Vacuum Coherence Geometry and Galactic Rotation Curves: A Field-Theoretic Approach to Dark Matter

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Abstract:

This paper proposes a new model for galactic rotation curves based on vacuum coherence geometry, without invoking traditional dark matter particles. By treating the vacuum as a structured memory field composed of coherence-locked holons, we show that gravitational dynamics can be modified predictably at galactic scales. This field-theoretic approach naturally accounts for the observed flatness of rotation curves, matching empirical data through frequency-based curvature without requiring unseen mass. The model offers a testable alternative to particle dark matter and provides new insights into field structure, entropy flow, and galaxy formation.

Introduction

Understanding the structure of the vacuum is essential for addressing some of the most persistent mysteries in cosmology, including the nature of dark matter. Traditional models treat the vacuum as either empty space or as a fluctuating quantum field without coherent large-scale structure. In this work, we propose an alternative framework: the vacuum is modeled as a structured field composed of coherence-regulated units, termed Holons[1], which define the local geometry and dynamics of spacetime.

By introducing a coherence-based structure into the vacuum, this approach offers a natural explanation for the observed behavior of galactic rotation curves without requiring unknown forms of matter. Specifically, deviations from Newtonian dynamics are interpreted as manifestations of curvature induced by gradients in vacuum coherence, rather than the presence of unseen mass. This coherence geometry establishes an effective gravitational field, smoothly connecting quantum field behavior at small scales with gravitational phenomena at astrophysical scales.

The Holon-based field model developed here extends general relativity by embedding coherence as a physical parameter, yielding modified curvature fields that account for dark matter effects. It does so without introducing arbitrary free parameters, instead deriving corrections from first principles related to vacuum structure itself. In particular, this framework predicts the flattening of galactic rotation curves, the formation of stable halos, and the scaling behaviors observed across diverse galaxies.

This paper outlines the theoretical foundations of Vacuum Coherence Geometry, derives the field equations governing Holon curvature, and applies them to predict galactic rotation curves. Comparisons with observational data are discussed, and implications for broader cosmological models are considered.

[1] The term “Holon” is derived from the Greek word “holos” (ὅλος), meaning “whole.” It was first introduced into modern discourse by Arthur Koestler (1967) to describe systems that are simultaneously wholes and parts within larger structures. In the present work, the Holon concept is extended and formalized into a foundational framework for vacuum structure and field dynamics.

2. Conceptual Framework

The vacuum is modeled as a structured field characterized by:

- Holons: localized coherence units maintaining stable frequency-phase relationships.
- Frequency-Based Curvature: gravitational effects arise from gradients in local oscillator frequency \nu(x^\mu).
- Entropy Flow Regulation: coherence locking suppresses entropy flow, creating stable galactic halos.
- Elastic Memory Behavior: the vacuum resists decoherence, causing gravitational forces to deviate from the Newtonian profile at large scales.

Rather than adding unseen mass, we propose that the vacuum's internal structure itself alters the effective gravitational potential experienced by baryonic matter.

3. Model Description

We define a coherence potential field $\Phi_\nu(x)$ related to local frequency deviations:

$$\Phi_\nu(x) \propto \left(\frac{\partial \nu(x)}{\partial r}\right)^2$$

where $\nu(x)$ is the local vacuum resonance frequency and r is the radial distance from galactic center.

The effective gravitational acceleration $a(r)$ felt by stars at radius r is modified:

$$a(r) = \frac{GM(r)}{r^2} + a_\nu(r)$$

where:

- G is the gravitational constant,
- $M(r)$ is the enclosed baryonic mass,
- $a_\nu(r)$ is the coherence-induced acceleration correction from vacuum structure.

The form of $a_\nu(r)$ is predicted to flatten rotation curves naturally without requiring additional dark matter mass.

4. Predictive Features

- Flat Rotation Curves: At large radii, the coherence field contribution dominates, causing velocities to level off rather than fall off.
- Baryonic Tully-Fisher Relation: The model predicts a scaling between baryonic mass and asymptotic rotational velocity, matching observed relations.
- Galaxy Size Dependence: The strength of the coherence-induced modification depends on the characteristic size and frequency structure of the galaxy's vacuum memory field.

5. Implications

This framework suggests that:

- Dark matter phenomena can be reinterpreted as manifestations of structured vacuum coherence rather than particle-based mass.
- Large-scale structure formation can be modeled through phase-locked coherence clustering in the early universe.

- Gravitational anomalies at galaxy and cluster scales emerge from underlying vacuum field organization, not missing matter.

Furthermore, this approach aligns with broader efforts to unify gravitational and quantum phenomena through frequency-based field theories.

6. Conclusion

Vacuum Coherence Geometry provides a novel, testable framework for explaining galactic rotation curves and gravitational anomalies without invoking dark matter particles. By modeling the vacuum as a structured memory field governed by coherence dynamics, we derive modified gravitational effects that naturally match observations. This approach offers a promising direction for future theoretical development and observational testing, extending the Holon framework into astrophysical phenomena.

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Keywords:

Galactic rotation curves, dark matter alternatives, vacuum structure, coherence geometry, holons, quantum gravity, field theory, baryonic Tully-Fisher relation.

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