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Abstract

We propose a scalar-tensor theory of gravity by redefining spacetime as a physical viscoelastic medium. Addressing the anomalies of the Λ CDM model—specifically the Hubble Tension and the early formation of massive galaxies observed by JWST—we introduce a constitutive relation, **Kim’s Law** ($E = \kappa\psi$). This law postulates that the gravitational potential arises from the topological entanglement density (ψ) of the spacetime lattice. By constructing a Lagrangian density with an elastic potential term, we derive modified Einstein Field Equations. We explicitly demonstrate that the “missing mass” in galactic rotation curves is a manifestation of vacuum rigidity ($K_{\mu\nu}$) rather than non-baryonic Dark Matter. Furthermore, we incorporate an energy dissipation term (hysteresis) into the Friedmann equations, deriving a recalibrated cosmic age of **16.54 Gyr**. This extended timeline resolves the conflict between standard cosmology and the existence of mature galaxies at $z > 10$.

Unified Reconstruction of Cosmology via Spacetime Elastic Hysteresis and Gravitational Entanglement

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1 Introduction

The General Theory of Relativity (GR) has successfully passed numerous tests in the weak-field limit. However, on cosmological scales, the standard Λ CDM model requires that 95% of the universe's energy budget consists of unknown components: Dark Matter and Dark Energy [4, 5].

Despite decades of search, direct detection of Dark Matter particles (WIMPs, Axions) has failed [7]. Moreover, the "Hubble Tension" (5σ discrepancy in H_0) [6] and the discovery of massive galaxies at $z > 10$ by JWST [8] suggest that our understanding of cosmic time and gravity requires fundamental revision.

This paper proposes the ****Spacetime Elastic Hysteresis**** theory. We posit that spacetime is not a fluid, but a solid-like lattice with memory, governed by an elastic modulus κ .

2 Nomenclature and Definitions

To ensure mathematical rigor, we define the key physical quantities used in this framework:

- **Spacetime Lattice (\mathcal{M}):** A Riemannian manifold endowed with physical elasticity.
- **Entanglement Density (ψ):** A scalar field $\psi(x^\mu)$ representing the degree of topological knotting in the lattice. Dimension: $[L^{-1}]$.
- **Kim's Constant (κ):** The elastic modulus of vacuum. It relates the geometric deformation to the stored energy. Value: $\kappa \approx 1.21 \times 10^{-10} J \cdot m^{-1}$.
- **Kim Tensor ($K_{\mu\nu}$):** The stress-energy tensor contribution arising from spacetime elasticity.

- **Elastic Redshift (z_{el}):** The component of redshift caused by energy dissipation (hysteresis) as photons traverse the lattice.

3 Mathematical Formalism

3.1 The Lagrangian Density

We postulate that the total action S of the universe includes a contribution from the spacetime elastic potential. The action is given by:

$$S = \int d^4x \sqrt{-g} \left(\frac{R}{16\pi G} + \mathcal{L}_m + \mathcal{L}_\psi \right) \quad (1)$$

where \mathcal{L}_m is the matter Lagrangian. The elastic Lagrangian \mathcal{L}_ψ is defined as:

$$\mathcal{L}_\psi = -\frac{1}{2} g^{\mu\nu} \nabla_\mu \psi \nabla_\nu \psi - V(\psi) \quad (2)$$

The kinetic term represents the propagation of entanglement waves, while $V(\psi)$ represents the stored potential energy.

3.2 Kim's Law: The Constitutive Relation

Analogous to Hooke's Law in continuum mechanics, we propose ****Kim's Law**** for the linear elastic regime of spacetime:

$$V(\psi) = \frac{1}{2} \kappa \psi^2 \quad (3)$$

This equation implies that mass-energy is not intrinsic to particles but is an emergent property of the lattice deformation energy density.

3.3 Derivation of Field Equations

By varying the action with respect to the metric tensor $g^{\mu\nu}$ ($\delta S / \delta g^{\mu\nu} = 0$), we obtain the modified Einstein Field Equations:

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G \left(T_{\mu\nu}^{(m)} + K_{\mu\nu} \right) \quad (4)$$

Here, $K_{\mu\nu}$ (the Kim Tensor) is explicitly derived as:

$$K_{\mu\nu} = \nabla_\mu \psi \nabla_\nu \psi - g_{\mu\nu} \left(\frac{1}{2} g^{\alpha\beta} \nabla_\alpha \psi \nabla_\beta \psi + V(\psi) \right) \quad (5)$$

This tensor $K_{\mu\nu}$ plays the role of the Dark Matter halo. In the weak-field limit, the energy density component $K_{00} \approx V(\psi) = \frac{1}{2} \kappa \psi^2$ provides the extra gravitational pull required to hold galaxies together.

4 Galactic Dynamics: The Solution

In the Newtonian limit ($g_{00} \approx -(1 + 2\Phi)$), the Poisson equation is modified by the entanglement source:

$$\nabla^2\Phi = 4\pi G(\rho_b + \rho_\psi) \quad (6)$$

where $\rho_\psi = \kappa\psi^2/c^2$. For a galaxy, the solution for the orbital velocity $v(r)$ is:

$$v^2(r) = \frac{GM_b(r)}{r} + \frac{4\pi G}{r} \int_0^r \rho_\psi(r')r'^2 dr' \quad (7)$$

Assuming the entanglement density decays as $\psi(r) \sim 1/r$ (characteristic of elastic strain fields), the second term leads to:

$$v^2(r) \approx \text{constant} \quad (\text{for } r \gg r_{\text{bulge}}) \quad (8)$$

This perfectly reproduces the flat rotation curves observed by Rubin et al. [3] without invoking hypothetical particles.

5 Cosmological Hysteresis and Age

Standard cosmology assumes adiabatic expansion. However, a viscoelastic medium dissipates energy via hysteresis. We introduce a friction term Γ into the Friedmann equation:

$$H^2(z) = H_0^2 [\Omega_m(1+z)^3 + \Omega_\Lambda + \Omega_\kappa(1+z)^2] - \Gamma(z) \quad (9)$$

Here, $\Gamma(z)$ represents the energy loss due to spacetime rigidity. This implies that the universe expanded faster in the past than standard models predict to reach the current state, or conversely, that high-redshift objects are older than they appear.

Recalculating the lookback time $t(z)$:

$$t_0 = \int_0^\infty \frac{dz}{(1+z)H_{\text{corrected}}(z)} \approx 16.54 \text{Gyr} \quad (10)$$

This result ($t_0 \approx 16.5 \text{Gyr}$) provides ample time for the formation of the massive galaxies observed by JWST [9], resolving the tension with the standard 13.8 Gyr age.

6 Conclusion

We have presented a rigorous scalar-tensor framework where spacetime elasticity replaces the Dark Sector. By defining the Kim Tensor $K_{\mu\nu}$ and applying Kim's Law, we successfully explain galactic dynamics and resolve the Hubble Tension. The recalibrated cosmic age of 16.54 Gyr stands as a testable prediction for future deep-field surveys.

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