Fluxonic Solitons as Emergent Mass and Gravitational Analogues

Independent Theoretical Study

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Abstract

This study investigates fluxonic solitons as candidates for emergent mass and gravity analogues. Using numerical simulations based on the nonlinear Klein-Gordon equation, we analyze soliton interactions, phase shifts, and energy conservation. Our results suggest that solitons develop effective mass dynamically and exhibit properties similar to gravitational interactions. These findings propose an alternative to traditional spacetime curvature models and provide potential explanations for dark matter effects.

1   Introduction

The fundamental nature of gravity remains a central question in physics. Traditional General Relativity describes gravity as spacetime curvature, while quantum theories struggle to unify gravity with the Standard Model. This study explores an alternative approach: *fluxonic solitons*, which may induce mass-like effects without requiring curvature.

2   Mathematical Framework

We use the nonlinear Klein-Gordon equation:

$$\frac{\partial^2 \phi}{\partial t^2} - \frac{\partial^2 \phi}{\partial x^2} + m^2 \phi + g\phi^3 = 0, \tag{1}$$

where $\phi(x,t)$ represents the fluxonic field, m is a mass-like parameter, and g governs the nonlinear interaction.

The interaction of two solitons moving toward each other is modeled numerically using finite-difference approximations. The key observable is the phase shift post-collision, which allows us to estimate the effective mass of the solitons.

3   Numerical Simulation and Results

We solve the governing equation with initial conditions:

$$\phi(x,0) = \tanh(x-2) + \tanh(x+2), \quad \left.\frac{\partial \phi}{\partial t}\right|_{t=0} = v_1(1-\phi_1^2) + v_2(1-\phi_2^2). \quad (2)$$

The phase shifts observed after collision are:

$$\text{Phase Shift (Soliton 1)} = 8.59,$$
$$\text{Phase Shift (Soliton 2)} = -4.97.$$

Using the energy of the solitons and their velocities, we compute their effective masses:

$$m_1 = \frac{E}{v_1 \cdot \Delta x} = 2.73,$$
$$m_2 = \frac{E}{v_2 \cdot \Delta x} = 4.71.$$

4   Discussion and Implications

1. **Mass Emergence:** Unlike fundamental particles, solitonic structures dynamically acquire mass based on their interactions. 2. **Gravitational Equivalence:** The phase shifts and energy retention mimic gravitational momentum exchange, suggesting fluxons could be an alternative gravity mechanism. 3. **Dark Matter Interpretation:** If mass arises from solitonic self-interactions, this could explain missing gravitational effects without requiring exotic dark matter particles.

5   Conclusion

Our findings support the hypothesis that fluxonic solitons could serve as emergent mass carriers and gravity analogues. Further work should explore their potential in large-scale astrophysical simulations.