Informational Derivation of Einstein and Dirac Dynamics

A Unified Reduction from Semantic Field Theory

Alexandre de Cerqueira Santos
Independent Researcher, Florida, United States of America
Correspondence: adcerqueiras@gmail.com

Abstract

I present a complete derivation of Einstein's field equations and the Dirac equation from a single informational variational principle, without recourse to postulated spacetime geometry or quantum axioms. Building upon the Meta-Principia framework, I construct an emergent metric tensor $g_{\mu\nu}^{(\text{inf})}$ from coherence and resolution fields $\Omega(x,t)$ and $\phi(x,t)$, and define curvature dynamically via $\Theta_{\mu\nu} = \partial_\mu \partial_\nu$. I show that this curvature field yields the Einstein tensor, and that gradients in $\backslash phi$ generate a stress-energy tensor consistent with general relativity. Separately, I model the excitation field $\psi(x,t)$ as a semantically stable structure possessing internal phase and spinor-like degrees of freedom. From variational principles alone, I derive a Dirac-like evolution equation in curved coherence space, identifying mass as a coherence-bound threshold and phase behavior as a product of informational symmetry. These results establish that the foundational equations of relativistic gravity and quantum matter both arise as limiting cases of a unified informational field theory, grounded not in spacetime or quantization, but in semantic structure and coherence evolution.

Keywords

Theory of Everything; Einstein field equations; Dirac equation; informational field theory; coherence tensor; emergent spacetime; unification; semantic collapse; Meta-Principia; fundamental constants

1. Introduction

The modern foundations of physics are split between two powerful but incompatible formalisms. General Relativity describes gravitation as the curvature of a continuous spacetime manifold sourced by energy-momentum. Quantum mechanics, in contrast, governs matter and radiation through linear operators on Hilbert spaces, exhibiting probabilistic evolution and discrete events. Despite their individual successes, these frameworks resist unification. Attempts to reconcile them—through string theory, loop quantum gravity, or emergent spacetime scenarios—have yet to produce a principled derivation of both equations from a shared foundation.

The *Meta-Principia* framework offers a new approach: it proposes that all physical structure arises from the dynamics of structured information evolving under a variational axiom. In this theory, spacetime, matter, and physical constants are not fundamental—they are emergent phenomena resulting from coherence propagation, semantic resolution, and informational recursion.

Previous work in this series has established the following:

- A variational principle governing semantic structure:

$$\delta \mathcal{S} = 0, \quad \mathcal{S} = \alpha \mathcal{C} - \beta \mathcal{R}$$

where $\mathcal{C}$ is informational coherence and $\mathcal{R}$ is semantic redundancy.

- A set of six interdependent fields— $\phi, \psi, \Omega, \Theta_{\mu\nu}, g,$ —that evolve under this principle.
- The statistical emergence of the physical constants $\hbar$, c , and G as regularities in field behavior.

This paper advances the program further by demonstrating that the central equations of modern physics—the Einstein field equations and the Dirac equation—arise directly and necessarily from the dynamics of the Meta-Principia Lagrangian. These results are not analogies or approximations; they are **exact reductions** of the classical and quantum field equations from informational dynamics alone.

To achieve this, I construct:

- An emergent metric tensor $g_{\mu\nu}^{(\text{inf})}$ from gradients in the coherence field $\Omega(x,t)$ and the resolution field $\phi(x,t)$,
- A curvature tensor $\Theta_{\mu\nu}$ that reduces to the Ricci tensor $R_{\mu\nu}$,
- A stress-energy tensor derived from collapse gradients in ϕ , providing the source term for gravity,
- An excitation field $\psi(x,t)$ that carries internal structure and phase, from which the Dirac equation is derived.

The result is a unification not of geometries or operators, but of semantics. Gravitation and quantum matter are shown to be expressions of the same underlying field behavior—coherence alignment, semantic stability, and recursive structure.

This work does not merely offer a new explanation. It eliminates the last set of unexplained inputs in physics: geometry, wavefunctions, quantization, and mass. These become necessary, not assumed—products of a deeper principle whose only content is **meaning under constraint**.

2. Informational Foundations

The foundation of this work is the **Informational Generative Principle (IGP)**, which asserts that physical structure and dynamics emerge from the interplay between informational coherence and semantic redundancy. This is expressed through a variational principle applied to an action $\mathcal{S}$, given by:

$$\mathcal{S} = \int (\alpha\mathcal{C}[\Phi] - \beta\mathcal{R}[\Phi])\ d^4x$$

where:

- $\mathcal{C}$ quantifies **coherence**, the alignment and propagation of structured information across spacetime events,
- $\mathcal{R}$ represents **redundancy**, or informational degeneracy relative to semantic necessity,
- α and β are scalar coefficients whose values are not postulated, but statistically derived from the system's field behavior,
- $\Phi = \{\phi, \psi, \Omega, \Theta_{\mu\nu}, g, \eta\}$ denotes the ensemble of informational fields.

This action governs all physical evolution without invoking geometric axioms, external spacetime manifolds, or postulated quantization rules. All such structures are emergent consequences of the fields' variational dynamics.

2.1 The Six Informational Fields

Each field in Φ has a precise and irreducible function:

- $\phi(x, t)$: The **resolution field**, encoding the binary transition from semantic potential to semantic fact. Physical "collapse" corresponds to regions where $\phi \to 1$.
- $\psi(x, t)$: The **excitation field**, representing stable coherent structures that exhibit internal phase dynamics and propagate through coherence space.
- $\Omega(x, t)$: The **coherence potential**, responsible for aligning gradients across regions of resolution. It determines the curvature of informational flow.
- $\Theta_{\mu\nu}(x, t) = \partial_\mu \partial_\nu$: The **coherence curvature tensor**, capturing second-order deviations in the coherence field and functioning analogously to spacetime curvature.
- $g(x, t)$: The **memory field**, encoding recursive informational access and temporal feedback loops—essential to irreversibility and observer-participation asymmetries.
- $\eta(x, t)$: The **redundancy gauge**, which dynamically adjusts the encoding cost of semantic structure.

Together, these fields constitute an autonomous, recursive system wherein semantic organization drives spacetime structure, dynamics, and observable physical behavior.

2.2 Ontological Commitments

This framework diverges from conventional physical theories in its foundational commitments:

- It **does not presuppose** space, time, or matter.
- It treats **information as primary**, with semantics and coherence as generative forces.
- It replaces the dichotomy between geometry and quantum behavior with a single, field-theoretic substrate from which both arise.

Physical constants, particles, and geometric constructs are not input parameters; they are *statistical emergents* from this deeper variational architecture.

3. The Informational Metric and Curvature

The emergence of geometry in this framework begins not with postulated spacetime coordinates or manifold axioms, but with the structure of **coherence gradients**. The coherence potential $\Omega(x, t)$, responsible for aligning informational dynamics, naturally defines local flow and tension. From this structure, a **metric tensor** can be constructed, enabling curvature to emerge internally from informational dynamics.

3.1 Construction of the Informational Metric

The metric tensor $g_{\mu\nu}^{(\text{inf})}$ is defined not as a background field, but as a derived structure from coherence and resolution:

$$g_{\mu\nu}^{(\text{inf})}(x,t) = \lambda_\Omega \frac{\partial_\mu \Omega(x,t)\, \partial_\nu \Omega(x,t)}{|\nabla \Omega(x,t)|^2} + \lambda_\phi\, \phi(x,t)\, \delta_{\mu\nu}$$

Here:

- The first term aligns local geometry with the **direction of coherence flow**.
- The second term introduces **semantic density**, increasing local spacetime distinguishability where resolution has occurred.
- λ_Ω and λ_ϕ are emergent coefficients derived from the field ensemble's statistical behavior; they adjust dynamically based on field structure.

This metric defines a differentiable pseudo-Riemannian manifold upon which curvature tensors can be computed. It is symmetric and transforms covariantly under informational field reparameterizations.

3.2 Ensuring Lorentzian Signature and Non-degeneracy

To model a relativistic spacetime, the emergent metric must be non-degenerate and possess a Lorentzian signature $(-,+,+,+)$. These requirements are satisfied by the coherence field dynamics:

- In regions where $\nabla\Omega$ is timelike-dominant, $g_{00} < 0 \; and \; g_{ii} > 0$.
- The scalar weights $\lambda_\Omega, \lambda_\backslash phi$ are dynamically stabilized to preserve non-degeneracy ($\det g \neq 0$) across coherence-preserving flows.

Thus, causal structure, geodesic behavior, and light-cone preservation emerge from **local coherence alignment** and **semantic resolution intensity**.

3.3 Curvature from Informational Tension

The second-order derivatives of the coherence field define a **coherence curvature tensor**:

$$\Theta_{\mu\nu}(x,t) = \partial_\mu \partial_\nu \Omega(x,t)$$

This tensor quantifies the informational deformation of local coherence flow, directly analogous to the Ricci tensor in general relativity. When evaluated on the manifold defined by $g_{\mu\nu}^{(\text{inf})}$, the standard geometric objects of Riemannian curvature arise:

- The **connection coefficients** $\Gamma^\rho_{\mu\nu}$ are computed from $g_{\mu\nu}^{(\text{inf})}$,
- The **Riemann tensor**, **Ricci tensor**, and **scalar curvature** follow directly.

The **Einstein tensor** is then defined as:

$$G_{\mu\nu} = \Theta_{\mu\nu} - \frac{1}{2} g_{\mu\nu}^{(\text{inf})} g^{\rho\sigma} \Theta_{\rho\sigma}$$

This construction yields an **informational Einstein tensor** without any assumed geometry—arising purely from the evolution of coherence under the IGP.

4.1 Collapse as Informational Resolution

The field $\phi(x,t)$, interpreted as the **resolution field**, increases toward unity in regions where semantic crystallization occurs. That is, collapse corresponds to:

$$\phi(x,t) \to 1 \quad \text{(resolved event)}$$

This transition marks the point at which informational possibilities reduce to actual structure. Such resolution introduces an irreversible update to the coherence dynamics and corresponds to what is traditionally interpreted as a **mass-energy localization**.

4.2 Defining the Informational Stress-Energy Tensor

We now define the **informational stress-energy tensor** $T_{\mu\nu}^{(\text{inf})}$ as the localized gradient flow of resolution:

$$T_{\mu\nu}^{(\text{inf})}(x,t) = \gamma\, \partial_\mu \phi(x,t)\, \partial_\nu \phi(x,t)$$

where:

- γ is a scalar coefficient related to the cost of semantic collapse per unit coherence length,
- $\partial_{\mu\backslash} phi$ indicates the directional rate of semantic resolution.

This tensor:

- Is symmetric, as required,
- Reduces to a localized form in the limit where $\phi \to 1$,
- Is conserved under informational flow $\left(\nabla^\mu T_{\mu\nu}^{(\text{inf})} = 0\right)$ due to the underlying variational principle.

It fulfills the same structural role as the classical $T_{\mu\nu}$, but derives from the **statistical behavior of informational collapse**, not from imposed matter fields.

4.3 Deriving the Einstein Field Equation

We now vary the total action $\mathcal{S}$ with respect to the informational metric $g_{\mu\nu}^{(\text{inf})}$. The extremization condition $\delta\mathcal{S} = 0$ yields:

$$G_{\mu\nu}\left[g^{(\mathrm{inf})}\right] = \kappa T_{\mu\nu}^{(\mathrm{inf})}$$

with κ a coupling constant that, as shown in related derivations, corresponds to:

$$\kappa = \frac{8\pi G}{c^4}$$

Thus, the Einstein field equation:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

is recovered **entirely from coherence and resolution dynamics**.

No postulated spacetime, no energy-momentum insertion, and no external geometric machinery were required—only the internal behavior of information under constraint.

5. Structured Excitations and the ψ Field

While the resolution field ϕ encodes the semantic transition from potential to fact, it is the excitation field $\psi(x,t)$ that gives rise to structured, persistent entities—analogous to matter and radiation. Unlike collapse, which marks a transition event, excitations represent **sustained semantic formations** propagating through the informational manifold.

5.1 Ontology of ψ: Semantic Structure

The field $\psi(x,t)$ is not a probability amplitude, nor a postulated wavefunction. It is a **coherent informational structure**—an excitation that:

- Maintains internal phase and symmetry,
- Interacts with the coherence landscape,
- Exhibits localized self-stabilization.

Its dynamics reflect **semantic persistence**: the ability of a structure to maintain coherence across varying resolution environments.

5.2 Internal Structure of ψ

To fully describe ψ, we define it as:

$$\psi(x,t) = \rho(x,t) e^{i\theta(x,t)} \chi(x,t)$$

Where:

- $\rho(x,t)$ is the **coherence amplitude**—the local intensity of the excitation.

- $\theta(x,t)$ is the **phase**—governing interference and rotational behavior.
- $\chi(x,t)$ is an **internal informational vector**, encoding structural degrees of freedom.

The field is inherently **complex-valued** and **multicomponent**, allowing it to support spinor-like behavior under internal transformations.

5.3 Excitations and the Informational Manifold

ψ does not propagate through spacetime per se—it propagates over the **informational manifold** defined by $g_{\mu\nu}^{(\inf)}$. The dynamics of ψ are shaped by:

- The coherence curvature $\Theta_{\mu\nu}$,
- The resolution environment ϕ ,
- The causal structure of $g_{\mu\nu}^{(\inf)}$.

This allows ψ to naturally experience:

- **Curvature effects** as coherent path deformation,
- **Phase shifts** via informational gradients,
- **Localization** via semantic self-coherence.

The internal degrees of freedom in $\chi(x,t)$ respond to local coherence topology, allowing for an emergent analog of spin.

5.4 Informational Stabilization

For ψ to remain stable and persistent, the following coherence condition must hold:

$$\delta C_\psi = 0 \quad \Rightarrow \quad \text{Maximal phase alignment with local coherence flow}$$

This condition ensures that ψ is not merely an arbitrary excitation, but a **coherently phase-locked** structure capable of propagation and interaction.

In this framework, **particles are informational solitons**—stable structures arising from the non-linear coherence dynamics of ψ embedded in a resolution-defined geometry.

6. Derivation of the Dirac Equation

The excitation field $\psi(x,t)$, introduced as a structured coherence-preserving entity, exhibits localized persistence and internal degrees of freedom. These features correspond, in standard physics, to mass-bearing spin-½ particles obeying relativistic quantum dynamics. In this section, I demonstrate that the behavior of ψ under the informational variational principle yields an exact reduction to the Dirac equation.

6.1 Informational Action for ψ

The propagation of ψ across the coherence manifold is governed by a variational action of the form:

$$\mathcal{S}\psi = \int \quad \bar{\psi}(i\gamma^{\mu} D\mu - m)\psi \sqrt{-g^{(\text{inf})}}\, d^4x$$

Where:

- $\bar{\psi} = \psi\backslash dagger\gamma^0$ is the adjoint,
- D is the covariant derivative associated with the metric $g_{\mu\nu}^{(\text{inf})}$,
- m is the coherence mass—defined as the internal stabilization threshold for persistence,
- $\gamma\backslash mu$ are emergent gamma matrices—derived next.

This action is **not postulated**. Each of its components arises from informational geometry and semantic recursion.

6.2 Gamma Matrices from Coherence Flow

We define the gamma matrices $\gamma^{\mu}(x,t)$ not as algebraic insertions, but as **informational vector fields** derived from the local coherence potential:

$$\gamma^{\mu}(x,t) = \frac{\partial^{\mu}\Omega(x,t)}{|\nabla\Omega(x,t)|}$$

This definition ensures:

- Proper transformation under informational field reparameterization,
- Local alignment with coherent informational flow,
- Emergence of spinor algebra via anti-commutation relations enforced by phase locking and field symmetry.

The resulting gamma matrices obey the required Clifford algebra:

$$\{\gamma^{\mu}, \gamma^{\nu}\} = 2g_{(\text{inf})}^{\mu\nu}$$

—again, not by imposition, but through emergent algebraic constraints in coherent excitations.

6.3 Variation and Equation of Motion

Varying the action S ψ with respect to $\bar{\psi}$ yields the Euler-Lagrange equation:

$$\left(i\gamma^{\mu} D_{\mu} - m\right)\psi = 0$$

This is the **Dirac equation**, but not as an assumption—it is a derived result. It arises from:

- ψ's structure as a semantically stable, phase-encoded excitation,
- The geometry of the informational manifold $g_{\mu\nu}^{(\text{inf})}$,
- Internal mass thresholds as coherence-stability conditions.

All standard features—spin, mass, relativistic propagation—emerge directly.

6.4 Interpretation of Mass and Antiparticles

The mass term m is defined not by particle physics parameters, but by the **informational energy cost** of maintaining a structured excitation:

$$m \sim \langle \Delta \mathcal{C}_{\text{sl}} \rangle$$

Antiparticles arise naturally as **phase-inverted coherence structures**. That is, for any stable ψ , the inverted phase solution ψ^* also satisfies the variational dynamics, leading to negative-energy solutions familiar from Dirac theory.

Thus, both matter and antimatter appear as informational excitations with opposite phase gradients—no additional postulates required.

7. Coupling Between ψ and Curvature

The derivation of both the Einstein and Dirac equations within an informational framework reveals that neither geometry nor matter is fundamental—both emerge from coherence dynamics. The final step in the unification is to show that these structures not only coexist, but are **dynamically coupled**: the evolution of ψ affects curvature, and curvature in turn governs the propagation of ψ . This reciprocity is what defines a unified physical field theory.

7.1 ψ in a Curved Informational Background

As derived in the preceding section, $\psi(x,t)$ evolves according to:

$$\left(i\gamma^{\mu} D_{\mu} - m\right)\psi = 0$$

Here, the covariant derivative D encodes parallel transport with respect to the informational metric $g_{\mu\nu}^{(\text{inf})}$, and the gamma matrices are adapted to the local coherence flow.

This implies:

- ψ is sensitive to **coherence curvature** $\Theta_{\mu\nu}$,
- ψ's propagation is **bent** by the semantic structure of the manifold,
- Effects analogous to gravitational redshift, geodesic deviation, and spin-connection arise from **field-induced geometry**, not external spacetime.

7.2 Informational Feedback Loop

The ψ field is not merely a passive test structure. Its internal dynamics—and especially its collapse interactions—alter the resolution field ϕ, which in turn modulates the curvature source $T_{\mu\nu}^{(\text{inf})}$.

This gives rise to a **closed feedback loop**:

$$\psi \rightarrow \delta\phi \rightarrow \delta\Omega \rightarrow \delta g_{\mu\nu}^{(\text{inf})} \rightarrow \delta D_\mu$$

The implication is profound:

- ψ shapes the geometry that governs it.
- The informational system is **self-curving** and **self-consistent**.
- There is no ontological distinction between "matter" and "space"; both are **phases of coherent structure**.

7.3 Informational Equivalence Principle

In this framework, the equivalence principle is reinterpreted:

- All stable excitations (ψ fields) follow **paths of maximal coherence**.
- These paths coincide with geodesics of $g_{\mu\nu}^{(\text{inf})}$,
- Local resolution dynamics are **indistinguishable from acceleration** in an informationally flat region.

This reproduces the inertial-gravitational equivalence from **semantic first principles**. The gravitational force is not a force—it is the expression of **informational tension gradients** experienced as coherent curvature.

8. Conclusion

This work demonstrates that the fundamental equations governing both gravity and quantum matter—Einstein's field equations and the Dirac equation—can be fully and rigorously derived from an informational variational principle. These results arise without assuming spacetime, quantization, spinor structure, or classical fields. Instead, both geometry and matter emerge from the same deeper substrate: **semantic coherence, resolution, and informational recursion**.

Through the fields $\phi, \psi, \Omega, \Theta_{\mu\nu}, g,$, the framework constructs:

- An emergent metric $g_{\mu\nu}^{(\text{inf})}$ from coherence gradients,
- A curvature tensor $\Theta_{\mu\nu}$ that produces the Einstein tensor,
- A stress-energy source $T_{\mu\nu}^{(\text{inf})}$ from collapse gradients in resolution,
- A coherent excitation field $\psi(x, t)$ whose dynamics yield the Dirac equation,

- An exact feedback loop coupling excitation to geometry.

These derivations are not conceptual approximations—they are **exact reductions** from the informational Lagrangian. Geometry is not assumed; it is resolved. Quantum behavior is not inserted; it is structured. Constants such as $\hbar$, c , and G arise not as external inputs but as statistical features of coherence dynamics.

The informational ontology dissolves the divide between space and matter, between classical and quantum, between geometry and energy. All are expressions of a single variational substrate: **information under constraint**.

This unified reduction positions the informational framework not merely as a reinterpretation of existing physics, but as a viable candidate for a foundational theory. It opens new avenues for modeling collapse, entanglement, gauge symmetry, and particle spectra—not by layering new structures, but by resolving deeper semantic dynamics already embedded in the fabric of reality.

References

De Cerqueira Santos, A. (2025). *Meta-Principia: The Informational Foundations of Physics* (Unpublished manuscript).