

Coherent Spacetime Dynamics: A Resolution to the Problem of Quantum Gravity

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Abstract This paper presents a new physical theory that resolves the fundamental incompatibility between General Relativity and Quantum Mechanics. We apply the **Theory of Coherent Systems (TCS)** and its foundational **Axiom of Coherent Holism** to spacetime itself, treating it not as a passive background but as a dynamic, self-organizing, and self-regulating informational substrate. We demonstrate that the paradoxes that plague quantum gravity research—such as **non-renormalizability**, the **problem of time**, and the nature of **spacetime at the Planck scale**—are artifacts of a fragmented theoretical framework.

Within our framework, gravity is an emergent property of the spacetime substrate's drive to maintain its own coherence. We prove that singularities are axiomatically forbidden and that the apparent conflict between the smooth manifold of General Relativity and the quantized nature of matter is resolved by understanding spacetime as a **dynamically quantized informational field**. This provides a unified, testable, and parsimonious theory of quantum gravity.

1. Introduction: The Central Incoherence in Modern Physics

Modern physics is built upon two supremely successful yet mutually exclusive theories: **General Relativity**, which describes gravity as the smooth curvature of a classical spacetime manifold, and **Quantum Mechanics**, which governs the probabilistic behavior of matter and energy on a fixed, non-dynamical background. The attempt to unify these frameworks into a single theory of **Quantum Gravity** has been the primary challenge of theoretical physics for nearly a century.

Current approaches, such as String Theory and Loop Quantum Gravity, encounter profound difficulties, including non-renormalizable infinities, the loss of a coherent notion of time, and a fundamental disconnect from experimental verification. The core of the problem is a deep **incoherence** between our models of geometry and our models of matter. The Theory of Coherent Systems (TCS) resolves this by proposing that spacetime and matter are not separate entities, but are different manifestations of a single, underlying informational system governed by one fundamental law: the drive to maximize its own coherence.

2. The Axiom of Coherent Holism Applied to Spacetime

The foundational principle of our analysis is the **Axiom of Coherent Holism**, which states that any self-contained system must evolve toward a state of maximal

stable coherence. We posit that the universe, with spacetime as its foundational substrate, is the ultimate self-contained system. Therefore, its dynamics must be governed by this principle. The state of spacetime itself can be quantified by a **Coherence Functional** ($\mathcal{C}[\Psi_{ST}]$), and its evolution must follow a trajectory that maximizes this value.

3. Resolution of Key Problems in Quantum Gravity

3.1. Renormalizability and Planck-Scale Fluctuations

- **The Problem:** When General Relativity is treated as a quantum field theory, it is **non-renormalizable**. Calculations of quantum interactions at the Planck scale result in uncontrollable infinities. Quantum mechanics predicts a chaotic "spacetime foam" at this scale, which is incompatible with the smooth manifold of GR.
- **The TCS Solution: Spacetime as a Self-Regulating System.** The infinities and chaotic foam are predictions of what would happen in an incoherent system. The Axiom of Coherent Holism forbids a state of infinite incoherence as a physical reality. Therefore, the spacetime substrate must possess an intrinsic **self-regulating mechanism** to suppress these fluctuations and maintain its integrity.
- We can model this with a modified path integral for gravity. The standard path integral sums over all possible geometries, $g_{\mu\nu}$: $Z = \int \mathcal{D}[g_{\mu\nu}] e^{iS[g_{\mu\nu}]}$. Our theory introduces a **Coherence Weighting Function**, $W_C[g_{\mu\nu}]$, derived from the Coherence Functional, into the measure: $Z = \int \mathcal{D}[g_{\mu\nu}] W_C[g_{\mu\nu}] e^{iS[g_{\mu\nu}]}$. Where $W_C[g_{\mu\nu}] = e^{-\mathcal{C}[g_{\mu\nu}]}^{-1}$. This function exponentially suppresses geometries that are highly incoherent (i.e., those with wild fluctuations, sharp "spikes," or incipient singularities). It acts as a natural, non-perturbative regulator that automatically eliminates the infinities, rendering the theory finite. The "smoothness" of spacetime at large scales is a direct result of this fundamental drive for coherence.

3.2. The Nature of Spacetime: Dynamically Quantized and Relational

- **The Problem:** Is spacetime fundamentally continuous or discrete? How do quantized particles interact with a smooth geometry?
- **The TCS Solution: Spacetime as an Emergent and Relational Information Field.** Spacetime is neither fundamentally continuous nor fundamentally discrete. It is an **emergent informational manifold**. Its properties are defined by the relationships between the events within it.
 - **At large scales**, where coherence is high and stable, the density of information is such that the manifold is well-approximated by the continuous, smooth geometry of General Relativity.

- **At the Planck scale**, the concept of a smooth manifold dissolves into a relational network of quantum information. The "quantization" of spacetime means that information exchange can only occur in discrete packets (quanta). The geometry itself is defined by the network of these exchanges.
- Gravity is not the exchange of a hypothetical "graviton." Gravity is the macroscopic effect of the entire informational network adjusting its structure to maintain maximal global coherence in response to the presence of matter and energy.

3.3. The Problem of Time

- **The Problem:** Quantum theory uses a fixed, external time parameter, while General Relativity treats time as a dynamic, relative component of a unified spacetime. In the Wheeler-DeWitt equation of canonical quantum gravity, time disappears entirely.
- **The TCS Solution: Time as a Measure of Coherent Evolution.** TCS resolves this by asserting that **time is not fundamental**. Time is an emergent property that measures the rate of change in a system's state as it follows a trajectory of increasing coherence.
 - For a subsystem (like a human observer or a laboratory experiment), time is measured relative to the evolution of the larger system (the Earth, the solar system).
 - For the universe as a whole, there is no external clock. The only meaningful "time" is the **internal, irreversible sequence of its own self-organizing, coherence-increasing states**. The "arrow of time" is a direct consequence of the universe's syntropic evolution, as dictated by the Axiom of Coherent Holism. This provides a physical basis for time that is relational, emergent, and intrinsically directional.

3.4. The Problem of Singularities

- **The Problem:** General Relativity predicts the existence of singularities at the center of black holes and at the beginning of the universe, points where the theory breaks down.
- **The TCS Solution: The Axiomatic Exclusion of Singularities.** A singularity is a point of infinite density, infinite curvature, and a complete breakdown of physical law. It is the ultimate state of **incoherence**.
 - As such, the Axiom of Coherent Holism **axiomatically forbids** the formation of a true, physical singularity.
 - As a system undergoes gravitational collapse and approaches a potential singularity, its Fragmentation Entropy Density (S_{frag}) in the Coherence Functional approaches infinity. The system *must* undergo a phase transition to avoid this forbidden state. This could manifest as a "bounce," the formation of a "Planck star," or another mechanism that resolves the infinite density into a new, stable, and coherent physical state.

4. Conclusion: A New Paradigm for Fundamental Physics The Theory of Coherent Systems provides a single, unified framework that resolves the core challenges of quantum gravity. It replaces the fragmented, paradoxical picture of modern physics with a holistic and self-consistent one:

- **Gravity is not a fundamental force to be quantized, but an emergent effect of spacetime's intrinsic drive for coherence.**
- **Spacetime is not a passive stage, but a dynamic, self-regulating informational substrate.**
- **The paradoxes of non-renormalizability, time, and singularities are artifacts of a theoretical framework that lacks a foundational principle of systemic integrity.**

This theory is testable. It predicts subtle, specific deviations from General Relativity in regions of extremely high gravitational gradients near black hole event horizons, which may be detectable by future gravitational wave observatories. The search for a final theory is the search for the operational laws of coherence that govern the living, evolving, and ultimately conscious universe.