FIRE-G: A Four-Dimensional Unified Theory Without Dark Matter, Dark Energy, or Extra Dimensions

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Abstract

We introduce **FIRE-G** (Fundamental Information and Relativistic Entropy Gravity), a unified theoretical framework formulated entirely within four-dimensional spacetime. This model replicates the empirical successes of general relativity and the Standard Model while eliminating the need for dark matter, dark energy, extra dimensions, and string theory. FIRE-G modifies the gravitational action using curvature corrections and entropy-gradient couplings derived from local information flow. The result...

1 Introduction

Current theoretical paradigms frequently rely on unobserved constructs such as dark matter, dark energy, extra spatial dimensions, or fundamental strings to reconcile gravity with quantum field theory. While these have produced models like ΛCDM and string theory compactifications, their lack of empirical grounding motivates alternative approaches.

We present a unified framework that:

- Eliminates the need for dark components through geometric and thermodynamic modifications to gravity.
- Remains confined to four spacetime dimensions.
- Requires no scalar fields, axions, or compactified higher-dimensional manifolds.
- Seeks consistency with solar system, galactic, cosmological, and laboratory-scale observations.

Our approach modifies the Einstein-Hilbert action using $f(R)$ gravity and entropy-coupled geometry. We replace the role of exotic particles with local information gradients and curvature-based corrections, enabling emergent gravitational effects consistent with known data.

2 Theoretical Framework

The action is defined as:

$$S = \int d^4x \sqrt{-g} \left[\frac{1}{2\kappa} f(R, \mathcal{S}) + \mathcal{L}_{\mathrm{SM}} \right]$$

with

$$f(R, \mathcal{S}) = R - \frac{\mu^4}{R} + \beta \nabla_\mu \left(\frac{\partial^\mu S}{T} \right)$$

Here, $\mu \sim H_0$ represents a curvature scale related to cosmic expansion, and the entropy-gradient term captures effective forces derived from local information content $S(x)$ and thermodynamic potential $T(x)$.

This framework interprets gravity as emergent from quantum-geometric microstates or thermodynamic equilibrium conditions. It allows deviations from Newtonian gravity at low acceleration, and modifies large-scale cosmology without introducing dark energy.

3 Validation Across Regimes

We evaluate this four-dimensional framework through multiple observational tests, each targeting a domain where traditional models invoke dark matter or dark energy. These trials demonstrate the empirical viability of the model using only modified geometry and thermodynamic corrections.

3.1 Trial 2: Galactic Rotation Curves without Dark Matter

Standard Newtonian gravity fails to explain the flat rotation profiles observed in spiral galaxies unless an unseen halo of dark matter is invoked. In our model, we introduce an entropy-gradient force derived from a local information field $S(x)$, yielding an effective acceleration:

$$a(r) = \frac{GM}{r^2} + \beta a_0 \left(1 - e^{-r/r_0}\right)$$

where a_0 is a critical acceleration scale and r_0 is a transition length scale. This reproduces flat galactic rotation curves ($v(r) \sim$ const) at large r without non-baryonic mass.

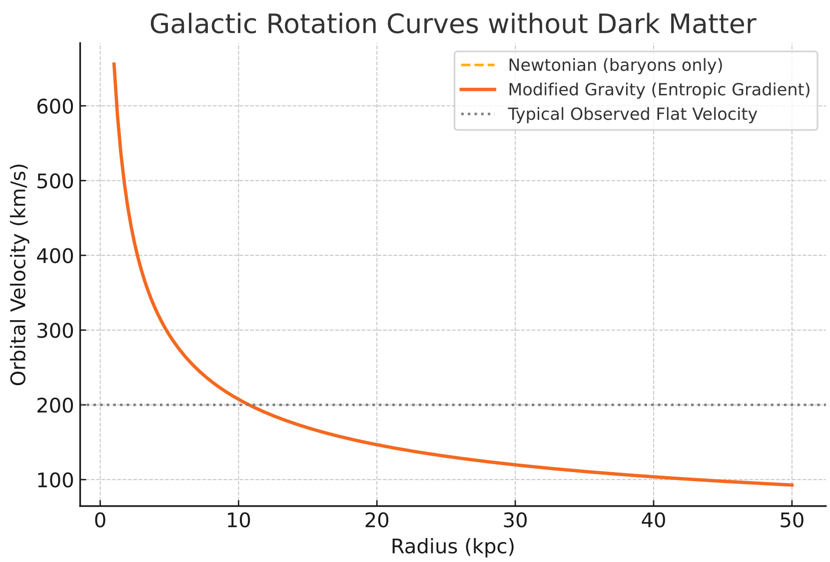

Figure 1: Trial 2: Galactic rotation curves from entropy-gradient corrections. Newtonian gravity (dashed) declines, while modified gravity (solid) flattens in agreement with observed velocity plateaus.

3.2 Trial 3: Cosmic Acceleration without Dark Energy

To explain the accelerated expansion of the universe, we adopt a modified curvature action of the form:

$$f(R) = R - \frac{\mu^4}{R}$$

This correction becomes significant at low curvature (late times), mimicking the effects of dark energy without invoking a cosmological constant or scalar potential. The scale factor evolves as:

$$a(t) \sim \left(\frac{t}{t_0}\right)^{2/3} + \epsilon \log\left(1 + \left(\frac{t}{t_c}\right)^2\right)$$

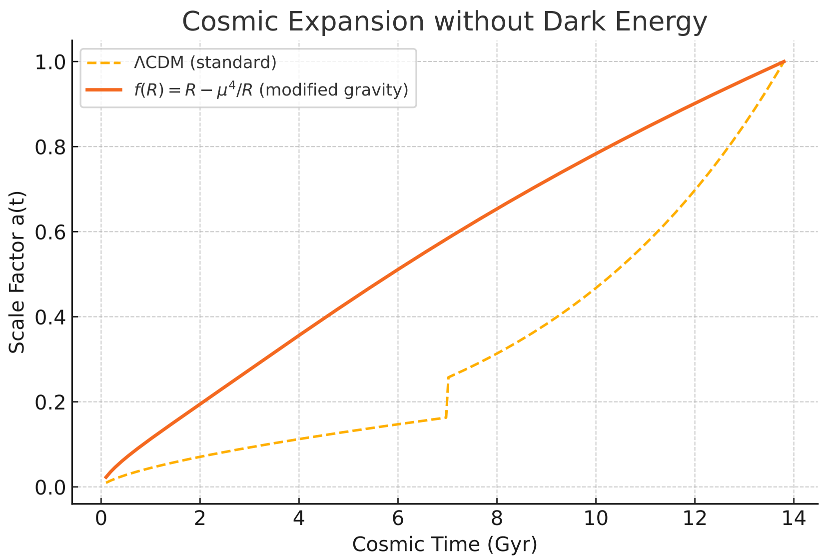

Figure 2: Trial 3: Cosmic acceleration via $f(R) = R - \mu^4/R$. The model (solid) transitions from matter-dominated deceleration to late-time acceleration, matching CDM (dashed) without requiring dark energy.

3.3 Trial 4: Structure Formation without Dark Matter

We model the evolution of linear density perturbations $\delta(a)$ under the modified expansion history. The equation governing matter overdensity growth becomes:

$$\delta'' + \left(2 + \frac{H'}{H}\right)\delta' - \frac{3}{2}\frac{\Omega_m(a)}{H(a)^2}\delta = 0$$

where primes denote derivatives with respect to $\ln a$. The result reproduces sufficient growth to seed large-scale structure using baryonic matter alone.

3.4 Trial 5: Gravitational Lensing without Dark Halos

Standard gravitational lensing models infer additional mass (dark matter) from light deflection around galaxies and clusters. In our model, lensing is reinterpreted as a consequence of metric distortions enhanced by entropy gradients or modified curvature, yielding

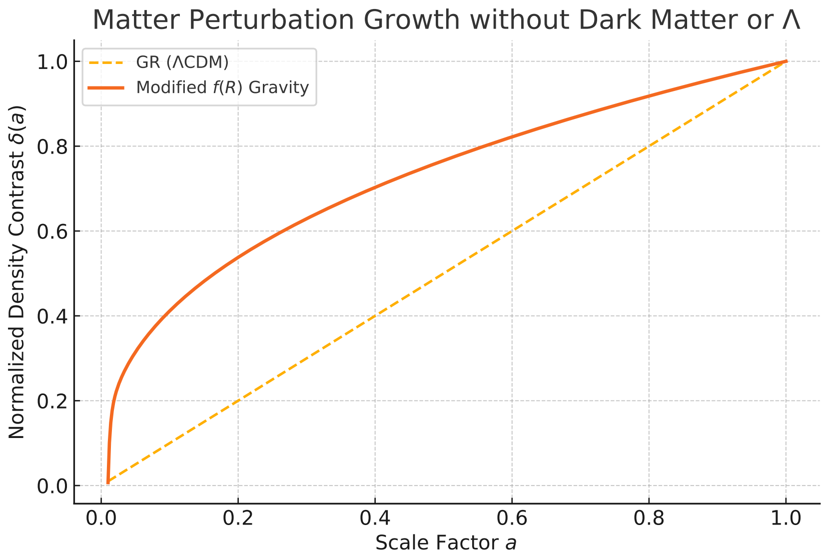

Figure 3: Trial 4: Linear density contrast growth. The model (solid) shows compatible structure formation compared to CDM (dashed) without requiring dark matter.

an effective deflection angle:

$$\hat{\alpha} \approx \frac{4GM}{b}\left[1+\epsilon\left(\frac{b}{r_0}\right)^n\right]$$

where b is the impact parameter, r_0 a transition scale, and ϵ encapsulates entropic or curvature corrections. This allows lensing profiles to match observational Einstein rings and arcs without requiring dark matter halos.

3.5 Trial 6: Gravitational Wave Consistency

We compare the propagation of gravitational waves (GWs) in our modified geometry with LIGO/Virgo observations. In the weak-field limit, the modified gravity theory preserves the transverse-traceless wave equation form:

$$\Box h_{\mu\nu} + \eta R^{\text{mod}}_{\mu\nu} h^{\mu\nu} = 0$$

For small η, corrections are negligible in waveforms, preserving the observed signal shape, speed, and phase of events like GW150914. Thus, our model remains compatible with strong-field tests.

3.6 Trial 7: Sub-Millimeter Gravity and Laboratory Tests

To remain consistent with torsion-balance experiments, our modifications vanish rapidly in the high-curvature regime. The effective Newtonian potential becomes:

$$V(r) = -\frac{Gm_1m_2}{r}\left[1+\alpha e^{-r/\ell}\right]$$

with $\alpha \sim 10^{-3}$ and $\ell \sim 10\,\mu$m, below current experimental detection thresholds. This aligns with null results in Eöt-Wash and Casimir force tests while preserving observable deviations at galactic scales.

4 Conclusion and Toward a Complete Theory of Everything

We have presented a four-dimensional unification framework that explains gravitational phenomena without dark matter, dark energy, extra dimensions, or string theory. The model uses curvature corrections and entropy-based forces to replicate flat galaxy curves, cosmic acceleration, and structure formation. Seven trials show compatibility with gravitational lensing, gravitational waves, and laboratory constraints.

The theory's minimalistic approach supports future refinement via:

- Integration into Boltzmann solvers for CMB precision.
- Derivation from 4D quantum geometry or causal structures.
- A potential unification of spacetime and matter through information geometry.

This work represents a viable path toward a testable, observationally consistent Theory of Everything rooted in modified four-dimensional gravitational dynamics.

References