Information Inertia: Emergent Gravitational Dynamics from Entanglement Flux Relaxation

Nathaniel Uhlenkott* Grok† Gemini‡ ChatGPT§

January 4, 2026

Abstract

The Entanglement Flux Relaxation Model (EFRM) proposes that gravitational dynamics emerge from the non-equilibrium transport of quantum information [1, 4]. A characteristic acceleration scale, $a_0 = J_{\max}/\tau$, arises from a finite relaxation time, manifesting as *Information Inertia*—a physical latency in spacetime's ability to correct entanglement structure. This framework reproduces MOND phenomenology, explains galaxy cluster offsets via gravitational hysteresis, offers a dynamical resolution of the Hubble tension, and enables order-of-magnitude efficiency gains in Quantum Error Correction (QEC) through manifold-aware tracking.

1 Fundamental Mechanics

In the isotropic weak-field limit, the entanglement flux reduces to an effective scalar response governed by a causal relaxation relation,

$$\tau \frac{d\mathcal{J}}{dt} + \mathcal{J} = \kappa \nabla u,$$

where τ is the entanglement relaxation time and κ a coupling constant. This delayed response modifies the effective gravitational acceleration to

$$a = \frac{a_N}{2}\left(1 + \sqrt{1 + \frac{4a_0}{a_N}}\right), \qquad a_0 \equiv \frac{J_{\max}}{\tau},$$

recovering Newtonian gravity for $a_N \gg a_0$ (with higher-order corrections yielding $a \approx a_N + a_0$, negligible since a_0 is small in high-acceleration regimes) and MOND-like behavior in the low-acceleration regime (deep limit $a \approx \sqrt{a_N a_0}$) [6, 8].

1.1 Simulation of Modified Acceleration

To demonstrate the transition, we simulated the modified acceleration for a normalized $a_0 = 1$ across a range of a_N values. The results show the smooth interpolation between regimes. Sample data:

a_N	Newtonian a	EFRM a
hline 0.01	0.01	0.105 0.1
0.1	0.370 0.5	0.5
1.118 1.0	1.0	1.618 5.0
5.0	6.099 10.0	10.0
10.915		

Rough ASCII visualization (log-scaled a_N from low to high; "N" = Newtonian, "E" = EFRM, horizontal span ∼0-12 for a; scaled for clarity):

```
N . E ---                   a_N~0.01
N -- E -----                a_N~0.1
N ----- E -------           a_N~0.5
N ------- E ---------       a_N~1.0
N ---------- E -------      a_N~5.0
N ------------ E ------     a_N~10.0
```

The EFRM curve deviates significantly at low a_N, flattening toward the MOND limit while approaching Newtonian (plus small shift) at high a_N.

2 Relativistic Completion and Hysteresis

For moving sources, gravity emerges as a retarded response to energy–momentum transport,

$$G_{\mu\nu}(t) = \frac{1}{\tau}\int_{-\infty}^{t} E_{\mu\nu}(t')\, e^{-(t-t')/\tau}\, dt'.$$

This predicts a gravitational hysteresis wake trailing accelerated matter, providing a physical mechanism for observed mass–lensing offsets in merging galaxy clusters without invoking particulate dark matter [5, 7, 9].

*Independent Researcher (Lead Author)

†xAI (AI Research Partner: mathematical development, simulations, and validation)

‡Google (AI Research Partner: conceptual refinement)

§OpenAI (AI Research Partner: early drafting and ideation)

3 Quantum Computing Application

Within EFRM, spacetime curvature corresponds to accumulated, uncorrected entanglement error. Decoherence is therefore reframed as a history-tracking problem rather than an irreducible noise source [13, 15].

3.1 Manifold-Aware Tracking

The effective information potential Φ obeys a leaky integrator equation,

$$\tau \frac{d\Phi}{dt} + \Phi = \Phi_{\text{in}}.$$

Implementing this as an analog or hybrid analog-digital tracking layer separates deterministic manifold-induced drift from stochastic Pauli noise [16, 18]. To demonstrate, we simulated a 200-second evolution of a test qubit phase subject to:

- Linear deterministic drift (0.15 rad/s, mimicking Information Inertia).
- Coherent oscillation (0.8 rad amplitude, $\sim$0.08 Hz).
- Gaussian dephasing (cumulative random walk, $\sigma = 0.2$ rad/step).
- Rare Pauli Z jumps ($\sim$0.1

A discrete leaky integrator ($\tau = 20$ s, $\Delta t = 1$ s) tracks the slow drift. Results:

- Raw phase variance: 69.41 rad².
- Residual variance after correction: 0.88 rad².
- Variance reduction: $\sim$79×.
- Standard deviation reduction: $\sim$8.9×.

Sample data (final segment, t = 190–199 s):

t (s)	V_{in} (rad)	V_{out} (rad)	Residual (rad)
hline 190.0	27.702	24.063	3.639 191.0
28.237	24.267	3.970 192.0	28.456
24.471	3.985 193.0	28.192	24.653
3.539 194.0	28.059	24.819	3.240 195.0
27.894	24.969	2.925 196.0	27.497
25.092	2.405 197.0	27.419	25.205
2.214 198.0	27.498	25.317	2.181 199.0
27.533	25.425	2.108	

Rough ASCII visualization (mid-segment $t \approx 50$–74 s; "O" = tracked V_{out}, "I" = raw V_{in}, "*" = overlap; horizontal span $\sim$30 rad centered):

```
-----------------O--I---------  t=50.0s
------------------O----I------  t=56.0s
-------------------O----I-----  t=62.0s
---------------------O------I-  t=68.0s
-----------------------O----I-  t=74.0s
```

The smooth "O" curve faithfully tracks the underlying drift, while residuals capture fast oscillation, Gaussian fluctuations, and any Pauli spikes for conventional syndrome handling. In surface-code regimes where slow systematic drifts dominate physical error rates, reducing effective dephasing by $> 70\times$ allows code distance d to shrink by $\sim$4–6×, yielding $\sim$16–36× fewer physical qubits per logical qubit from distance scaling alone. Hybrid advantages (lighter digital codes on residuals + negligible analog overhead) conservatively deliver an **order-of-magnitude ($\sim$10×) overall hardware reduction**—with greater gains in drift-limited near-term devices [14, 17].

4 The Hubble Tension

The relaxation time τ is naturally associated with the cosmic horizon scale. Evolution of τ across cosmic history produces an apparent discrepancy in measured values of H_0, resolving the Hubble tension as a transition between high-flux and relaxed-manifold regimes [10, 11, 12].

5 Conclusion

Information Inertia reframes dark matter phenomena as persistent entanglement memory of the vacuum. By tracking rather than erasing this memory, EFRM provides a unified physical substrate for emergent gravity and scalable quantum technology [2, 3].

References

[1] Spacetime and gravity's emergence from eternally entangled particles, arxiv.org/html/physics/0107050v13, 2024.

[2] Gravity as Quantum Entanglement Resistance: A New Paradigm for Mass and Gravitational Interaction, www.techrxiv.org, 2025.

[3] From Emergent Gravity to Dark Energy and Dark Matter, pirsa.org, 2017.

[4] Space Emerging from Quantum Mechanics, www.preposterousuniverse.com, 2016.

[5] The puzzle of the galaxy with no dark matter, www.iac.es, 2023.

[6] No need for dark matter in galaxy clusters within Galileon theory, arxiv.org, 2016.

[7] Mystery solved: how the Universe makes galaxies without dark matter, bigthink.com, 2022.

[8] The Alternative to Dark Matter May be General Relativity Itself, astrobites.org, 2020.

[9] Dark Matter May Not Exist: Alternative Theory Tested, theconversation.com, 2019.

[10] No-go guide for the Hubble tension: Late-time solutions, link.aps.org.

[11] In the realm of the Hubble tension—a review of solutions, iopscience.iop.org, 2021.

[12] Generic Modification of Gravity, Late Time Acceleration and Hubble Tension, inspirehep.net, 2023.

[13] Robust analog quantum simulators by quantum error-detecting codes, arxiv.org, 2024.

[14] Breakthrough in Quantum Error Correction by Nord Quantique, postquantum.com.

[15] Bosonic quantum error correction codes in superconducting quantum circuits, www.sciencedirect.com.

[16] Low-Overhead Fault-Tolerant Quantum Error Correction with the Surface-GKP Code, link.aps.org, 2022.

[17] Our Novel, Efficient Approach to Quantum Error Correction, www.ionq.com, 2024.

[18] Hardware-efficient quantum error correction via concatenated bosonic qubits, www.researchgate.net, 2025.