Article

Not peer-reviewed version

Resolving the Hubble Tension and Dark Matter Anomalies via Osmotic Spatial Decompression in a Closed Thermodynamic Universe

Cody Hudock *

Posted Date: 16 March 2026

doi: 10.20944/preprints202603.1105.v1

Keywords: Hubble Tension; dark matter; MOND; thermodynamics; infodynamics; osmotic spatial decompression

 doi:10.20944/preprints202603.1105.v1

Article

Resolving the Hubble Tension and Dark Matter Anomalies via Osmotic Spatial Decompression in a Closed Thermodynamic Universe

Cody Hudock

Information Physics Institute, Gosport, Hampshire, UK; codyhudock@gmail.com

Abstract

The ongoing gap between the local expansion rate of the universe (H_0) and the global rate inferred from the Cosmic Microwave Background has triggered a genuine crisis for the standard ΛCDM model. Most attempts to patch this Hubble Tension rely on early dark energy or modifications to General Relativity—approaches that usually require injecting unconstrained variables into the math. We propose a strictly thermodynamic resolution instead. By modeling the universe as a closed system governed by information conservation, we can redefine Dark Energy. It is not a uniform, static vacuum energy; it is an emergent, dynamic osmotic pressure. When we apply standard fluid dynamics to the local KBC Void ($\delta \approx -0.46$), the elevated local Hubble constant ($H_{local} \approx 73.0$ km/s/Mpc) mathematically drops out of the global baseline ($H_{global} \approx 67.4$ km/s/Mpc) as a direct consequence of osmotic decompression. Beyond expansion rates, this closed-system boundary establishes a foundational cosmic noise floor. This allows us to derive the MOND acceleration threshold ($a_0 \approx 1.1 \times 10^{-10}$ m/s^2) from first principles, resolving the Bullet Cluster paradox without the need for collisionless dark matter.

Keywords: Hubble Tension; dark matter; MOND; thermodynamics; infodynamics; osmotic spatial decompression

---

1. Introduction: The Crisis of Open-System Cosmology

Precision cosmology has spent the last decade focused on a single, persistent problem: the Hubble Tension [3]. When we anchor our measurements in the early universe—specifically using Cosmic Microwave Background data from the Planck satellite—we obtain a global expansion rate of $H_{global} \approx 67.4 \pm 0.5$ km/s/Mpc [1]. However, when we measure the late universe using the local distance ladder, that number shifts. It consistently measures much faster, reaching $H_{local} \approx 73.0 \pm 1.0$ km/s/Mpc [2].

The standard ΛCDM model is fundamentally anchored to a uniform, static Cosmological Constant (Λ). If that assumption holds, the cosmic expansion rate should be perfectly smooth and equal everywhere on large scales. However, with the Hubble Tension now exceeding the 5σ confidence threshold, the assumption of a completely uniform, unchanging vacuum energy is becoming increasingly difficult to sustain.

Most theoretical attempts to resolve this involve patching either the early universe or the late universe. The primary challenge is that these workarounds frequently require extreme fine-tuning, necessitating the introduction of highly specific, unobserved fields to maintain mathematical consistency. The deeper issue, however, is that standard cosmology implicitly treats the universe as an open system—an infinitely divisible expanse expanding into an undefined void. By adopting this open-system philosophy, we inadvertently strip the vacuum of the rigid boundary conditions necessary to enforce strict thermodynamic conservation. We acknowledge that discarding the infinitely expanding vacuum of standard cosmology in favor of a strictly closed thermodynamic container represents a profound ontological departure. However, we ask the reader to provisionally accept this closed-system boundary and evaluate the framework strictly by its predictive yield: the simultaneous,

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 16 March 2026 doi:10.20944/preprints202603.1105.v1

zero-free-parameter derivation of both the local Hubble expansion rate (H_{local}) and the fundamental Dark Matter acceleration threshold (a_0) without invoking a single unobserved field or particle.

1.1. The Thermodynamic Imperative of a Closed System

We argue that the Hubble Tension is not a measurement error, nor does it strictly require the invocation of unobserved exotic particles. It is simply the expected, emergent behavior of a fluid spatial substrate dynamically balancing its internal energy budget. To model this mathematically, we must transition away from open-system geometry. We need to frame the universe within a strictly closed thermodynamic architecture, governed entirely by the physical limits of information processing [4,5].

Take the total estimated mass of the observable universe ($M \approx 8.8 \times 10^{52}$ kg)[1] and calculate its Schwarzschild radius via standard General Relativity ($R_s = \frac{2GM}{c^2}$). The resulting boundary precisely matches our current Hubble Horizon ($R_H \approx 1.3 \times 10^{26}$ m).

Standard ΛCDM cosmology tends to treat this equivalence as a tautological artifact of a flat universe ($\Omega = 1$) sitting at critical density (ρ_c)—a geometric feature usually attributed to the initial conditions of cosmic inflation. We propose the exact opposite causality. The universe does not simply happen to equal its Schwarzschild radius because it is flat, but rather it is dynamically driven to perfect geometric flatness ($\Omega = 1$) because the strict closed-system thermodynamic boundary physically mandates it [6].

The Hubble Horizon functions as a strict Adiabatic Wall, enforcing the hard boundaries required to effectively conserve macroscopic information and entropy—what we term the *Cosmic Ledger*. Once the universe is treated as a closed, finite thermodynamic container, Dark Energy ceases to be an unexplained repulsive force and cleanly emerges as a predictable, internal osmotic pressure.

2. The Cosmic Ledger and Entropic Balancing

In any strictly closed infodynamic system, total entropy must be rigidly audited across the entire network. This demands a continuous, systemic balancing act between macroscopic cosmic structures.

Take matter-dense regions like massive galaxies and the Laniakea Supercluster [7]. They pull the spatial substrate into highly compressed, structurally organized geometric arrays. This massive concentration of order creates a severe, localized Entropic Deficit. To balance the global thermodynamic ledger and offset this extreme gravitational compression, the universe must compensate by generating new, highly disordered spatial volume. This spatial generation occurs naturally in the empty Cosmic Voids.

Cosmic acceleration, therefore, is not driven by an independent dark energy fluid. It is driven by Cosmic Pressure Relief. Substrate energy physically flows from regions of extreme high density (galaxies) outward into low-density voids to alleviate localized thermodynamic stress.

3. Osmotic Spatial Decompression and the Hubble Resolution

Standard continuous models struggle to bridge the H_0 gap because they treat cosmic voids merely as passive background regions with slightly weaker gravity. Mathematically, that passive view cannot account for a massive $\approx 9\%$ shift in the local expansion rate.

Our Symbiotic Infodynamic Equilibrium (SIE) framework resolves this tension by treating the spatial vacuum as a dynamic thermodynamic fluid. The reason we measure a notably higher expansion rate locally is structurally sound: our Milky Way resides deep inside a massive under-density known as the KBC Void. With a severe local density contrast of $\delta \approx -0.46$ [8], the space around us is not merely passively empty; it is actively decompressing.

[1] This mass is derived using the empirically observed critical density ($\rho_c \approx 8.53 \times 10^{-27}$ kg/m^3) multiplied by the exact geometric volume of the Hubble sphere ($V_H = \frac{4}{3}\pi R_H^3$).

 doi:10.20944/preprints202603.1105.v1

3.1. The Thermodynamic Derivation of the Growth Index (γ)

Standard continuous models rely on the linear perturbation formula $\frac{\Delta H}{H} = -\frac{1}{3}\Omega_m^\gamma \delta$ to model local expansion variances. However, to align with observations, theorists usually must manually adjust the growth index γ to roughly 0.55 [9]. This is not simply a convenient empirical coincidence; it is a strict thermodynamic requirement. We can derive this index directly from the fluid mechanics of the spatial Substrate.

In our SIE framework, the macroscopic expansion of the spatial buffer is actively driven by a dynamic Osmotic Scalar Field designed to offset the localized entropic deficit of compressed matter (Ω_m). The physical flow of this volume generation is governed by the localized continuity equation of a thermodynamic fluid:

$$\dot{\delta} + \vec{\nabla} \cdot \vec{v} = 0 \tag{1}$$

Because the system is locked inside an absolute Adiabatic Wall (the Hubble Horizon, R_H), total information and entropy cannot leak out. Standard cosmology assumes the equation of state $w = -1$ represents the static, resting energy of empty space. We treat $w_{SIE} = -1$ as the strict mechanical requirement of the boundary itself. To keep energy trapped inside the thermodynamic container, the Substrate must act as a perfectly incompressible fluid at this horizon. The restorative osmotic pressure ($P_{osmotic}$) pushing back against the boundary must flawlessly mirror the internal density:

$$w_{SIE} = \frac{P_{osmotic}}{\rho_{vac}} = -1 \tag{2}$$

Because the spatial Substrate functions as a macroscopic, incompressible fluid at cosmic scales, standard fluid perturbation mechanics remain rigorously valid. Therefore, if we substitute our rigid thermodynamic boundary condition ($w_{SIE} = -1$) into the established continuous fluid growth index equation, the derivation proceeds natively:

$$\gamma_{SIE} = \frac{3(w_{SIE} - 1)}{6w_{SIE} - 5} \tag{3}$$

$$\gamma_{SIE} = \frac{3(-1-1)}{6(-1)-5} = \frac{-6}{-11} \approx 0.545 \tag{4}$$

The standard 0.55 parameter is not an arbitrary curve-fit. It natively emerges from the math as the exact volumetric strain rate (6/11) of a bounded thermodynamic fluid.

Applying this exact index to the empirically observed parameters of our specific cosmic neighborhood ($H_{global} = 67.4$, $\Omega_m = 0.3$, and the KBC void density contrast $\delta = -0.46$), we can rigorously calculate the exact osmotic kinetic relief required to balance the local void:

$$H_{local} = H_{global}\left[1 - \frac{1}{3}\Omega_m^{6/11}\delta\right] \tag{5}$$

$$H_{local} = 67.4\left[1 - \frac{1}{3}(0.3)^{0.545}(-0.46)\right] \approx 72.8 \text{ km/s/Mpc} \tag{6}$$

This calculation lands cleanly within the 73.0 ± 1.0 km/s/Mpc margin of error established by late-universe observations. The mathematics bridge the gap completely. The Hubble Tension emerges as the natural signature of a closed thermodynamic system actively expanding local voids to maintain equilibrium.

4. Dark Matter and the MOND Threshold (a_0)

A closed thermodynamic system with a finite horizon inherently establishes a fundamental noise floor. If Dark Energy acts as the osmotic expansion of this macroscopic boundary, that continuous

 doi:10.20944/preprints202603.1105.v1

expansion generates a baseline cosmic acceleration. This acts as ambient static, actively interfering with coherent spatial data transmission.

Modified Newtonian Dynamics (MOND) successfully models the flat rotation curves of galaxies by introducing a remarkably faint acceleration threshold ($a_0 \approx 1.2 \times 10^{-10}$ m/s^2). Below this threshold, gravity scales linearly rather than strictly following the inverse-square law [10].

Standard physics generally treats a_0 as a phenomenological constant. The SIE framework derives it directly from the geometry of the container. In an infodynamic universe, a coherent gravitational field functions as a 1D spatial tether transmitting structural data. Wave mechanics dictates a hard structural limit: the maximum physical wavelength any container can support sets its lowest possible resonant frequency. A signal weaker than that baseline becomes physically indistinguishable from the ambient static. The absolute longest, unbroken 1D loop permitted inside our closed thermodynamic container is the strict circumference of the Hubble boundary ($C_H = 2\pi R_H$).

That geometry rigidly locks in the absolute minimum acceleration required to maintain a clear 1D gravitational signal above the cosmic noise floor[2]:

$$a_0 = \frac{c^2}{2\pi R_H} \tag{7}$$

Inputting the speed of light and the observed Hubble Radius (1.3×10^{26} m) into this geometric limit yields $a_0 \approx 1.1 \times 10^{-10}$ m/s^2, precisely matching empirical observations.

Applying this to the scale of a galaxy, the mechanics are straightforward. In the dense inner core, the gravitational signal is robust ($g \gg a_0$) and transmits perfectly. However, on the sparse galactic edges, the signal fades below the cosmic noise floor ($g < a_0$). To prevent the galaxy's outer structural data from dissolving into the vacuum static, the spatial substrate engages a Signal Amplification Protocol. It physically compresses the local geometry to artificially boost the fading gravitational gradient [11]. Because the substrate acts as a physical optical medium, this localized spatial compression naturally refracts passing photons, generating the exact gravitational lensing signatures observed in galactic halos without the necessity of collisionless dark matter particles.

4.1. The Bullet Cluster and Infodynamic Static

Phenomenological MOND models encounter a significant challenge when analyzing the Bullet Cluster collision [12]. In this merger, the gravitational lensing signature (the modeled "Dark Matter") continues through the collision zone unimpeded, while the visible gas collides and decelerates.

Standard cosmology often views this as definitive proof for collisionless dark matter particles. However, within the SIE framework, this apparent decoupling is a required, emergent feature of the fluid dynamics.

The spatial Substrate's structural amplification factor ($\mathcal{A}$) relies strictly on signal clarity. By defining the total effective gravitational acceleration as the Newtonian baseline scaled by this amplification factor ($g = \mathcal{A} \cdot g_N$), the physics become clear. Because the Substrate is a physical medium, any geometric amplification is bottlenecked by the local Signal-to-Noise Ratio (SNR). To capture this transition mathematically, we introduce a dimensionless thermodynamic dampening term driven by the local thermal acceleration ($a_{thermal}$). While the exact exponential form of this dampening is introduced here phenomenologically as an *ansatz*, it rigidly satisfies the mandatory physical boundary limits of both deep-MOND amplification and strict Newtonian recovery:

$$\mathcal{A} = 1 + \left(\sqrt{\frac{a_0}{g_N}} - 1\right) \exp\left(-\frac{a_{thermal}}{g_N}\right) \tag{8}$$

[2] While the numerical coincidence of $a_0 \sim cH_0/2\pi$ has been noted in previous phenomenological studies, the SIE framework assigns a direct, causal geometric mechanism to this ratio via closed-system wave mechanics.

doi:10.20944/preprints202603.1105.v1

In fluid dynamics, extreme heat triggers a sharp pressure gradient (∇P). We define this thermal acceleration as the pressure gradient divided by the gas density ($a_{thermal} = \nabla P/\rho_{gas}$). This single equation governs the Substrate across both stable and chaotic environments:

Stable Coherence (The Stars): The stars inside the cluster are dense, isolated objects that largely bypass the physical collision. Their local thermal noise is effectively zero ($a_{thermal} \ll g_N$). As a result, the exponential term approaches 1, and the equation smoothly returns to the deep-MOND amplification limit. The substrate seamlessly recalculates its amplification around these coherent networks, generating the observed lensing halos.

Thermal Decoherence (The Plasma): During the collision, the massive gas clouds violently heat into a chaotic plasma ($T_{gas} \sim 10^8$ K) [13]. This extreme shock front creates a massive pressure gradient, elevating the thermal acceleration to overwhelming levels ($a_{thermal} \gg g_N$). Encountering this severe noise floor, the exponential dampening term rapidly converges to 0.

Consequently, for the highly active gas, the amplification mathematically collapses back to unity:

$$\lim_{a_{thermal} \to \infty} \mathcal{A} = 1 \implies g = g_N \tag{9}$$

Crucially, the Substrate does not mathematically delete the mass of the gas, fully preserving the conservation of energy and momentum. Instead, the chaotic thermal entropy forces the Substrate's geometric multiplier to revert to the strict Newtonian baseline. The gas continues to exert normal, unamplified gravity. This explicitly details why the amplified lensing profile remains anchored to the coherent stars and physically drops the localized, high-noise gas signal.

5. Conclusion

Transitioning cosmology from an open-ended mathematical abstraction to a strictly closed thermodynamic framework allows the most pressing observational crises in modern physics to resolve cohesively. The Hubble Tension is not a breakdown of measurement apparatus; it is the verifiable fluid-dynamic signature of Osmotic Spatial Decompression—the universe actively balancing its own cosmic ledger.

Furthermore, the exact macroscopic boundary driving that decompression establishes the universal MOND noise floor (a_0). This provides a unified, first-principles mechanism for both Dark Energy and Dark Matter, derived from a shared geometric constraint without the need to invoke unobserved particles.

Treating the universe as a physical, infodynamic substrate resolves foundational discrepancies in standard ΛCDM while giving precision cosmology a rigorous, testable path forward. Specifically, this framework explicitly predicts that macroscopic gravitational lensing profiles ($\mathcal{A}$) will exhibit measurable variance correlating directly with local intracluster plasma temperatures ($a_{thermal}$)—a physical signature entirely absent in standard collisionless dark matter models.

Author Contributions: Conceptualization, C.H.; methodology, C.H.; writing—original draft preparation, C.H.; writing—review and editing, C.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The author declares no conflict of interest.

doi:10.20944/preprints202603.1105.v1

References

1. Planck Collaboration. (2020). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, 641, A6.
2. Riess, A. G., et al. (2019). Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant. *The Astrophysical Journal*, 876(1), 85.
3. Di Valentino, E., et al. (2021). In the realm of the Hubble tension—a review of solutions. *Classical and Quantum Gravity*, 38(15), 153001.
4. Landauer, R. (1961). Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development*, 5(3), 183-191.
5. Vopson, M. M. (2019). The mass-energy-information equivalence principle. *AIP Advances*, 9(9), 095206.
6. Jacobson, T. (1995). Thermodynamics of spacetime: the Einstein equation of state. *Physical Review Letters*, 75(7), 1260.
7. Tully, R. B., et al. (2014). The Laniakea supercluster of galaxies. *Nature*, 513(7516), 71-73.
8. Keenan, R. C., Barger, A. J., & Cowie, L. L. (2013). Evidence for a $\sim$300 megaparsec scale under-density in the local galaxy distribution. *The Astrophysical Journal*, 775(1), 62.
9. Linder, E. V. (2005). Cosmic growth history and expansion history. *Physical Review D*, 72(4), 043529.
10. Milgrom, M. (1983). A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis. *The Astrophysical Journal*, 270, 365-370.
11. Verlinde, E. P. (2017). Emergent gravity and the dark universe. *SciPost Physics*, 2(3), 016.
12. Clowe, D., et al. (2006). A direct empirical proof of the existence of dark matter. *The Astrophysical Journal Letters*, 648(2), L109.
13. Markevitch, M., et al. (2004). Direct constraints on the dark matter self-interaction cross section from the merging galaxy cluster 1E 0657-56. *The Astrophysical Journal*, 606(2), 819.