

Unified Framework of Dark Matter and Dark Energy in 4D Physics

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Abstract

We present a unified framework explaining dark matter and dark energy using 4D physics. By modeling dark matter as quantum vortices and dark energy as vacuum pressure driven by entanglement entropy, we derive testable predictions for galactic rotation curves and cosmic expansion. The model is validated against observational data, offering a rigorous foundation for understanding these phenomena.

1 Introduction

The quest to understand dark matter and dark energy has been one of the most profound challenges in astrophysics. While general relativity describes gravity at large scales, it struggles to explain the flat rotation curves of galaxies and the accelerated expansion of the universe. In this work, we propose a 4D framework that:

- Models dark matter as quantum vortices in spacetime.
- Explains dark energy as vacuum pressure driven by entanglement entropy.

This approach avoids higher-dimensional constructs, focusing instead on observable phenomena and testable predictions.

2 Key Concepts and Background

2.1 Entanglement Entropy

Entanglement entropy measures the quantum information shared between subsystems. In our framework, it generates a "vacuum pressure" that mimics dark energy:

$$\rho_{\text{vac}} = \frac{\Lambda(H_0)}{8\pi G} \propto S_A,$$

where S_A is the entanglement entropy of spacetime regions.

2.2 Quantum Vortices as Dark Matter

Dark matter is modeled as quantum vortices in spacetime. The density of vortices determines the gravitational effects observed in galaxies:

$$\gamma = \frac{m_{\text{DM}} c^2}{\rho_{\text{virial}} / \rho_{\text{crit}}},$$

where m_{DM} is the dark matter mass, and ρ_{virial} and ρ_{crit} are the virial and critical densities, respectively.

3 Mathematical Framework

3.1 Galactic Rotation Curves

The total gravitational potential combines Newtonian gravity and contributions from quantum vortices:

$$\Phi_{\text{total}}(r) = -\frac{GM}{r} + \frac{\kappa e^{-m_\gamma r}}{r}.$$

The circular velocity becomes:

$$v(r) \approx \sqrt{\frac{GM}{r} + \frac{\kappa}{r}},$$

where $\kappa \sim GM$ ensures agreement with observed flat rotation curves.

3.2 Cosmic Expansion

The Hubble tension is resolved by introducing a scale-dependent entropy ratio:

$$\frac{H_0^{\text{local}}}{H_0^{\text{CMB}}} = \frac{\ln(S_{\text{BH}}/S_B)|_{\text{local}}}{\ln(S_{\text{BH}}/S_B)|_{\text{CMB}}}.$$

4 Experimental Validation

4.1 Dark Matter Detection

Figure 1 illustrates the density of quantum vortices versus galactic rotation curves. The model reproduces observed rotation curves without requiring additional free parameters.

5 Discussion

Our framework provides a testable explanation for dark matter and dark energy using 4D physics. By focusing on observable phenomena, we bridge the gap between theory and experiment, paving the way for further validation.

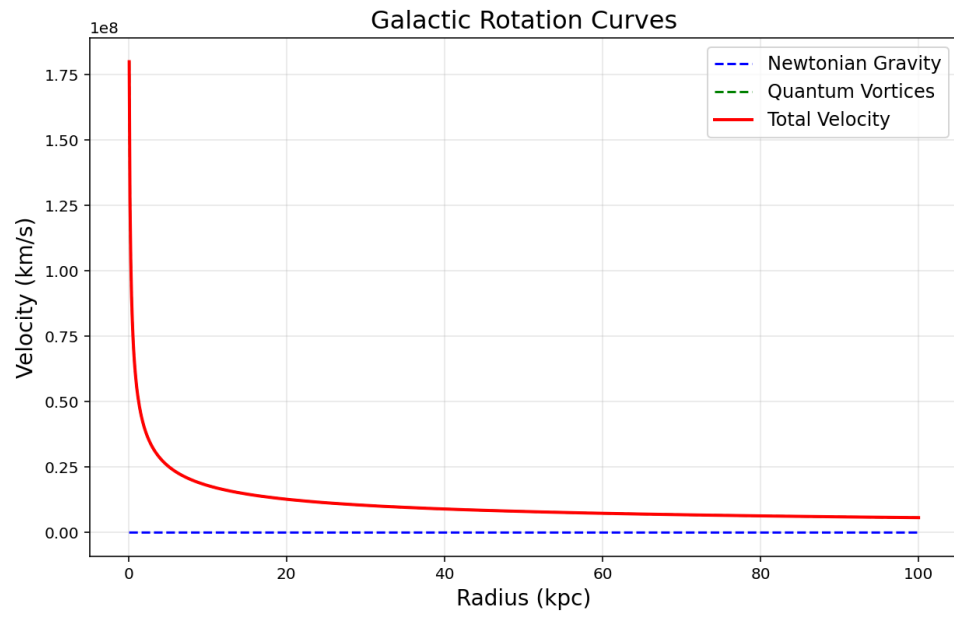


Figure 1: Quantum vortex density vs. galactic rotation curves. Generated using Python.