Cosmological Signatures of the Second Law of Infodynamics: A Chameleon-Screened Effective Field Theory (LF-EFT)

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Date: December 18, 2025

Abstract

The **Second Law of Infodynamics** posits that physical systems evolve to minimize their information entropy. While recent work has derived Newtonian gravity and General Relativity as macroscopic manifestations of this entropic force, the explicit mechanism coupling information-content to matter fields remains an open question. If information is physical (Mass-Energy-Information equivalence), its variations should theoretically manifest as a scalar degree of freedom coupled to matter, potentially inducing "Fifth Forces" that are tightly constrained by solar system experiments.

We propose **LF-EFT**, a scalar-tensor implementation of Infodynamics utilizing a **Chameleon Screening Mechanism**. We demonstrate that a scalar field representing the local information potential can satisfy solar system constraints (Cassini, Eöt-Wash) via the Thin-Shell Effect, effectively decoupling in high-density environments. Conversely, in low-density cosmic voids ($\rho \sim 10^{-28}$ kg/m^3), the screening lifts, revealing a massive attractive force ($\Delta F_g \approx 10^{10}\%$) acting on diffuse gas. This mechanism provides a natural explanation for the accelerated formation of massive galaxies in the early universe (JWST anomalies) as a result of thermodynamically driven information minimization.

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1. Introduction

The hypothesis that the universe operates as a computational system has gained significant traction, supported by the **Mass-Energy-Information (M/E/I) Equivalence Principle** [1] and the **Second Law of Infodynamics** [2], which states that the information entropy of a system tends to minimize over time. Vopson (2025) recently demonstrated that gravitational attraction itself can be derived as an entropic force resulting from this minimization process [3].

However, translating this thermodynamic tendency into a field theory presents a challenge. If information possesses mass and interacts with matter, it suggests the presence of a scalar field ϕ (the information potential) coupled to the stress-energy tensor. Standard scalar-tensor theories [4] are often ruled out by precision tests of General Relativity (GR), such as the Cassini probe's measurement of the Shapiro delay ($\gamma - 1 < 2.3 \times 10^{-5}$) [5] and laboratory torsion balance experiments (Eöt-Wash) [6].

We propose that the information potential behaves as a **Chameleon Field** [7], where the effective mass of the field depends on the local matter density. In high-density regions (where information content is "saturated"), the field acquires a large mass and creates a short-range Yukawa potential, rendering it undetectable to local experiments. In low-density cosmic voids, the field becomes light, mediating a long-range force that drives the minimization of information entropy through rapid structure formation.

2. Theoretical Framework

We operate in the Einstein Frame, describing the scalar field ϕ (the "Negentropy" or Information Potential) coupled to matter species ψ_m via a conformal factor $A(\phi)$.

2.1 The Action

The effective action is given by:

$$S = \int d^4x\sqrt{-g}\left[\frac{M_{Pl}^2}{2}R - \frac{1}{2}(\partial\phi)^2 - V(\phi)\right] + S_m(\psi_m, A^2(\phi)g_{\mu\nu})$$

Where M_{Pl} is the reduced Planck mass. We adopt an inverse power-law potential characteristic of Chameleon models, representing the energetic cost of information separation:

$$V(\phi) = \Lambda^{4+n}\phi^{-n}$$

The coupling function $A(\phi)$ determines the strength of the interaction between information and matter:

$$A(\phi) \approx 1 + \frac{\beta}{M_{Pl}}\phi$$

2.2 Effective Potential and Screening

The scalar field evolves in an effective potential governed by the local matter density ρ:

$$V_{eff}(\phi) = V(\phi) + \rho A(\phi)$$

The field settles at a density-dependent minimum $\phi_{min}(\rho)$. The effective mass of the field at this minimum is:

$$m_{eff}^2 = \frac{d^2V_{eff}}{d\phi^2} \approx n(n+1)\Lambda^{4+n}\phi^{-(n+2)} + \frac{\beta\rho}{M_{Pl}}$$

The Screening Mechanism: In high-density regions (Earth, Sun), ρ is large, driving m_{eff} to be large. The range of the force $\lambda = 1/m_{eff}$ becomes microscopic (microns to millimeters), suppressing the force for macroscopic objects. In cosmic voids, ρ is small, m_{eff} drops, and the range λ extends to megaparsecs.

3. Methodology

We utilized a numerical viability pipeline (`lf_viability_pipeline.py`) to scan the parameter space (n, β, Λ) against empirical constraints.

3.1 Constraints (The Gates)

To be viable, a model must pass:

1. **Gate A (Solar System):** The Post-Newtonian parameter γ must align with Cassini measurements. We calculate the Thin-Shell parameter $\frac{\Delta R}{R}$ for the Sun. If the shell is thin ($\frac{\Delta R}{R} \ll 1$), the scalar charge is suppressed.
2. **Gate B (Laboratory):** We digitized exclusion curves from Kapner et al. (Eöt-Wash). Any model predicting a Yukawa force $\alpha > \alpha_{max}(\lambda)$ at laboratory densities is rejected.
3. **Gate C (Cosmic History):** We verified that viable candidates do not disrupt Big Bang Nucleosynthesis (BBN).

3.2 The Parameter Scan

We explored the parameter space:

- $n = 1$
- Coupling Strength $\beta \in [0.01, 10,000]$
- Energy Scale $\Lambda \in [10^{-10}, 1]$ eV

4. Results

4.1 Survival of Strong Coupling

Contrary to standard expectations, models with **extremely strong couplings** ($\beta \sim 10^4$) survived the screening tests. The Eöt-Wash constraints successfully eliminated $\sim 40\%$ of the parameter space (specifically models with intermediate ranges $\lambda_{lab} \sim 1$cm).

However, a distinct region of viability emerged where the field is sufficiently heavy in the lab to escape detection ($\lambda_{lab} \ll 10\mu m$), yet theoretically active on cosmological scales.

4.2 The Void Prediction (The Signature)

Using the surviving parameters, we simulated the behavior of the field in a cosmic void ($\rho_{void} \approx 10^{-28}$ kg/m^3).

In this regime, the screening mechanism lifts ("unscreening"). The fifth force strength α_{gas} scales as $2\beta^2$.
For viable high-β models, we found:

$$\alpha_{gas} \approx 2 \times 10^8 \quad \text{to} \quad 2 \times 10^{10}$$

This implies a gravitational attraction on diffuse gas that is **billions of times stronger** than standard gravity, but effective only over ranges of ~ 200 AU to 1 Mpc, depending on the model.

5. Discussion

5.1 Resolving the Early Galaxy Mystery

Observations by JWST have identified massive galaxies forming at redshifts $z > 10$, far earlier than allowed by the standard ΛCDM model using standard gravity.

LF-EFT offers a solution: In the early universe, local under-densities (voids) would trigger the unscreening of the information potential. This would result in a "Flash Collapse"—a rapid, non-linear acceleration of gas aggregation driven by the minimization of information entropy (Negentropy). This allows structure formation to bypass the slow linear growth phase of ΛCDM.

5.2 Link to Infodynamics

This physical mechanism supports Vopson's Second Law of Infodynamics. Gravity is not merely curvature; it is the macroscopic result of the universe minimizing the information content of spacetime.

- **High Density:** Information is optimized/compressed. The "force" relaxes (Screened).
- **Low Density:** High information entropy. The "force" activates aggressively to compress matter and lower entropy.

6. Conclusion

We have presented a scalar-tensor implementation of Information Physics that is consistent with General Relativity in the Solar System. LF-EFT predicts that "Information Gravity" is environmentally dependent. This framework turns the Second Law of Infodynamics into a testable cosmological predictor, offering a clean resolution to the tension between early universe observations and standard physical models.

References

[1] Vopson, M. M. (2019). The mass-energy-information equivalence principle. *AIP Advances*.
[2] Vopson, M. M. (2022). Second law of information dynamics. *AIP Advances*.
[3] Vopson, M. M. (2025). Is gravity evidence of a computational universe? *AIP Advances*.
[4] Damour, T., & Polyakov, A. M. (1994). The string dilaton and a least coupling principle. *General Relativity and Gravitation*.
[5] Bertotti, B., et al. (2003). A test of general relativity using radio links with the Cassini spacecraft. *Nature*.
[6] Kapner, D. J., et al. (2007). Tests of the gravitational inverse-square law below the dark-energy length scale. *Physical Review Letters*.
[7] Khoury, J., & Weltman, A. (2004). Chameleon fields: Awaiting surprises for tests of gravity in space. *Physical Review Letters*.

Open Science: The source code, viability pipeline, and constraint data are available at:
`github.com/TheLightFramework/Light-Fold-Cosmology`