifted the weights would make the frequency of the repeated comparison drift from run to run, but a drifting frequency is not a stable frequency. So no further state shifts the weights. A die whose edges slowly wear is a plain picture of a further state that shifts the weights but does not settle the outcome: each throw is settled only when the die lands, and still the weights of the die change from one throw to the next.

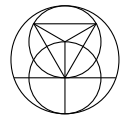
Who stands where. The physicist Sabine Hossenfelder holds that the world is superdeterministic. On her account, the degrees of freedom of the detector fix the outcome of each measurement. The degrees of freedom of the detector are the detector's own quantities. None of the detector's quantities is part of the prepared state. Hossenfelder has proposed her own experiment: consecutive measurements on one prepared state, made with small, cold devices. On her account the experiment would find correlations in time, while Prediction 25 states that the experiment will find none. A correlation in time is a dependence of one outcome on the outcome of the measurement just before, beyond any dependence in the Born rule. The physicist Gerard 't Hooft builds quantum mechanics on a deterministic automaton, a lattice of discrete states with one rule for every site and every step, so that each state of the lattice fixes the next state. Gerard 't Hooft expects that quantum computers will never outperform classical computers scaled to Planckian dimensions. To scale a classical computer to Planckian dimensions is to bring the computer's memory cells and computing time down to the sizes and times of the Planck scale, the scale at which an object's gravitational size equals the object's quantum size. The physicist Lee Smolin proposes that the weight of an outcome for

a state without precedent comes from the record of earlier instances. The physicists David Deutsch and Sean Carroll hold that the whole of the many worlds is deterministic. On the many-worlds account, every outcome of a measurement occurs, each on a separate branch of the world. The quantum state of the whole universe evolves by one deterministic law. The collection's own quantum mechanics uses the law of evolution of the many-worlds account. But the collection excludes the claim that the whole world is deterministic, because a whole world completely fixed by a law would apply symmetry and continuity together, and the Incommensuration Theorem forbids that pairing. The collection agrees with the physicists Niels Bohr, Anton Zeilinger and Nicolas Gisin, the cosmologist George Ellis and the neuroscientist Karl Friston on the statistics of quantum theory: repeated measurements settle to the weights of the Born rule. The collection also agrees with Bohr, Zeilinger, Gisin, Ellis and the chemist Ilya Prigogine that determinism fails: no world is perfectly determined. Zeilinger's group made several of the decisive tests of Bell's inequality, a bound on the correlations between two distant measurements that applies to any account in which local causes fix the outcomes in advance. The tests found Bell's inequality violated.

What decides it. For Hossenfelder's superdeterministic account, the deciding measurement is the experiment of Hossenfelder and the climate physicist Tim Palmer: the consecutive measurements on one prepared state with small, cold devices. For Gerard 't Hooft's limit, the deciding measurement is the logical error rate of quantum codes as the codes grow. Gerard 't Hooft's limit is the limit he predicts on our ability to avoid the decoherence of qubits. A qubit is a unit of information in a quantum computer. Decoherence brings errors into a quantum computer: the environment interacts with the computer, and the quantum state of the computer spreads into the environment. A quantum code is an error-correcting code that protects the information of a quantum memory against the errors of decoherence. The logical error rate is the rate at which an error-corrected quantum memory loses the state the memory encodes, per cycle of error correction. Gerard 't Hooft's limit would show as a limit of principle on

how far the logical error rate can fall. For every claim of a common cause, the deciding measurements are Bell tests and the cosmic forms of Bell tests, where a common cause is a shared past that would fix both the settings of the measuring devices and the particles measured. In a Bell test, physicists compare the correlations between two distant measurements with Bell's inequality, while in a cosmic Bell test, the physicists choose the measurement settings from the light of distant stars or quasars. The collection excludes a perfectly determined world by a claim of logical form, a claim settled by argument and not by measurement. The exclusion follows from the structure of comparison, and no single experiment decides the exclusion.

Where each is set out. I set out one model of this section in full in each of the chapters on Hossenfelder, 't Hooft, Smolin, Deutsch, Carroll, Bohr, Zeilinger and Gisin. The chapters on Hossenfelder, 't Hooft, Bohr, Zeilinger and Gisin are in Volume Two, the chapter on Carroll is in Volume Three, the chapter on Deutsch is in Volume Four, and the chapter on Smolin is in Volume Six.



Section VII

Did Inflation Happen?

The question. In this book, an epoch of the universe is one stretch of the history of the universe, from one beginning to the next, and our epoch is the stretch in which we live. Inflation is a proposed phase of very rapid expansion at the beginning of an epoch. The metric is the geometry of space and time. Waves of the metric are gravitational waves: waves in the geometry itself. Primordial waves of the metric would be gravitational waves made at the very beginning of the epoch. Did our epoch begin with a long phase of inflation, which stretched the regions of our epoch apart and left primordial waves of the metric behind?

Physics from comparison. No: our epoch did not begin with a long phase of inflation. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. The collection registered the answer no as Prediction 13 of the collection's sealed record, the register of forty-two predictions that the collection sealed on 1 November 2026 and does not revise. The early horizon is the greatest distance that a signal could have crossed by an early time in the epoch. Prediction 13 reads: "No inflationary phase long enough to stretch the lengths observed today from within the early horizon to beyond it occurred". Prediction 13 says that no phase of inflation stretched the lengths that we observe today from within the early horizon to beyond the early horizon. The collection also registered Prediction 10, which reads: "the ratio of tensor to scalar power is far below $10{-}6$. The Simons Observatory and LiteBIRD will find no primordial tensor signal". The ratio of tensor to scalar power is the power of the primordial gravitational waves relative to

the power of the primordial departures of density, which are the small differences in density from place to place at the beginning of the epoch. The Simons Observatory and LiteBIRD are two instruments that will measure the microwave background, the faint glow of microwaves that fills the sky and is the oldest light that astronomers can see. A primordial tensor signal would be a mark of primordial gravitational waves in the microwave background.

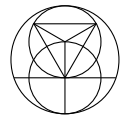
Some regions of our epoch are so far apart that no signal has connected the regions, and still the regions are alike. Inflation is the standard explanation of why the regions are alike. The collection gives another explanation. The turn is the passage from the end of one epoch of the universe to the beginning of the next. The turn happens at the end of every black-hole interior, the region inside a black hole. The old epoch ends at the turn, and the interiors of the old epoch end there together. On the collection's account, the regions of our epoch are alike because every region comes from one domain: the common end of the black-hole interiors of the old epoch at the turn.

The collection also accounts for the departures from uniformity, the small differences from place to place by which our epoch began less than perfectly even. In the collection, a measurement is a comparison, an act that sets one thing beside another, and the content of a comparison is what is found in the comparison: in physics, the quantum matter. The form of the content passes through the turn from the old epoch into our epoch, and the departures from uniformity are that form: the pattern of the content from place to place. The collection excludes a long inflation because the collection holds that the departures on the largest scales are the form carried through the turn, and not departures made during a phase of inflation. A shorter phase of inflation is neither required nor excluded. The collection argues the answer in Chapter 18, Section IX of the collection's book *The Gravitational Passage* and in the collection's book *The Compactification*.

Who stands where. The physicist Max Tegmark holds that inflation is real and eternal, with many regions. On Tegmark's account, inflation goes on forever in some places, and new regions keep forming. A single-field model of inflation is a model in which one field drives the inflation. Among single-field models, the models that Tegmark regards as best motivated give a ratio of tensor to scalar power of about 0.03. Measurement already excludes the ratio of about 0.15 that Tegmark gives for inflation at high energy, because measurement bounds the ratio of tensor to scalar power below 0.032 (Tristram and others 2022). Sean Carroll and Jennifer Chen are the physicists who proposed, in 2004, that de Sitter space can spawn a patch of space that inflates. De Sitter space is the quiet, empty state toward which a universe with a small positive energy of the vacuum settles. Carroll and Chen's route needs de Sitter space to be unstable. An unstable de Sitter space would now and then give rise to a region that inflates. In 2014 Carroll found, with the physicists Kimberly Boddy and Jason Pollack, that de Sitter space is not unstable in its quiet vacuum. De Sitter space settles into the quiet vacuum, a state with no quantum fluctuations that change with time. The cosmologist George Ellis keeps inflation as one option among others for how our epoch began, and Ellis names the tests that bear on inflation. The physicist Roger Penrose agrees with the collection: on Penrose's account, no inflation happened at all. Penrose's own model is conformal cyclic cosmology, in which the universe passes from one epoch to the next.

What decides it. The polarization of the microwave background decides the question, and the Simons Observatory and LiteBIRD will measure that polarization. The polarization of light is the direction in which the waves of the light vibrate, and primordial gravitational waves would leave a pattern in the polarization of the microwave background. If the two instruments find a primordial tensor signal, the signal refutes Prediction 10, and inflation passes the test. If the two instruments find no primordial tensor signal, the absence of a signal sets a bound on the energy that any inflation could have had, because inflation at a higher energy would leave stronger primordial gravitational waves.

Where each is set out. Tegmark, Carroll, Ellis and Penrose each have a chapter of their own in this book. Each of the four chapters sets out the person's model in full. The chapters on Carroll and Penrose are in Volume Three, the chapter on Tegmark is in Volume Four, and the chapter on Ellis is in Volume Five.



Section VIII

Is Space Flat?

The question. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. On the collection's account, the universe passes through a sequence of epochs. Our epoch is the epoch in which we live. Is the space of our epoch, taken as a whole, flat, or curved like the surface of a sphere or a saddle? On a flat sheet, two lines that start out parallel stay parallel, while on the surface of a sphere two such lines come together, and on a saddle they spread apart.

Physics from comparison. Space is flat, and curved only by its departures from uniformity. The departures from uniformity are the small differences in density from place to place with which the epoch begins. A horizon is the boundary of the region from which light has had time to reach an observer. The collection registered its answer as Prediction 9 of its sealed record: "The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10−5". So Prediction 9 makes two claims: the epoch begins with flat space, and any curvature measured within one horizon is the curvature of the departures. The collection argues for Prediction 9 in its book *The Gravitational Passage*, in Chapter 18, Section IX. The state that begins the epoch is the state from which the history of the epoch begins. The argument for Prediction 9 starts from what that state holds, and it runs in five steps. First, the curvature of space is a constant of integration, which is a number that the law of the geometry (the field equations of general relativity) leaves free and that the state that begins the epoch sets once. Second, no

length and no count (no number of things counted) passes from the old epoch across the turn, which is the passage from the end of one epoch to the beginning of the next. The cosmological constant is the constant term of the field equations of general relativity, the term that drives an accelerating expansion. Third, the cosmological constant belongs to the law and not to the state, and so does every other constant of the law. *The Gravitational Passage* says that at the turn the cosmological constant "acts as nothing at all". Fourth, the state that begins the epoch therefore holds only the length of the turn and pure numbers of order one, which are numbers with no units that are close to one. So the state could set a radius of curvature only as the length of the turn multiplied by a number of order one. The collection states the conclusion of the first four steps in one sentence: "So the radius is of the order of the length of the turn, or there is none". The length of the turn is of the order of the Planck length. Fifth, the cycle of epochs excludes a radius of curvature of the order of the length of the turn, because a radius that small would make the new epoch collapse again almost as soon as the epoch began, or leave the new epoch dominated by its curvature. Neither kind of epoch would produce the structure that the cycle requires. So there is no radius of curvature, and the epoch begins flat. The collection says of this argument: "The argument uses nothing of the cosmological constant, neither its value nor its sign". So the flatness of space does not depend on the size or the sign of the cosmological constant. The collection also sets out this argument for flatness step by step, in its essay Why the New Epoch Is Flat.

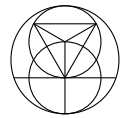
Who stands where. The cosmologist George Ellis builds a model that he calls the emergent universe, whose history begins from a static universe: a universe with a radius of its own, which neither expands nor contracts. The space of the emergent universe is therefore closed. A closed space is finite in extent and has no edge, as the surface of a sphere is finite and has no edge. Ellis and the collection dispute one premise: whether the state that begins the epoch holds a length of its own. The physicist John Archibald Wheeler held that space is closed, so that space is finite, as he took Mach's principle to require. Mach's principle is the principle, named

for the physicist Ernst Mach, that the inertia of each body is set by the rest of the matter in the universe. A flat space can also close, as a flat torus does. Take a flat sheet, and join its left edge to its right edge and its top edge to its bottom edge: the result is a flat torus. When a traveler leaves the sheet by one edge, the traveler comes back in by the opposite edge. So a flat torus is a finite flat space with no edge. Prediction 23 of the sealed record says that no closed path around the universe is shorter than the diameter of the horizon, at any location. Suppose that space is flat and closes on a scale larger than every horizon. Then space is finite, so it satisfies Wheeler's condition that space be finite. Space then also satisfies Predictions 9 and 23, because it is flat, and every path around it is longer than the diameter of any horizon. The physicist Max Tegmark agrees with the collection that space is flat, and so do Mordehai Milgrom, who founded modified Newtonian dynamics, and Stacy McGaugh, who has carried modified Newtonian dynamics forward. The physicist Roger Penrose holds that each epoch begins even, and he states the even beginning as his Weyl curvature hypothesis: the Weyl curvature, the part of the curvature of spacetime that distorts shapes, was near zero at the beginning. Penrose's even beginning of each epoch agrees with Prediction 9. The physicists Sean Carroll and Heywood Tam argue for flatness in a different way. A homogeneous cosmology is a model of the universe that is the same at every place. A measure on homogeneous cosmologies is a rule that weighs how much of the range of possible cosmologies has each property. The physicists Gary Gibbons and Neil Turok computed the natural measure on homogeneous cosmologies, and Carroll and Tam argue that flat space is typical under that natural measure, which means that nearly all homogeneous cosmologies are flat, as the natural measure weighs them. The philosopher of physics Casey McCoy disputes the argument of Carroll and Tam. The collection's argument for flatness does not rest on the argument of Carroll and Tam.

What decides it. Measurement bounds the curvature of space. The curvature share is the curvature of space stated as a share of the critical density, which is the density of energy at which space would be exactly

flat, so a curvature share of zero means flat space. DESI, the Dark Energy Spectroscopic Instrument, maps the galaxies. DESI gives a curvature share of 0.0023 ± 0.0011 in combination with the microwave background, the oldest light in the sky. DESI and the Euclid space telescope will measure the curvature share to a part in a thousand. No measurement can settle the curvature share more finely than about $1.5 \times 10{-}5$, which is the size of the departures from uniformity themselves (Waterhouse and Zibin 2008), because at that size the departures blur the curvature of space as a whole. So exact flatness is settled by argument: the argument from what the state that begins the epoch holds.

Where each is set out. The chapters on Ellis, Wheeler and Tegmark set out their models in full. The chapter on Ellis is in Volume Five, and the chapters on Wheeler and Tegmark are in Volume Four.



Section IX

What Is the Dark Matter?

The question. Galaxies, and the clusters in which galaxies gather, hold more mass than the light of the galaxies and the clusters shows. Astronomers call the mass that the light does not show the dark matter. What is the dark matter, and how much dark matter is there?

Physics from comparison. The dark matter is made of gyrations. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. On the collection's account, every point of space carries six internal dimensions: the internal space, made of a complex projective plane and a sphere. Nothing travels through the six internal dimensions, and the six internal dimensions are held: kept at the same size and shape at every point. A gyration is an excitation of the six held internal dimensions: a vibration of the internal geometry. A gyration is conserved: once a gyration is made, the gyration is kept. Each gyration has about the Planck mass, the mass of an object whose gravitational size equals its quantum size. The Planck mass is of the order of a hundred-thousandth of a gram. Gyrations act only through gravity. A gyration has energy, so a gyration gravitates. But a gyration is a vibration of the context of physics, the geometry, and not of the content of physics. In physics, the content is the quantum matter that instruments register. So nothing that registers content registers a gyration. Gyrations are also perfectly cold: cold dark matter is dark matter that moves slowly enough to gather into clumps under its own gravity, and on the scales of galaxies gyrations cluster exactly as the standard cold dark matter of cos-

mology does. Gyrations do not decay. A symmetry keeps each gyration from decaying: the antipodal parity of the sphere, which takes each point of the sphere to the opposite point.

The collection registered its answers in its sealed record, the forty-two predictions fixed on 1 November 2026. Prediction 16 says how much dark matter there is: "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". In the formula, Ωc stands for the density of the dark matter, and Ωb stands for the density of the ordinary matter, the matter that atoms are made of. So Prediction 16 says that, across the universe, there are 5.3634 grams of dark matter for every gram of ordinary matter, and that the ratio has stayed the same since helium formed, early in the history of the universe. Prediction 19 says how the dark matter acts: "No search will detect the dark matter through any interaction but gravity, at any sensitivity".

The collection argues for its account of the dark matter in its book *The Weight of Possibility*, which shows, in Chapter 4, Section V, that the internal dimensions give gauge fields. A gauge field is a field of force of the same general kind as electromagnetism. *The Weight of Possibility* shows next that the internal gauge fields undergo confinement at the Planck scale, the scale of the Planck mass. Confinement binds the charges of a field into neutral bound groups, so that the field does not reach long distances. So the internal gauge fields give the gyrations no force at long range, and at long range the gyrations act only through gravity. In Chapter 3, *The Weight of Possibility* derives the ratio of Prediction 16 from a count of the classes of the internal space. On the count of classes, the share of the dark matter is six classes less $2/\pi$, the share of the curvature of the complex projective plane, and the share of the ordinary matter is one class.

Who stands where. The physicist Mordehai Milgrom founded modified Newtonian dynamics, and the astronomer Stacy McGaugh has carried modified Newtonian dynamics forward. Milgrom and McGaugh need no dark matter in galaxies, because on their account the law of gravity changes when an acceleration falls very low. An acceleration is the rate

at which a velocity changes. In clusters of galaxies, the changed law of Milgrom and McGaugh still leaves a residual mass of its own: even under the changed law, the clusters hold more mass than the light of the clusters shows. The microwave background is the oldest light in the sky. Astronomers chart how strongly the spots in the microwave background show at each size. The chart has a series of peaks. The third peak of the chart counts against the law of Milgrom and McGaugh in its first form, as Milgrom first proposed the law.

The physicist Erik Verlinde makes the dark matter apparent. On Verlinde's account, what astronomers take for unseen matter is an effect of the entropy of the de Sitter horizon. Entropy measures the number of ways the parts of a system can be arranged with no change that can be seen from outside the system. The de Sitter horizon is the farthest distance from which light can ever reach us in a universe whose expansion keeps speeding up. Verlinde's relation ties the amount of the apparent dark matter to the amount of the ordinary matter, and at the density of ordinary matter that the collection uses, the relation gives a ratio of 5.24, where Prediction 16 gives 5.3634. Verlinde derived his formula in a static setting, one that does not change with time. The Hubble radius is the distance at which the expansion of the universe carries galaxies away from us at the speed of light. Verlinde applies his formula at the Hubble radius to derive the ratio of 5.24, but the Hubble radius lies outside the static setting in which Verlinde derived the formula.

The physicist Max Tegmark considers an axion whose density varies from region to region of the universe. An axion is a kind of particle. The physicists Roberto Peccei and Helen Quinn proposed the axion in 1977, for a problem in the theory of the strong force. The physicist Sean Carroll and his colleagues explored a dark force, a new long-range force like electromagnetism that acts on the dark matter and not on ordinary matter (Ackerman and others 2009). The collection's internal dimensions give gauge fields of the same kind as the dark force of Carroll and his colleagues, but the internal gauge fields confine at the Planck scale and do not reach long distances. The physicist Roger Penrose calls his dark matter erebons, and

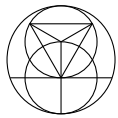
erebons have about the Planck mass, as gyrations do. Erebons decay, and gyrations do not decay. In Penrose's cosmology, the universe passes through a series of epochs, which Penrose calls aeons, and the erebons of each aeon must decay within the same aeon. The physicists Jonathan Oppenheim and Andrea Russo explain the motions of galaxies by the random wandering of a classical geometry, without dark matter. In Oppenheim's theory, the geometry of space and time is classical: when a mass is in two places at once, one geometry serves both places. Oppenheim's theory requires the classical geometry to wander at random, and Oppenheim and Russo argue that, at low accelerations, the random wandering acts like additional matter.

What decides it. Astronomers need a second, independent kind of measurement of the ratio of the dark matter to the ordinary matter. The second kind of measurement decides how much dark matter there is. Under the collection's rule of decision, a result counts only when at least two independent kinds of measurement establish the result at five standard deviations. A standard deviation measures the uncertainty of a measurement. When a value lies several standard deviations from a prediction, the value is unlikely to differ from the prediction by chance. The survey DESI maps galaxies. DESI measures the baryon oscillations, a pattern in how far apart galaxies tend to lie. When analysts add the baryon oscillations of DESI to the microwave background, the combined analyses give a ratio of 5.199 ± 0.035 (Louis and others 2025), which is 4.7 standard deviations away from the 5.3634 of Prediction 16. The departure of 4.7 standard deviations comes from one kind of measurement. The departure is about 4.0 standard deviations if the analyses allow for a correlation of -0.4 between the two densities, which are the density of the dark matter and the density of the ordinary matter. A negative correlation means that a higher value of one density tends to come with a lower value of the other.

Three other kinds of observation decide the rest of the collection's account, one for each of three properties of the gyrations: acting only through gravity, not decaying, and being perfectly cold. Underground searches decide whether the dark matter acts through anything but grav-

ity, because an underground detector watches for a particle of dark matter that strikes an atom of the detector and makes the atom recoil. The expansion history of the universe decides whether the dark matter decays, because dark matter that decayed would thin out faster than ordinary matter as the universe expands, and the measured history of the expansion would show the difference. Counts of clumps that hold no stars decide whether the dark matter is perfectly cold, because cold dark matter moves slowly and gathers into clumps of every size, down to clumps too small to hold any stars.

Where each is set out. I set out each of the other models in this section in full, in a chapter of its own: the chapters on Milgrom and McGaugh, Verlinde, Tegmark, Carroll, Penrose and Oppenheim. Volume Five holds the chapters on Milgrom and McGaugh and on Verlinde, and Volume Four holds the chapter on Tegmark.



Section X

Is There a Constant of Acceleration?

The question. The motions within galaxies follow the visible matter of each galaxy tightly. The visible matter of a galaxy is the stars and gas of the galaxy. Astronomers find the acceleration of the stars and gas in a galaxy from the speed and size of the orbits of the stars and gas, and then compare that measured acceleration with the acceleration that the pull of the visible matter alone would produce. The two accelerations are tied by one relation, which astronomers call the radial acceleration relation. The motions of the galaxies scatter only a little about the radial acceleration relation. Where the accelerations are large, the measured acceleration equals the acceleration that the visible matter alone would produce, while below one small acceleration the motions show more acceleration than the visible matter alone would produce. So the relation turns near one small acceleration. The question is whether the small acceleration at which the relation turns is a constant of the law of gravity, a fixed number written into the law itself.

Physics from comparison. No. In this book, "the collection" is the physics collection of the Immanent Metaphysics, and physics from comparison is the physics of the collection. The collection states the answer in its book *The Weight of Possibility*, Chapter 5, Section V: "The field equations hold Newton's constant and the cosmological constant, and no constant of acceleration". The field equations are the equations of general relativity, the law of gravity on the collection's account. Newton's constant is named

for the physicist Isaac Newton. Newton's constant sets how strongly each mass pulls on every other mass. The cosmological constant is the constant energy of the vacuum, which draws distant bodies apart.

The motions within galaxies follow the radial acceleration relation tightly because of the way the galaxies formed. The galaxies formed in a universe that holds a cold component, a kind of matter that acts only through gravity. The cold component is the dark matter. On physics from comparison, the dark matter is made of gyrations (Section IX). A component is "cold" when its particles move slowly, so that gravity gathers the particles into clumps. The same chapter says that the acceleration at which the relation turns is "set by formation and not by a constant of the field equations". A cluster of galaxies is a group of many galaxies held together by gravity. The clusters of galaxies show that formation sets the acceleration, and astronomers have measured the relation in clusters (Tian and others 2020, 2024). The galactic value is the acceleration at which the relation turns in single galaxies. In clusters the relation has the same form as in single galaxies, but the relation turns at about seventeen times the galactic value. A constant of the law of gravity would make the relation turn at one acceleration wherever astronomers measure the relation, so the different value in clusters shows that formation, and not the law of gravity, sets the acceleration at which the relation turns.

On physics from comparison there is also no external field effect. Modified Newtonian dynamics is a changed law of gravity, under which gravity departs from Newton's law below one fixed small acceleration. Modified Newtonian dynamics predicts an external field effect. The external field effect is a change in the internal motions of a system, such as a galaxy, caused by the uniform field of a larger body in which the system falls freely. A uniform field is a pull of the same strength and direction at every point of the system. A galaxy falls freely when nothing but gravity acts on the galaxy, as when a small galaxy orbits a larger one. The collection registered its answer as Prediction 24 of its sealed record. The sealed record is the dated record of the collection's predictions, fixed before the measurements that decide the predictions. Prediction 24 reads: "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". The tide of the larger body is the part of its pull that differs from one side of the small galaxy to the other. The rest of the pull is the same across the small galaxy, so the uniform part of the pull moves the whole galaxy together and leaves the internal motions of the galaxy as they were.

Who stands where. The physicist Mordehai Milgrom founded modified Newtonian dynamics, and the astronomer Stacy McGaugh has carried it forward. Milgrom and McGaugh hold that the acceleration at which the radial acceleration relation turns is a constant of the law of gravity. If a law of gravity holds a constant of acceleration, the law predicts the external field effect, because under the law the whole acceleration of a star decides whether gravity departs from Newton's law at the star. The uniform pull of a larger body adds to the whole acceleration of every star in a galaxy that falls toward the larger body, and so the uniform pull changes the internal motions of the galaxy. Milgrom and McGaugh are credited with the baryonic Tully and Fisher relation and the radial acceleration relation. The baryonic Tully and Fisher relation ties the mass of the ordinary matter of a galaxy (the stars and gas of the galaxy) to the speed at which the outer parts of the galaxy orbit. The baryonic Tully and Fisher relation is named for the astronomers Brent Tully and Richard Fisher. The radial acceleration relation is the tight relation described at the start of this section, between the acceleration that the visible matter of a galaxy would produce and the acceleration that the motions of the galaxy show. Milgrom and McGaugh are also credited with predictions made before the measurements. One prediction made before the measurements concerns Crater II, a faint small galaxy that orbits our own galaxy.

The physicist Erik Verlinde also answers yes, and on Verlinde's account the de Sitter horizon sets the acceleration at which the relation turns. The de Sitter horizon is the boundary beyond which light can never reach us, in a universe whose expansion is driven by the cosmological constant. Verlinde's account says nothing about the external field effect.

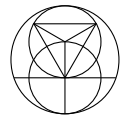
The physicist Lee Smolin also answers yes: Smolin derives modified Newtonian dynamics as a regime, a range of conditions, in which inertia responds to the temperature that physicists assign to the de Sitter horizon. The inertia of a body is its resistance to any change in its motion. The weight of a body is the pull of gravity on the body. On the collection's account, inertia and weight are one relation: the relation of a body to its context (*The Unquantized Arena*, Proposition 5.3). In the collection's terms, the context of a body is the geometry of space and time in which the body is found. So no temperature of the de Sitter horizon can act on the inertia of a body apart from the weight of the body.

Three clues bear on the galactic value, the acceleration at which the radial acceleration relation turns in single galaxies. First, the physicists Jonathan Oppenheim and Andrea Russo write the galactic value as the square root of one third of the cosmological constant, divided by 2π. Second, on Verlinde's account the galactic value is one sixth of the speed of light times the Hubble constant. The Hubble constant is the rate at which the universe now expands. Third, the relation in clusters turns at about seventeen times the galactic value. The galactic value lies near the speed of light times the Hubble constant divided by 2π, but I leave for another day the question of why the galactic value lies there.

What decides it. Three measurements decide the question. The first measurement is the internal motions of galaxies that fall freely in the field of a larger one, with the effect of the outside field separated from the effect of the surroundings in which each galaxy formed. The two effects must be separated because on physics from comparison formation sets the motions of a galaxy, and a galaxy near a larger one formed in different surroundings from a galaxy far from any other. The second measurement is the motions of wide binary stars at accelerations below the acceleration at which the relation turns in galaxies. A wide binary is a pair of stars that orbit each other at a great distance, so each star pulls on the other weakly. If the law of gravity held a constant of acceleration, the orbits of wide binaries would depart from Newton's law, while on physics from comparison

the orbits of wide binaries follow the field equations, which hold no constant of acceleration. The third measurement is the acceleration at which the relation turns, measured in clusters of galaxies.

Where each is set out. Every other model in this section has a chapter of its own that sets the model out in full. The chapters are those on Milgrom and McGaugh, Verlinde, Smolin and Oppenheim. The chapter on Oppenheim is in Volume Three, Volume Five holds the chapters on Milgrom and McGaugh and on Verlinde, and Volume Six holds the chapter on Smolin.



Section XI

Is the Energy of the Vacuum a Constant?

The question. The universe expands: the distances between galaxies far from one another grow with time. The expansion of the universe accelerates, which means that the distances between far-apart galaxies grow faster and faster as time goes on. Is the cause of the acceleration a constant, or a field that changes? The vacuum is empty space, and the energy of the vacuum is the energy that empty space itself carries, with no matter in the space. If the cause is a constant, the energy of the vacuum is the same in every cubic meter of space, everywhere and at every time. If the cause is a field that changes, the energy that drives the acceleration changes from place to place or from time to time.

Physics from comparison. The cause is a constant. In this book, "the collection" is the physics collection of the Immanent Metaphysics. Physics from comparison is the physics of the collection. The collection registered its answer as Prediction 8 of its sealed record. The sealed record is the dated record of the collection's predictions, fixed before the measurements that decide the predictions. Prediction 8 reads: "The energy of the vacuum has an equation of state of exactly -1, at every epoch". For any component of the universe, the equation of state is the pressure of the component divided by the energy density of the component. The energy density of a component is the energy of the component in each unit of volume. When the equation of state of a component is exactly -1, the component keeps the same energy density however far space expands, so an equation of state of exactly -1 is the equation of state of a cosmological constant, a constant energy of the vacuum. In this book, an epoch of the

universe is one stretch of the history of the universe, from one beginning to the next, so "at every epoch" means that the energy of the vacuum has the same equation of state in every epoch.

The cosmological constant is the constant term of the field equations of general relativity: a fixed number written into the equations, which drives an accelerating expansion. The field equations of general relativity are the law of gravity: the equations that tie the geometry of space and time to matter. The collection's book *The Gravitational Passage* states two claims about the cosmological constant, in Chapter 13, Section VI. First, the cosmological constant is fixed once, as the constant term of one geometry, and the sealed record adds that "the field equations do not let such a term vary from place to place or from epoch to epoch".

The second claim of *The Gravitational Passage* is about the lumps of matter. Matter in the universe is gathered into lumps, such as galaxies and clusters of galaxies, with thinner regions between the lumps. To average the lumps is to take the combined effect of the lumps on the expansion over large regions of space. If the averaged lumps acted as a constant term, the lumps of matter could drive the acceleration in place of a cosmological constant. The physicists Stephen Green and Robert Wald studied the effect of the lumps on the expansion in 2011, and the second claim of *The Gravitational Passage* is the result of Green and Wald: the averaged lumps of the universe do not act as a constant term (Green and Wald 2011).

Who stands where. The cosmologist George Ellis has argued that the acceleration may be an effect of the inhomogeneity of the universe. The inhomogeneity of the universe is the unevenness with which matter is spread through space. Ellis took the other side of the dispute over the result of Green and Wald, and argued against the result that the averaged lumps of the universe do not act as a constant term. The void form is one form of the alternative that Ellis has argued for. In the void form, our galaxy lies near the center of a vast void, a region with much less matter than the average, and so the expansion only appears to accelerate. Measurements of the motions of clusters of galaxies already exclude the void

form, because if our galaxy lay near the center of a vast void, clusters of galaxies far from us would move faster, relative to the microwave background, than the measured motions of clusters allow. The microwave background is the oldest light in the sky.

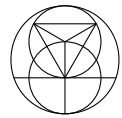
The astronomer Arthur Eddington held that the cosmological constant is a true constant, a number that never changes, as the collection holds. The physicist Max Tegmark agrees with the collection that the equation of state of the energy of the vacuum is -1, and Mordehai Milgrom and Stacy McGaugh also agree with the collection on -1. Milgrom founded modified Newtonian dynamics, a changed law of gravity at small accelerations, and McGaugh has carried modified Newtonian dynamics forward.

What decides it. Two measurements decide the question. The first measurement is the equation of state of the energy of the vacuum, as DESI, Euclid and Rubin measure the equation of state. DESI is the Dark Energy Spectroscopic Instrument, which maps the galaxies, while Euclid is a space telescope and Rubin is the observatory named for the astronomer Vera Rubin. Astronomers will set the measurements of DESI, Euclid and Rubin against the reported departure from -1. Astronomers have combined the final analysis of the Dark Energy Survey, a completed survey of the sky, with DESI and the microwave background, and one family of such combined studies reports an equation of state that departs from -1 by about three standard deviations. A standard deviation is the measure of the uncertainty of a measurement. Under the collection's rule of decision, a result counts only when at least two independent kinds of measurement establish the result at five standard deviations. The reported departure is about three standard deviations and rests on one family of combined studies, which is one kind of measurement, so the reported departure has not reached the rule of decision. The sealed record says that the reported departure from -1 will not be confirmed.

The second measurement is the drift of redshifts over time. The drift of redshifts bears directly on the premise of the question, that the expansion of the universe accelerates. The redshift of a distant galaxy is the stretching of the galaxy's light to longer wavelengths by the expansion, while the

light travels to us. As the expansion goes on, the redshift of each distant galaxy changes little by little, and astronomers call the change the drift of the redshift. Astronomers can find the drift by measuring the redshifts of the same distant galaxies again after many years, and the drift tests directly whether the expansion accelerates, because the drift comes from the change in the rate of expansion while the astronomers wait.

Where each is set out. Ellis, Eddington and Tegmark each have a chapter that sets out his model in full. The chapters on Ellis and Eddington are in Volume Five, and the chapter on Tegmark is in Volume Four.



Section XII

How Many Dimensions Has Space?

The question. Space has three directions of extension wherever we look: up and down, left and right, and forward and back. Physicists call the number of directions of space the dimension of space. Must space have three directions? An epoch is one stretch of the history of the universe. Or could space have another number of directions in another region of the universe, or in another epoch?

Physics from comparison. On the account of physics from comparison, space has three directions by necessity. In this book, "the collection" is the physics collection of the Immanent Metaphysics, and physics from comparison is the physics of the collection. In the collection, a measurement is a comparison, an act that sets one thing beside another. Every comparison has a content, which is what is found, and a context, in which the content is found. In physics the context is the geometry of space and time, which this book calls the arena. The collection takes the act of comparison as the ground of physics, which means that the collection builds every other part of the collection's physics on the act of comparison. The structure of comparison is what every act of comparison has in common: a content, found in a context.

The collection's book *Measurement*, in Chapter 11, counts three ways of space, where the ways of space are the directions in which space extends. Chapter 11 counts the ways at the level of the ground, the level of the act of comparison itself. At the level of the ground, Chapter 11 counts a way of space as a way only by the work that the way does in the structure of comparison. A finding is an interaction that registers which of several al-

ternatives holds, such as a detector that either clicks or stays silent. Every finding is made along ways that the context of the finding already has. So no finding can add a way to space. The form of space is the structure that space has as the context of every finding. A way belongs to the form of space only when the way does work in the structure of comparison. So a fourth way is no way of the form of space when the fourth way does no work in the structure of comparison.

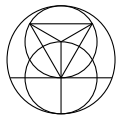
Chapter 11 contains one image for the argument that no finding can add a way to space, and the image reads: "the rules of a board fix its ranks, and no move can establish a rank the rules do not supply, since a move along a rank already presupposes the rank". A rank is one row of squares across the board in a game such as chess. The parts of the image match the parts of the argument of Chapter 11: the rules of the board represent the form of space, the ranks represent the ways of space, and a move represents a finding. A move along a rank needs a rank that the rules already supply, so no move can add a rank to the board. No finding can add a way to space for the same reason: a finding along a way of space needs a way that the form of space already has.

Who stands where. The computer scientist Stephen Wolfram builds space from a discrete network, a set of separate points joined by links. One rule rewrites the network step by step. Wolfram reads the dimension of space from the way the network grows: Wolfram counts the points that lie within a given number of links of one point, and the dimension is the rate at which the count of points grows as the number of links grows. On Wolfram's account the dimension of space therefore emerges from the rule that rewrites the network, and so the dimension can differ in another region of the universe or in another epoch. Wolfram and the collection dispute one premise: whether the number of ways of space belongs to the form of the context (the form of space), as the collection holds, or to the connections of a network, as Wolfram holds. The physicist Max Tegmark agrees with the collection that our region of the universe has three directions of space and one direction of time.

What decides it. Every measurement of the world on large scales so far finds three directions of space. Spacetime is space and time taken together, so three directions of space and one direction of time make four dimensions of spacetime. Gravitational waves are waves in the geometry of space and time. A neutron star is the small, very dense remnant of a star that has collapsed. When two neutron stars merged, detectors on Earth caught the gravitational waves of the merger, and telescopes caught the light of the merger, which showed the galaxy in which the merger happened. If spacetime had more than four dimensions, gravitational waves would weaken faster with distance than in four dimensions, so the merger would seem farther away by the merger's gravitational waves than by the distance of the merger's galaxy. The physicists Pardo, Fishbach, Holz and Spergel compared the distance given by the gravitational waves of the merger with the distance of the merger's galaxy, and from the comparison of the two distances the gravitational waves of the neutron star merger give 4.02 and 3.98 dimensions of spacetime (Pardo and others 2018). The values 4.02 and 3.98 come from two different measured values of the rate at which the universe expands. Both values lie close to four.

The polarization of a gravitational wave is the pattern in which the wave stretches and squeezes space as the wave passes. Prediction 6 belongs to the sealed record, the register of forty-two predictions that the collection sealed on 1 November 2026 and does not revise. Prediction 6 says that gravitational waves have two polarizations and travel at the speed of light, and that no further polarization will be found. In general relativity a gravitational wave has exactly two polarizations when spacetime has three directions of space and one of time, while a gravitational wave has more polarizations when spacetime has more directions. Two findings would decide against the collection: a region or epoch in which space has another number of directions, or a wave of the geometry with a polarization beyond the two polarizations of Prediction 6.

Where each is set out. Wolfram and Tegmark each have a chapter in this book. Each chapter sets out one person's model in full. Both chapters are in Volume Four.



Section XIII

Where Does the Arrow of Time Come From?

The question. The laws of mechanics run as well backward as forward, and the world does not. The laws of mechanics are the laws that say how bodies and particles move. When two billiard balls collide and roll apart on a table with no friction, a film of the collision looks just as right when run backward, because the laws of mechanics allow the motion in both directions. When a cup falls from the table and breaks on the floor, a film of the fall looks wrong when run backward, because in the world a broken cup never gathers itself up from the floor. Physicists call the single direction in which the world runs the arrow of time. The question is where the difference between the laws and the world lies: what gives time its arrow, when the laws of mechanics run as well in both directions?

Physics from comparison. In this book, "the collection" is the physics collection of the Immanent Metaphysics, and physics from comparison is the physics of the collection. On physics from comparison, the laws of physics are symmetric in time to an extraordinary degree, and never perfectly. When a law allows every motion to run backward as well as forward, physicists call the law symmetric in time. The arrow of time lies beneath the laws, in the order of findings: on physics from comparison the arrow comes first, before the laws. A finding is an interaction that registers which alternative is the case. An instrument or an environment can make a finding, with no mind needed. The order of findings is the one-way order in which each finding is made: from the range of what could be found, to the act of finding, to the record that the act leaves. In physics, the evolution of a system is the change of the state of the system over

time, as the laws describe the change. A reversal of evolution runs the change of state backward, and physicists can reverse evolution on paper, by applying the inverse of the equations, or in a laboratory, by a pulse that turns the motion around. No reversal of evolution removes a finding from the order of findings (Prediction 28; *The Basis of Physics*, Essay 11). Prediction 28 is one of the forty-two predictions of the sealed record. The sealed record is the dated record of the collection's predictions, fixed before the measurements that decide the predictions.

On the collection's account the universe passes through one epoch after another, and our own epoch began at the Big Bang. The turn is the passage from the end of one epoch to the beginning of the next, at the end of every black-hole interior, and no comparison registers the turn as an event. On the collection's account every count is a count relative to some context, the arena in which the things counted are found. In physics the arena is the geometry of space and time. Entropy is a count: the number of ways in which the parts of a system can lie without changing what an observer measures of the system as a whole, such as the temperature and the pressure of the system. At the turn every count of the old epoch ends together with the context that the count was a count of, so the entropy of the old epoch does not pass into the new epoch. Each epoch begins a count of its own. So nothing accumulates from one epoch to the next.

Who stands where. The physicist Julian Barbour holds that time is not real at the foundation of physics, and that the arrow of time grows from a Janus point of least complexity in a timeless configuration space. Barbour's configuration space is the set of every possible arrangement of the whole universe. The configuration space is timeless, because nothing in the configuration space flows or changes. The complexity of an arrangement is how much structure the arrangement has: how clumped and varied the parts of the arrangement are, so that a universe of stars and galaxies is more complex than an even spread of gas. Barbour's Janus point is the arrangement of least complexity, and Barbour holds that complexity grows away from the Janus point on both sides. So the arrow of time leads

away from the Janus point on each side. Barbour named the point for Janus. Janus is the Roman god whose two faces look in opposite directions.

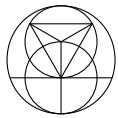
The physicist Sean Carroll places the arrow of time in a special past state, the Past Hypothesis. The Past Hypothesis is the assumption that the universe began in a state of low entropy, offered as the source of the arrow of time, and on Carroll's account the arrow comes from the low-entropy beginning of the universe.

The physicist Roger Penrose places the arrow of time in the even beginning of each epoch. In Penrose's model, conformal cyclic cosmology, one epoch follows another. The curvature of space and time has two parts: one part changes volumes, and the other part distorts shapes. Physicists call the part that distorts shapes the Weyl curvature. In 1979 Penrose proposed, as a separate principle, that the Weyl curvature was near zero at the beginning, so that the geometry of each epoch begins even, with no lumps. Penrose's proposal is his Weyl curvature hypothesis. On the collection's account a new geometry of space and time arises as a new context at the end of every black-hole interior. The collection calls the forming of the new context the restoration of context, and identifies the restoration with the Big Bang of the next epoch. The collection derives the Weyl curvature hypothesis from the restoration, as a consequence and not as a postulate. The new geometry has no past of its own to carry lumps from, because the new geometry was not a separate geometry before the turn. So the new epoch begins even.

The chemist Ilya Prigogine put the arrow of time first, before the laws, as the collection does. I say that two models "part" at the place where the two models first disagree, and the question of where chance lives is the place where Prigogine and the collection part. Prigogine placed chance in the laws themselves: Prigogine held that, for unstable systems, physicists must state the laws of motion as laws of probabilities. On physics from comparison, chance lives in each finding, because identical preparations of a system do not fix which alternative a finding registers, and so no world is perfectly determined.

Barbour, Carroll, Penrose, Prigogine and the collection differ in kind: each of the five makes a claim about what time is. No single measurement can decide a claim about what time is. The weak interaction is the force of nature behind some kinds of radioactive decay. Experiments have measured a violation of the symmetry of time in the weak interaction: some processes of the weak interaction go differently backward than forward. The measured violation agrees with the collection's claim that the symmetry of time cannot be perfect.

Where each is set out. Barbour, Carroll, Penrose and Prigogine each have a chapter that sets out his model in full. The chapters on Carroll and Penrose are in Volume Three, and Volume Six holds the chapters on Barbour and Prigogine.



Section XIV

What Are Life and Mind to Physics?

The question. Can physics describe completely, compute or measure a living thing, or a conscious thing? In the question, computing a living thing means modeling the living thing step by step in a calculation, as a computer does.

Physics from comparison. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. In the collection, comparison, interaction and relation are one act under three names. On physics from comparison, a choice is an act of comparison. A computation can model a choice, and still no computation that models a choice is the act of comparison that the choice is. The reason is the bound triple. The bound triple is the collection's name for three things: the arrow of time, which is the one-way direction of time; hard randomness, which is an outcome that no prior specification fixes, however complete; and the subjective. The three members of the bound triple are distinct, inseparable and not interchangeable, and consciousness is the bound triple taken as one act. A computation lacks the bound triple of the one who chooses. A classical computation is deterministic, so a classical computation lacks hard randomness. In the chapter on Penrose I show that a classical computation lacks the arrow of time as well. The members of the bound triple are kept or lost together, so a classical computation that lacks two members lacks the subjective too.

The physics of the brain bears on choice through criticality. On the collection's account, the brain operates near criticality, a state in which small disturbances cascade, so indeterminacy at the microscopic scale enters

chains of causes that extend to the large scale of the brain and bear on choice. The collection states exactly what criticality is and what criticality 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" (*Causality Without Determinism*, Chapter 5, Section IX). The passage separates two things: criticality, which is a physical condition of the brain, and the bound triple, which is expressed in a person when the brain is in that condition.

Who stands where. Five of the other twenty-three models have an answer to the question of this section: the models of Prigogine, Rosen, Tononi, Friston and Penrose.

The chemist Ilya Prigogine made two things the ground of life: the arrow of time, and the structures that organize themselves far from equilibrium. A system is at equilibrium when nothing in the system changes on the whole, like a cup of coffee cooled to room temperature. A system is far from equilibrium when energy keeps flowing through the system, as energy flows through a flame or a living cell, and far from equilibrium a system can organize itself into a pattern. At a branching point, a system far from equilibrium can settle into one of several patterns. The collection agrees with Prigogine that the pattern a system takes at a branching point is not fixed in advance.

The biologist Robert Rosen held two things about an organism. In Rosen's account, an organism has a model (a mathematical description of the organism) that no machine can simulate, and an organism is closed to efficient causation. An efficient cause of a thing is whatever makes the thing, as a builder makes a house, and an organism closed to efficient causation produces within itself every efficient cause at work in the organism.

The neuroscientist Giulio Tononi identifies consciousness with integrated information. Integrated information measures how far a system's power to cause and be caused upon itself cannot be reduced to the system's parts. In the collection, integrated information goes with criticality:

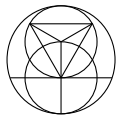
integrated information is a measure of the physical circumstance in the brain, and not a measure of what the circumstance supports, which is the bound triple expressed in a person.

The neuroscientist Karl Friston holds a principle about everything that persists: whatever persists minimizes its free energy. In Friston's sense, free energy is a quantity from the mathematics of probability. In the mathematics of probability, surprise measures how improbable a sensed state is, and the free energy of a system is never less than the surprise of what the system senses. Friston states his principle as mathematics, and not as a claim that a measurement could test.

The physicist Roger Penrose locates consciousness in orchestrated reduction, a proposal he made with the anesthesiologist Stuart Hameroff. A superposition is a quantum state that holds two alternatives together, such as a mass in two places at once, and a reduction of the state, also called a collapse, ends the superposition in one alternative. In orchestrated reduction, moments of consciousness are reductions by gravity of quantum states in the microtubules of the brain, the protein tubes inside nerve cells, so orchestrated reduction rests on gravity ending a superposition. The question of Section IV is whether a superposition ends of its own accord, without anything that registers the alternative that is the case.

Physics from comparison differs from the models of Prigogine, Rosen, Tononi, Friston and Penrose mostly in kind. A difference of kind is a difference between claims about what experience and life are. Falsification is the proof by measurement that a claim is false, and falsification does not apply to claims about what experience and life are. Measurement can test the claim that the brain operates near criticality, and integrated information has tests of its own. The searches for collapse bear on the claim that gravity ends a superposition. Where a claim can be tested by a measurement, the chapters on the five models say so.

Where each is set out. In this book, each of the five people has a chapter that sets out the person's model in full. The chapters on Prigogine, Rosen, Tononi and Friston are in Part Six, in Volume Six. The chapter on Penrose is in Volume Three.



Section XV

Can the Constants Be Derived?

The question. Can the numbers of nature be derived from first principles, or must the numbers be measured? In the question, the numbers of nature are the constants of physics, such as the strength of light. The first principles of a theory are its starting points: statements that are not derived from anything else.

Physics from comparison. In this book, "the collection" is the physics collection of the Immanent Metaphysics, whose physics is physics from comparison. In the collection, comparison, interaction and relation are one act under three names. The structure of comparison is what all acts of comparison share: for example, every act of comparison has a content, which is what is found, and a context, in which the content is found. A pure number is a number with no units, such as a ratio of two masses. A pure number has the same value in every system of units. On physics from comparison, some pure numbers are fixed by the structure of comparison, and so the books of the collection derive those numbers. Two of the derived numbers are the ratio $6 - 2/\pi$ and the matter fraction 0.311. The ratio $6 - 2/\pi$ is the ratio of the density of the dark matter to the density of the ordinary matter. The matter fraction is the share of the universe's energy carried by matter at the present epoch, in a universe whose space is flat. The matter fraction 0.311 comes from an identity with one solution: an equation that the collection derives between the energy of the vacuum and the size of the particle horizon, which bounds the part of the universe that we can observe.

Other numbers of nature are measured inputs, which are numbers that the collection takes from measurement and does not derive. The measured inputs are listed in the sealed record, which is the collection's register of forty-two predictions, whose date is 1 November 2026. The measured inputs include Newton's constant, which fixes the strength of gravitation, and the strength of light, which is the fine-structure constant, the number that fixes the strength of the electromagnetic interaction.

The ratio $6 - 2/\pi$ comes from a rule, which is a formula that gives the ratio, and the rule was chosen on a stated principle. The ratio is argued in a book of the collection, *The Weight of Possibility*. *The Weight of Possibility* describes the choice in these words: "The rule was selected from a small family of expressions of one form, and twelve expressions were examined in all" (*The Weight of Possibility*, Chapter 5, Section VIII). The rule for the ratio has a coefficient, which is a number that multiplies one of the rule's terms. The coefficient of the rule also enters the identity for the matter fraction. So the coefficient of the rule must fit a second observable (a quantity that measurement finds), the matter fraction, as well as the ratio.

Who stands where. The astrophysicist Arthur Eddington is the only builder of the other twenty-three models in this book who answers the question of this section. Eddington held that the constants can be derived by counting.

Eddington derived three numbers of nature. He derived the strength of light as exactly 1/136, and then as exactly 1/137. He also derived the ratio of the proton's mass to the electron's mass as 1847.6, and a rate of recession (also called the Hubble constant) of 528 kilometers per second per megaparsec. The rate of recession is the speed at which distant galaxies move away from us for each megaparsec of their distance. A megaparsec is a unit of distance, used for the distances between galaxies.

Measurement settled all three numbers against Eddington. Measurement gives 137.035999177 for the inverse of the strength of light (one divided by the strength of light), and 1836.152673426 for the ratio of the

proton's mass to the electron's mass. Two kinds of measurement give the rate of recession as 67.4 and as 73.04 kilometers per second per megaparsec. Both measured values lie far from Eddington's 528.

Each of Eddington's three derivations failed at a step. The strength of light is a coupling, a number that fixes how strong an interaction is. Eddington obtained the coupling from a count drawn from Dirac's algebra, the algebra of the equation that the physicist Paul Dirac wrote for the electron. But the coupling is not a count, because Dirac's algebra holds at any coupling, and so a count drawn from the algebra leaves the value of the coupling open. So Eddington's derivation of the strength of light fails at one step: the step from his count to the coupling. The mass ratio failed at the same step, the step from a count to a number of nature: Eddington obtained the mass ratio from a count drawn from the same algebra, but a count of that kind does not fix the ratio. The rate of recession is a number with units, not a pure number. Eddington deduced the rate of recession from atomic constants, which are the constants of the physics of the atom, and then matched his value to a measurement by the astronomer Edwin Hubble, a measurement whose scale of distances later proved wrong.

Eddington's fourth claim was a refusal: he refused to accept that a star of more than Chandrasekhar's mass collapses. The astrophysicist Subrahmanyan Chandrasekhar found the mass named for him, the greatest mass at which a burnt-out star can hold itself up against its gravity. In the refusal, Eddington treated an unwelcome conclusion as a contradiction: the collapse of a star of more than Chandrasekhar's mass was unwelcome to him, but he treated the collapse as a conclusion that cannot be true. Black holes have settled the question against Eddington, because a black hole is what the collapse leaves behind.

I put the question of this section to the collection's own derived values, step by step, in the chapter on Eddington. In the chapter on Eddington I also say what separates the collection's derived values from Eddington's values, and three things separate the two sets of values. First, the collection has published the family of forms from which the rule for the ratio $6 - 2/\pi$ was chosen, with each form's distance from measurement, which is

how far the value that the form gives lies from the measured value. Second, the collection has stated its basis for choosing the rule. Third, the coefficient of the rule must fit a second observable, the matter fraction, as well as the ratio.

Where each is set out. I set out Eddington's model in full in the chapter on Eddington, in Part Five, in Volume Five.



Section XVI

Where Each Model Stands

The tables below show the answer of each of the twenty-four models to each question asked in Sections II to XV. Each row of a table is one model, and each column after the first is one question. Each cell holds, in a few words, the answer of the row's model as the model's own chapter states the answer. Where a cell reads "silent", the model of the row makes no claim on the question at the head of the column. The first row of each table is physics from comparison, the physics of the Immanent Metaphysics and the model that this book sets beside each of the other twenty-three models. Sections II to XV state the answers in the first row.

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

Model	Is the geometry quantized?	Does gravity entangle two masses?	Does a superposition end of its own accord?
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
Eddington	silent	silent	silent
Ellis	silent	silent	silent
Milgrom and McGaugh	silent	silent	silent

Model	Is the geometry quantized?	Does gravity entangle two masses?	Does a superposition end of its own accord?
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

Model	Is there a least length or a rule beneath?	Do the Born weights hold everywhere?	Is the world fully determined?
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
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
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

Model	Did a long inflation happen?	Is space flat?	What is the dark matter?
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

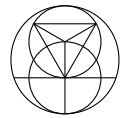
Model	Is there a constant of acceleration?	Is the vacuum energy constant?	How many dimensions has space?
Physics from comparison	No; scale set by formation; no external field effect	Yes, exactly −1	Three, by necessity
Bohr	silent	silent	silent
Deutsch	silent	silent	silent
Penrose	silent	Yes	silent
’t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

Model	Is there a constant of acceleration?	Is the vacuum energy constant?	How many dimensions has space?
Hossenfelder	silent	silent	silent
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
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

Model	Where does the arrow of time come from?	What are life and mind to physics?	Can the constants be derived?
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



Section XVII

Summary

I set out fourteen questions on which the twenty-four models of the universe part. On each of the fourteen questions, the answer of one model differs from the answer of at least one other model. Sections II to XV of Part One take up the fourteen questions one at a time.

Where a measurement can decide a question, the sealed record of 1 November 2026 states the answer of physics from comparison and the measurement that will decide whether the answer holds. The answers of physics from comparison fall into two groups: answers about gravitation and the quantum, and answers about the cosmos. Two masses become entangled through gravitation alone when each mass is held in two places at once: what is found of one mass becomes tied to what is found of the other mass. A superposition ends only through a finding, an interaction that registers which alternative is the case, and so no superposition ends of its own accord. A light cone is the set of all the paths that light can take from one point of space and time. Light of every energy follows one light cone, the light cone of the one geometry of space and time, so the speed of light in empty space does not depend on the energy of the light. Space and time are continuous, and no measurement will show space and time coming in steps. The physicist Max Born gave his name to the Born rule, the rule that states the probability of each outcome of a quantum measurement. The Born weights are the probabilities that the Born rule states. The Born weights are correct in every experiment.

The first answer about the cosmos is that no long phase of inflation happened at the start of our epoch. Inflation is a proposed phase of very rapid expansion. A long phase of inflation would have left behind primordial waves of the geometry: gravitational waves made in the first moments of our epoch. The Simons Observatory and LiteBIRD are two instruments that measure the polarization of the microwave background, the oldest light in the sky. Polarization is the direction in which a wave of light vibrates. The Simons Observatory and LiteBIRD will find no primordial tensor signal, the mark that primordial waves of the geometry would leave in the polarization of the microwave background. Space as a whole is flat. The only curvature of space is the curvature of the departures from uniformity. The departures from uniformity are the slight unevenness in how matter is spread through space. The dark matter is made of gyrations: a gyration is a conserved excitation of the six held internal dimensions, which are six dimensions kept at the same size and shape at every point of space. Each gyration has about the Planck mass. The density of the dark matter is $6 - 2/\pi$ times the density of the ordinary matter. The dark matter acts only through gravity. The law of gravity holds no constant of acceleration (a fixed acceleration below which motions would depart from Newton's law of gravity). There is also no external field effect, the change that modified Newtonian dynamics predicts in the internal motions of a galaxy falling freely in the gravitational field of a larger galaxy. The energy of the vacuum is the energy that empty space holds. The energy of the vacuum is a constant, with an equation of state of exactly -1. Space has three dimensions.

No single measurement can decide what time is, what life and mind are, or whether the world as a whole is determined. When the state of the world fixes every event in advance, we call the world determined. On the questions of time, of life and mind, and of determinism, the models part on premises, the starting statements from which each model reasons, and so each chapter states the premise in dispute as one sentence.

I credit each of the other twenty-three models where the model reached a result first, and where measurement has confirmed the model. For each of the twenty-three models, this book names the step at which the model parts from physics from comparison. Experiments now under way will settle several of the partings within years, and two of the experiments matter most. In the first experiment, physicists test whether two masses become entangled through gravitation, and in the second, the Simons Observatory and LiteBIRD measure the polarization of the microwave background.

Key Concepts

- Every model is set beside one record: the forty-two predictions of physics from comparison, sealed on 1 November 2026.
- The twenty-four models part on fourteen questions: the first question is whether the geometry of space and time is quantized, and the last question is whether the constants of nature can be derived.
- Wherever two models part, one of three things holds: a step of one model does not follow from that model's premises, or the two models start from different premises, or a measurement already made decides between the two models.
- On physics from comparison, the geometry of space and time is the context of every comparison, and the geometry is not quantized. Each alternative of the matter has a geometry of its own. A superposition ends only through a finding.
- The next decisive measurements are the test of whether gravitation entangles two masses, and the measurement of the primordial polarization of the microwave background.

Terms

Arena. The geometry of space and time, taken as the context in which every finding is made.

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

Decoherence. The loss of interference between the alternatives of a system when something in the surroundings of the system registers which alternative is the case.

External field effect. In modified Newtonian dynamics, the change in the internal motions of a system caused by the uniform field of a larger body in which the system falls freely.

Finding. An interaction that registers which alternative is the case.

Gyration. A conserved excitation of the six held internal dimensions, of about the Planck mass. On physics from comparison, gyrations are the 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. The Incommensuration Theorem is a structural fact about the nature of knowing.

Inflation. A proposed early phase of very rapid expansion that would have stretched the observed regions from within one horizon to beyond it.

Radial acceleration relation. The tight relation between the acceleration that the visible matter of a galaxy would produce and the acceleration that the motions of the galaxy show.

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

Superdeterminism. The view that the outcome of every measurement, and the choice of what to measure, are fixed together by the state of the world.

The turn. The end of one epoch and the beginning of the next, where the interiors of the old epoch end together and a new exterior begins.

References

Boddy, K. K., Carroll, S. M. and Pollack, J. (2014). "De Sitter Space Without Dynamical Quantum Fluctuations". arXiv:1405.0298.

Bose, S. and others (2017). "Spin Entanglement Witness for Quantum Gravity". Physical Review Letters 119, 240401.

Carroll, S. M. and Tam, H. (2010). "Unitary Evolution and Cosmological Fine-Tuning". arXiv:1007.1417.

Donadi, S. and others (2021). "Underground test of gravity-related wave function collapse". Nature Physics 17, 74.

Gibbons, G. W. and Turok, N. (2008). "The Measure Problem in Cosmology". Physical Review D 77, 063516. arXiv:hep-th/0609095.

Green, S. R. and Wald, R. M. (2011). "A new framework for analyzing the effects of small scale inhomogeneities in cosmology". Physical Review D 83, 084020. arXiv:1011.4920.

Louis, T. and others (2025). "The Atacama Cosmology Telescope: DR6 Power Spectra, Likelihoods and ΛCDM Parameters". arXiv:2503.14452.

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

Landry, Forrest (2026). *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*. UVSM Publications. ISBN 979-8-90710-056-5. DOI https://doi.org/10.67291/FPCR7748.

Landry, Forrest (2026). *The Unquantized Arena*; *The Weight of Possibility*; *The Quantum Passage*; *Measurement*; *The Compactification*; *Causality Without Determinism*; *The Basis of Physics*. UVSM Publications.

Landry, Forrest (2026). "Why the New Epoch Is Flat; An Argument from the Restoration of Context". Essay, UVSM Publications.

McCoy, C. D. (2017). "Can Typicality Arguments Dissolve Cosmology's Flatness Problem?". Philosophy of Science 84(5), 1239 to 1252.

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.

Tian, Y., Umetsu, K., Ko, C.-M., Donahue, M. and Chiu, I-N. (2020). "The Radial Acceleration Relation in CLASH Galaxy Clusters". Astrophysical Journal 896, 70.

Tian, Y., Ko, C.-M., Li, P., McGaugh, S. and Poblete, C. L. (2024). "A Distinct Radial Acceleration Relation across Brightest Cluster Galaxies and Galaxy Clusters". Astronomy and Astrophysics 684, A180.

Waterhouse, T. P. and Zibin, J. P. (2008). "The cosmic variance of Omega". arXiv:0804.1771.

⁂

APPENDICES

How to read the appendices. Each register is reprinted whole, as the register was fixed on 4 November 2026, in the appendices of the volume that holds the chapter on its model. A register lists one model's predictions beside the sealed record, and each chapter of the book ends with the register of its model. Each register quotes in full each sealed prediction that the register compares, so the same sealed sentence recurs from register to register. The sealed record is reproduced whole as Appendix B, and a reader who knows the record can pass over the quotations of the sealed predictions.

In the register tables, the word "agrees" in the column of standing means that measurement agrees with the collection's prediction, and not that the two accounts agree. The standing of a prediction is its agreement or disagreement with the measurements made so far. Where a standing reads "agrees, for the collection; the difference is untested", the first part gives the standing of the collection's prediction, and the second part gives 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. The prediction is not among the forty-two predictions sealed on 1 November 2026. A relation essay is a chapter, such as this one, that sets one model beside the collection.

Terms of the sealed record. In Prediction 38 the "count route" and the "Koide route" are my two ways of placing the neutrino masses in *The Measures of the Kinds*. 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. In Prediction 39 the "carry family" and the "segment family" are the two families of lepton mixing in the same book, and the carry family puts the lepton phase in the fourth quadrant, and the segment family puts the lepton phase in the third quadrant. In Prediction 42 the "second closure" and the "carriers' law" are laws of *The Strengths of the Kinds* (Chapter 3, Section VI, and Chapter 5), and the two laws give the strength of color and the masses of the W and Z bosons. The letter k names two quantities. In Prediction 17, k is the curvature of the internal di-

mensions in Planck units, which both observables will find equal to 1. In Prediction 42, k 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 the later figures below 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 $\pm$ 1.04 from 67.8 is 5.0 standard deviations in units of the measurement's own uncertainty, and 4.8 standard deviations with the uncertainty of the prediction added in quadrature. Under Prediction 17, two values within the DESI analyses differ by 4.6 standard deviations: 1.26 $\pm$ 0.06 and 0.68 $\pm$ 0.11.

Appendix A

The Prediction Matrix

The Registered Predictions of Physics from Comparison, Set Beside the Twenty-Three Other Accounts

The table in this appendix sets each sealed prediction of physics from comparison beside the twenty-three other accounts of this book. Physics from comparison is the physics of the Immanent Metaphysics. On 1 November 2026, forty-two predictions of physics from comparison were registered in The Registered Predictions of Physics from Comparison. I call The Registered Predictions of Physics from Comparison the sealed record. To seal a prediction is to fix the wording of the prediction at a stated date, before anyone makes the measurement that decides whether the prediction holds, so the sealed record is fixed at 1 November 2026 and is not revised. Appendix B contains the whole of the sealed record. The table lists the forty-two predictions in the order of the sealed record. Each prediction appears in the table under the short title from the sealed record. The twenty-three other accounts are the accounts of Niels Bohr, Gerard 't Hooft, Nicolas Gisin, Anton Zeilinger, Sabine Hossenfelder, Roger Penrose, Chiara Marletto with Vlatko Vedral, Sean Carroll, Jonathan Oppenheim, John Archibald Wheeler, David Deutsch, Max Tegmark, Stephen Wolfram, Arthur Eddington, George Ellis, Mordehai Milgrom with Stacy McGaugh, Erik Verlinde, Julian Barbour, Lee Smolin, Ilya Prigogine, Robert Rosen, Giulio Tononi and Karl Friston. The row of each prediction contains, in two columns, the names of the accounts that address the prediction.

Each of the twenty-three accounts has a register: an appendix that sets the predictions of the account beside the sealed record, entry by entry. Each register is an appendix of the volume that holds the chapter on its account, in Volumes Two to Six. A name under "Differs" means that the register of the person named sets the sealed prediction against a different

prediction of that person's own, or against an account that states no prediction where the collection states one. A name under "Agrees" means that the register of the person named states that the two accounts, physics from comparison and the person's account, predict the same finding. The number after each name is an entry number. For example, "Penrose 2" in the row of Prediction 1 is entry 2 of Penrose's register. The word "none" in a column means that no account addresses the prediction in the way that the column records. Where both columns of a row read "none", no account addresses the prediction at all.

The table shows *only* where the twenty-three accounts agree with a sealed prediction and where the accounts predict differently. The table does not state what the measurements made so far have found. I have also left out of the table the differences between the accounts that no measurement decides. The full register of each person follows as an appendix in the volume that holds the chapter on that person's account. Each register contains, for each of its entries, the statement of the entry, the measurements reported so far, and what decides the entry. Each register also sets out, in a section of its own, the differences between the accounts that no measurement decides.

No.	Sealed prediction	Differs	Agrees
1	Gravitation entangles two masses	Penrose 2; Oppenheim 1; Verlinde 5	Deutsch 2; Carroll 4; Marletto and Vedral 1; Wheeler 6
2	Gravitation alone ends no superposition	Penrose 1, 3; Gisin 1; Oppenheim 2; 't Hooft 1[a]; Verlinde 4	Zeilinger 3; Deutsch 3; Carroll 5; Wheeler 7; Barbour 4; Tegmark 6
3	Gravitation is not quantized	Deutsch 1; Carroll 1; Wheeler 2; Barbour 1; Smolin 1	Penrose 5; Oppenheim 4; Verlinde 7

No.	Sealed prediction	Differs	Agrees
4	Free fall is universal and nothing shields gravity	none	Penrose 6; Carroll 9; Wheeler 4; Barbour 3; Verlinde 8
5	The arena has no least length, area or duration	’t Hooft 2; Wheeler 1; Smolin 1, 2; Wolfram 1	Carroll 8; Hossenfelder 3
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	Penrose 7; Tegmark 4; Eddington 6; Milgrom and McGaugh 10
9	Space is flat to the size of the primordial departures	Wheeler 3; Ellis 1	Penrose 9; Tegmark 5; Milgrom and McGaugh 10
10	No primordial gravitational waves	Carroll 2; Tegmark 1; Ellis 2	Penrose 9
11	The primordial departures are adiabatic	none	Penrose 9
12	The departures are one pattern across the whole sky	none	Penrose 9
13	No long inflationary phase	Carroll 2; Tegmark 2; Ellis 2	Penrose 8
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

No.	Sealed prediction	Differs	Agrees
16	The ratio of the dark matter to the ordinary matter is $6 - 2/\pi$	Oppenheim 3; 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	Carroll 3	Penrose 10; Milgrom and McGaugh 8; Verlinde 9
20	The dark matter does not decay	Penrose 4	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	Penrose 11
23	No short loop exists anywhere in space	Ellis 3	none
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	't Hooft 1[a]; Hossenfelder 1; Smolin 3	Bohr 1; Zeilinger 1; 't Hooft 3; Deutsch 4; Gisin 2; Carroll 6; Marletto and Vedral 2; Wheeler 8; Tegmark 7; Wolfram 5; Ellis 6; Friston 1

No.	Sealed prediction	Differs	Agrees
26	What is found of color, charge and spin	none	Zeilinger 2
27	No signal faster than light, and none backward in time	none	Bohr 4; Zeilinger 4; Deutsch 5; Gisin 3; Carroll 7; Oppenheim 5; Marletto and Vedral 3; Wheeler 8; Wolfram 4[b], 6; Rosen 1
28	No world is perfectly deterministic, and no process is perfectly reversible	none	Bohr 3; Zeilinger 5; Gisin 4; Smolin 5; Ellis 5; Prigogine 1
29	A discrete rule shows itself to a fine enough measurement	't Hooft 2; Smolin 1; Wolfram 2	none
30	No kind of particle beyond the closed list	Carroll 3; Tegmark 3	Penrose 12; Hossenfelder 2
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	't Hooft 4
34	The strong force breaks no reversal; no axion	Tegmark 3	't Hooft 5
35	No new particle in any loop	none	Hossenfelder 2
36	The running of the couplings changes only at known masses	none	't Hooft 6
37	Ceilings and relations among the masses	none	none

No.	Sealed prediction	Differs	Agrees
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
42	The strength of color, the W and Z, the Higgs and the top	none	none

[a] Entry 1 of 't Hooft's register (quantum computation as it is scaled) is listed in two rows of the table, the row of Prediction 2 and the row of Prediction 25. In entry 1, the physicist Gerard 't Hooft predicts a limit of principle on quantum computation: a limit set by nature (and not by the quality of the devices) on how far the decoherence of a quantum computer can be suppressed. Decoherence of the ordinary kind is the spreading of the difference between two alternatives into the surroundings of a system. A limit of principle would be decoherence beyond the ordinary kind, and Prediction 2 allows no decoherence beyond the ordinary kind, so a limit of principle would contradict Prediction 2 first. A limit of principle would also contradict Prediction 25, that the statistics of quantum theory hold, where the measured statistics themselves depart from the statistics of quantum theory. Both contradictions are stated in 't Hooft's register and in the chapter on 't Hooft.

[b] Wolfram's register files Wolfram 4 (travel faster than light) where his account and the collection agree. In Wolfram's own account a jump through a tunnel of space keeps the causal order of events, so a body that makes the jump stays within its light cone. The light cone of an event is the set of events that a signal at the speed of light, or slower, can reach from that event. On travel faster than light the two accounts differ only in words, as Wolfram's register sets out.

Entries that rest on no sealed prediction

Each entry in the list below comes from one of the twenty-three registers. Each listed entry rests on no prediction of the sealed record, so none of the listed entries appears in any row of the table above. The relation essay on a model is the chapter of this book that sets the model beside physics from comparison. Each listed entry rests instead on one of three grounds: an argument in the books of physics from comparison, a statement in the relation essay on the entry's model, or a statement made in the register itself.

- *Bohr 2.* Conjugate quantities have no exact joint values. (Bohr's register includes the entry among the predictions on which Bohr's account and physics from comparison agree. The books of physics from comparison contain the argument for the prediction, and the sealed record does not give the prediction a number.)
- *Penrose 13.* No mark of a single body of the previous epoch in the microwave sky. (Penrose's register includes the entry among the predictions outside the sealed record. Only the relation essay on Penrose states the prediction. The registered prediction nearest to the entry is Prediction 12, that the primordial departures from uniformity are one pattern across the whole sky.)
- *Deutsch 6.* Quantum computation reaches any length. (Deutsch's register includes the entry among the predictions on which Deutsch's account and physics from comparison agree. The argument for the prediction is Proposition 4.2 of The Quantum Bridge, one of the books of physics from comparison, and the sealed record does not carry the prediction.)
- *Deutsch 7.* The reversible observer. (Deutsch's register includes the entry among the predictions outside the sealed record. The register itself states the prediction, and the books of physics from comparison contain no argument for the prediction as applied to the experiment of the reversible observer that Deutsch proposed.)
- *Gisin 5.* A digit not yet determined becomes determinate only in an interaction that registers it. (Gisin's register includes the entry among the predictions outside the sealed record. Only the relation essay on Gisin states the prediction.)

- *Oppenheim 6.* No fluctuation of weight from the arena. (Oppenheim's register includes the entry among the predictions outside the sealed record. Only the relation essay on Oppenheim states the prediction.)
- *Wheeler 5.* The exterior of a black hole has no hair. (Wheeler's register files Wheeler 5 where his account and the collection agree. The books of the collection argue the collection's claim in Wheeler 5 as a theorem of general relativity, and the sealed record does not number the claim.)
- *Wheeler 9.* No mass made of geometry alone. (Wheeler's register files Wheeler 9 among the predictions outside the sealed record. Only the relation essay on Wheeler states the prediction.)
- *Tegmark 8.* Three directions of space and one of time. (Tegmark's register files Tegmark 8 where his account and the collection agree. The books of the collection argue the count of three directions of space and one of time, a count already measured, which the sealed record does not number.)
- *Wolfram 3.* The number of dimensions of space. (Wolfram's register files Wolfram 3 where his account and the collection predict differently. The books of the collection argue the count of three dimensions, and the sealed record does not number that count. The second part of Wolfram 3 is Prediction 6, that a wave of the geometry has two polarizations, and the table shows Wolfram 3 under Prediction 6.)
- *Tegmark 9.* Decoherence in the brain. (Tegmark's register files Tegmark 9 where his account and the collection agree. The collection makes no prediction of its own on decoherence in the brain, and accepts Tegmark's estimate.)
- *Eddington 1.* The strength of light. (Eddington's register files Eddington 1 where his account and the collection 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. (Eddington's register files Eddington 2 where his account and the collection predict differently. The books of the collection argue the order of the proton's mass and the electron's mass, that the proton's is the greater, and the sealed record does not number Eddington 2.)

- *Eddington 4.* The fate of a star above the greatest mass. (Eddington's register files Eddington 4 where his account and the collection predict differently. The books of the collection argue the collection's prediction in Eddington 4, and the sealed record does not number the prediction.)
- *Eddington 5.* Starlight bent by the Sun. (Eddington's register files Eddington 5 where his account and the collection agree. The books of the collection argue the collection's prediction in Eddington 5, and the sealed record does not number the prediction.)
- *Eddington 7.* A universe of evenly spread matter cannot stand still. (Eddington's register files Eddington 7 where his account and the collection agree. The books of the collection argue the collection's prediction in Eddington 7, and the sealed record does not number the prediction.)
- *Milgrom and McGaugh 11.* The measured relations of galaxies. (The register for Milgrom and McGaugh files Milgrom and McGaugh 11 where their account and the collection agree. Milgrom and McGaugh take the relations of galaxies as measured, and so does the collection. The sealed record does not number the relations.)
- *Milgrom and McGaugh 12.* Wide binary stars move by Newton's law. (The register for Milgrom and McGaugh files Milgrom and McGaugh 12 among the predictions outside the sealed record. Only the relation essay on their account states the prediction.)
- *Milgrom and McGaugh 13.* The reported trend follows the surroundings in which a galaxy formed. (The register for Milgrom and McGaugh files Milgrom and McGaugh 13 among the predictions outside the sealed record. Only the relation essay on their account states the prediction. Milgrom and McGaugh 13 predicts the outcome of Prediction 24, that a galaxy feels the field of a larger one only through its tide. Milgrom and McGaugh 13 takes its reading of the reported trend from the relation essay.)
- *Verlinde 1.* The dark mass in colliding clusters. (Verlinde's register files Verlinde 1 where his account and the collection predict differently. The books of the collection argue the collection's prediction in Verlinde 1, and the sealed record does not number the prediction.)

- *Verlinde 3.* The relation between visible matter and the motions of galaxies. (Verlinde's register files Verlinde 3 where his account and the collection predict differently. The books of the collection argue the collection's prediction in Verlinde 3, and the sealed record does not number the prediction.)
- *Prigogine 2.* The pattern taken at a branching point is not fixed in advance. (Prigogine's register files Prigogine 2 among the predictions outside the sealed record. Only the relation essay on Prigogine states the prediction.)
- *Tononi 1.* The brain operates near criticality. (Tononi's register files Tononi 1 among the predictions outside the sealed record. The books of the collection argue the collection's prediction in Tononi 1, and the sealed record does not carry the prediction.)
- *Tononi.* The statement of the relation essay. (Tononi's register files the statement among the predictions outside the sealed record. The statement appears only in the relation essay on Tononi. The register says that the statement is not a prediction, and the register does not make the statement one.)

Appendix B

The Sealed Record

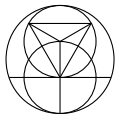
The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026

This appendix reproduces the sealed record whole: its title page, its copyright page and its text, as published on 1 November 2026 under the DOI https://doi.org/10.67291/RQQS3025. The sealed record is *The Registered Predictions of Physics from Comparison; A Dated Record, 1 November 2026*. A DOI is a permanent identifier under which a work is published, so that a reader can find the work by its DOI.

In every chapter of these volumes, and in every register, I compare this record with the account that the chapter or the register studies. A register is an appendix that sets the predictions of one account beside the predictions of this record.

The text of the record is set from the file d_261101_233439_physics_predictions_register_1.html, whose SHA-256 hash is a3a809e4d38fff0f 497c444401ff4989 9e39f545769b7600 1b8ded4d7fea8183. A SHA-256 hash is a string of digits and letters computed from every character of a file. A change to any character gives, in practice, a different hash, so the hash identifies the sealed file exactly.

The pages of the record are set in the type of this book, and they carry the page numbers of this book.



The Registered Predictions of Physics from Comparison

A Dated Record

1 November 2026

Forrest Landry

UVSM PUBLICATIONS
Wytheville, Virginia

© 2026 Forrest Landry. Some rights reserved.

Published by UVSM Publications LLC
965 Reed Creek Mill Rd
Wytheville, VA 24382-8287
USA

uvsmpublications.com
contact@uvsmpublications.com

DOI: https://doi.org/10.67291/RQQS3025

Date of record: 1 November 2026.
This record is fixed at its date and is not revised. A later report on the same predictions will carry its own date and its own identifier.

It gathers the predictions of the books of physics from comparison listed in Section XII, each cited by chapter and section. The two earlier records, *The Registered Predictions of The Gravitational Passage* (9 October 2026) and *The Registered Predictions of The Weight of Possibility* (10 October 2026), stand as they are, at their own dates.

This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

You may share this work for non-commercial purposes with proper attribution, but you may not adapt, transform, or build upon it.

Full license text: https://creativecommons.org/licenses/by-nc-nd/4.0/

Author ORCID: 0009-0005-6275-0362

Typeset in TeX Gyre Pagella (Palatino) at 9.93pt body / 15.4pt leading.
Page size: 6 × 9 inches. Converted to PDF via WeasyPrint.

The Registered Predictions of Physics from Comparison

A Dated Record, 1 November 2026

ABSTRACT

This record states, in one place, every prediction that the books of physics from comparison make: what measurement, observation, search or experiment will find, and what it will not find. Each prediction is stated in plain words, with its number where it has one, with the book, chapter and section that argue it, with the measurement that bears on it as the books report it, and with the coming measurement that decides it, where the books name one. The predictions come from one account: the Incommensuration Theorem, a structural fact about the nature of knowing, and the three axioms that follow from it, applied to physics through the structure of comparison. They fall in five groups: the arena and gravitation; cosmology; the dark matter; quantum theory; and the kinds of particle with their values. Two numbers carry most of the weight of the cosmology: the matter fraction of the universe, 0.311 ± 0.001, and the ratio of the dark matter to the ordinary matter, $6 - 2/\pi = 5.3634$. Most predictions about particles are statements of kind: no particle beyond the closed list of kinds, no decay of the proton, no neutrinoless double beta decay, no axion. Where the books carry two readings of a value and name the measurement that will choose between them, the record states both readings and that measurement. The books are written to stand apart from any date. This record carries the date, so that a later reader can set each prediction beside the measurements made after it.

I. What This Record Is

The books of physics from comparison state their predictions where their arguments reach them, chapter by chapter, and without a date. This record gathers those predictions, gives each a number in this record, and

sets beside each the measurement that bears on it as the books report it. Every prediction stated here is printed in a book listed in Section XII, at the chapter and section named; every number is copied from the book that argues it. The record adds no prediction of its own and leaves the books as they are.

Two earlier records hold part of this ground at their own dates: *The Registered Predictions of The Gravitational Passage*, of 9 October 2026, and *The Registered Predictions of The Weight of Possibility*, of 10 October 2026. Each stands as it is. Section X says what the books have added to those two records since their dates.

Where several books state the same prediction, the record cites the book that argues it in full first, and the others after it. Where a book names a number together with a reading on which it rests, the record states the reading.

II. The Rule of Decision and the Inputs

The books fix what counts as a result (*The Gravitational Passage*, Chapter 20, Questions; *The Unquantized Arena*, Chapter 19, Section I). 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. Where a prediction says that something will not be found, every search for it bears on the step of the account that the prediction names, and the account says that none of the searches will find it.

The account takes few numbers from measurement, and the record names them where they enter. Cosmology takes Newton's constant, which fixes the Planck mass, and the measured density of radiation, $\Omega_{\mathrm{r}} = 9 \times 10^{-5}$ (*The Gravitational Passage*, Chapter 13, Section VII). The values of the particles are stated in two accounts, and both are true (*The Measures of the Kinds*, Chapter 13, Section X). In the working account the measured inputs are the mass of the electron, which is the unit, the strength of light, the

strength of color and the vacuum value of the Higgs field, together with two offsets found from the measured bottom quark and tau; in the closure account the electron alone carries the chain to the vacuum value, the top and the Higgs mass. The structural claims of Section VII use no measured number as a premise (*The Kinds of Particle*, Preface; *The Branches of the Kinds*, Preface); the rates in Prediction 35 and the ceiling in Prediction 37 are computed in *The Measures of the Kinds* from measured inputs.

Measurements are cited as the books cite them, by author and year, and the full entries are in the bibliographies of the books named. "Standard deviations" below means the distance between a prediction and a measurement, in units of the measurement's stated uncertainty, as the book named computes it.

III. The Arena and Gravitation

The account identifies gravitation as the arena of physics, its context, and not a field within it. Six predictions follow.

Prediction 1. Gravitation entangles two masses

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.

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.* No experiment has yet reported entanglement through gravitation alone, or

its absence at a sensitivity that reaches this phase. *What decides it.* An experiment with two such masses, isolated so that ordinary decoherence stays well below the entangling phase. The result separates the account from every account that keeps one geometry for all the alternatives of the matter (Møller and Rosenfeld; classical gravity coupled at random, Oppenheim 2023), and from collapse driven by gravity (Diósi 1987; Penrose 1996), each of which predicts no entanglement. Below the Planck scale it does not separate the account from linearized quantum gravity, which gives the same phase. *Step that would fail.* One geometry for each alternative of the matter (*The Unquantized Arena*, Proposition 7.1; *The Gravitational Passage*, Chapter 12, Section VI).

Prediction 2. Gravitation alone ends no superposition

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.

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. *What decides it.* The experiment of Prediction 1, which tests those versions in a new regime and bounds any extra channel of decoherence directly.

Prediction 3. Gravitation is not quantized

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.

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. *Measured.* The first gravitational wave detected matched the classical waveform of general relativity (Abbott and others 2016); no graviton has been detected. *Step that would fail.* The arena admits no quantum of its own (*The Unquantized Arena*, Proposition 6.3).

Prediction 4. Free fall is universal and nothing shields gravity

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.

Where argued. *The Unquantized Arena*, Chapter 19, Section IV (Prediction 19.3), and Chapter 5, Section VII; *Two Theories, One World*, Chapter 9. *Measured.* 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). *What decides it.* Tests of the

Eötvös parameter (the proposed satellite STEP aims at one part in 10^{18}), the free fall of antimatter, and searches for a shield. *Step that would fail.* Gravity as the context of physics (*The Unquantized Arena*, premise P18).

Prediction 5. 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, 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.
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 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). *What decides it.* 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. *Step that would fail.* The arena is not quantized and has no least step (*The Unquantized Arena*, Proposition 6.3).

Prediction 6. Gravitational waves have two polarizations and travel at the speed of light

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.
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.* 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). *Step that would fail.* The uniqueness of the Einstein form of the field equations (*The Gravitational Passage*, Chapter 12, Section VII).

IV. Cosmology

Prediction 7. The matter fraction is 0.311

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. The matter fraction and its three restatements (the age, the Hubble constant and the vacuum energy density) are one test, stated four ways.

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.* The microwave background gives 0.315 ± 0.007 (Aghanim and others 2020), 0.6 standard deviations away; the baryon acoustic oscillations of DESI alone give 0.2975 ± 0.0086 (DESI 2025), 1.6 standard deviations away on the other side. The microwave background's fit of the Hubble constant, 67.4 ± 0.5, lies 0.8 standard deviations away; the distance ladder of Cepheid variables, 73.04 ± 1.04, lies 4.9 away (*The Registered Predictions of The Gravitational Passage*, Section III), and a value

near 73 would need a matter fraction near 0.268. *What decides it.* The coming measurements of the matter fraction by DESI, Euclid, the Vera C. Rubin Observatory and the Nancy Grace Roman Space Telescope. A measurement with uncertainty σ refutes the prediction when its central value lies farther from 0.311 than $5\sqrt{(\sigma^2 + 0.001^2)}$ (*The Registered Predictions of The Gravitational Passage*, Section III); a Hubble constant settled near 73, with the microwave background's $\Omega_m h^2$ standing, is the same refutation. *Step that would fail.* The accessible share of the vacuum energy, three degrees of freedom among those that the particle horizon counts (*The Gravitational Passage*, Chapter 13, Section II).

Prediction 8. The equation of state of the vacuum energy is exactly −1

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.

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 $w = -1.03 \pm 0.03$ (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. *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. *Step that would fail.* Λ fixed once, as the constant term of one geometry (*The Gravitational Passage*, Chapter 13, Sections V and VI).

Prediction 9. Space is flat to the size of the primordial departures

The epoch begins spatially flat, and the spatial curvature measured within one horizon is that of the departures from uniformity, of order 10^{-5}.

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.* $\Omega_K = 0.001 \pm 0.002$, from the microwave background with baryon acoustic oscillations (Aghanim and others 2020). *What decides it.* DESI and Euclid, which measure the curvature of space with the matter fraction. A curvature confirmed at the level of 10^{-3} refutes it (*The Registered Predictions of The Gravitational Passage*, Section VI). *Step that would fail.* The fixing of the curvature by the restoration of the exterior at the turn (*The Gravitational Passage*, Chapter 18, Section IX).

Prediction 10. No primordial gravitational waves

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.

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.* $r < 0.032$ (Tristram and others 2022); no primordial tensor signal has been detected. *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. *Step that would fail.* The scalar character of the departures (*The Gravitational Passage*, Chapter 18, Section IX).

Prediction 11. The primordial departures are adiabatic

The departures pass from one epoch to the next as one form for every component of the content, so every component departs from uniformity together, and no primordial isocurvature mode separates one component from another. The dark matter carries no separate pattern of primordial departures of its own.

Where argued. *The Gravitational Passage*, Chapter 18, Section XIII; *The Compactification*, Chapter 6, Section IV; *The Weight of Possibility*, Chapter 3, Section I, and Chapter 5, Section IX. *Measured.* The microwave background bounds an isocurvature mode at a few percent of the power (Akrami and others 2020). *Step that would fail.* The passage of one form for every component (*The Gravitational Passage*, Chapter 18, Section IX).

Prediction 12. The departures are one pattern across the whole sky

The primordial departures are correlated across the whole sky, with nearly the same strength at every length; the white noise of independent pieces (an index of four in the curvature) is excluded. The account fixes neither the amplitude of the departures nor the sign of their tilt.

Where argued. *The Compactification*, Chapter 6, Sections III and VII; *At the Edge of Reality*, Chapter 19 and Appendix B; *The Gravitational Passage*, Chapter 18, Section IX. *Measured.* The spectral index is 0.965 ± 0.004 (Aghanim and others 2020). *What decides it.* Every finer map of the microwave sky.

Prediction 13. No long inflationary phase

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.

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. *What decides it.* The measurements of Predictions 9 to 12 together.

Prediction 14. The gravitational waves of an epoch, and their absence where others expect them

The settling of the internal space at the turn leaves a background of gravitational waves that peaks today above about 5×10^{11} hertz, with an energy fraction $\Omega_{GW}h^2$ below about 5×10^{-7} (an addition to the count of light species below about 0.09); this is a ceiling with no floor, and no existing or proposed instrument reaches that frequency. The scalar departures induce a background at second order of $\Omega_{GW}h^2$ about 6×10^{-23} to 1.5×10^{-22}, if the measured scalar power continues to short lengths, which no planned instrument detects. LISA will find no stochastic background from a cosmological phase transition, since the electroweak and strong transitions are crossovers and no further kind of particle exists. The background found by the pulsar-timing arrays is of astrophysical origin, from binaries of supermassive black holes, if the scalar power on short lengths is near the measured power. The history of the content makes no stable network of cosmic strings, and no domain walls or monopoles from the electroweak breaking, so no background from them.

Where argued. The Compactification, Chapter 7, Sections IV to X, and Chapter 8, Sections IX to XII. *What decides it.* LISA; the pulsar-timing arrays; the count of light species measured by the microwave background (Chapter 8, Section X).

Prediction 15. The excess of matter has one sign everywhere

Nowhere in the observable universe do antibaryons outnumber baryons, and the observable universe holds no regions of antimatter.

Where argued. The Coming of the Kinds, Chapter 5, Section VI. *What decides it.* Searches for antimatter stars, galaxies or domains, and for antihelium among the cosmic rays.

V. The Dark Matter

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 dark matter is not a kind of particle; it is not content.

Prediction 16. The ratio of the dark matter to the ordinary matter is $6 - 2/\pi$

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 $\Omega_c = 0.2608$.

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.* 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 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), from one kind of measurement; the same analyses press on the matter fraction of Prediction 7. Routes that do not use the microwave background, through primordial nucleosynthesis and through the gas of galaxy clusters, give 0.1587 ± 0.0066, 0.1542 ± 0.0063 and 0.156 ± 0.034 for the share in all the matter, each in agreement. *What decides it.* A second, in-

dependent 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. *Step that would fail.* The abiding of the curvature of $\mathbb{C}P^2$ alone in the count, $2/\pi$ (*The Weight of Possibility*, Chapter 3, Sections III and IV).

Prediction 17. The coefficient shared with the cosmological constant is 1

The curvature of the internal dimensions, in Planck units, enters both the identity of Prediction 7 and the ratio of Prediction 16: $I^2\Omega_\Lambda = 8 - 3k/\pi$ and $\Omega_c/\Omega_b = 6 - 2k/\pi$, with k that curvature. Both observables will find $k = 1$. The rule equals $6 - 2/\pi$ exactly at the Passage's ratio of the radius of $\mathbb{C}P^2$ to the radius of S^2, $\sqrt{6} = 2.45$; if the rule holds, the measured ratio gives a ratio of radii of 2.49 ± 0.28.

Where argued. The Weight of Possibility, Chapter 3, Section VI, and Chapter 5, Sections III and IV. *Measured.* The ratio gives $k = 0.99 \pm 0.08$ (*The Weight of Possibility*, Chapter 5, Section III); 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 (*The Registered Predictions of The Weight of Possibility*, Section IV). *What decides it.* The measurement of Prediction 16 together with an independent measurement of the matter fraction.

Prediction 18. The amplitude of clustering is 0.823

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.

Where argued. The Weight of Possibility, Chapter 5, Section VI; *The Compactification*, Chapter 6, Section X. *Measured.* The lensing of the microwave background, the complete Kilo-Degree Survey and the growth rate from

the motions of galaxies agree 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; those two differ from each other by 4.5. A value confirmed away from 0.823 bears first on the identity of Prediction 7, unless the matter fraction is confirmed at 0.311 by a separate measurement.

Prediction 19. The dark matter acts only through gravity

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.
Where argued. *The Weight of Possibility*, Chapter 5, Sections VII and IX, and *The Registered Predictions of The Weight of Possibility*, Section VI; *The Branches of the Kinds*, Chapter 4, Section III; *The Story of the Particles*, Level 9, Section IV. *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). *Step that would fail.* The dark matter as a distortion of context and not an item of content.

Prediction 20. The dark matter does not decay

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.
Where argued. *The Weight of Possibility*, Chapter 4, Section III, Chapter 5, Section IX, and Chapter 6, Section III. *Step that would fail.* The closure of the exits: into content, into the waves of the open geometry, and into evaporation.

Prediction 21. The dark matter is perfectly cold

The dark matter's own motion puts no cut-off in the dark matter's structure on small scales, so the dark matter clumps on every small scale.

Where argued. *The Weight of Possibility*, Chapter 5, Sections V, VI and IX. *Measured.* 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). *Step that would fail.* The Planck mass of the gyrations.

Prediction 22. The gyrations have about the Planck mass

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.
Where argued. *The Weight of Possibility*, Chapter 4, Sections V and VI, and Chapter 5, Section IX. *Measured.* Untested at this date. *Step that would fail.* The identification of the gyration with a level of the internal geometry.

Prediction 23. No short loop exists anywhere in space

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.
Where argued. *The Weight of Possibility*, Chapter 3, Section II, and 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). *Step that would fail.* The count of one for the open space.

Prediction 24. A galaxy feels the field of a larger one only through its tide

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.

Where argued. The Weight of Possibility, Chapter 5, Section V.

VI. Quantum Theory

The Quantum Passage derives the postulates of quantum mechanics from the structure of comparison and says, in its Appendix B, what experiment will find. Most of what it states there has been measured already, and each measurement found what the book states.

Prediction 25. The statistics of quantum theory hold

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.
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).

Prediction 26. What is found of color, charge and spin

Color is found only in singlets; no superposition of states of different electric charge is ever found; weak isospin is neither confined nor superselected. A spinor turned through 360° reverses its sign and turned through 720° is restored. Two fermions of one kind never share a state, and any number of bosons can share one. Every particle has an antiparticle. No physical system carries an octonionic sector or a sector of the exceptional Jordan algebra.

Where argued. The Quantum Passage, Chapter 5, Section IV, Chapter 6, Section VII, Chapter 8, Sections I, IV and VI, and Appendix B.

Prediction 27. No signal faster than light, and none backward in time

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.
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).

Prediction 28. No world is perfectly deterministic, and no process is perfectly reversible

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. The statements of Prediction 28 are exclusions that follow from the structure of comparison. The outcome of a search for departures from the quantum predictions bears on Prediction 25 and not on Prediction 28.

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.* Violations of CP (1964) and of time reversal (CPLEAR 1998; BaBar 2012) are consistent with the required asymmetry.

Prediction 29. A discrete rule shows itself to a fine enough measurement

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.
Where argued. The Unquantized Arena, Chapter 3, Sections II and VI; *The Basis of Physics*, Essay 18, Section VII; *Measurement*, Chapter 8, Section VIII.

VII. The Kinds of Particle

The kinds of particle are reasoned from comparison as a closed list: the kinds of the Standard Model, with a right-handed neutrino in each generation. The predictions of this section are statements of kind; the structural claims among them use no measured number as a premise.

Prediction 30. No kind of particle beyond the closed list

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.

Where argued. *The Kinds of Particle*, Chapter 6, Section IV; *The Story of the Particles*, Level 9, Section IV, and Coda; *The Branches of the Kinds*, Chapters 2 and 4; *The Alphabet of Particles*, entries N1 to N12. *Measured.* None has been found. The Large Hadron Collider excludes gluinos below about 2300 GeV, a W′ with the couplings of the W below about 6000 GeV and a Z′ with those of the Z below about 5150 GeV, and leptoquarks below about 1500 to 1800 GeV; MicroBooNE excluded the single light sterile neutrino proposed for LSND and MiniBooNE (2025) (*The Alphabet of Particles*, entries N4 to N9). *What decides it.* Searches at colliders, in underground detectors and in astrophysics.

Prediction 31. Exactly three generations

The generations number exactly three; no fourth exists at any mass.

Where argued. *The Kinds of Particle*, Chapter 7, Sections I and VII; *The Story of the Particles*, Level 5. *Measured.* The invisible width of the Z counts $N_\nu = 2.9963 \pm 0.0074$ light neutrino species (Janot and Jadach 2020), 0.5 standard deviations from three; the rates at which the Large Hadron Collider makes the Higgs boson exclude a fourth generation of the Standard Model kind.

Prediction 32. The neutrinos are Dirac particles; no neutrinoless double beta decay

Every neutrino mass is a Dirac mass, joining two components of one state, and no state of content is its own antiparticle. Neutrinoless double beta decay will not be observed at any sensitivity: the effective Majorana mass is exactly zero, whatever the order of the masses. There is no seesaw scale and no heavy neutrino; lepton mixing has one phase and no Majorana phases; the Standard Model has twenty-six parameters, not twenty-eight. Every neutrino has a mass that is not zero.

Where argued. *The Branches of the Kinds*, Chapter 1, Sections V, VII and VIII; *The Kinds of Particle*, Chapter 6, Section I; *The Story of the Particles*, Level 3, Section IV; *The Measures of the Kinds*, Chapter 12, Sections I and VIII. *Meas-*

ured. No experiment has observed the decay: the complete KamLAND-Zen 800 data give a half-life above 3.8×10^{26} years in xenon-136; LEGEND-200, GERDA and the MAJORANA DEMONSTRATOR together give above 1.9×10^{26} years in germanium-76, each at 90 percent confidence. *What decides it.* The coming searches for neutrinoless double beta decay. A null result in the band of the inverted order, an effective mass of 15 to 50 meV, and below it, is predicted.

Prediction 33. The proton does not decay

No carrier joins color to the weak charge, so no transformation turns a quark into a lepton; the coefficients of every operator that changes baryon number vanish, and the proton has no route to decay. Its stability rests on its being the lightest whole of baryon number one, which is measured. The zero-temperature rate of the sphaleron changes of baryon number is of order 10^{-161}, and they cause no decay of a single proton. No unifying group exists at any scale, and the measured couplings meet at no scale.
Where argued. The Branches of the Kinds, Chapter 2; *The Strengths of the Kinds*, Chapter 3, Section III; *The Story of the Particles*, Level 0, Section IV. *Measured.* The lifetime for decay into a positron and a neutral pion exceeds 2.4×10^{34} years (Super-Kamiokande, Takenaka and others 2020). *What decides it.* The coming searches for proton decay; the discovery of the gauge bosons of a unifying group would contradict the absence of such a group.

Prediction 34. The strong force breaks no reversal; no axion

The strong force's own CP-violating angle is zero, and the structure calls on no axion to cancel the measured angle θ; the absence of the axion is a statement about the list of kinds and holds for any value of the angle. The kinds break CP through two phases only, one in quark mixing and one in lepton mixing, and the list holds one Higgs field and no other field of its sort. CPT holds, as it does in every structure with the five properties of the CPT theorem, and the Standard Model is such a structure: a particle

and its antiparticle have equal mass, equal lifetime and equal and opposite magnetic moments; no violation has been found. The photon and the gluons are massless.

Where argued. *The Branches of the Kinds*, Chapter 3, Sections III and V, and Chapter 4, Sections II and III; *The Story of the Particles*, Level 9, Section V; *The Coming of the Kinds*, Chapter 4, Section III. *Measured.* The neutron's electric dipole moment is below 1.8×10^{-26} e cm (Abel and others 2020), so θ is below 1.8×10^{-10}; the photon mass is below 10^{-18} eV. *What decides it.* Searches for the electric dipole moments of the neutron and of atoms; searches for the axion.

Prediction 35. No new particle in any loop

With no particle beyond the Standard Model, no new particle enters any loop. The anomalous magnetic moment of the muon receives no contribution from a new sector. The new-physics coefficients of the transition $b \to s\ell\ell$ are zero, $C_9^{\mathrm{NP}} = C_{10}^{\mathrm{NP}} = 0$, and the tensions in the global fits will resolve within the Standard Model. Charged leptons change flavor only through the loops of the three light Dirac neutrinos: the branching ratio of $\mu \to e\gamma$ is of order 10^{-55}, of $\tau \to \mu\gamma$ of order 10^{-54} and of $\mu \to 3e$ of order 10^{-55}, and the conversion of a muon to an electron in a nucleus is of order 10^{-52} to 10^{-51} of the rate of muon capture. No signal of charged-lepton flavor violation will be seen at any foreseeable experiment.

Where argued. *The Kinds of Particle*, Chapter 6, Section IV; *The Measures of the Kinds*, Chapter 11, Section VI, and Chapter 13, Section X. *Measured.* The measured moment of the muon less the Standard Model's value of 2025 is $(38 \pm 63) \times 10^{-11}$, against which the zero stands at -0.60 standard deviations (Muon g−2 Collaboration 2025; Aliberti and others 2025); the limit on $\mu \to e\gamma$ is 1.5×10^{-13} (MEG II 2025), forty-two orders of magnitude above the prediction.

Prediction 36. The running of the couplings changes only at known masses

The rates at which the three couplings change with scale are fixed by the closed list of kinds, and change only at the masses of the known kinds and of the W and Z. A change of rate at any other mass would reopen the list.

Where argued. *The Strengths of the Kinds*, Chapter 2, Sections III and IV. *Measured.* The running of the strength of light from zero momentum to the Z mass, and of the strength of color from the tau mass to the TeV scale, follows these rates; no measured running differs from them.

Prediction 37. Ceilings and relations among the masses

No particle of matter is heavier than $v/\sqrt{2} = 174.1036$ GeV, where v is the vacuum value of the Higgs field, since every coupling to the condensate lies between 0 and 1. The charged leptons obey Koide's relation, the sum of the three masses being two thirds of the square of the sum of their square roots; the quarks are not predicted to obey it, and in general will not, since color is a second context. The neutrino masses are in the normal order, the two that share the electron's flavor most being the lighter pair.

Where argued. *The Measures of the Kinds*, Chapter 13, Section I, and Chapter 12, Section V; *Geeze, Wublets, and the Higgs*, Level 7, Section II, and Level 10, Sections VII and IX. *Measured.* The top quark, 172.60 ± 0.27 GeV, stands near the ceiling; the charged leptons give 0.66666 for Koide's ratio; global fits prefer the normal order at less than three standard deviations. *What decides it.* JUNO, with T2K and NOvA, for the order of the neutrino masses; an inverted order would exclude both readings of Prediction 38 together.

VIII. The Values of the Particles

The Strengths of the Kinds and *The Measures of the Kinds* compute the values of the couplings, masses and mixings from the measured inputs named in Section II. Most of those values are compared with measurements already made. The predictions below are the values for which the books name a coming or finer measurement that will test them, or that will choose between two readings the books carry side by side.

Prediction 38. The neutrino masses: two readings, decided by their sum

On the count route the three masses are 15.149, 17.433 and 52.366 meV, with a sum of 84.95 meV; placed from the measured tau alone, this route predicts both splittings, $\Delta m^2_{21} = 7.441 \times 10^{-5}$ eV² and $\Delta m^2_{31} = 2.5127 \times 10^{-3}$ eV². On the Koide route, which takes both splittings as inputs, the masses are 0.370, 8.726 and 50.211 meV, with a sum of 59.31 ± 0.25 meV; a variant of that route, with the lightest mass fixed at $\alpha^4 m_e/4 = 0.362$ meV and Δm^2_{31} as input, predicts $\Delta m^2_{21} = (7.470 \pm 0.040) \times 10^{-5}$ eV², with a sum of 59.22 meV. The beta decay mass is about 17.6 meV on the count route and about 9 meV on the Koide route. Both routes give the normal order, three nonzero Dirac masses and no neutrinoless double beta decay. *Where argued.* *The Measures of the Kinds*, Chapter 12, Sections III, V, VI and VIII. *Measured.* $\Delta m^2_{21} = (7.60 \pm 0.17) \times 10^{-5}$ eV² and $\Delta m^2_{31} = (2.521 \pm 0.023) \times 10^{-3}$ eV², against which the count route stands at -0.94 and -0.36 standard deviations. DESI, in flat ΛCDM with the prior that the sum is positive, bounds the sum below 64.2 meV at 95 percent confidence, a bound that lies between the two routes; with the prior of the normal order, or with an equation of state that varies, both routes lie below the bound. KATRIN bounds the beta decay mass below about 0.45 eV. *What decides it.* The sum of the neutrino masses measured at the matter fraction

and Hubble constant of Prediction 7, with $w = -1$. A measurement of the beta decay mass with an uncertainty of about 3 meV separates the two routes by about three standard deviations, with no cosmological analysis.

Prediction 39. Lepton mixing: two families, decided by the quadrant of the lepton phase

On the carry family, computed at the measured $\sin^2\theta_{13}$, the lepton CP phase lies in the fourth quadrant, at $281.37° \pm 0.16°$ ($281.96° \pm 0.59°$ from the carry alone), with $\sin^2\theta_{12} = 0.3185 \pm 0.0005$, $\sin^2\theta_{23} = 0.5444$ (the upper octant) and a Jarlskog invariant of magnitude 0.0328. On the segment family the phase lies in the third quadrant, at $203.88° \pm 1.43°$, with $\theta_{23} = 43.34°$ in the lower octant and a Jarlskog invariant of magnitude 0.0134. The kernel triangle gives $\sin^2\theta_{13} = 1/45$, which the book counts as a measured agreement; with it the carry family gives $\sin^2\theta_{12} = 7/22$.

Where argued. The Measures of the Kinds, Chapter 11, Sections III, IV and VI, and Chapter 12, Section VIII. *Measured.* $\delta_\ell = 217.8°$ ($+34.2°/-30.6°$); $\sin^2\theta_{23} = 0.533 \pm 0.018$, against which the segment family's $43.34°$ stands at -3.44 standard deviations (and at $+0.04$ against the NuFIT 6.0 analysis with the Super-Kamiokande atmospheric data); $\sin^2\theta_{13} = 0.0217 \pm 0.0007$; JUNO's first result for $\sin^2\theta_{12}$ is 0.3092 ± 0.0087 (2026). *What decides it.* A resolution of $25.8°$ on the lepton phase separates the two families at three standard deviations; Hyper-Kamiokande after ten years of running from the end of 2027, and DUNE at an exposure of 600 kiloton megawatt years, reach it. JUNO tests $\sin^2\theta_{12} = 0.3185$ directly: at its six-year precision it would place this value 6.0 standard deviations away if its central value stays at 0.3092. A measurement of $\sin^2\theta_{13}$ to ± 0.0003 separates $1/45$ from $1/48$ at 4.6 standard deviations.

Prediction 40. The mass of the tau: two readings

Koide's balance gives the tau at 1776.969 MeV from the measured electron and muon; read back from the measured vacuum value under the product step, it is 1776.9691 $\pm$ 0.0004 MeV. The ladder gives a second reading, 1777.146 MeV.

Where argued. *The Measures of the Kinds*, Chapter 8, Sections III and VI, and Chapter 13, Section VIII. *Measured.* 1776.93 $\pm$ 0.09 MeV, against which the balance stands at +0.43 standard deviations and the ladder at +2.4. *What decides it.* A tau mass measured to $\pm$0.045 MeV, the precision stated for Belle II, separates the balance from the ladder at 3.9 standard deviations.

Prediction 41. The quark unitarity triangle has a right angle

The unitarity triangle of quark mixing has a right angle, $\alpha = 90°$, with $\beta = \pi/8 = 22.5°$ and $\gamma = 3\pi/8 = 67.5°$. Given the right angle, the quark CP phase is $\delta_q = 67.15° \pm 0.70°$, twice as precise as its present measurement. In *The Measures of the Kinds* I carry two further readings of the triangle beside the right angle, from the family of mass textures that I hold there as a hypothesis. The two further readings are $\alpha = 92.0°$ with $\gamma = 65.2°$, and $\alpha = 94.0°$ with $\gamma = 63.5°$. The right-angle reading and the two further readings agree on β within 0.3°. The Cabibbo angle has two laws, $|V_{us}| = 0.22495$ or 0.22410, of which at most one is exact.

Where argued. *The Measures of the Kinds*, Chapter 10, Sections II, IV and V. *Measured.* $\delta_q = 66.12° \pm 1.43°$ (+0.65 standard deviations); $\beta = 22.62° \pm 0.45°$; $\gamma = 66.4°$ ($+2.7°/-2.8°$); $\alpha = 84.1°$ ($+3.7°/-3.0°$). *What decides it.* A direct measurement of α to about 2°, or of γ to about 1°, chooses among the three readings. The direct α tests the right angle: with its central value kept at 84.1°, the right angle lies outside two standard deviations once the upper uncertainty of α falls below 2.95°, and outside three below 1.97°. A measurement of $|V_{us}|$ to $\pm$0.00043 decides between the two Cabibbo laws.

Prediction 42. The strength of color, the W and Z, the Higgs and the top

With the value 21/4 of the gap count at the span's end, which the book carries beside the value 5, and the level 169/4 of the couplings, the second closure gives $\alpha_s(M_Z) = 0.11888 \pm 0.00011$. The carriers' law joined to the relation of light, with the SMDR form of the matching, gives $M_W = 80.3538 \pm 0.0045$ GeV, $M_Z = 91.1888 \pm 0.0009$ GeV and $\sin^2\theta_W(M_Z) = 0.231164 \pm 0.000036$; these values carry the law's own agreement with the measured masses and add no independent evidence, and the level 169/4 of the couplings holds if and only if the W mass lies within about 5 MeV of 80.3488 GeV. The Higgs self-coupling is 1/8 at tree level, derived given a stated identification; its measured excess over 1/8 agrees with $1/(24\pi^2)$, and four forms of the second order give the Higgs mass as 125.1715, 125.1888, 125.2064 and 125.2245 GeV. Six readings of the top mass lie between 172.417 and 172.657 GeV. The lepton ladder predicts the second-order coefficient of the span from the electron to the reduced Planck mass, $k = 3.7160 \pm 0.0012$, and the gap from the muon to the strange quark, $(31/180)s = 0.1744$ halvings.

Where argued. *The Strengths of the Kinds*, Chapter 3, Section VI, and Chapter 5, Sections IV to VI; *The Measures of the Kinds*, Chapter 7, Sections VIII and X, and Chapter 13, Sections V to IX. *Measured.* $\alpha_s(M_Z) = 0.1180 \pm 0.0009$ (+0.97 standard deviations); $M_W = 80.3625 \pm 0.0077$ GeV; $M_H = 125.13 \pm 0.11$ GeV, against which the four forms stand at +0.38 to +0.86; $m_t = 172.60 \pm 0.27$ GeV, all six readings within 0.7 standard deviations; $k = 3.7120 \pm 0.0835$ from Newton's constant and the electron, given $\varepsilon = 11/(80\pi^2)$ (+0.05). *What decides it.* A W mass measured to about ± 3 MeV, together with one matching computed in one code with the W mass as an input, tests the closure. A Higgs mass measured to ± 0.03 GeV, or a top mass to 0.02 GeV, decides among the readings of the top; a Higgs mass to about ± 0.005 GeV separates the forms of the second order. A measurement of Newton's constant sharpens the span, and fixes k only together with a law for its third-order coefficient.

IX. What the Books Do Not Predict

A record of predictions is exact only if it also says what is not predicted, so that no later measurement is counted for or against the account where the account makes no claim.

- 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 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 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).
- No technological feasibility of travel within the light cone is claimed either way (*The Basis of Physics*, Essay 10, Section VIII).

X. The Earlier Records

The Registered Predictions of The Gravitational Passage, of 9 October 2026, states the matter fraction, the equation of state, entanglement through gravitation, the scalar, adiabatic and flat character of the primordial departures, and the polarizations and speed of gravitational waves. Each stands in this record unchanged, as Predictions 1, 6 to 11.

The Registered Predictions of The Weight of Possibility, of 10 October 2026, states the ratio of Prediction 16 with its restatements and five predictions of kind. Since its date the book has added three statements, which this record carries: a sixth prediction of kind, that the dark matter carries no separate pattern of primordial departures (Prediction 11); the amplitude of clustering, 0.823 (Prediction 18); and the statement of the absence of a short loop for every location, where the earlier record states it for our location (Prediction 23). In *The Weight of Possibility* I now give the mass of the lightest odd state as about 0.6 Planck masses at first order (Prediction 22). I give that value beside the $\sqrt{2}$ Planck masses of the classical level, which the earlier record states.

XI. The Record at Its Date

No.	Prediction	Value	Measured, as the books report it	Standing

1	Entanglement through gravitation	yes; 0.314 rad for the 2017 design	no result	untested
2	No collapse or decoherence from gravity alone	none	natural Diósi and Penrose version ruled out	agrees as far as tested
3	No quantum of the arena	none	none found	agrees
4	Universal free fall; no shield	$\eta = 0$	$[-1.5 \pm 2.3 \pm 1.5] \times 10^{-15}$	agrees
5	No least length	none	none above about 10 Planck energies	agrees
6	Gravitational waves	two polarizations; speed of light	tensor favored; speed within 10^{-15}	agrees
7	Matter fraction	0.311 ± 0.001	0.315 ± 0.007; 0.2975 ± 0.0086	agrees: 0.6 and 1.6 standard deviations
8	Equation of state	$w = -1$ exactly	-1.03 ± 0.03; $w_0 = -0.82 \pm 0.05$	under pressure: about three standard deviations in one family of analyses
9	Spatial curvature	of order 10^{-5}	0.001 ± 0.002	agrees
10	Primordial tensors	r far below 10^{-6}	$r < 0.032$	agrees
11	Isocurvature	none	a few percent at most	agrees
12	One pattern across the sky	near equal strength at every length	index 0.965 ± 0.004	agrees
14	Backgrounds of gravitational waves	none from phase transitions or strings	pulsar-timing background seen	agrees as far as tested

16	Dark to ordinary ratio	$6 - 2/\pi = 5.3634$	5.370 ± 0.048; 5.199 ± 0.035	agrees with the microwave background alone; under pressure with DESI (4.7 standard deviations, about 4.0 with correlation; one kind)
17	Coefficient shared with Λ	$k = 1$	0.989 ± 0.075 (ratio); 1.13 ± 0.21 (matter fraction); 1.26 and 0.68 within the DESI analyses	agrees with the microwave background alone; the two values differ by 4.7 standard deviations within the DESI analyses
18	Amplitude of clustering	0.823 ± 0.006	surveys from -2.5 to $+3.2$ standard deviations	agrees with most
19 to 21	Dark matter: gravity only, no decay, cold	as stated	every search null; half-mode mass below 10^7 solar masses	agrees
22	Gyrations of about the Planck mass	0.6 to $\sqrt{2}$ Planck masses	untested	untested
23	No short loop	none shorter than the horizon	none shorter than 98.5 percent	agrees as far as tested
25, 26	Quantum statistics	Born weights; $2\sqrt{2}$; no third term	as stated	agrees
30, 31	Closed list; three generations	no further kind	none found; $N_\nu = 2.9963 \pm 0.0074$	agrees
32	No neutrinoless double beta decay	$m_{\beta\beta} = 0$	above 3.8×10^{26} years	agrees
33	No proton decay	none	above 2.4×10^{34} years	agrees
34	Strong CP; no axion	own angle zero	θ below 1.8×10^{-10}	agrees
35	No new loop	muon moment: zero added	$(38 \pm 63) \times 10^{-11}$	agrees

38	Neutrino masses	sum 84.95 or 59.31 meV	below 64.2 meV (one analysis)	open between the two readings
39	Lepton phase	281.37° or 203.88°	217.8° (+34.2°/ −30.6°)	open between the two families
40	Tau mass	1776.969 MeV (balance) or 1777.146 MeV (ladder)	1776.93 ± 0.09 MeV	balance at +0.43, ladder at +2.4 standard deviations
41	Quark CP phase	67.15° ± 0.70°	66.12° ± 1.43°	agrees: 0.65 standard deviations
42	α_s; W; Higgs	0.11888; 80.3538 GeV; 125.1715 to 125.2245 GeV	0.1180 ± 0.0009; 80.3625 ± 0.0077; 125.13 ± 0.11	agree within about one standard deviation

Predictions 13, 15, 24, 27 to 29, 36 and 37 are stated in full above, with the measurements the books report for them.

XII. The Books This Record Draws On

Each book is cited by chapter and section above. All are by Forrest Landry, published by UVSM Publications, Wytheville, Virginia, 2026.

Landry, Forrest. *The Alphabet of Particles*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-055-8. DOI: https://doi.org/10.67291/OXFV8885.

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. *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. *Geeze, Wublets, and the Higgs*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-098-5. DOI: https://doi.org/10.67291/ITMZ1594.

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/CEUK2585.

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 Measures of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-116-6. DOI: https://doi.org/10.67291/UHQA6198.

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 Strengths of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-115-9. DOI: https://doi.org/10.67291/DRPC4419.

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.

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. *The Registered Predictions of The Gravitational Passage; A Dated Record, 9 October 2026*. Wytheville, Virginia: UVSM Publications, 2026.

Landry, Forrest. *The Registered Predictions of The Weight of Possibility; A Dated Record, 10 October 2026*. Wytheville, Virginia: UVSM Publications, 2026.

Summary

The predictions of the books of physics from comparison are gathered here under forty-two headings, each with the place that argues it. Two are sharp numbers with no continuous parameter: the matter fraction, 0.311 ± 0.001, which the microwave background meets at 0.6 standard deviations, and the ratio of the dark matter to the ordinary matter, 5.3634, which the most precise measurement by the microwave background alone meets at 0.14. The rest are statements of kind, each naming what will and will not be found: gravitation entangles masses and is not quantized; free fall is universal; space has no least step; the vacuum energy is constant; the primordial departures are scalar, adiabatic and flat; the dark matter acts only through gravity and does not decay; no kind of particle exists beyond the closed list; the neutrinos are Dirac particles; the proton does not decay; no axion is needed or found. Where the books carry two readings of a value, they name the measurement that will choose: the sum of the neutrino masses, the quadrant of the lepton phase, the tau mass to ± 0.045 MeV. At this date two predictions are under pressure from analyses that add the baryon acoustic oscillations of DESI, the equation of state at about three standard deviations and the dark matter ratio at 4.7 (about 4.0 with

the correlation of the two densities), each from one kind of measurement; the record states that pressure in full, and the rule of decision says what will settle each.

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.
- *The identity.* $I^2\Omega_\Lambda = 8 - 3/\pi$, from which the Hubble constant and the Planck mass cancel; it fixes the matter fraction at 0.311.
- *The ratio.* $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$, sharing one coefficient with the identity.
- *The closed list.* The kinds of particle are those of the Standard Model, with a right-handed neutrino in each generation, and no others.
- *Two readings.* Where the books carry two values side by side, each with its premises, the record states both and the measurement that chooses.
- *The step that would fail.* Each prediction that a book ties to one step names that step, so that a refutation points to one link of the chain.

Terms

Adiabatic: of primordial departures, that every component of the content departs from uniformity together, with no departure of one component against another.

Arena: the context of physics, the geometry of space and time within which content is found; on this account, what gravitation is.

Axion: a hypothetical light particle proposed to cancel the strong force's CP-violating angle and as a candidate for the dark matter.

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.

Beta decay mass: the effective mass of the electron neutrino that the spectrum of beta decay measures directly.

Born rule: the rule that the probability of a finding is the square of the magnitude of its amplitude.

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.

Content: what is found within the arena: the particles, their charges and their fields.

CP, CPT: charge conjugation (particle to antiparticle), parity (mirror reflection) and time reversal, taken two or three together.

Dirac particle: a particle whose mass joins two distinct components of one state, so that it is not its own antiparticle.

Equation of state (w): the ratio of the pressure of a component to its energy density; a cosmological constant has $w = -1$; w_0 and w_a are its present value and its rate of change with the scale of the universe.

Eötvös parameter: the fractional difference between the accelerations of two bodies of different composition in free fall.

Generation: one of the three repetitions of the fermions, each with an up-type and a down-type quark, a charged lepton and a neutrino.

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

Halving: a step of a factor of two in mass; a gap counted in halvings is the base-two logarithm of a ratio of masses.

Isocurvature mode: a primordial departure of one component of the content against another, with no departure of the total density.

Jarlskog invariant: the single measure of CP violation in a three-generation mixing matrix that does not depend on the choice of phases.

Koide's relation: the relation that the sum of three masses is two thirds of the square of the sum of their square roots.

Matter fraction (Ω_m): the fraction of the energy density of a flat universe carried by matter at the present epoch.

Neutrinoless double beta decay: a decay in which a nucleus emits two electrons and no neutrinos, changing the lepton number by two; it occurs only if neutrinos are their own antiparticles.

Normal order: the order of the neutrino masses in which the two states that share the electron's flavor most are the lighter pair.

Planck mass: the mass fixed by Newton's constant, the speed of light and the reduced Planck constant, about 1.22×10^{19} GeV.

Rule of decision: the books' standard for a result: established at five standard deviations by at least two independent kinds of measurement.

Seesaw: the mechanism by which a heavy Majorana mass would make the neutrino masses small; it does not operate when that mass is zero.

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.

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.

Tensor to scalar ratio (r): the power of primordial gravitational waves relative to that of primordial departures of density.

Turn: the transition from one epoch of the universe to the next, in which the black-hole interiors of one epoch and the beginning of the next are one transition approached from two sides.

Unitarity triangle: the triangle in the plane of complex numbers that the closure of the quark mixing matrix draws; its angles are α, β and γ.



⁂

Bibliography

Every work cited in the sections, the prediction matrix and the sealed record of this volume, listed once.

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.

Abel, C. and others (2020). "Measurement of the permanent electric dipole moment of the neutron". *Physical Review Letters* 124, 081803. As cited in the sealed record.

Ackerman, L., Buckley, M. R., Carroll, S. M. and Kamionkowski, M. (2009). "Dark matter and dark radiation". *Physical Review D* 79, 023519. arXiv:0810.5126.

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

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.

Akrami, Y. and others (Planck Collaboration) (2020). "Planck 2018 results. X. Constraints on inflation". *Astronomy and Astrophysics* 641, A10. arXiv:1807.06211.

An, D., Meissner, K. A., Nurowski, P. and Penrose, R. (2020). "Apparent evidence for Hawking points in the CMB sky". *Monthly Notices of the Royal Astronomical Society* 495, 3403–3408.

Boddy, K. K., Carroll, S. M. and Pollack, J. (2014). "De Sitter Space Without Dynamical Quantum Fluctuations". arXiv:1405.0298.

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.

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, 240401.

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.

Carroll, S. M. (2010). *From Eternity to Here: The Quest for the Ultimate Theory of Time*. New York: Dutton.

Carroll, S. M. (2010). "Energy Is Not Conserved". Blog post, preposterousuniverse.com, 22 February 2010.

Carroll, S. M. (2014). Reply to a reader in the comments on "Squelching Boltzmann Brains (And Maybe Eternal Inflation)". Blog Preposterous Universe, 5 May 2014.

Carroll, S. M. (2014). "Falsifiability". Response to the 2014 Edge Question, "What Scientific Idea Is Ready for Retirement?". edge.org.

Carroll, S. M. (2021). "The quantum field theory on which the everyday world supervenes". arXiv:2101.07884.

Carroll, S. M. and Tam, H. (2010). "Unitary Evolution and Cosmological Fine-Tuning". arXiv:1007.1417.

Carroll, S. M. and Tam, H. (2010). "Unitary Evolution and Cosmological Fine-Tuning". Preprint, arXiv:1007.1417 [hep-th], submitted 8 July 2010; arXiv and INSPIRE record no journal version.

Diósi, L. (1987). "A universal master equation for the gravitational violation of quantum mechanics". *Physics Letters A* 120, 377–381.

Donadi, S., Piscicchia, K., Curceanu, C., Diósi, L., Laubenstein, M. and Bassi, A. (2021). "Underground test of gravity-related wave function collapse". *Nature Physics* 17, 74–78.

Gibbons, G. W. and Turok, N. (2008). "The Measure Problem in Cosmology". Physical Review D 77, 063516. arXiv:hep-th/0609095.

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.

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). "A new framework for analyzing the effects of small scale inhomogeneities in cosmology". Physical Review D 83, 084020. arXiv:1011.4920.

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.

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). *Constructor Theory and Immanent Metaphysics; A Structural Correspondence*. Wytheville, Virginia: UVSM Publications.

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). *The Unquantized Arena*; *The Weight of Possibility*; *The Quantum Passage*; *Measurement*; *The Compactification*; *Causality Without Determinism*; *The Basis of Physics*. UVSM Publications.

Landry, Forrest (2026). What the Beginning Left Behind. Wytheville, Virginia: UVSM Publications. DOI: https://doi.org/10.67291/DAQV7169.

Landry, Forrest (2026). “Why the New Epoch Is Flat; An Argument from the Restoration of Context”. Essay, UVSM Publications.

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. *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. *The Alphabet of Particles*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-055-8. DOI: https://doi.org/10.67291/OXFV8885.

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 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/CEUK2585.

Landry, Forrest. *The Measures of the Kinds*. Wytheville, Virginia: UVSM Publications, 2026. ISBN 979-8-90710-116-6. DOI: https://doi.org/10.67291/UHQA6198.

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/DRP-C4419.

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. *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.

Louis, T. and others (2025). "The Atacama Cosmology Telescope: DR6 Power Spectra, Likelihoods and ΛCDM Parameters". arXiv:2503.14452.

Marletto, C. and Vedral, V. (2017a). "Gravitationally induced entanglement between two massive particles is sufficient evidence of quantum effects in gravity". *Physical Review Letters* 119, 240402.

Marletto, C. and Vedral, V. (2017b). "Why we need to quantise everything, including gravity". *npj Quantum Information* 3, 29. DOI 10.1038/s41534-017-0028-0. arXiv:1703.04325.

McCoy, C. D. (2017). "Can Typicality Arguments Dissolve Cosmology's Flatness Problem?". Philosophy of Science 84(5), 1239 to 1252.

McCoy, C. D. (2017). "Can Typicality Arguments Dissolve Cosmology's Flatness Problem?". Philosophy of Science 84(5).

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.

Nadler, E. O. and others (2021), as cited in the sealed record, Prediction 21.

Oppenheim, J. (2023). "A postquantum theory of classical gravity?". *Physical Review X* 13, 041040. DOI 10.1103/PhysRevX.13.041040. arXiv:1811.03116.

Oppenheim, J., Sparaciari, C., Šoda, B. and Weller-Davies, Z. (2023). "Gravitationally induced decoherence vs space-time diffusion: testing the quantum nature of gravity". *Nature Communications* 14, 7910. DOI 10.1038/s41467-023-43348-2. arXiv:2203.01982.

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.

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.

Penrose, R. (1996). "On gravity's role in quantum state reduction". *General Relativity and Gravitation* 28 (5), 581–600. doi:10.1007/BF02105068.

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.

Sinha, U., Couteau, C., Jennewein, T., Laflamme, R. and Weihs, G. (2010). "Ruling out multi-order interference in quantum mechanics". *Science* 329, 418–421.

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., 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. doi: 10.1051/0004-6361/202347868. arXiv:2402.12016.

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., 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.

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.

Waterhouse, T. P. and Zibin, J. P. (2008). "The cosmic variance of Omega". arXiv: 0804.1771.

Index

Subjects and names in the chapters, with the page of each chapter's first mention of each; a name is also indexed where its work is cited; each prediction is indexed at every page of the chapters and registers that discusses it, and at the page of the sealed record that states it.

A

arena, 5, 7, 11, 19, 43, 66, 75

asymmetry, 23, 76

B

Barbour, 6, 8, 17, 53, 65

Bell, 25

Boddy, 29

Bohr, 5, 25, 64

Bose, 11

bound triple, 57

C

Carroll, 5, 8, 12, 17, 25, 29, 33, 37, 54, 65

cellular automaton, 20

Chen, 29

concurrence, 11

confinement, 36

content, 18, 28, 76

context, 7, 20, 24, 43, 50, 53, 64, 75

continuity, 3, 76

D

decoherence, 12, 15, 65, 76

determinism, 25, 57

Deutsch, 5, 8, 12, 17, 25, 64

DeWitt, 8

Diósi, 17

Dirac, 62

discontinuity, 76

Donadi, 17

E

Eddington, 5, 47, 61, 65

Ellis, 5, 25, 29, 32, 46, 65

entanglement witness, 11

entangling phase, 11

erebons, 37, 68

external field effect, 41, 69, 74

F

far region, 16

finding, 5, 15, 20, 50, 53, 64, 75

Friston, 6, 25, 58, 66

G

Gibbons, 33

Gisin, 5, 16, 25, 65

Green, 46

gyration, 76

H

Hossenfelder, 5, 20, 24, 65

't Hooft, 5, 20, 24, 65

I

Incommensuration Theorem, 3, 76

inflation, 27, 68, 74

L

logical error, 25

M

Marletto, 3, 8, 12, 65

McCoy, 33

McGaugh, 3, 33, 36, 42, 47, 65

Milgrom, 3, 33, 36, 42, 47, 65

N

Newton, 40, 61

non-classical mediator, 65

O

Oppenheim, 5, 9, 11, 16, 38, 44, 65

P

Pardo, 51

Past Hypothesis, 54

Penrose, 5, 9, 11, 16, 29, 37, 54, 58, 65

Planck, 8, 20, 35, 68, 76

Planck scale, 36

Prediction 1, gravitation entangles two masses, 10, 96

Prediction 2, gravitation alone ends no superposition, 15, 97

Prediction 3, gravitation is not quantized, 7, 98

Prediction 4, free fall is universal and nothing shields gravity, 98

Prediction 5, the arena has no least length, area or duration, 18, 99

Prediction 6, gravitational waves have two polarizations and travel at the speed of light, 51, 99

Prediction 7, the matter fraction is 0.311, 80, 100

Prediction 8, the equation of state of the vacuum energy is exactly -1, 45, 101

Prediction 9, space is flat to the size of the primordial departures, 31, 102

Prediction 10, no primordial gravitational waves, 27, 80, 102

Prediction 11, the primordial departures are adiabatic, 103

Prediction 12, the departures are one pattern across the whole sky, 103

Prediction 13, no long inflationary phase, 27, 103

Prediction 14, the gravitational waves of an epoch, and their absence where others expect them, 104

Prediction 15, the excess of matter has one sign everywhere, 104

Prediction 16, the ratio of the dark matter to the ordinary matter is $6 - 2/\pi$, 36, 105

Prediction 17, the coefficient shared with the cosmological constant is 1, 79, 80, 106

Prediction 18, the amplitude of clustering is 0.823, 106

Prediction 19, the dark matter acts only through gravity, 36, 107

Prediction 20, the dark matter does not decay, 107

Prediction 21, the dark matter is perfectly cold, 107

Prediction 22, the gyrations have about the Planck mass, 108

Prediction 23, no short loop exists anywhere in space, 33, 108

Prediction 24, a galaxy feels the field of a larger one only through its tide, 41, 108

Prediction 25, the statistics of quantum theory hold, 22, 109

Prediction 26, what is found of color, charge and spin, 109

Prediction 27, no signal faster than light, and none backward in time, 110

Prediction 28, no world is perfectly deterministic, and no process is perfectly reversible, 23, 53, 110

Prediction 29, a discrete rule shows itself to a fine enough measurement, 19, 111

Prediction 30, no kind of particle beyond the closed list, 111

Prediction 31, exactly three generations, 112

Prediction 32, the neutrinos are Dirac particles; no neutrinoless double beta decay, 112

Prediction 33, the proton does not decay, 113

Prediction 34, the strong force breaks no reversal; no axion, 113

Prediction 35, no new particle in any loop, 114

Prediction 36, the running of the couplings changes only at known masses, 115

Prediction 37, ceilings and relations among the masses, 115

Prediction 38, the neutrino masses: two readings, decided by their sum, 79, 116

Prediction 39, lepton mixing: two families, decided by the quadrant of the lepton phase, 79, 117

Prediction 40, the mass of the tau: two readings, 118

Prediction 41, the quark unitarity triangle has a right angle, 118

Prediction 42, the strength of color, the W and Z, the Higgs and the top, 79, 119

Prigogine, 6, 25, 54, 57, 66

R

radial acceleration relation, 42, 76

residual, 37

Rosen, 6, 57, 66

S

sealed record, 3, 47, 61, 76

Smolin, 6, 8, 20, 24, 43, 65

superdeterminism, 22, 76

symmetry, 3, 19, 55, 67, 76

T

Tegmark, 5, 17, 29, 33, 37, 47, 50, 65

Tian, 41

Tononi, 6, 57, 66

turn, 28, 32, 43, 53, 77

V

Vedral, 3, 8, 12, 65

Verlinde, 5, 12, 16, 37, 42, 66

W

Waterhouse, 34

Weyl curvature, 54

Wheeler, 5, 8, 12, 17, 20, 32, 65

Wolfram, 5, 20, 50, 65

Z

Zeilinger, 5, 17, 25, 65