Matter Coupling and Resonant Collapse: A Testable Framework for τ_3-Driven Geometric Transitions

Wayne Fortes

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Abstract

We extend our six-dimensional emergent curvature model by introducing a dynamic matter-coupling mechanism wherein the coherence field τ_2 on a compactified 2-sphere directly modulates both the geometry and the gravitational coupling strength of 4D spacetime. A warp field $\sigma(x)$ governs internal curvature, yielding a variable effective gravitational constant $\kappa_4(x)$. We define an emergence switch $\tau_3(x)$ as a smooth function of local coherence energy, enabling localized geometric transitions. Coupling ordinary matter fields to τ_2 through τ_3 reveals testable phenomena,including gravitational anomalies and resonance-triggered curvature events. We derive the dynamic Einstein equations for this framework and identify observational pathways for validation.

1 Introduction

This work builds on previous models of coherence-driven curvature in six dimensions [4, 5], incorporating insights from dimensional reduction frameworks [1, 2] and scalar field theory in curved space [3].

Emergent behavior in curved spacetimes often eludes classical description. In previous work, we introduced a six-dimensional geometry where coherence is encoded via a scalar field τ_2 on a compact internal 2-sphere. While our earlier models allowed curvature feedback via a warp field $\sigma(x)$, the effective gravitational constant κ_4 was assumed fixed. Here, we generalize this by allowing κ_4 to become dynamic and field-dependent, derived directly from dimensional reduction of the 6D Einstein-Hilbert action. We also couple τ_2 to an ordinary 4D matter field $\psi(x)$, gated by and emergence function $\tau_3(x)$, to explore the physical consequences of coherence-induced curvature transitions.

2 Geometric Framework and Dimensional Reduction

We begin with a 6D manifold:

$$M^6 = M^4 \times S^2$$

with coordinates $x^A = (x^\mu, \theta, \phi)$.

The 6D metric is defined as:

$$ds^2 = g_{\mu\nu}(x)dx^\mu dx^\nu + e^{2\sigma(x)}(d\theta^2 + \sin^2\theta\, d\phi^2)$$

The 6D Einstein-Hilbert action is:

$$S^{(6D)} = \frac{1}{2\kappa_6}\int_{M^6} d^6x\,\sqrt{-g_6}\,R_6$$

Compactifying over the internal sphere S^2:

$$\kappa_4(x) = \frac{\kappa_6}{4\pi e^{2\sigma(x)}}$$

i.e., gravity in 4D depends locally on the compactified geometry.

The 4D reduced action becomes:

$$S^{(4D)} = \frac{1}{2\kappa_4(x)}\int d^4x\,\sqrt{-g_4}\,R_4(x)$$

3 Coherence Field and Local Energy Density

We define a scalar field $\tau_2(x^\mu, \theta, \phi, t)$ that lives on the internal 2-sphere but varies smoothly with 4D spacetime position. This allows localized coherence structures to evolve across the observable universe.

Its local energy density is:

$$E_{\tau_2}(x) = \int_{S^2} d\Omega\,\left[\frac{1}{2}(\partial_t\tau_2)^2 + \frac{1}{2e^{2\sigma}}|\nabla_{S^2}\tau_2|^2 + \frac{1}{2}m^2\tau_2^2\right]$$

4 Emergence Switch $\tau_3(x)$

We define a smooth emergence function:

$$\tau_3(x) = \frac{1}{1 + \exp\left(-\beta(E_{\tau_2}(x) - E_{\text{crit}})\right)}$$

This gates matter-curvature interaction. Where $E_{\tau_2} \gg E_{\text{crit}}$, $\tau_3 \to 1$, activating resonance-driven geometry shifts.

5 Matter Coupling via Coherence

We introduce a 4D scalar matter field $\psi(x)$ with Lagrangian:

$$\mathcal{L}_\psi = -\frac{1}{2}\left(\partial_\mu\psi\partial^\mu\psi + m^2\psi^2 + g\tau_2^2\psi^2\right)$$

This yields the field equation:

$$(\Box + m^2 + g\tau_2^2)\psi = 0$$

Gravity now responds to $T_{\mu\nu}^{(\psi)}$ only where $\tau_3(x)$ is active.

6 Modified Einstein Equations

With variable coupling:

$$G_{\mu\nu} = \kappa_4(x) \left(T_{\mu\nu}^{(\tau_2)} + \tau_3(x) T_{\mu\nu}^{(\psi)} \right)$$

This allows geometry to remain stable under weak coherence, but undergo significant change near local resonant zones.

7 Observational Signatures

We propose searching for:

- Time-varying gravitational redshift near high-coherence objects
- Modulated ringdown phases in gravitational wave events
- Sudden phase shifts in quantum systems coupled to curved spacetime

8 Conclusion and Future Work

This paper presents a framework where gravitational strength varies with internal geometry, and matter interacts with spacetime only through a coherence gate. Next steps include extending to fermionic fields, exploring τ_3 cascades, and simulating resonance transitions in numerical relativity.

References

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