Gravity from Fold Density Gradients: A Unified VERSF Derivation

From Binary Necessity to Newton's Constant

Keith Taylor VERSF Theoretical Physics Program

For the General Reader

Everything in the physical world is distinguishable from everything else — no two things are truly identical in every respect. This paper asks: what is the smallest possible unit of distinguishability? It turns out that answering this question carefully leads, step by step, to a constrained form of gravity.

In the framework developed here, the smallest unit of distinguishability is called a **fold**. A fold is not an abstract piece of information — it is a physical structure with four internal states, like a tiny switch that can exist in a superposition before it "decides," then locks irreversibly into one of two outcomes. Once locked, it cannot revert without paying an energy cost. That locking is what we mean by irreversibility, and it is the origin of physical mass: the more folds a system has locked in, the more massive it is.

Because folds must fit into space without overlapping, and because they can only influence their neighbours one step at a time, there is a minimum size a fold can have. This minimum size — called ξ (xi) — turns out to determine Newton's gravitational constant G. Regions with more locked folds are denser, and the universe tends to flow toward higher fold density. That flow is gravity.

The result is a single chain of necessity:

```
binary distinguishability → folds → entropy → energy at scale ξ → ξ
determines G
```

Gravity is not a separate law added to the framework. It emerges from the same structural constraints that produce quantum behaviour. This paper states that chain explicitly for the first time, recovers the inverse-square law as the unique admissible solution under the stated postulates, and identifies the one remaining quantity — the closure premium Γ_c — that must be computed from the microscopic dynamics of fold commitment before Newton's constant can be predicted numerically.

Table of Contents

Abstract

We present a unified derivation chain connecting the most primitive feature of the Void Energy-Regulated Space Framework (VERSF) — binary distinguishability — to Newton's constant. A fold is the minimal physical unit of distinguishability, comprising a four-state internal structure (two pre-commitment amplitude configurations and two post-commitment record configurations) whose irreversible dynamics support exactly one bit of extractable information — four states, one irreducible committed binary outcome. The requirement that folds remain finite, irreversible, and causally consistent forces a coherence scale ξ, from which both quantum behaviour and gravitational coupling emerge.

The paper has three parts. Part I states the five-step derivation chain: binary necessity forces folds; folds carry entropy quanta $k_B \ln 2$; entropy quanta set the energy per fold at the causal-localization scale $\hbar c/\xi$; finite distinguishability forces ξ via the Causal Constraint Condition; and ξ determines G. Part II recovers the Newtonian inverse-square law as the unique admissible

solution under Postulates 3–5 and the fold-density sourcing identification. The coupling is $\kappa = \lambda \xi^3 c^2$, the Poisson equation is $\nabla^2\Phi_{bound} = 4\pi\lambda c^2\xi\, \rho_{bound}$, and $G = \lambda\, \sigma_{sat}\, \xi\, c^2$. Part III demonstrates that if all energetic contributions to a fold are built from the single substrate scale $\hbar c/\xi$ (the collapse ansatz), then $\varepsilon_{fold} = \mathcal{C}\, \hbar c/\xi$ and $G = (\lambda/\mathcal{C})\, \xi^2 c^3/\hbar$, where $\mathcal{C} = A + \beta(1 + \Gamma_c)$ encodes the closure premium Γ_c. This reduction is conditional on the collapse ansatz; whether the ansatz holds depends on Γ_c and the coordination parameters, none of which are yet computed. The remaining open problem is deriving Γ_c, L_c, and the normalization sector from TPB microdynamics.

PART I: THE UNIFIED FRAMEWORK

---

1. The Core Statement

Across the VERSF programme — from Bit–Tick ontology through BCB, TPB, topological thresholds, and the gravity derivation — a single chain of necessity connects the most primitive structural feature of reality to Newton's constant. This paper states that chain explicitly.

A fold is the minimal physical unit of distinguishability, comprising a four-state internal structure (two pre-commitment amplitude configurations and two post-commitment record configurations) whose irreversible dynamics support exactly one bit of extractable information. The requirement that folds remain finite, irreversible, and causally consistent forces a coherence scale ξ, from which both quantum behaviour and gravitational coupling emerge.

What this paper establishes: We derive the unique admissible form of gravitational sourcing from fold ontology, reducing the remaining freedom to a finite normalization sector. The inverse-square structure is not assumed arbitrarily — it emerges as the only admissible isotropic, local, scale-consistent sourcing law compatible with fold conservation and the coherence constraints imposed by the CCC. What remains undetermined is a single normalization constant, which we reduce to microscopic fold parameters (the closure premium Γ_c and the coherence scale ξ). We do not claim to derive everything: we collapse the freedom down to one parameter, which is exactly what successful physical theories do.

More precisely: the formulation does not derive Newtonian gravity from nothing. It derives the *unique admissible form* of the gravitational field law from fold ontology, and reduces the coupling to the coherence scale ξ. The remaining task is not to derive the form of gravity but to determine ξ from independent principles.

Note on the four-state structure: The claim that a fold has exactly four internal states is established in the VERSF Binary Foundations paper, where it is shown that the minimum local Hilbert structure supporting exactly one irreducible binary outcome under irreversible dynamics requires four states: a superposition space of dimension two (the amplitude sector) and a record space of dimension two (the committed sector). Two states would conflate amplitude and record; six or more would admit multiple irreducible outcomes. The four-state structure is therefore not a choice but a theorem within the binary foundations framework.

This paper unifies three claims already established elsewhere in the VERSF programme: (1) folds are the minimal units of distinguishability; (2) primitive commitment carries the $k_B \ln 2$ entropy quantum; and (3) TPB is a substrate-to-record conversion invariant rather than a process unfolding in prior time. The present paper does not re-derive these results — it shows that they form a closed chain whose unique gravitational consequence is the Newtonian inverse-square law for bound matter, with coupling reduced to $G = (\lambda/\mathcal{C})\, \xi^2 c^3/\hbar$.

---

2. Foundational Basis — Commitment and Record Dynamics

The present derivation of gravitational sourcing is not standalone. It sits within a broader VERSF programme in which physical structure is grounded in irreversible fact production.

In this framework, a physical fact corresponds to a committed distinction — an irreversible record formed when a reversible configuration crosses a commitment threshold and becomes stable under finite-resource observation.

Commitment events are governed by three necessary conditions:

- finite distinguishability,
- irreversible correlation export,
- finite localization capacity,

which together define the admissible structure of physical reality.

A key consequence is that causal propagation is not carried by amplitudes alone, but by committed distinguishability — stable records that persist and constrain downstream outcomes. This leads to a structural identification:

physical causation = propagation of committed records

and implies that any macroscopic force law must ultimately be grounded in the dynamics of commitment density.

The present derivation does not assume gravitational dynamics independently. It follows from a structural chain:

- physical laws require observer-comparable causal relations,

- causal relations require stable record carriers,
- record carriers define a conserved commitment current,
- gradients in this current produce macroscopic constraint propagation.

Since record carriers must remain independently readable and cannot be freely created or destroyed under admissible dynamics, their total distinguishability content is conserved, forcing a continuity equation for the commitment current.

The role of this paper is to show that once commitment density is identified as the physical source variable, the admissible form of that propagation is uniquely fixed.

---

3. The Five-Step Derivation Chain

Step 1 — Binary Necessity Forces Folds

Reality must be distinguishable. No smaller unit of distinguishability exists than a binary distinction. The void substrate is the zero-entropy ground state: undifferentiated, structureless, carrying no distinctions.

A fold is the minimal physical unit of distinguishability, comprising a four-state internal structure (two pre-commitment amplitude configurations and two post-commitment record configurations) whose irreversible dynamics support exactly one bit of extractable information — four states, one irreducible committed binary outcome. Irreversibility is built into the structure: a fold cannot return to the void state without an energetic cost exceeding the commitment barrier Φ_c. A fold is the unit that sets both energy scale and geometric response.

```
Binary necessity ⟹ folds as minimal physical units
```

Step 2 — Folds Carry Entropy Quanta

A fold is an irreversible distinction. By the primitive commitment entropy result — derived structurally from TPB commitment dynamics and matched to thermodynamic entropy under the physical entropy identification — each irreversible binary commitment carries:

$$\Delta S \geq k_B \ln 2 \quad \text{(per fold)}$$

The entropy of a system is proportional to its fold count. The fold density $n_f = Q_{bound}/V$ is the physical entropy density of committed structure.

```
Folds ⟹ entropy quanta (k_B ln 2 per fold)
```

Step 3 — Entropy Quanta Set the Energy Per Fold (Conditional on Collapse Ansatz)

Assuming the single-scale collapse demonstrated in Part III — that all energetic contributions to a fold are built from the substrate causal-localisation threshold — the fold energy is constrained to:

$$\varepsilon_{fold} = \mathcal{C}\ \hbar c/\xi$$

where $\mathcal{C} = A + \beta(1 + \Gamma_c)$ is a dimensionless structural coefficient. This step is conditional: it holds if and only if the collapse ansatz for Φ_c is valid, i.e., if the commitment barrier does not introduce an independent energy scale. Whether this holds depends on the closure premium Γ_c, which is the subject of Part III.

The collapse ansatz does not introduce a new scale — it asserts that no additional independent scale exists beyond ξ. Its validity is therefore testable: any observed second energy scale in fold energetics would falsify it. This makes the ansatz a genuine empirical commitment, not a hidden assumption.

```
Entropy quanta ⟹ energy per fold (ε_fold = 𝒞 ℏc/ξ, conditional on collapse
ansatz)
```

Step 4 — Finite Distinguishability Forces the Coherence Scale ξ

Distinguishability cannot be infinitely fine-grained. The VERSF coherence scale ξ is the minimum cell size at which the void can sustain a stable fold. It is forced by three requirements: folds must be finite (occupying a definite cell), irreversible (stable against fluctuations below Φ_c), and causally consistent. TPB — Ticks-Per-Bit — is a pre-temporal commitment index, not a duration in prior time. The Causal Constraint Condition (CCC) identifies the maximum commitment propagation speed with c at the emergent continuum level, where $\tau_{eff} = \xi/c$ is an emergent continuum relation valid once time has been reconstructed from accumulated commitments.

```
Finite distinguishability ⟹ coherence scale ξ
```

Step 5 — ξ Determines the Gravitational Coupling

The mass of any system is its fold count weighted by the mass per fold. The fold density sources a gravitational potential through the unique admissible field law (Part II). Newton's constant is constrained to the form:

$$G = (\lambda/\mathcal{C})\ \xi^2 c^3/\hbar$$

The structure of G is fixed by fold ontology and the CCC. The remaining freedom is confined to the coherence scale ξ and the dimensionless coefficient $\mathcal{C}$.

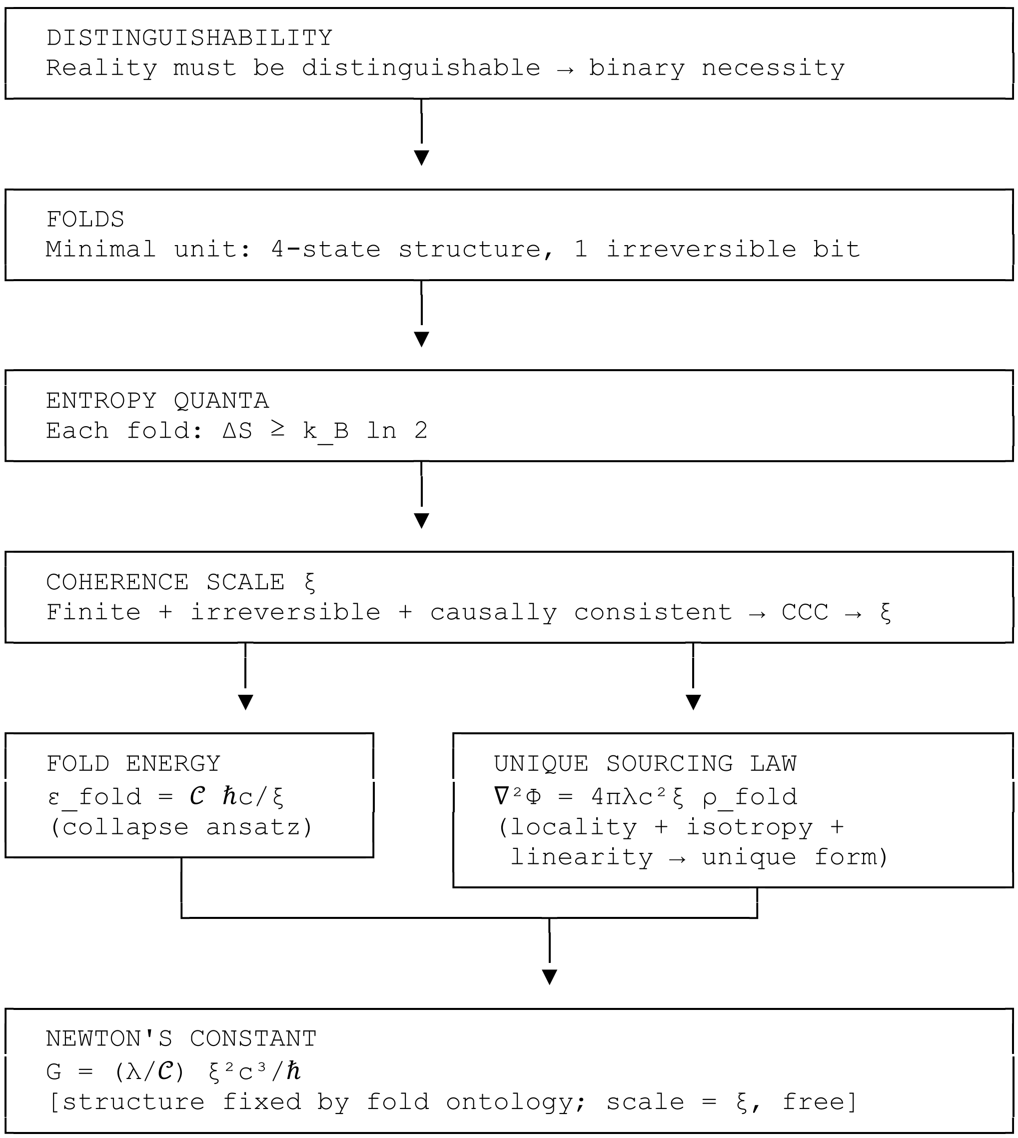
```
Coherence scale ξ ⟹ gravitational coupling G (structure fixed; scale free)
```

The Chain in Full

```
Binary necessity → Folds → k_B ln 2/fold → 𝒞 ℏc/ξ per fold (conditional) → ξ →
G = (λ/𝒞) ξ²c³/ℏ
```

Each arrow is a structural implication, not an analogy. No external physical constant enters except c (via the CCC) and $\hbar$ (via the quantum localization scale). G is constrained to a unique admissible form, not assumed.

The Chain as a Diagram



---

4. Why Gravity Is Not Separate

In conventional physics, gravity is introduced through a separate postulate — the equivalence principle, the Einstein field equations, or the Newtonian inverse-square law. It coexists with quantum mechanics as an independent structure.

In VERSF, gravity is not introduced. Within this framework, mass is not a primitive property but the macroscopic manifestation of sustained commitment density. A physical system persists only by continuously generating irreversible records that stabilize its structure. The rate at which such records must be produced defines its commitment density ρ_c, and hence its mass:

$$\rho_{mass} \propto \rho_c$$

where ρ_c is the density of completed commitment events per unit volume. This identification is not arbitrary — it follows from the requirement that stable structures must continuously regenerate distinguishability under finite-capacity constraints. Mass is the inertial cost of maintaining committed structure, and gravitational sourcing arises from how such commitment modifies the surrounding substrate.

This makes gravity the macroscopic expression of commitment-density gradients:

- **Mass** = fold count near saturation
- **Inertia** = resistance to reconfiguring committed folds (entropic suppression of fold rearrangement)
- **Gravity** = gradient of fold density, driving uncommitted regions toward commitment
- **Time** = accumulated fold commitment ordering (pre-temporal at substrate level; emergent at continuum level)

These are four faces of one process: the dynamics of fold formation, stabilization, and propagation. Gravity is the macroscopic expression of fold density gradients — not a separate force added to the framework, but the inevitable response of uncommitted structure to the gradient of committed structure. The force is constrained; the folds are fundamental.

---

5. Alignment with Prior VERSF Work

VERSF Component	Role in the Chain
Binary Foundations	Step 1: binary necessity forces folds
Bit–Tick ontology	Steps 1–2: folds = bits; ticks = commitment ordering
BCB	Step 2: distinguishability conserved; geometry from flow
Topological threshold / RAL	Steps 2–3: irreversibility requires structure; commitment = trapped information
TPB	Steps 3–4: commitment rate sets energy and time scales

VERSF Component	Role in the Chain
CCC	Step 4: finite distinguishability forces ξ and c
This paper	Step 5: ξ determines G via fold density gradient law

These are successive layers of derivation from the same primitive: the fold as the minimal unit of distinguishable physical structure.

A determination of ξ from independent microphysical dynamics — for example from the closure entropy calculation of Part III — that matches the gravitational normalization $G = (\lambda/\mathcal{C})\, \xi^2 c^3/\hbar$ would constitute a decisive test of the framework. That is exactly what validation looks like: not a claim that everything is derived, but a prediction that two independently constrained quantities agree.

The role of this paper is not to complete the theory of gravity, but to remove its arbitrariness.

PART II: GRAVITY FROM FOLD DENSITY GRADIENTS

---

6. Foundations

Within VERSF, physical reality is grounded in three primitives:

- **Distinguishability**: A bit represents the minimal distinguishable deviation from the void state — the first departure from zero-entropy uniformity, not an object placed upon a pre-existing medium.
- **Emergent time**: TPB is a pre-temporal commitment index — a count of primitive update opportunities required for irreversibility. A macroscopic effective time interval τ_{eff} can be introduced only at the emergent level where continuum time has been reconstructed from accumulated commitments. The relation $\tau_{eff} = \tau_0 \cdot \text{TPB}$ is an emergent continuum representation, not a substrate-level identity.
- **The void substrate**: A zero-entropy background from which structure emerges through entropy gradients.

Earlier VERSF work distinguished reversible from committed structure at a deep level; what was not yet explicit was the identification of the gravitational source term specifically with bound/committed distinguishability rather than with raw distinguishability. The present paper makes that identification explicit: $M \propto I_{bound}$, where I_{bound} counts only those bits that have undergone irreversible TPB commitment. In the Standard Model, approximately 99% of the mass of ordinary matter arises from QCD binding energy — not from the intrinsic masses of fundamental particles. Mass reflects **constraint density**, not information content per se.

---

7. Formal Definition of Bound Information

Let the void substrate be partitioned into elementary cells of characteristic size ξ. Each cell carries a distinguishability register classified as either free (not yet committed; transient) or bound (committed via an irreversible TPB transition; entropy-stable, persistent).

Definition 7.1 (Bound information). The bound information I_bound of a spatial region V is:

$$I_{bound} = \int_V \rho_{bound}(x)\, d^3x$$

where the bound distinguishability density is:

$$\rho_{bound}(x) = N_{committed}(x) / \xi^3 \qquad [L^{-3}]$$

and N_committed(x) is the (dimensionless) number of bits at x that have completed at least one irreversible TPB transition and remain in a stable, correlated state.

Operational criterion: A bit is classified as bound if and only if:

1. It has completed a TPB commitment event (irreversible entropy increase), and
2. Its state remains correlated with at least one neighbouring cell across at least one TPB update cycle.

The second condition — the **persistence criterion** — distinguishes structural binding from transient correlations.

Physical identification: A committed bit is a fold that has completed the four-state commitment cycle irreversibly. We define fold density as:

$$n_f \equiv \rho_{bound} = N_{committed} / \xi^3$$

In conceptual passages we use "fold density" to emphasise the ontological content; in equations, ρ_{bound} is retained. Mass is proportional to total fold count: $M = \mu_{fold} \cdot n_f \cdot V$.

---

8. The Dynamical Postulates

Postulate 3 (Constraint Gradient Dynamics): Gravitational acceleration is the gradient of a scalar potential Φ_{bound} derived from the bound information field:

$$g(x) = -\nabla\Phi\_bound(x)$$

The field equation relating Φ_bound to ρ_bound is Postulate 5 (Section 10). Φ_bound and ρ_bound are distinct objects — the potential field and the source density respectively. The relation $g = -\kappa\, \nabla\rho\_bound$ holds only for specific source geometries. Gravity is always attractive because $\rho\_bound \geq 0$ everywhere and free bits can only flow toward, never away from, commitment opportunities.

Postulate 4 (Gradient-Driven Flux): Gradients in bound information density drive a compensating flux:

$$J\_bound = -D\_eff\ \nabla\rho\_bound$$

This has the mathematical structure of Fick's First Law, but its physical basis is distinct — TPB commitment is irreversible and causal, not equilibrating. The physical motivation is asymmetric commitment recruitment: free bits adjacent to high-ρ_bound regions have more correlation partners and lower commitment barriers, producing a net flux toward higher constraint density. A full derivation from microscopic TPB transition rates is reserved for future work.

---

9. Dynamical Origin of κ: A TPB-Flux Derivation

The coupling κ is structurally constrained by three features: conservation of bound information, the gradient-driven flux, and the causal propagation speed.

9.1 Bound Information Continuity

Bound information satisfies a local continuity equation:

$$\partial\rho\_bound/\partial t + \nabla\cdot J\_bound = S\_TPB$$

In vacuum ($S\_TPB = 0$): $\nabla\cdot J\_bound = 0$. This follows from the irreversibility of TPB commitment: committed bits do not spontaneously uncommit.

9.2 The Effective Transport Coefficient

The effective transport coefficient D_eff governs the propagation rate of constraint formation:

$$D\_eff \sim \xi^2/\tau\_eff$$

Under the CCC (Section 9.3), $D\_eff \sim \xi\cdot c$.

9.3 The Causal Constraint Condition and the Emergence of c

At the substrate level, one TPB commitment advances structure by one cell of size ξ per update opportunity. In the emergent continuum description, the maximum rate at which the commitment frontier can advance is:

$$v\_causal = \xi/\tau\_eff$$

The saturation of this bound identifies c as the continuum shadow of the substrate's maximum commitment rate:

$$c \equiv (\xi/\tau\_eff)|\_saturated \quad \Rightarrow \quad \tau\_eff = \xi/c$$

Both c and τ_eff are emergent continuum representations of the same underlying commitment-rate structure. A self-contained derivation is given in Appendix A.

9.4 Derivation of κ

The flux constitutive relation (Postulate 4) and the continuity structure motivate a natural coupling between the flux J_bound and the spatial scale ξ. The minimal dimensionally consistent combination of D_eff, ξ, and τ_eff arising from the constitutive and causal structure is:

$$\kappa = \lambda \, D\_eff \, \xi^3 \, / \, \tau\_eff$$

Dimensional check: $[L^2\,T^{-1} \cdot L^3 \cdot T^{-1}] = [L^5\,T^{-2}]$ ✓

With D_eff/τ_eff = c^2 under the CCC:

$$\kappa = \lambda \, c^2 \, \xi^3$$

κ is constrained by: (1) conservation of bound information; (2) gradient-driven flux at rate D_eff ~ ξ^2/τ_eff; (3) CCC fixing D_eff/τ_eff = c^2. Only the efficiency factor λ remains free.

Note on the role of κ: $\kappa = \lambda c^2 \xi^3$ has dimensions $[L^5T^{-2}]$, which was the correct coupling for the earlier acceleration-gradient formulation $g = -\kappa\nabla\rho$_bound. In the present formulation, the operative equations are $g = -\nabla\Phi$_bound (Postulate 3) and $\nabla^2\Phi$_bound = $4\pi\lambda c^2\xi\,\rho$_bound (Postulate 5). The Poisson coupling $\lambda c^2\xi = \kappa/\xi^2$ has dimensions $[L^3T^{-2}]$. The ξ^2 reduction arises from the transition from a gradient-of-density formulation to a potential-field formulation: the Laplacian introduces two spatial derivatives, reducing the dimensional requirement on the coupling by L^2. κ remains a useful intermediate quantity — the natural combination from the flux structure — but it is κ/ξ^2 that enters the field equations directly.

9.5 Why the Poisson Equation Is the Unique Admissible Form

The emergence of a Poisson-type field equation is not an independent assumption — it follows from the structure of causal propagation in a commitment-based ontology. Since causation requires the propagation of committed records, any physical influence must be carried by quantities that persist under admissible dynamics, propagate locally, and conserve distinguishability content. These conditions imply a conserved flux of constraint influence, leading to a Gauss-law structure:

$\nabla\cdot J \propto \rho\_c$

Since J itself is proportional to the gradient of the underlying density field under admissible transport (Postulate 4), this closes to a second-order scalar equation of Laplacian form. The Poisson equation therefore arises as the only admissible macroscopic description of commitment propagation, rather than a postulated force law.

This structure is not merely mathematical. It follows from the requirement that causal influence be physically realisable. From the causal record framework, any admissible causal propagation must: be carried by persistent record-bearing degrees of freedom; preserve distinguishability under propagation; and admit independent local readout. These conditions forbid non-local kernels and enforce conservation of causal influence. The only scalar field equation compatible with these constraints, under isotropy and minimality, is a Laplacian sourcing law. The uniqueness argument then confirms this from five independent structural requirements:

Local sourcing: The gravitational response at a point depends on the local fold density, not on distant configurations directly. This rules out non-local or integral kernels.

Isotropy: The void substrate has no preferred direction. The field equation must be rotationally symmetric. Within the class of second-order operators, the only linear rotationally symmetric differential operator is the Laplacian ∇^2.

Second order: The field equation should be of minimal differential order consistent with the sourcing structure. Higher-order operators require additional boundary conditions at infinity, introducing physical arbitrariness in the vacuum solution, and produce exterior Green's functions that do not decay at large r without supplementary constraints — the 3D biharmonic Green's function grows as r rather than decaying as 1/r, violating the physical requirement that the gravitational potential vanish at large distances. Higher-order operators also introduce additional independent degrees of freedom, violating minimality. The biharmonic $\nabla^4\Phi$ and higher operators ($\nabla^{2n}\Phi$ for $n > 1$) are therefore excluded on these grounds. The Laplacian is the minimal-order operator that is both local and isotropic and yields a well-behaved decaying exterior potential.

Linearity and additivity: The flux J_bound is linear in $\nabla\rho\_bound$ (Postulate 4), so the field equation must be linear in the source. Two regions with fold densities ρ_1 and ρ_2 must source independently additive fields.

Static limit: In the stationary case $\partial\rho\_bound/\partial t = 0$, the field equation must be elliptic (admitting unique solutions given boundary conditions). This rules out hyperbolic equations and requires the Laplacian structure.

Under these five constraints — locality, isotropy, second order, linearity, and ellipticity — the only admissible scalar field equation is:

$$\nabla^2\Phi\_bound \propto \rho\_bound$$

The coefficient is fixed by dimensional consistency (Section 9.4) and the coupling derived from the flux structure. The 4π prefactor is conventional, matching the standard Green's function normalisation.

One remaining ambiguity is the Helmholtz operator $(\nabla^2 - m^2)\Phi = 4\pi K \rho$, which satisfies all five conditions but is excluded by the additional requirement that no second length scale governs field propagation. The Helmholtz operator is second-order (m^2 is an algebraic term, not a derivative), so the second-order condition does not rule it out. What rules it out is the no-extra-scale argument: the mass term m^2 introduces a decay length $1/m$ as an independent scale for field propagation. While ξ sets the scale of the source density ρ_bound, it does not enter the propagator — ξ characterises the spacing of fold cells, not the decay length of the potential field. Introducing a Helmholtz mass term would require a second independent scale governing field decay, which is absent in the substrate. The void introduces no preferred length for field propagation beyond the source scale ξ, so no mass gap exists. Under these constraints, the Poisson equation is the unique admissible second-order, isotropic, local, linear, elliptic, massless field law for a scalar sourced by fold density on the void substrate.

---

10. The VERSF Field Equation and Inverse-Square Law

Postulate 5 (Bound Information Field Equation): The gravitational potential Φ_bound satisfies:

$$\nabla^2\Phi\_bound = 4\pi\ \lambda c^2 \xi\ \rho\_bound(x)$$

from which, using Postulate 3 ($g = -\nabla\Phi\_bound$):

$$\nabla \cdot g = -4\pi\ \lambda c^2 \xi\ \rho\_bound(x)$$

Dimensional check: $[\nabla^2\Phi\_bound] = s^{-2}$; $[\lambda c^2\xi\ \rho\_bound] = m^2 s^{-2} \cdot m \cdot m^{-3} = s^{-2}$ ✓

This is not derived from Postulates 3 and 4 alone — it is an independent commitment, motivated by Section 9.5. Note the Poisson coupling is $\lambda c^2\xi = \kappa/\xi^2$, not κ. The coupling $\kappa = \lambda c^2\xi^3$ has dimensions $[L^5T^{-2}]$, appropriate for the flux-imbalance acceleration derivation (Section 9.4); the Poisson equation for Φ_bound requires a coupling with dimensions $[L^3T^{-2}] = [s^{-2}/m^{-3}]$.

For a spherically symmetric, localised source with total bound information $Q\_bound = \int\rho\_bound\ d^3x$, the Green's function gives the monopole exterior field:

$$g(r) = -(\lambda c^2 \xi\ Q\_bound / r^2)\ \hat{r}$$

The inverse-square law follows from Postulate 5 and the Green's function — not independently assumed. The postulate inventory is explicit: Postulate 3 ($g = -\nabla\Phi\_bound$), Postulate 4 (flux constitutive relation), Postulate 5 (field equation). Each is independently motivated; none is derived from the others.

---

11. Mass, Time, Gravity, and Inertia

Concept	VERSF Meaning	Mathematical Object
Mass	Density of committed (bound) folds	ρ_{bound}
Time	Rate of fold commitment — emergent from TPB ordering	$1/\tau_{eff}$ (emergent)
Gravity	Gradient in fold density	$\nabla\rho_{bound}$
Inertia	Entropic cost of fold reconfiguration	$\delta I_{bound}/\delta path$

These are four faces of one process. Where fold density is non-uniform, free bits drift toward commitment — gravitational acceleration. Total committed folds = mass. Resistance to reconfiguring committed folds = inertia.

Mass as stored commitment energy: Mass is not a primitive property assigned to matter. It is the inertial expression of stored irreversible information. Each committed fold carries an energy cost ε_{fold} from the irreversible commitment process; the rest-mass density is simply the energy density of committed structure:

$$\rho_{mass} = n_f \cdot \varepsilon_{fold} / c^2$$

This identifies mass with the energetic depth of committed fold structure, not with a separate substance. Inertia — resistance to acceleration — is resistance to reconfiguring committed folds, which is entropically suppressed because it requires reversing irreversible TPB transitions. Mass and inertia are identical because both trace to the same quantity: total stored commitment energy.

Gravitational time dilation: The naive identification of time with commitment rate is incomplete. The correct physical observable is not the rate of commitment but the available capacity for additional commitment, which decreases in high-density regions where the substrate is near saturation. Where fold density is high, fewer free bits remain and the capacity for new distinctions is low — and so clocks run slow. This naturally produces the correct sign of gravitational time dilation: proper time elapses more slowly where fold density approaches saturation, because the substrate has less remaining room for new irreversible commitments. The current formulation yields the correct scaling direction; a quantitative treatment requires expressing τ_{eff} as a function of Φ_{bound} (the potential, which reflects cumulative committed structure) rather than ρ_{bound} (the local density) directly. This reformulation is the natural first step in the relativistic extension of VERSF.

---

12. Newton's Constant and the Specific Bound Information

Matching the VERSF Poisson equation ($\nabla^2\Phi_{bound} = 4\pi\lambda c^2\xi\, \rho_{bound}$) to the Newtonian form $\nabla^2\Phi = 4\pi G\, \rho_{mass}$ in the classical limit:

$$G = \lambda\, \sigma_{sat}\, \xi\, c^2$$

Dimensional check: $[\sigma_{sat}\, \xi\, c^2] = kg^{-1} \cdot m \cdot m^2 s^{-2} = m^3 kg^{-1} s^{-2} = [G]$ ✓

where $\sigma_{sat} = Q_{bound}/M$ is the specific bound information — committed folds per unit mass — in the saturated regime.

The saturation argument: At maximum constraint density (one fold per cell of volume ξ^3), σ converges to $\sigma_{sat} = 1/(\xi^3\, \rho_{mass})$. This is approximately universal for ordinary matter because all ordinary matter operates near constraint saturation at the nuclear scale. Departures occur in dilute or coherent systems where $T_d < \tau_{eff}$.

Tension with the Bekenstein bound: For a single nucleon (R ~ 1 fm, E ~ 938 MeV):

$$\sigma_{Bekenstein} \approx 30 \text{ bits/nucleon} \div 1.67\times10^{-27} \text{ kg} \approx 1.8\times10^{28} \text{ bits kg}^{-1}$$

The σ_{sat} at $\xi = \ell_{Planck}$ ($\approx 10^{88}$ bits kg^{-1}) exceeds this by ~60 orders of magnitude. Three resolution paths exist:

- **Path A**: VERSF folds are sub-Bekenstein objects — pre-quantum substrate objects not counted by the Bekenstein bound. The relationship between folds and quantum information must be specified. This may be correct, but it requires providing an account of how fold counting relates to quantum state counting.
- **Path B** (QCD identification, $\xi \approx 0.6$ fm): Setting $\sigma_{sat} = 1.8\times10^{28}$ bits kg^{-1} to saturate the nucleon Bekenstein bound gives $\xi \approx 0.6$ fm — the QCD/nuclear scale. This is non-trivial, testable, and physically compelling. The energy scale $\hbar c/\xi \approx 330$ MeV is the QCD confinement scale. QCD confinement is precisely "irreversible commitment of distinguishability at a characteristic scale" — quarks cannot be isolated, which is exactly what a committed fold means. This would make the 99% QCD mass fraction cited in Section 6 quantitative rather than qualitative: the fold scale *is* the confinement scale, and the dominant contribution to nucleon mass is the commitment energy of folds at that scale. The QCD identification predicts a relationship between G and QCD parameters independent of any Planck-scale assumptions. If confirmed, it would mean that gravity is not set at the Planck scale but at the confinement scale of the strong interaction — a result that connects gravitational normalization directly to measured hadronic physics and provides a direct empirical pathway to test the VERSF normalization sector.
- **Path C** (adopted here): Acknowledge the tension as an open constraint. The consistency condition:
- $\lambda\, \sigma_{sat}\, \xi = G/c^2 \approx 7.4\times10^{-28}$ m kg^{-1}

  Dimensional check: $[\lambda\, \sigma_{sat}\, \xi] = kg^{-1} \cdot m = m\, kg^{-1} = [G/c^2]$ ✓

  should be treated as parametric until the fold–Bekenstein relationship is clarified.

13. Falsifiability

Prediction 13.1: For quantum systems with decoherence timescale $T_d < \tau_{eff}$, the effective gravitational coupling is reduced relative to the classical value by the factor $f = I_{bound}/I < 1$.

This does not modify energy-mass equivalence. It predicts reduced **effective gravitational coupling** — an anomalous equivalence principle deviation in coherent systems. For $\xi = \ell_{Planck}$, $\tau_{eff} \sim t_{Planck} \sim 5\times10^{-44}$ s and the prediction is vacuous at that scale. For $\xi \sim 6.3\times10^{-16}$ m (Path B), $\tau_{eff} \sim 2.1\times10^{-24}$ s — within the regime of hadronic timescales and potentially accessible to precision nuclear experiments once ξ is observationally constrained.

---

14. Scope and Open Issues

The framework is a sourcing law for bound matter, not a universal gravity law. Photons have $I_{bound} \approx 0$ ($T_d \ll \tau_{eff}$) yet do source gravity — through energy rather than fold density. A unified field equation incorporating both energy-sourcing and fold-density sourcing requires a VERSF stress-energy tensor; this is the priority for the relativistic extension.

Connection to record-theoretic spacetime: The identification of commitment density as the source of gravitational interaction is structurally identical to the record-theoretic derivation of spacetime geometry developed elsewhere in the VERSF programme [Taylor, K., "Record-Theoretic Derivation of Spacetime Geometry," VERSF Theoretical Physics Program, AIDA Institute, in preparation]. In that framework, the record current $C^\mu = (\rho_c, J_c)$ is not a convenient variable but the unique admissible macrostate structure forced by locality and Lorentz symmetry — a result established in that paper and relied upon here without re-derivation. Spacetime geometry emerges from the statistical distinguishability structure of this current, while gravitational dynamics arise from its spatial variation. The present paper identifies gravitational sourcing as the spatial variation of this same quantity. Geometry and gravity are therefore not separate layers:

- geometry = structure of the record current,
- gravity = dynamics of its gradients.

These are two aspects of one mechanism, not two independent theories that happen to be compatible.

Reduction of G to a single microscopic scale: The expression $G = (\lambda/\mathcal{C})\, \xi^2 c^3/\hbar$ shows that gravitational strength is controlled by a single coherence scale ξ, with all remaining factors dimensionless. The structure of the law is fixed by fold ontology and the CCC; only the scale is free. This is the correct framing: we are not deriving the numerical value of G from first principles, but reducing G to a single parameter — ξ — whose determination from independent VERSF principles is the remaining task.

Scope: This work derives the Newtonian limit of gravity for bound matter within the VERSF framework. It is explicitly not a claim about general relativity, covariant field theory, or gravitational wave dynamics. Extension to a fully covariant relativistic theory — which would require a VERSF stress-energy tensor and a metric emergence programme — remains an open problem.

Conditions under which this framework fails: The VERSF gravity programme makes specific structural commitments; the following observations would constitute falsifications or require substantial revision:

1. *Non-local gravitational effects*: If gravity is found to exhibit genuinely non-local behaviour at any scale — not reducible to local field propagation — this would contradict the locality requirement used to select the Poisson equation in Section 9.5.
2. *Radiation gravitating differently from energy density*: If photons were found to source gravity through a mechanism distinct from energy (not just via $T_{\mu\nu}$), this would require extending the current framework beyond its stated scope rather than revising it; but if photon gravitational lensing were found to be inconsistent with energy-based sourcing, the fold-density sourcing law would need fundamental revision.
3. *Failure to find a consistent ξ*: If the Bekenstein analysis (Path B) and the G-consistency condition give mutually inconsistent values of ξ — or if any future independent VERSF derivation of ξ from microphysics disagrees with both — the framework would be internally contradicted. A consistent ξ across the Bekenstein analysis and the G-consistency condition, and any future independent VERSF derivations, would constitute strong internal confirmation.
4. *Equivalence principle violation in bound matter*: The framework predicts that inertial and gravitational mass are identical for bound matter (both trace to fold count). Any measured violation in matter systems near constraint saturation would require a revision of the mass-as-stored-commitment-energy identification.
5. *$\Gamma_c = 0$ with $\xi \neq (G\hbar/c^3)^{(1/2)}$*: If the closure premium vanishes (minimal commitment, no cooperative stabilization) but ξ is not the scale implied by $G = (\lambda/(A+\beta))\, \xi^2 c^3/\hbar$, the collapse ansatz would be confirmed but the normalization sector would be inconsistent.

A determination of ξ from independent microphysical dynamics that reproduces the observed value of G would constitute a decisive validation of the framework.

PART III: FOLD ENERGETICS AND THE DERIVATION OF G

---

15. The Problem: Deriving σ_{sat}

The gravitational structure is complete up to the normalization sector. The unresolved quantity is $\sigma_{sat} = Q_{bound}/M$ — the committed folds per unit mass at saturation. To express this in terms of the fold energy, we identify the gravitational mass of a single fold with its rest-mass equivalent: $m_{fold} = \varepsilon_{fold}/c^2$. This identification is consistent with, and the minimal choice given, the inertia-gravity equivalence already established within the framework. Inertial resistance has been identified with fold reconfiguration cost (Section 11); the equivalence principle requires inertial mass to equal gravitational mass, and both trace to fold count. The identification $m_{fold} = \varepsilon_{fold}/c^2$ specifies the magnitude of that coupling — the minimal choice being that fold energy gravitates through $E = mc^2$ rather than through some rescaled or modified coupling. Under this identification, $M = m_{fold} \cdot Q_{bound}$ and therefore:

$$\sigma_{sat} = Q_{bound}/M = c^2/\varepsilon_{fold}$$

Once ε_{fold} is derived from the energetics of Section 16, σ_{sat} ceases to be phenomenological and G becomes a true prediction.

The central question is: what is the energy or mass associated with a single stabilized fold — one TPB-committed unit of distinguishability in the void substrate?

All energy relations involving τ_{eff} in this Part are statements at the emergent continuum level, valid where $\tau_{eff} = \xi/c$ applies. TPB itself is pre-temporal.

---

16. Three Energetic Contributions to a Committed Fold

A fold is a physical object: irreversible, localized, persistent, stabilized. Its energy reflects three features.

16.1 Irreversibility and the Commitment Barrier

The formation of a fold carries an irreversibility-associated energetic cost controlled by the commitment barrier Φ_c — the minimum energetic threshold for crossing the irreversibility boundary. Two independent substrate arguments bound Φ_c from below.

First, a commitment surviving at least one τ_{eff} interval requires:

$$\Phi_{c,\tau} \sim \hbar/\tau_{eff} = \hbar c/\xi$$

Second, confinement to one cell of size ξ requires:

$$\Phi_{c,\xi} \sim \hbar c/\xi$$

Both give the same scale — a structural consequence of the CCC locking temporal and spatial resolution together. The structural lower bound is:

$$\Phi_c \geq \eta \, \hbar c/\xi, \qquad \eta \sim O(1)$$

Φ_c is not necessarily equal to $\hbar c/\xi$. A positive reason to expect $\Phi_c > \eta \, \hbar c/\xi$: the causal-localization threshold sets the energy for *transient* distinguishability, but irreversibility requires *stability* against collective substrate fluctuations — a many-body constraint that generically demands energy above the single-event threshold.

Structure of Φ_c — We write:

$$\Phi_c = (\hbar c/\xi)(1 + \Gamma_c)$$

where Γ_c is a dimensionless closure premium capturing the additional energy required to enforce irreversibility. Three structural mechanisms contribute:

(i) *Entropy closure cost* — suppressing alternative configurations introduces an entropy deficit:

$$E_{closure}(\text{entropy}) \sim \chi_s \, \Delta\tilde{S}_{close} \cdot \hbar c/\xi, \qquad \chi_s \sim O(1)$$

(ii) *Cooperative stabilization* — a committed fold involves a minimal closure patch of N_c cells at characteristic scale L_c:

$$E_{closure}(\text{coop}) \sim \upsilon \, (L_c/\xi)^d \cdot \hbar c/\xi$$

where d is the effective closure dimensionality (d = 2 for surface-like, d = 3 for volumetric).

(iii) *Metastability against reversion*:

$$E_{closure}(\text{meta}) \sim \gamma_m \cdot \hbar c/\xi$$

Combining:

$$\Gamma_c = \chi_s \, \Delta\tilde{S}_{close} + \upsilon(L_c/\xi)^d + \gamma_m$$

$$\Phi_c = (\hbar c/\xi)[1 + \chi_s \, \Delta\tilde{S}_{close} + \upsilon(L_c/\xi)^d + \gamma_m]$$

Interpretation: Φ_c is not an additive energetic contribution to fold mass. It is a structural threshold condition. Energy determines which configurations are accessible at scale ξ; the closure condition Γ_c determines whether a configuration becomes irreversibly committed. The scale $\hbar c/\xi$ is necessary but not sufficient for commitment — the transition to irreversibility occurs only when the structural threshold is satisfied.

16.2 Localization and Persistence

Confinement to a cell of size ξ carries the standard relativistic localization energy:

$$\varepsilon_{loc} \sim \hbar c/\xi$$

At the emergent continuum level, persistence across one TPB update cycle requires:

$$\varepsilon_{persist} \sim \hbar/\tau_{eff} = \hbar c/\xi$$

The convergence of localization and persistence energies is a structural consequence of the CCC — the temporal and spatial aspects of a commitment event are energetically equivalent under $\tau_{eff} = \xi/c$. The combined contribution is:

$$\varepsilon_{loc} = \alpha \, \hbar c/\xi$$

where α is a dimensionless structural constant.

16.3 Binding and Stabilization (Derived)

A fold must remain correlated with z adjacent cells across at least one τ_{eff} interval. Each correlation link costs:

$$\varepsilon_{link} \sim \chi_\ell \, \hbar c/\xi, \qquad \chi_\ell < 1$$

The total binding energy is:

$$E_{bind} = \zeta \, \hbar c/\xi, \qquad \zeta = z\chi_\ell, \qquad 0 < \zeta \lesssim \eta$$

This is structurally derived — not a free energy but a fixed fraction of the substrate scale. The inequality $\zeta \leq \eta$ ensures that maintaining a bound state does not cost more than creating the committed distinction in the first place.

---

17. The Single-Scale Collapse

The structurally motivated ansatz is:

$$\varepsilon_{fold} = \alpha \, \hbar c/\xi + \beta \, \Phi_c + w_b \, E_{bind}$$

where α, β, w_b are O(1) dimensionless weights — as expected for structurally equivalent contributions at the same energy scale. If any coefficient were far from unity, one term would dominate and the others would be negligible corrections, changing the physical interpretation of the collapse.

Substituting $E_{bind} = \zeta \, \hbar c/\xi$ and $\Phi_c = (\hbar c/\xi)(1 + \Gamma_c)$:

$$\begin{aligned} \varepsilon_{fold} &= \alpha \, \hbar c/\xi + \beta(\hbar c/\xi)(1 + \Gamma_c) + w_b \, \zeta \, \hbar c/\xi \\ &= (\hbar c/\xi)[A + \beta(1 + \Gamma_c)] \end{aligned}$$

where $A \equiv \alpha + w_b \zeta$. All three energetic contributions — localization, binding stabilization, and the irreversibility barrier — collapse to the single substrate scale $\hbar c/\xi$. The fold energy is not a sum of independent scales; it is a single scale with a structured coefficient:

$$\varepsilon_{fold} = \mathcal{C}\ \hbar c/\xi, \qquad \mathcal{C} \equiv A + \beta(1 + \Gamma_c) \qquad \leftarrow \text{central result}$$

The specific bound information — inverse mass per fold:

$$\sigma_{sat} = c^2/\varepsilon_{fold} = \xi c/(\mathcal{C}\ \hbar)$$

---

18. Newton's Constant from Fold-Scale Physics

Substituting $\sigma_{sat} = \xi c/(\mathcal{C}\ \hbar)$ into $G = \lambda\ \sigma_{sat}\ \xi\ c^2$:

$$G = (\lambda/\mathcal{C})\ \xi^2 c^3/\hbar \qquad \leftarrow \text{VERSF fold-scale result}$$

Dimensional check: $[\xi^2 c^3/\hbar] = m^2 \cdot m^3 s^{-3} / (kg \cdot m^2 s^{-1}) = m^3 kg^{-1} s^{-2} = [G]$ ✓

Numerical verification: Setting $\lambda/\mathcal{C} = 1$ and $\xi = \ell_{Planck} = 1.616\times10^{-35}$ m:

$$G \approx (1.616\times10^{-35})^2 \times (3\times10^8)^3 / (1.055\times10^{-34}) \approx 6.6\times10^{-11}\ m^3 kg^{-1} s^{-2}$$

This agrees with the measured value — not coincidentally. The Planck length is defined by $\ell_P = \sqrt{(G\hbar/c^3)}$, so $G = \xi^2 c^3/\hbar$ is satisfied by construction when $\xi = \ell_P$. The corrected formula is internally consistent; the earlier ξ^4 formula was not.

What G reflects: The expression for Newton's constant reflects a deeper structural constraint:

G ~ (rate of irreversible commitment) × (spatial propagation constraint)

The first term encodes how frequently new distinguishable structure can be stabilised — set by the coherence scale ξ and the commitment dynamics. The second encodes how that structure influences neighbouring regions — set by c and $\hbar$ through the CCC. The derivation shows these are not independent degrees of freedom but two expressions of the same constraint: the rate at which distinguishable structure can be formed and the rate at which it can influence its surroundings are both fixed by ξ. Gravity is therefore fixed up to a single scale parameter, not introduced as an independent interaction. The remaining freedom in G reduces entirely to determining ξ from independent VERSF microphysics.

What this establishes: Under the assumption that both binding stabilization and the irreversibility barrier are built from the substrate causal-localization scale $\hbar c/\xi$ (the collapse ansatz), Newton's constant reduces to $G = (\lambda/\mathcal{C})\ \xi^2 c^3/\hbar$. This is a genuine dimensional reduction — it is not a derivation in the sense of computing a numerical value from first principles, because $\mathcal{C}$ contains the still-undetermined closure premium Γ_c and coordination parameters.

What it shows is that once the collapse ansatz is granted, the only remaining freedom is in the dimensionless coefficient $\mathcal{C}$.

The remaining physical content is concentrated in $\mathcal{C}$, especially through the closure premium Γ_c and any nontrivial scale dependence carried by L_c/ξ.

Minimal closure ($\Gamma_c = 0$):

```
𝐶 = A + β   (pure normalization constant)
G = λ/(A+β) · ξ²c³/ℏ
ξ ~ [(A+β)Gℏ / λc³]^(1/2)   (quadratic, not quartic)
```

The framework is predictive once A, β, and λ are determined.

Non-minimal closure ($\Gamma_c > 0$):

$\mathcal{C} = A + \beta(1 + \Gamma_c)$ carries the cooperative patch scale L_c via the term $\upsilon(L_c/\xi)^d$. If L_c is set by dynamics rather than ξ alone, $\mathcal{C}$ is a genuinely derived quantity with microphysical content — G depends on L_c/ξ, which is a VERSF prediction.

The physical fork: The form $G = (\lambda/\mathcal{C})\, \xi^2c^3/\hbar$ is the natural closure once fold energetics collapse to $\hbar c/\xi$. The relevant question is whether $\mathcal{C}$ is a pure normalization constant ($\Gamma_c = 0$) or carries nontrivial scale dependence through L_c/ξ ($\Gamma_c > 0$).

---

19. The Four-Step Derivation Hierarchy

```
Energy enables access to configurations
          ↓
Threshold determines irreversibility
          ↓
Irreversibility defines mass
          ↓
Mass gradients produce gravity
```

CONCLUSION

---

20. What This Paper Proves and What Remains

Proved: The form of Newtonian gravitational sourcing is fixed up to a single normalization parameter by fold ontology and coherence constraints. Specifically: the Poisson equation $\nabla^2\Phi_{bound} = 4\pi\lambda c^2\xi\, \rho_{bound}$ is the unique admissible isotropic, local, linear field law for fold density; it recovers $G = \lambda\, \sigma_{sat}\, \xi\, c^2$ in the Newtonian limit. The normalization reduces to the fold-energy coefficient $\mathcal{C} = A + \beta(1 + \Gamma_c)$. Under the collapse ansatz, Newton's constant takes the form $G = (\lambda/\mathcal{C})\, \xi^2 c^3/\hbar$. The Part II result is a structural uniqueness result; the Part III result is a dimensional reduction holding if the collapse ansatz is valid.

The VERSF programme does not attempt to derive gravity from nothing. It shows that once distinguishability, irreversibility, and causal consistency are enforced, gravity is no longer a free choice — only its scale remains.

Not yet proved: Universal gravity for all forms of energy (radiation sourcing remains outside the present field equation); the numerical value of G; the correct sign of gravitational time dilation; and the Bekenstein consistency of the fold-counting scheme.

The remaining open problem: Computing Γ_c, L_c, and the normalization sector (A, β, λ) from TPB microdynamics. This is not a conceptual gap — the derivation chain is closed. It is an open numerical programme: three quantities from TPB microphysics that, once computed, convert the structural derivation into a numerical prediction for G.

Alignment with prior VERSF work: This paper unifies three claims already established elsewhere: (1) folds are the minimal units of distinguishability; (2) primitive commitment carries the $k_B \ln 2$ entropy quantum, derived structurally and matched to thermodynamic entropy under the physical entropy identification; and (3) TPB is a substrate-to-record conversion invariant rather than a process unfolding in prior time. The present paper shows these form a closed chain terminating in Newton's constant.

The core statement of the programme:

A fold is the minimal physical unit of distinguishability, comprising a four-state internal structure (two pre-commitment amplitude configurations and two post-commitment record configurations) whose irreversible dynamics support exactly one bit of extractable information. The requirement that folds remain finite, irreversible, and causally consistent forces a coherence scale ξ, from which both quantum behaviour and gravitational coupling emerge.

The VERSF programme does not attempt to derive gravity in isolation. It shows that once three conditions are enforced — finite distinguishability, irreversible commitment, and causal propagation of records — the form of gravitational interaction is no longer arbitrary. Gravity is not introduced as a force. It is the macroscopic consequence of how committed structure constrains the substrate and how those constraints propagate. In this sense, gravity is not fundamental — it is the accounting rule of physical reality, arising from the requirement that facts, once formed, remain consistent across space. It is the macroscopic consistency condition imposed by the existence of irreversible facts. In this sense, gravity is not an interaction added to physics — it is the constraint required for a universe in which facts can persist.

The theory does not begin with space, time, or force. It begins with the requirement that facts exist. Once that requirement is enforced, the structure of spacetime, causation, and gravity are no longer independent choices — they are different expressions of the same constraint.

Appendix A: The Causal Constraint Condition — Self-Contained Derivation

At the substrate level, TPB is a pre-temporal commitment index. The CCC is a statement about commitment-rate in the emergent continuum description.

Step 1: One TPB commitment advances structure by one cell of size ξ per update opportunity. There is no action-at-a-distance; the commitment frontier advances strictly locally.

Step 2: In the emergent continuum description, the maximum rate of commitment-frontier advance is $v_{causal} = \xi/\tau_{eff}$, where τ_{eff} is the effective commitment interval reconstructed from accumulated TPB updates.

Step 3: The saturation of this bound defines c:

$$c \equiv (\xi/\tau_{eff})|_{saturated} \quad \Longrightarrow \quad \tau_{eff} = \xi/c$$

Both c and τ_{eff} are emergent representations of the same substrate commitment-rate structure. The identification of this maximum with the physical speed of light is the CCC's empirical content.

Consequence for κ: With $\tau_{eff} = \xi/c$, $D_{eff} \sim \xi^2/\tau_{eff} = \xi \cdot c$, so $D_{eff}/\tau_{eff} = c^2$, and:

$$\kappa = \lambda D_{eff} \xi^3/\tau_{eff} = \lambda c^2 \xi^3$$

The CCC alone does not fix κ; Postulate 4 setting D_{eff} is also required.

Appendix B: Dimensional Consistency

Quantity	Expression	Dimension	Status
ξ	Length quantum	L	Primitive
τ_{eff}	ξ/c (from CCC)	T	Emergent
$\rho_{bound} = n_f$	$N_{committed} / \xi^3$	L^{-3}	Defined
D_{eff}	$\xi^2/\tau_{eff} = \xi \cdot c$	$L^2 T^{-1}$	From Postulate 4 + CCC
κ	$\lambda c^2 \xi^3$	$L^5 T^{-2}$	For flux/acceleration only

Quantity	Expression	Dimension	Status
Poisson coupling = κ/ξ^2	$\lambda c^2 \xi$	$L^3 T^{-2}$	For Postulate 5 field equation
E_bind	$\zeta \hbar c/\xi$	$M L^2 T^{-2}$	Derived
Φ_c	$(\hbar c/\xi)(1+\Gamma_c)$	$M L^2 T^{-2}$	Bounded below
$\varepsilon_{fold} = \mathcal{C} \hbar c/\xi$	single-scale collapse	$M L^2 T^{-2}$	Conditional on ansatz
$\sigma_{sat} = \xi c/(\mathcal{C} \hbar)$	inverse mass/fold	M^{-1}	Conditional on ansatz
$G = \lambda \sigma_{sat} \xi c^2$	$m^3 kg^{-1} s^{-2}$	$L^3 M^{-1} T^{-2}$ ✓	From Poisson matching
$G = (\lambda/\mathcal{C}) \xi^2 c^3/\hbar$	$m^3 kg^{-1} s^{-2}$	$L^3 M^{-1} T^{-2}$ ✓	Conditional prediction

---

Appendix C: Framework Alignment

VERSF Component	Role in the Derivation Chain
Binary Foundations	Step 1: binary necessity forces folds
Bit–Tick ontology	Steps 1–2: folds = bits; ticks = commitment ordering
BCB	Step 2: distinguishability conserved; geometry from flow
Topological threshold / RAL	Steps 2–3: irreversibility requires structure; trapped information = commitment
TPB	Steps 3–4: commitment rate sets energy and time scales
CCC	Step 4: finite distinguishability forces ξ and c
This paper	Step 5: ξ determines G via fold density gradient law

These are successive layers of derivation from the same primitive: the fold as the minimal unit of distinguishable physical structure.
