One-Parameter Theory of Everything: Existence, Compression, and the Emergence of Physical Law

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Abstract

We sketch a programme in which both quantum mechanics and general relativity emerge from a single principle: *observers exist, and their probability of existence is determined by the compressibility of their description.* The central object is a Boltzmann-like probability measure over histories γ compatible with an observer O:

$$\mathbb{P}(\gamma \mid O) = \frac{1}{Z_O} \exp\bigl(-\mathcal{C}_O[\gamma]\bigr), \qquad \gamma \in \Gamma_O,$$

where $\mathcal{C}_O[\gamma]$ is the total description cost of history γ given observer O.

Rather than deriving this from first principles — a task left for future work — we collect here the evidence that it is the correct organising equation. Papers VII and VIII of this series establish exact, analytically verified results: the off-diagonal density matrix of a purely fermionic system yields a photon-like boson with amplitude $\|B(\theta)\| = \sin(2\theta)/\sqrt{2}$; the identical decomposition applied to metric configurations yields the Ricci/Weyl split, gravitational wave polarisations, and a Newtonian potential $V(r) = -Mm/(8\pi r)$ in Planck units. These results share a single structure: $\rho \mapsto \mathrm{diag}(\rho) + (\rho - \mathrm{diag}(\rho))$, the local/non-local split of any compressed configuration. We conjecture that this structure forces the cost functional to decompose into three regimes — discrete ($\mathbf{D}$), spectral ($\boldsymbol{\psi}$), and geometric ($\mathbf{G}$) — corresponding to quantised spacetime, quantum mechanics, and general relativity respectively. The value $n \approx 184$ bits for the universe's information content, derived independently from inflationary cosmology and black hole thermodynamics in Papers IV and V, is expected to emerge as the saddle point of the observer's own existence probability, though the explicit computation remains open. This paper is a progress report and a research agenda, not a completed derivation.

Keywords: theory of everything, Solomonoff induction, spectral complexity, quantum gravity, information theory, observer self-selection, Kolmogorov complexity, Wheeler–DeWitt, De Sitter, Bekenstein–Hawking

1 Introduction

General Relativity and quantum mechanics each require an input the other cannot supply. General Relativity takes the geometry of spacetime as given and derives how matter curves it. Quantum mechanics takes the Hilbert space structure of states as given and derives how they evolve. Neither theory explains why its own input exists.

The programme pursued across this series of papers begins from an observation: both inputs may be consequences of a single integer n, the total bit count of a finite, static, timeless universe, together with the rule that structures dominate the measure in proportion to how compressibly they can be described. Papers I–VIII [10, 5, 7, 11, 9, 12, 6, 8] develop this programme in steps: establishing the observer axiom, deriving the aspect ratio of spacetime, recovering Bekenstein–Hawking entropy, matching the Friedmann equation, and most recently proving exact results about the emergence of bosons and gravitational structure from the density matrix of a compressed fermionic system.

The present paper attempts to draw these threads together into a unified picture. It is written frankly as a sketch: the exact results of Papers VII and VIII are solid, but the claim that they fit into a single zero-parameter framework is a conjecture whose full justification remains to be constructed. We state what is proved, what is strongly suggested, and what is open.

2 The Organising Equation

2.1 The Observer as the First Principle

We take as the starting point:

> **Axiom (Observer Existence).** There exists at least one observer.

An observer is defined operationally, following Paper I [10]: a finite information structure whose state sequence encodes causally efficacious subjective experience. Paper I establishes from four modest axioms that such a structure must be finite, substrate independent, and that the universe containing it must be static and timeless. We take those results as working hypotheses and build on them here.

2.2 Probability of Existence via Solomonoff Induction

Given the observer axiom, which universe does the observer find herself in? By substrate independence, the observer is a finite information structure and the universe is the minimal information structure that contains her. The natural prior over universes is then determined by description length:

$$\mathbb{P}(\gamma \mid O) = \frac{1}{Z_O} \exp\bigl(-\mathcal{C}_O[\gamma]\bigr), \qquad \gamma \in \Gamma_O, \tag{1}$$

where Γ_O is the set of all histories compatible with the existence of O, $\mathcal{C}_O[\gamma]$ is the total description cost of γ given O, and $Z_O = \sum_{\gamma \in \Gamma_O} \exp(-\mathcal{C}_O[\gamma])$. This is Solomonoff induction [13] in path-integral form.

The apparent free parameter λ (an inverse temperature in the Boltzmann analogy) has been set to unity: rescaling λ is equivalent to rescaling $\mathcal{C}_O$, and only the ordering of histories by cost is physically meaningful. λ is a units choice, not a physical constant.

2.3 Physical Law as Large-Deviation Minimiser

The conjecture is that the observed regularities of physics are the histories γ^* that minimise $\mathcal{C}_O[\gamma]$ subject to observer compatibility:

$$\gamma^* = \arg\min_{\gamma \in \Gamma_O} \mathcal{C}_O[\gamma].$$

A universe that is chaotic or structureless is not forbidden by this equation; it simply has a higher description cost and contributes negligibly to Z_O. We do not assume finiteness; we expect to derive it, because finite universes compress better than infinite ones. We do not assume order; we expect to derive it, because ordered histories are shorter to describe. Whether equation (1) alone is sufficient to force these properties in full generality, without additional structure, is an open question.

3 Evidence from Papers VII and VIII

The strongest evidence for the programme comes from two recent exact results, which we summarise here. Both concern the same mathematical object: the off-diagonal density matrix $B = \rho - \mathrm{diag}(\rho)$ of a compressed configuration.

3.1 Bosons as Compression Residuals (Paper VII)

Paper VII [6] encodes two-frame fermion configurations as complex wavefunctions $\psi = f_0 + if_1$ and computes the density matrix $\rho = |\psi\rangle\langle\psi|$. The off-diagonal part B captures everything the codec records when a fermion moves between frames.

Four results are established analytically and verified numerically:

1. **Pauli exclusion.** For any stationary single fermion, $B = 0$ exactly. Double occupancy produces no compression residual; it is informationally invisible. Pauli exclusion is not a postulate but the statement that double occupancy has nothing for the codec to encode.
2. **Universal boson.** Every single fermion hop produces $\|B\| = 1/\sqrt{2}$, independent of chain length, hop distance, and encoding. The residual carries a universal $-\pi/2$ phase, the defining signature of a propagator.
3. **Born rule identity.** For a fermion in superposition $\psi(\theta) = \cos\theta\, e_i + i\sin\theta\, e_j$,

$$\|B(\theta)\| = \frac{\sin 2\theta}{\sqrt{2}} = \sqrt{2\,P(1-P)}, \tag{2}$$

   where $P = \sin^2\theta$ is the Born-rule hop probability. The boson amplitude is the interference term of the Born rule, expressed as a matrix norm.
4. **Virtual propagator lifecycle.** $\|B\| = 0$ when the fermion is stationary, rises to $1/\sqrt{2}$ at equal superposition, and returns to 0 when the hop is complete — the lifecycle of a virtual particle, derived without field theory.

These results follow from the single definition $B = \rho - \mathrm{diag}(\rho)$ and the normalisation of ψ. No interaction terms, coupling constants, or particle species were introduced.

3.2 Gravitational Structure as Compression Residual (Paper VIII)

Paper VIII [8] applies the identical decomposition to metric configurations: a two-frame metric pair $(g^{(0)}, g^{(1)})$ is encoded as $\psi(x) = g^{(0)}(x) + ig^{(1)}(x)$. The same $\rho \mapsto \mathrm{diag}(\rho) + B$ split then yields:

1. **Curvature decomposition.** ρ decomposes exactly as $\rho_{\mathrm{Ricci}} + \rho_{\mathrm{tidal}} + \rho_{\mathrm{graviton}}$, with $\mathrm{Tr}(\rho_{\mathrm{Weyl}}) = 0$ in every case. The diagonal is identified with local Ricci curvature (the Einstein source term); the symmetric off-diagonal with tidal (Coulomb Weyl) forces; the antisymmetric off-diagonal with gravitational waves.

2. **Two polarisations.** The two degenerate graviton polarisation modes emerge as eigenvectors of ρ_{tidal} with eigenvalue $-1/4$, protected by the reflection symmetry of the metric profiles. No spin-2 field is postulated.

3. **Graviton amplitude theorem.** For orthogonal metric profiles at mixing angle ϵ,

$$\|W(\epsilon)\| = \frac{\sin 2\epsilon}{\sqrt{2}}, \tag{3}$$

the exact gravitational analogue of equation (2). The formula is independent of metric profiles, system size, and overall scale.

4. **Newtonian potential.** Graviton flux conservation over spherical shells gives $A(r) \propto 1/r$ exactly, and the overlap integral yields

$$V(R) = -\frac{GMm}{R}, \qquad G = \frac{1}{8\pi} \quad \text{(Planck units)}. \tag{4}$$

The factor $8\pi = 2 \times 4\pi$ arises from spherical geometry alone — the same factor that recovers Bekenstein–Hawking entropy in Paper IV [11].

5. **Minimum-complexity orbits.** The minimum spectral-complexity closed worldline is $\psi(t) = Ae^{i\omega t}$ — a single Fourier mode, tracing an ellipse. Under Solomonoff induction, all other closed trajectories are exponentially suppressed. Keplerian orbits are selected by minimum description length, not by a force law.

3.3 The Shared Structure

Equations (2) and (3) are identical in form. This is not a coincidence of presentation. Both follow from the density matrix decomposition applied to a normalised superposition of two orthogonal configurations. The formula $\sin(2\alpha)/\sqrt{2}$ is the unique consequence of this structure, regardless of whether α parametrises a fermion in quantum superposition or a metric in gravitational superposition.

The conjecture is that this shared structure reflects a shared origin: quantum field theory and general relativity are two projections of the same compression principle onto different physical degrees of freedom.

4 The Conjectured D-ψ-G Trinity

4.1 Three Regimes of the Cost Functional

The exact results of Papers VII and VIII suggest, but do not yet establish, that the cost functional $\mathcal{C}_O[\gamma]$ naturally decomposes into three regimes:

$$\mathcal{C}_O[\gamma] = \underbrace{C_D[n]}_{\text{bit budget}} + \underbrace{C_\psi[\psi_\gamma]}_{\text{spectral cost}} + \underbrace{C_G[g_\gamma]}_{\text{geometric cost}} . \tag{5}$$

The intuition is as follows. Any observer requires well-defined boundaries. The cost of specifying those boundaries depends on the representation:

- **D** (Discrete): Boundaries are subsets of a bitstring. Cheap but structureless.

- ψ (Spectral): Boundaries are subspaces of a function space. The spectral cost C_ψ suppresses high-frequency (rough) wavefunctions, producing the wave-like behaviour observed at quantum scales.
- **G** (Geometric): Boundaries are surfaces in a metric space. Closed surfaces in three dimensions admit compact, low-frequency descriptions. The geometric cost C_G is minimised for smooth manifolds.

The claim that these three regimes are *forced* by the boundary structure of any self-describing observer — rather than chosen by hand — is the key conjecture of this paper. A derivation of the decomposition (5) from equation (1) alone has not yet been carried out.

4.2 Scale Dependence

Under this conjecture, the three regimes dominate at different scales:

Scale	**Dominant cost**	**Emergent description**
Planck	$C_D[n]$	Discrete, quantised spacetime
Quantum	$C_\psi[\psi_\gamma]$	Quantum mechanics, Born rule
Observer	$C_G[g_\gamma]$	General Relativity, Friedmann

The evidence that C_ψ produces quantum mechanical structure is solid (Paper VII). The evidence that C_G produces gravitational structure is solid for toy models (Paper VIII). The claim that the crossover between C_ψ and C_G corresponds to the Planck scale, and that C_D governs the discrete regime, is physically motivated but not yet derived.

5 The Emergence of n

5.1 n as a Candidate Fixed Point

The bit count n appears in equation (5) as $C_D[n] = \log_2 n$. It would be tempting to conjecture that n is not a free parameter but the saddle point of the observer's own existence probability.

The probability that observer O exists at all, marginalising over all histories at bit count n, is then:

$$\mathbb{P}(O \mid n) = \frac{Z_O(n)}{Z(n)}.$$

The prior over n is $\mathbb{P}(n) \propto 1/n$ (description length of n itself). The joint probability is:

$$\mathbb{P}(O, n) \propto \frac{Z_O(n)}{Z(n) \cdot n}.$$

The saddle-point condition — the value of n that maximises the observer's probability of existence — is formally:

$$\frac{\partial}{\partial n}\Big[\log Z_O(n) - \log Z(n) - \log n\Big] = 0. \tag{6}$$

5.2 Consistency with Independent Estimates

Papers IV and V [11, 9] derive a preferred value $n \approx 184$ by two independent routes: matching the inflationary aspect ratio and recovering Bekenstein–Hawking entropy for a solar-mass black hole.

If equation (6) independently selects $n^* \approx 184$, the three routes converge, which would constitute strong evidence for the framework.

That convergence has not yet been verified. The saddle-point equation requires an explicit model of $Z_O(n)$ — the partition function of observer-compatible histories as a function of n — for which no tractable expression is currently available.

6 Summary of Recovered Physics

We summarise what has been established, what is strongly suggested, and what remains open.

Established (exact, verified).

- Pauli exclusion as zero compression residual (Paper VII).
- Boson amplitude $\|B(\theta)\| = \sin(2\theta)/\sqrt{2}$, independent of system size (Paper VII).
- Born rule as interference term of the density matrix (Paper VII).
- Ricci/Weyl decomposition from the diagonal/off-diagonal split of metric density matrices (Paper VIII).
- Two graviton polarisations as degenerate eigenmodes (Paper VIII).
- Graviton amplitude $\|W(\epsilon)\| = \sin(2\epsilon)/\sqrt{2}$ (Paper VIII).
- Newtonian $1/r$ potential from graviton flux conservation, with $G = 1/(8\pi)$ in Planck units (Paper VIII).
- Keplerian orbits as minimum-complexity closed worldlines (Paper VIII).

Strongly suggested (structural agreement, not yet derived).

- The aspect ratio $\mathcal{A}(n) = 2^n/(n \ln n)$ matching inflationary expansion in Planck units (Papers IV–V).
- The ΛCDM expansion profile recovered from the lognormal emergence law without a cosmological constant (Paper V).
- The Friedmann equation under the identification of matter as bound bit structures (Paper V).
- The proportionality $\|W\| \propto M$ needed to make Theorem 4 of Paper VIII fully self-contained.
- The correct topology: why the boundary is a 3-sphere rather than some other manifold? The minimum-complexity compact boundaryless 2-boundary in 3D Euclidean space is S^2, with surface area $4\pi r^2$. Under Solomonoff induction, all other topologies are exponentially suppressed. The factor 4π is therefore not a free parameter but a topological selection result.

Open.

- Solving the saddle-point equation (6) and recovering $n^* \approx 184$.
- Deriving the decomposition (5) from equation (1) without additional assumptions.

- The continuum limit: recovering the full Einstein field equations from the discrete toy model of Paper VIII.
- The emergence of energy: how $E \propto \hbar\omega$ arises from the spectral cost C_ψ in physical units.
- Massive bosons (W, Z, Higgs) and the gauge structure of the Standard Model.

7 Discussion

7.1 Why the Same Formula Governs Bosons and Gravitons

The most striking result across Papers VII and VIII is that the formula $\sin(2\alpha)/\sqrt{2}$ appears in both the boson amplitude and the graviton amplitude, for entirely different physical degrees of freedom. The explanation is structural: both follow from the off-diagonal norm of a rank-one density matrix formed from a superposition of two orthogonal unit vectors. For a state $\psi = \cos\alpha\, u + i \sin\alpha\, v$ with $u \perp v$,

$$\|\rho - \mathrm{diag}(\rho)\|_F = \frac{|\sin 2\alpha|}{\sqrt{2}}$$

is an algebraic identity, independent of what u and v represent.

This universality suggests that the density matrix decomposition is not a feature of quantum mechanics or of gravity separately but of the compression principle itself. Whether this observation can be elevated to a theorem — a proof that any two-regime compression of normalised configurations yields this formula — is an open question.

7.2 The Role of 4π

The factor 4π appears in three independent calculations in this series: recovering Bekenstein–Hawking entropy (Paper IV), recovering the Newtonian potential (Paper VIII Theorem 4), and the aspect ratio between discrete and spherical geometry (Papers IV–V). In each case it is not a free parameter but the geometric conversion between flat counting and spherical propagation. Its consistent appearance is encouraging but not yet understood at the level of the cost functional. We settle to assuming sperical symmetry is the minimal geometric shape satisfying the observer condition.

7.3 What This Framework Is and Is Not

The programme is not a completed theory. It is a collection of exact results in discrete toy models, a set of structural correspondences with known physics, and a conjectured organising equation. The toy models use 1D chains, conformal metrics, and two-frame sequences. Extensions to four continuous dimensions, the full tensorial Riemann curvature, and the Fock space of many-fermion systems remain to be carried out.

The framework does not yet contain a derivation of the Standard Model, does not address the origin of energy in physical units, and does not derive the masses of elementary particles. These are long-term targets, not current achievements.

What the framework does suggest — and what the results of Papers VII and VIII make concrete — is that the separation between quantum mechanics and general relativity may be an artifact of working in different effective descriptions of the same underlying compression principle. The density matrix decomposition $\rho \mapsto \mathrm{diag}(\rho) + B$ produces local/non-local structure whether applied to fermion configurations or metric configurations. The quantum/gravitational duality, in this view, is not a coincidence to be explained but a consequence to be proved.

7.4 Relation to Existing Approaches

Jacobson [4] derived the Einstein equations from thermodynamics of local Rindler horizons. Verlinde [14] derived Newtonian gravity from entropic forces. The present approach derives geodesics, curvature decomposition, graviton polarisations, and the Newtonian potential from spectral complexity minimisation alone, without postulating thermodynamics, entropy, or holography as inputs. Whether entropy and thermodynamics emerge as consequences within the framework is an interesting open question.

Reconstructions of quantum mechanics from information-theoretic axioms [3, 1] and the Bayesian/QBist programme [2] seek to derive the formalism of quantum mechanics without a physical model of the underlying degrees of freedom. The present approach is complementary: it proposes a specific physical model (fermions as pixels, bosons as compression residuals) and derives the quantum formalism from it, but does not yet have a proof that the model forces the full Hilbert space structure.

7.5 Is the Zero-Parameter Goal Realistic?

I initially tried to set the first principle of the framework as assume nothing, which was itself an assumption. Any axiomatic system — mathematics included — requires at least one axiom. The minimum may be just one parameter: the definition of the observer. Everything else could then follow from that.

8 Open Problems

We list the primary open problems in order of foundational priority.

1. **Continuum limit.** The fullEinstein field equations should emerge as the large-deviation stationarity conditions of C_G over metric configurations in the continuum limit of the discrete model of Paper VIII. This requires a treatment of the limit that is beyond the scope of the current toy models.

2. **Emergence of energy.** The spectral cost C_ψ is an information-theoretic quantity. Its identification with physical energy ($E \propto \hbar\omega$) requires a derivation of the unit conversion from Planck units to SI, analogous to the treatment of G in Paper VIII.

3. **The Multi-fermion Machinery.** The single-fermion results already establish the essential structure. Extending to tensor products is a technical programme, not a conceptual one.

4. **The topology question.** Why is the observer's boundary a 3-sphere? The spherical topology emerges naturally from the minimal boundary extension of the 1D encoding, but a proof that no other topology can dominate the measure has not been given.

5. **The saddle-point equation.** Solving equation (6) requires an explicit model of $Z_O(n)$. A tractable approximation to the observer partition function, even in a toy model, would be a significant step.

6. **Derivation of the D-ψ-G decomposition.** Equation (5) is conjectured, not derived. A proof that the boundary structure of any self-describing observer forces this three-way split would convert the conjecture into a theorem.

9 Conclusion

We have sketched a programme in which a single equation — the Solomonoff-weighted measure over observer-compatible histories — is conjectured to be sufficient to derive the structure of spacetime, the origin of quantum mechanics, and the unification of General Relativity with quantum field theory.

The evidence for this conjecture, assembled across this series of papers, includes exact analytical results: bosons emerge as compression residuals of fermionic systems with amplitude $\sin(2\theta)/\sqrt{2}$; gravitational wave structure, polarisations, and the Newtonian potential emerge from the identical decomposition applied to metric configurations; Keplerian orbits are selected by minimum description length; Bekenstein–Hawking entropy and the inflationary aspect ratio are recovered from a single bit count $n \approx 184$.

None of these results required the postulation of interaction terms, coupling constants, force laws, or Hilbert spaces. They follow from one operation — the diagonal/off-diagonal split of a density matrix — applied to compressed configurations of different physical degrees of freedom.

Whether this operation is itself a theorem of the organising equation (1), or whether additional structure is needed, is the central unresolved question. The present paper is a progress report on the way to an answer.

10 Simulations

- `emergent_smoothness.py` - Minimal POC demonstrating the $G - \psi - D$ trinity. Not physics yet, but something smooth - emergent motion, inertia and interference.

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