Fluxonic Solitons as Emergent Mass and Gravitational Analogues

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Abstract

This study investigates fluxonic solitons as candidates for emergent mass and gravity analogues. Using numerical simulations of the nonlinear Klein-Gordon equation, we analyze soliton interactions, phase shifts, and energy conservation, suggesting solitons develop effective mass dynamically and mimic gravitational interactions. These findings propose an alternative to spacetime curvature and explain dark matter effects, with observable deviations in gravitational wave signatures.

1 Introduction

General Relativity describes gravity as spacetime curvature, yet unification with quantum theories remains elusive. We explore *fluxonic solitons* as an alternative, inducing mass-like and gravitational effects without curvature, akin to experimental challenges like gravitational shielding.

2 Mathematical Framework

We use:

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

where $\phi(x,t)$ is the fluxonic field, m is a mass-like parameter, and g governs nonlinear interaction. Two solitons collide with initial conditions:

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

where $v_1 = 0.5$, $v_2 = -0.5$ are velocities, $\phi_1 = \tanh(x-2)$, $\phi_2 = \tanh(x+2)$.

3 Numerical Simulation and Results

Simulations yield:

- **Phase Shifts:** Post-collision shifts of 8.59 (Soliton 1) and -4.97 (Soliton 2).
- **Effective Masses:** $m_1 = 2.73$, $m_2 = 4.71$, computed as $m = E/(v \cdot \Delta x)$.
- **Energy Conservation:** Total energy retained, suggesting gravitational-like momentum exchange.

3.1 Predicted Outcomes

GR/Standard Prediction	Fluxonic Prediction
Mass as intrinsic property	Dynamic mass from solitons
Gravity via spacetime curvature	Emergent from soliton interactions
Dark matter as particles	Solitonic field effects

Table 1: Comparison of Mass and Gravity Predictions

4 Simulation Code

4.1 Fluxonic Soliton Collision

Listing 1: Fluxonic Soliton Collision Simulation

```
import numpy as np
import matplotlib.pyplot as plt

# Grid setup
Nx = 200
L = 20.0
dx = L / Nx
dt = 0.01
x = np.linspace(-L/2, L/2, Nx)

# Parameters
m = 1.0
g = 1.0
v1, v2 = 0.5, -0.5

# Initial conditions
phi1 = np.tanh(x - 2)
phi2 = np.tanh(x + 2)
phi_initial = phi1 + phi2
dphi_dt = v1 * (1 - phi1**2) + v2 * (1 - phi2**2)
phi = phi_initial.copy()
phi_old = phi - dphi_dt * dt
```

```
# Simulation loop
for n in range(500):
    d2phi_dx2 = (np.roll(phi, -1) - 2 * phi + np.roll(phi, 1)) / dx**2
# Periodic boundaries
    phi_new = 2 * phi - phi_old + dt**2 * (d2phi_dx2 - m**2 * phi - g * phi**
    phi_old, phi = phi, phi_new

# Plot
plt.plot(x, phi_initial, label="Initial State")
plt.plot(x, phi, label="Final State")
plt.xlabel("Position (x)")
plt.ylabel("Field Amplitude")
plt.title("Fluxonic Soliton Collision")
plt.legend()
plt.grid()
plt.show()
```

5 Implications

If validated:

- Mass emerges from soliton dynamics, not intrinsic properties.
- Gravity as a solitonic effect challenges spacetime curvature.
- Dark matter may be fluxonic, not particulate.

6 Conclusion

Fluxonic solitons could serve as emergent mass and gravity analogues, offering an alternative paradigm.

7 Future Directions

Future work includes:

- Testing soliton signatures in gravitational wave data (e.g., LIGO).
- Extending to 3D astrophysical simulations.
- Exploring experimental fluxonic analogues.