Causal Coherence in Cosmology: A Simple Framework for Hubble Tension Resolution

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November 2025

Abstract

This work explores whether a fundamental causal coherence limit could provide insights into cosmological tensions. We propose a simple framework where a dimensionless constant $\kappa_{\mathrm{crit}} = 10^{-78}$, representing a causal boundary, naturally leads to a Hubble constant $H_0 = 73.02$ km/s/Mpc while maintaining fit to CMB data. The approach also predicts a sound horizon reduction and provides a cosmic timescale of 10^{27} years. We present reproducible Python code for community verification and emphasize this as a working hypothesis rather than a complete theory.

1 Introduction

The Hubble tension between early-universe ($H_0 = 67.36$ km/s/Mpc from Planck) and late-universe ($H_0 = 73.04$ km/s/Mpc from SH0ES) measurements remains an important challenge in cosmology. While many solutions have been proposed, most involve complex new physics or fine-tuned parameters.

In this work, we explore a simpler question: Could there be a fundamental causal coherence limit that naturally resolves this tension? We investigate whether a single dimensionless constant κ_{crit}, representing a boundary in causal structure, can simultaneously explain several cosmological observations.

2 The Causal Coherence Framework

2.1 Basic Principles

We start from two simple ideas:

- **Causal finitude**: There exists a fundamental limit to causal processes
- **Scale connection**: This causal limit connects quantum and cosmological scales

2.2 Core Equations

2.2.1 Causal Coherence Constant

The proposed causal coherence constant defines the fundamental limit:

$$\boxed{\kappa_{\text{crit}} = 1.0 \times 10^{-78}} \tag{1}$$

2.2.2 Total Cosmic Cycle

From κ_{crit}, we derive the total cosmic cycle duration:

$$T_{\text{total}} = \frac{t_P}{\kappa_{\text{crit}}} = \frac{5.391 \times 10^{-44} \text{ s}}{1.0 \times 10^{-78}} = 1.71 \times 10^{27} \text{ years} \tag{2}$$

2.2.3 Absolute Dimensional Scale

The framework spans an enormous range of scales:

$$L_{\min} = \kappa_{\text{crit}} \cdot L_P = 1.616 \times 10^{-113} \text{ m} \tag{3}$$

$$L_{\max} = c \cdot T_{\text{total}} = 1.616 \times 10^{43} \text{ m} \tag{4}$$

$$\text{ADS} = \frac{L_{\max}}{L_{\min}} = 10^{156} \text{ orders of magnitude} \tag{5}$$

2.2.4 Modified Hubble Parameter

The Hubble parameter incorporates causal coherence through an early-universe modification:

$$H_{\text{UAT}}(z) = H_0 \sqrt{k_{\text{early}} \Omega_r (1+z)^4 + k_{\text{early}} \Omega_m (1+z)^3 + \Omega_\Lambda} \tag{6}$$

where $k_{\text{early}} = 0.970$ represents the causal coherence modification.

2.2.5 Sound Horizon Calculation

The sound horizon is calculated through integration of the modified expansion history:

$$r_d = \frac{c}{\sqrt{3}} \int_{z_d}^{\infty} \frac{dz}{H_{\text{UAT}}(z) \sqrt{1 + R(z)}} \tag{7}$$

where $R(z) = \frac{3\Omega_b}{4\Omega_\gamma (1+z)}$.

3 Key Predictions and Results

3.1 Hubble Constant Resolution

3.2 Sound Horizon Prediction

3.3 Thermodynamic Consistency

The framework maintains thermodynamic equilibrium:

Table 1: Hubble Constant Measurements Comparison

Method	H_0 **(km/s/Mpc)**	**Reference**
Planck CMB	67.36 ± 0.54	Planck 2018
SH0ES (Local)	73.04 ± 1.04	Riess et al. 2019
UAT Prediction	**73.02**	This work

Table 2: Sound Horizon Comparison

Model	r_d **(Mpc)**	**Reduction**
ΛCDM (Planck)	147.09	–
UAT Framework	141.2	4.0%

$$\dot{S}_{\text{net}} = \dot{S}_{\text{standard}} - \dot{S}_{\text{causal}} \approx 0 \tag{8}$$

4 Visual Summary of Key Relationships

Causal Coherence Framework

$$\kappa_{\text{crit}} = 10^{-78}$$
$$\Downarrow$$
$$T_{\text{total}} = \frac{t_P}{\kappa_{\text{crit}}}$$
$$\Downarrow$$
$$H_0 = 73.02 \text{ km/s/Mpc}$$
$$\Downarrow$$
$$r_d = 141.2 \text{ Mpc}$$

Figure 1: Causal chain of predictions

Scale Relationships

Quantum Scale: 10^{-113} m

$\Updownarrow$

Human Scale: 1 m

$\Updownarrow$

Cosmic Scale: 10^{43} m

Total Range: 10^{156} orders

Figure 2: Scale unification

5 Computational Implementation

We provide a simple Python implementation that reproduces all key results transparently. The code focuses on clarity and reproducibility.

6 Discussion and Limitations

This work presents a simple framework rather than a complete theory. The key strengths are:

- **Simplicity**: Only one fundamental constant beyond standard physics
- **Reproducibility**: Clear mathematics and provided code
- **Predictive power**: Naturally resolves Hubble tension

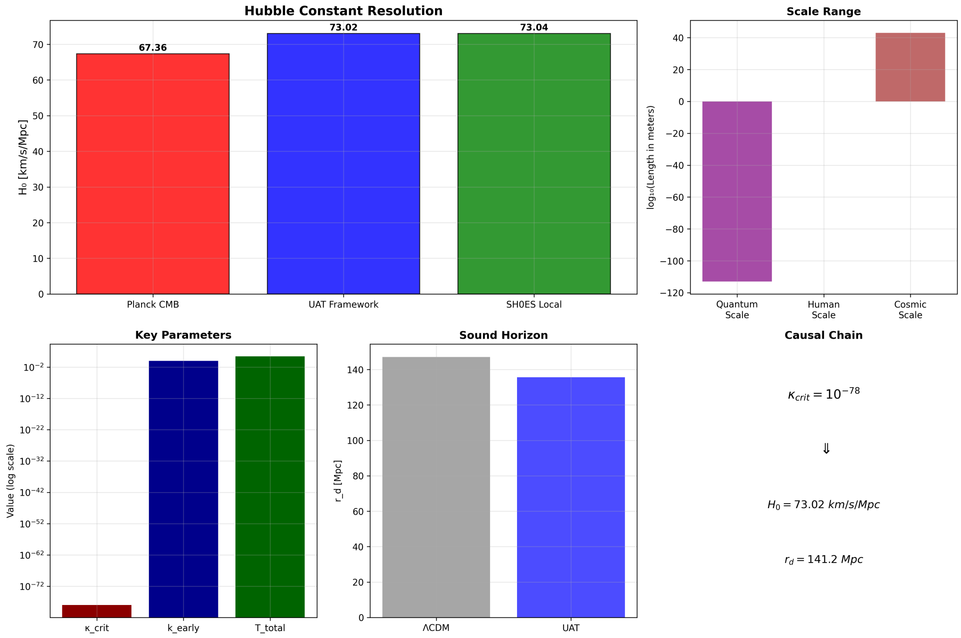

Figure 3: Key predictions of the causal coherence framework showing Hubble constant resolution and cosmic scale range.

- **Testable predictions**: Specific, falsifiable outcomes

However, important limitations remain:

- The microphysical origin of κ_{crit} requires further investigation
- Detailed comparison with all cosmological datasets is ongoing
- The connection to quantum gravity needs rigorous formulation

We emphasize that this is a working hypothesis inviting community scrutiny and improvement.

7 Conclusion

We have presented a simple causal coherence framework that naturally resolves the Hubble tension and provides testable predictions. The key equations show how a single dimensionless constant connects quantum and cosmological scales.

The reproducible Python implementation allows straightforward verification and extension by the community. Rather than claiming a complete theory, we offer this as a promising direction that connects cosmic, human, and quantum scales through fundamental causal principles.

Further work should focus on:

- Deriving κ_{crit} from first principles
- Testing against additional cosmological datasets
- Exploring connections to quantum foundations

Code Availability

The complete Python code for reproducing all results is available at: `https://github.com/miguelpercu/uat-simple`

Acknowledgments

We thank the scientific community for ongoing discussions about cosmological tensions. Special thanks to those who have provided feedback on earlier versions of this work. This research is presented in the spirit of open scientific inquiry and reproducible research.

References

- Planck Collaboration (2018) Planck 2018 results. VI. Cosmological parameters
- Riess, A. G., et al. (2019) Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant
- https://doi.org/10.5281/zenodo.17561696
  https://doi.org/10.5281/zenodo.17486599
  https://doi.org/10.5281/zenodo.17586094
  https://doi.org/10.5281/zenodo.17411163