

The Weight of Possibility

Dark Matter as a Vibration of Context

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UVSM PUBLICATIONS
Wytheville, Virginia

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

uvsmpublications.com
contact@uvsmpublications.com

ISBN 979-8-90710-059-6

DOI: https://doi.org/10.67291/QFIN9517

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A Note to the Reader

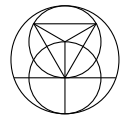
I make one claim. The dark matter is a conserved excitation of the six internal dimensions that *The Gravitational Passage* identifies as the dimensions of possibility: a vibration of context, and not an item of content. It is made at the turn, the transition from one epoch to the next, and the antipodal parity of the sphere keeps it from decaying. Its ratio to the ordinary matter is an identity of the present measurement, $6 - 2/\pi = 5.3634$, of the same form as the Passage's identity for the cosmological constant, with which it shares one coefficient.

I take the Passage's context as given: the internal space $\mathbb{C}P^2 \times S^2$ and its radii, the floor that holds the internal space, the identity for the cosmological constant, and the turn. I take nothing about content from the Passage. Pointers of the form (the Passage, Chapter 13, Section II) refer to the Passage; bare pointers, such as (Chapter 4, Section V), refer to this book.

Three kinds of reader may take three paths. A physicist may read Chapter 1, then Chapters 3 to 6, and then Chapter 2 and Appendix A, which give the reading by the grid of measures that the count of Chapter 3 uses. A reader of the Immanent Metaphysics may read in order, and may pass over Chapter 4, Sections III to V, on the spectrum of the internal space, on a first reading. A philosopher of science may read Chapter 1, Chapter 3, Sections I and II, on a ratio fixed at registration and not by a mechanism, and Chapter 5, Sections VIII and IX, on the weight of the match and on what the account predicts. Chapter 3, Section II gives the topology of the universe that the count requires, with no closed path around the universe anywhere in space shorter than the horizon.

The argument of this book, at a glance:

Step	Ground	Where
Each context must distort, and the three distortions are gravitation, the cosmological constant and the dark matter.	the Incommensuration Theorem and the three axioms, from the Passage	Chapter 2, Section I; Appendix A
The dark matter is a conserved excitation of the internal space, made at the turn, with no exit afterward.	an identification, argued: the hold of the internal space rests on the modal boundary (the Passage, Chapter 11, Section II), and the parity and the floor close the exits	Chapter 1, Section IV; Chapter 4
Its ratio to the ordinary matter is an identity of the present measurement.	the Passage's Axiom I, as for its identity for the cosmological constant	Chapter 3, Section I
A registration counts classes: six for the dark residue, one for the ordinary residue.	this book's principle; the Passage counts its channels in the same way	Chapter 3, Section II
The count of six is reduced by the share of the curvature of $\mathbb{C}P^2$, $2/\pi$.	the measure of the Passage's identity; the theorem of Gauss and Bonnet for the choice of factor	Chapter 3, Sections III and IV
$6 - 2/\pi = 5.3634$, against the measured 5.370 ± 0.048.	computed; measured	Chapter 3, Section V; Chapter 5, Section I
The lightest odd state persists, with a mass of the order of the Planck mass.	the antipodal parity, gauged; the spectrum of the reduction, with the floor's response at one loop	Chapter 4, Sections III and V
The energy released as the internal space settles at the turn stays within the measured bound on extra radiation.	a requirement on the turn: a gentle settling, or a later stage of the content that outweighs the waves	Chapter 4, Section III; Chapter 6
Six predictions of kind.	the steps above	Chapter 5, Section IX



Chapter 1

The Question and Its Ground

What the Dark Matter Is Asked to Be, and What This Book Takes as Given

> Rests on: the observed dark component; *The Gravitational Passage* on the geometry of the six internal dimensions, on general relativity, on the cosmological constant and on the turn. Used by: every later chapter.

I. What Is Observed

The universe contains a component of matter that has never been seen to do anything except gravitate. It bends light around clusters of galaxies, it holds together galaxies that rotate faster than their visible matter could hold, and it set the pattern of the microwave background before any star had formed. It was first inferred from the speeds of the galaxies in the Coma cluster, too fast for the visible galaxies to hold together (Zwicky 1933). The outer parts of the Andromeda galaxy turn about as fast as its inner parts, so that the galaxy's mass keeps growing far from its center (Rubin and Ford 1970). The bending of light weighs the dark component without any assumption about how the matter moves. The dark component has not been seen to scatter, to annihilate, or to decay. When two clusters of galaxies collide, their gas is slowed and heated, and this component passes through without measurable collision. In the colliding cluster 1E 0657-56 (the Bullet Cluster), the mass mapped by gravitational lensing lies with the galaxies, apart from the hot gas that holds most of

the ordinary matter (Clowe and others 2006). The same collision bounds the scattering of this component on itself below about one square centimeter per gram (Markevitch and others 2004). Electric and magnetic forces in the gas of galaxies cannot stand in for the dark component, since they act on charged gas and not on whole stars. A magnetic field bends light only through the mass of its own energy, and for a galactic field of five microgauss that mass is about two parts in a billion of the local density of the dark matter.

The amount of the dark component has not changed since the microwave background was released. A component that decayed into anything unseen would have changed the expansion since then, and the measurements bound such a decay to lifetimes beyond about 160 billion years (Poulin, Serpico and Lesgourgues 2016). A decay into anything seen would be bounded far more tightly.

By mass the dark component is about 5.4 times the ordinary matter. That ratio is the same everywhere the microwave background can measure it: the departures from uniformity with which the present epoch began carry no difference between the two components that the measurements detect. In models that mix the two kinds of departure, a separate pattern in the cold dark matter (an isocurvature mode) carries less than 1.3 percent of the observed variance of the microwave background's temperature, at 95 percent confidence (Akrami and others 2020).

The galaxies themselves require the dark component. When the light of the microwave background went free, its temperature varied across the sky by about one part in a hundred thousand (Smoot and others 1992). In departures of the kind the measurements find, in which every component is compressed alike, the density of the matter departs about three times as much as the temperature, so the ordinary matter then departed from evenness by about three parts in a hundred thousand. Until then the ordinary matter was held in the sound of the hot plasma of light and matter, and could not gather. Once matter rules the expansion, a small excess of density grows in proportion to the distances between things, and dis-

tances have grown about 1,090 times since the light went free (Aghanim and others 2020). So ordinary matter alone would have reached departures of only a few parts in a hundred by now (three parts in a hundred thousand, grown 1,090 times, is about three parts in a hundred), and less than that, since the growth slows once the cosmological constant rules. A region stops spreading out and draws together into a galaxy only when its excess of density reaches about one, so ordinary matter alone would have formed no galaxy. The dark component takes no part in the sound, so its departures from evenness are not held back by the light's pressure: they grow slowly, as the logarithm of the scale of distances, while light rules the expansion, and in proportion to the scale once matter rules it (Mészáros 1974), so they were already growing before the light went free (Peebles 1982); Chapter 2, Section VII, gives the step that follows: structure forms in the wells of the dark component.

The same difference between the two components shapes every galaxy. The gas of ordinary matter radiates as it falls inward, loses energy, sinks, and breaks up into stars; the dark component radiates nothing, keeps its motion, and stays spread out. So each galaxy forms as a concentrated, shining core of stars and gas within a larger cloud of the dark component, the galaxy's halo, and the halos gather in a hierarchy, each level forming as smaller ones draw together and merge (White and Rees 1978). In the largest clusters of galaxies the gas cannot radiate fast enough to sink, so it stays hot and spread out (Rees and Ostriker 1977).

In this book I have to account for the observed facts: a component that persists, that acts only through gravitation, and that stands to the ordinary matter in a fixed ratio.

II. Where Exchange Can Happen

A component that gives energy to nothing after it is made, and takes energy from nothing, can have exchanged energy with the rest of the world only where conditions were extreme enough for its kind of ex-

change to occur. *The Gravitational Passage* describes two such places, and they are one place seen from two sides: the deep interior of a black hole and the origin of an epoch. The collapse inside the black holes of one epoch and the origin of the next "are one transition in a cycle, approached as a limit from its two sides" (the Passage, Chapter 18). The Passage calls that transition the turn, and I use the same name.

At the turn, and only there, the six internal dimensions and the three open dimensions re-form together. I take the turn to be the only place where the dark component is made. Dark matter made at the transition from one epoch to the next has been proposed before. In conformal cyclic cosmology an initial form of dark matter is created at each such transition (Penrose 2014); in a later statement of the account it has about the Planck mass and only gravitational interaction, and must decay within each epoch (Penrose 2018). Stable relics of the Planck mass carried in from earlier universes (Markov 1993), remnants formed before a bounce (Rovelli and Vidotto 2018c), and black holes formed before a bounce that survive it (Carr, Clifton and Coley 2017) have also been proposed. After the turn, the one remaining channel is the production of pairs by a hot plasma through gravity alone, and this book's account requires that the temperature of the new epoch keep that channel closed (Chapter 4, Section VI). That channel has been studied for dark matter whose only interaction is gravitational (Garny, Sandora and Sloth 2016; Tang and Wu 2016; Kolb and Long 2024).

III. What This Book Takes from the Passage, and What It Does Not

The Gravitational Passage derives general relativity from the structure of comparison. On the ground of that derivation, in *The Gravitational Passage* I fix the context of the world. The context of the world includes six internal dimensions in the shape $\mathbb{C}P^2 \times S^2$, held at radii of $\sqrt{6}$ Planck lengths ($\mathbb{C}P^2$) and one Planck length (S^2). The context of the world also includes

the exact form of the field equations at every scale of the smooth description, the description that holds below the Planck curvature. The context of the world also includes the cosmological constant, the matter fraction 0.311 and an equation of state of exactly -1. Last, the context of the world includes a spatially flat epoch whose primordial departures are adiabatic, and the turn. I take all of that context as given. The product $\mathbb{C}P^2 \times S^2$ has served in theories of the Kaluza and Klein kind since the first searches for a realistic one: as the base of seven-dimensional internal spaces in eleven-dimensional supergravity (Witten 1981; Castellani, D'Auria and Fré 1984), and as the internal space itself in ten dimensions (Watamura 1983; Shaya 2026). In the earlier of those uses it is held by fluxes; the most recent leaves its holding to a companion paper (Shaya 2026). The radii, and an internal space held by the metric alone, are the Passage's own.

The Passage "makes no claim about the Standard Model or about the particle spectrum" (the Passage, front matter, On scope); which fields exist, how they couple to the internal dimensions, and what the matter is made of are outside it. It says that "the split between baryonic and other matter is outside this book" (the Passage, Chapter 13, Section VII). I take nothing about content from the Passage. In particular, I do not assume that the six internal dimensions are the arena of particle physics, and I do not assume that the dark component belongs to the content that particle physics describes.

What the Passage does say about the internal space is that it is a space of possibility. "$\mathbb{C}P^2$ is the space of possibilities of a system with three alternatives, and S^2, which is $\mathbb{C}P^1$, is that of a system with two. The internal space is a space of possibility in the plain mathematical sense" (the Passage, Appendix C, Section VIII). And the Passage identifies the six internal dimensions with the six of possibility: "I identify the two sixes as one set" (the same section).

The same section also calls the internal space the content factor: "In Chapter 9 the internal space is the content factor, relative to the external spacetime as its context. Here possibility is a context, relative to the find-

ing as its content. These are two comparisons of one set." The internal space is content relative to the open dimensions, and context relative to what is found in it. I use the second comparison: the dark matter is an excitation of possibility as the context of what could be found, and the dark matter is not an item of the actual content that measurements register.

IV. The Identification

The dark matter is a conserved excitation of the six dimensions of possibility, made at the turn, with no exit afterward. This statement is an identification, and its argument has two parts. First, the internal space is held, because each direction of the internal space stands at the modal boundary, which is the same throughout the exterior (the Passage, Chapter 11, Section II). Second, the parity and the floor close every exit from the excitation.

An excitation of the internal space is a distortion of a context, not an item of content. The dark matter is made of gyrations: a gyration is a conserved excitation of the six held internal dimensions. A gyration is a vibration of the internal geometry, as a wave of sound in a crystal is a vibration of its lattice: in role it is a vibration of context. The comparison with a lattice holds because the internal space is held: each of its directions stands at the modal boundary, so it keeps the same size and the same shape at every point of the exterior (the Passage, Chapter 11, Section II), as a crystal keeps its lattice, and so each of its modes of vibration has a definite energy. The floor is one mechanism that holds it there (the Passage, Appendix D). The open dimensions, the arena, are not held in that way, and gravitation, the distortion of space, is not quantized (Note 5). A gyration has energy, so it gravitates. A gyration is not content, so nothing that registers content registers a gyration. A gyration therefore shows gravitation and nothing else, which is the observed signature of the dark matter. Neutral relics of the Planck mass are invisible to every search except through gravity (Lehmann, Johnson, Profumo and Schwemberger 2019),

and dark matter that interacts far more weakly than the weak interaction escapes every conventional search for dark matter (Feng, Rajaraman and Takayama 2003).

For a gyration to persist, every exit must be closed. There are three.

Into content. An excitation of the internal geometry and an item of actual content are not interchangeable. The geometry of possibility is reformed only where the comparison itself re-forms, at the turn. So no process within an epoch turns an excitation of the internal geometry into an item of actual content.

Into the waves of the open geometry. The action of the metric contains the metric alone. It is unchanged when the sphere S^2 is mapped to its antipodes, so an excitation that changes sign under that map cannot pass its energy to waves of the open geometry, which keep their sign under the map (a parity of the Kaluza and Klein kind; Chapter 4, Section III). The lowest motion of the internal space cannot radiate, for a reason of its own: it is already the lowest state (the Passage, Chapter 11, Section II). For excitations that keep their sign under the map and lie above the lowest motion, the coupling vanishes at the order the Passage computes, but the term of Gauss and Bonnet in the ten-dimensional action opens it for the breathing of the internal volume, which decays within about a Planck time for a coefficient of that term of natural size (Chapter 4, Section III). So the excitation that persists is the lightest one that changes sign under the map.

Into evaporation. An excitation of the Planck scale has no lower level of its kind into which to evaporate. Remnants of evaporated black holes at the Planck mass have been proposed as the dark matter (MacGibbon 1987; Barrow, Copeland and Liddle 1992), and a reason of the same kind has been given for their stability: their evaporation stops at the Planck mass, where no lower state is open to them (Chen and Adler 2003; Rovelli and Vidotto 2018b).

With the exits closed, the excitation is made only at the turn, where the context of possibility re-forms, and it keeps its energy wherever it moves afterward. Its amount relative to the ordinary matter is fixed at registration, by an identity of the present measurement, as the Passage's identity fixes the cosmological constant. Chapter 3 states the identity for the ratio.

V. One of Three Distortions

The dark matter is one of three phenomena that distort a context, one for each of the three contexts of the grid of measures. Gravitation distorts space, locally, around content. The cosmological constant distorts time, uniformly, everywhere. The dark matter distorts possibility. Chapter 2 sets out the three as one triple, and binds each to the edge of reality that belongs to its context: the horizon to space, the turn to time, and the Planck scale to possibility.

Questions

Is the dark matter made of particles?

The dark matter is made of gyrations, and a gyration is not a particle: a particle is an item of content, and on the identification of Section IV the dark matter is not content. Physically, a gyration is a massive excitation of the metric of the six held internal dimensions, a state of the Kaluza and Klein kind (Salam and Strathdee 1982; Hinterbichler, Levin and Zukowski 2014). A gyration is a vibration of a held structure, as the vibrations of a crystal are; it is no quantum of the arena and no quantum of gravitation. Three states share its lowest mass at every order computed so far, a triplet of spin two and two octet-triplets of spin one; Chapter 4, Section V, sets them out. The claim of this book concerns a gyration's role: it is a vibration of context, and not an item of content; the book does not claim that a gyration differs physically from a state of the Kaluza and Klein kind, which theories of that kind call a particle. I make no claim about which

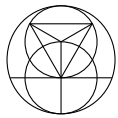
particles do exist, since a claim about which particles exist is a claim about content. The identification of Section IV gives the book's prediction: the dark matter is registered through its weight alone, and every search for it through any other interaction finds nothing.

Why should anything persist forever?

A state persists when every exit from it is closed. The Passage already contains one such state, the lowest motion of the internal space. Section IV names the exits for the dark matter and the ground on which each is closed, and Chapter 4 shows which excitations persist: the lightest one that changes sign under the antipodal map persists, and the even excitations of the breathing kind decay.

Does this book change the Passage?

No. It takes the Passage's context as given and adds a claim the Passage does not make. Chapter 3 shows that the claim fixes the ratio of the dark matter to the ordinary matter in the way the Passage fixes the cosmological constant, and that it shares one of the Passage's coefficients, so that a measurement of either bears on both.



Chapter 2

Three Distortions of Context

Gravitation, the Cosmological Constant and the Dark Matter as One Triple

> Rests on: the grid of measures (*The Gravitational Passage*, Chapter 7); the three axioms of the modalities (the Passage, Chapter 4, Section V); the three edges of reality (the horizon, the turn and the Planck scale; Appendix A); the Incommensuration Theorem (the Passage, Chapter 3, Section IV); the identification (Chapter 1, Section IV). Used by: Chapter 3 (which curvature reduces the count), Chapter 5 (the measurements).

I. Why Context Must Distort

Perception is continuous: in the Passage's words, “An infinitesimal change in context produces an infinitesimal change in content” (the Passage, Chapter 2, Section II). The Incommensuration Theorem holds that “Any comparison, perfected at its foundation, must be either continuously asymmetric or discontinuously symmetric” (the Passage, Chapter 3, Section IV). Content is discontinuously symmetric, so context, which carries the continuity, is continuously asymmetric. An asymmetry of context is a difference of content across a difference of context; in a geometry it is a departure from uniformity, and that departure is what this book calls a distortion.

The context has three columns, time, space and possibility, and each is a domain of comparison in its own right. The theorem applies to each, since it "applies to any domain in which comparison occurs" (the Passage, Chapter 3, Section IV), so no column of context can be perfectly uniform. The three axioms of the modalities (Section V) then require that the asymmetry fall in every column, and in each by a distortion of its own: the three contexts are inseparable, so none can be undistorted while another is distorted; they are non-interchangeable, so no column's distortion can stand in for another's; and they are distinct, so the distortions are three. Each column therefore carries a distortion that is not zero: in space, gravitation; in time, the cosmological constant; in possibility, the dark matter. On this account the dark matter is required, not merely permitted; how much of it there is, against the ordinary matter, is the registered ratio of Chapter 3. Appendix A gives the argument in full, with the three edges of reality to which the three distortions bind.

II. Three Things That Bend the Arena

Every physical measurement involves six measures in two rows of three. The contents are pattern, force and probability; the contexts are space, time and possibility; each content is measured in its own context: "pattern in space, force in time, probability in possibility" (the Passage, Chapter 7). The columns are the three modalities: pattern and space are omniscient, force and time immanent, probability and possibility transcendent.

A content is what a measurement registers. A context is where the measurement registers it. A context can be distorted: its shape can depart from the shape it has when nothing distorts it. There are three contexts, and there are three distortions.

Gravitation distorts space. Around content, the arena curves; bound structures form in the curvature, and light follows it. The distortion is local: it is where content is, and in proportion to it.

The cosmological constant distorts time. In a flat epoch the large-scale space is undistorted, and the large-scale distortion is all in the course of the whole over time. The cosmological constant is the same at every place and at every time, and it increases the distance between every pair of distant places. Its value is fixed through the time elapsed since the turn, by the Passage's identity $I^2\Omega_\Lambda = 8 - 3/\pi$ (the Passage, Chapter 13, Section III). There I is "the comoving distance light has traveled over the whole expansion" (the same section), the conformal time since the turn in units of the Hubble time. The identity gives $\Omega_\Lambda = 0.689$ and $I = 3.20$, and so the matter fraction 0.311.

The dark matter distorts possibility. It is an excitation of the six internal dimensions, which the Passage calls "a space of possibility in the plain mathematical sense" (the Passage, Appendix C, Section VIII). It is held at the Planck scale, where the internal space is held.

III. The Binding to the Three Edges

The account has three edges of reality, three limits of what actual comparison made from inside the world can reach: the cosmological horizon H, which bounds comparison in extent; the Planck scale P, which bounds it in scale; and the turn T, which bounds it in time. They form one triple, bound to the three contexts by role: H to space, T to time, P to possibility.

The three distortions bind to the same three contexts, so each distortion meets the edge of its own context.

Column	Content	Context	Distortion of the context	Edge of the context
omniscient	pattern	space	gravitation	the horizon
immanent	force	time	the cosmological constant	the turn

Column	Content	Context	Distortion of the context	Edge of the context
transcend-ent	probabil-ity	possibil-ity	the dark matter	the Planck scale

The pairing is tightest in the third column: the dark matter is a distortion held exactly at its column's edge, the Planck scale. In the second, the cosmological constant is fixed by the time since the turn. In the first, gravitation acts within the horizon, and in an epoch whose matter has thinned away, the horizon bounds a geometry with almost no gravitation, at its most symmetric.

IV. The Binding Is by Role

The binding does not say which components of the metric each distortion bends. For a slow body in a weak field, gravitation acts through the time component of the metric, and in static coordinates the cosmological constant appears there too. Which components carry a distortion depends on how the arena is sliced. The binding is by what each distortion does, in the slicing that the flat epoch itself picks out: gravitation makes structure, locally, around content; the cosmological constant shapes the course of the whole, uniformly; the dark matter carries what could occur, held where possibility is held. The Planck scale is bound to possibility in the same way, by what it does and not by its unit, though it is a length.

V. The Three Axioms

The Passage states three axioms of the modalities (the Passage, Chapter 4, Section V). Axiom I: “The immanent is more fundamental than the omniscient and/or the transcendent. The omniscient and the transcendent are in conjugate relationship to one another.” Axiom II: “A class of the transcendent will precede an instance of the immanent. A class of

the immanent will precede an instance of the omniscient. A class of the omniscient will precede an instance of the transcendent." Axiom III: "The (classes/instances) of the immanent, omniscient, and transcendent are distinct, inseparable, and non-interchangeable." The first three heads below are the three clauses of Axiom III. The cycle is Axiom II. The clear immanent is the first sentence of Axiom I, and the conjugate pair of Section VI is its second.

Distinct (*Axiom III*). The cosmological constant is uniform and never clumps. Gravitation is local and follows content. The dark matter clumps, and never dissipates or collides.

Inseparable (*Axiom III*). The three distortions appear together in one equation of the expansion: in a flat epoch the shares of the cosmological constant, of the matter and of the radiation sum to one, and gravitation is the equation itself. The Passage's identity fixes the cosmological constant through an expansion history in which the dark matter is the larger part of the matter. The dark matter, acting only through gravitation, cannot be registered apart from it.

Non-interchangeable (*Axiom III*). No amount of the cosmological constant makes a halo; no amount of dark matter accelerates the expansion; gravitation is the response of the arena to content and is not a component of the budget at all.

The cycle (*Axiom II*). The three distortions, bound to the edges, run in the order of Axiom II. The transcendent precedes the immanent: the internal space is released from the Planck scale, and the turn follows. The immanent precedes the omniscient: the cosmological constant, fixed by the time since the turn, fixes the radius of the horizon of the emptied epoch. The omniscient precedes the transcendent: within the horizon, gravitation clumps matter into black holes, whose interiors reach the Planck scale again. The reverse order matches no step of the account.

The clear immanent (*Axiom I*). The cosmological constant is the clear immanent. The Passage makes it the share of the vacuum's energy that is accessible to "an observer inside the vacuum" (the Passage, Chapter 13, Section II): it is fixed by the act of comparison made from inside, and registered only through the channels of that act. Gravitation and the dark matter must then be the conjugate pair.

VI. Gravitation and the Dark Matter as the Conjugate Pair

With the cosmological constant as the clear immanent, the second sentence of Axiom I makes gravitation and the dark matter the conjugate pair: the omniscient and the transcendent of the triple. The Passage defines the two characters that stand in that relation: "Symmetry, sameness of content across a difference of context, is what can be repeated, shared and laid out: the omniscient character. Continuity, sameness of content within a sameness of context, is what is unbroken and encompassing: the transcendent character" (the Passage, Chapter 4, Section IV); and the Incommensuration Theorem states that "no framework can simultaneously perfect both symmetry and continuity" (the Passage, Chapter 9, Section V).

I propose the reading by column. As distortions of context, all three share the character of the context row. They differ by column. Gravitation distorts the context in which pattern is laid out, and what it does is itself laid out: the bending of light maps it. The dark matter distorts the context of what could occur, and what it does is laid out nowhere except through the first: it registers only as a distortion of space, by gravitating. The two meet in exactly that one way, which is the one way the dark matter is observed.

Appendix A gives the full argument for the conjugacy, in the form in which the three edges are shown to be one triple: the three distortions bind one to one to the three edges, so they take the edges' roles, and gravitation and the dark matter stand where the horizon and the Planck scale stand, as the limits of perfected symmetry and of perfected continuity.

VII. The Budget Is the Grid

The Friedmann equation of a flat epoch divides the energy into shares. Read by the grid, each share has a cell.

Column	Content: what the turn emits	Context: what is distorted
omni-scient	pattern in space: the ordinary matter	space: gravitation; at the largest scale its term, the spatial curvature, is zero
immanent	force in time: the radiation	time: the cosmological constant
transcendent	probability in possibility: the form of the primordial departures	possibility: the dark matter

The term for the large-scale distortion of space, the spatial curvature, is zero in a flat epoch. The measured spatial curvature is consistent with zero (Aghanim and others 2020). So the distortion of space is all local: gravitation is structure, and has no share of its own in the budget. The distortion of time is all global: the cosmological constant is uniform. The distortion of possibility is both: global in its amount, which Chapter 3 fixes, and local in its halos.

The content of the third column is probability, measured in possibility. The primordial departures are specified only as a distribution of probability, a random field with a spectrum of power, and the Passage gives their amplitude a count of states: it “is set by the count of states over which the

form of the content is shared" (the Passage, Chapter 18, Section XI). The dark matter carries them first: it does not oscillate with the radiation and the ordinary matter, so the departures grow first in the dark component, and structure forms in its wells.

VIII. What the Triple Gives

Two consequences follow, and Chapter 3 uses both.

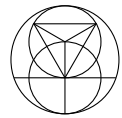
The first concerns where the share of a curvature falls. The reduction of a count by the share of a curvature (Chapter 3, Section III) appears in exactly two places in the budget: in the cosmological constant and in the dark matter, the two distortions of context that carry a share of their own. It does not appear in the ordinary matter, which is content. The reduction falls on what is registered as a distortion of context, and never on registered content. The channels through which the cosmological constant is registered are counted, and are not reduced.

The second concerns what is fixed by what. The cosmological constant is fixed by the act of comparison made inside the horizon, through the time elapsed since the turn; the dark matter is made at the turn and held at the Planck scale, and its amount relative to the ordinary matter is fixed by an identity of the same present act of comparison, which the reconstructed history carries back to the turn. The two are fixed by different identities, and by one measure. Because the cosmological constant and the dark matter are fixed by one measure, the two share one coefficient, and a measurement of either reaches both.

Questions

Is gravitation not simply the response to all three?

In the field equations, the cosmological constant and the dark matter are both sources of curvature. The triple does not deny that: gravitation is the arena's response to content, the cosmological constant is the arena's own constant term, and the dark matter is a distortion of another arena, the internal one, which the open arena feels as mass. Each is a distortion of a different context, and each acts on the open arena through the one metric.



Chapter 3

The Registered Ratio

The Ratio of the Dark Matter to the Ordinary Matter

> Rests on: the identification (Chapter 1, Section IV); the three distortions of context (Chapter 2); *The Gravitational Passage*, Chapters 7, 9, 11, 13 and 18. Used by: Chapter 5, the measurements.

I. Two Residues and a Registered Ratio

The turn sends nearly all of its energy into radiation. Two residues remain: an excess of ordinary matter over its antimatter, and the dark matter. Both are conserved in number. Since the helium of the first minutes formed, both have diluted as matter, so their ratio has not changed since then. Before then, the binding of helium lowered the mass of the ordinary matter by about 0.18 percent. The identity concerns the two densities as they stand after helium formed, which are what the microwave background measures.

The Passage fixes the cosmological constant by an identity of what a measurement made inside the vacuum registers, and not by a mechanism at the turn: “So Λ is fixed once, by the present measurement, as the constant term of one geometry, and the reconstructed history carries that value at every epoch, before the present and after it” (the Passage, Chapter 13, Section VI). The ground of that step is the Passage's Axiom I, which “makes the immanent act prior to the structure reconstructed from

it" (the same section). I fix the ratio of the dark matter to the ordinary matter in the same way. The rule acts at registration, as an identity, like the Passage's identity for Λ. The rule is an identity of the present measurement, $\Omega_c/\Omega_b = 6 - 2/\pi$, and the reconstructed history carries that value at every time since helium formed. The gyrations are made at the turn (Chapter 1, Section IV); their amount relative to the ordinary matter is what the identity fixes, as the Passage's identity fixes the value of Λ.

The identity fixes the ratio everywhere a registration reaches. So the account predicts that no separate pattern of departures from uniformity will be found in the dark component. The measurements find none, to about a percent of the variance (Chapter 1, Section I).

An identity whose terms are all fixed by structure, with no count of the particle horizon (which changes with the epoch), can govern only a quantity that is constant in time. Of the ratios of the matter budget, the ratio of the dark matter to the ordinary matter is the one that has stayed constant since helium formed. Because the ratio of the dark matter to the ordinary matter has stayed constant since helium formed, the identity applies to that ratio.

The Passage does not fix whether the ratios of the content repeat from epoch to epoch: they "concern the composition of the content, which is outside this book, so whether they repeat from epoch to epoch is not fixed in this book" (the Passage, Chapter 18, Questions). The rule does not ask the turn to set a dark mass per baryon, so it requires neither that the ratio of the proton's mass to the Planck mass nor that the excess of baryons be fixed by structure from epoch to epoch.

Asymmetric accounts of the dark matter tie the dark mass per baryon to the proton's mass: in them an equal excess of dark and ordinary particles requires a dark particle of about five proton masses (Kaplan, Luty and Zurek 2009; Zurek 2014). Those accounts relate the numbers and, for the most part, leave the masses unexplained (Petraki and Volkas 2013; Ritter and Volkas 2023). The identity of this chapter ties neither the number nor the mass of the gyrations to the proton; it fixes only the ratio

of the two densities. With gyrations of about the Planck mass, that ratio means about one gyration for every 1.5 to 3.4 × 10^{18} baryons (Chapter 4, Section VI). Mechanisms that fix the ratio from the side of the content act on baryons already formed, and so at or after the transition in which the proton acquires most of its mass (Farrar 2018; Brzeminski and Hook 2024; Bai and Chen 2026; Banerjee, Brzeminski and Hook 2026); the rule does not need them. The hypothesis of cosmological natural selection holds that the low-energy parameters of physics change by a small random amount at each bounce, from one universe to the next (Smolin 2006); the rule does not depend on whether the ratios of the content repeat, since the identity concerns what the present measurement registers.

The amount of the ordinary residue, its number for every photon, is a fact of content, and I take that amount as measured. The rule then fixes the amount of the dark residue relative to it. With the Passage's matter fraction, the two identities also fix the shares of both residues in the whole budget (Section V).

II. The Count: Six Against One

A registration counts kinds, not holders of energy. The Passage already counts in this way: "The count of channels is therefore the Euler characteristic of $\mathbb{C}P^2$, the number of its independent classes" (the Passage, Chapter 13, Section II). The account's principle is that a registration counts the residues it registers by classes too, as the Passage counts its channels. An independent class is one member of a basis of a space's cohomology; when every class lies in even degree, as the Passage requires of the internal space, the number of independent classes is the Euler number (the Passage, Chapter 9, Sections I and IV). The rule of counting is one statement. A registration counts the independent classes of what it counts: every class of a factor over which the counted thing ranges, and one class of a factor at one class of which the counted thing is fixed.

The Passage's channels belong to the act of registering, and each registers in the row of content: “content is what a measurement registers, and context is where the measurement registers it” (the Passage, Chapter 13, Section II). So the count of channels takes every class of $\mathbb{C}P^2$ and one class of S^2: “The classes that share one class of S^2 number three, whichever class of S^2 it is: $\chi(\mathbb{C}P^2) \times 1 = 3$. So the S^2 factor enters the count: it fixes the row in which every channel registers, and it contributes the factor one, not its Euler characteristic, two” (the same section). The channels number $3 \times 1 = 3$.

The dark residue is an excitation of the whole internal space, and it ranges over both factors. Its count takes every class of both: the three classes of $\mathbb{C}P^2$ times the two classes of S^2, $3 \times 2 = 6$. To range over a factor is to be a distortion of the whole factor, and not of one class of it. The count does not depend on which odd state of Chapter 4 is the lightest: it counts the classes of the space the residue distorts, and not the harmonics of a gyration. The account's principle is that the dark residue ranges over both classes of S^2, which are the row of content and the row of context, and two facts support that principle. The dark residue is not content, so nothing fixes it to the row of content. And the antipodal map of S^2, the parity that keeps the gyrations (Chapter 4, Section III), acts on the two classes of S^2 with opposite signs: $+1$ on the class of degree zero, and -1 on the class of degree two.

The ordinary residue is registered in the open space, and a registration reaches the open space only within its horizon: the particle horizon “is the only horizon a first-person measurement holds” (the Passage, Chapter 13, Section II). That horizon is defined by a limit of comparison: “the bound of what has been compared is the bound of the information available to the comparison” (the same section). The region a registration holds is the region within its horizon, which is a ball, and a ball has one class. Within the limit of comparison, that ball cannot be told apart by any comparison from a ball of an infinite flat space. Two descriptions that no comparison can tell apart are one, by the principle of identity; so, for a registration,

space is infinite up to the limit of distinguishability. So the open space counts as one, whatever it is beyond the horizon. The region within the horizon would fail to be a ball only if some closed path through our location that goes around the universe, and so cannot be shrunk to a point, were shorter than the diameter of the horizon. The identity fixes the ratio for every registration, wherever it is made (Section I), so the count of one holds for every registration in the universe, and not only for ours. The count of one is the count of a ball, one class over every field, so the region within the horizon of every location is a ball, and no closed path anywhere in space that goes around the universe, and so cannot be shrunk to a point, is shorter than the diameter of the horizon. I call a closed path that cannot be shrunk to a point and is shorter than the diameter of the horizon, wherever it lies, a short loop. Searches of the microwave background find that every closed path through our location that goes around the universe is longer than 98.5 percent of the diameter of the last scattering surface, the width of the visible microwave sky (Petersen and others 2023). So the region within the horizon is shown to be a ball out to 96.5 percent of the horizon's radius. A short loop would change the count, and with it the ratio. If the region within the horizon held N independent classes, the ordinary residue would count N, since it fills the region, and the dark residue 6N, since it fills the region and ranges over both factors of the internal space. The abiding of $\mathbb{C}P^2$ is built from the three channels of the registering act and from the count of a formal horizon that the curvature of $\mathbb{C}P^2$ sets; neither is a quantity of the open region. A registration is one act, so the abiding is one term of its own, taken once whatever the count, and the ratio would be $6 - 2/(N\pi)$. A region with a short loop is not a ball, so it counts at least two classes. For two classes the ratio is $6 - 1/\pi = 5.682$, the value that the abiding of S^2 alone would give, which the combined measurement excludes (Chapter 5, Section I); more classes give larger ratios, which it excludes further.

So the dark residue is counted by six classes, and the ordinary residue by one. On $\mathbb{C}P^2$, on S^2 and on their product, the usual ways of counting classes agree: the number of independent classes over any field, the Euler number, the number of cells, and the number of points that a generic rotation fixes all give three, two and six. On a ball, the number of independent classes and the Euler number both give one. So, on every space the count uses, the usual ways of counting classes give the same count, and the way of counting is not a free choice.

The rule of counting classes applies, factor by factor, to all three counts that the account uses:

What is counted	$\mathbb{C}P^2$	S^2	The ball within the horizon	Count
the channels of the registering act (the Passage)	ranged over: 3	fixed to one class: 1	not a factor	3
the dark residue	ranged over: 3	ranged over: 2	one class: 1	6
the ordinary residue	no extent	no extent	one class: 1	1

The channels belong to the act of registering, which ranges over possibility. The ordinary residue is what is registered as actual. It has no extent in possibility, so it takes no class of the internal space, and the ball alone counts it.

A division of six against one has been proposed on other grounds: domain walls of a vacuum with seven states trap baryon number six to one, and the six are reduced slightly because baryons are lighter in the false vacua (Bai and Chen 2026). There the six are vacua and the dark matter is baryon number; here the six are the classes of the internal space and the dark matter is an excitation of the metric of the six held internal dimensions.

No count of holders of energy gives six to one. A wave of the ten-dimensional metric has 35 independent polarizations. Counted by direction, the internal and the open stand 6 to 3; counted by polarization, 33 to 2 or 21 to 2; counted by the massless modes, 12 to 1 or 11 to 1. The Passage's measure of the vacuum rests on a theorem of equal parts: “Degrees of freedom that nothing distinguishes hold equal parts” (the Passage, Chapter 13, Section II). Near the turn the open and the internal directions are distinguished by how they scale, so that theorem fixes no ratio between them, and the rule does not use it. The count of classes gives six to one.

The ordinary residue registers as mass. The Passage places mass in the measure of pattern: “The content triad consists of pattern (inertia, mass, structure), force (the directed flow of change), and probability” (the Passage, Chapter 7), and pattern is measured in space, the open dimensions. The ordinary residue is registered in one measure, in the open. Of the three contents, only pattern remains as a residue: force leaves the turn as radiation, which is the bulk of its energy and not a residue, and probability carries the form of the departures from uniformity, not a density of energy.

The count does not depend on how finely the measures are resolved. A measure is one kind of thing in one domain and a triple of kinds in another: mass is one measure where all its forms convert to energy, and three where the photon, the electron and the proton each carry their own kind; time resolves in the same way, and probability plausibly does. The six classes are the instance of the schema $\mathbb{C}P^2 \times S^2$ in the domain of possibility: three modal kinds by two rows. And the ordinary residue is one kind of mass on either reading of mass: the single measure, or the baryonic one of the three.

III. The Share of a Curvature

The open dimensions are flat: “The new epoch begins spatially flat” (the Passage, Chapter 18, Section XIII). The class registered in the open carries no curvature, and stands whole. The internal dimensions are curved, each at the Planck curvature, and the count registered there is reduced by its curvature.

I read the measure of such a reduction from the Passage's identity. The curvature of the internal space enters the four-dimensional equations as a bare term (the Passage, Chapter 11, Section III), an energy density of magnitude $R/(16\pi)$ in Planck units, where R is the scalar curvature: 6 for the whole internal space, 4 for $\mathbb{C}P^2$, 2 for S^2. A density ρ has, through the Friedmann equation, a curvature radius L with $1/L^2 = 8\pi\rho/3$, and a horizon of that radius has the count $S_L = \pi L^2$, in the measure the Passage uses for the particle horizon. The count πL^2 of a horizon of radius L is the count A/4 of Bekenstein and Hawking for a sphere of that radius (Bekenstein 1973; Hawking 1975). The share of a curvature is three channels among that count: c_1/S_L, with $c_1 = 3$, the count of the channels through which a measurement registers (the Passage, Chapter 13, Section II). The numerator is the count of the channels of the registering act, and not the count of what is registered. Every registration reaches what it registers through the same three channels, so the same three stand in the numerator for the cosmological constant and for the dark residue.

For the whole internal space, L is exactly one Planck length, $S_L = \pi$, and the share is $3/\pi$. The bare term of the six internal directions has a curvature radius of one Planck length, the radius of the internal directions themselves. The share $3/\pi$ of the whole internal space is the $3/\pi$ of the Passage's identity for the cosmological constant, $I^2\Omega_\Lambda = 8 - 3/\pi$ (the Passage, Chapter 13, Section III), which the Passage obtains as $8 \times 3/(8\pi)$. The two readings of $3/\pi$, as the share of a curvature and as $8 \times 3/(8\pi)$,

are equal for every density, since $c_1/S_L = 8\rho$. The bare term has the sign of anti-de Sitter space, which has no horizon, so S_L is a formal count; no observer has a horizon of that radius.

For $\mathbb{C}P^2$ alone, $S_L = 3\pi/2$, and the share is $2/\pi$. For S^2 alone, $S_L = 3\pi$, and the share is $1/\pi$.

The abiding. To abide is to hold fast. I use the word for one quantity. The abiding of a factor of the internal space is the share of that factor's curvature, c_1/S_L, that holds fast in a registration as a term of its own, and by which it reduces a count of classes. In it, c_1 is the three channels of the registering act for every factor, and S_L is the count of the formal horizon that the factor's curvature sets. The abiding of $\mathbb{C}P^2$ is $2/\pi$, the abiding of S^2 is $1/\pi$, and the abiding of the whole internal space is $3/\pi$. A factor's curvature abides in a count unless the count already holds that curvature, as a count that includes the Euler number of a surface holds the whole curvature of the surface; Section IV says which counts those are.

The same quantity has a second reading. The density of the curvature term that one degree of freedom induces, through its quantum fluctuations at the Planck scale, in units of the coefficient of the Einstein and Hilbert action, is $R/(6\pi)$ in four dimensions; so $2/\pi$ is the curvature term that three degrees of freedom, one for each channel, induce from the curvature of $\mathbb{C}P^2$, which has the dimension of spacetime.

IV. Which Curvature Abides

In the count of the dark residue the curvature of $\mathbb{C}P^2$ abides, and that of S^2 does not. One principle accounts for it, and four further considerations agree with it.

The principle: a count that includes a factor's Euler number is not reduced again by that factor's curvature. By the theorem of Gauss and Bonnet, the Euler number of a surface is its whole linear curvature, $(1/4\pi)\int R\, dA$, at

any radius. So the two classes of S^2 are the sphere's total curvature divided by 4π, which is 2 at any size. $\mathbb{C}P^2$'s Euler number, three, comes wholly from an integral of the squared curvature, half from its Weyl part and half from its scalar part; it includes none of $\mathbb{C}P^2$'s ordinary curvature, which grows with its size. So the curvature of $\mathbb{C}P^2$ abides in every count. In the ratio, the count is three times two, the classes of $\mathbb{C}P^2$ times the classes of S^2 (Section II): it includes $\chi(S^2)$, so the curvature of S^2 does not abide in it, and the count is reduced only by the abiding of $\mathbb{C}P^2$, $2/\pi$. In the Passage's identity, the count takes one class of S^2, which "contributes the factor one, not its Euler characteristic, two" (the Passage, Chapter 13, Section II): the count does not include $\chi(S^2)$, so the curvature of S^2 abides there as well, and the identity is reduced by the abiding of the whole internal space, $3/\pi$. Exempting S^2 in the Passage's identity too would give the matter fraction 0.300 in place of 0.311. One statement gives both numbers. The principle is a principle of bookkeeping, and it is the account's: it states what a count already contains, and it is not a statement about the dynamics of the turn. Near the turn no internal curvature acts: the curvature of each factor falls away against the rate of collapse, the two at the same rate at the end of the Passage's arc of collapse (the Passage, Appendix B), and the six internal directions move as one block. So the rule does not rest on the turn's dynamics.

The factors are used apart. $\mathbb{C}P^2 \times S^2$ is a schema, and the reasoning that uses it takes its factors together or apart as the question requires. The Passage already takes $\mathbb{C}P^2$ apart in its count of channels: the channels are the classes of $\mathbb{C}P^2$, and S^2 "contributes the factor one, not its Euler characteristic, two" (the Passage, Chapter 13, Section II). Letting the curvature of $\mathbb{C}P^2$ alone abide is the same kind of use.

A surface exerts no stress on what it holds. In two dimensions the Einstein tensor vanishes identically, for every metric: the curvature of a surface, however large, exerts no stress on what the surface holds. In n dimensions the trace of the Einstein tensor is $R(1 - n/2)$: for $\mathbb{C}P^2$, of four dimensions, it is -4; for S^2, of two, it is zero. Read as bookkeeping, each factor's own

Einstein trace sets how much of that factor's curvature abides in what it holds, at the measure of Section III: the abiding of $\mathbb{C}P^2$ in the dark residue is $2/\pi$, and that of S^2 is zero, at any radius. What the open dimensions receive is different: the vacuum energy of the open feels the whole internal curvature, because the open's own field equations receive it from the whole product, and so in the Passage's identity the curvature of all six directions abides. The factors must be taken apart for the dark residue and together for the vacuum energy of the open. Within the product, each factor's curvature does stress the other's directions, and in the accelerations of the motion each factor's curvature acts on its own size, S^2's as strongly per direction as $\mathbb{C}P^2$'s. The rule takes each factor's own Einstein trace, which is bookkeeping and not the motion. Read from the accelerations, the abiding in the dark residue would be $3/\pi$, and the ratio would be $6 - 3/\pi = 5.045$, which the data exclude. Taken together as one space of six dimensions, the abiding in the dark residue would be $6/\pi$, and the ratio would be 4.09, which the measurement excludes.

The rows divide, and their curvature does not abide. S^2 is the factor that carries the two rows of the grid, content and context. The split between the ordinary residue and the dark residue is a split between those rows: the ordinary residue is content, and the dark residue is a distortion of context. The curvature of the factor that does the dividing abides on neither side. The same number can be written as the two rows over the count π of a horizon of one Planck length, the curvature radius of the whole internal space's bare term, $\chi(S^2)/S_L = 2/\pi$, as the Passage's $3/\pi$ is the three columns over the same disk. The two forms agree because the ratio of the curvatures of $\mathbb{C}P^2$ and of the whole, $4/6$, equals the ratio of the Euler numbers of S^2 and of $\mathbb{C}P^2$, $2/3$; for a grid of a columns carried by $\mathbb{C}P^{a-1} \times S^2$, that equality holds only when a is three.

The abiding falls on distortions of context. The abiding reduces the cosmological constant, the distortion of time, and the dark residue, the distortion of possibility, and not the ordinary residue, which is content (Chapter 2, Section VIII).

These considerations agree with one another and with the measurement, and the choice of factor is supported by a theorem.

V. The Result

The dark residue is the count of six classes less the share of the curvature of $\mathbb{C}P^2$; the ordinary residue is the one class of the open:

$$\Omega_c / \Omega_b = 6 - 2/\pi = 5.3634.$$

The share of the ordinary matter in the cold matter is $1/(7 - 2/\pi) = 0.15715$. The Passage's identity gives the matter fraction 0.3108, which the Passage rounds to 0.311. With that fraction, and the neutrinos of the smallest masses oscillation experiments allow ($\Omega_\nu = 0.0014$), the cold matter is 0.3094. The neutrinos are content, and they are a residue of neither kind. They left the turn as radiation, and their density against that of the ordinary matter kept changing until they slowed, long after the ordinary matter was cold. So the identity, which can govern only a ratio constant in time (Section I), does not reach them. The two densities are then $\Omega_b = 0.0486$ and $\Omega_c = 0.2608$, each rounded from a pair whose ratio is exactly $6 - 2/\pi$. The rule has the same form as the Passage's identity: a whole set by the structure, less an abiding. In the Passage's identity, $I^2\Omega_\Lambda = 8 - 3/\pi$, the whole is 8: "The 8π of the Einstein equations, divided by the π of the horizon entropy, gives 8; the three channels, $c_1 = 3$, cancel the 3 of the critical density" (the Passage, Chapter 13, Section III). The abiding there is that of the whole internal space, $3/\pi$. In the rule the whole is the count of six classes, and the abiding is that of $\mathbb{C}P^2$, $2/\pi$. Written as $6(1 - 1/(3\pi))$, the rule takes the form of six terms each reduced by one fraction, the form also found for domain walls of a vacuum with seven states (Bai and Chen 2026). There the reduction depends on the strong interaction; here it is a pure number. In the rule the reduction is one abiding, a term of its own taken once, and not a reduction of each class (Section II). Chapter 5, Section VIII, weighs the chance that a match this close arises by accident.

VI. The Coefficient Shared with the Identity

The Passage places each internal direction at a curvature of $1/l_{Pl}^2$, and names that coefficient as one of three of order one that its identity takes as fixed (the Passage, Chapter 13, Questions). Write it k. Both the identity and the rule then depend on it in the same way: $I^2\Omega_\Lambda = 8 - 3k/\pi$, and $\Omega_c/\Omega_b = 6 - 2k/\pi$.

So two observables measure one coefficient. The matter fraction measures it loosely, since the identity is not very sensitive to it; the ratio measures it two to three times more closely. The book's claim is that both find the value the Passage identifies, $k = 1$.

The rule also reaches what the Passage says no observation of its own reaches: the shape of the internal space. The Passage notes that an internal metric with another ratio of radii and the same scalar curvature gives the same cosmological constant (the Passage, Chapter 9, Section IX). A product of two Einstein spaces is an Einstein space exactly when the two factors have equal Ricci constants (Besse 1987); for $\mathbb{C}P^2$ and S^2 this happens when the ratio of their radii is $\sqrt{6}$. A flux of the kind used by Freund and Rubin (1980), filling the open dimensions, would also select it: with such a flux alone, the field equations make the internal space an Einstein space. The rule depends on the curvature of $\mathbb{C}P^2$ alone, $6 - R_{\mathbb{C}P^2}/(2\pi)$, so the measured ratio fixes how the internal curvature divides between the factors. If the rule holds, the microwave background gives $R_{\mathbb{C}P^2} = 3.96 \pm 0.30$ against the 4 of the Passage's Einstein condition, and, with the whole curvature held at 6, a ratio of radii of 2.49 ± 0.28 against the Passage's $\sqrt{6} = 2.45$. Chapter 5, Section IV, states the rule as a function of the ratio of the radii, and shows that the shape and the choice of the rule are one measurement.

VII. The Family and What the Measurement Selects

The rule belongs to a family: a count of six, less an abiding chosen in some way the Passage's quantities allow. No abiding gives 6; the abiding of S^2 gives $6 - 1/\pi = 5.682$; the abiding of the whole internal space gives $6 - 3/\pi = 5.045$; the abiding of $\mathbb{C}P^2$ gives 5.363. The measured ratio lies near 5.36, with an uncertainty of under one percent. Of these four, the measurement admits one. Other forms with the Passage's quantities lie near it, and the measurement does not yet separate them all; Chapter 5 states them and what would separate them.

Questions

Is $6 - 2/\pi$ not a number chosen to fit?

The form is the form of the Passage's identity, and within that form the measurement excludes every other choice of which curvature abides. Other proposals give the ratio from counts of dimensions or from the geometry of horizons: $(26 - 4)/4 = 5.5$ (Sarici 2025) and $2\pi - 1 = 5.283$ (Agyemang 2026). None gives $6 - 2/\pi$, and the first lies outside the present measurement. The rule needs no derivation from the dynamics of the turn, because it is an identity of the present measurement.

Why is the ordinary residue counted as the one class of the open, and not as one of the classes of the internal space?

Because it is registered in the open, which is flat, and the region of the open that a registration holds is a ball, of one class. If it were counted as one of the internal classes, it would take that class's part of the abiding, and the ratio would be exactly 6, which the measurement excludes.

Does the rule fix how much dark matter there is?

It fixes the dark matter relative to the ordinary matter. No other account of dark matter of very large mass fixes its amount relative to the baryons. There the amount is set by the rate of expansion at the end of inflation (Chung, Kolb and Riotto 1998), by the temperature of reheating (Garny, Sandora and Sloth 2016), or by the abundance of primordial black holes (MacGibbon 1987). The amount of ordinary matter, about six baryons for every ten billion photons, is a fact of content, which this book takes as measured.

Does the turn have to know the proton's mass?

No. The identity concerns what a measurement registers, as the Passage's identity for Λ does. The Passage does not ask the history to set the value of Λ, and this chapter does not ask the turn to set a dark mass per baryon. The turn makes the gyrations, and the reconstructed history carries the ratio that the present measurement fixes. A ratio set at the turn would have to tie a gyration of the Planck mass to the proton's mass across nineteen orders of magnitude; the identity, which acts at registration, requires no such tie, and it requires nothing of the proton's mass or of the excess of baryons.

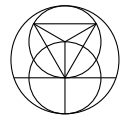
Could the turn have made more gyrations than the identity allows?

On this account the question asks for a history that no present registration could reconstruct. The identity is a condition on every history that the present measurement can carry back. The conditions of Chapter 4, Section VI, are what such a history requires of the turn. So the account predicts that a computation of the re-forming, when it can be made, returns the registered amount.

Could the neutrinos be the dark matter?

No. The neutrinos are content, a residue of neither kind (Section V), and on the identification of Chapter 1, Section IV, the dark matter is not content. A measurement of galaxies agrees, from a premise of its own: the

exclusion principle, by which no two neutrinos of one kind can share a state. In a galaxy of a given size whose stars move at given speeds, the states slow enough to stay in the galaxy number in proportion to the cube of a particle's mass, and each state holds one particle, so the galaxy can hold of one kind of neutrino at most a mass that grows as the fourth power of that neutrino's mass (Tremaine and Gunn 1979). The dwarf spheroidal galaxies, small and faint galaxies that hold much dark matter in a small region and whose stars move slowly, would need a particle that obeys the exclusion principle to have a mass of at least 130 electronvolts to hold their dark matter (Alvey and others 2021, at 95 percent confidence). The sum of the three neutrino masses lies below 0.064 electronvolts in the standard model of cosmology (DESI Collaboration 2025), and the mass of the electron's neutrino, measured directly, lies below 0.45 electronvolts (Aker and others 2025, at 90 percent confidence), so the neutrinos fall short of that need by a factor of at least about three hundred in mass.



Chapter 4

Why the Dark Persists, and Its Gyrations

The Exits, the Floor and the Lightest Odd Level

> Rests on: the identification (Chapter 1, Section IV); the region a registration holds (Chapter 3, Section II); *The Gravitational Passage*, Chapter 11 (the reduction, the floor and the higher Lovelock terms) and Chapter 17 (the first eigenvalue of the internal space). Used by: Chapter 5.

I. What Persistence Requires

A state persists when no exit from it is open. An exit is a lower state that the state can reach through a coupling that exists. The dark matter has three possible exits: into the content of the world, into the waves of the open geometry, and into evaporation. In this chapter I take each of the three exits in turn.

II. No Exit into Content

The dark matter is an excitation of the space of possibility. The content of the world is actual. An excitation of the internal geometry and an item of actual content are not interchangeable: the geometry of possibility is reformed only where the comparison itself re-forms, at the turn. So no process within an epoch turns an excitation of the internal geometry into an item of actual content. Physically a gyration is a massive excitation of the

metric of the six held internal dimensions, a state of the Kaluza and Klein kind, whose candidates Section V sets out. In its role a gyration is a vibration of the internal geometry, a vibration of context, and not an item of content. On the identification, this is the ground of the observed silence of the dark matter in every search through an interaction other than gravity: it couples to the content through gravity alone.

III. No Exit into the Waves of the Open Geometry

The action of the geometry contains the metric alone. It contains no orientation of the internal space, and so it is unchanged when the sphere S^2 is mapped to its antipodes. The condition known for the parity on an interval is that the action carry no orientation. A term carrying the orientation, such as a term of the Chern and Simons kind, is odd under the reflection and would threaten the stability of the lightest odd state (Agashe, Falkowski, Low and Servant 2008); how such a term ties the parity to the parity of the open spacetime is worked out by Hill (2006). Quantum effects that distinguish the orientation in a theory of gravity come from chiral fields, namely Weyl fermions of spin one half or three halves and self-dual antisymmetric tensor fields (Alvarez-Gaumé and Witten 1984); a theory of the metric alone in ten dimensions contains none of these fields. The map is a symmetry of the whole dynamics of the context, and every state of the metric is either even or odd under it.

A symmetry of this kind is known in theories of extra dimensions as a parity of the Kaluza and Klein kind: a reflection of the internal space that the action respects, under which the levels of the reduction alternate in sign and odd states couple only in pairs (Cheng, Matchev and Schmaltz 2002; Servant and Tait 2003; Agashe, Falkowski, Low and Servant 2008). Here the reflection is the antipodal map of the sphere itself, which leaves no point fixed. So the terms at fixed points that break such a parity in orbifold constructions, when they differ between the two fixed points, do not arise (Datta, Raychaudhuri and Shaw 2014). The sphere is not identi-

fied with its antipodes. Were it identified, the internal factor would be the real projective plane, which keeps only the states that are even under the antipodal map, so the odd gyration would not exist there; on the projective plane, fields identified without a change of sign keep only their harmonics of even degree (Dohi and Oda 2010). The sign of a harmonic of degree l under the antipodal map is $(-1)^l$, as for the parity of the spherical harmonics in quantum mechanics; it plays the part of the sign $(-1)^n$ of the n-th level on an interval (Hooper and Profumo 2007).

Forms on the sphere	**Laplacian eigenvalue × R_T^2**	**Sign under the map**
functions of degree l	$l(l+1)$	$(-1)^l$
exact one-forms, degree $l \geq 1$	$l(l+1)$	$(-1)^l$
co-exact one-forms, degree $l \geq 1$ (degree 1: the Killing forms)	$l(l+1)$	$(-1)^{l+1}$

The waves of the open geometry are even: they are constant over the internal space. Within the geometry, the map is a symmetry of every coupling, so a single odd excitation cannot decay into even states alone, and the lightest odd state, having no lower odd state to fall to, cannot decay at all. The argument that the lightest odd state cannot decay is the argument by which the lightest odd state of a parity of the Kaluza and Klein kind is stable (Cheng, Matchev and Schmaltz 2002; Servant and Tait 2003). It has been applied to a heavy excitation of the graviton as dark matter (Garny, Palessandro, Sandora and Sloth 2018). Where this book reports those papers, the word "graviton" names at most a quantum of a description, the description of small waves of a classical geometry, and never a quantum of the arena: gravitation is not quantized (Note 5). Without such a symmetry, dark matter that interacts only through gravity decays through loops of gravitation, mostly into gravitons (Tang and Wu 2016),

and excitations of the graviton decay down their tower (Gonzalo, Montero, Obied and Vafa 2023). Here the antipodal map forbids that decay, since the waves of the open geometry are even.

Couplings of the geometry to content are outside this book; a content coupling that distinguished the orientation of the sphere could break the symmetry, and the account requires that none does. How such a coupling breaks the parity is worked out for a single extra dimension by Hill (2006). In the mainstream account a theory of gravity is expected to have no global symmetries (Banks and Seiberg 2011; Harlow and Ooguri 2021). Dark matter held stable by a global symmetry would then decay through effects of quantum gravity, as has been assumed for dark matter of the Planck mass that interacts only through gravity (Garny, Palessandro, Sandora and Sloth 2018). Garny, Palessandro, Sandora and Sloth (2018) also point out that a discrete symmetry may keep dark matter of the Planck mass absolutely stable. A gyration, which has about the Planck mass, is protected only by an exact symmetry. The mainstream account expects quantum gravity to break a global symmetry by effects suppressed only by powers of the mass over the Planck mass, and for a gyration that ratio is about one, so on that account a parity that was only global would protect nothing. On this account gravitation is not quantized; the parity of this book is exact on either account, since it is gauged, so it protects the gyrations on both. A gauged discrete symmetry is exact: nothing can violate a discrete gauge symmetry (Krauss and Wilczek 1989).

I take the antipodal parity as gauged, on the ground of the principle of identity. The antipodal map is a change of coordinates of the internal geometry. The principle applies to whole configurations of the geometry, and not to points of the sphere. Two configurations of the whole geometry that differ only by the antipodal map cannot be told apart by any comparison, so they are one configuration. Identifying the points instead would make the internal factor the projective plane, on which the odd gyration does not exist. Identifying the configurations makes the parity a discrete gauge symmetry, and a single odd gyration is then a discrete gauge charge. No

local comparison detects the sign of that charge; it shows itself only around a closed path along which the sphere returns to its antipodes (Krauss and Wilczek 1989). For symmetries that invert spacetime, Harlow and Numasawa (2026) write: "In quantum gravity there are no global symmetries, so any spacetime inversion symmetries must be gauge symmetries". This book's own step is that the antipodal map of the internal sphere is such an inversion, and is gauged. Taking the parity as gauged has three consequences. First, geometries in which the sphere returns to its antipodes around a closed path of the open space must be admitted. Within the ball that a registration holds (Chapter 3, Section II), such a return can be undone by a change of coordinates, so nothing changes there, and the odd gyration stays stable. Second, in a closed space the odd gyrations number an even total, since the total discrete gauge charge of a closed space is zero; within an open region they need not. Their production in pairs, from states that are even, agrees with that. Third, nothing in the world may couple to the orientation of S^2; that is a prediction about the content. The weak interaction does not contradict it. The weak interaction distinguishes left from right in the open spacetime, and the antipodal map of the internal sphere leaves the orientation of the open spacetime unchanged. The prediction requires only that the handedness of the content be carried by nothing that the antipodal map reverses, which agrees with reading any $\mathbb{C}P^2 \times S^2$ of the content as a separate instance of the schema (Section V).

Conjugation on $\mathbb{C}P^2$. $\mathbb{C}P^2$ has a discrete isometry of its own that lies outside $SU(3)$: complex conjugation. It keeps the orientation of $\mathbb{C}P^2$, and it changes the sign of the class of degree two of $\mathbb{C}P^2$. The principle of identity applies to it as to the antipodal map, so it too is a discrete gauge symmetry. Conjugation acts on the gauge fields of the isometries of $\mathbb{C}P^2$ as charge conjugation acts on the gauge field of the group $SU(3)$: of the eight fields, three keep their sign and five change it. The spin-two triplet of Section V is constant over $\mathbb{C}P^2$, so it is even under conjugation, and so is the change of the size of $\mathbb{C}P^2$ across the sphere. The spin-one octet-triplet built

from the isometries transforms as those gauge fields do. The other spin-one octet-triplet and the spin-zero octet-triplet transform as the functions on $\mathbb{C}P^2$ do, and member by member they carry the sign opposite to that of the first. If the gauge fields of the isometries are free, a massive state that is odd under conjugation alone can decay into lighter states together with three of those fields in their symmetric combination, which is odd under conjugation, so conjugation keeps no further state from decaying. If they confine, every state lighter than the lightest state of the confined spectrum that is odd under conjugation is even under it, and so is every combination of such states. That state therefore cannot decay, and, unless it is the lightest odd state of the antipodal map itself, it persists beside the lightest odd state. Such a state would also be a vibration of the internal geometry, so it would add nothing to the count of Chapter 3, which counts the classes of the space and not the holders of energy.

Two odd gyrations can annihilate together into even states, which the symmetry allows; at the density of the dark matter near the Sun, with a cross section of the order of the Planck area, that happens about once in 10^{78} seconds for each gyration, which is no exit at all. Their scattering on one another, through gravity alone, is also negligible. At the speeds of matter in galaxies and in clusters, from a few hundred to a few thousand kilometers per second, the cross section per unit mass for the transfer of momentum is between about 10^{-45} and 10^{-50} square centimeters per gram for a gyration of about the Planck mass. The cross section per unit mass of a gyration is at least forty-five orders of magnitude below the bound of about one square centimeter per gram that colliding clusters set (Chapter 1, Section I). So the dark matter is collisionless with itself, as well as with the content.

The lowest motion of the internal space cannot radiate, for a reason of its own, which the Passage states: “That motion is already the lowest state, so it cannot radiate or dissipate” (the Passage, Chapter 11, Section II).

The breathing excitations. The even excitations of the breathing kind, which lie above the lowest motion, do not persist. Their coupling to the open waves vanishes at the order the Passage computes, but the term of Gauss and Bonnet, which the ten-dimensional action admits with a coefficient the Passage does not fix (the Passage, Chapter 11, Section I), couples the breathing of the internal volume to the waves of the open geometry, and no symmetry forbids that coupling. The Lovelock terms (Lovelock 1971), of which the term of Gauss and Bonnet is the first, can by themselves hold a curved internal space under flat open dimensions, without a cosmological constant, once terms cubic in the curvature are present (Müller-Hoissen 1985); the same class of theories gives four dimensions with a small cosmological constant (Canfora, Giacomini, Troncoso and Willison 2009). So their coefficients bear on the hold as well as on the decay of the breathing excitations. For a coefficient of natural size, the lowest breathing excitation decays within about a Planck time. The estimate from perturbation theory, about 10^{-46} seconds, is shorter than the Planck time of 5.4×10^{-44} seconds, so it shows only that nothing suppresses the decay. A lifetime above 10^{11} years would need the coefficient below about 8.8×10^{-33} Planck areas, and the floor's own energy at one loop is expected to produce a larger effective coefficient even where the coefficient of the action is zero. So the breathing excitations made at the turn have long since decayed, and the persistent dark matter is the lightest odd excitation alone. Other even levels, which are not invariant under the isometries of the internal space, cannot pass their energy to the waves of the open geometry in this way, since those waves are invariant under the isometries; their other channels of decay are open.

The settling. As the internal space settles into its held size at the turn, the energy of its motion goes into the breathing excitations, and their decay sends that energy into gravitational waves of the open dimensions. The microwave background registers such waves as extra radiation, counted in the effective number of light species, N_{eff} (Pagano, Salvati and Melchiorri 2016). The floor holds the internal space in a well about one twen-

tieth of the Planck density deep, computed from the energy the Passage gives for the held internal space (the Passage, Appendix D, Section III), and the settling releases between a tenth of that depth and most of it. The measured number of light species allows those waves less than about three percent of the content's radiation at the time when the content had about a hundred species (Aghanim and others 2020; Calabrese and others 2025; Goldstein and Hill 2026). The release is about forty to three hundred times the largest energy that a plasma cool enough for the limit of Section VI can hold, so a plasma formed at once beside it could not outweigh the waves. So either the internal space settles far more gently than that, or a later stage of the content releases enough radiation to outweigh the waves (Chapter 6, Section I). The account predicts no particular excess in the effective number of light species; it requires only that the waves stay within the measured bound.

IV. No Exit into Evaporation

An excitation of the Planck scale has no lower level into which to evaporate: the next scale at which evaporation could act lies some thirty orders of magnitude away, and the floor of the internal space is the lowest state of its kind. Remnants of black holes at the Planck mass have been held stable for the same reason (Chapter 1, Section IV).

V. The Lightest Odd Level

The lowest level of the internal space that holds odd states is the first harmonic of the sphere: a function of degree one on S^2, constant over $\mathbb{C}P^2$. Its Laplacian eigenvalue is $2/R_T^2 = 2/l_{Pl}^2$, the value the Passage gives as the slowest variation the internal space admits: “the first eigenvalue of its Laplacian, $12/R_O^2 = 2/R_T^2$, is twice the Planck curvature” (the Passage, Chapter 17, Section V). The first harmonic of $\mathbb{C}P^2$, an octet under its isometries, has the same eigenvalue, because both factors curve by the same

amount. The antipodal map leaves $\mathbb{C}P^2$ in place, so every factor taken from $\mathbb{C}P^2$ is even. Every odd state therefore takes its sign from a function, or the gradient of a function, of degree one on the sphere.

At the classical level four odd multiplets share the lowest mass, a squared mass of 2 in Planck units, which is $\sqrt{2}$ Planck masses, about 1.7×10^{19} GeV. The table gives each, with the components of the metric it comes from, its factor on each part of the internal space, its spin, its representation under $SU(3) \times SO(3)$ (the isometries of $\mathbb{C}P^2$ and the rotations of S^2), its sign under the antipodal map, and its classical squared mass in Planck units.

Spin	**Components of the metric**	**Factor on $\mathbb{C}P^2$**	**Factor on S^2**	**$SU(3) \times SO(3)$**	**Sign**	**Mass squared**
2	open with open	constant	function of degree one	$(1, 3)$	odd	2
1	open with $\mathbb{C}P^2$	an isometry (octet)	function of degree one	$(8, 3)$	odd	$4 - 2 = 2$
1	open with internal	first harmonic (octet), with its gradient	function of degree one, with its gradient	$(8, 3)$	odd	$4 - 2 = 2$
0	$\mathbb{C}P^2$ with S^2	gradient of the first harmonic (octet)	gradient of the function of degree one	$(8, 3)$	odd	$4 - 2 = 2$

The first row is the spin-two triplet. For spin two the squared mass is the eigenvalue of the Laplacian on the function the state carries over the internal space (Hinterbichler, Levin and Zukowski 2014), and that eigenvalue is 2 for the function of degree one on the sphere. The second row is

the gauge field of the isometries of $\mathbb{C}P^2$, which the reduction gives over the open spacetime and the sphere together, taken at its first harmonic on the sphere. The third and fourth rows are built from the product of the two first harmonics, the octet on $\mathbb{C}P^2$ and the function of degree one on S^2, whose Laplacian eigenvalue is $2 + 2 = 4$. For spin one and spin zero the squared mass is the eigenvalue of the operator on one-forms or on symmetric tensors less 2, which is twice the Ricci curvature of each direction. For the last three rows that eigenvalue is 4, so their squared mass is 2, the same as the spin-two triplet's. The third row is the combination of the two gradients that is not itself a gradient; the gradient of the product is absorbed by the spin-two field on the same product. That spin-two field takes the eigenvalue without reduction, so it lies higher, at a squared mass of 4. The fourth row is a change of shape that tilts the directions of $\mathbb{C}P^2$ toward those of the sphere.

Two further states of the first harmonic of the sphere are not in the table. The level's vector is absorbed by the massive spin-two field, so the level has no spin-one member of its own. Its one spin-zero member, the size of $\mathbb{C}P^2$ varying across the sphere, would be unstable without the floor; the floor's response, estimated from its response to a uniform change of size, lifts it to about 3.2 Planck masses. It stays above the lightest odd state if the floor resists an uneven change of the size of $\mathbb{C}P^2$ with more than about a fifth to a third of the stiffness it shows for a uniform one: a fifth if the lightest odd state has its first-order mass, and a third if it has its classical mass.

The masses of the table hold under two conditions: that the higher Lovelock terms do not alter the operators, and that the floor acts as an ordinary source. At one loop the floor does not act only as an ordinary source. Its local term, the least extent, lowers the squared masses of all four states by the same amount, so it splits none of them. At first order it takes the squared mass from 2 to about 0.4, and so the mass from $\sqrt{2}$ to about 0.6 Planck masses. The rest of the floor, read locally, lifts the spin-zero octet-triplet, which changes the local shape of the internal space, and

leaves the other three where they are. No local term built from the curvature without its derivatives separates the spin-two triplet from the spin-one octet-triplets at this order. The least extent that the Passage fixes is the term $\kappa \operatorname{tr} \mathrm{Ric}^5$, the fifth power of the curvature that each of the six directions sees, summed over the six (the Passage, Appendix D, Section III). Its response multiplies the squared mass of every spin-two level of the internal space by one factor, about 0.19 at first order, and it leaves the gauge fields of the isometries massless. Only the part of the floor that is not local can separate the three candidates. The mass of the lightest odd state is about 0.6 Planck masses at first order and $\sqrt{2}$ Planck masses at the classical level, and the candidates are the spin-two triplet and the two spin-one octet-triplets. The internal space whose levels these are is held by the Passage: "the internal space has the same size and the same shape at every point of the exterior" (the Passage, Chapter 11, Section II). The term of Gauss and Bonnet, whose coefficient the Passage does not fix, splits the candidates already at the classical level, and within the range that coefficient may take it can put either spin lowest. The lightest of them is the one that persists. Whichever it is, it cannot decay, and the numbers of Section VI hold for it, with its own mass.

The odd states form triplets under the rotations of the sphere. The rotations do not by themselves keep them from decaying. The fields that the reduction gives for the rotations are also a triplet, so a triplet could pass its charge to one of those fields; only the antipodal map forbids it, since those fields are even. The first study of stable excitations of a compact space at the Planck scale already distinguished a conserved charge of the internal symmetry from a class of its representations as the source of stability (Kolb and Slansky 1984).

The rotations of the sphere are symmetries of the internal geometry, and in a reduction of the geometry they give fields over the open spacetime under which the triplet is charged, at a strength of the order of gravitation's own. The standard result of the reduction is that the symmetries of an internal space become gauge fields, and that the massive harmonics

of the metric carry charges of those fields and include states of spin two (Salam and Strathdee 1982). For a circle, every harmonic carries a charge proportional to its mass, with one ratio for all of them (Overduin and Wesson 1997); when the radius is free to vary, that ratio is the one of an extremal black hole, and when the radius is held fixed the harmonics satisfy the bound without saturating it (Heidenreich, Reece and Rudelius 2016). Weinberg's prescription gives each coupling as the ratio of $2\pi(16\pi G)^{1/2}$ to a root-mean-square circumference of the internal space (Weinberg 1983). Computed here by that prescription, with each generator normalized so that the trace of its square is one half and so that its flow has a period of 2π, the coupling at the Passage's radii is about 6 for the rotations of S^2 and about 16/3 for the isometries of $\mathbb{C}P^2$, in the units in which electromagnetism has 1/137. These two values are this book's computation; Weinberg gives the prescription, not these values. So the fields are strongly coupled at the Planck scale. They confine there and do not reach the open spacetime as a long-range force, because they are non-abelian and already strongly coupled at the Planck scale. Three steps give this. First, no state lighter than the Planck mass carries their charge: the states that carry it are the massive harmonics of the internal metric, the lightest of which, the odd level of this section, lies at about 0.6 Planck masses at first order and $\sqrt{2}$ Planck masses at the classical level; the internal space is held at one size and one shape at every point (the Passage, Chapter 11, Section II), so no light deformation of it carries the charge; and the isometries of this internal space are not the forces of particle physics (below), so no field of the content carries it. Second, below the Planck mass the fields therefore run as pure non-abelian fields, with no charged matter at all, and a non-abelian coupling grows at longer distances when its charged fields are few enough (Gross and Wilczek 1973; Politzer 1973); with none, it grows. Third, a non-abelian field that is strongly coupled at the shortest length of its description binds its charges and leaves none free, “in this limit the binding mechanism applies and there are no free quarks” (Wilson 1974), and these fields are strongly coupled already at the Planck length, the shortest length at which the reduction that gives

them holds. So the triplet is dressed with the field into a singlet that is still odd under the antipodal map, since the field is even; the singlet cannot decay, and at long range it acts only through gravity. The couplings of about 6 and 16/3 are about 300 times the weak and strong couplings at the Planck scale (Buttazzo and others 2013), so the isometries of this internal space are not the forces of particle physics. That supports reading any $\mathbb{C}P^2 \times S^2$ of the content as a separate instance of the schema. Were the triplet to carry a charge of the content, it would be tested directly: a charged relic of the Planck mass would be visible to detectors on Earth (Lehmann, Johnson, Profumo and Schwemberger 2019), and slow, heavy, ionizing particles of the Planck mass have been proposed as dark matter and as a target for search (Meissner and Nicolai 2019).

Confinement leaves bound states of about the Planck mass. The dressed triplets are the gyrations, odd and kept. The bound states of the fields alone are even under the antipodal map, so the exit into the waves of the open geometry, which Section III closes only to odd states, is open to them. At the Planck mass the strength of gravitation, Newton's constant times the square of the mass in natural units, is of order one, so they take that exit at the turn. One of them is kept: the lightest state of the confined spectrum that is odd under the conjugation of $\mathbb{C}P^2$, which that symmetry keeps from decaying (Section III). That state, like every gyration, is a vibration of the internal geometry: it acts only through gravity, and it adds nothing to the count of Chapter 3, which counts the classes of the internal space and not the states that hold energy (Section III). Nothing of these fields therefore reaches the present epoch as a long-range force, or as a kind of particle other than a vibration of the internal geometry, so the dark component stays the one kind the account names. Prediction 30 of *The Registered Predictions of Physics from Comparison* states that the dark component stays the one dark kind that the account names. Among the kinds that will not be found, Prediction 30 lists “no dark photon, no mirror particle and no hidden sector”.

VI. The Number of the Gyrations

A gyration of about the Planck mass has about 10^{19} times the mass of a proton. With the ratio of Chapter 3, there is about one gyration for every 1.5 to 3.4 × 10^{18} baryons (for a gyration of 0.6 to $\sqrt{2}$ Planck masses, the first-order and the classical values of Section V), and about 2 to 4 × 10^{-28} gyrations for every photon of the microwave background. The small number of gyrations for each baryon is the opposite of the asymmetric accounts, in which dark and ordinary particles are about equal in number (Barr, Chivukula and Farhi 1990; Kaplan, Luty and Zurek 2009). It differs also from the account in which the anomalies of the weak interaction make that account's dark particles comparable in number with the baryons, with dark masses of the weak scale (Kaplan 1992). In the neighborhood of the Sun, at the measured local density of dark matter, there is about one gyration in every few tens of thousands of cubic kilometers. An estimate of the same kind, about one white hole of the Planck scale in every 10,000 cubic kilometers, has been made for remnants of the Planck mass (Rovelli and Vidotto 2018a). No detector yet built registers a single one through gravity alone; arrays of sensors proposed for the purpose would need reductions of quantum noise far beyond present reach. Such arrays were proposed by Carney, Ghosh, Krnjaic and Taylor (2020). A realistic study finds that they would need about 80 decibels of reduction of quantum noise (Qin and others 2025).

Even taken as made independently of one another, the gyrations leave by their number alone a departure of about 5 to 8 × 10^{-27} in a region twenty megaparsecs across, the scale at which the amplitude of the primordial departures is quoted. The measured departures are about 10^{-5}, so the finite number of the gyrations adds no measurable noise to them.

The gyrations are made only at the turn. Anything that gravitates can be made in pairs by a hot plasma through gravity alone. If the plasma of the new epoch formed at once, the measured amount of dark matter requires that the plasma never have been hotter than about one thirtieth of the mass of a gyration. The divisor of the mass runs from about twenty-eight to about thirty-four according to the strength of the coupling; for a gyration of $\sqrt{2}$ Planck masses the limit is about 5×10^{17} GeV, and for 0.6 Planck masses about 2×10^{17} GeV. The making of gyrations in pairs by a hot plasma is the production studied for dark matter that interacts with the plasma through gravity alone. The yield of that production falls exponentially once the mass exceeds the temperature (Garny, Sandora and Sloth 2016; Garny, Palessandro, Sandora and Sloth 2018). The divisor is computed here from their method and their cross sections; they do not state it. The limit concerns the highest temperature the epoch reaches, which can exceed any later temperature of reheating (Chung, Kolb and Riotto 1999). If the turn's energy reached the plasma gradually, through a stage that behaved as matter and decayed into the content, the condition falls instead on the end of that stage: the reheating that ended it must lie below about one hundredth of the mass of a gyration, even if the energy at its start was of the Planck density. The plasma may then have been as hot as about one thirtieth of the mass at its hottest moment, because the radiation that the stage releases afterward dilutes the gyrations made at that moment. In an epoch whose observed departures were made by inflation, the bound on primordial gravitational waves (BICEP/Keck Collaboration 2021) would keep the temperature far below this limit, and dark matter of this mass could not be made after that inflation in the measured amount (Garny, Sandora and Sloth 2016; Kolb and Long 2024). The gyrations here are made at the turn, and the Passage "excludes an inflationary phase long enough to stretch the scales observed today from within the early horizon to beyond it", while a shorter phase "is neither required nor excluded by the account" (the Passage, Chapter 18, Questions). The limit on the temperature assumes couplings suppressed by the Planck mass; exchange of a massive particle of spin two coupled more strongly than

gravitation, as posited in the account of a portal of spin two (Bernal and others 2018), would produce more gyrations from the plasma and so tighten it. The fields of the rotations of the sphere, which couple to the gyrations at a strength of about 6 (Section V), would tighten the limit only to about one thirty-fourth of the mass if they were present and free in the plasma, and would leave it unchanged if they are confined. Stable excitations of a compact space would be about as numerous as the photons if the epoch began near the Planck temperature (Kolb and Slansky 1984). The account therefore requires that the plasma of the new epoch never be hotter than this limit, or, if the turn's energy reached the plasma gradually, that the stage that released it end below about one hundredth of the mass of a gyration (Chapter 6). The gyrations made directly as the internal space re-forms must number about 10^{-27} of what an abrupt re-forming would make; this requires the re-forming, and the capture of the internal space by the floor at the end of it, to be slow and gentle compared with the period of the lightest odd level. A suppression of 10^{-27} is about e^{-62}. Where the yield falls as $e^{-\omega\tau}$, with ω the frequency of the level and τ the time over which the change is smooth, that needs $\omega\tau$ of about 62, a change smooth over about ten periods of the level. On the Passage's arc each internal direction contracts as the inverse ninth root of the time (the Passage, Appendix B, Section IV), which is slow compared with that period once the time exceeds about the time light takes to cross the internal radius. On the Passage's account, the description of the new epoch begins where the curvature falls below the Planck curvature, while the internal space is re-forming (the Passage, Chapter 18, Section VII, and Chapter 19, Section I). This requirement is a condition on the turn and not a result (Chapter 6, Section I).

Questions

Is this not a parity of the Kaluza and Klein kind?

Yes, in kind. Dark matter in theories of extra dimensions is held stable by a reflection of the internal space under which odd states couple only in pairs (Cheng, Matchev and Schmaltz 2002; Servant and Tait 2003), and stable excitations of a compact space at the Planck scale were first studied as relics of the early universe (Kolb and Slansky 1984). The account differs in four ways. The reflection is the antipodal map of a sphere that is not identified with its antipodes, and it has no fixed points. The action contains the metric alone. The scale is the Planck scale. The lightest odd state is the spin-two triplet of the first harmonic of the sphere, or one of the two spin-one octet-triplets that share its mass. On the projective plane, where antipodal points are identified, the states of the metric that are odd under the antipodal map do not exist, as fields identified there without a change of sign keep only their harmonics of even degree (Dohi and Oda 2010); the account requires the sphere.

Is the dark matter a remnant of evaporated black holes?

No. Remnants of the Planck scale have been proposed as dark matter (MacGibbon 1987; Barrow, Copeland and Liddle 1992; Chen and Adler 2003; Rovelli and Vidotto 2018b). Those remnants are held stable because their evaporation stops at the Planck mass, where no lower state is open to the remnants (Chen and Adler 2003; Rovelli and Vidotto 2018b). I share that reason for stability. Remnants formed before a bounce and carried into the present epoch (Rovelli and Vidotto 2018c), and black holes formed before a bounce that survive it (Carr, Clifton and Coley 2017), have also been proposed. My account differs in what the dark matter is, an excitation of the internal geometry and not a black or white hole, and in the dark matter's being made at the turn rather than carried through

the turn. The bound from gravitational waves on remnants formed at a peak of a Gaussian primordial spectrum (Trivedi and Loeb 2025) does not apply here, since nothing here needs such a peak.

How does this differ from the dark matter of conformal cyclic cosmology?

There the dark matter, which Penrose calls erebons, also has about the Planck mass, is created at the transition between epochs, and interacts only through gravity (Penrose 2018). There it must decay within each epoch, with a lifetime of the order of a hundred billion years, so that it does not accumulate from epoch to epoch. The bound on the lifetime of the dark component in Chapter 1, Section I, already presses on that decay. Here it does not decay. It need not decay: in conformal cyclic cosmology the remote future of each epoch must be free of mass for the next epoch to join it (Penrose 2018), whereas here every gyration ends, with all other matter, where the internal space de-compactifies, and each new epoch holds only the gyrations that its own turn makes (Chapter 6). A decay of the dark component, seen in the expansion, would favor that account over this one.

Is a gyration of the Planck mass not a black hole?

A gyration of 0.6 to $\sqrt{2}$ Planck masses has a gravitational radius of about one to three Planck lengths, comparable to its reduced wavelength and to the size of the internal space it vibrates, and stable objects of the Planck mass have been described as elementary black holes (Markov 1993) and as the remnants of evaporated black holes (Chen and Adler 2003). A gyration is a level of vibration of the internal geometry, with a definite energy and a definite sign under the antipodal map; it is not a collapsed region of the open geometry.

How does this differ from Planckian interacting dark matter?

That proposal also has dark matter of up to about the Planck mass that interacts only through gravity, and it names an excitation of the graviton of the Kaluza and Klein kind as one realization (Garny, Sandora and Sloth 2016; Garny, Palessandro, Sandora and Sloth 2018). There the amount is made by scattering in the hot plasma after inflation, and it is set by the temperature of reheating; its most natural masses, above about a hundredth of the Planck mass, are already excluded by the absence of primordial gravitational waves at the level they need. There the stability is not exact, and the dark matter may decay through effects of quantum gravity. Here the parity that keeps the gyrations is a property of the geometry, and it is gauged (Section III). Here the amount is fixed by an identity of the present measurement, and not by a temperature (Chapter 3). Here the gyrations are made at the turn, and the plasma must stay below about one thirtieth of their mass (Section VI). A detection of primordial gravitational waves at the level that proposal needs would support its production, which this account does not need.



Chapter 5

The Measurements

What the Measurements Say of the Account

Rests on: Chapters 1 to 4. Used by: Chapter 6.

I. The Ratio

The account predicts $\Omega_c/\Omega_b = 6 - 2/\pi = 5.3634$. Planck alone gives 5.364 ± 0.065 (Aghanim and others 2020). The microwave background measures the two densities from the heights of its acoustic peaks. Those heights are set by general relativity, by sound in the plasma of photons and ordinary matter, by the scattering of light on free electrons, and by the forming of hydrogen atoms. They depend on the dark matter only through its gravitation and through its taking no part in that sound. The combination of the South Pole Telescope, Planck and the Atacama Cosmology Telescope gives 5.370 ± 0.048 (Camphuis and others 2026), and every analysis of the microwave background alone lies within 1.3 standard deviations of the prediction. These two ratios are computed here from the two published densities, treated as uncorrelated. A correlation of -0.4 between the densities would enlarge each uncertainty by about 15 to 18 percent. The neighbors of the rule within its form, $6 - 1/\pi$ and $6 - 3/\pi$, would then still lie more than five standard deviations from the combined measurement.

Analyses that add the baryon acoustic oscillations of the Dark Energy Spectroscopic Instrument (DESI) lie lower: the densities fitted with its second data release give 5.199 ± 0.035 (Louis and others 2025, Table 5). That ratio and its uncertainty are computed in the same way; a correlation of -0.4 between the two densities would enlarge the uncertainty by about 18 percent. The oscillations do not measure the dark density: they measure the matter fraction, and they lower the fitted dark density where they prefer a lower matter fraction. The same analyses press on the matter fraction of the Passage. The two pressures, read through the coefficient of Section III, pull in opposite directions: in the most precise of these analyses the ratio asks for a coefficient of 1.26 ± 0.06 and the matter fraction for 0.68 ± 0.11, 4.7 standard deviations apart, while the ratio itself lies 4.7 standard deviations from the prediction, or about 4.0 with that correlation. Both figures rest on one kind of measurement, and a single kind can carry an error of its own that its stated uncertainty does not include. Within the standard model itself, the oscillations of DESI and the microwave background differ by 2.3 standard deviations (DESI Collaboration 2025), so a combination of the two measures that difference along with the ratio. The account holds the matter fraction at 0.311 and the cosmological constant fixed at one value (the Passage, Chapter 13, Sections III and VI), so it expects the pull of the oscillations toward a lower matter fraction to recede as their data grow.

The Passage's external value is $f = 1 - 3/(8\pi) = 0.8806$: the vacuum's energy at the Planck scale in Planck units, one for its ground-state part less $3/(8\pi)$ for the bare curvature term (the Passage, Chapter 13, Section II). Two other forms built from the Passage's quantities lie within two standard deviations of the measurement: six shares of the external value, $6f = 5.284$; and $(6 - 3/\pi)/((1 + f)/2) = 5.365$, which lets the curvature of the whole internal space abide and holds the ordinary residue at the mean of one and f. The second of the two other forms differs from the rule by 0.036 percent, a difference that no foreseeable measurement separates, and the rule needs one step fewer than the second form. The first would

be separated from the rule at about three standard deviations by a ratio measured to half a percent. The same measurement would separate the rule from $2\pi - 1 = 5.283$ (Agyemang 2026), which lies within 0.001 of the first form. Within the rule's own form, no abiding, the abiding of S^2, and the abiding of the whole internal space are excluded.

II. A Second Kind of Measurement

Routes that do not use the microwave background measure the share of the ordinary matter in all the matter, for which the prediction, with the lightest neutrinos, is 0.15644. The baryon density from primordial nucleosynthesis (Schöneberg 2024) with the oscillations of the Dark Energy Spectroscopic Instrument (DESI Collaboration 2025) gives 0.1587 ± 0.0066; the same baryon density with the full-shape analysis of that instrument (Forero-Sánchez and others 2026) gives 0.1542 ± 0.0063; the gas of galaxy clusters gives 0.156 ± 0.034 (Mantz and others 2022). Each agrees with the prediction; the most precise of them is about five times less precise than the microwave background, and the cluster gas about thirty times less.

III. The Shared Coefficient

The ratio and the Passage's matter fraction depend on one coefficient, the curvature of the internal dimensions in Planck units, which the Passage identifies as one. The ratio measures it at 0.99 ± 0.08, two to three times more closely than the matter fraction does, and the two agree with the microwave background alone.

IV. The Shape of the Internal Space

The ratio depends on the curvature of $\mathbb{C}P^2$ alone, so it measures how the internal curvature divides between the two factors. With the whole internal curvature held at 6, and with x the ratio of the radius of $\mathbb{C}P^2$ to the radius of S^2, the rule reads

$$\Omega_c / \Omega_b = 6 - 36/(\pi(12 + x^2)),$$

which equals $6 - 2/\pi$ exactly at the Passage's $x = \sqrt{6}$. The reading by the theorem of Gauss and Bonnet and the reading by each factor's own Einstein trace (Chapter 3, Section IV) give this same function at every shape. If the rule holds, the combined measurement of Section I gives $R_{\mathbb{C}P^2} = 3.96 \pm 0.30$, against the 4 of the Passage's Einstein condition, and $x = 2.49 \pm 0.28$, against $\sqrt{6} = 2.45$. Planck alone gives $x = 2.45 \pm 0.38$, and the analysis with the oscillations that gives 5.199 (Section I) gives $x = 1.52 \pm 0.21$. The Simons Observatory with Planck would measure x to about 8 percent, which is the ratio to about 0.6 percent, according to its published forecast (Ade and others 2019). On the condition that the rule holds, the ratio is the one measurement of the shape of the internal space. The shape test and the choice of the rule are one measurement, not two. At $x = 2$ the rule equals $6 - 9/(4\pi)$, which is 6f exactly (Section I), so a measured ratio can confirm the rule at the Passage's shape, or fit the rule at another shape, but it cannot do both. The dated record fixes the shape at the Passage's $x = \sqrt{6}$.

V. Small Scales

A perfectly cold, collisionless component meets every present bound that separates cold dark matter from its warmer or wavier alternatives: the forest of hydrogen absorption (the Lyman-alpha forest), the counts of the faintest satellite galaxies, and the substructure seen by strong lensing. A

combined analysis of the last two places the half-mode mass, the mass scale at which a cut-off would halve the amplitude of the primordial departures relative to cold dark matter, below about ten million solar masses at 95 percent confidence (Nadler and others 2021). The forest of hydrogen absorption places the mass of a thermal relic of warm dark matter above 5.3 keV at 95 percent confidence (Palanque-Delabrouille and others 2020). The account also inherits what cold dark matter on small scales must account for, chief among them the tightness of the relation between the visible matter and the motions of galaxies. The relation, known as the radial acceleration relation, is measured at 2693 points in 153 disc galaxies of the SPARC sample of 175 (Lelli, McGaugh and Schombert 2016; McGaugh, Lelli and Schombert 2016). At each radius the acceleration found from the rotation is one function of the acceleration that the visible stars and gas alone would produce. Its scatter is about 0.13 dex, and the errors of measurement account for most of it. The function follows the visible matter where the acceleration that matter alone would produce is large, and departs from it more and more as that acceleration falls to about 1.2×10^{-10} meters per second per second and below, the acceleration scale proposed by Milgrom (1983). The tightness of that relation follows from galaxy formation under general relativity with a cold component that acts only through gravity, and the account inherits it because the gyrations are such a component: they couple to the content through gravity alone (Chapter 4, Section II), and they are cold whatever speed the turn gives them, so that on the scales of galaxies they cluster exactly as standard cold dark matter does (Section VI). Simulations of galaxy formation with such a component reproduce the relation and its small scatter (Keller and Wadsley 2017; Ludlow and others 2017; Dutton and others 2019). The relation's origin lies in the self-similar profiles of cold halos, in the narrow range of halo mass in which disc galaxies form, and in the slow relaxation of the dark component around the gathering ordinary matter (Navarro and others 2017; Paranjape and Sheth 2021). The acceleration at which the relation turns is therefore set by formation and not by a constant of the field equations, and the clusters of galaxies show it: there the same form turns

at $(2.02 \pm 0.11) \times 10^{-9}$ meters per second per second, about seventeen times the galactic value (Tian and others 2020; Tian and others 2024). The acceleration scale lies close to the speed of light times the Hubble constant divided by 2π, which is 1.05×10^{-10} meters per second per second at the Passage's Hubble constant of 67.8 kilometers per second per megaparsec. The Hubble constant is the present rate of the expansion, and in a flat epoch the share of the cosmological constant in the budget is that constant times the square of the speed of light, divided by three times the square of the Hubble constant. So, at a given share, the speed of light times the Hubble constant is fixed by the cosmological constant, and a reader may ask whether the cosmological constant, which makes the expansion speed up today, sets the scale in the galaxies, where the scale is measured. The field equations hold Newton's constant and the cosmological constant, and no constant of acceleration. The acceleration with which the cosmological constant draws two free bodies apart is that constant times the square of the speed of light times their distance, divided by three; with the Passage's Hubble constant and the Passage's share of the cosmological constant in the budget, 0.689, that acceleration is about 1.0×10^{-15} meters per second per second across ten kiloparsecs, the size of a galaxy, which is less than a hundred-thousandth of the scale. Inertia and the coupling to gravitation are one relation of a content to its context: "For a context-modal phenomenon, the coupling of every content to it equals that content's inertia" (*The Unquantized Arena*, Proposition 5.3), and gravitation is such a phenomenon, since it is a distortion of a context: "Gravitation distorts space" (Chapter 2, Section II). That holds at every acceleration and in every environment, so the ratio of gravitational to inertial mass is one everywhere, and no temperature of the horizon enters inertia apart from weight. This answers the second route by which the horizon has been proposed to set the scale, in which below the de Sitter temperature "the ratio of gravitational to inertial mass is a function of environmental and global parameters" (Smolin 2017). So in this account the scale belongs, with the tightness of the relation, to how the galaxies formed under general relativity; the field equations give the scale no value at any place in a galaxy.

Changing the law of gravity instead, as the modified dynamics (modified Newtonian dynamics, MOND) does, still leaves clusters of galaxies short of mass (Sanders 2003; Famaey, Pizzuti and Saltas 2025). Without dark matter the modified dynamics predicts a third peak of the microwave background lower than the one measured (McGaugh 2004; Aghanim and others 2020). With the field equations exact throughout the domain of the smooth description, below the Planck curvature, as the Passage derives them, a galaxy falling freely in the field of a larger one feels that field only through its tide, as general relativity requires, and not through the external field effect that the modified dynamics predicts.

Cold dark matter has three further standing questions on small scales. Simulations of cold dark matter alone give cusps at the centers of dwarf galaxies, where cores are found. They give more small halos than there are faint satellite galaxies. And they give dense, massive satellites that are not seen, the problem known as too big to fail. Within cold dark matter the explanations most studied are the feedback of stars on the gas of small galaxies, the suppression of star formation in the smallest halos after reionization, and the faint satellites that deep surveys continue to find (Bullock and Boylan-Kolchin 2017).

VI. The Amplitude of Clustering

The account fixes how strongly matter has clumped by today, once the primordial amplitude is taken from the microwave background, which the account does not predict. With the Passage's matter fraction, 0.311, the ratio of Chapter 3, and the primordial amplitude and tilt of Planck 2018, the amplitude of clustering today is $S_8 = \sigma_8 (\Omega_m / 0.3)^{1/2} = 0.823 \pm 0.006$. That value is computed at the matter density that keeps the angular size of the acoustic scale the microwave background measures; with the Passage's Hubble constant taken at its central value, $h = 0.678$, it is 0.827 ± 0.007. The standard model fitted to the same measurement gives 0.832 ± 0.013

(Aghanim and others 2020). The account's value is lower, and its uncertainty half as large, because the account fixes the matter fraction where the standard model fits it.

The lensing of the microwave background agrees with the account within one standard deviation (Qu and others 2026; Omori and others 2026), as do the complete Kilo-Degree Survey (Wright and others 2025) and the growth rate measured from the motions of galaxies (Alam and others 2021). The final galaxy clustering and weak lensing of the Dark Energy Survey lies 2.5 standard deviations below the account (Abbott and others 2026). The clusters counted by eROSITA lie 3.2 standard deviations above it (Ghirardini and others 2024). Those two measurements differ from each other by 4.5 standard deviations. The gyrations are cold whatever speed the turn gives them, because the momentum of each falls as the universe expands. A gyration moving with the speed it would have in a plasma at one thirtieth of its mass travels about two centimeters in the whole history of the universe. Even a gyration that left the turn with a hundred times its mass in momentum, when the universe was at the Planck temperature, travels less than a meter. So on these scales the gyrations cluster exactly as standard cold dark matter does. The amplitude of clustering is not independent of the matter fraction: a value confirmed away from 0.823 bears first on the identity for the cosmological constant, unless the matter fraction is confirmed at 0.311 by a separate measurement.

VII. The Searches

The dark matter is registered through its weight alone: on the identification of Chapter 1, Section IV, every search for it through any interaction but gravity finds nothing, at any sensitivity. From the identification of Chapter 1, Section IV, I predict that every search for the dark matter through any interaction but gravity finds nothing. Physically a gyration is a massive excitation of the metric of the six held internal dimensions, a

state of the Kaluza and Klein kind (Chapter 4, Section V). What the identification excludes is any coupling of a gyration to the content except through gravity. Other accounts of dark matter that interacts only through gravity make the same prediction for these searches (Feng, Rajaraman and Takayama 2003), and so do relics of the Planck mass if they are neutral; if they carry electric charge, as has been argued, detectors on Earth would see them (Lehmann, Johnson, Profumo and Schwemberger 2019). So a lasting null result separates this account from particles of weak interaction, not from those accounts.

VIII. The Weight of the Match

The rule was selected from a small family of expressions of one form, and twelve expressions were examined in all. The table gives each, with its distance from the measurement in standard deviations: from Planck alone, 5.364 ± 0.065, and from the combination of the South Pole Telescope, Planck and the Atacama Cosmology Telescope, 5.370 ± 0.048.

Expression	What it takes	Value	Planck	Combined
$6 - 2/\pi$	the abiding of $\mathbb{C}\mathrm{P}^2$ (the rule)	5.3634	−0.01	−0.14
6	no abiding	6.0000	+9.8	+13.2
$6 - 1/\pi$	the abiding of S^2	5.6817	+4.9	+6.5
$6 - 3/\pi$	the abiding of the whole internal space	5.0451	−4.9	−6.8
$6 - 6/\pi$	the internal space as one factor of six dimensions, by its Einstein trace	4.0901	−19.7	−26.8
$6(1 - 1/(4\pi))$	six shares, each less the bare term of $\mathbb{C}\mathrm{P}^2$	5.5225	+2.4	+3.2

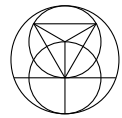
Expression	What it takes	Value	Planck	Combined
$6\mathrm{f} = 6(1 - 3/(8\pi))$	six shares of the external value	5.2838	−1.2	−1.8
$(6 - 3/\pi)/((1 + \mathrm{f})/2)$	the whole abiding, with the ordinary residue at the mean of one and f	5.3653	+0.01	−0.10
$(6 - 2/\pi)/(1 - 1/(3\pi))$	the rule, with the ordinary residue also reduced by an abiding; identically 6	6.0000	+9.8	+13.2
16/3	a simple fraction	5.3333	−0.5	−0.8
27/5	a simple fraction	5.4000	+0.6	+0.6
38/7	a simple fraction	5.4286	+1.0	+1.2

The distances are computed from the unrounded ratios of the two measurements, 5.3643 ± 0.0646 and 5.3701 ± 0.0478.

One simple fraction near the rule, 16/3, is the value that a relaxation of the masses of the axion and the proton gives for a gauge group of eight colors (Banerjee, Brzeminski and Hook 2026). It lies 0.56 percent below the rule, and a ratio measured to about 0.2 percent would separate the two at three standard deviations. The weight of the rule rests on its form, on the exclusion of its neighbors within that form, and on the coefficient it shares with the Passage's identity. The shape of the internal space found through the rule adds no weight of its own, since it is the same measurement as the choice of the rule (Section IV).

IX. What the Account Predicts

The account's own prediction of number is the ratio $6 - 2/\pi = 5.3634$. With the Passage's matter fraction, it also gives the share of the ordinary matter in the cold matter, 0.15644, and the amplitude of clustering, 0.823 (Section VI); those values rest on the two books together. The account makes six predictions of kind: the dark matter acts only through gravity; it does not decay; it is perfectly cold, with no cut-off in its structure on small scales; it is made of gyrations of about the Planck mass; no short loop exists anywhere in space (Chapter 3, Section II); and the dark component carries no separate pattern of primordial departures (Chapter 3, Section I). The first four it shares with other accounts of a stable, cold dark matter that acts only through gravity, and the sixth with every account in which the dark matter and the ordinary matter vary together from place to place. The ratio, the coefficient it shares with the Passage's identity (Section III), and the absence of a short loop are the account's alone.



Chapter 6

What the Account Requires, and What It Claims

The Conditions on the Turn and on the Internal Fields, and the Claims in Brief

> Rests on: Chapters 1 to 5; Appendix A; *The Gravitational Passage*, Chapters 11, 13 and 18.

I. What the Account Requires of the Turn

The Passage does not fix "the temperature at which the reconstructed history of the new exterior begins" (the Passage, Chapter 18, Section XI). On the Passage's account, the description of the new epoch begins where the curvature falls below the Planck curvature, while the internal space, de-compactified at the turn, is re-forming (the Passage, Chapter 18, Section VII, and Chapter 19, Section I). The floor then holds the internal space in a well about one twentieth of the Planck density deep: the held internal space has an energy density of about -0.049 in Planck units (the Passage, Appendix D, Section III), and that energy rises to zero, with no barrier, as the internal space grows. The account requires three things of the turn. First, the plasma must never be hotter than about one thirtieth of the mass of a gyration; or, if the turn's energy reached the plasma through a stage that behaves as matter, that stage must end below about one hundredth of the mass (Chapter 4, Section VI). Second, the energy released as the internal space settles, which leaves as gravitational waves of the open dimensions, must stay below about three percent of the content's radiation

(Goldstein and Hill 2026; Chapter 4, Section III): either the internal space arrives at its held size displaced by no more than about one part in a thousand of its radius, or a stage that behaves as matter carries at least as much energy as the waves and decays into the content, not into gravitational waves, so that the radiation it releases outweighs them. Third, the gyrations made as the internal space re-forms must be about 10^{27} times fewer than an abrupt re-forming would make, which requires both the re-forming and the capture at its end to be slow and gentle compared with the period of the lightest odd level (Chapter 4, Section VI). A stage that behaves as matter belongs to the content, which is outside this book; the breathing of the internal space cannot be that stage, since it decays at once, and into gravitational waves. The first requirement excludes an epoch that began with a hot plasma near the Planck temperature, which would make the gyrations about as numerous as the photons (Kolb and Slansky 1984).

II. What the Account Requires of the Internal Fields

The lightest odd level is a triplet under the rotations of the sphere, and the fields that the reduction gives for those rotations couple to it with a strength of about 6 in the units in which electromagnetism has 1/137. If the field reached the open spacetime as a long-range force, and the charges of the gyrations did not cancel, that force would be excluded: the tidal streams of the Sagittarius dwarf galaxy disfavor a difference of more than ten percent between the accelerations of dark and ordinary matter (Kesden and Kamionkowski 2006), and a force acting on the dark matter alone is bounded at about five percent of gravitation (Bean, Flanagan, Laszlo and Trodden 2008). The account therefore requires that these fields not reach the open spacetime as a long-range force on charges that do not cancel. At the coupling that this book computes by Weinberg's prescription at the Passage's radii, of order six (Weinberg 1983; Chapter 4, Section V), the field is strongly coupled at the Planck scale and confines there,

since no state lighter than the Planck mass carries its charge; confined, it dresses each gyration into a state that is neutral and still odd, which stays dark and persists (Chapter 4, Section V). The account also requires that nothing in the world couple to the orientation of S^2; that is a prediction about the content (Chapter 4, Section III).

III. The Gyrations of the Previous Epoch

The gyrations do not decay. Conformal cyclic cosmology requires its dark matter to decay so that it does not accumulate from epoch to epoch (Penrose 2017; Penrose 2018). In this book no decay is needed, on the Passage's own account of the turn. Every gyration, like all other matter, either ends in the interior of a black hole or is carried away alone, and in both cases the internal space of which it is an excitation de-compactifies (the Passage, Chapter 18, Sections VI and VII, and Questions). At the turn the Passage constructs no geometry and "defines no field there, of any spin" (the Passage, Chapter 18, Section VII). It also holds that "no count is carried across the turn, for the matter or for the geometry, since each count is relative to the context that ends" (the Passage, Chapter 18, Section VIII). So a gyration of one epoch does not pass into the next as a gyration. What returns is the law that protects the gyrations: "In the new epoch the product re-forms with the same internal topology" (the Passage, Chapter 18, Section VII), so the new epoch has the same odd levels and the same antipodal parity. Each epoch's gyrations are therefore made at its own turn, and the ratio registered in an epoch counts all the gyrations present in it. If every gyration passed into the next epoch, their number would grow without bound, since "the cycle has no first iteration" (the Passage, Chapter 18, Section VIII); if only some passed, a count would pass the turn, which the same section excludes.

IV. What the Account Claims

What the account claims is short. The dark matter is a conserved excitation of the six dimensions of possibility, made at the turn and kept by the antipodal parity of the sphere. Its ratio to the ordinary matter is an identity of the present measurement, $6 - 2/\pi = 5.3634$, which shares its one coefficient with the Passage's identity for the cosmological constant. The account predicts, in kind, that no search through any interaction but gravity will find the dark matter, that it does not decay, that its structure has no cut-off on small scales, that its gyrations are of the Planck mass, that no short loop exists anywhere in space, and that it carries no separate pattern of primordial departures.

Appendix A

The Three Edges of Reality, and Why Context Must Distort

Horizon, Scale and Turn as One Triple; the Three Distortions as Its Image

> Rests on: *The Gravitational Passage* on what is real (Chapter 5), the modalities and their characters (Chapter 4), the grid of measures (Chapter 7), the Incommensuration Theorem (Chapter 3, Section IV), the Planck length (Chapter 9, Section IX), the horizon and the turn (Chapters 13, 17, 18 and 19); the three axioms of the modalities. Used by: Chapter 2.

I. Three Edges

The phrase "the edge of reality" names three limits in the account of the Passage, and each is a limit of the same thing. The word "reality" carries one exact sense throughout. The Passage states that sense in its fifth chapter: "To say that something is real is to say that it is given in an actual act: temporal, occurring now, with the future still open to possibilities not yet settled." What exists stands as structure; what is real is given in an actual act of comparison. An edge of reality, in this sense, is a limit of what actual comparison, made from inside the world, can reach.

The account has three such limits, written here with three letters.

The first of the three limits, H, is the cosmological horizon. The Passage says of the event horizon, in its eighteenth chapter, third section: "Content beyond the horizon, in its present and its future, is not comparable with the observer in principle, and so it is no part of that observer's exterior." H bounds comparison in extent: across space, and over the whole future of the observer.

The second of the three limits, P, is the Planck scale. The Passage calls the Planck length, in its ninth chapter, ninth section, "the bound of every comparison a located comparer makes". P bounds comparison in scale. P is not a wall: the Passage says the boundary "is not a wall that matter cannot cross" (the Passage, Chapter 17, Section II), and that beyond the boundary "the structure of comparison does not cease" (the Passage, Chapter 19, Section IV). What P bounds is the comparison a located comparer makes, and the domain of the smooth description of space and time.

The third of the three limits, T, is the turn. The Passage says that the collapse inside the black holes of one epoch and the origin of the next "are one transition in a cycle, approached as a limit from its two sides", and that no comparison registers the turn between the two sides as an event (the Passage, Chapter 18). T bounds comparison in time: every history of an epoch runs back toward T and does not pass it, and every interior of the epoch before runs forward toward T and does not reach it.

The question of this appendix is whether the three are a mere list, three limits that happen to share a name, or one structure seen three ways; and then what follows, for the three distortions of context, if they are one structure.

II. What a Triple Is, and How One Is Found

A triple is three terms that stand to one another as the three modalities stand: the immanent, the omniscient and the transcendent. The immanent is the role of the act itself, as it occurs. The omniscient is the role of what is laid out as structure and held in view. The transcendent is the role of the stance from which an act proceeds, and of the range of what could occur (Note 6).

Three axioms state how the modalities stand (the Passage, Chapter 4, Section V). Axiom III: they are distinct, inseparable and non-interchangeable. Axiom II: a class of the transcendent precedes an instance of the immanent, a class of the immanent precedes an instance of the omniscient,

and a class of the omniscient precedes an instance of the transcendent. Axiom I: the immanent is more fundamental than the omniscient and the transcendent, and those two are in conjugate relation.

A candidate triple is tested in the order in which the axioms are most often relevant. Axiom III is tested first, because it is the weakest requirement and the cheapest to fail: three terms that are not distinct, or that can come apart, or that can stand in for one another, are not a triple at all. Axiom II is tested second, because it fixes orientation: a cycle that runs the wrong way is a mirror image, and a mirror image is a different assignment, not a rotation of the same one. Axiom I is tested last, because it needs the other two: the immanent can be named only once the three are known to be a triple, in one orientation.

A second principle shortens the work. A list of three becomes a known triple by binding unambiguously, one to one, to a triple already known. The binding is what makes the association not arbitrary.

III. The Binding to the Grid of Measures

The known triple to which the three edges bind is the triple of contexts in the grid of measures. Any physical measurement involves six kinds of measure, in two rows of three. The row of contents is pattern, force and probability. The row of contexts is space, time and possibility. Each content is measured in its own context: pattern in space, force in time, probability in possibility. The columns are the three modalities: pattern and space are omniscient; force and time are immanent; probability and possibility are transcendent. The Passage sets out this grid in its seventh chapter.

H, the horizon, binds to space, and so to the omniscient. T, the turn, binds to time, and so to the immanent. P, the Planck scale, binds to possibility, and so to the transcendent.

For H the binding is direct. The horizon is the boundary of the space in which findings can ever be laid out for a given observer. What lies inside it is the observer's comparable world, held in view as one structure; what lies outside it is no part of that world.

For T the binding is equally direct. The turn is the limit of the time of every history. The last moment of every interior lies on one side of it, and the first finding of every new history lies on the other. Time is the context of the order in which findings are found, and T is where that order, for one epoch, begins and ends.

For P the binding needs an argument, because the Planck scale is a length, and a length suggests space; Section V gives it. For H there is a prior question, since the account has two cosmological horizons; Section IV answers it.

IV. Which Horizon

The account uses two horizons, and the Passage names them side by side, in its eighteenth chapter, third section: "Chapter 13 reckons the cosmological constant from the entropy of an observer's horizon; there the horizon is the particle horizon, the bound of what has reached the observer, and here it is the event horizon, the bound of what can ever reach the observer." The particle horizon bounds the past of what is compared: everything whose light has already arrived. The event horizon bounds the future of what can be compared: everything whose light ever can arrive.

Read separately, the particle horizon might look like the omniscient term, the record already laid out, and the event horizon like a transcendent term, the range of what could still be found. If that reading held, the horizon would split across two roles, and the triple would fail. It does not hold, because in the account the two horizons are one structure.

The particle horizon fixes the cosmological constant: the Passage takes the constant to be the accessible share of the vacuum's energy, three of the degrees of freedom that the particle horizon counts (the Passage, Chapter 13, Section II). The constant, in turn, fixes the event horizon. In a universe with a positive cosmological constant, as the matter thins, the geometry approaches the vacuum geometry of de Sitter; Wald (1983) proved that homogeneous models of this kind "exponentially evolve toward the de Sitter solution". The event horizon of that geometry has a fixed radius, the de Sitter radius, set by the constant alone. So what has already been laid out, at the particle horizon, fixes the bound of what can ever be laid out, at the event horizon. The two are the past face and the future face of one boundary of comparison, and the record determines the bound. The boundary of comparison, with its past face and its future face, is an omniscient structure: the laid-out, held-in-view whole of what an observer's world can contain.

H, in the triple, is the cosmological horizon in this full sense: the boundary whose past face is the particle horizon and whose future face is the event horizon with the de Sitter radius. Gibbons and Hawking (1977) stated the comparison-theoretic side of this: an observer in a universe with a repulsive cosmological constant "will have an event horizon whose area can be interpreted as the entropy or lack of information of the observer about the regions which he cannot see." The horizon's size is a count of what the observer cannot compare.

V. Why the Planck Scale Belongs to Possibility

The objection to binding the Planck scale to possibility is that lengths are measured in space. The binding does not rest on P being a length. It rests on the roles that the Passage gives P, and every one of those roles is a role of the transcendent column.

The first role is the size of the six dimensions of possibility. The internal space of the account, the complex projective plane times the sphere, is the space of possibilities of a three-way and of a two-way alternative. The Passage says that "The modal boundary fixes the size of the internal geometry" (the Passage, Chapter 17, Section V), and the modal boundary is the Planck scale. P is where the context of possibility is held.

The second role is the bound of the located comparer. The Planck length is "the bound of every comparison a located comparer makes". What P bounds is the stance: the position from which a comparison is made, and what a comparison made from there could find. The stance and the range of what could be found are the transcendent role.

The third role is the exchange of the two characters. At the Planck scale the smooth description of space and time and the stepwise description of content exchange dominance, and neither can be extended across the other. Continuity is the transcendent character, "what is unbroken and encompassing", in the Passage's words (the Passage, Chapter 4). P is the limit of perfected continuity: the scale below which the continuous description of the arena no longer holds.

So P bears a length, as every limit in a physical account must be stated in some unit, but what it does is transcendent in each of its three roles. The same is true, in reverse, of H: the horizon is also a length, the de Sitter radius, and it is omniscient because of what it does, not because of its unit. The binding is by role, and by role it is one to one.

VI. Axiom III: Distinct, Inseparable, Non-Interchangeable

Distinct. Each edge bounds a different one of the three contexts, and each is fixed by different quantities. H is fixed by the cosmological constant, through the de Sitter radius. P is fixed by the strength of gravity, the speed of light and the quantum of action. T is fixed by no length at all, since no comparison registers it. The Passage counts the two lengths that a

new epoch has of its own as the de Sitter radius and the length of the turn, of the order of the Planck length; H and P are those two lengths, and T is the limit that carries neither.

Inseparable. In the account the three occur together, and each is reached through the other two. An interior reaches T only when both conditions that hold the six dimensions compact have failed (the Passage, Chapter 18, Section VI). The first condition fails because the exterior, bounded by H, has emptied and has no moment at the end; it also fails because the smooth description has reached P. The second condition fails because no reference for inertia survives. So T is reached through H and through P. After T, the new epoch has, in the Passage's words, "a new cosmological horizon" (the Passage, Chapter 18, Section VII), and its smooth description again has the Planck scale as its edge. So H and P are restored through T. No epoch has one of the three edges without the other two.

Non-interchangeable. The three are limits of three different kinds, and no one of them can do the work of another. Content crosses H away from an observer, and the observer still compares the light that the content sent before crossing: H is a limit approached by the record. Content reaches P, where each existing description of it, the smooth one and the stepwise one, reaches the edge of its domain and no description takes over (the Passage, Chapter 17, Section IV): P is a limit reached at the end of every description. Nothing is registered crossing T: T is a limit approached from both sides and reached from neither.

VII. Axiom II: The Cycle

Axiom II orders the modalities in one direction: the transcendent precedes the immanent, the immanent precedes the omniscient, and the omniscient precedes the transcendent. Under the binding, that order reads: P precedes T, T precedes H, and H precedes P.

The cycle of the account runs in exactly that order. At the end of every interior, the curvature reaches P, the conditions fail, and the six dimensions of possibility are released. The turn, T, follows. The restored large world then has its own horizon, H, whose past face fixes its cosmological constant and whose future face bounds its exterior. Within H, matter clumps, every bound structure ends in a black hole, the exterior empties, and each interior approaches P again.

The reverse order, P then H then T, matches no step of the account: the horizon of an epoch is never reached between the release of the six and the turn, and the turn never follows the restoration of a horizon. So the binding gives a valid cycle in the orientation of Axiom II, and not its mirror image.

VIII. Axiom I: The Turn as the Clear Immanent

The immanent is the act itself: the finding of sameness and difference, as it occurs. The act is never laid out as content; what is laid out comes after the act that finds it. T fits that role exactly. The turn is the transition of the cycle, and no comparison registers it as an event, which is to say that the turn is never found as content. It appears in a reconstructed history only as a beginning, the way an act appears afterward only in its record. So T is the clear immanent, and its place fixes how the other two stand.

H and P must then be conjugate, and they are, as the limits of the two characters that the Incommensuration Theorem holds apart. The omniscient character is symmetry: in the Passage's words, "what can be repeated, shared and laid out". The transcendent character is continuity. The theorem says that the two cannot both be perfected in one comparison; each can be perfected only at the expense of the other.

H is the limit of perfected symmetry. As an epoch empties, its geometry tends to de Sitter, and the de Sitter geometry has ten independent symmetries, the greatest number a geometry of four dimensions can have:

a theorem of geometry gives at most $n(n+1)/2$ independent symmetries in n dimensions, and for n equal to four that number is ten (the ten Killing vectors of de Sitter spacetime: Obukhov and Puetzfeld 2011). The horizon of that geometry is where an epoch's comparable world reaches the most symmetric form a geometry of four dimensions can take.

P is the limit of perfected continuity. The Planck scale is the scale at which the continuous description of the arena reaches the edge of its domain, and the stepwise description of content reaches the edge of its own; below it no description takes over (the Passage, Chapter 17, Section IV). So the horizon is where symmetry is perfected, at the cost of all content within it, which has thinned away; and the Planck scale is where continuity reaches its limit, at the scale where the smooth and the stepwise descriptions meet on equal terms. Each is perfected only where the other is absent, which is the conjugate relation that Axiom I states. The three edges are therefore one triple: the edge of reality is the limit of actual comparison, and, like comparison itself, it has three aspects.

IX. Why Each Context Must Distort

The three edges bound the three contexts. Each context must also be distorted, and the three distortions are three, one to each column, and none of the three distortions is zero. Two grounds give it, and each needs the other.

The first ground is the theorem, applied to each column. Perception is continuous: "Continuity is a sameness of content where there is a sameness of context. An infinitesimal change in context produces an infinitesimal change in content. Nothing is sudden." (the Passage, Chapter 2, Section II). The Incommensuration Theorem holds that "Any comparison, perfected at its foundation, must be either continuously asymmetric or discontinuously symmetric" (the Passage, Chapter 3, Section IV), and the Passage assigns the two survivors: "I identify discrete, symmetric observables as the character of content, and continuous, asymmetric observables as

the character of context." The theorem has no physical premise: "The theorem therefore applies to any domain in which comparison occurs" (the Passage, Chapter 3, Section IV). Each column of the grid is such a domain: pattern is compared in space, force in time, probability in possibility. So the context of each column is continuously asymmetric, and none can be perfectly uniform; a perfectly uniform context would perfect continuity and symmetry together, which the theorem forbids. An asymmetry of context is a difference of content across a difference of context; in a geometry it is a departure from uniformity, and that departure is a distortion.

The second ground is the axioms, applied to the three distortions. The theorem alone requires that context be asymmetric; the axioms require that the asymmetry fall in every column, and in each by a distortion of its own. Because the contexts are inseparable, an epoch cannot have a distorted context in one column and an undistorted one in another: the three occur together, as the three edges do. Because they are non-interchangeable, the distortion of one context cannot supply the asymmetry of another: no amount of the cosmological constant makes a halo, and no amount of dark matter accelerates the expansion. Because they are distinct, the three distortions are three, and not one distortion seen three ways.

The two grounds together give the result. In every epoch each context is distorted, by a distortion of its own that is not zero: space by gravitation, around content; time by the cosmological constant, uniformly; possibility by the dark matter, held at the Planck scale and gathered in halos. On this account the dark matter is not an addition to the world that might have been absent. A world with a continuous context of possibility must carry it, as it must carry gravitation and a cosmological constant. How much of it there is, against the ordinary matter, is the registered ratio of Chapter 3.

X. The Three Distortions as a Triple

Each distortion is a distortion of exactly one context, so the three distortions bind one to one to the three contexts, and through them to the three edges. By the second principle of Section II, a list of three that binds unambiguously, one to one, to a known triple is itself a known triple, and each term takes the role of the term it binds to.

The cosmological constant binds to time, and so to the turn, the clear immanent. It is the clear immanent of the three distortions: the Passage fixes it as the share of the vacuum's energy accessible to an observer inside the vacuum, through the time elapsed since the turn (the Passage, Chapter 13, Sections II and III), which is to say by the act of comparison made from inside.

Gravitation binds to space, and so to the horizon, the limit of perfected symmetry. The dark matter binds to possibility, and so to the Planck scale, the limit of perfected continuity. Since the horizon and the Planck scale are conjugate, gravitation and the dark matter are the conjugate pair. The roles agree with what each does. Gravitation is strongest where symmetry is least, around content, and it vanishes as an epoch empties toward the ten symmetries of de Sitter at its horizon. The dark matter is held at the Planck scale, where continuity reaches its limit, and what it does is laid out nowhere except through gravitation, by which alone it registers. The two meet in that one way, which is the one way the dark matter is observed.

This completes the argument that Chapter 2 gives in brief: the three distortions of context are required, they are three, and they stand as a triple, with the cosmological constant as its clear immanent and gravitation and the dark matter as its conjugate pair.

Glossary

abiding. To abide is to hold fast. In this book, the abiding of a factor of the internal space is the share of its curvature, c_1/S_L, that holds fast in a registration as a term of its own and reduces a count of classes: $2/\pi$ for $\mathbb{C}P^2$, $1/\pi$ for S^2, and $3/\pi$ for the whole internal space. In it, c_1 is the three channels of the registering act for every factor, and S_L is the count of the formal horizon that the factor's curvature sets. A factor's curvature does not abide in a count that already holds it, as a count that includes the Euler number of S^2 holds the whole curvature of S^2 (Chapter 3, Sections III and IV).

antipodal map. The map of the sphere S^2 that sends each point to the point opposite it. The geometry is unchanged by it, so every state of the metric is either even or odd under it (Chapter 4, Section III).

channel. One of the three ways through which a measurement made inside the vacuum registers what reaches it. The count of channels is the Euler number of $\mathbb{C}P^2$, three: "The count of channels is therefore the Euler characteristic of $\mathbb{C}P^2$, the number of its independent classes" (the Passage, Chapter 13, Section II).

class. The word has two senses in this book. In Axiom II a class is a kind, as against an instance of it. In the count of Chapter 3 an independent class is one member of a basis of a space's cohomology (see independent class).

clear immanent. The term of a triple that plays the immanent role most plainly. Among the three distortions of context it is the cosmological constant (Chapter 2, Section V).

conjugate pair. The omniscient and the transcendent terms of a triple, which Axiom I sets in conjugate relation. Among the three distortions of context they are gravitation and the dark matter (Chapter 2, Section VI).

content. What a measurement registers: pattern, force and probability, the row of content of the grid of measures.

context. Where a measurement registers its content: space, time and possibility, the row of context of the grid of measures.

distortion of context. A departure of a context from the shape it has when nothing distorts it. Gravitation distorts space, the cosmological constant distorts time, and the dark matter distorts possibility (Chapter 2).

edges of reality. The three limits of what actual comparison, made from inside the world, can reach: the horizon, the turn and the Planck scale (Appendix A).

epoch. The span of the world between one turn and the next (the Passage, Chapter 18).

even and odd states. States of the metric that keep their sign, or change it, under the antipodal map. The waves of the open geometry are even; the gyrations are odd.

floor. The least extent and the least motion that the internal space cannot lose, which hold it at its size (the Passage, Chapter 11, Section II).

grid of measures. The six measures of every physical measurement, in two rows of three: the contents pattern, force and probability, and the contexts space, time and possibility (the Passage, Chapter 7).

gyration. A conserved excitation of the six held internal dimensions; the dark matter is made of gyrations. In role a gyration is a vibration of context, and not an item of content (Chapter 1, Section IV); physically it is a massive excitation of the metric of those dimensions, a state of the Kaluza and Klein kind (Chapter 4, Section II).

harmonic. A mode of vibration of a compact space, an eigenfunction of its Laplacian. On the sphere the harmonic of degree l has the eigenvalue $l(l+1)/R_T^2$ and the sign $(-1)^l$ under the antipodal map (Chapter 4, Section III).

independent class. One member of a basis of a space's cohomology. When every class lies in even degree, the number of independent classes is the Euler number: three for $\mathbb{C}P^2$, two for S^2, six for their product and one for a ball (Chapter 3, Section II).

internal space. The six compact dimensions of the Passage, $\mathbb{C}P^2 \times S^2$, with radii $\sqrt{6}$ and one Planck length: the dimensions of possibility (Note 1).

isometry. A map of a space onto itself that keeps every distance. The continuous isometries of $\mathbb{C}P^2$ form $SU(3)$, those of S^2 are its rotations, and in the reduction each gives a gauge field over the open spacetime (Chapter 4, Section V). Each factor also has a discrete isometry that this book uses: the antipodal map of S^2 and the conjugation of $\mathbb{C}P^2$ (Chapter 4, Section III).

least extent. The size below which the internal space cannot shrink, since a size held at zero with no spread is excluded by the uncertainty relation; in the computed floor it is a local term of fifth order in the curvature (the Passage, Chapter 11, Section II, and Appendix D).

lightest odd level. The lowest level of the internal space that holds states odd under the antipodal map: the first harmonic of the sphere, together with the states that share its mass (Chapter 4, Section V).

modalities. The three columns of the grid of measures: the omniscient (pattern and space), the immanent (force and time) and the transcendent (probability and possibility).

open dimensions. The three dimensions of space that are not compact, which with time make the open spacetime, as against the six internal dimensions.

principle of identity. Two descriptions that no comparison can tell apart are one. This book applies it to the region a registration holds (Chapter 3, Section II) and to whole configurations of the internal geometry (Chapter 4, Section III).

registration. The act by which a measurement made inside the world fixes what it registers. An identity of registration fixes a quantity by what the present measurement registers, and not by a mechanism (Chapter 3, Section I).

residue. What remains of the turn's energy besides its radiation: the excess of ordinary matter over its antimatter, and the dark matter (Chapter 3, Section I).

share of a curvature. Three channels among the count $S_L = \pi L^2$ of a horizon whose curvature radius L is set by the energy density of that curvature: c_1/S_L (Chapter 3, Section III).

short loop. A closed path anywhere in space that goes around the universe, and so cannot be shrunk to a point, and is shorter than the diameter of the horizon (Chapter 3, Section II).

the Passage. The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics, whose results on the context this book takes as given (Note 1).

the turn. The transition from one epoch to the next, where the collapse inside the black holes of one epoch and the origin of the next meet (the Passage, Chapter 18).

triple. Three terms that stand to one another as the three modalities stand, the immanent, the omniscient and the transcendent, under the three axioms of the modalities (Appendix A, Section II).

vibration of context. The role of a gyration: a vibration of the internal geometry, as a wave of sound in a crystal is a vibration of its lattice (Chapter 1, Section IV).

Notes

1. What this book takes as given.

This book takes as given, from *The Gravitational Passage; Deriving General Relativity from the Immanent Metaphysics*: the internal space $\mathbb{C}P^2 \times S^2$ and its radii, $\sqrt{6}$ and one Planck length; the reduction of the ten-dimensional geometry and the floor that holds the internal space at its size; the identity that fixes the cosmological constant; and the turn, the transition from one epoch to the next.

Each of these is quoted where it is used, by chapter and section of that book, so the argument of this book can be followed on its own, with those statements as its premises.

Pointers of the form (the Passage, Chapter 13, Section II) refer to that book; bare pointers, such as (Chapter 4, Section V), refer to this book.

Their derivations are in the Passage and are not repeated here.

The Passage carries no authority in this book on the content of the world (which fields exist, and how they couple) or on the dark matter.

2. Units and conventions.

Lengths are in Planck lengths and masses in Planck masses, with the speed of light, the reduced Planck constant and Newton's constant equal to one.

The Planck mass is the full Planck mass, 1.22×10^{19} GeV, unless the text says otherwise.

At the Passage's radii each of the six internal directions has a Ricci curvature equal to its metric, in Planck units: the scalar curvature is 4 on $\mathbb{C}P^2$, 2 on S^2 and 6 on the product.

The couplings of the internal isometries, 6 for S^2 and 16/3 for $\mathbb{C}P^2$, are computed with each generator normalized so that the trace of its square is one half.

3. The predictions at their date.

The predictions of this book, the ratio $6 - 2/\pi$ and the first five of the six predictions of kind of Chapter 5, Section IX, are fixed at their date, with their standing against the measurements of that date, in *The Registered Predictions of The Weight of Possibility; A Dated Record*.

The dated record states the fifth for our location; this book states it for every location, which includes ours (Chapter 3, Section II).

The sixth, that the dark component carries no separate pattern of primordial departures, is stated in this book.

Where the dated record speaks of the charge of a curvature, or of a curvature charged, this book speaks of its abiding (Chapter 3, Section III).

4. Where the ground is set out at length.

The ground that this book takes from the Passage is set out at length in three volumes: *Comparison; The Necessary Basis* (the principle of identity, in its Chapter 11), *Incommensuration; The Theorem and the Three Axioms* (the theorem, and the three axioms derived from it, the conjugacy of Axiom I among them), and *Measurement; The Steps from Comparison to Physics* (the grid of measures, and the six dimensions of possibility, in its Chapter 11).

The View from Inside gives, for the general reader, the account of the cosmological constant whose identity shares its one coefficient with the rule of Chapter 3.

No step of this book depends on these four books.

5. Gravitation and the gyrations.

The gyrations of this book are levels of the internal space, which the floor holds at one size and one shape. Gravitation, the distortion of the open dimensions, is not quantized (*Two Theories, One World*; *The Unquant-*

ized Arena). The open dimensions are the arena, and the arena is not a held structure. A description of small waves of the open geometry has quanta of its own, which it calls gravitons; a graviton is at most a quantum of that description, never a quantum of the arena.

6. The triple.

The notion of a triple, three terms that stand to one another as the three modalities stand, is from *An Immanent Metaphysics* (Landry 2001). The three axioms of the modalities are quoted in this book from the Passage, Chapter 4, Section V.

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