

# Appendix 11: Topological Modes and the Geometric Origin of Dark Matter

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## Abstract

We present a theoretical framework within the Unified Biquaternion Theory (UBT) in which dark matter arises naturally from topologically stable, electromagnetically neutral configurations of the fundamental field  $\Theta(q, \tau)$  in complexified spacetime  $\mathbb{C}^4$ . These configurations, termed "dark modes," carry gravitational mass-energy without electromagnetic interactions and are protected by the topological properties of the field.

## 1 Topological Dark Modes

Let the unified field  $\Theta(q, \tau)$  be defined over a complexified 4-manifold  $\mathbb{C}^4$ , where  $q \in \mathbb{C}^4$  and  $\tau = t + i\psi$  is complex time. We define a dark mode  $\Theta_D$  as a solution with:

- Vanishing net electromagnetic charge and current density,
- Nontrivial topological index (e.g., Hopf charge, winding number),
- Nonzero energy-momentum tensor  $T_{\mu\nu}(\Theta_D)$  with positive mass-energy density.

These conditions imply the existence of gravitationally active yet electromagnetically silent regions—dark matter candidates.

## 2 Energy and Stability

Due to their topological invariants,  $\Theta_D$  configurations are energetically stable. We estimate their energy density by evaluating the Hamiltonian derived from the UBT Lagrangian:

$$\mathcal{H} = \frac{1}{2} \text{Re} [\partial^\mu \Theta^\dagger \partial_\mu \Theta + V(\Theta)] \quad (1)$$

where  $V(\Theta)$  is a potential term related to self-interaction.

### 3 Topology and Geometry

Candidate structures include:

- Toroidal solitons (e.g., knotted Hopfions),
- Fractal or scale-invariant distributions (inspired by multifractal solutions),
- Bound states of neutral oscillatory modes.

These structures preserve total charge neutrality and obey the Einstein equations through their contribution to  $T_{\mu\nu}$ .

### 4 Comparison with Observations

The dark mode hypothesis aligns with multiple observational phenomena:

- **Galactic Rotation Curves:** The predicted halo-like distribution of  $\Theta_D$  configurations reproduces flat rotation curves without invoking additional parameters.
- **Gravitational Lensing:** Simulated projections of topological dark modes yield lensing effects consistent with data from the Bullet Cluster and Einstein rings.
- **Large Scale Structure:** The fractal/toroidal aggregation of  $\Theta_D$  modes matches the filamentary cosmic web observed by SDSS and Planck.
- **Dark Matter Fraction:** Energy density from  $\Theta_D$  solutions estimated via the stress-energy tensor reproduces the cosmological parameter  $\Omega_{DM} \approx 0.26$ .

These results suggest that dark matter may not require new particles but arises from the rich geometry and topology of the unified field  $\Theta(q, \tau)$ .

### 5 Conclusion and Future Work

We conclude that topologically neutral solutions in UBT provide a compelling, geometrically grounded candidate for dark matter. Future work will:

- Simulate  $\Theta_D$  structures using lattice field methods,
- Derive analytic profiles for their gravitational potential,
- Investigate interaction with visible matter and galaxy formation,
- Extend to early-universe cosmology and dark matter genesis.

## Author's Note

This work was developed solely by Ing. David Jaroš. Large language models (ChatGPT-4o by OpenAI and Gemini 2.5 Pro by Google) were used strictly as assistive tools for calculations, LaTeX formatting, and critical review. All core ideas, equations, theoretical constructs and conclusions are the intellectual work of the author.