Residual Curvature as Emergent Memory: A Field-Based Resolution of Dark Matter Phenomena

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1. Abstract

This paper redefines the concept of residual curvature using a six-dimensional curvature-memory framework incorporating a compactified 2-sphere (S^2) geometry and the emergence field τ_3. By holding coordinate time ($\tau_1 \equiv t$) as standard and fully compatible with general relativity, we present $\kappa(t)$ as a curvature activation function that governs the onset and persistence of the τ_3 field. A formal memory operator is introduced to map spacetime curvature into the internal geometry. We demonstrate that τ_3 can account for observed galactic-scale gravitational phenomena typically attributed to dark matter without invoking exotic particles.

2. Framework Geometry and Field Definitions

We model spacetime as:

$$\mathcal{M}_6 = \mathbb{R}^3 \times \mathbb{R}^1 \times S^2$$

Where:

- $\mathbb{R}^3$ represents observable space (x, y, z)
- $\mathbb{R}^1$ corresponds to coordinate time ($\tau_1 \equiv t$)
- S^2 is a compactified internal curvature space encoding field memory

Field Structures:

- $\kappa(t)$: Curvature readiness function, triggering field transitions
- $\tau_2(x, \theta, \phi, t)$: Coherence field on S^2, defined dynamically
- $\tau_3(x)$: Emergence field; activated when coherence energy exceeds Planck-threshold

3. Curvature-Memory Mapping

We introduce a curvature-memory operator $\mathcal{C}_S(x)$ mapping spacetime curvature history into internal field states:

$$\mathcal{C}_S(x) = \int_{t_0}^{t} \int_{\Sigma} f(R_{\mu\nu}(x', t'))W(x, x')\, d^3x'\, dt'$$

This expression defines how historical curvature is projected into S^2 coherence field τ_2, allowing memory encoding within compactified geometry. $W(x, x')$ is a weighting kernel (e.g., Gaussian falloff), and $f(R_{\mu\nu})$ is a curvature-based filter.

4. Emergence Dynamics and τ_3 Activation

The local coherence energy $E_{\tau_2}(x)$, integrated over S^2, triggers emergence when it surpasses a critical threshold, now defined as the Planck power limit $P_{\text{Planck}} = c^5/G$:

$$\tau_3(x) = \frac{1}{1 + \exp[-\beta(E_{\tau_2}(x) - P_{\text{Planck}})]}$$

This models τ_3 as a continuous phase-transition field, activating resonance-based emergence via compactified memory [1, 2].

5. Dark Matter Phenomena as τ_3 Residual Geometry

- **Galaxy Rotation Curves:** Emergent τ_3 geometry sustains curvature without baryonic mass [3, 4].
- **Bullet Cluster:** τ_3 persists spatially decoupled from hot gas via curvature-memory inertia [5].
- **Weak Lensing in Voids:** Fossil τ_3 fields from early structure encode lensing geometry [6].

6. Coupling and Observational Predictions

- τ_3 modifies Einstein field equations locally via $\kappa_4(x) = \kappa_6/(4\pi e^2\sigma(x))$ [2]
- RCEM predicts spatial variation of τ_3 correlated to galactic formation history
- Curvature without mass (e.g., void lensing) offers a falsifiable signature

7. Conclusion

The Residual Curvature as Emergent Memory (RCEM) model, grounded within the Coherence-Driven Curvature Model (CDCM) framework, offers a fully GR-compatible explanation for dark matter phenomena via a geometric memory mechanism encoded in a compactified 2-sphere. Unlike particle-based models, RCEM reframes dark matter as a curvature echo—emergent from historical gravitational dynamics, and sustained through a resonance-based scalar field τ_3.

Compared to broader emergent spacetime proposals such as the Topological Tension Residual Curvature Model (TTRCM), RCEM is distinguished by its mechanistic specificity. It features:

- A dynamically stabilized extra-dimensional geometry [2]
- A formally defined curvature-memory operator $\mathcal{C}_S(x)$ [1]
- An energy threshold for emergence explicitly linked to the Planck power [2]
- Local causality-preserving dynamics of τ_3 evolution [2]

This positions RCEM as a model with strong internal completeness, offering both explanatory clarity and testable predictions.

References

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