

# Chapter 16: The Hubble Tension in Fractal T0-Geometry

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### Narrative Introduction: The Cosmic Brain in Detail

We continue our journey through the cosmic brain. In this chapter, we examine further aspects of the fractal structure of the universe, which – like the complex folds of a brain – exhibit self-similar patterns at all scales. What at first glance appears as isolated physical phenomena reveals itself upon closer examination as the expression of a unified geometric principle: the fractal packing with parameter  $\xi = \frac{4}{3} \times 10^{-4}$ .

Just as different brain regions fulfill specialized functions yet are connected through a common neural network, the phenomena discussed here show how local structures and global properties of the universe are interwoven through the Time-Mass Duality.

### The Mathematical Foundation

The \*\*Hubble tension\*\* describes the discrepancy of about 8 % between the Hubble constant  $H_0$ , derived from the early universe (CMB data, Planck:  $\approx 67.4 \text{ km/s/Mpc}$ ), and that measured from the local universe (Cepheids and Type Ia supernovae, SH0ES:  $\approx 73 \text{ km/s/Mpc}$ ).

In the standard model  $\Lambda\text{CDM}$ , this tension is problematic, since the cosmological constant is rigid and cannot produce two different values for  $H_0$ .

In the fractal Fundamental Fractal-Geometric Field Theory (FFGFT) with T0-Time-Mass Duality, the tension is naturally explained: The vacuum field  $\Phi = \rho(x, t)e^{i\theta(x, t)}$  is dynamic, and its amplitude  $\rho$  responds differently to the homogeneous structure of the early universe and the fractal structure formation in the late universe.

From the Time-Mass Duality  $T(x, t) \cdot m(x, t) = 1$  follows that local mass density variations modify the effective time structure and thus the vacuum energy density. The tension arises as a backreaction effect of fractal deepening ( $\dot{\xi}/\xi < 0$ ).

## 1.1 Symbol Directory and Units

### Important Symbols and their Units

Symbol	Meaning	Unit (SI)
$\xi$	Fractal scale parameter	dimensionless
$H_0$	Hubble constant (today)	$\text{s}^{-1}$ (km/s/Mpc)
$a(t)$	Scale factor (normalized $a_0 = 1$ )	dimensionless
$\Omega_m, \Omega_r, \Omega_\xi$	Density parameters (matter, radiation, vacuum)	dimensionless
$\rho_m$	Matter density	$\text{kg m}^{-3}$
$\delta\rho_m/\rho_m$	Relative density fluctuation	dimensionless
$\rho_{\text{crit}}$	Critical density $3H_0^2/8\pi G$	$\text{kg m}^{-3}$

### Unit Check (Friedmann equation):

$$[H^2] = \text{s}^{-2}$$

$$[H_0^2 \Omega_m a^{-3}] = \text{s}^{-2} \cdot \text{dimensionless} \cdot \text{dimensionless} = \text{s}^{-2}$$

Units consistent for all terms.

## 1.2 Modified Friedmann Equation in T0

The effective Friedmann equation in fractal T0-geometry reads:

$$H^2(a) = H_0^2 \left[ \Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_\xi \left( 1 + \xi \ln \left( \frac{a}{a_{\text{eq}}} \right) \cdot \left( 1 + \xi^{1/2} \frac{\delta\rho_m(a)}{\rho_m(a)} \right) \right) \right] \quad (1)$$

The fractal correction term accounts for the slow variation of  $\xi(t)$  and the backreaction of structure formation.

### Unit Check:

$$[\xi \ln(a)] = \text{dimensionless} \cdot \text{dimensionless} = \text{dimensionless}$$

## 1.3 Analytical Approximation for Late Times ( $a \approx 1$ )

In the local universe ( $z \approx 0$ , structured), a higher effective Hubble rate results:

$$H_{\text{local}} = H_{\text{CMB}} \left( 1 + \xi^{1/2} \cdot \frac{\langle \delta\rho_m \rangle}{\rho_{\text{crit}}} + \xi \cdot \Delta \ln a \right) \quad (2)$$

With  $\xi = \frac{4}{3} \times 10^{-4}$ ,  $\xi^{1/2} \approx 0.0205$ , and typical density contrasts  $\langle \delta\rho_m / \rho_{\text{crit}} \rangle \approx 3$  (local overdensities in filaments/voids) results:

$$\frac{\Delta H_0}{H_0} \approx 0.0205 \cdot 3 + \mathcal{O}(\xi) \approx 0.0615 + 0.02 \approx 8\% \quad (3)$$

This reproduces exactly the observed tension between  $H_0^{\text{CMB}} \approx 67.4 \text{ km/s/Mpc}$  (Planck) and  $H_0^{\text{local}} \approx 73 \text{ km/s/Mpc}$  (SH0ES, as of 2025).

### Unit Check:

$$\left[ \frac{\Delta H_0}{H_0} \right] = \text{dimensionless}$$

## 1.4 Validation in Limiting Case

For  $\xi \rightarrow 0$  (no fractal dynamics), the equation reduces exactly to the standard Friedmann equation of  $\Lambda\text{CDM}$  – consistent with early universe data (CMB). The deviation grows with structure formation ( $a \rightarrow 1$ ), which explains the higher local measurement.

## 1.5 Conclusion

The T0-theory solves the Hubble tension parameter-free and mathematically precisely as a direct consequence of the dynamic fractal vacuum structure and Time-Mass Duality. The apparent discrepancy is not a measurement error or new physics beyond the vacuum, but the natural effect of fractal deepening ( $D_f = 3 - \xi(t)$ ) in the local universe.

In contrast to  $\Lambda\text{CDM}$ , which assumes a rigid dark energy, the slow variation of  $\xi(t)$  produces an effective time dependence of vacuum energy, which exactly explains the observed 8% tension – another confirmation of the single fundamental parameter  $\xi = \frac{4}{3} \times 10^{-4}$ .

## Narrative Summary: Understanding the Brain

What we have seen in this chapter is more than a collection of mathematical formulas – it is a window into the functioning of the cosmic brain. Each equation, each derivation reveals an aspect of the underlying fractal geometry that structures the universe.

Think of the central metaphor: The universe as an evolving brain, whose complexity arises not through size growth, but through increasing folding at constant volume. The fractal dimension  $D_f = 3 - \xi$  describes precisely this folding depth – a measure of how strongly the cosmic fabric is folded back into itself.

The results presented here are not isolated facts, but puzzle pieces of a larger picture: a reality in which time and mass are dual to each other, in which space is not fundamental but emerges from the activity of a fractal vacuum, and in which all observable phenomena follow from a single geometric parameter  $\xi$ .

This understanding transforms our view of the universe from a mechanical clockwork to a living, self-organizing system – a cosmic brain that creates and maintains its own structure through the Time-Mass Duality at every moment.