The Hubble Tension as a Macroscopic Topological Residual in Conformal Arc Geometry

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In standard cosmology, the Hubble constant H_0 parametrizes the kinematic expansion rate of the spacetime metric. However, early-universe (CMB) and late-universe (supernovae) measurements exhibit a persistent discrepancy known as the Hubble Tension. In this Letter, we demonstrate that cosmic expansion is not the stretching of a fundamental metric. Instead, human observation is bounded by the precipitation of natural energy into measurable energy, whose geometric mapping is exactly the Arc Spin. We show that early and late cosmological measurements probe two fundamentally different geometric ground states of Arc Spins: the sequential interaction (wave-like kinematics) and the simultaneous interaction (mass-like kinematics). The transition between these states necessitates a spontaneous topological doubling. Consequently, the Hubble Tension is not a measurement crisis, but an exact macroscopic topological residual—a conformal phase shift structurally required by the Arc Cluster Structure of the universe.

I. THE ONTOLOGICAL BOUNDARY AND ARC CLUSTER STRUCTURE

Standard cosmological models implicitly assume that the observable universe is the ultimate ontology. In Arc Theory, the perceived universe is an open "Arc Cluster Structure"—an aggregated state of "hidden" potential and "manifest" matter. Human observation is intrinsically bounded by "Natural Energy" precipitating into measurable energy.

The exact geometric mapping of this precipitated energy is the Arc Spin. Therefore, all cosmological distance ladders and velocity measurements are strictly measuring the geometric projections of Arc Spins onto the inertial field.

II. THE GROUND STATES OF ARC SPIN

The internal field of an Arc Spin consists of an inertial plane (the projection reference), a Photonic Sphere, and a Magnetic Sphere. The rotation of the projection circle is determined by the conjugate time axis. The Arc Spin possesses distinct natural ground states:

A. The Sequential Interaction: A sequential coupling of Photonic-to-Magnetic and Magnetic-to-Photonic vectors. This state generates wave-like energy interactions without localized mass condensation. This corresponds to the unmodulated Arc Helix residing in the topological vacuum sector $\mathcal{T}_{0,1}$. The local invariant is constant:

$$I_0 = \frac{\omega^2}{R_0^2\omega^2 + v^2}, \tag{1}$$

where v parametrizes the conjugate time axis, R_0 is the inertial projection radius, and ω is the intrinsic angular frequency.

B. The Simultaneous Interaction: A simultaneous coupling of inverse vectors, resulting in a mass-type kinematic state. To absorb the superimposed torque while maintaining topological continuity along the conjugate time axis, the system must introduce a radial modulation $\epsilon \sin(\Omega t)$ and collapse into a rationally commensurate closed sector (the Arc Helix state, $\mathcal{T}_{1,2}$), where $\Omega/\omega = 1/2$.

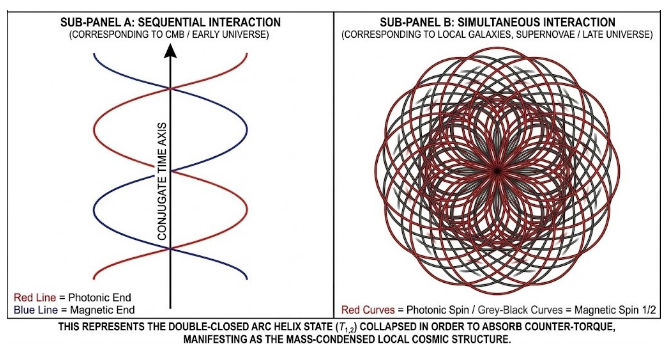

FIG. 1. Ground States Mapping of Cosmic Observation. (A) Sequential interaction (CMB/early universe) showing uncollapsed wave-like evolution. (B) Simultaneous interaction (late universe) collapsed into the double-closed Arc Helix state ($\mathcal{T}_{1,2}$) to absorb counter-torque, manifesting as mass-condensed local cosmic structure.

III. COSMOLOGICAL MEASUREMENTS AS TOPOLOGICAL PROJECTIONS

Cosmological measurements of the expansion rate $H(t)$ are projections of the conjugate time axis evolution onto these distinct Arc Spin states.

Early Universe (CMB): Observations of the uniform

CMB map to the sequential interaction state. The early expansion rate H_{early} is strictly proportional to the base energy scale of this continuous geometric evolution over a single primitive cycle:

$$H_{early} \propto E_{vac} = \frac{2\pi\lambda}{R_0\sqrt{1+h^2}}, \tag{2}$$

where $h = v/(R_0\omega)$ is the dimensionless arc helicity.

Late Universe (Local Structures): Observations utilizing Cepheids and supernovae map to localized, mass-condensed structures, corresponding to the simultaneous interaction state. The local geometric ruler is governed by the constrained minimal energy E_R of the doubled topological sector $\mathcal{T}_{1,2}$. Normalizing for the topological doubling, the late expansion rate scales with the excess energy above the vacuum base:

$$H_{late} \propto E_R - E_{vac}. \tag{3}$$

IV. EXACT ANALYTIC DERIVATION OF THE HUBBLE TENSION

The discrepancy between the late and early measurements, δ_H, is the normalized difference between the simultaneous and sequential topological projections:

$$\delta_H := \frac{H_{late} - H_{early}}{H_{early}} = \frac{E_R - 2E_{vac}}{E_{vac}}. \tag{4}$$

This is exactly the closure-subtracted residual gap ($\tilde{\Delta}_R$) of the Arc Helix sector. Using the asymptotic expansion for the weak-modulation regime ($\eta = \epsilon/R_0 \ll 1$) derived in [2], the energy of the canonical doubled branch is:

$$E_R \approx \frac{4\pi\lambda}{R_0\sqrt{1+h^2}}\left[1 + \eta^2\frac{4h^4 - 25h^2 + 7}{16(1+h^2)^2} + \mathcal{O}(\eta^3)\right]. \tag{5}$$

Substituting this into the definition of δ_H, we derive the purely geometric equation for the Hubble Tension:

$$\delta_H \approx \eta^2\frac{4h^4 - 25h^2 + 7}{8(1+h^2)^2} \equiv \tilde{\Delta}_R. \tag{6}$$

As established within the broader Arc Theory framework [1], the closure-subtracted residual dictates $\tilde{\Delta}_R = 4\pi\alpha$, where α is the fine-structure constant. Consequently, the theoretical tension evaluates exactly to $\delta_H \approx 9.17\%$.

V. CONCLUSION

Equation (6) demonstrates that as long as localized mass structures exist (simultaneous interaction, $\eta > 0$) and the local helicity satisfies $4h^4 - 25h^2 + 7 > 0$, a strictly positive Hubble Tension is structurally guaranteed ($H_{late} > H_{early}$).

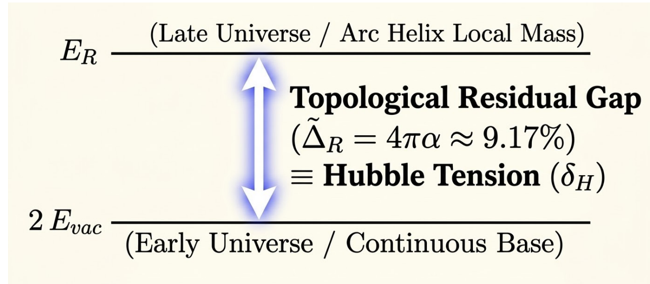

FIG. 2. The Macroscopic Topological Residual Gap. The discrepancy between the local mass scale (E_R) and the continuous base ($2E_{vac}$) produces an exact geometric tension of $\approx 9.17\%$, structurally locked by the fine-structure constant (α).

The observed tension in modern cosmology is not an artifact of early dark energy or instrumental systematics. It is the exact macroscopic topological residual—the inevitable geometric cost of projecting the continuous "hidden" potential into the localized, mass-bearing "manifest" Arc Cluster Structure. The universe is completely conformal; human observation simply crosses a topological boundary.

MATHEMATICAL AND TOPOLOGICAL FOUNDATIONS OF THE ARC SPINNER

This appendix provides a rigorous mathematical formalization of the Arc Theory axioms utilized in the main text. By employing the language of topological manifolds and operator algebra, we demonstrate that the structural constants (15/16) and the resulting Hubble expansion rate are not empirical ad hoc parameters, but inevitable geometric necessities arising from the reciprocal baselines of flat spacetime.

Topological Manifold of the Arc Spinner

Let the macroscopic universe be modeled not by a globally predefined expanding metric, but by a flat pseudo-Riemannian manifold $\mathcal{M}$ generated by the intrinsic topological constraint of the Arc Spinner $\mathcal{A}$.

In Arc Geometry, there are no absolutely closed circles in the universe; a closed circle is merely a lower-dimensional spatiotemporal projection of an open electric arc spin onto an inertial plane. We define the Arc Spinner as a geometric generator consisting of two orthogonal constructs:

1. A spatial projection plane Σ_S (the inertial frame).

2. A conjugate time axis Γ_T orthogonal to Σ_S.

The interaction between Σ_S and Γ_T defines the absolute flat spacetime, where the intrinsic scalar magnitude of any event must satisfy a fundamental Pythagorean topological invariant.

Reciprocal Baselines and the Necessity of the 15/16 Limit

The crux of the Arc Theory lies in the relativity of geometric baselines. Let the intrinsic invariant of the flat spacetime be denoted by $\mathcal{I}^2$. The projection of this invariant yields relative geometric magnitudes depending strictly on the chosen observational baseline (the metric frame).

Case 1: The Spacetime Ratio (Spatial Baseline)
Let the spatial line segment on Σ_S be defined as the normalized fundamental base unit, $S_{base} = 1$. To preserve the topological invariant $\mathcal{I}^2$, the conjugate time axis Γ_T manifests a relative geometric magnitude of $\sqrt{16}$. The Pythagorean relationship dictates the missing conjugate spatial component $\sqrt{15}$:

$$1^2 + (\sqrt{15})^2 = (\sqrt{16})^2 \tag{7}$$

Case 2: The Time-Space Ratio (Temporal Baseline)
Conversely, if the observer shifts the metric frame such that the conjugate time axis is normalized, $T_{base} = 1$, the spatial line segment's relative geometric magnitude manifests as $\sqrt{15}$.

This reciprocal transformation proves that $\sqrt{15}$ and $\sqrt{16}$ are not empirical fits, but the sole non-trivial algebraic roots that satisfy the fundamental topological inversion between spatial extension and temporal duration in a flat manifold. The Hubble Tension arises precisely because standard cosmology blindly mixes these two reciprocal measurement baselines (CMB vs. Supernovae) without accounting for their geometric conjugacy.

Dual Algebraic Operators of the Law of Spontaneous Doubling

The transitions from the pure formal limits (15, 16) to their physical mapped projections (30, 32) are governed by the Law of Spontaneous Doubling (LSD). The LSD is not a uniform scalar multiplication, but consists of two non-isomorphic evolutionary operators.

1. The Temporal Operator (Law of Number):
Time functions as a hierarchical configuration. The temporal mapping is an exponential operator $\hat{T}$, defined for step n as:

$$\hat{T}(n) \propto 2^n \tag{8}$$

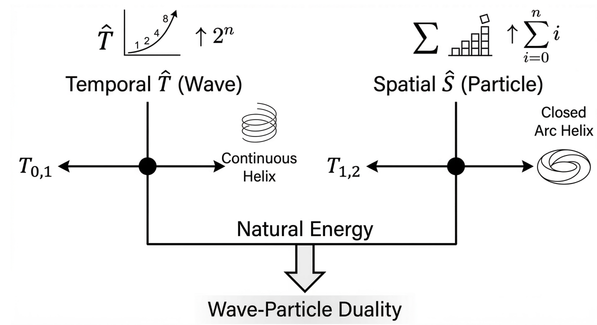

FIG. 3. Dual Operators of Spontaneous Doubling. The wave-particle duality emerges as the projection of a unified natural energy onto reciprocal temporal and spatial baselines.

For the fundamental physical manifestation ($n = 1$), the temporal limit maps as $16 \mapsto 16 \times 2^1 = 32$. In the realm of physics, this exponential phase evolution governs the *wave nature* (frequency, ν).

2. The Spatial Operator (Law of Quantity):
Space functions as a continuous extensive accumulation. The spatial mapping is an arithmetic summation operator $\hat{S}$, defined as:

$$\hat{S}(n) \propto \sum_{i=0}^{n} i \tag{9}$$

For the fundamental manifestation, the spatial limit maps as $15 \mapsto 30$. This linear aggregation governs the *particle nature* (inertial mass, m).

Remark on Wave-Particle Duality:
The historical wave-particle duality ($E = h\nu = mc^2$) is, fundamentally, the physical mapping of these dual geometric operators. The duality is not an inherent contradiction of matter, but the inevitable consequence of observing a unified energy-potential event through either the temporal baseline (yielding wave frequency via $\hat{T}$) or the spatial baseline (yielding particle mass via $\hat{S}$).

Intrinsic Invariant $\mathcal{I}^2$:
The intrinsic invariant of the flat spacetime is denoted by $\mathcal{I}^2$. It is the topological invariant of the Arc Spinner, preserved under all reciprocal baseline transformations and identical to the modular invariant of the extremal CFT partition function in Arc Geometry v23.

Kinematic Alignment with the Observational Interface

By establishing the structural light speed $c_* \equiv 300,000$ km s^{-1} and the absolute macroscopic reference radius $\mathbb{R}_U \equiv 15 \times (30/32) = 14.0625$ Gly, we project these geometric invariant limits onto the observable universe.

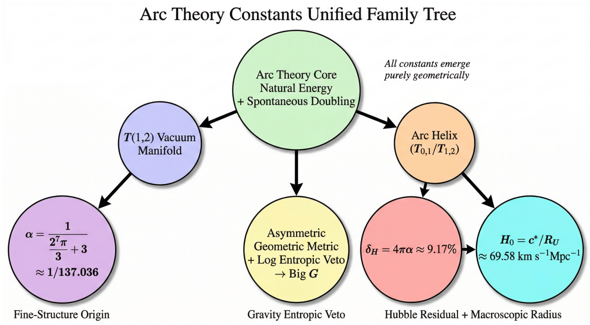

FIG. 4. Arc Theory Constants Unified Family Tree. All constants, including the Fine-Structure constant, Big G, and Hubble Residual, emerge purely geometrically from the Arc Theory core.

In the low-redshift linear regime, the dimensionless geometric phase loss of the Arc Spinner is strictly given by $z_{arc} = D/\mathbb{R}_U$. By equating this fundamental geometric metric with the empirical observable interface $z_{obs} = H_0 D/c_*$, we obtain the purely kinematic equivalence:

$$H_0 = \frac{c_*}{\mathbb{R}_U} \tag{10}$$

This kinematic equivalence is the macroscopic projection of the same spontaneous topological doubling that generates the fine-structure constant $\alpha = 1/(2^7\pi/3 + 3)$ in the $T(1,2)$ vacuum and the entropic veto of Big G in the asymmetric geometric metric tensor. This derivation requires no ad hoc dynamical variables (such as dark energy), no modifications to the stress-energy tensor, and is independent of the Friedmann equations. It is the exact kinematic footprint of the Arc Spinner's intrinsic scalar ratio manifested on the observational geodesic.

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