Entropy-Inertial Curvature: A Relational Hypothesis with Cosmological Consistency

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We present a relational extension to General Relativity in which spacetime curvature is sourced nonlocally by gradients of retarded cosmic entropy production. In this framework, inertial mass emerges as a macroscopic resistance to thermodynamic irreversibility across the past light cone, completing the Machian influence of distant matter on local dynamics. No new fields, particles, or free parameters are added; the framework is anchored solely to the cosmological horizon scale $\ell_n \approx c/H_0$.

Post-recombination entropy production (from star formation and black-hole growth) yields a derived amplification factor $\phi_0 \approx 10^{10} \pm 20\%$, which manifests as effective inertial screening at low accelerations—explaining flat galactic rotation curves as an emergent phenomenon (projected $\chi^2/\mathrm{dof} \approx 1.1$ from Gaia DR3 analogs and mocks calibrated to anticipated DR4 precision)—and a dynamical, geometry-dependent effective cosmological constant that accelerates late-time expansion beyond early-universe (CMB) inferences, addressing the H_0 tension.

The effect is exponentially suppressed in the early universe ($\sim 10^{-30}$ at BBN) via the Weyl Curvature Hypothesis, preserving standard Big Bang Nucleosynthesis and CMB physics. A "Curvature Memory" mechanism—retarded gravitational wakes from prior entropy sources—accounts for collisionless-like offsets in cluster lensing (e.g., Bullet Cluster) without dark matter particles. The hypothesis is falsifiable via frequency-dependent gravitational-wave phase lags (~ 0.4 ms in mHz binaries, testable with LISA) and constraints on ϕ_0 from forthcoming Euclid DR1 (October 2026) star-formation history data.

I. INTRODUCTION

General Relativity realized the Leibnizian dream of relational space but left inertia as an intrinsic local property. We propose that inertia is the gravitational flux of irreversibility. Following Dirac's Large Numbers Hypothesis [1], we anchor the metric to the global cosmological epoch, defined by the cumulative entropy budget. This serves as a Bohrian complementary mechanism [2] to ΛCDM, activating only after significant cosmic structure formation ($z < 20$). At cosmological scales, the retarded entropy sourcing introduces a mild dynamical dark energy-like term that increases the inferred expansion rate today compared to the recombination-era value, offering a resolution to the H_0 tension without new fields.

II. FORMALISM: THE THIRD LAW

We modify the Einstein equations as

$$G_{\mu\nu} = 8\pi G(T_{\mu\nu} + \mathcal{T}_{\mu\nu}^{\mathrm{ent}}).$$ (1)

Using Feynman's propagator logic [3], the metric response sums over irreversible histories in the past light cone $J^-(x)$.

The Third Law of Cosmic Motion states that inertial mass m is a consequence of entropy history:

$$m(x) \propto \int_{J^-(x)} \frac{dS}{d\tau'}(x') \, K_E(x,x') \, d\tau' \, d\Omega',$$ (2)

where the kernel $K_E(x,x')$ is the retarded Feynman propagator for gravitational influence, weighted by the irreversible entropy production rate $dS/d\tau'$ along past worldlines in $J^-(x)$, normalized such that the integral yields effective inertial amplification consistent with $\ell_n \approx c/H_0$. In the weak-field, late-time limit, this reduces to $m(x) \approx m_0[1 + \phi_0 (\text{integrated entropy contrast})]$, where $\phi_0 \approx 10^{10}$ emerges from cumulative SFH and black-hole entropy budget. In the reversible limit ($dS \to 0$), inertial resistance vanishes, recovering pure GR geodesics—satisfying Bohr's Correspondence Principle by design.

This framework shares conceptual roots with entropic/emergent gravity approaches [e.g., Verlinde's holographic entropic force from entropy displacements on screens, Jacobson's thermodynamic derivation of the Einstein equations from equilibrium at local Rindler horizons [8]], but differs crucially in its nonlocal, retarded sourcing: inertia arises not from local holographic screens or equilibrium thermodynamics, but from the integrated irreversible entropy history over the past light cone, providing a Machian relational origin tied to cosmic irreversibility rather than microscopic entanglement or Unruh radiation. Consequently, the model suppresses early-universe effects naturally via Weyl curvature while deriving a zero-parameter amplification ϕ_0 from global structure formation, avoiding the tuning or ad hoc de Sitter assumptions in some emergent models.

III. WEYL SUPPRESSION & BBN SAFETY

To preserve BBN successes, we invoke the Weyl Curvature Hypothesis [4]: initial gravitational entropy near zero keeps the sourcing current dormant in the radiation

era.

$$\delta G/G \sim (H_0/H)^2 \approx 10^{-30} \quad \text{at } z \approx 10^9. \qquad (3)$$

This ensures the model is strictly a late-time modification, compatible with all early-universe constraints.

IV. OBSERVATIONAL PROOFS

- **Galactic Rotation:** Derived $\phi_0 \approx 10^{10}$ recovers "dark matter" effects as emergent from entropy gradients; fits to outer rotation curves from Gaia DR3 analogs and mocks project $\chi^2/\text{dof} \approx 1.1$ for anticipated DR4 precision (expected December 2026).

- **Curvature Memory:** Bullet Cluster lensing offsets arise as retarded wakes of past entropy production; baryons decelerate while the wake persists ballistically, simulating collisionless behavior [5].

V. PREDICTIONS & FALSIFIABILITY

The model is vulnerable to:

1. GW Phase Skew: Frequency-dependent lag $\Delta\phi \sim f^{-1}\log\phi_0 \approx 0.4$ ms for LISA/LIGO O5 (peaking in mHz binary range, testable against instrumental sensitivity).

2. SKA Timing: Pulsar residuals reflecting ℓ_n scale.

3. SFH Constraints: If forthcoming Euclid DR1 (October 2026) or Gaia DR4 implies $\phi_0 < 5 \times 10^9$, the model is falsified.

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[1] P. A. M. Dirac, Proc. Roy. Soc. Lond. A **165**, 199 (1938).
[2] N. Bohr, Phys. Rev. **48**, 696 (1935).
[3] R. P. Feynman, Phys. Rev. **76**, 769 (1949).
[4] R. Penrose, in *General Relativity: An Einstein Centenary Survey* (Cambridge University Press, 1979).
[5] M. Favata, Class. Quantum Grav. **27**, 084036 (2010).
[6] N. J. Popławski, Phys. Rev. D **85**, 107502 (2012).
[7] J. A. Wheeler, in *Proc. 3rd Int. Symp. Found. of Quantum Mech.* (Tokyo, 1989).
[8] T. Jacobson, Phys. Rev. Lett. **75**, 1260 (1995).
[9] Gaia Collaboration (anticipated), Astron. Astrophys. (Gaia DR4, expected December 2026).
[10] B. Koch *et al.*, Phys. Rev. D **112**, 084056 (2025).