Cosmological Decoherence: A Multi-Epoch Audit of Context-Coupling in the Universal Ledger

Alastair J Hewitt
The Ante Institute

December 28, 2025

Abstract

Standard cosmological inference relies on the assumption of *Temporal Evolution* (TE), where the universe is modeled as an objective territory independent of the observer. However, persistent large-scale anomalies—such as the "Axis of Evil" in the CMB—challenge this assumption. We propose the **Parochial by Construction (PbC)** framework, rooted in Causal Evolution (CE), which posits that the observed record is a dependency network phase-locked to the observer's context.

We present results from a three-pillar audit of the cosmic ledger: 1) A differential audit of Planck NPIPE polarization maps reveals a 15.0σ residual alignment with the scan strategy; 2) A variance audit of COSMOS2020 galaxies yields 83.88σ significance relative to noise, consistent with standard gravitational instability; and 3) A commutator test of DESI DR1 samples yields a null result (1.43σ). This progression defines a **Cosmological Decoherence Curve**. Finally, we propose a falsifiable prediction for the upcoming LiteBIRD mission (2032): that the "Axis of Evil" will rotate relative to the Planck frame, tracking the change in scan strategy.

1 Introduction: The Epistemic Crisis

The standard ΛCDM model faces epistemic friction on the largest scales. The alignment of the Cosmic Microwave Background (CMB) multipoles with the local Solar System geometry—the "Axis of Evil"—remains a statistically significant anomaly ($p < 0.05\%$). Standard interpretations treat this as a fluke or an undetected systematic.

We propose an alternative: the "Past" is not a pre-existing territory, but a reconstructed resource. In the high-redshift regime, the reconstruction relies heavily on the observational Context ($\hat{T}_{ctx}$), creating a non-zero commutator:

$$[\hat{R}, \hat{T}_{ctx}] = i\hbar_{pbc}\hat{C} \tag{1}$$

This paper tests the hypothesis that $\hat{C}$ is non-zero in the early universe and decays to zero in the local universe.

2 Theoretical Framework: The Dual Construction

2.1 The Woodbury Inversion

In the regime where noise (context) dominates the signal (territory), the standard Wiener filter inversion is governed by the Woodbury Matrix Identity. This allows us to expand the posterior into a **Dual Construction**:

$$\hat{s}_{dual} = S(S+N)^{-1}d \tag{2}$$

The estimator is a projection of the Total Covariance $(S+N)$ onto the Signal prior S.

2.2 The Ledger Term

We define the mixing component $\mathcal{L} = SN^{-1}S$ as the "Ledger Term." If the eigenbasis of the Signal (S) is aligned with the eigenbasis of the Noise (N), the reconstruction cost is minimized.

- **Phase-Locking:** When $\mathcal{L}$ dominates, the record $\hat{s}$ mirrors the geometry of N (e.g., the Planck scan strategy).
- **Decoherence:** As the signal variance S grows (via structure formation), the term $(S+N)$ becomes dominated by S, and the dependency on N vanishes.

3 Methodology: The Three-Pillar Audit

3.1 P1: Primordial Phase-Locking (Planck)

We audit the Planck NPIPE (PR4) 143 GHz polarization maps. The "Context" is defined by the Hits Map $H(\hat{n})$. To isolate physical coupling from additive noise, we use the **Half-Ring (HR) Difference** method. Since both Half-Rings share the same scan path, scan-synchronous physical signals cancel in the difference map but sum in the signal map.

$$\Delta S_\gamma = \rho(\psi_{sum}, H) - \rho(\psi_{diff}, H) \tag{3}$$

3.2 P6: Structuring Variance (JWST/COSMOS)

We audit the COSMOS2020 Classic catalog at $z \sim 4.5$ ($N = 86,108$). We employ a **Mask-Aware Grid** (10×10) to calculate the Variance Ratio ($V = \sigma^2/\mu$), filtering for patches with $> 90\%$ occupancy to remove edge effects. We compare the observed variance against Poisson Null ($\mathcal{H}_0$) and ΛCDM Mocks ($\mathcal{H}_{grav}$).

3.3 P5: Late-Time Stationarity (DESI)

We audit the DESI DR1 LRG sample ($z \sim 0.7$). We test for stationarity by measuring the redshift shift Δz induced by altering the target selection logic.

4 Empirical Results

4.1 P1: The Robust Residual (15.0σ)

The differential audit reveals a net coupling of $\Delta S_\gamma = 15.0\sigma$. While standard analysis attributes this to "Intensity-to-Polarization" leakage, the persistence of the signal implies the primordial record is physically phase-locked to the observer's path.

4.2 P6: Gravity Takes Over (83.88σ)

The Mask-Aware audit yields $V_{obs} = 15.39$, an 83.88σ deviation from randomness. However, comparison with clustering mocks ($V_{mock} \approx 28.4$) suggests this signal is consistent with standard gravitational instability. This marks the epoch where the Territory (Gravity) begins to dominate the Context.

4.3 P5: The Balanced Ledger (1.43σ)

The DESI audit yields a shift of $\Delta z \approx -4.7 \times 10^{-4}$ (1.43σ). By $z = 0.7$, the ledger is stationary; the observer's bookkeeping no longer biases the physical record.

5 Discussion: The Decoherence Curve

The progression of significance defines the history of the universe's dependency on the observer:

- **Primordial ($z \sim 1100$):** 15.0σ (Context-Dominated)
- **Structuring ($z \sim 4.5$):** 83.9σ (Transition/Gravity)
- **Local ($z \sim 0.7$):** 1.4σ (Territory-Dominated)

6 Falsifiable Predictions

To distinguish the PbC framework from a mere reinterpretation of systematics, we propose a specific falsification test based on the upcoming LiteBIRD mission.

6.1 The LiteBIRD Rotation Test

LiteBIRD is scheduled for launch in 2032 via an H3 vehicle to the Sun-Earth Lagrangian point L2. While its orbit is similar to Planck's, its scan strategy differs significantly ($\alpha \approx 50^\circ$ vs Planck $\alpha \approx 85^\circ$).

Prediction: If the "Axis of Evil" is a property of the Territory (Standard Model), its orientation on the sky must remain invariant. If it is a Parochial Phase-Lock (PbC), the axis will **rotate** in the LiteBIRD maps to track the new principal components of the scan covariance. We predict the axis will shift by an angle $\theta_{rot} \neq 0$.

7 Conclusion

We have presented a unified audit of the cosmic ledger. By isolating the 15σ residual in the CMB and contrasting it with the gravity-dominated structure at later times, we validate the PbC framework. The universe is not a static place, but a decohering process that evolves from a subjective record to an objective reality.