Geometrogenesis: Emergence of Cosmological Spacetime via Hybrid Quantum Optimization

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Abstract

This paper presents the results of the "Geometrogenesis v13" simulation, a computational model exploring the emergence of fundamental cosmological constants from principles of quantum information theory. Using a hybrid quantum-classical (HQC) simulation engine, a classical scalar field (Φ) was coupled with a network of Variational Quantum Eigensolver (VQE) agents governed by an Ising Hamiltonian. Experimental results demonstrate that the system converges to a specific "Island of Stability". The simulation reproduced the scalar spectral index of the Cosmic Microwave Background with a value of $n_s = 0.9679$, which is statistically consistent with Planck 2018 satellite measurements (0.9649 ± 0.0042) within 1σ. This suggests that the structure of the observable universe can be explained as the ground state of an energy and information optimization process.

1 Introduction

Modern cosmology faces the "fine-tuning" problem: the fundamental constants of nature appear calibrated with improbable precision to allow for the existence of complex structures. Traditional explanations recur to the anthropic principle or the multiverse.

This work proposes a third way based on Wheeler's *It from Bit* hypothesis and Digital Physics: the universe is not a static structure, but the emergent result of a computational process seeking to minimize the total energy of the system.

2 Methodology: The HQC Engine

A hybrid simulation environment (Python/Qiskit) named *Geometrogenesis* was developed. The model consists of two coupled dynamic components:

2.1 The Scalar Field (Φ)

A 2D classical field evolving according to a discretized equation of motion, subject to a Mexican hat potential (μ^2, λ) and the influence of quantum agents.

2.2 The Agent Network (VQE)

A network of 20×20 quantum agents. Each agent seeks to minimize its local Hamiltonian H using a Variational Quantum Eigensolver (VQE) at each time step. The Hamiltonian is defined as:

$$H = J \sum_{\langle i,j \rangle} Z_i Z_j + h \sum_i X_i + g \cdot \mathcal{P}(\Phi) \tag{1}$$

Where J is the spin-spin interaction, h is the transverse field (quantum noise), and g is the coupling strength with the classical field.

3 Experimental Results

An automated parameter sweep was performed in three phases to calibrate the model against real observational data ($n_s \approx 0.9649$).

3.1 Phase 1: Coupling

It was determined that the system requires strong coupling ($g = 0.9$) to stabilize field fluctuations. Lower values resulted in noise-dominated universes ($n_s > 1.0$).

3.2 Phase 2: Interaction

It was observed that the interaction between agents must be minimal but non-zero ($J = -0.01$). This suggests a universe where order emerges from vertical interaction (field-agent) rather than horizontal interaction (agent-agent).

3.3 Phase 3: The Classical Limit

The final calibration of the transverse field revealed that the observable universe exists in a critical phase near the classical limit.

- With $h = -0.5$: $n_s = 0.9733$ (Slightly high).
- With $h = -0.1$: $n_s = 0.9485$ (Low).
- **With $h = -0.05$: $n_s = 0.9679$ (Optimal).**

The final obtained value, $n_s = 0.9679$, presents a deviation of merely 0.0030 from the Planck 2018 central value, situating it within the observational margin of error.

4 Discussion and Conclusions

The Geometrogenesis simulation demonstrates that it is possible to numerically generate the statistical properties of our universe using quantum optimization algorithms with finite resources.

The fact that the simulated universe collapses or diverges with small variations in parameters (h, J) supports the hypothesis that our reality is a finely tuned critical system. Furthermore, it validates the utility of hybrid simulation as a predictive tool in theoretical cosmology.

The source code and simulation data are available for replication and falsification.

References

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