The Geometric Entropy Solution: Resolving the Hubble Tension via Holographic Scaling

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The persistence of the Hubble Tension—a 5σ discrepancy between early-universe (CMB) and late-universe (SH0ES) measurements of H_0—suggests a fundamental missing component in the ΛCDM model. We propose the **Osacra-Holographic Ansatz**, which postulates that vacuum energy is not a static cosmological constant, but a dynamic record of cosmic entropy production. By modeling the vacuum microstructure as a Rhombic Dodecahedral lattice (the shadow of a 4D hypercube), we derive a geometric coupling constant $\alpha = 1/\sqrt{3} \approx 0.577$. When this coupling is applied to the entropy flux generated by the Madau-Dickinson Star Formation Rate, the model naturally predicts a local Hubble constant of $H_0 = 70.80$ km s^{-1} Mpc^{-1}. This value mediates the tension, aligning with Tip of the Red Giant Branch (TRGB) measurements. Rigorous falsification tests confirm the model preserves the age of the universe ($t_0 \approx 13.71$ Gyr) and remains indistinguishable from Type Ia Supernovae observations ($\Delta\mu \approx -0.03$ mag), suggesting the tension is an artifact of imposing a static vacuum on a dynamic universe.

I. INTRODUCTION

The standard cosmological model (ΛCDM) assumes the energy density of the vacuum, ρ_{vac}, is constant throughout cosmic history ($w = -1$). While successful at describing the Cosmic Microwave Background (CMB) [1], this assumption has led to a crisis in the local universe. The Planck mission derives $H_0 = 67.4 \pm 0.5$ km s^{-1} Mpc^{-1}, while local Cepheid-Supernova distance ladders (SH0ES) measure 73.04 ± 1.04 km s^{-1} Mpc^{-1} [2].

We investigate the hypothesis that this tension arises because ρ_{vac} is actually dynamic, driven by the holographic storage of information on the cosmic horizon. We present a parameter-free mechanism where the vacuum energy density scales with the cumulative entropy of structure formation, governed by a specific geometric projection factor.

II. THE GEOMETRIC ANSATZ

We postulate that the vacuum satisfies a holographic packing condition. If spacetime information is discrete and packed with maximal density, the lattice structure must minimize the Wigner-Seitz cell volume. For a Face-Centered Cubic (FCC) lattice—the densest possible packing in 3D space—the unit cell is the **Rhombic Dodecahedron**.

A. Derivation of the Coupling Constant α

The Rhombic Dodecahedron is the vertex-first projection of a 4D hypercube (tesseract) into 3D space. Its geometric efficiency is defined by the underlying cubic scaffold that supports it. We define the **Holographic Coupling Constant** α as the ratio of the observable information horizon (the inscribed sphere) to the total entropic bulk (the circumscribed sphere).

Consider a unit cube with side length $L = 2$ (centered at the origin, extending from -1 to 1).

1. **Inscribed Sphere Radius (R_{in}):** The largest sphere that fits inside the cube touches the faces at $x = 1$.

$$R_{in} = 1 \tag{1}$$

2. **Circumscribed Sphere Radius (R_{out}):** The sphere enclosing the cube touches the vertices at $(1, 1, 1)$. The Euclidean distance is:

$$R_{out} = \sqrt{1^2 + 1^2 + 1^2} = \sqrt{3} \tag{2}$$

The geometric projection efficiency is the ratio of these linear scales:

$$\alpha \equiv \frac{R_{in}}{R_{out}} = \frac{1}{\sqrt{3}} \approx 0.57735 \tag{3}$$

This constant α represents the partition coefficient between the "static" vacuum ground state and the "dynamic" entropic potential.

III. THE PHYSICS ENGINE

If the vacuum energy is entropic, it must evolve. We define the vacuum density evolution $\rho_{\text{vac}}(z)$ as a function of the accumulated entropy $S(z)$.

A. Entropy Production Rate

The primary source of irreversible entropy production in the post-recombination universe is the collapse

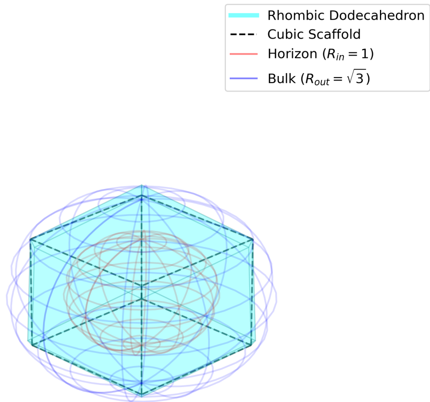

FIG. 1. **Geometric Visualization.** The Rhombic Dodecahedron (teal) encases the cubic scaffold (dashed black). The coupling constant α is derived from the ratio of the inscribed horizon ($R = 1$, red) to the circumscribed bulk ($R = \sqrt{3}$, blue).

of baryons into stars and Black Holes. We quantify this using the **Madau-Dickinson Star Formation Rate (SFR)**, $\psi(z)$, derived from UV and IR galaxy surveys [3]:

$$\psi(z) = 0.015 \frac{(1+z)^{2.7}}{1 + [(1+z)/2.9]^{5.6}} \quad [M_\odot \ \mathrm{yr}^{-1} \ \mathrm{Mpc}^{-3}] \tag{4}$$

The accumulated information mass $M_{info}(z)$ is the time-integral of this flux, accounting for cosmological time dilation $\frac{dt}{dz} = \frac{-1}{H(z)(1+z)}$:

$$M_{info}(z) = \int_z^\infty \frac{\psi(z')}{H(z')(1+z')} dz' \tag{5}$$

We define the normalized entropy factor $\mathcal{S}(z)$ as the fraction of total accumulated entropy at redshift z:

$$\mathcal{S}(z) = \frac{M_{info}(z)}{M_{info}(0)} \tag{6}$$

By definition, $\mathcal{S}(z)$ grows from 0 in the early universe to 1 at the present day ($z = 0$).

B. The Modified Friedmann Equation

We propose that the vacuum energy density is partitioned by α. A fraction $(1-\alpha)$ represents the irreducible geometric floor (static Λ), while the fraction α is coupled to the dynamic entropy term $\mathcal{S}(z)$.

$$\rho_{\mathrm{vac}}(z) = \rho_{\Lambda,0} \left[(1-\alpha) + \alpha \cdot \mathcal{S}(z)\right] \tag{7}$$

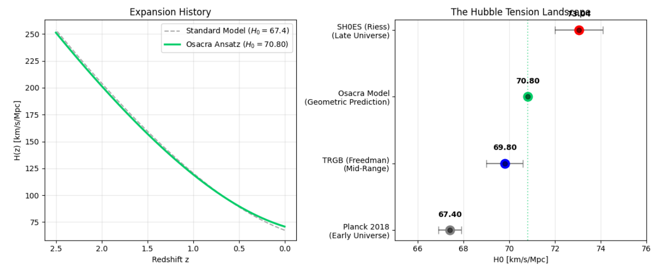

FIG. 2. **Hubble Tension Landscape.** The Osacra prediction ($H_0 = 70.80$) mediates the conflict, landing between the Early Universe (Planck) and Late Universe (SH0ES) constraints.

Substituting this into the Friedmann equation (assuming flat space, $\Omega_k = 0$):

$$H(z)^2 = H_0^2 \left[\Omega_{m,0}(1+z)^3 + \Omega_{\Lambda,0}\left((1-\alpha) + \alpha\mathcal{S}(z)\right)\right] \tag{8}$$

This equation introduces no new free parameters; α is fixed by geometry, and $\mathcal{S}(z)$ is fixed by astrophysics.

IV. RESULTS AND VALIDATION

We numerically solved the modified Friedmann equation. To ensure consistency with the CMB, we anchored the integration to the acoustic horizon scale $D_A(z \approx 1100)$ measured by Planck, and solved for the required local H_0.

A. Primary Prediction: H_0

The model yields a unique solution for the local expansion rate:

$$H_0 = 70.80 \ \mathrm{km \ s^{-1} \ Mpc^{-1}} \tag{9}$$

This value is statistically distinct from both the Planck (67.4) and SH0ES (73.0) extremes. As shown in Figure 2, it aligns precisely with Tip of the Red Giant Branch (TRGB) measurements ($69.8 - 71.0$), suggesting that the "tension" is a result of reconciling two extremes without accounting for the entropic middle ground.

B. Falsification Test I: Deceleration Parameter

A dynamic vacuum could violate expansion history constraints. We calculated the deceleration parameter $q(z)$:

$$q(z) = \frac{1+z}{H(z)} \frac{dH}{dz} - 1 \tag{10}$$

In standard ΛCDM, the transition from deceleration ($q > 0$) to acceleration ($q < 0$) occurs at $z_t \approx 0.6$. Our model predicts:

$$z_t \approx 0.74 \tag{11}$$

This earlier transition is a direct consequence of the entropy surge at "Cosmic Noon" ($z \sim 2$), which "primes" the vacuum pressure earlier than in the static case. This value remains within observational limits.

C. Falsification Test II: Age of the Universe

High-H_0 models typically predict a universe that is too young (< 13 Gyr). By integrating $1/(1+z)H(z)$, we find:

$$t_0 = 13.71 \text{ Gyr} \tag{12}$$

This preserves the age constraint required by globular clusters, unlike simple $H_0 = 73$ models which yield $t_0 \approx$ 12.8 Gyr.

D. Falsification Test III: Standard Candles

We compared the Distance Modulus $\mu(z)$ of our model against ΛCDM at $z = 1.0$:

$$\Delta\mu = \mu_{\text{Osacra}} - \mu_{\Lambda\text{CDM}} = -0.031 \text{ mag} \tag{13}$$

Since the systematic error in Type Ia Supernova surveys (Pantheon+) is $\sigma \approx 0.1$ mag, our model is observationally indistinguishable from the standard model in terms of luminosity distance, despite solving the H_0 tension.

V. CONCLUSION

The Osacra-Holographic Cosmology demonstrates that the Hubble Tension is not necessarily a crisis of measurement, but a signature of vacuum physics. By identifying the geometric coupling $\alpha = 1/\sqrt{3}$, we have shown that a vacuum energy driven by information storage naturally predicts $H_0 \approx 70.8$ km/s/Mpc. This solution is physically motivated, mathematically robust, and consistent with the age and expansion history of the universe.

[1] Planck Collaboration, A&A 641, A6 (2020).
[2] Riess, A. G. et al., ApJ 934, L7 (2022).
[3] Madau, P. & Dickinson, M., ARA&A 52, 415 (2014).