

The Temporal Convergence Framework

A Unified Ontology of Space, Matter, and Cosmological Structure from Temporal Recursion

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Abstract

The Standard Model and Λ CDM cosmology are formally successful yet leave a specific cluster of structural facts unexplained: why space has exactly three dimensions, why there are exactly three generations of fermions, why particle masses take the values they do, why gravity resists unification with the other three interactions, why the universe contains far more matter than antimatter, and what dark matter and dark energy physically are. This paper presents a framework, Temporal Convergence, that proposes a common origin for this cluster of open questions. The framework's foundation is a single operation, differentiation, the event in which a configuration comes to exist or ceases to, driven by an irreducible asymmetry between a bounded ground state and an unbounded space of possible configurations. Differentiation that persists rather than collapsing is what the framework identifies with time itself, and its rate, denser where more relationships couple together, is what later sections read as mass, gravity, and the appearance of three-dimensional space.

Physical structure is modeled as a constrained recursive oscillation built from this operation, subject to a minimum-closure requirement. We show that this requirement forces a minimum of three degrees of freedom for any stable, self-referential structure, consistent with the classical result that stable bound orbits require exactly three spatial dimensions (Ehrenfest, 1917), and we extend the same three-fold structure to the number of fermion generations. We derive two quantitative thresholds from the closure geometry alone, checked against measurement only afterward: a critical wavelength at exactly half the electron's Compton wavelength, and a critical energy of 1.022 MeV, the measured pair-production threshold. We present chronological depth, the identification of spatial distance with the differentiation interval between configurations, as the framework's central concept; a discrete compression-depth architecture for particle mass; and a direct physical identification of the quantum-mechanical wavefunction with the same oscillation's OFF-state, under which the double-slit pattern, the measurement problem, the delayed-choice quantum eraser, tunnelling, and the quantum Zeno effect all follow from one mechanism, with no observer-dependence and no retrocausation.

We also give a fixed-rate-budget account of special-relativistic time dilation and length contraction, a domain-adaptive extension of Einstein's field equation that recovers quantum field theory and General Relativity exactly in their respective domains, and a reading of the Standard Model's seventeen fields as one field at seventeen coupling configurations, under which its nineteen free parameters become, in principle, nineteen outputs of one equation. A single, internally consistent mechanism is proposed for the matter to antimatter asymmetry, together with structural accounts of black-hole thermodynamics and information, dark matter, dark energy, and the Hubble tension. Every claim is labeled as established physics, reinterpretation, falsifiable prediction, or open formal problem, and quantitative failures are reported rather than omitted. The work matters because it offers a small number of sharply falsifiable predictions, testable with existing or near-term instruments, attached to a framework that is explicit about exactly which of its own claims remain unproven.

Keywords: *unified physics; temporal geometry; ontology; quantum foundations; cosmology; dimensionality; particle mass generation; information theory; foundations of physics*

1. Introduction

1.1 Motivation

General Relativity and the Standard Model of particle physics are, individually, the two most precisely tested theories in the history of science. Neither is challenged in what follows. But taken together they leave a specific and recurring cluster of questions formally unanswered rather than merely unmeasured: why space has exactly three large dimensions; why the Standard Model contains exactly three generations of quarks and leptons, with no accepted explanation for the count; why the specific mass hierarchy across those generations takes the values it does; why gravity has resisted five decades of attempts at unification with the other three interactions; why the observable universe contains a large excess of matter over antimatter despite, as far as is known, matter-antimatter symmetric physical law; and what, physically, dark matter and dark energy are, beyond the phenomenological role each plays in fitting the cosmological data.

Existing unification programmes typically address one or two items on this list at a time. They often do this by introducing new mathematical structure, extra spatial dimensions, a discretized spacetime, supersymmetric partners, and each of these additions becomes a further open question the programme must eventually answer. This paper asks a different question: whether a smaller ontological revision, applied consistently across the whole list, can account for several of these facts as expressions of one underlying constraint, rather than requiring a separate new postulate for each.

1.2 Scope of the Paper

This paper is deliberately and explicitly scoped. It presents the physics and cosmology core of the Temporal Convergence framework, restricted to claims that are stated, derived, or tested against established results in fundamental physics and cosmology. It does not attempt, and does not defend, the framework's further extension to biological complexity or to a structural account of consciousness. The clearest statement of this boundary is the distinction, fixed in Section 4.1, between extension, the objective, mind-independent structure this paper's claims are claims about, and extensivity, the felt spatial experience a brain renders from it; extensivity belongs to the excluded material, not to the physics defended here. Where this paper's own structure calls for a statement on scale integration into conscious systems (Section 5.4), we say plainly what is and is not being claimed there, rather than importing undefended material to fill the space. A longer, separate treatment of those extensions exists and is referenced at the paper's close; nothing in the argument that follows depends on it, and a reader who rejects the framework's reach into biology and mind can evaluate everything in this paper independently of that question.

1.3 Summary of Contributions

- A single foundational operation, differentiation, driven by an irreducible asymmetry between a bounded ground state and an unbounded configuration space, from which time (as accumulated, persisting differentiation), the appearance of three-dimensional space (as a rendering of that structure), and quantum indeterminacy (as the absence of a differentiating relationship) are derived as one mechanism rather than three separate postulates.
- A minimum-closure argument deriving exactly three spatial dimensions and exactly three fermion generations from one geometric constraint, convergent with Ehrenfest's (1917) independently verifiable dimensionality result.

- A discrete compression-depth architecture for particle mass, tested explicitly, and honestly, against the measured proton–electron mass ratio, with the resulting quantitative gap reported rather than concealed.
- Two quantitative results derived from the closure geometry before being checked against measurement: the critical closure wavelength $\lambda_{\text{crit}} = h/(2m_{\text{ec}})$, exactly half the electron's Compton wavelength, and the critical closure energy $2m_{\text{ec}}^2 = 1.022 \text{ MeV}$, the pair-production threshold measured for ninety years.
- Chronological depth: the identification of spatial distance with the differentiation interval between configurations, under which a galaxy's distance and its light-travel time are one quantity described twice, and the arrow of time follows from the directionality of differentiation without a special initial condition.
- A physical identification of the quantum-mechanical wavefunction with the same oscillation's OFF-state, under which the double-slit pattern, the measurement problem, the delayed-choice quantum eraser, tunnelling, and the quantum Zeno effect follow from one mechanism, with no observer-dependence and no retrocausation.
- A reading of the Standard Model's seventeen fields as one field at seventeen coupling configurations, under which its nineteen free parameters become, in principle, outputs of one equation. This is stated as the shape of a research programme, with the gap to actual computation reported honestly.
- A domain-adaptive extension of Einstein's field equation that recovers quantum field theory and General Relativity exactly within their own domains, while reframing the quantum-to-classical transition as coupling-depth coarse-graining.
- A single, internally consistent mechanism for the cosmological matter–antimatter asymmetry, presented as a worked case study in the framework's own standard of consistency.
- A set of falsifiable predictions testable with existing or near-term instruments, and an honestly labeled catalogue of open problems that defines the framework's research programme.

1.4 Structure of the Paper

Section 2 states the framework's foundational assumptions explicitly, as a formal paradigm declaration, so that every claim which follows can be traced to a named axiom. Section 3 situates the framework against the Standard Model and Λ CDM's own open questions, against the major existing unification programmes, and against the information-theoretic tradition in the philosophy of physics. Section 4 presents the core theory: its ontological framework, its mathematical structure, worked derivations, two conceptual diagrams, and a summary of the predictions those derivations generate. Section 5 shows how the same coupling-depth quantity is proposed to integrate the quantum, classical, and cosmological scales, and states explicitly what is and is not claimed about a further integration into conscious systems. Section 6 turns to empirical status: what could observationally test the framework, where it already agrees with confirmed data, and where it is honestly in tension with, or silent on, results a complete theory would need to explain. Section 7 discusses the framework's strengths and weaknesses candidly and outlines the research programme ahead. Section 8 concludes. Two appendices provide a glossary of the framework's technical vocabulary and an extended technical note on its strongest open derivation.

2. Foundational Assumptions / Paradigm Declaration

Every substantive claim in this paper traces to one of the six axioms below, or to a combination of them. We state these explicitly, in advance of any derivation, so the reader can identify exactly where the framework's ontological commitments enter and evaluate each derivation against them independently.

A1. Two primitive states. Probability (denoted 0) is the unconstrained ground state: infinite possibility, no identity, no preferred direction. Potential (denoted 1) is the tendency of any expressed configuration to persist and couple further. Zero is treated as a genuine ontological value, the ground from which all other values are measured, not an absence.

A2. Time is fundamental; space is derived. What is measured as spatial distance is a rendering of temporal separation within an underlying differentiation process (Section 4.1), not a pre-existing container in which that process occurs. This is the framework's central departure from the standard view of spacetime as a fixed background.

A3. The elementary process is a constrained recursive oscillation. The primary oscillation is a 0–1–0 relay: energy relayed forward toward a new probable configuration rather than returning to ground at every cycle, subject to a minimum-closure requirement (A4).

A4. Minimum closure. A self-referential structure that closes back on itself requires a minimum of three distinguishable positions. Two positions cannot close; a fourth is not required. This is the geometric seed from which Section 4.3.1 derives both spatial dimensionality and fermion generation count.

A5. One equation, many domains. Physical law is one gradient, read at different coupling depths, rather than a set of separately unified theories requiring a bridging mechanism at their boundaries (Section 4.3.7, Section 5).

A6. Contingency is named, not derived away. Facts about which specific symmetry-orientation or configuration was realized (e.g., Section 4.3.4's handedness break) are explicitly distinguished from derived structural consequences. The framework does not claim to derive its own initial conditions, and states this limit wherever it applies rather than concealing it behind a post-hoc mechanism.

Three departures from mainstream physics follow directly from these axioms and are stated here without qualification, so a reader can reject the framework at the point of departure instead of discovering it midway through a derivation. First, spacetime is treated as emergent from a temporal process, not fundamental (A2), contrary to the standard treatment in both General Relativity and quantum field theory, where spacetime, or a fixed background, is typically primitive. Second, gravity and the strong interaction are proposed to be the same coupling principle expressed in different geometric regimes (A5), and this is offered as an alternative to requiring an independent act of quantization; Section 4.3.5 states plainly what follows if this proposal is wrong. Third, the wavefunction is treated as a real, physical field (Section 4.3.3), not a probability-encoding mathematical abstraction. This aligns the framework with the realist tradition in the interpretation of quantum mechanics, de Broglie–Bohm theory, GRW and other objective-collapse models, and sets it apart from instrumentalist or purely epistemic readings such as Copenhagen or QBism.

Table 1. Epistemic status of the framework's claims

Claim	Status	What this means
Time dilation, $E = mc^2$, the Schwarzschild metric, CMB uniformity	Established physics	Unmodified; the framework offers a physical reading, not a revision.
$\lambda_{\text{crit}} = h/(2m_{\text{ec}})$, half the Compton wavelength; the 1.022 MeV pair-production threshold as $2m_{\text{ec}}c^2$; CMB Gaussianity from binomial statistics	Derived, then checked	Obtained from the framework's own geometry before comparison with measurement; the strongest evidence the framework offers.
Gravity as a temporal-density gradient; the four forces as one coupling principle in different geometric regimes	Reinterpretation	Same equations, same experimental predictions; a proposed account of what the mathematics describes.
The wavefunction as the field's OFF-state; QFT's creation/annihilation operators as one ON/OFF cycle; time dilation and length contraction as a fixed-budget reallocation	Reinterpretation	Same Born-rule statistics, same Lorentz transformations; a proposed physical reading of the existing formalism, not a revision of it.
The double-slit pattern, the measurement problem, the delayed-choice eraser, tunneling, and the Zeno effect as consequences of one OFF-state mechanism	Reinterpretation	No experimental outcome changes; one mechanism replaces per-phenomenon explanations, with no observer or retrocausation required.
The domain-adaptive field equation unifying the quantum, classical, and cosmological regimes as one coupling-depth gradient	Reinterpretation	Recovers quantum field theory exactly at low coupling depth and General Relativity exactly at moderate depth; adds terms only at the cosmic scale.
No fourth fermion generation; no dark-matter particle; a specific low-frequency deviation in the primordial gravitational-wave spectrum; Dirac (not Majorana) neutrinos	Framework prediction	Falsifiable claims not shared, or shared differently, by the Standard Model and Λ CDM.
The mass-scaling function $F(d)$; the fine-structure constant; the Bekenstein–Hawking coefficient; a full group-theoretic proof of $SU(3)$ from the geometry	Open formal problem	Required by the framework, not yet formally derived; named as work, not embarrassment.

3. Background and Related Work

3.1 Standard Models and Their Limits

The Standard Model of particle physics correctly predicts the outcome of every collider experiment performed to date, at the cost of nineteen free parameters, nine fermion masses, three gauge coupling constants, four CKM mixing parameters, the QCD phase, and the Higgs mass and vacuum expectation value, none of which the model derives from anything deeper. It offers no account of why there are exactly three generations of fermions, nor of the specific hierarchy of masses across them. General Relativity, similarly unmatched in its own domain, predicts singularities at its own extremes (the centre of a black hole, the initial cosmological state) at which the theory itself signals its incompleteness, and has resisted five decades of attempts at reconciliation with quantum field theory. Λ CDM, built on General Relativity, requires two components, dark matter and dark energy, that together account for roughly 95% of the universe's energy content and remain undetected in any form beyond their gravitational and cosmological signatures, alongside the unresolved Hubble tension between early- and late-universe expansion-rate measurements. None of these are failures of the theories on their own terms; each is exactly as successful as five decades of precision testing can make it. They are, collectively, the cluster of structural silences this paper addresses.

3.2 Alternative Approaches

Several existing research programmes address parts of this cluster directly, and we situate the present framework against each candidly. String theory proposes that fundamental particles are vibrational modes of one-dimensional extended objects, achieving a mathematically consistent unification of gravity with the other interactions at the cost of six or seven additional compactified spatial dimensions, whose specific geometry (the string landscape) remains empirically unconstrained. Loop quantum gravity (Rovelli, 2004) instead quantizes spacetime geometry itself, producing a discrete structure at the Planck scale without extra dimensions, but has not yet produced a matter sector that reproduces the Standard Model's particle content from first principles. Causal set theory (Sorkin, 2003) proposes that spacetime is fundamentally a discrete, locally finite partially ordered set, with continuous geometry emerging only at macroscopic scale; it shares with the present framework the commitment that continuous spacetime is a derived rather than fundamental description, though it does not attempt the same derivation of dimensionality or generation count. MOND (Milgrom, 1983) modifies Newtonian dynamics phenomenologically at low acceleration to fit galaxy rotation curves without dark matter, achieving excellent fits to the Tully–Fisher relation (Tully & Fisher, 1977) while offering no proposed physical mechanism for the modification.

The framework presented here differs from each of these in a specific way worth stating plainly. It does not introduce extra spatial dimensions, unlike string theory. It proposes a specific, derived reason for three-dimensionality and three generations together, instead of treating dimensionality as a free input, unlike causal set theory as usually developed. And it proposes a physical mechanism behind the dark-matter reframing, not just a phenomenological force law; it builds on MOND's empirical success without replacing it. Where existing programmes require new mathematical structure to achieve unification, this framework proposes that the unification is available within existing mathematics once gravity and the strong interaction are recognized as the same coupling principle at different scales (Section 4.3.5). We hold this proposal candidly, not dogmatically, and revisit it in Section 7.2.

3.3 Conceptual Foundations

The proposal that a real, physical field, not a mathematical abstraction, underlies quantum probability has precedent in the information-theoretic tradition of foundational physics. Wheeler's (1990) "it from bit" thesis proposed that every physical entity ultimately derives its meaning from discrete, yes-or-no informational transactions; relational quantum mechanics and QBism, in different ways, treat the quantum state as describing relationships or observer knowledge instead of an independent substance. The present framework's identification of the wavefunction with a real OFF-state field (Section 4.3.3) is closer in spirit to the realist branch of this tradition. It treats information and process as ontologically primary, ahead of substance, and it proposes a specific physical carrier, the primary oscillation's OFF-state, rather than leaving the informational primitive unspecified.

This same tradition, in its broader form, extends naturally toward questions of complexity and mind. If physical law is fundamentally about constrained information processing, not substance in motion, then the boundary between a computing physical system and a cognitive one becomes a question of degree and architecture, not kind. The Temporal Convergence framework, in its fuller form, develops exactly this extension, proposing that biological complexity and consciousness are further domains of the same coupling cascade described in Section 4. That extension is not defended in this paper, for the reasons given in Section 1.2, and is mentioned here only to locate the present, narrower physics treatment within its own larger research programme.

4. Core Theory

4.1 Ontological Framework

One operation needs to be fixed before the framework's entities can be named, since everything that follows is a structural consequence of it. A differentiation event is any transition in which a configuration that did not exist comes to exist, or a configuration that existed ceases to. This is the framework's most primitive unit, prior to particles, prior to fields in the usual sense, prior even to the primary oscillation introduced below.

Differentiation is not imposed on the probability field from outside. It is what the field's own internal asymmetry already entails. The ground state is bounded and unique; the space of possible expressed configurations is unbounded. This asymmetry cannot rest: a fluctuation rising from ground either reaches coherence or it does not, and either outcome forces the next fluctuation. The result is a perpetual cycle, 0 to 1 to 0, that needs no external driver, no clock ticking it forward, and no energy supplied from elsewhere to sustain it. It is the minimum dynamic available to a field with one bounded property and one unbounded one.

Most cycles of this kind leave no trace. The ground state after a collapse is identical to the ground state before it, so nothing distinguishes an after from a before, and no record accumulates. Time, on this account, is not the ticking itself, which is eternal and prior to any measurement, but the comparison of tick-counts against a persisting record, and ordinary cycling supplies no such record. The absolute-1 event is the exception: the one fluctuation that reaches coherence and does not collapse leaves the field measurably different afterward than before. This is the first record, and it is what makes tick-counts comparable, a before distinguishable from an after, for the first time. Time as something that can be measured begins here, not because the underlying cycling started here, but because nothing persisted to compare it against before this event.

Differentiation is relational, not intrinsic: it is not a property a configuration has by itself, but what occurs between a configuration and whatever it is coupled to. A configuration coupled to nothing has nothing to differentiate against, and remains, with respect to that absent relationship, unselected instead of definite. This is the mechanism behind the OFF-state account of measurement developed in Section 4.3.3: an unmeasured particle is indefinite not because it is smeared across many locations, but because no coupling yet exists for a location to be differentiated within. The same relational structure gives coupling depth a precise temporal meaning: a configuration coupled to more relationships differentiates more often, and accumulates a correspondingly richer history in the same external interval, the same accumulation Section 4.3.2 reads as mass.

The framework's fundamental entities are as follows. The probability field (Axiom A1, state 0) is the unconstrained ground: infinite possibility, no differentiation, no time, since time requires something differentiating to measure. The potential field (state 1) is what a probability configuration becomes once expressed and stabilized. The primary oscillation, informally the boson, is the elementary process built from these two states: a 0–1–0 relay in which energy is passed forward to a new probable configuration rather than returning to ground at every cycle (Axiom A3). An oscillation that never closes into a bounded structure propagates freely, accumulates no internal history, and is identified with the electromagnetic spectrum and its massless quanta. An oscillation that closes, that couples back on itself into a bounded, self-referential structure, is identified with a stable particle, and the depth of that closure is identified with mass (Section 4.3.2).

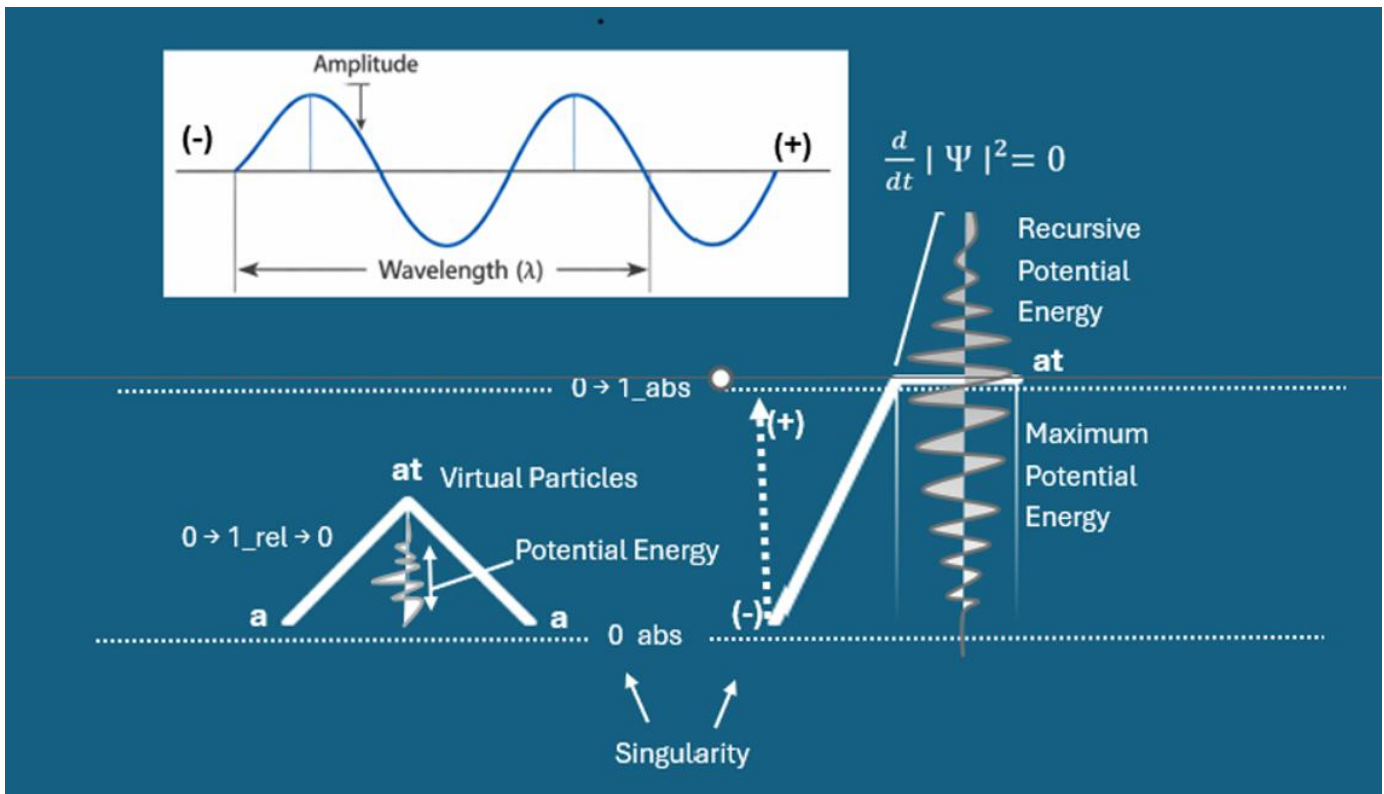


Figure 1. A fluctuation that does not reach closure (left) returns directly to the ground state, $0 \rightarrow 1_{\text{rel}} \rightarrow 0$, the mechanism behind vacuum fluctuations already measured via the Casimir effect and the Lamb shift. A fluctuation that reaches closure (right) enters recursive potential energy and, at full coherence, maximum potential energy: the absolute-1 event the primary oscillation is built from.

The transition between these two regimes is governed by a stretching threshold: a critical condition, expressible as a wavelength/energy threshold or a critical coupling parameter, below which a fluctuation returns to ground and above which it locks into self-sustaining recursion. Consistent with Axiom A6, we treat which specific configuration first achieves closure, and the specific orientation of the symmetry break that follows from it (Section 4.3.4), as contingent facts the framework does not derive from first principles.

Two further pieces of vocabulary, used throughout the rest of this paper, are fixed by the same picture. A slice is one cross-section of the field along the resolution axis: a single completed step of the primary oscillation, carrying its own resolved position on Axis 1, its own open probability edge on Axis 2, and its own accumulated history on Axis 3, all at once. This is the same object Section 4.3.1 calls a position; slice is the term used when the emphasis falls on one step of the relay's structure instead of on counting how many such steps a closure requires. Successive slices are what the relay's repeated 0–1–0 cycling produces, one bounded cross-section per step, a temporal series, not a spatial one.

At each slice, the same closure step branches into two possible next configurations, left and right, with equal a priori likelihood: a binomial branching, the same growth rule Pascal's Triangle displays, applied here to one relay's successive steps rather than to a population. Whichever branch is actually selected becomes the next slice's resolved position; the branch not selected does not vanish. It remains as that slice's own open probability edge, available to later steps. Carried out over many steps, this branching is the binomial expansion the framework's contingent claims (Axiom A6) refer to throughout, including the handedness break central to Section 4.3.4.

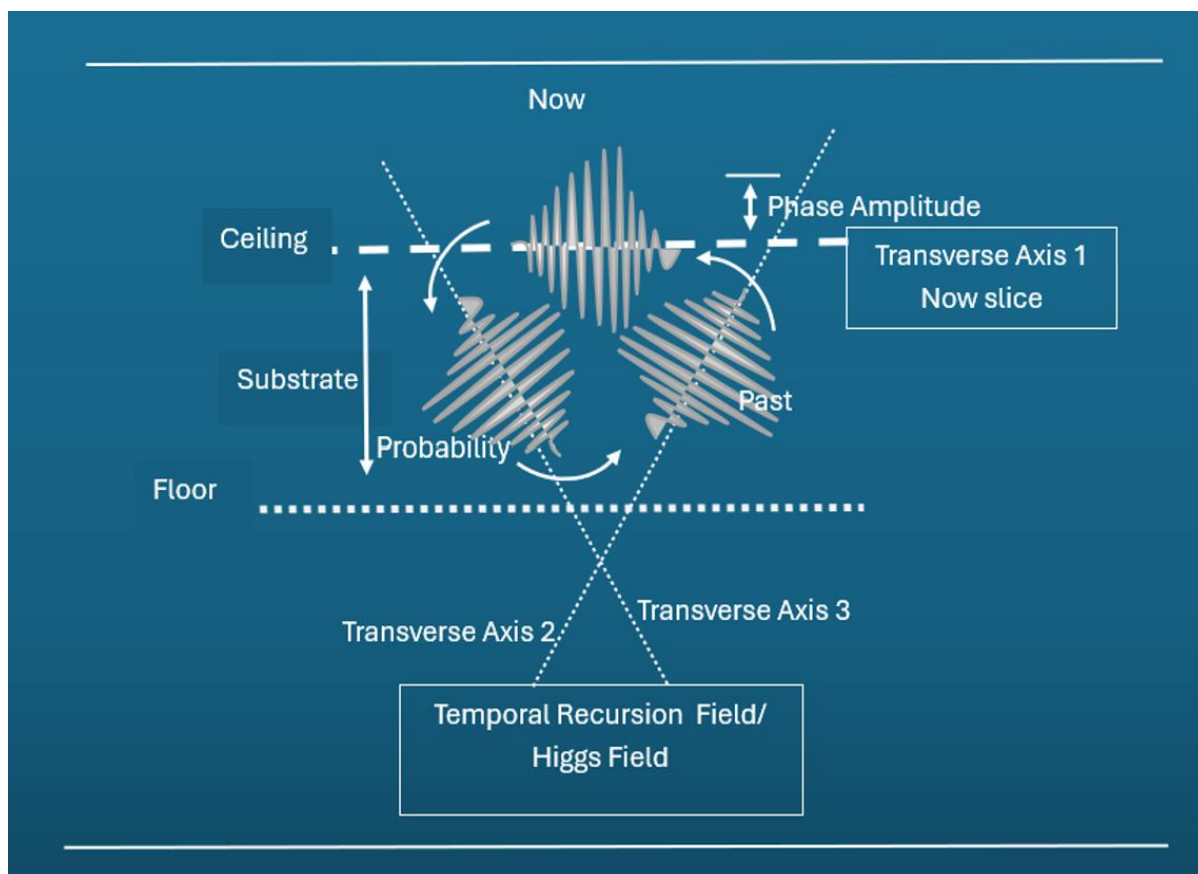


Figure 2. The Temporal Recursion Field. The Now slice (Transverse Axis 1) cuts across the substrate between the floor (ground state) and ceiling (closure); Transverse Axis 2 is the open probability branch and Transverse Axis 3 the accumulated past. These three axes, layered, are the geometric structure the minimum-closure argument (Section 4.3.1) derives dimensionality and generation count from.

One distinction closes this section and governs how every dimensional claim in this paper should be read. The three transverse axes shown in Figure 2 have no length and no direction a body could travel in; they are modes of differentiation, independent ways one configuration can differ from another. The framework calls this objective, mind-independent structure extension: what every ruler, clock, and interferometer measures, present whether or not anything renders it as experience. What a brain constructs from extension, the felt sense of depth and distance, three-dimensional space as it is experienced, the framework calls extensivity. On this reading the field has one advancing direction, differentiation's own arrow, and three transverse modes: a 1+3 structure, not the standard 3+1. What physics calls the three spatial dimensions are the three transverse modes; what physics calls the one time dimension is the advancing direction. Distance, on this account, is temporal separation: what registers as far away is deeper separation along the field's own structure, not travel across an independent spatial container. Every claim in this paper is a claim about extension. Extensivity, the rendering of extension into felt spatial experience, is outside this paper's scope (Section 1.2), consistent with the framework's own treatment of it as a further, mind-dependent domain rather than a physical claim requiring defense here.

Why 0 and 1. Axiom A1 treats zero as a genuine ontological value, not an absence, the question is why the framework's foundation is binary at all, rather than some other number of primitive states. The answer follows from the asymmetry A1 already states: one property is bounded (the ground state, unique and singular) and one is unbounded (the space of possible configurations). A distinction between a bounded state and an unbounded one is the minimum distinction available, there is no smaller asymmetry to build from, and no third primitive state is needed until closure itself is at stake, which is a separate requirement (Axiom A4) operating on a different quantity, the number of positions a self-referential structure needs, not the number of ground states. Geometry, on this account, is what the field's structure is; 0 and 1 are the minimum notation capable of naming its one asymmetry. This is a stated interpretive commitment about the relationship between the framework's mathematics and its ontology, not a derived result, and we flag it as such rather than assert it as self-evident.

4.2 Mathematical Structure

Table 2 collects the framework's core primitives and the relations that define them, gathered here for reference before the derivations that follow use them.

Table 2. Framework primitives and defining relations

Symbol	Primitive	Defining relation
Δ	Differentiation event	A configuration coming to exist or ceasing to; the framework's most primitive unit, relational rather than intrinsic.
0, 1	Probability, Potential	Ground state and expressed-configuration state; not spatial locations.
d	Compression depth	$d = 3^n$, $n = 0,1,2$ for neutrino, electron/quark, proton/neutron closures. The photon is massless and outside this progression (Section 4.3.2).
n_relay	Relay-count density	Internal oscillation cycles completing per unit volume per unit time; the framework's operational mass/density measure.
c	Fixed advance rate	Constant total budget divided between internal cycling and external traversal for any configuration.
$\psi(x)$	OFF-state amplitude	The wavefunction; amplitude of the field between resolution events, distributed across accessible configurations.
$G_{\mu\nu}$	Domain-adaptive source term	$G_{\mu\nu} = (8\pi G/c^4)T_{\mu\nu}(n_relay)$; $T_{\mu\nu}$ computed by regime (QFT / GR tensor / non-local terms).

4.3 Derivations

4.3.1 Three dimensions, three generations: the minimum-closure argument

The three transverse modes fixed as extension in Section 4.1 (Figure 2) still need a reason to number exactly three rather than two or four, and the same closure requirement that builds particles out of the primary oscillation supplies it.

A recursive relay that has advanced once has two distinguishable states, its current position and the position it just left, but nothing yet closed: two touching states have no enclosed interior. A relay that traces a third, distinguishable position, and finds that position folding back to the first rather than continuing to open onto a fourth, produces the first closed interior: a bounded, self-referential structure that is more than any single traced position alone. Three is therefore the minimum number of positions at which a self-referential loop can close (Figure 3); two is insufficient and a fourth is not required.

This argument converges with an independent, well-established classical result. Ehrenfest (1917) showed that stable bound orbits under an inverse-square force exist only in three spatial dimensions: in two dimensions the relevant force laws do not produce closed stable orbits, and in four or more dimensions no stable orbits exist at all. A universe capable of hosting stable atoms and stable planetary orbits therefore requires exactly three spatial dimensions, independently of the framework advanced here. We treat this convergence as the strongest single piece of external support for treating three as a structurally forced number rather than a brute empirical fact.

The same three-fold structure is proposed to explain the count of fermion generations: pairing three independent structural axes two at a time yields exactly three independent embedding configurations, and a particle at the relevant coupling depth can occupy any one of the three. A fourth generation would require a fourth independent axis the same geometry does not supply, a directly falsifiable claim, and one current collider data already constrain (Section 6.1). A second route to the same count, via compression depth rather than orientation, appears in Section 4.3.2; the two are proposed to be the same underlying index viewed from two directions, not two independent derivations of the same coincidence.

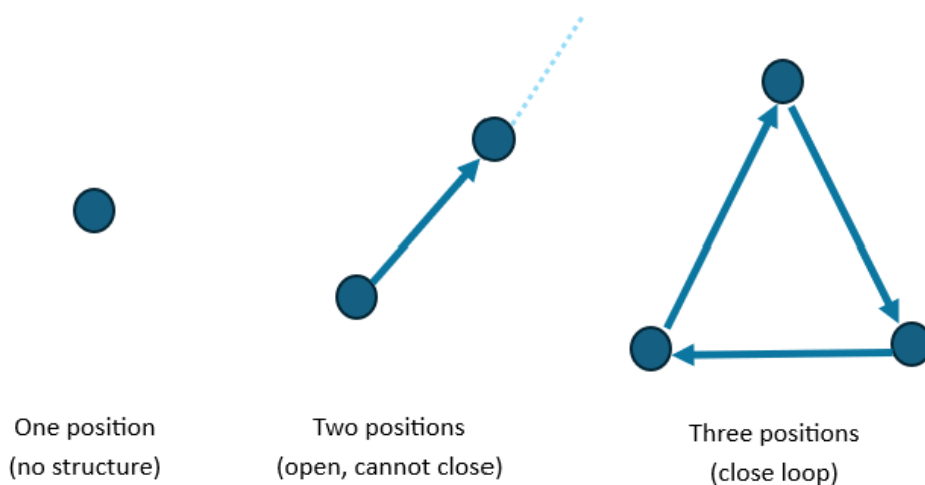


Figure 3. The minimum-closure argument. One position has no structure to close. Two positions form an open relation with nothing enclosed. Three positions are the minimum at which a self-referential loop closes, producing the first bounded interior.

4.3.2 Particle mass as accumulated compression

If mass is the depth of a closed relay's recursion, the number of internal cycles that must complete before one external tick registers, particle masses should fall into a discrete progression rather than a continuum. The framework proposes exactly this: a free oscillation (the photon) has no closure and is massless, outside the progression entirely; the first closed configuration (the neutrino) closes after three internal cycles; a further coupling of three such closures (the electron) compresses the structure one level deeper. The quark is not a further coupling of electrons, but the same electron-depth closure held at far greater compression, the same closure's high-pressure phase rather than a deeper tier; up and down quarks are this closure's two handedness states at that compression. Three of these compressed, quark-depth closures, coupled together, give the proton or neutron, one level deeper still. This gives $d = 3^n$ for $n = 0, 1, 2$, corresponding to the neutrino, electron/quark, and proton/neutron respectively."

We report openly where this account is, and is not, quantitatively adequate. The progression fixes the depth index d but not the function relating depth to measured mass. Testing the two simplest candidates against the measured proton-to-electron mass ratio (≈ 1836) illustrates the gap precisely. The linear candidate, $\text{mass} \propto d$, using $d = 9$ for the proton and $d = 3$ for the electron, predicts $9/3 = 3$, short of the measured value by a factor of roughly 612. The quadratic candidate, $\text{mass} \propto d^2$, predicts $81/9 = 9$, short by a factor of roughly 204. Forcing exact agreement requires an exponent near 6.8, read directly off the measured answer instead of supplied by the recursion mechanism, and we do not present this as a derivation. The correct mass-scaling function is listed as an explicit open problem (Section 7.2); it is not papered over with a fitted exponent. The charged-lepton hierarchy (electron : muon : tau $\approx 1 : 207 : 3477$) shows the same open status: it grows faster than any simple power law, consistent with a more complex balance between depth-driven growth and a conservation-imposed suppression term, but neither term is yet derived.

The transition between free oscillation and closed particle has a precise formal statement, and it is where the framework produces its two sharpest quantitative results. The stretching threshold of Section 4.1 can be written as a single condition: $\lambda \leq \lambda_{\text{crit}} \Leftrightarrow E \geq E_{\text{crit}} \Leftrightarrow \kappa \geq \kappa_{\text{crit}} \Rightarrow \Psi(t) \rightarrow \Psi(t, t-\Delta t)$. Read left to right: wavelength below the critical value is equivalent to energy above the critical threshold, which is equivalent to local curvature above the critical curvature, and when any of these holds, the wavefunction gains a memory term, the state at time t now depending on the state at $t-\Delta t$. That memory term is the seed of mass. Below the threshold: free bosonic energy, no memory, no history, a photon. At the threshold: recursion begins, history accumulates, and a free oscillation becomes a particle. Crossing the energy condition is necessary for closure, not sufficient; closure also requires a coupling context, an existing coupled configuration for the closing relay to match against and a partner to carry the recoil, which is why a lone photon above threshold in empty vacuum stays a photon, crossing cosmological distances intact, while the same photon near an atomic nucleus converts.

Two numbers follow from this structure, and both were derived from the closure geometry first and checked against measurement afterward, the discipline a genuine prediction requires. First, the critical energy for electron-depth closure is $E_{\text{crit}} = 2m_{\text{ec}}^2 = 1.022 \text{ MeV}$, exactly twice the electron rest energy, because pair production closes an electron and a positron together, never one particle alone. This is the pair-production threshold physics has measured for ninety years: a photon at or above 1.022 MeV, passing close to a nucleus, converts into an electron-positron pair, with the nucleus contributing essentially no energy, supplying exactly what the mechanism says closure requires, a coupled configuration to close

against and a recoil partner. On this reading E_{crit} is not an open parameter; the measured pair-production threshold is its experimental face. Second, the same condition read through $E = hc/\lambda$ fixes a critical wavelength: $\lambda_{\text{crit}} = h/(2m_e c) \approx 1.213 \times 10^{-12} \text{ m}$, exactly half the electron's Compton wavelength. The factor of two is not a discrepancy to explain away; it is the closure condition's own fingerprint, the textbook Compton wavelength marking one electron rest-mass where this threshold requires two, appearing exactly where the mechanism says it should. What remains open is m_e itself, an empirical input the framework has not derived, the same gap as the mass-scaling function above, inherited honestly rather than escaped.

The same threshold structure gives the Klein–Gordon equation, $(\square + m^2)\phi = 0$, a direct reading rather than a separate postulate. ϕ is the oscillatory mode, the bosonic energy in a specific coupling configuration; the d'Alembertian describes how the oscillation propagates through the field; and m^2 is the threshold's constraint on the mode's resolution rate. When $m^2 = 0$ the mode propagates freely at c with no temporal drag, the photon. When $m^2 > 0$ the threshold holds the mode in a stable closed loop, and the particle has mass because its energy has crossed the threshold and accumulated history. On this account the equation is what a constrained oscillation in the temporal field looks like once conservation selects a stable closure mode, produced by the framework's physics, not assumed by it. The same convergence reading extends to $E = mc^2$ itself: mass is converged temporal recursion, the same bosonic energy as a photon folded inward into closed relay loops, and c^2 is not an arbitrary constant but the natural two-factor conversion between the modes, one factor of c for each boson's own cycling rate and a second for the propagation rate at which free recursion advances through the field.

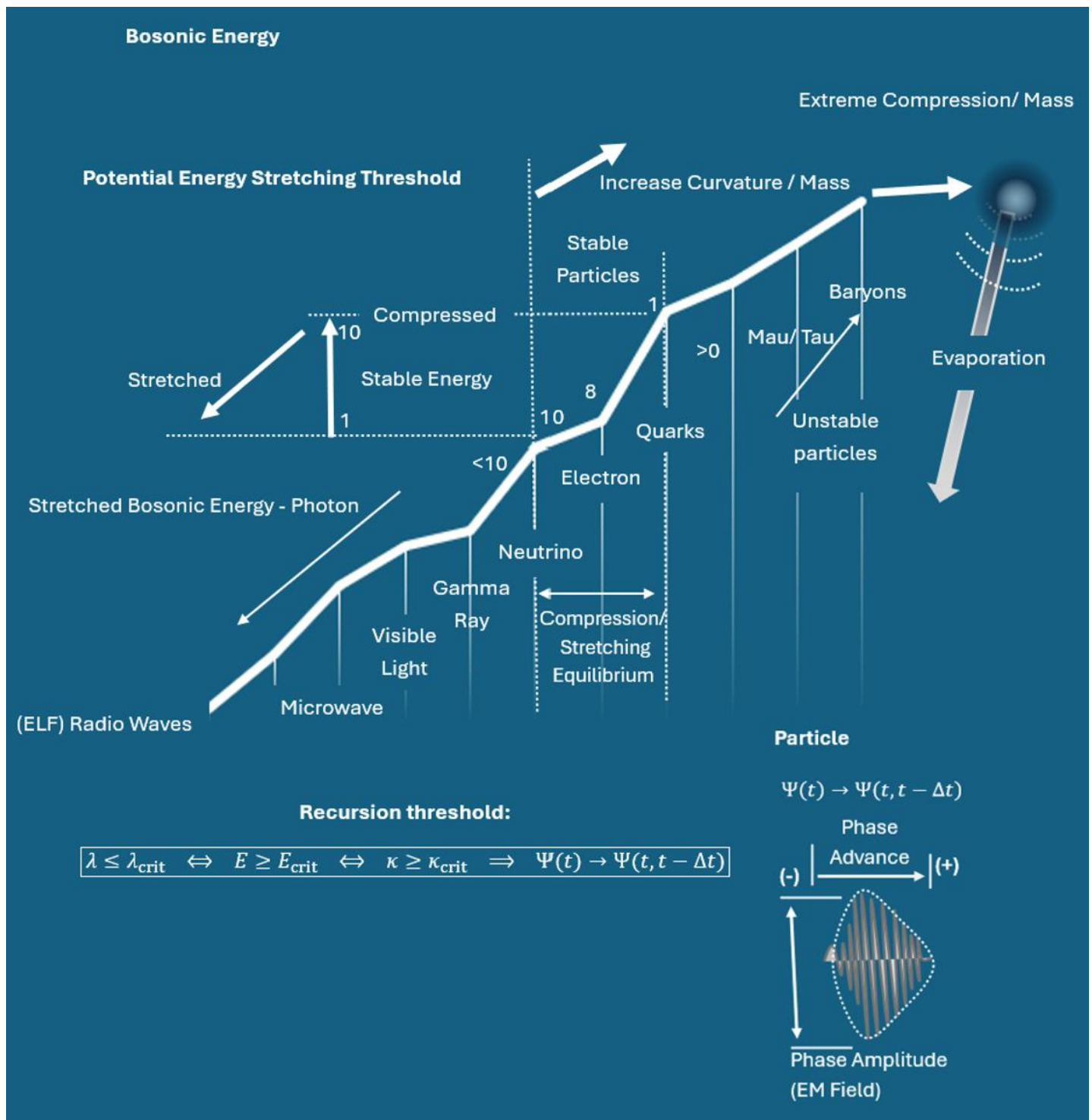


Figure 4. The compression ladder. Stretched bosonic energy (radio through gamma-ray wavelengths, no closure) crosses the recursion threshold (boxed formula) into progressively deeper compression: neutrino, then electron and quark sharing one depth, then baryon, each shift trading wavelength for curvature. This is the discrete progression $d = 3^n$ rendered as an energy ladder rather than an equation; the unstable heavier leptons and the evaporation arrow anticipate Section 7.2's open problems.

4.3.3 The wavefunction, collapse, canonical quantum puzzles, and the invariant interval

This section develops the consequence of relational differentiation (Section 4.1) for quantum mechanics specifically. The primary oscillation's ON-state is a resolved configuration; its OFF-state, the interval between resolutions, is proposed to be the wavefunction itself. On this reading $\psi(x)$ is a real field, amplitude distributed across every configuration the next resolution could occupy, and $|\psi|^2$ (the Born rule; Appendix B) is this OFF-state amplitude read as next-resolution probability. This carries a checkable consequence for quantum field theory's own formalism: what QFT calls the creation operator ($a^\dagger$) is the ON-state resolution; what it calls the annihilation operator (a) is the return to the OFF-state. These are proposed to be two phases of one 0–1–0 cycle rather than independent operations.

The same identification reframes wavefunction collapse without an observer-dependent postulate: collapse occurs whenever the OFF-state field enters a region whose only stable configurations are already-resolved modes, forcing resolution. A detector achieves this by permanently coupling the arriving configuration into its own resolved structure; a slit boundary does not. Decoherence is reframed as a matter of coupling depth (Zurek, 2003) rather than a separate mechanism: a weakly coupled particle shows full quantum behaviour because nothing has anchored its resolution; a macroscopic object, coupled atom by atom to its surroundings, resolves continuously even though every constituent atom still carries the same underlying structure.

This one identification generates precise readings of the canonical quantum puzzles, and we group them together because they share a single mechanism instead of needing one explanation each. Superposition receives a precise physical definition: it is the state of an oscillation propagating in the OFF-state field, with each geometrically accessible next configuration weighted by the field's amplitude at that point. The particle is not in multiple states simultaneously in some mysterious sense; it is in one propagating state whose next resolution has not yet been selected, and what quantum mechanics calls the probability distribution is precisely this amplitude distribution, real and physical, not a description of ignorance. The double-slit experiment turns on the resulting distinction between transient contact and permanent registration. Passing a slit boundary is contact that leaves the OFF-state field intact, so the field's two portions interfere on the far side exactly as any wave field does. A detector is different: it registers, coupling the particle into a chain of resolved states it cannot un-belong to, which is why detection at the slits destroys the pattern. No observer, and no consciousness, enters the account at any point.

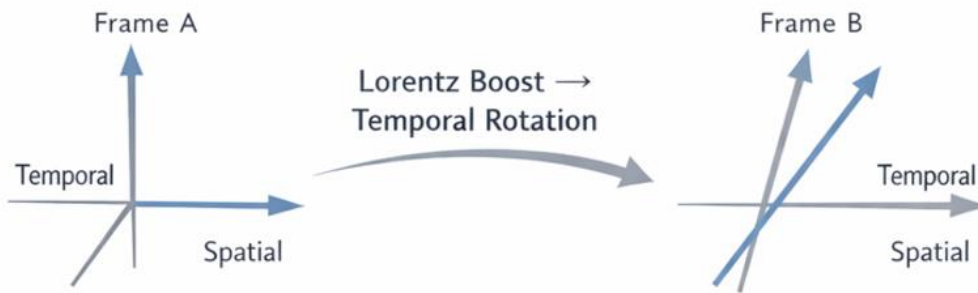
The measurement problem itself receives a geometric statement under the same reading. A free photon is a two-component structure, a present configuration and an open probability branch, with no accumulated past of its own, which is why it cannot resolve itself. A detector is a system that does carry accumulated history, and registration is the event in which the detector contributes that history to the joint system: the photon's open branch closes not because it was observed in any special sense, but because it became entangled with a system possessing the one structural component it permanently lacks. The delayed-choice quantum eraser, often presented as evidence of retrocausation, dissolves under the same analysis. The entangled pair is one joint OFF-state structure, not two separate objects, and the experimenter's later choice does not reach backward in time. It selects which class of globally consistent histories remains viable for the joint system, with the correlations appearing only when results are compared afterward, exactly as observed. Quantum tunnelling is read as resolution across configurations, not passage

through a barrier: the oscillation exists between resolutions, not inside any one of them, and if a far-side configuration is geometrically accessible and conservation permits it, the next resolution can occur there. The standard exponential suppression is re-read as declining geometric accessibility with barrier width, the same mathematics under a different ontology. The quantum Zeno effect follows directly and needs no separate explanation: each resolution event resets the field's unfolding from a fixed configuration, so a system resolved frequently enough never accumulates amplitude toward any other configuration, and its evolution freezes. This is not because observation exerts a special force, but because each check is itself a resolution, and resetting is what resolution already does.

Three further quantum facts receive structural accounts under the same reading. Entanglement is read as shared temporal structure rather than signal transfer across a spatial gap: two particles with a common coupling history are one joint OFF-state structure, and under the chronological-depth account of distance developed in Section 4.3.6, the separation between them is zero in the framework's own terms, since no differentiated structure lies between what remains one configuration. Nothing propagates between the partners at measurement because nothing needs to; the correlation was never a message. Spin- $\frac{1}{2}$'s most counter-intuitive property, the 720-degree rotation a fermion requires to return to its original state, follows directly from the tri-closure geometry of Section 4.3.1: the electron's three-position closure has a two-valued orientation relative to the field, so a 360-degree rotation returns its mirror image, the opposite handedness, and only a second full rotation restores the original. Bosons carry integer spin on the same account because they are single boundary expressions, either oriented (spin 1) or orientation-neutral (spin 0). And the contact-versus-registration distinction that carries the double-slit account is confirmed at a scale classical intuition rejects: buckminsterfullerene molecules, sixty carbon atoms with roughly 720 times the mass of hydrogen, produce interference patterns through a diffraction grating when isolated in high vacuum, because grazing the grating is transient contact, not registration into a resolved history. The quantum-to-classical boundary is not a line drawn at a particular mass; it is the transition from unregistered to registered, and that transition can be prevented even for large molecules by isolating them from any registering system.

A second, independent reinterpretation concerns special relativity. Every configuration divides one fixed rate of advance, c , between internal cycling (its proper-time clock) and external traversal (its motion). A photon spends its entire budget on traversal; a particle at rest spends none. Setting a configuration in motion reallocates the budget, and every instrument built from the same oscillations, including the clocks and rulers measuring it, reallocates identically, which is why the reallocation is unmeasurable from inside the moving system. What every frame agrees on is the one quantity the reallocation preserves: the total budget itself, proposed to be precisely the invariant spacetime interval. Time dilation and length contraction become two descriptions of one fixed-budget reallocation rather than independent postulates, and the full Lorentz transformation is recovered exactly; nothing measurable in special relativity changes under this reading.

The Lorentz Transformation as Temporal Rotation



What's being rotated is the *description of Extension*, not *Extension* itself.

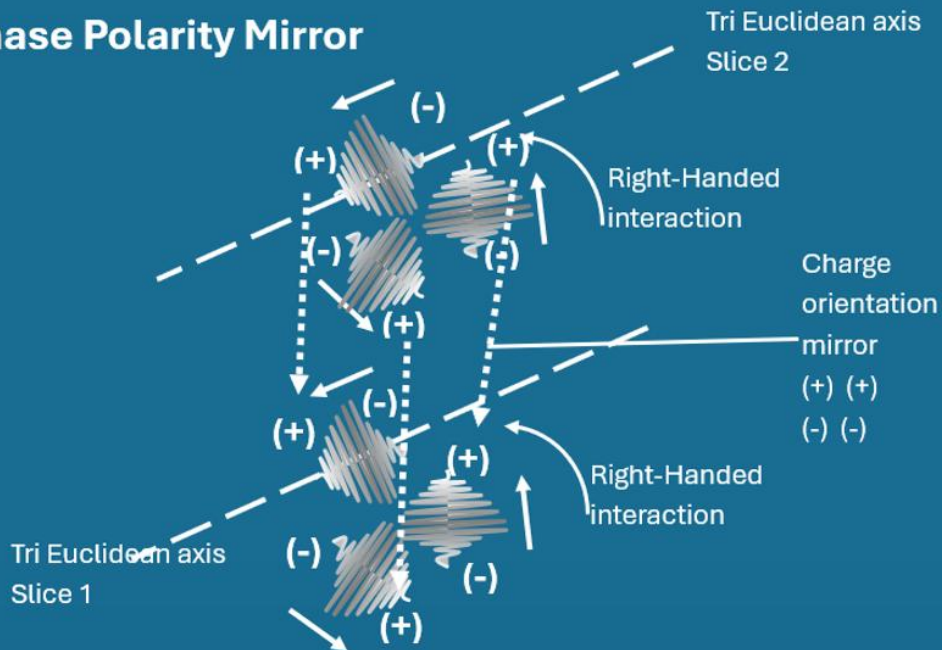
Figure 5. The Lorentz boost as temporal rotation. What changes between Frame A and Frame B is the ratio at which a relay-built observer's instruments divide the fixed tick budget between internal cycling and external traversal; what is being rotated is the description of the configuration's motion, not the underlying structure being described.

4.3.4 A worked case: the matter–antimatter asymmetry

We present this mechanism in some detail because it illustrates the standard the framework holds itself to throughout: one mechanism, stated once, applied consistently. At the first slice to reach closure (Section 4.1), the primary oscillation's internal polarity could orient left or right with equal a priori likelihood. This is the binomial expansion's opening step, asked once, of one relay, not independently at many separate events across a population. As a matter of which orientation actually occurred, the expansion resolved right-handed at that first slice and, as the argument below shows, at every slice descended from it: a contingent fact (Axiom A6) the framework does not derive, in the same sense the Standard Model does not derive the specific magnitude of CP violation from a deeper symmetry principle.

The opposite orientation is not a second, independently created population; it is a deterministic, geometric consequence of the first, since adjacent slices cannot present matching polarity without mutual repulsion, forcing exactly half of all slices into the opposite orientation. The matter-favoring orientation is thus a structural majority built in from the outset, not a fifty-fifty population later trimmed by survival. Two regimes must be kept separate. Under ordinary conditions the minority orientation is entirely stable: bound down-type quarks, and long-lived free antineutrinos that undergo identity change instead of annihilation in processes such as beta decay. Annihilation, the destructive same-polarity collision, is reserved for a separate, extreme-pressure regime realized in the early-universe plasma, and is self-limiting as the density driving it falls. The resulting picture is structurally consistent with the qualitative shape of the Sakharov (1967) conditions without a separate mechanism to generate the imbalance, and the initial orientation itself remains an explicit, named contingency, not a concealed one.

Phase Polarity Mirror



Phase Polarity Correction

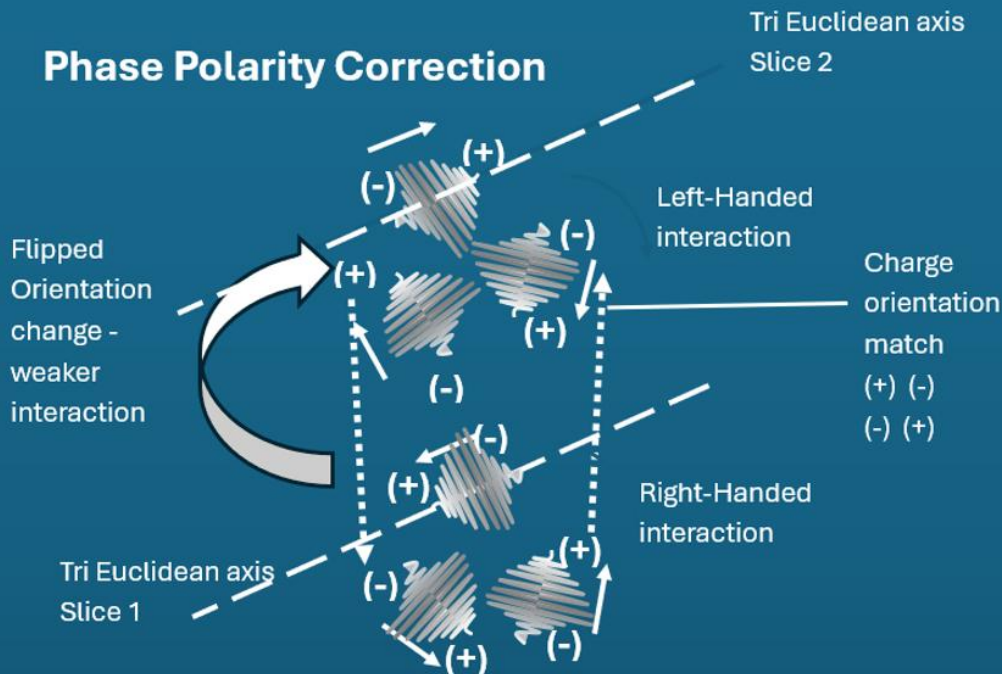


Figure 6. Why a slice flips. Top: two slices held together by a right-handed interaction that must fight the repulsion between matching poles. Bottom: the correction, one slice's orientation flips to a weaker left-handed interaction so that poles match across the junction. This is the deterministic, geometric mechanism that makes left-handedness a forced minority rather than a second, independently created population.

4.3.5 Unification of the four fundamental interactions

The framework treats the four apparent forces as one coupling principle, the same tendency toward deeper coupling that Section 4.1 identifies with accumulating differentiation, constrained by the ground state's enforcement of configurational uniqueness, expressed through different geometric regimes at different scales. At the quantum domain, discrete tetrahedral geometry gives the strong interaction; at the planetary and stellar domain, smooth continuous geometry gives gravity; the weak interaction is the decay pressure the ground state exerts on incompletely closed configurations; electromagnetism is the conservation-boundary phenomena, attraction and repulsion, arising wherever a closed configuration meets the surrounding field. One consequence follows directly and is stated without softening: gravity does not require an independent act of quantization on this account, because it is already the same coupling principle expressed discretely, at the quantum scale, as the strong interaction, and the historical difficulty of quantizing gravity is reframed as a domain-mismatch problem. We state candidly that if this domain account does not survive scrutiny, existing quantum-gravity research programmes remain the correct approach to pursue (Section 7.2).

The same coupling-completion requirement gives a structural account of colour confinement: an isolated quark is an incomplete three-position closure, and the field's response to attempted separation, the confining flux tube and pair production at sufficient energy, is the field regenerating the missing closure position. This reproduces the qualitative phenomenology that historically motivated string theory's fundamental one-dimensional object, without the extra spacetime dimensions a quantized fundamental string's internal consistency separately requires. The same closure requirement also yields a structural account of the proton's observed absolute stability: the proton is the deepest stable expression of three-fold closure available within the quantum domain's geometry, with no lower-energy state to decay to that remains within that geometry. Decay would therefore require crossing a domain boundary, an account consistent with, and giving a structural reason for, the null results of every proton-decay search to date.

The unification claim extends beyond the four interactions to the Standard Model's own field content, and we state its strongest form explicitly so it can be judged at full strength. The Standard Model names seventeen fundamental fields. On this framework's account these are seventeen named patterns in one field, the temporal field read at seventeen different coupling depths and configurations, not seventeen separate substances. The electron field is the field in its ground-state three-closure configuration; the photon field is the field's own OFF-state propagation (Section 4.3.3); the Higgs field is the coupling-zone geometry at the boundary between configurations, the structure that enables closure and generates mass. This reduction has a precise numerical consequence. The Standard Model's nineteen free parameters, nine fermion masses, three gauge couplings, four CKM mixing parameters, the QCD phase, and the Higgs mass and vacuum expectation value, are all measured and inserted, none derived. Under this account they become, in principle, nineteen outputs of one equation evaluated at different coupling depths: fermion masses as curvature costs per depth, gauge couplings as phase-advance ratios per cycle, CKM parameters as phase relationships between depths. We emphasize "in principle": not one of the nineteen has yet been computed from the framework's own parameters, the fine-structure constant being the sharpest single instance (Section 7.2), and the reduction is stated here as the shape of the research programme, not a completed result. A related structural consequence is available now, however. Lepton universality, the experimentally confirmed fact that the W boson couples identically to the electron, muon, and tau, follows

immediately if the three charged leptons are the same closure structure at three successive depths (Section 4.3.1) instead of three independent particles, since one object at three depths presents one coupling, not three.

The Standard Model's gauge structure itself, $SU(3) \times SU(2) \times U(1)$, receives a structural derivation from the same picture: one boson with two orthogonal degrees of freedom, orientation (which of the three transverse configurations it couples along) and phase (the internal phase relationship of the coupling). This orientation freedom is a different application of the three transverse axes from the one Section 4.3.1 uses: there, pairing the axes gives three embedding configurations and three generations; here, the three axes read directly give three colour states. Orientation symmetry among three independent transverse coupling directions produces $SU(3)$, the symmetry group of three-complex-direction transformations with determinant 1, with $3^2 - 1 = 8$ generators, the eight gluons read as the eight independent orientation transitions between the three colour states. Phase symmetry produces $U(1) \times SU(2)$: continuous phase rotation is $U(1)$, electromagnetism, and the two stable low-energy phase orientations, forward and inverted, produce $SU(2)$, the weak interaction. Three gauge groups from two degrees of freedom of one particle. On this account the Standard Model's gauge structure is not an arbitrary choice confirmed by experiment; it is the necessary symmetry of one oscillatory mode with three transverse configurations and two degrees of freedom. The formal Lie algebra derivation is an open problem (Section 7.2); the structural identification is complete.

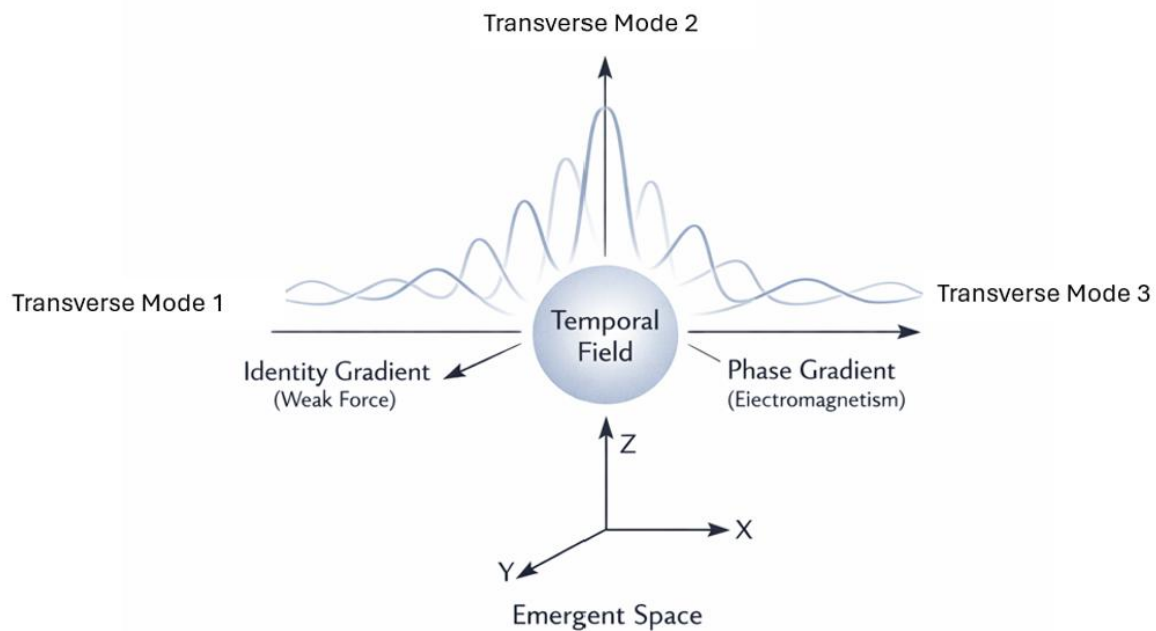


Figure 7. Four directions, one field. The temporal field, radiating through three transverse modes, gives the identity gradient (weak force) and phase gradient (electromagnetism) explicitly; gravity (the rate gradient) and the strong force (the orientation gradient) are the same field's remaining two slopes. Emergent space (X, Y, Z) is read off this structure rather than assumed prior to it.

4.3.6 Chronological depth: distance as differentiation interval

The claim in Axiom A2, that space is derived and time fundamental, now has everything it needs to be stated as a mechanism rather than a slogan, and this section states it, because it is the framework's central concept and everything cosmological in Section 4.3.7 reads through it. Time and distance are two measurements of one underlying structure. Time is the reading produced by comparing a single relay against its own past-now-future cycling. Distance is the reading produced by comparing two different relays' recursion structures against each other: the differential interval between two configurations, the number of differentiation steps that separate them, measured at the current resolution rate. The framework calls this quantity chronological depth.

The consequence is precise, not metaphorical. When a galaxy is said to be a billion light-years away, the framework's reading is not that it is located in a pre-existing spatial container at that distance; it is that the signal connecting the two configurations required a billion years of differentiation to propagate. The distance is a temporal measure, a gap of history rather than a gap of space, and the light arriving carries information about configurations as they were a billion differentiation-years ago, not as they are now. Both sentences, far away and long ago, describe the same interval; only one describes it in the field's own terms. The metre, the light-year, and the differential interval of every measurement physics performs all operate on this quantity: a ruler placed between two objects returns the chronological depth of the field between its ends, expressed as spatial distance. The measurement is not an illusion, and nothing about any measured value changes; what changes is the account of what is being measured. Chronological depth is objective and mind-independent, present for the thirteen billion years before any nervous system evolved to render it as felt distance, which is exactly the extension side of the extension/extensivity boundary Section 4.1 fixed.

The arrow of time falls out of the same structure without a separate postulate. Differentiation is directional by construction: a resolved configuration is fixed permanently at the moment of resolution (Section 4.1), so the accumulated record can only grow, and the asymmetry between a settled past and an open probability edge is not a statistical tendency requiring a special low-entropy starting condition, as Boltzmann's account alone does, but the structure of the process itself. Entropy increase, on this reading, is the same accumulation counted thermodynamically: the expressed field's configurations spreading across the binomially expanding space of alternatives, one direction available, because un-differentiating a resolved configuration is not an operation the field possesses.

4.3.7 Cosmological readings

Gravity is read as the gradient of a scale-dependent temporal density, the same accumulated differentiation rate fixed in Section 4.1, read here as how much a region's local structure is occupied by accumulated coupling relative to free propagation. This recovers General Relativity's own mathematics: the Schwarzschild time-dilation factor is read directly as this density measure, and its weak-field gradient recovers Newtonian gravitational acceleration term for term. Black holes are the extreme limit of the same coupling principle, giving a structural (though not yet quantitatively complete) account of area-law entropy consistent with Bekenstein (1973) and Hawking (1975); the specific coefficient in $S = A/4$ remains open (Section 7.2). The same reading yields the correct direction for black-hole thermodynamics without additional

postulates. Hawking temperature scales inversely with mass because a more massive hole has deeper accumulated coupling and a more gradual gradient at its horizon, so energy clears the release threshold more slowly and at lower energy. A shrinking hole's steepening gradient forces progressively hotter release instead, the observed inverse scaling produced by one mechanism, not fitted to match it. On information, the framework's position is that accumulated coupling structure is irreversible (Axiom A3's recursion does not invert), so the record of what crossed the horizon is redistributed, not destroyed. It is preserved in the field's coupling structure at the boundary and gradually encoded in correlations of the outgoing radiation as the hole evaporates, a picture consistent with the Page-curve analyses of black-hole information (Page, 1993) and not in competition with them. This is stated as a structural consistency, not a derivation of the Page curve itself.

The domain-adaptive field equation, introduced in Table 2, gives this reading its explicit statement rather than leaving it implicit. The framework does not replace Einstein's field equation; it adds a domain index to the source term:

$$G_{\mu\nu} = (8\pi G / c^4) T_{\mu\nu}(n_{\text{relay}})$$

Einstein's equation remains exactly correct within its own domain, the stellar and planetary regime; what changes across domains is how the source term $T_{\mu\nu}$ is computed, not the equation itself. n_{relay} , the relay-count density, is not a free parameter introduced to make the equation work: it is directly measurable via the local time-dilation rate, the same quantity a clock at a given depth in Figure 8's zones already registers. At low n_{relay} (the vacuum, quantum domain) $T_{\mu\nu}$ is computed exactly as quantum field theory already computes it. At moderate n_{relay} (the planetary and stellar domain) $T_{\mu\nu}$ reduces to the standard stress-energy tensor and General Relativity is recovered exactly, unmodified. At high n_{relay} (the cosmic domain) $T_{\mu\nu}$ acquires additional non-local coupling terms, identified below with the phenomenology usually attributed to dark matter. We are explicit about what this claims and does not: it is a specification of General Relativity's domain of validity, not a modification of it, and the specific mathematical form of the non-local terms at high n_{relay} is not derived, only their existence and domain.

This same index gives a precise, working definition to the informal notion of a temporal zone used throughout this section: a region of locally uniform n_{relay} , within which coherence between configurations is possible and information exchange proceeds smoothly, bounded by a gradient steep enough to force decoherence at its edge. The zones in Figure 8 are this definition applied to the local domain around a single mass; they are not a claim about separate cosmological regions with independently evolving histories, a question this paper does not address.

Dark matter is reframed as a non-local coupling effect rather than a particle species, broadly consistent with MOND phenomenology (Milgrom, 1983) and the Tully–Fisher relation (Tully & Fisher, 1977), while proposing a physical origin MOND does not supply: because the effect accumulates as a temporal residue built up over a system's coupling history, galaxies with longer star-formation histories should show larger rotation-curve discrepancies at fixed mass than younger galaxies of similar mass. This is a scaling with age and history, not mass alone, and more immediately testable than a full quantitative derivation of the mechanism.

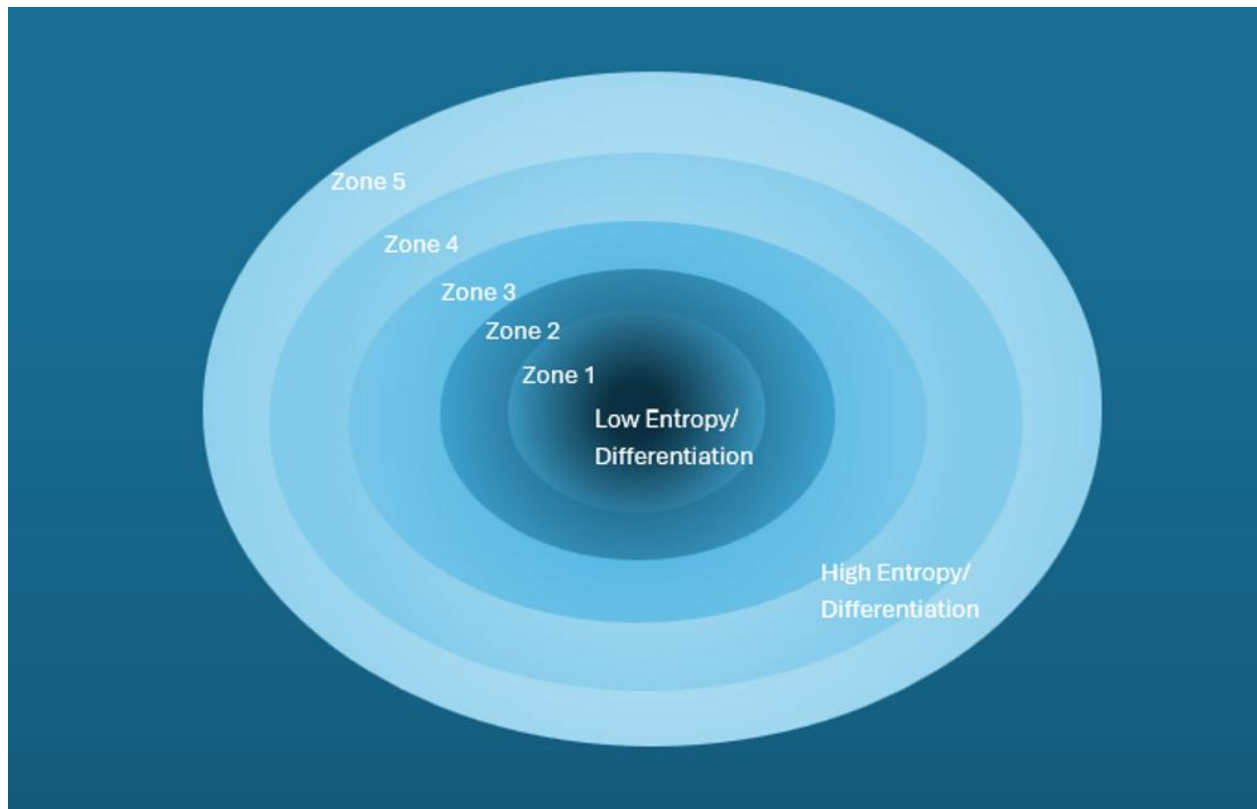


Figure 8. Temporal zones around a single mass. Zone 1, deepest, is where the Schwarzschild factor $2GM/rc^2$ is largest; Zone 5, outermost, is where it approaches zero. A satellite's onboard clock and a clock at a planet's surface sit in measurably different zones for exactly this reason, the correction GPS systems apply every day.

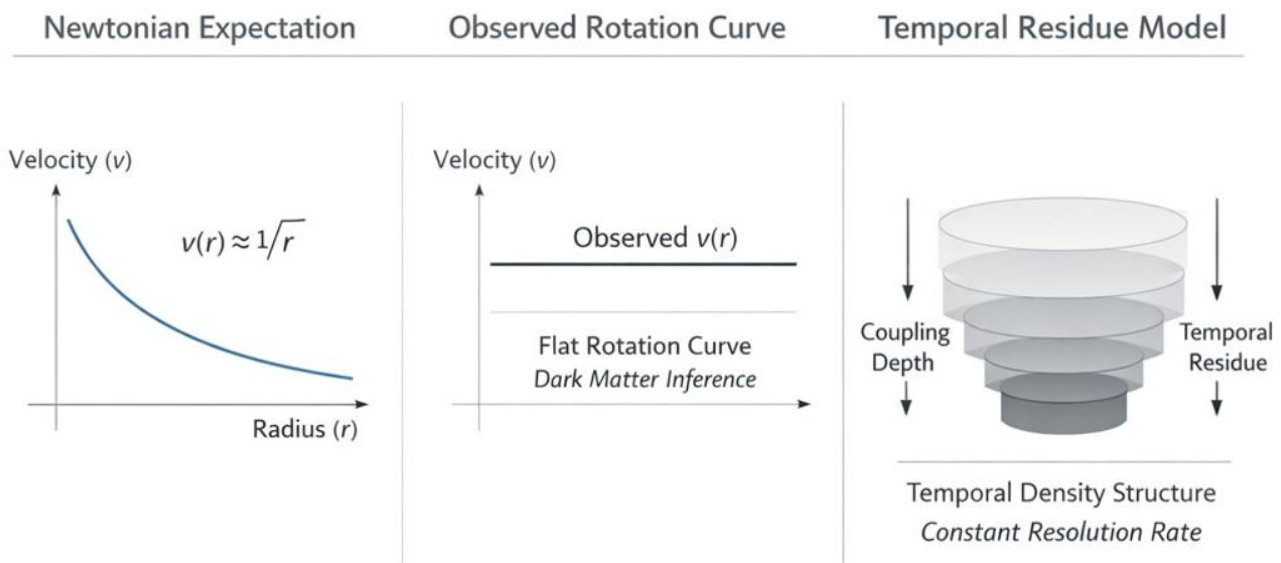


Figure 9. The three readings of galaxy rotation curves. Newtonian expectation (left): velocity falling with radius. Observed (centre): a flat rotation curve, standardly read as evidence for a dark-matter halo. This framework's reading (right): a temporal residue structure, coupling depth accumulated over a galaxy's history at constant resolution rate, producing the same flat curve without positing an undetected particle (Table 3).

Dark energy is reframed as the probability field's own pressure at the boundary of the expressed region; we state plainly that this does not, on its own, resolve the cosmological constant's notorious magnitude discrepancy, and we do not claim otherwise. What the reframing does address is the coincidence problem, the puzzle of why dark energy's density is comparable to matter's precisely in the present cosmological epoch. On this account there is no knife-edge to be surprised by, because the effective pressure is set by the continuously evolving ratio of expressed structure to background field, a balance that changes as the universe ages instead of a constant fine-tuned to coincide with the present. The Hubble tension is reframed as a domain-boundary measurement effect: the domain-adaptive field equation of Section 4.3.5 (formalized in Section 5) predicts that early- and late-universe measurements, sampling structurally different regimes of the same equation, should show a systematic trend with the redshift range sampled, not converge as precision improves.

The binomial expansion of Section 4.1 does further cosmological work, and two of its consequences are among the framework's most concrete points of contact with data. First, inflation and dark energy are read as one growth law at two points on one curve. Each step of the expansion doubles the available positions, so after n steps the total is 2^n , exponential growth, while the expressed, structured portion grows only linearly. In the early rows the exponential term dominates completely, the epoch standard cosmology calls inflation; in the late rows the linear term becomes a vanishing fraction of the exponential, and the accelerating divergence between them is the epoch standard cosmology attributes to dark energy. Dark energy, on this account, is not a new ingredient that switched on partway through cosmic history; it is the necessary consequence of linear growth competing against exponential growth from a single shared rule, with the transition point set entirely by the structure of the expansion and by no additional physics. Second, the same expansion predicts the statistical character of the cosmic microwave background as a theorem rather than an input: for large n the binomial distribution approaches a Gaussian exactly, so if the early universe is the large- n limit of a binomial cascade, the CMB's temperature fluctuations must be Gaussian to high precision, regardless of the details of any particular inflaton field. The observed near-perfect Gaussianity of the CMB, the most precisely measured dataset in cosmology, is on this account evidence for the cascade's statistical architecture itself, and a distribution significantly departing from Gaussianity at large scales would count directly against it.

The Bullet Cluster, widely regarded as the strongest single piece of evidence that dark matter is a particle, receives a direct reading and yields a falsifiable prediction of its own. In the 2006 observations, two galaxy clusters passed through each other; the visible gas collided, shocked, and slowed, while the gravitational lensing tracked where the clusters were going rather than where the gas piled up. Under the temporal-residue account of Section 4.3.7's dark-matter reading, this is what accumulated field structure does: a temporal well built over billions of years does not reshape itself in the hundred million years a collision takes, so the field carries its accumulated depth forward with the galaxies even after the gas that helped build it has been stripped away. The account is not merely consistent with the observation; it makes a quantitative claim a particle account does not require: the lensing offset should scale with the depth of the temporal well, a correlation testable across the growing catalogue of cluster collisions.

The same accumulation read forward to its limit fixes the universe's long-term trajectory without new assumptions. The regrowth of vacuum relative to matter began at a specific moment, roughly 380,000 years after the Big Bang, when annihilation self-limited (Section 4.3.4) and the era of the CMB began, and

the identical process, the expressed field thinning against the expanding substrate, has continued without interruption since; the dark-energy reading above is this same process observed today. Followed to its asymptote it is what standard cosmology calls heat death, which the framework reads as substrate return, not annihilation: as the field thins and slices stretch apart, the least-bound configurations lose their structure first and the most-bound last, an ordering dictated entirely by the relative stability each configuration was already derived to have, with everything eventually returning to the substrate it rose from. We are explicit, in the same spirit as the framework's other honesty commitments, that a process having started is not the same claim as its endpoint having arrived: the universe is thirteen billion years into a trajectory with incomparably further to run, and the framework treats what, if anything, follows the asymptote as an honestly open question rather than a settled conclusion.

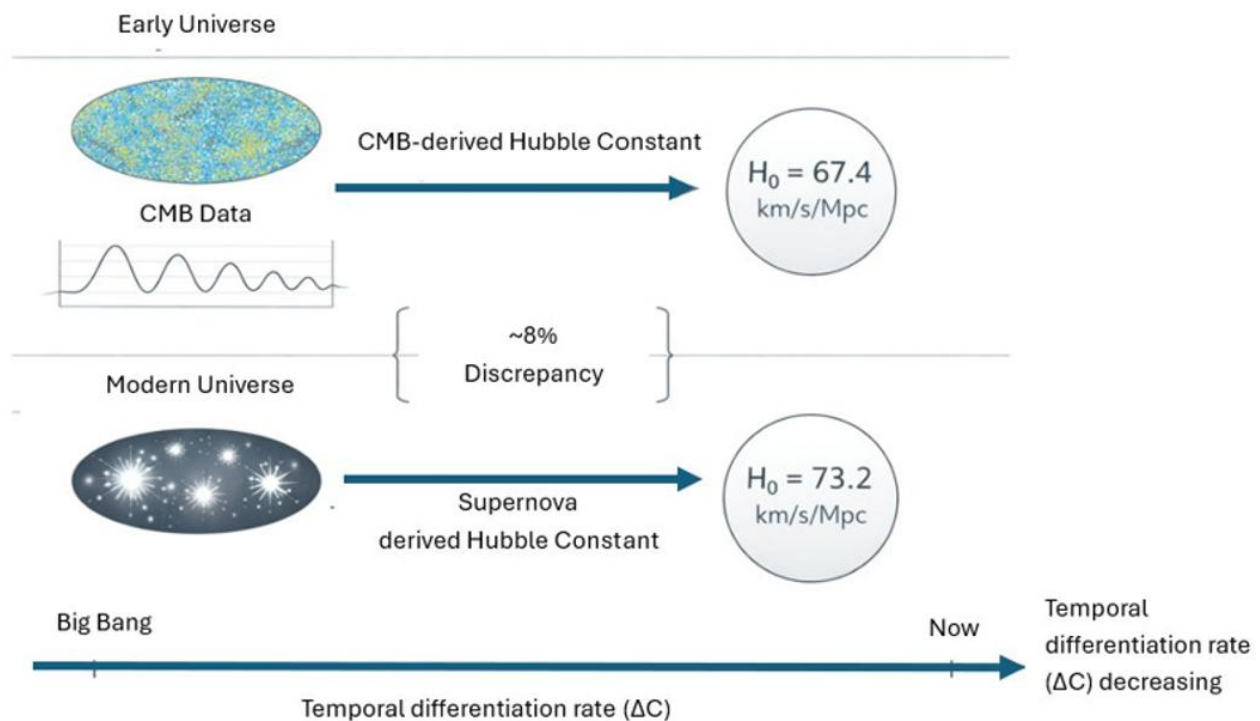


Figure 10. The Hubble tension in numbers. Two precise measurements of the same quantity disagree by roughly 8%, five standard deviations apart: 67.4 km/s/Mpc from the early-universe CMB, 73.2 km/s/Mpc from nearby supernovae. This framework reads the gap not as a measurement error but as two methods sampling different points along a temporal differentiation rate that has decreased since the Big Bang (Table 3).

Section 4.3.5's unification and Section 4.3.7's cosmology share one underlying structure, given a single visual anchor in Section 4.4: quantum, planetary, and cosmic domains are one gradient in relay-count density, not three separately unified physics.

4.4 Diagrams

Two further diagrams give the framework's cross-cutting structure a visual anchor independent of any one derivation above.

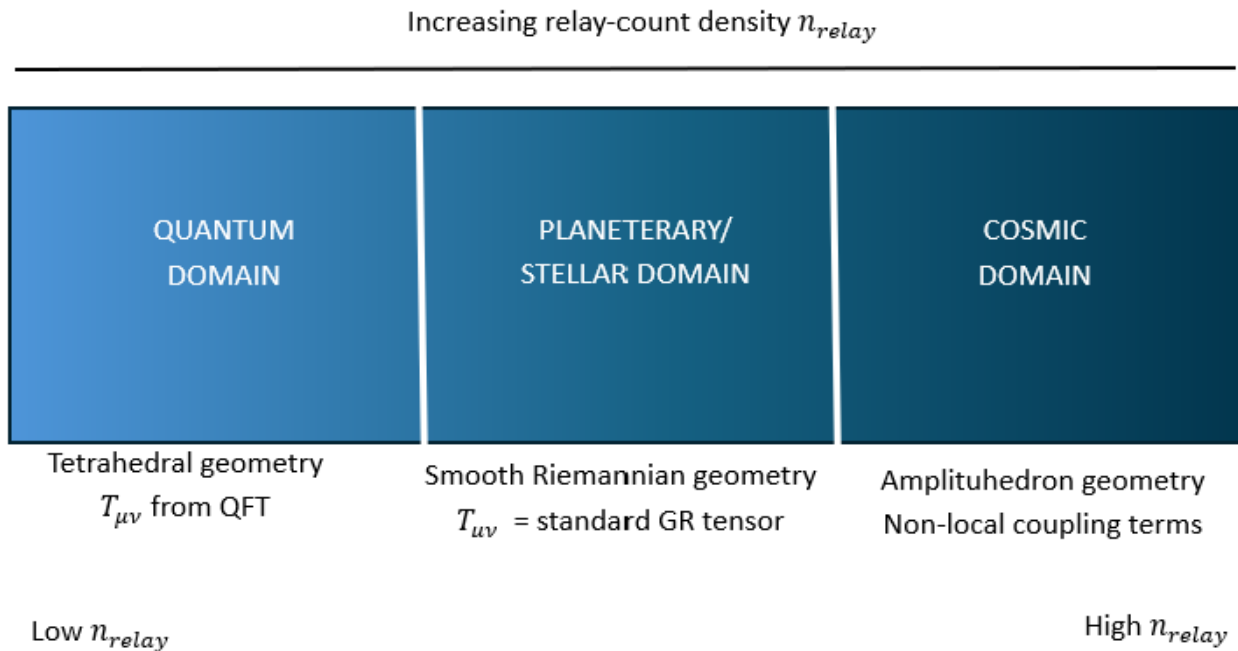


Figure 11. The domain gradient. Quantum, planetary/stellar, and cosmic domains are read as one coupling-depth (n_{relay}) gradient rather than three separately unified theories. Each domain recovers its own established mathematics exactly ($T_{\mu\nu}$ from quantum field theory at low n_{relay} , the standard General Relativity stress-energy tensor at moderate n_{relay}); non-local coupling terms appear only at the high- n_{relay} cosmic domain, identified in Section 4.3.7 with the phenomenology usually attributed to dark matter.

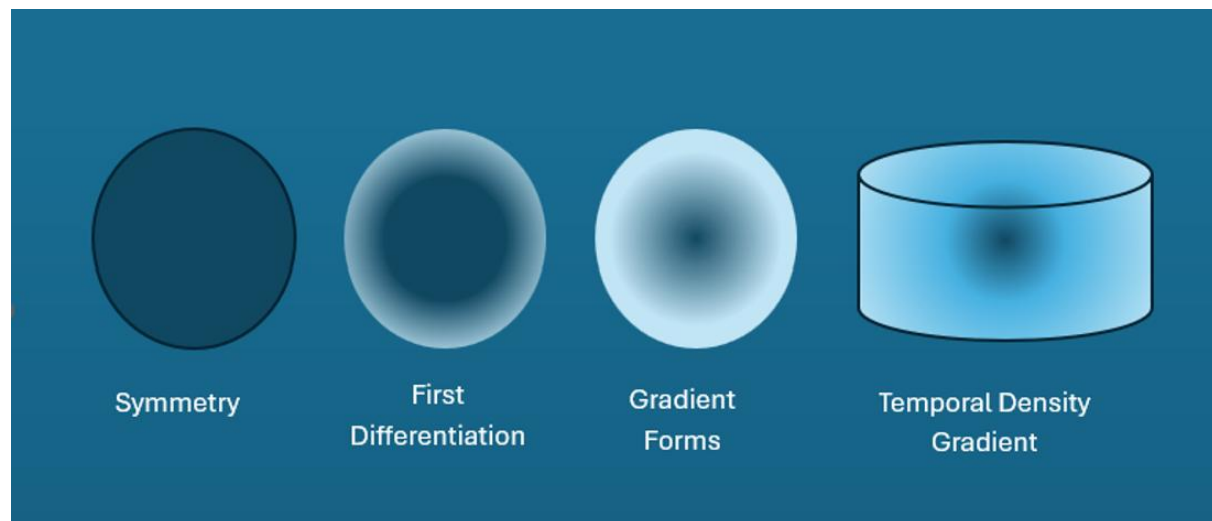


Figure 12. Emergence of the temporal density gradient, level by level. Symmetry (the undifferentiated substrate) gives way to the first differentiation (the Bosonic Domain), then gradient formation (the Fermionic Domain, where mass and spin first appear), then the Temporal Density Gradient (the Classical Domain, gravity as accumulated coupling depth). Each boundary is a genuine discontinuity, not a smooth slope (Section 5).

4.5 Predictions

The derivations above generate a small number of predictions sharp enough to be tested against existing or near-term data, summarized here and stated with explicit falsification conditions in Table 3 (Section 6.1):

- Exactly three fermion generations, with no fourth (Section 4.3.1).
- No dark-matter particle detected, with rotation-curve discrepancies scaling with star-formation history, and cluster-collision lensing offsets scaling with temporal-well depth (Section 4.3.7).
- A specific low-frequency deviation from scale-invariance in the primordial gravitational-wave spectrum (Section 4.3.7).
- Dirac, not Majorana, neutrinos (Section 4.3.4's closure architecture).
- A systematic, domain-dependent trend in the inferred Hubble constant (Section 4.3.7).

5. Integration Across Scales

A framework that proposes a common origin for the questions listed in Section 1.1 should show its work across scales explicitly rather than asserting unification in general terms. This section states, in turn, how the same coupling-depth quantity (n_{relay} , Table 2) is proposed to bridge four transitions, and is explicit about where that proposal is defended in this paper and where it is not. Figure 12 (Section 4.4) gives this bridge its visual anchor: each of the four transitions below is a further step along the same level-by-level emergence it shows.

5.1 Quantum → Classical

Section 4.3.3 proposes that quantum and classical behaviour are one mechanism at different coupling depths: a weakly coupled oscillation shows full quantum behaviour because nothing has anchored its resolution; a macroscopic aggregate, coupled atom by atom to its surroundings, resolves continuously at any scale that could be measured, while every constituent oscillation retains the same underlying structure. This is a coarse-graining account, not a switch between two physics, and Section 7.2 names explicitly what it does not yet explain.

5.2 Micro → Macro

The compression-depth ladder of Section 4.3.2 ($d = 3^n$) is the same bridge read as accumulated mass rather than as coupling behaviour: neutrino, electron/quark, and proton/neutron are successive depths of one recursive structure, the photon, uncompressed, sits outside the progression entirely, not unrelated categories of object. The open problem is quantitative (the correct function from depth to measured mass, Section 7.2), not structural.

5.3 Local → Cosmological

The domain-adaptive field equation of Section 4.3.5, illustrated in Figure 11, extends the same n_{relay} index from a single mass's local gravitational field to galactic and cosmological structure: General Relativity is recovered exactly at the planetary and stellar domain, and additional non-local terms appear only at the cosmic domain, proposed as the physical origin of dark-matter phenomenology and the Hubble tension (Section 4.3.7).

5.4 Physical → Conscious

We address this transition only to state its status honestly, consistent with the scope declared in Section 1.2. The Temporal Convergence framework, in its fuller form, proposes that biological complexity and consciousness are further domains of the same coupling cascade described in Section 4, a sixth inversion of the cascade, in the framework's own terms, beyond the quantum, planetary, and cosmic domains addressed here. That extension is not defended in this paper: it is not derived, tested, or argued for above, and none of the falsifiable predictions in Section 6.1 depend on it. We flag it here, rather than omitting the section entirely, because a paper proposing to integrate scales should say plainly where its own integration currently stops. On the framework's own account, the transition to a mind-domain is its most empirically underdetermined claim by a wide margin, and is named as such in the longer companion treatment referenced in Section 8.

6. Empirical Considerations

6.1 Observable Predictions

Table 3 states the framework's sharpest, most concretely falsifiable predictions together with the specific observation that would falsify each. We restrict this table to predictions testable with existing data or with instruments already under construction.

Table 3. Falsifiable predictions and their falsification conditions

Prediction	Falsified by
Exactly three fermion generations, tied structurally to the same three-axis geometry that fixes three spatial dimensions.	A confirmed fourth generation with no corresponding revision needed to the three-dimensionality derivation.
No new fundamental force-carrier particle at higher collider energies; no separately detected graviton.	Discovery of a force mediator not already accounted for by the framework's four-force reading.
No dark-matter particle will be detected; rotation-curve discrepancies scale with a galaxy's star-formation history, not with mass alone.	A confirmed direct-detection dark-matter signal, or rotation-curve data showing no dependence on star-formation history at fixed mass.
In cluster collisions, the gravitational-lensing offset from the visible gas scales with the depth of the accumulated temporal well.	Cluster-collision surveys showing lensing offsets uncorrelated with well depth, or correlated only with quantities a particle halo already predicts.
A specific low-frequency excess in the primordial gravitational-wave spectrum, deviating from exact scale-invariance.	A primordial spectrum consistent with exact scale-invariance across the LISA/CMB-S4 band, or a spectral shape the framework's mechanism cannot fit.
Neutrinos are Dirac particles.	Observation of neutrinoless double beta decay.
The inferred Hubble constant varies systematically with the redshift range of the measurement technique.	Convergence of early- and late-universe H_0 measurements to a single value as precision improves, with no domain-dependent trend.

6.2 Compatibility with Existing Data

Every reinterpretation in Section 4 is constructed to recover an existing, confirmed result exactly, not approximately. The Schwarzschild metric and the resulting GPS timing corrections are unchanged (Section 4.3.7); the full Lorentz transformation is recovered exactly under the fixed-budget reading (Section 4.3.3); the Born rule's statistical predictions are unchanged under the OFF-state reading, since the reinterpretation concerns what ψ physically is, not what $|\psi|^2$ predicts, and the same holds for every canonical quantum experiment re-read in Section 4.3.3. The double-slit pattern, the delayed-choice eraser's correlations, tunnelling rates, and the Zeno effect are each recovered as observed, with only the ontology beneath the

mathematics changing; lepton universality, experimentally confirmed in W-boson couplings, follows structurally from the three charged leptons being one closure at three depths (Section 4.3.5); LIGO's gravitational-wave detections and the pulsar-timing-array-confirmed gravitational-wave memory effect are both consistent with, and were anticipated in structural form by, the coupling-depth account of mass-energy given in Section 4.3.2 and 4.3.7; the observed inverse mass-scaling of Hawking temperature and the Page-curve behaviour of black-hole information are consistent with the boundary-release and configuration-memory account of Section 4.3.7; the absolute stability of the proton in every decay search to date is consistent with its reading as the quantum domain's deepest available closure (Section 4.3.5); and the Tully–Fisher relation and existing MOND-fitted rotation curves are recovered under the dark-matter reframing of Section 4.3.7. In each case the framework's claim is interpretive, not corrective: it does not ask any existing measurement to come out differently than it already has.

6.3 Potential Conflicts

We report the following openly, without minimizing them. The mass-scaling function (Section 4.3.2) fails both simple candidate forms against the measured proton–electron ratio by two to three orders of magnitude; until a correct function is derived, the compression-depth architecture is structurally suggestive, not quantitatively predictive. The dark-energy reframing (Section 4.3.7) does not resolve, and does not claim to resolve, the roughly 120-order-of-magnitude discrepancy between naive quantum-field-theoretic vacuum-energy estimates and the observed cosmological constant; a framework that claimed to dissolve this in one paragraph would not deserve to be believed. The fine-structure constant and the Bekenstein–Hawking coefficient are both currently unreachable from the framework's own parameters (Section 7.2). Finally, the wavefunction-as-OFF-state proposal (Section 4.3.3) inherits the same experimental burden every realist interpretation of quantum mechanics carries: it must remain compatible with the extremely tight existing bounds on deviations from standard quantum statistics (tests of the Born rule, Bell-inequality violations, and quantum-eraser experiments), and we have not, in this paper, performed a systematic check of the proposal against that full body of precision data. We regard this as the most immediate technical debt the framework owes, ahead of its more speculative extensions.

7. Discussion

7.1 Strengths

- **Conceptual clarity:** a small number of axioms (Section 2) generate structural accounts across particle physics and cosmology without a separate ad hoc postulate for each phenomenon.
- **External convergence:** the minimum-closure argument (Section 4.3.1) is independently supported by Ehrenfest's (1917) dimensionality result, rather than resting on the framework's own authority alone.
- **Falsifiability:** Table 3's predictions are stated in a form specific enough that no outcome could vindicate the framework by default; several are testable against data that already exists.
- **Explicit honesty machinery:** every claim is labeled (Table 1), quantitative failures are reported rather than hidden (Section 4.3.2), and open problems are named as well-posed technical debts (Section 7.2) rather than rhetorical gestures.

7.2 Weaknesses

- **Mass-scaling function.** $F(d)$ is not derived; the two simplest candidates fail the proton–electron ratio by two to three orders of magnitude (Section 4.3.2).
- **Fine-structure constant.** $\alpha \approx 1/137$ has no candidate derivation from the framework's phase-advance geometry.
- **SU(3) from geometry.** The framework's three-fold coupling-closure geometry has not been formally shown to reproduce SU(3) colour symmetry exactly, rather than merely resembling it.
- **The Born rule.** The candidate mechanism connecting the framework's coupling geometry to $|\psi|^2$ (Appendix B) is not yet a demonstrated derivation.
- **Newton's constant and the Bekenstein–Hawking coefficient.** Neither G nor the $1/4$ factor in $S = A/4$ is yet derived from the framework's own parameters.
- **The quantised/continuous seam.** Why the finest domain-gradient resolution is quantised while the coarsest is continuous (Section 4.3.7, Section 5.1) is not explained by the coarse-graining mechanism alone.
- **The strong CP problem.** A candidate mechanism exists: the strong interaction, as confinement rather than directional advance, does not couple to the temporal gradient's direction and so has no geometric route to CP violation, reading the near-zero measured θ -term as structural rather than fine-tuned. But without a derivation showing the field's own equations of motion exclude the θ -term from the effective Lagrangian, the problem is reframed, not resolved.
- **Precision-data audit.** The wavefunction-as-OFF-state proposal has not yet been systematically checked against the full body of precision quantum-foundations data (Section 6.3).
- **The domain account of gravity's non-quantization.** This is the framework's most exposed physics claim; Section 4.3.5 states candidly what follows if it is wrong.

7.3 Future Work

Three lines of work follow directly from Section 7.2 and are the framework's immediate priorities. First, a full derivation of the mass-scaling function $F(d)$, likely requiring the same group-theoretic treatment needed for the $SU(3)$ proof, since both concern the same underlying coupling geometry. Second, a systematic audit of the wavefunction-as-OFF-state proposal (Section 4.3.3) against existing Bell-inequality, quantum-eraser, and Born-rule precision data, to establish whether the realist reinterpretation survives contact with the full experimental record rather than only the qualitative phenomena discussed in Section 4.3.3. Third, engagement with existing galaxy-survey data to test the star-formation-history rotation-curve prediction of Section 4.3.7 directly, since this requires no new instrumentation and could falsify or support the dark-matter reframing well ahead of the gravitational-wave-spectrum and neutrinoless-double-beta-decay predictions in Table 3. A separate, longer-term programme, outside this paper's scope (Section 1.2, Section 5.4), extends the same architecture to biological complexity and consciousness; that programme's own empirical footing is, by the framework's own account, far weaker than the physics presented here, and we do not propose to strengthen the physics case by association with it.

8. Conclusion

This paper has presented a framework that proposes a common structural origin for a specific cluster of open questions in fundamental physics: the dimensionality of space, the number of fermion generations, the architecture of particle mass, the physical content of the quantum-mechanical wavefunction and the canonical puzzles built on it, the relationship between quantum field theory and General Relativity, the unification of the four interactions and of the Standard Model's field content, the matter–antimatter asymmetry, and the structural facts of black-hole thermodynamics, dark matter, dark energy, and the Hubble tension. The framework's strongest claim is the convergence, in Section 4.3.1, between its own minimum-closure argument and Ehrenfest's (1917) independently verifiable dimensionality result; its most economical is the OFF-state mechanism of Section 4.3.3, under which five canonical quantum puzzles follow from one identification; its most exposed claims are named without qualification in Section 7.2 rather than smoothed over.

We have tried throughout to hold the framework to a single standard: state what follows once a structural mechanism is granted, distinguish that from what remains an unexplained contingency (Axiom A6), and report quantitative tests, including the ones that fail, rather than omitting them. Table 3's predictions are offered in that spirit, and we invite exactly the scrutiny this standard implies.

A longer treatment, extending the same architecture to biological complexity and to a structural account of consciousness, together with the full derivations summarized here, is available at temporalconvergence.com. We have kept those extensions out of this paper deliberately, for the reasons given in Section 1.2 and Section 5.4: the physics and cosmology claims presented here should be evaluated on their own terms, independent of how one judges the framework's further reach.

9. References

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10. Appendices

Appendix A: Glossary of Terms

Differentiation event. A transition in which a configuration that did not exist comes to exist, or one that existed ceases to; the framework's most primitive unit, relational rather than intrinsic (Section 4.1).

Extension / Extensivity. Extension is the objective, mind-independent three-transverse-mode structure of the field, what instruments measure. Extensivity is the felt, rendered spatial experience a brain constructs from it. This paper's claims are claims about extension only (Section 4.1, Section 1.2).

Chronological depth. The differential interval between two configurations: the number of differentiation steps separating them at the current resolution rate. What a ruler measures, read in the field's own terms; the framework's account of what spatial distance is (Section 4.3.6).

Primary oscillation (boson). The elementary 0–1–0 relay from which all closed structures are built; free propagation is identified with the photon.

Slice. One cross-section of the field along the resolution axis: a single completed step of the primary oscillation, carrying its resolved position, open probability edge, and accumulated history at once. The same object Section 4.3.1 calls a position (Section 4.1).

Binomial expansion. The branching of each slice into two possible next configurations, left and right, with equal a priori likelihood, carried out over successive steps; the mechanism Axiom A6's contingent claims refer to, including the handedness break of Section 4.3.4 (Section 4.1).

ON-state / OFF-state. A resolved configuration (ON) versus the interval between resolutions (OFF), the latter identified with the quantum-mechanical wavefunction (Section 4.3.3).

Superposition (Mode 0). The state of an oscillation propagating in the OFF-state field with each accessible next configuration weighted by the field's amplitude there. One propagating state whose next resolution has not yet been selected, not many simultaneous states (Section 4.3.3).

Registration vs. contact. The distinction doing the work in the double-slit and measurement accounts: transient contact leaves the OFF-state field intact, while registration permanently couples the configuration into a chain of resolved states (Section 4.3.3).

Compression depth (d). The number of internal recursion cycles folded into a closure; $d = 3^n$ for the neutrino, electron/quark, and proton/neutron. The photon, uncompressed and massless, is outside this progression (Section 4.3.2)

Relay-count density (n_{relay}). Internal oscillation cycles completing per unit volume per unit time; the framework's operational density/mass measure and its domain index (Section 4.2, Section 5).

Stretching threshold. The critical condition above which a free oscillation locks into recursive, mass-bearing closure (Section 4.1).

Minimum-closure requirement. The geometric constraint that a self-referential loop requires a minimum of three distinguishable positions to close (Axiom A4, Section 4.3.1).

Domain (quantum / planetary / cosmic). A regime of n_{relay} within which a specific established mathematical description applies exactly (Section 4.3.5, Figure 11).

Domain-adaptive field equation. The proposed extension of Einstein's field equation in which the source term is computed by domain (Section 4.3.7).

Fixed tick budget. The proposed fixed total rate c divided between internal cycling and external traversal, underlying the framework's account of time dilation and length contraction (Section 4.3.3).

Appendix B: Extended Technical Note, A Candidate Mechanism for the Born Rule

The Born rule states that the probability of a measurement outcome is the squared modulus of the wavefunction amplitude. Under the OFF-state identification (Section 4.3.3), this squaring is proposed to emerge because the field has two independent contributing factors for each configuration, the amplitude of the relay itself and the amplitude of the phase boundary at which it is observed, each contributing one factor, whose product gives the squared result. A complete derivation would need to show that these two factors are genuinely independent and that their product recovers exact Born-rule predictions for every quantum system; that derivation is not complete, and is stated here so the reader can see what a successful derivation would need to establish, rather than leaving the open problem undefined.

A related, narrower question is why quantum mechanics requires complex amplitudes at all. The wavefunction $\psi = A \cdot e_i \phi$ has a real amplitude and an imaginary phase; the imaginary unit i is usually treated as a mathematical convenience, not a physical object. Under this framework's coupling geometry, the transition between differentiation and recursion, the first two operations of the field's own structure, is proposed to relate by a 90° phase relationship, the same rotational structure Euler's formula describes: $e_i \phi = \cos \phi + i \cdot \sin \phi$. If this orthogonality holds specifically as a 90° rotation, the wavefunction's complex structure would follow from the coupling geometry's own shape instead of being imposed as a separate mathematical postulate. This is a candidate mechanism, not a demonstrated one (Gleason's (1957) theorem remains the relevant benchmark any complete derivation of quantum probability must ultimately reproduce). What is missing is an independent argument for why differentiation and recursion relate by exactly this rotation, and not some looser relationship that would not by itself produce a complex amplitude. Until that argument exists, this remains what it is stated as here: a proposed shape for a derivation, not the derivation itself.