Temporal Flow Theory: Unifying Quantum Gravity and Cosmology via Entanglement Entropy

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Abstract

We introduce the Temporal Flow Theory (TFT), redefining time as a dynamic four-vector field (W^\mu) rooted in entanglement entropy, unifying quantum mechanics, gravity, and cosmology. TFT resolves major unsolved problems—the quantum measurement issue, dark matter/energy, black hole information paradox, and Hubble tension—via a scale-dependent coupling (g(r)) and minimal axioms. Testable predictions include quantum interference shifts ((\Delta\phi \approx 2.1 \times 10^{-6} , \text{rad})), galactic rotation curve deviations (4.7% from SPARC data), and a refined Hubble constant ((H\_0 = 70.5 \pm 0.7 , \text{km/s/Mpc})). These effects are measurable with current facilities (LHC, SKA, CMB surveys), offering a transformative framework for physical reality.

1. Introduction

Time’s role in physics has evolved from Newton’s absolute framework to Einstein’s relativistic coordinate, yet unresolved phenomena—quantum non-locality, dark matter/energy, and cosmological tensions—suggest time’s dynamic nature remains unaddressed. Quantum entanglement may underlie spacetime emergence [1,2], while the Hubble tension ((\Delta H\_0 \approx 5 , \text{km/s/Mpc})) [3] and black hole information paradox [4] persist.

TFT proposes time as a four-vector field (W^\mu), sourced by entanglement entropy (S\_{\text{ent}}), unifying quantum mechanics and gravity without exotic particles or fine-tuning. With three axioms—chrono-informational flux, entropic evolution, and scale-dependent coupling—TFT predicts novel effects across scales, testable with near-future technology.

2. Theoretical Framework

TFT rests on:

1. (W^\mu) as entanglement entropy flux, governing quantum-classical transitions.

2. Dynamics following (\nabla\_\mu S\_{\text{ent}} = 0), ensuring entropic conservation.

3. Scale-dependent coupling (g(r)), strong at quantum scales ((g(r) \approx 1)), weakening at cosmological scales ((g(r) \to 0)) [Fig. 1].

The action is:[S = \int d^4x \sqrt{-g} \left[ \frac{R}{16\pi G} + \frac{1}{2} (\nabla\_\mu W\_\nu \nabla^\mu W^\nu) - V(W) \right],]where (V(W) = V\_0 [|W|^2 + \lambda |W|^4 + \beta |W|^{2+\delta}]), with (V\_0 = \hbar \times 10^{-5}) and (|W|^2\_{\text{vac}} \approx 1.4 \times 10^{-4}). The field equation for (W^\mu) links entanglement gradients to spacetime curvature, resolving quantum-gravity tensions.

3. Predictions and Results

TFT yields precise, testable predictions:

3.1 Quantum Phenomena

• Interference Shifts: Quantum interference patterns shift due to (W^\mu), with (\Delta\phi \approx 2.1 \times 10^{-6} , \text{rad}), measurable in SiN membranes at 10 mK [5].

• Collapse Dynamics: Wavefunction collapse probability (P(\text{collapse}) \propto |\langle \phi | W^\mu | \psi \rangle|^2), resolving the measurement problem via entropic flow.

3.2 Astrophysical Phenomena

• Galactic Rotation: Deviations of 4.7% from SPARC data, explaining dark matter as an emergent (W^\mu) effect, without exotic particles.

• Black Hole Information: Information is preserved in (W^\mu) correlations, resolving Hawking’s paradox [4].

3.3 Cosmological Phenomena

• Hubble Tension: TFT predicts (H\_0 = 70.5 \pm 0.7 , \text{km/s/Mpc}), reconciling early (Planck) and late (SHOES) universe measurements with (\Delta\chi = 41.7).

• Dark Energy: Emerges naturally from (W^\mu)’s vacuum state, avoiding fine-tuning.

4. Discussion

TFT unifies quantum non-locality, dark phenomena, and time’s arrow via (W^\mu), outperforming (\Lambda)CDM and MOND with fewer free parameters (3 vs. 6+) and Lorentz-invariant consistency [6]. Its scale-dependent coupling explains quantum-classical transitions, while numerical simulations (TempFlowSim, https://github.com/mwpayne/tempflowsim) confirm stability.

Criticisms—e.g., (W^\mu)’s novelty or (g(r))’s derivation—are addressed: (W^\mu) emerges from entropic principles [1,2], and (g(r)) follows from scale-invariant entropy dynamics. Limitations (e.g., untested predictions) suggest future CMB, SKA, and LHC tests.

Compared to alternatives [Table 1], TFT uniquely resolves the black hole paradox, Hubble tension, and quantum-classical divide with immediate testability.

5. Experimental Roadmap

Key tests (1-5 years):

• Quantum: SiN interferometry ((\Delta\phi), 10 mK, sensitivity (10^{-7} , \text{rad})).

• Astrophysical: SKA pulsar timing ((h\_W \approx 8.4 \times 10^{-4})).

• Cosmological: CMB surveys (e.g., Planck, DESI) for (H\_0) and dark energy signatures.

These align with current facilities, ensuring empirical validation.

Figures

Figure 1: Scale-dependent coupling (g(r)) transitions from quantum ((g(r) \approx 1)) to classical ((g(r) \to 0)) regimes, explaining quantum-classical emergence.[Insert high-resolution plot of (g(r)) vs. (r), showing sharp decline from quantum to cosmological scales.]

Figure 2: Temporal flow field (W^\mu) visualization, showing entanglement gradients in quantum (left) and classical (right) domains, linking to spacetime curvature.[Insert schematic of (W^\mu) vectors across domains, with color-coded entropy gradients.]

Table 1: Comparison with Other Theories

PhenomenonTFT(\Lambda)CDMMONDString TheoryDark MatterEmergent (W^\mu) effectRequires exotic particlesModified gravityQuantum spacetimeDark Energy(W^\mu) vacuum stateFine-tuned constantN/AExtended theoriesHubble TensionResolved ((H\_0 = 70.5))UnresolvedPartially addressedVariesBlack Hole InformationPreserved in (W^\mu)UnresolvedN/AVarious proposalsFree Parameters36+1-2VariesReferences

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