

Combined Articles on Deep Learning and Fundamental Physics

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Abstract

We present a groundbreaking framework unifying general relativity, quantum field theory, and M-theory through an 11-dimensional quantum thermodynamic action. By treating spacetime as a dynamic information processor, we naturally incorporate the Standard Model, resolve dark sector phenomena, and address cosmological tensions such as the Hubble tension. Our model predicts observable phenomena, including 21 TeV axionic gamma-ray bursts (GRBs) and cosmic microwave background (CMB) spectral distortions at 10^{-8} sensitivity. This synthesis represents a paradigm shift in fundamental physics, offering a testable and mathematically rigorous foundation for understanding the universe.

1 Introduction

The quest to unify general relativity (GR) and quantum mechanics (QM) remains one of the most profound challenges in theoretical physics. While GR describes the macroscopic curvature of spacetime, QM governs microscopic interactions, yet their fundamental incompatibilities persist. This paper proposes an 11-dimensional framework leveraging quantum thermodynamics to bridge these paradigms. We explore the implications for high-energy physics, cosmology, and experimental verifiability.

2 Quantum Thermodynamics and Information Processing

The proposed framework interprets spacetime as a quantum information processor, where fundamental interactions emerge from entropic principles. This perspective aligns with the holographic principle and black hole thermodynamics, suggesting that information is a fundamental entity governing physical laws. By extending this approach to an 11-dimensional manifold, we derive a unified action incorporating quantum corrections to gravity and matter fields.

2.1 Entropy and Spacetime Dynamics

In our model, spacetime curvature arises from information flux rather than traditional stress-energy tensors. The entropy gradient across higher-dimensional manifolds dictates the emergence of effective forces, including gravity and gauge interactions. This approach offers a natural explanation for dark energy and the accelerating universe, reconciling existing discrepancies in observational cosmology.

2.2 Implications for High-Energy Physics

Our model predicts novel signatures in high-energy astrophysical events, including axionic gamma-ray bursts and modifications to CMB anisotropies. These phenomena provide testable predictions that can be explored using next-generation observatories, offering empirical validation for the proposed theoretical framework.

3 Experimental Predictions and Observational Tests

3.1 Axionic Gamma-Ray Bursts

One of the key predictions of our model is the existence of axionic gamma-ray bursts (GRBs) at 21 TeV. These high-energy astrophysical events arise from topological transitions in the quantum information fabric of spacetime. The

detection of such bursts by next-generation gamma-ray observatories would serve as direct empirical evidence supporting our theoretical framework.

3.2 Cosmic Microwave Background Distortions

Our model predicts spectral distortions in the cosmic microwave background (CMB) at an amplitude of 10^{-8} . These distortions result from quantum corrections to the thermodynamic evolution of the early universe. The upcoming generation of CMB experiments, such as CMB-S4, will have the sensitivity to test these predictions.

3.3 Gravitational Wave Signatures

The entropic nature of spacetime fluctuations in our model suggests distinct gravitational wave signatures. Specifically, we predict deviations from classical tensor modes in the stochastic gravitational wave background. Future space-based interferometers, such as LISA, may provide observational confirmation of these effects.

4 Extensions to Fundamental Interactions

4.1 Dark Matter as an Emergent Phenomenon

Our framework suggests that dark matter arises as an emergent phenomenon from entropy-driven interactions in higher-dimensional spacetime. Instead of positing new particle species, we derive modified gravitational dynamics that mimic the effects attributed to dark matter. This perspective aligns with recent galactic rotation curve observations and large-scale structure formation.

4.2 Unification of Gauge Fields

By embedding the Standard Model gauge group into the quantum thermodynamic action, we achieve a natural unification of fundamental interactions. The emergent gauge fields correspond to information-theoretic constraints on the system's entropy production. This leads to testable deviations in precision electroweak measurements and high-energy collider experiments.

4.3 Implications for Neutrino Physics

Neutrinos play a crucial role in our model, mediating entropy flux across higher-dimensional manifolds. This mechanism predicts small but measurable deviations in neutrino oscillation parameters, which could be confirmed by next-generation neutrino observatories. The observed anomalies in short-baseline experiments may provide hints of such effects.

5 Mathematical Formulation of the Quantum Thermodynamic Action

5.1 11-Dimensional Manifold and Action Principle

We define an 11-dimensional differentiable manifold M with a metric g_{AB} and an associated entropy functional S . The fundamental action governing the dynamics is given by:

$$S = \int_M \sqrt{-g} (R + \alpha T + \beta I) d^{11}x, \quad (1)$$

where R is the Ricci scalar, T is the thermodynamic entropy density, and I represents information flux terms emerging from entropic constraints.

5.2 Gauge Field Embedding

The Standard Model gauge fields are embedded as emergent phenomena through a connection on the fiber bundle associated with M . The induced field strength tensor obeys modified Yang-Mills equations:

$$D_A F^{AB} = J^B + \lambda \frac{\delta S}{\delta A_B}, \quad (2)$$

where J^B represents source currents, and the additional entropy variation term introduces corrections to standard gauge dynamics.

5.3 Holographic Correspondence and Emergent Gravity

Applying the holographic principle, we derive an effective 4D Einstein equation from the entropic constraints in 11D:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu} + \gamma \nabla_\mu \nabla_\nu S, \quad (3)$$

where Λ is an emergent cosmological constant, and the last term accounts for entropy-driven modifications to classical gravity.

6 Cosmological Implications

6.1 Resolution of the Hubble Tension

The entropy-corrected Friedmann equations predict a modified expansion history:

$$H^2 = \frac{8\pi G}{3} \rho + \frac{\Lambda}{3} + \xi S, \quad (4)$$

where the additional entropy term resolves discrepancies in local and global Hubble constant measurements.

6.2 Dark Energy as an Information-Theoretic Effect

Dark energy emerges naturally as a manifestation of quantum information processing constraints. The accelerated expansion follows from a generalized equation of state:

$$w_{\text{eff}} = -1 + \delta \frac{dS}{dV}, \quad (5)$$

suggesting a fundamental link between information entropy and vacuum energy density.

6.3 Primordial Perturbations and Large-Scale Structure

Our framework modifies the standard inflationary power spectrum by introducing entropy-dependent corrections to scalar perturbations:

$$P(k) = P_0(k) (1 + \eta S(k)), \quad (6)$$

which could be tested via upcoming galaxy surveys and CMB anisotropy measurements.

7 Conclusion

Our exploration of an 11-dimensional quantum thermodynamic action has led to novel insights into the interplay between gravity, quantum mechanics, and information theory. The proposed framework provides testable predictions, including entropy-driven modifications to fundamental interactions, corrections to gravitational wave propagation, and nonlocal quantum effects. Future experimental and observational efforts will be critical in validating or refining this approach, potentially leading to a paradigm shift in our understanding of spacetime and fundamental physics.