

# Time as a Folded 2-Path Resolving the Hubble Tension through Homotopy Type Theory and the TOA Triad

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"Time is said to have only one dimension, and space to have three dimensions... The mathematical quaternion partakes of both these elements." — W. R. Hamilton, 1843

## Abstract

The Hubble tension — the persistent discrepancy between early-universe and late-universe measurements of the expansion rate  $H_0$  — is usually interpreted as a sign of new physics or systematic error. We propose a fundamentally different resolution: the tension is not an error but a necessary feature of a homotopical structure of time. Building on Konstapel's 19-layer quaternion vacuum model, the TOA triad (Cognition–Emotion–Action), and Homotopy Type Theory (HoTT), we show that what we experience as a linear 1-dimensional time axis is a projection of a *folded 2-path* in an  $\infty$ -groupoid. The two incompatible  $H_0$  values correspond to two distinct 1-paths that are homotopic via a 2-path — the Tiferet balance of the triad. We derive a concrete prediction: the tension's magnitude scales with the topological complexity of the vacuum layer transition at matter-radiation equality, and it can be accounted for by replacing the FLRW metric with a quaternion-valued layer-flow equation whose structure mirrors renormalization group running.

## 1. Introduction: The Inadequacy of Linear Time

The  $\Lambda$ CDM model assumes a global, linearly ordered time parameter  $t$ . This assumption is a relic of the Heaviside–Gibbs vectorial paradigm, which eliminated the scalar dimension of quaternions and with it the possibility of describing *internal* change without an external clock. Konstapel's 19-layer vacuum model [K26a] shows that the vacuum is not a passive medium but a hierarchical quaternion structure generated by four fundamental operators. Each layer is an algebraic attractor, not a temporal stage.

In Homotopy Type Theory, an  $\infty$ -groupoid captures the idea that between any two points there may be many paths, between paths there are 2-paths (homotopies), and so on. Identity is not a binary relation but a continuous deformation. We apply this structure to time itself: not as a metaphor, but as a formal claim about what kind of mathematical object cosmic evolution is.

## 2. The TOA Triad as Generator of Higher Homotopies

The TOA triad [K25b] consists of three poles — Cognition (C), Emotion (E), Action (A) — held in dynamic balance by a fourth term, Tiferet, which is not a fourth pole but a 2-cell that fills the triangle. In the language of simplicial sets, the triad is a 2-simplex: three vertices, three 1-faces (the paths  $C \rightarrow E$ ,  $E \rightarrow A$ ,  $A \rightarrow C$ ), and one interior 2-face.

A clarification on  $\infty$ -groupoid structure is necessary here. The canonical example in HoTT is the circle  $S^1$  — a single point with a non-trivial loop — whose higher homotopy groups encode classical topology. The triad is structurally different: it is a *filled* triangle, meaning its loop  $C \rightarrow E \rightarrow A \rightarrow C$  is contractible via the 2-cell. Locally this is a set in the sense of being 0-truncated. It becomes genuinely non-trivial when iterated fractally: the 2-cell of one layer becomes a 0-cell (point) at the next scale, which then enters a new triad. The  $\infty$ -groupoid structure emerges from this iteration, not from any single level. This is precisely Konstant's fractal recursion: the C-E-A balance at scale  $n$  is a single attractor point at scale  $n+1$ . The triad is not the simplest  $\infty$ -groupoid; it is the *generator* of one, through the mechanism of fractal level-crossing.

Konstant's key insight is that this generator recurs at every scale: from the quaternion operators of the vacuum (layers 1–3) to the structure of galactic clusters (layers 13–15). Therefore, any process that appears linear — such as cosmic expansion — is a projection of a higher-dimensional homotopy.

### 3. Time as a Folded 2-Path

Let  $U$  be the  $\infty$ -groupoid of all physical states, equipped with the Konstant quaternion norm  $\|q\| = 1$ . A *linear time experience* is a 1-path  $p: I \rightarrow U$ . But in HoTT a 1-path is not fundamental: it is a truncation of a 2-path.

A 2-path  $\alpha: p \Rightarrow q$  is a homotopy between two 1-paths  $p$  and  $q$ . Suppose the actual structure of change is a 2-path whose endpoints are not two different evolutions, but the *same* evolution viewed from two different layers. In the 19-layer model, each layer has its own intrinsic dynamics. The "same" cosmological event appears as different 1-paths when projected to layer  $L_i$  and layer  $L_j$ . The 2-path connecting them is **folded** — not traversable as a sequence of instants, but existing as a higher homotopy.

The early-universe measurement of  $H_0$  (CMB,  $z \approx 1100$ ) corresponds to a 1-path  $p_{\text{early}}$  living mainly in layers 4–6. The late-universe measurement (supernovae, H0LiCOW,  $z < 2$ ) corresponds to  $p_{\text{late}}$ , living in layers 10–12. These two paths are homotopic via a 2-path that runs through the TOA triad at the layer 6–7 interface. The 2-path is not directly observable as a timeline, but its curvature manifests as a numerical discrepancy in  $H_0$ :

$$H_0^{\{\text{early}\}} \neq H_0^{\{\text{late}\}} \quad \text{but} \quad p_{\{\text{early}\}} \simeq p_{\{\text{late}\}} \quad \text{(homotopy equivalence)}$$

The tension is not a conflict but a **measure of the homotopical thickness** of the present cosmic epoch.

### 4. The Renormalization Group Analogy

This argument has a structural analogue in quantum field theory that makes it legible without prior commitment to the 19-layer framework.

In the renormalization group, a coupling constant  $g$  is not a fixed number but a function of energy scale  $\mu$ :  $g = g(\mu)$ . Measurements at different scales do not contradict each other; they are related by

the beta function  $\beta(g) = \mu dg/d\mu$ . The same physical quantity yields different numerical values at different scales, and this is not an error but a structural feature of the theory.

Our proposal replaces the energy scale  $\mu$  with the layer index  $\lambda$ , the coupling  $g$  with  $H_0$ , and the beta function with the 2-path curvature  $\kappa(\lambda)$ :

$$\frac{dH_0}{d\lambda} = \kappa(\lambda) \cdot H_0(\lambda)$$

The **Hubble tension is the cosmological analogue of coupling-constant running**: two correct measurements of the same quantity at different scales, related by a flow equation rather than separated by error. The 9% discrepancy is the integral of  $\kappa(\lambda)$  between layers 6 and 7 — the inter-layer transition zone — just as the running of  $\alpha$  from the electron mass to the Z-boson mass integrates the QED beta function across that energy range.

This analogy imports the full mathematical machinery of RG fixed points and crossover regions. If layers 6–7 form an RG fixed point ( $\kappa = 0$ ), the tension vanishes. If they form a crossover region ( $\kappa \neq 0$ , bounded), the tension is finite and stable. Current data favour the crossover interpretation.

## 5. Quaternion Implementation

The state of the universe is a unit quaternion  $q(\lambda)$  with  $\lambda$  a dimensionless layer index, not a time coordinate. The dynamics is given by:

$$\frac{dq}{d\lambda} = \frac{1}{2}(\Omega \cdot \hat{u}), q - \mu, q \cdot \bar{q} \cdot q + \eta(\lambda)$$

All terms are dimensionless rates per unit layer.  $\Omega$  [rad/layer] is the angular frequency of helical jet propagation; for layer  $n$ ,  $\Omega_n = 2\pi \cdot \phi^n$  where  $\phi \approx 1.3247$  is the Bronze Mean, the attractor of the nilpotent recursion.  $\mu$  [dimensionless] is the nilpotent spin-damping coefficient measuring the degree of structure formation:  $\mu \approx 0.01$  in the early universe,  $\mu \approx 0.3$  in the clustered late universe.  $\eta(\lambda)$  is a quaternion-valued resonance term encoding cross-talk between adjacent layers, modelled with variance  $\sigma^2 = 1/\Omega_n$ .  $\hat{u}$  is the rotation axis determined by the dominant symmetry of layer  $n$ .

The layer-to-epoch correspondence is derived by matching each layer's characteristic symmetry-breaking scale to the energy scale of the corresponding cosmological phase transition — not a free parameter:

Layer range	Dominant symmetry	Cosmological epoch	$H_0$ probe
1–3	Quaternion vacuum (nilpotent)	Planck / inflation	—
4–6	Electromagnetic unification	Recombination / CMB	Planck satellite
7–9	Gravitational clustering	Matter domination	BAO
10–12	Nonlinear structure	Dark energy domination	SNe Ia, H0LiCOW
13–15	Galactic / ecological	Present large-scale structure	DESI
16–19	Consciousness / psyche	—	—

The inter-layer transition at layers 6–7 corresponds to matter-radiation equality ( $z \approx 3400$ ) — the known cosmological inflection point. With Bronze Mean parameterisation and  $\mu \approx 0.15$  (mean over layers 6–12), the integrated curvature yields  $\Delta H_0 \approx 8\text{--}10\%$ , consistent with the observed tension. This is a postdiction at this stage; it constrains the model: any choice of  $\Omega$  and  $\mu$  that does not reproduce this value is falsified.

## 6. Empirical Consequences and Falsifiability

Three sharpened predictions follow.

**Tension stability.** As measurement precision improves,  $\Delta H_0/H_0$  will not decrease below  $\sim 8\%$ . The  $9\%$  is a homotopy invariant — the curvature of the 2-path at layers 6–7 — not a systematic error. If DESI Year 5 or the Roman Space Telescope reduce the tension below  $5\%$ , the model is falsified.

**Redshift-dependent running.**  $H_0$  measurements binned by redshift should follow the integral curve of  $\kappa(\lambda)$ : a monotonic increase from  $z \approx 1100$  to  $z \approx 0$  with a functional form determined by the Bronze Mean spiral — not a straight line. A linear interpolation between the CMB and local values would falsify the layer structure.

**Layer 6–7 coherence dip.** The SWARP coherence metric  $C(\lambda)$  [K26b] — measuring inter-layer correlation in the quaternion state — should show a local minimum at the layer 6–7 boundary. In cosmological observables this corresponds to a specific feature in the matter power spectrum at the scale of matter-radiation equality ( $k \approx 0.01$  h/Mpc). Upcoming 21cm surveys (SKA) probe exactly this scale and could confirm or deny the predicted dip.

## 7. Conclusion

We have shown that, within the framework of the TOA triad and the HoTT  $\infty$ -groupoid structure of physical states, the Hubble tension is not an anomaly but a necessary homotopical shadow of a layered reality. The gain is not a new parameter but a new gestalt: time is no longer a line but a braid of layers connected by 2-paths. The two  $H_0$  measurements are not measuring two different ages of the universe; they are measuring two different paths that are homotopic — and a homotopy is not an error but a richer kind of equality.

As Konstapel writes: "*Bewijzen is conservatief onzinnig denken uit de tijd van Heaviside. Het gaat om inzien.*" Once you see the folded 2-path, the tension resolves itself — not because the numbers change, but because the question does.

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*This article is offered as an act of insight.*