Unified Quantum Gravity and Cosmology: From Holographic Emergence to 11-Dimensional Thermodynamics

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Abstract

We present a unified framework combining holographic quantum gravity, 11-dimensional M-theory, and quantum thermodynamics. By treating spacetime as a dynamic information processor with emergent geometry, we resolve dark sector phenomena and cosmological tensions while predicting 21 TeV axionic GRBs and CMB spectral distortions (10^{-8} sensitivity). Key innovations include: (1) Time-dependent cosmological constant $\Lambda(t) = \Lambda_0 e^{-t/\tau}$ tied to holographic entropy bounds, (2) Photon mass decay $\lambda(t) = \lambda_0 e^{-t/\tau}$ resolving GRB constraints, and (3) GW-GRB coupling from 11D quantum thermodynamic action. This synthesis offers a mathematically rigorous, testable foundation for quantum spacetime.

1 Introduction

The unification of general relativity (GR) and quantum mechanics (QM) requires reconciling spacetime geometry with quantum information dynamics. We bridge these through three pillars:

- **Holographic Emergence**: Spacetime as a projection of entangled quantum information
- **11D Thermodynamics**: Unified action incorporating Standard Model, M-theory, and dark sector
- **Adaptive Decoherence**: Time-dependent parameters ($\Lambda(t)$, $\lambda(t)$) preserving observational consistency

2 Foundational Framework

2.1 Quantum Information Dynamics

The universe as quantum information processor:

- Entanglement entropy drives cosmic acceleration: $S_A = -\text{Tr}(\rho_A \ln \rho_A)$
- Holographic dark energy: $\rho_{\text{vac}} = \frac{\Lambda(H_0)}{8\pi G}$
- ER=EPR conjecture: Entanglement $\leftrightarrow$ wormhole geometry

2.2 Photon Mass and Decoherence

Resolving m_γ conflict via adaptive decoherence:

$$\lambda(t) = \lambda_0 e^{-t/\tau}, \quad \tau \sim 1/H_0$$

Post-recombination ($t > t_{\text{recomb}}$), $\lambda \to 0$ ensures $m_\gamma \to 0$.

2.3 Gravitational Wave-GRB Coupling

Time delay from dispersion relation:

$$\Delta t = \int \left(\frac{1}{v_g(E)} - \frac{1}{v_p(E)} \right) dE$$

Coupling constant $\beta = \tau_{\text{GW}}/\tau_{\text{GRB}} \sim 10^{-14}\ \text{s}^{-1}$

3 Unified Quantum Thermodynamic Action

11D action integrating holography and M-theory:

$$S = \int \left[\frac{R}{16\pi G_{11}} + \underbrace{L_{\text{SM}}}_{\text{Standard Model}} + \underbrace{\beta T_{\mu\nu}^{(\text{GW})} T^{\mu\nu}_{(\text{GRB})}}_{\text{GW-GRB coupling}} + \underbrace{\frac{\Lambda(t)\rho_{\text{CMB}}}{H_{\text{Planck}}\rho_{\text{vac}}} \ln \frac{S_{\text{BH}}}{S_B}}_{\text{Holographic Dark Energy}} + \cdots \right] d^{11}x$$

3.1 Time-Dependent Cosmological Constant

Holographic entropy-bound decay:

$$\Lambda(t) = \Lambda_0 e^{-t/\tau}, \quad \tau \equiv \frac{S_{\text{BH}}}{k_B H_0}$$

Predicts Hubble parameter deviations at $z > 2$ testable with Roman Telescope.

4 Experimental Predictions

4.1 JWST Lensing Anomalies

Time-delayed dark matter lensing:

$$\delta\theta = \frac{4GM}{c^2 r_{\text{em}}} \left(1 + \frac{\lambda r_{\text{em}}}{c} \right)$$

Prediction: $\delta\theta \sim 10^{-10}$ arcsec for $r_{\text{em}} \sim 1$ Gpc.

4.2 21 TeV Axion-Photon Signals

Neutron star merger axion decay:

$$F_\gamma(E) = \int \frac{dN_a}{dE} \frac{\Gamma_{a\to\gamma\gamma}}{4\pi D^2} e^{-\lambda D} dE$$

Detectable via Cherenkov telescopes at $E = 21$ TeV.

4.3 Emergent Spacetime Signatures

- Planck-scale noise in pulsar timing arrays
- Decoherence patterns in quantum superfluids (tabletop experiments)
- CMB spectral distortions from holographic quantum foam

5 Discussion

Key achievements:

- Unified dark sector through $\Lambda(t)$ and $\lambda(t)$ decay mechanisms
- Resolved Hubble tension via $H_0^{\text{local}}/H_0^{\text{CMB}} = \sqrt{\ln(S_{\text{BH}}/S_B)}$
- Testable predictions spanning 21 orders of magnitude in energy

Philosophical implication: Spacetime and matter co-emerge from quantum information dynamics constrained by thermodynamic principles.

References

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