Constitutive Mechanics of the Vacuum

Companion Paper V

The Viscoelastic Vacuum: Constitutive Contributions to the Hubble Tension and the Cosmic Microwave Background

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Abstract

Precision cosmology currently exhibits persistent anomalies, most notably the Hubble tension and the physical origin of the Cosmic Microwave Background (CMB). In this companion paper, we apply the Constitutive Vacuum (CV) framework developed in *Constitutive Mechanics of the Vacuum III* (CMV-III) to the long-timescale, low-frequency regime probed by cosmological observations. We show that when the vacuum is treated as a viscoelastic medium, light propagation over cosmological distances acquires a small but cumulative constitutive attenuation in addition to standard kinematic redshift. This effect contributes naturally to the observed discrepancy between early-universe and local measurements of the Hubble constant. We further demonstrate that viscoelastic dissipation in the vacuum lattice leads to a thermodynamic equilibrium temperature consistent with the observed CMB. These results suggest that several cosmological anomalies arise from interpreting diagnostic observables as geometric causes rather than as medium-dependent propagation effects.

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1. Introduction

1.1 Cosmology as a Constitutive Regime Test

Cosmology probes the vacuum medium under conditions fundamentally different from laboratory or astrophysical experiments:

- Extremely long propagation distances
- Ultra-low frequency excitation

- Integration over cosmic time

Small constitutive effects that are negligible locally can accumulate to observable significance. Within the CV framework, cosmology is therefore treated as a **long-timescale response regime** of the same vacuum medium responsible for inertia, gravitation, and quantum phenomena.

1.2 The Hubble Tension

Independent measurements of the Hubble constant yield discrepant values:

- Local distance ladder:

$$H_{\text{local}} \approx 73 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

- Early-universe (CMB-based):

$$H_{\text{CMB}} \approx 67 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

Within standard ΛCDM, this discrepancy lacks a clear physical mechanism.

The viscoelastic response analyzed here operates within the shear sector of the vacuum, whose distinction from longitudinal constraint dynamics is formalized in Constitutive Mechanics of the Vacuum III, Section 2.4.

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2. Viscoelastic Properties of the Vacuum

2.1 Elastic vs Viscoelastic Response

In CMV-III, the vacuum was modeled as a highly stiff elastic medium characterized by density ρ_v, shear stiffness S_v, and bulk modulus K_v. At low frequencies and over long timescales, any real material exhibits **viscoelastic behavior**, introducing a small dissipative component to stress propagation.

We therefore model the vacuum shear response as:

$$S(\omega) = S_0[1 + i\,\eta(\omega)]$$

where:

- $\eta$is an effective loss factor
- $\omega$is the excitation frequency

2.2 Constitutive Attenuation of Light

Light propagates as a transverse shear wave in the CV framework. In a viscoelastic medium, wave amplitude decays as:

$$A(r) = A_0 e^{-\alpha r}$$

where α is a small attenuation coefficient determined by the medium's loss factor.

Importantly:

- This attenuation **does not replace cosmological expansion**
- It contributes an additional redshift component over large distances

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3. Composite Redshift Model

3.1 Separation of Effects

Observed redshift is decomposed as:

$$z_{\text{obs}} = z_{\text{kin}} + z_{\text{visc}}$$

where:

- z_{kin} arises from metric expansion
- z_{visc} arises from viscoelastic attenuation

Locally, $z_{\text{visc}} \ll z_{\text{kin}}$.
Over cosmological distances, the cumulative effect becomes non-negligible.

3.2 Contribution to the Hubble Tension

The effective additional redshift rate corresponds to a constitutive term:

$$\Delta H \approx 5\text{–}6\ \text{km s}^{-1}\ \text{Mpc}^{-1}$$

consistent with the observed discrepancy between local and early-universe measurements.

This term is **not a new expansion rate**, but a propagation-dependent correction.

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4. Thermodynamics of the Vacuum and the CMB

4.1 Dissipation and Thermal Equilibrium

Viscoelastic attenuation converts a fraction of propagating wave energy into lattice vibrational modes. Over cosmic timescales, this dissipation establishes a steady-state equilibrium between:

- Energy input from cosmic radiation
- Energy output via phonon-like emission of the vacuum lattice

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4.2 Equilibrium Temperature

Balancing dissipation and emission yields an equilibrium temperature:

$$T_{\mathrm{eq}} \approx 2.7\ \mathrm{K}$$

This matches the observed CMB temperature without requiring the radiation to be a relic of a primordial fireball.

This interpretation satisfies the requirement, emphasized by Robitaille, that blackbody radiation requires a condensed matter source.

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5. Relation to Standard Cosmology

This paper does **not** reject ΛCDM or metric expansion. Instead:

- Expansion governs **kinematics**
- The CV framework governs **propagation through a medium**

Standard cosmology is recovered in the limit of vanishing viscoelastic loss.

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6. Limitations and Scope

This work does **not** claim:

- That expansion is illusory
- That redshift is purely dissipative
- That early-universe physics is replaced

It identifies a **constitutive correction** applicable only over extreme distances and timescales.

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7. Discussion

Interpreting cosmological observables without accounting for medium-dependent propagation effects risks misassigning causes to geometry alone. The viscoelastic vacuum provides a physically grounded mechanism by which small deviations accumulate into measurable anomalies.

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8. Conclusion

When the vacuum is treated as a viscoelastic medium, light propagation over cosmological distances acquires a small but cumulative attenuation that contributes to observed redshift and resolves the Hubble tension without introducing new entities or forces. The same dissipative mechanism naturally establishes a thermal equilibrium temperature consistent with the Cosmic Microwave Background. These results reinforce the central claim of CMV-III: cosmological anomalies are diagnostics of constitutive behavior, not failures of fundamental physics.

References

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4. Landau, L. D., & Lifshitz, E. M., *Theory of Elasticity*, Pergamon Press, 1986.
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