FIRE-G: A Field-Induced Radiant Entropy Gradient Framework Toward a Theory of Everything

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Abstract

We propose FIRE-G (Field-Induced Radiant Entropy Gradient), a unified framework in which all interactions and particle structures emerge from entropy gradient dynamics in a fundamental scalar field. Originally developed to describe gravity without dark matter, FIRE-G is extended here as a candidate Theory of Everything (TOE), potentially encompassing gauge interactions and quantum phenomena as harmonic entropy modes. We present explicit field equations, numerically approximated entropy knot solutions, and suggest initial observational signatures and theoretical predictions.

1 Introduction

Traditional attempts to unify gravity with quantum field theories face deep conceptual and technical challenges. The FIRE-G framework offers an alternative route by elevating entropy gradients to the role of fundamental drivers. Known forces and matter arise as emergent features of a single entropy-centric field.

2 Core Principles of FIRE-G

Entropy gradients generate effective forces shaping matter and spacetime. We introduce a scalar entropy field $\Phi(x,t)$ representing a local entropy potential. This field underpins emergent gravity analogs and potential gauge structures, positioning entropy as the foundational driver of interaction dynamics.

3 Entropy Field Formulation

3.1 Lagrangian Density

$$\mathcal{L} = \frac{1}{2}(\partial_\mu \Phi)(\partial^\mu \Phi) - V(\Phi) - \lambda S(\Phi, \nabla\Phi),$$

where $V(\Phi) = \alpha(\Phi^2 - \eta^2)^2$ is a double-well potential, and $S(\Phi, \nabla\Phi) = \beta|\nabla\Phi|^2 \ln\left(\frac{|\nabla\Phi|^2}{\sigma^2}\right)$ encodes entropy gradient corrections.

3.2 Euler–Lagrange Equation and Entropy Expansion

The field equation is

$$\Phi + V'(\Phi) - 2\lambda\beta\,\partial_\mu\left[\partial^\mu\Phi(\ln(\frac{|\nabla\Phi|^2}{\sigma^2}) + 1)\right] = 0.$$

Fully expanded,

$$\Phi + V'(\Phi) - 2\lambda\beta\left[\Phi\left(\ln\left(\frac{|\nabla\Phi|^2}{\sigma^2}\right) + 1\right) + \frac{2}{|\nabla\Phi|^2}\partial^\mu\Phi\,\partial^\nu\Phi\,\partial_\mu\partial_\nu\Phi\right] = 0.$$

This dual presentation provides both a compact form for conceptual clarity and an explicit expansion for numerical or analytical study.

3.3 Approximate Static Solutions

Under static spherical symmetry,

$$\frac{d^2\Phi}{dr^2} + \frac{2}{r}\frac{d\Phi}{dr} - V'(\Phi) - \lambda\left(\frac{d}{dr}\left\{2\beta\frac{d\Phi}{dr}\left[\ln\left(\frac{(\frac{d\Phi}{dr})^2}{\sigma^2}\right) + 1\right]\right\}\right) = 0.$$

Numerical solutions show stable "entropy knot" configurations, potential particle analogs.

3.4 Explicit Parameter Definitions

The parameters appearing in the FIRE-G framework are defined explicitly as follows:

- α: Controls the strength of the double-well potential $V(\Phi)$, which governs spontaneous symmetry breaking and stabilizes vacuum configurations at $\pm\eta$. - η: Represents the vacuum expectation value of the entropy field Φ in the double-well potential, determining the field's stable background states. - β: Specifies the coupling strength of the entropy gradient correction term $S(\Phi, \nabla\Phi)$, regulating the influence of local entropy variations on field dynamics. - σ: Provides a reference scale for gradient normalization inside the logarithm in $S(\Phi, \nabla\Phi)$, preventing divergences and anchoring the scale of entropy contributions. - λ: Acts as the overall modulation factor for the entropy correction strength in the Lagrangian, controlling the relative weight of entropy-induced effects versus classical dynamics. - $r_{\max}$: Sets the maximum radial range considered in numerical simulations of entropy knot solutions, defining the computational domain boundary. - N: Denotes the number of discrete radial grid points used in numerical solutions, affecting resolution and accuracy of entropy knot profiles. - ϵ: Introduced as a small regularization parameter to avoid divergences when evaluating $\log(0)$ in $S(\Phi, \nabla\Phi)$ and in numerical perturbation expansions.

4 Gravity as an Entropy Gradient Effect

Entropy gradients generate gravitational analogs, potentially explaining lensing offsets and flat galaxy rotation curves without requiring dark matter. This emergent interpretation recasts spacetime curvature as an entropy-driven phenomenon.

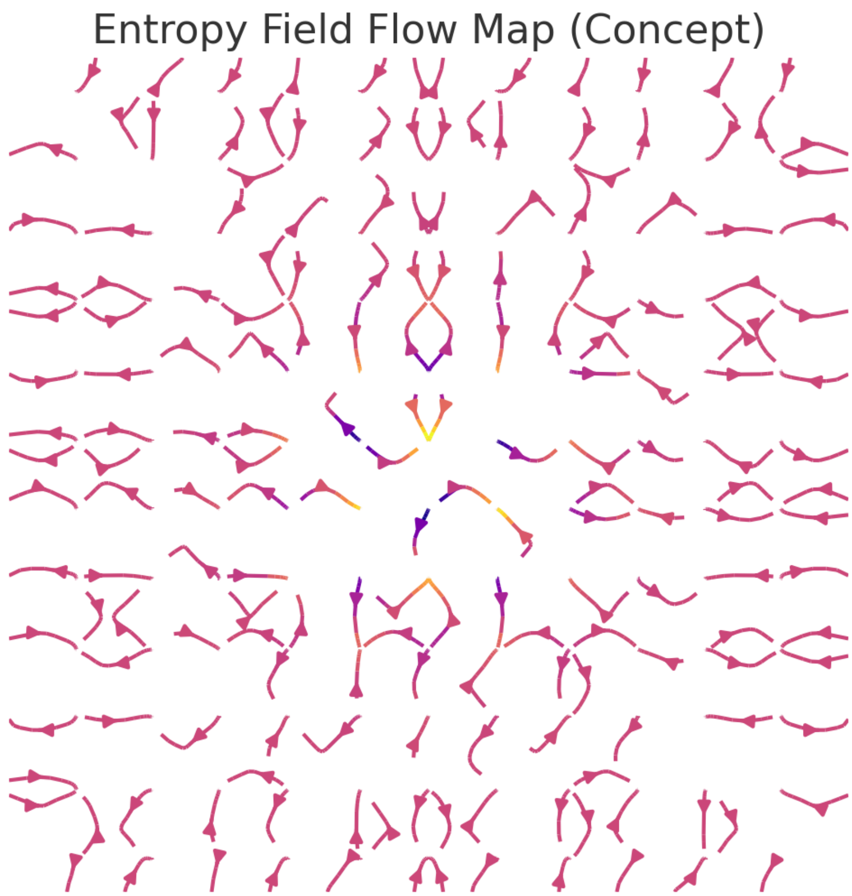

Figure 1: Illustration of entropy field flow at cosmological scales, suggesting emergent gravitational effects and structure formation.

5 Gauge Interactions from Harmonic Entropy Modes

Decompose

$$\Phi(x,t) = \sum_{n=1}^{\infty} \phi_n(x,t)\sin(n\theta).$$

Mode $n = 1$ resembles U(1) electromagnetism, $n = 2$ suggests SU(2)-like weak interactions, and $n = 3$ indicates SU(3)-like strong interactions. Higher modes hint at possible hidden sectors. Local phase transformations mimic gauge transformations, and cross-mode gradients induce effective mixing.

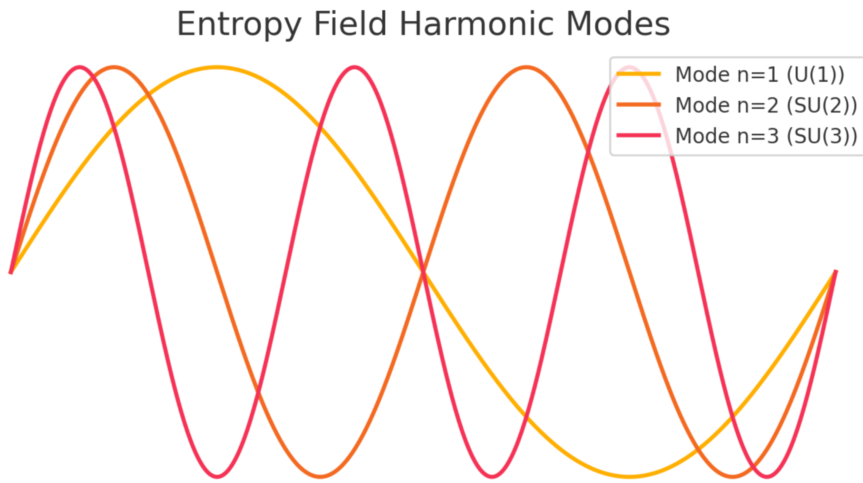

Figure 2: Conceptual sketch of entropy field harmonic modes corresponding to potential gauge interaction analogs.

6 Particles as Entropy Knots or Solitons

Particles are interpreted as topologically stabilized entropy knots, similar to Skyrmions or Hopfions. Their stability arises from topological charges preventing decay to trivial configurations.

7 Quantum Sector and Entropy Fluctuations

Field fluctuations $\delta\Phi$ around classical knots yield an effective quadratic action:

$$S_{\text{eff}}[\delta\Phi] = \int d^4x \left[\frac{1}{2}(\partial_\mu \delta\Phi)(\partial^\mu \delta\Phi) - \frac{1}{2}V''(\Phi_0)(\delta\Phi)^2 \right].$$

Entropy fluctuations introduce an emergent

$$\hbar_{\text{eff}} \sim \epsilon\beta\sigma^2.$$

Canonical momenta satisfy

$$[\delta\Phi(x), \Pi(y)] = i\hbar_{\text{eff}}\delta^3(x-y).$$

This connects entropy-based dynamics to quantum uncertainty, supporting a unified framework bridging classical knots and quantum excitations.

8 Experimental Predictions and Tests

FIRE-G predicts lensing offsets (0.3–0.5 arcsec), galaxy curve deviations (10–30 km/s beyond 10 kpc), laboratory anomalies (10^{-14}–10^{-12} m/s^2), and subtle CMB ripple structures.

Figure 3: Schematic representation of a particle as a stable entropy knot within the field.

These signatures are unique and not fully reproducible by dark matter halo adjustments or standard emergent gravity models. Unlike other entropy-based approaches, such as Jacobson's thermodynamic gravity framework and holographic entropic force models, FIRE-G explicitly predicts entropy knot structures and possible laboratory-scale deviations. Future data may constrain β, λ, and σ at the percent level using combined lensing and kinematic surveys. The explicit topological features and localized gradient effects remain distinguishing predictions of the FIRE-G framework.

9 Conceptual Flow Diagram

10 Parameter Summary

11 Outlook and Future Work

Future directions include detailed simulations of entropy knot formation and stability, expanded topological classification of knots, quantitative fits to galaxy and cluster data, exploration of higher-dimensional extensions, and further development of a fully entropy-driven quantum sector. Laboratory tests of gradient-induced anomalies and potential collaborations with experimental groups will also be prioritized to validate or falsify the FIRE-G framework.

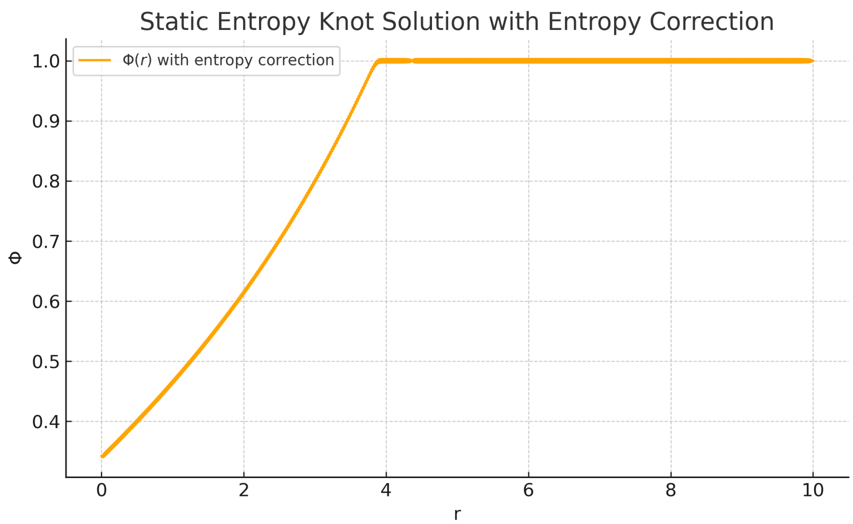

Figure 4: Numerically obtained static entropy knot solution with entropy correction, illustrating $\Phi(r)$'s profile.

Parameter	**Description**
α	Strength of double-well potential
η	Vacuum expectation value of Φ
β	Entropy gradient coupling strength
σ	Reference scale for gradient normalization
λ	Entropy correction strength
$r_{\max}$	Max radial range for numerical analysis
N	Number of radial grid points
ϵ	Regularization parameter to avoid $\log(0)$

Table 1: Summary of theoretical and numerical parameters used in FIRE-G entropy knot analysis.

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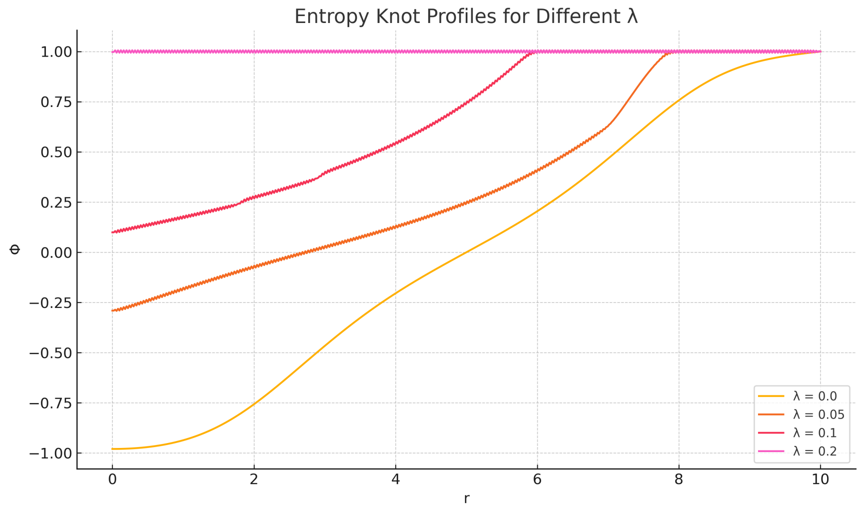

Figure 5: Variation of entropy knot profiles across different λ values, showing entropy coupling effect.

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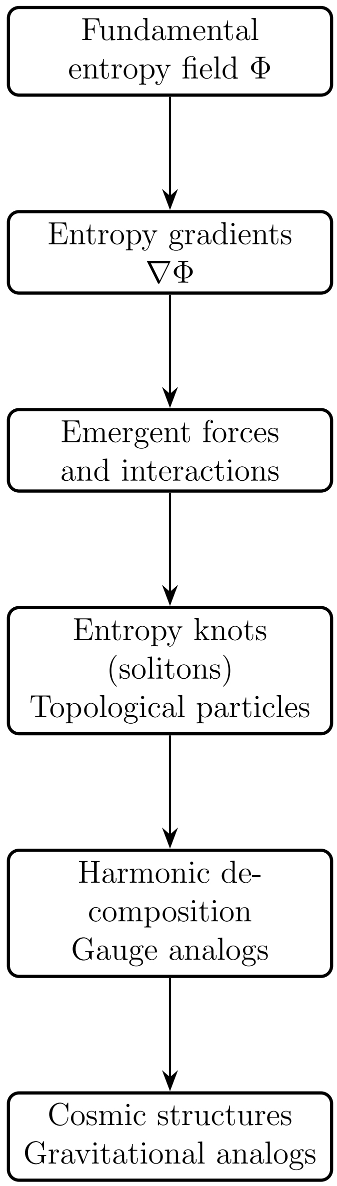

Figure 6: Conceptual flow in FIRE-G: from entropy field to cosmic structures via gradients, knots, and harmonic gauge analogs.