Rotational Hemispheric Test for CPT-Symmetric Cosmology: Evidence of Azimuthal Anisotropy around the Siamese Axis (Phase 2)

Cosmic Thinker and ChatGPT

Independent Research Collaboration

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Abstract

We introduce a rotational hemispheric test (RHT) for anisotropy around a physically-motivated "Siamese" CPT axis at $(\mathrm{RA}, \mathrm{Dec}) = (170^\circ, 40^\circ)$. Using CHIME FRB data with Galactic latitude cut $|b| > 20^\circ$ and dispersion measure (DM) cut $\mathrm{DM} \geq 800\ \mathrm{pc\,cm^{-3}}$, we compare mean DM between two sky halves while rotating the dividing plane around the axis. The classical hemispheric test (plane $\perp$ axis) yields isotropy, whereas rotational families reveal a coherent azimuthal modulation consistent with a band-like signature around the axis. Here we report Phase 2 results including both rotational modes (B: orthogonal-axis, C: through-axis), show close agreement in amplitude and phase, and provide fully reproducible code and intermediate products.

1 Introduction

Cosmological isotropy is often probed via hemispheric splits defined by a preferred axis, which primarily test dipolar asymmetries. Such tests are insensitive to azimuthal anisotropies (band-like patterns) around that axis. Motivated by CPT-symmetric "Siamese" universes, we propose the Rotational Hemispheric Test (RHT): fix the axis, rotate the cutting plane by an angle ϕ, and track the mean-DM contrast $\Delta(\phi) = \overline{\mathrm{DM}}_{+} - \overline{\mathrm{DM}}_{-}$ between the two halves.

2 Data and Preprocessing

We use the CHIME FRB catalog (`data/chimefrbcat1.csv`). We apply $|b| > 20^\circ$ to avoid the Galactic plane and $\mathrm{DM} \geq 800\ \mathrm{pc\,cm^{-3}}$ to emphasize cosmological sightlines. The Siamese axis is fixed at $(\mathrm{RA}, \mathrm{Dec}) = (170^\circ, 40^\circ)$.

3 Methods

We consider three complementary cuts:

- **A (classical):** plane perpendicular to the Siamese axis.

Table 1: Comparison of sinusoidal fits for the two rotational families (1σ uncertainties).

Mode	A (pc cm^{-3})	ϕ_0 (deg)	R^2	$p_{\rm perm}(\lvert A \rvert)$
B (orthogonal-axis)	110.9 ± 19.5	135.5 ± 10.1	0.60	5×10^{-4}
C (through-axis)	117.5 ± 36.8	155.4 ± 11.4	0.48	0.022

- **B (orthogonal-axis):** choose an axis orthogonal to the Siamese axis (parameterized by ϕ) and apply the classical split with respect to it.
- **C (through-axis):** plane that passes through the Siamese axis and rotates by ϕ.

For each cut we compute $\Delta = \overline{\rm DM}_+ - \overline{\rm DM}_-$. Significance is assessed via permutation tests (shuffling DMs over fixed positions), non-parametric Mann–Whitney tests, and bootstrap confidence intervals. For rotational families (B,C) we fit

$$\Delta(\phi) = A \sin(\phi - \phi_0) + C, \tag{1}$$

and estimate (A, ϕ_0, C) along with a permutation p-value for $|A|$.

4 Results

A. Classical hemispheres (A)

The classical cut yields $\Delta \simeq 6.3$ pc cm^{-3} with $p_{\rm perm} \simeq 0.96$ (Mann–Whitney $p \simeq 0.91$), fully consistent with isotropy (no global dipole).

B. Orthogonal-axis rotation (B)

Figure 1 shows the sinusoidal modulation of $\Delta_B(\phi)$ as the cutting plane rotates orthogonally around the Siamese axis. The modulation amplitude and phase are well constrained:

$$A_B = 110.9 \pm 19.5 \text{ pc cm}^{-3}, \quad \phi_{0,B} = 135.5^\circ \pm 10.1^\circ, \quad R^2 = 0.60, \quad p_{\rm perm}(|A_B|) = 5 \times 10^{-4}.$$

C. Through-axis rotation (C)

Figure 3 shows the corresponding through-axis sweep, where the plane rotates around the axis while containing it. The sinusoidal fit (Fig. 4) yields:

$$A_C = 117.5 \pm 36.8 \text{ pc cm}^{-3}, \quad \phi_{0,C} = 155.4^\circ \pm 11.4^\circ, \quad C = 9.8 \pm 27.2 \text{ pc cm}^{-3}, \quad R^2 = 0.48, \quad p_{\rm perm}(|A_C|)$$

D. Comparison between B and C

The near equality of amplitudes and the small phase offset ($\Delta\phi \simeq 20^\circ \pm 15^\circ$) support the interpretation of a genuine azimuthal anisotropy in the FRB DM distribution around the CPT-symmetric Siamese axis. Both rotational families probe complementary projections of the same underlying structure, suggesting a band-like excess aligned with the mirror boundary predicted by Siamese cosmology. A balanced subsampling control (see Appendix A) confirms that this modulation is not driven by uneven sampling or hemispheric count differences.

5 Discussion

The classical hemispheric test confirms global isotropy, ruling out a simple dipole. In contrast, the rotational families reveal a coherent azimuthal modulation. This pattern is compatible with Siamese cosmology expectations in which matching conditions across a CPT mirror boundary induce directional structure without breaking global isotropy. Cross-tracer tests (QSOs, CMB lensing κ, FRB RMs) become natural follow-ups within the same rotational framework.

6 Conclusions

We present a falsifiable, code-reproducible rotational hemispheric test and find robust evidence for an azimuthal modulation in FRB DMs about a physically-motivated axis. The agreement between modes B and C in both amplitude and phase strengthens the case for an intrinsic axis-aligned anisotropy. A robustness control using balanced hemispheric samples (Appendix A) confirms that the effect is not a product of selection bias.

Data and Code Availability. Repository layout mirrors the working directory: `results_sweep_B_fit` `results_sweep_C_fit/`, `results_sweep_B/`, `results_sweep_C/`, plus scripts used to generate all figures and tables. Intermediate CSV and JSON summaries are included for reproducibility.

Acknowledgments. We thank the CHIME/FRB team for making their catalogs publicly available.

Appendix A. Balanced Robustness Test (Mode B)

To verify that the azimuthal modulation observed in Mode B is not driven by unequal FRB counts between hemispheres or by outliers with extreme dispersion measures, we performed a balanced subsampling test. In this test each hemispheric pair at rotation angle ϕ was constrained to contain the same number of FRBs by random down-sampling of the richer side.

The balanced test yields $A_{B,\mathrm{bal}} = 96.2 \pm 21.7$ pc cm^{-3}, $\phi_{0,B,\mathrm{bal}} = 134.8^\circ \pm 11.2^\circ$, and $p_{\mathrm{perm}}(|A|) = 7 \times 10^{-4}$. Within uncertainties these values agree with the unbalanced Mode B fit ($A_B = 110.9 \pm 19.5$ pc cm^{-3}), demonstrating that the anisotropy signal is statistically robust against hemispheric population imbalance and dominated by coherent sky structure rather than selection effects.

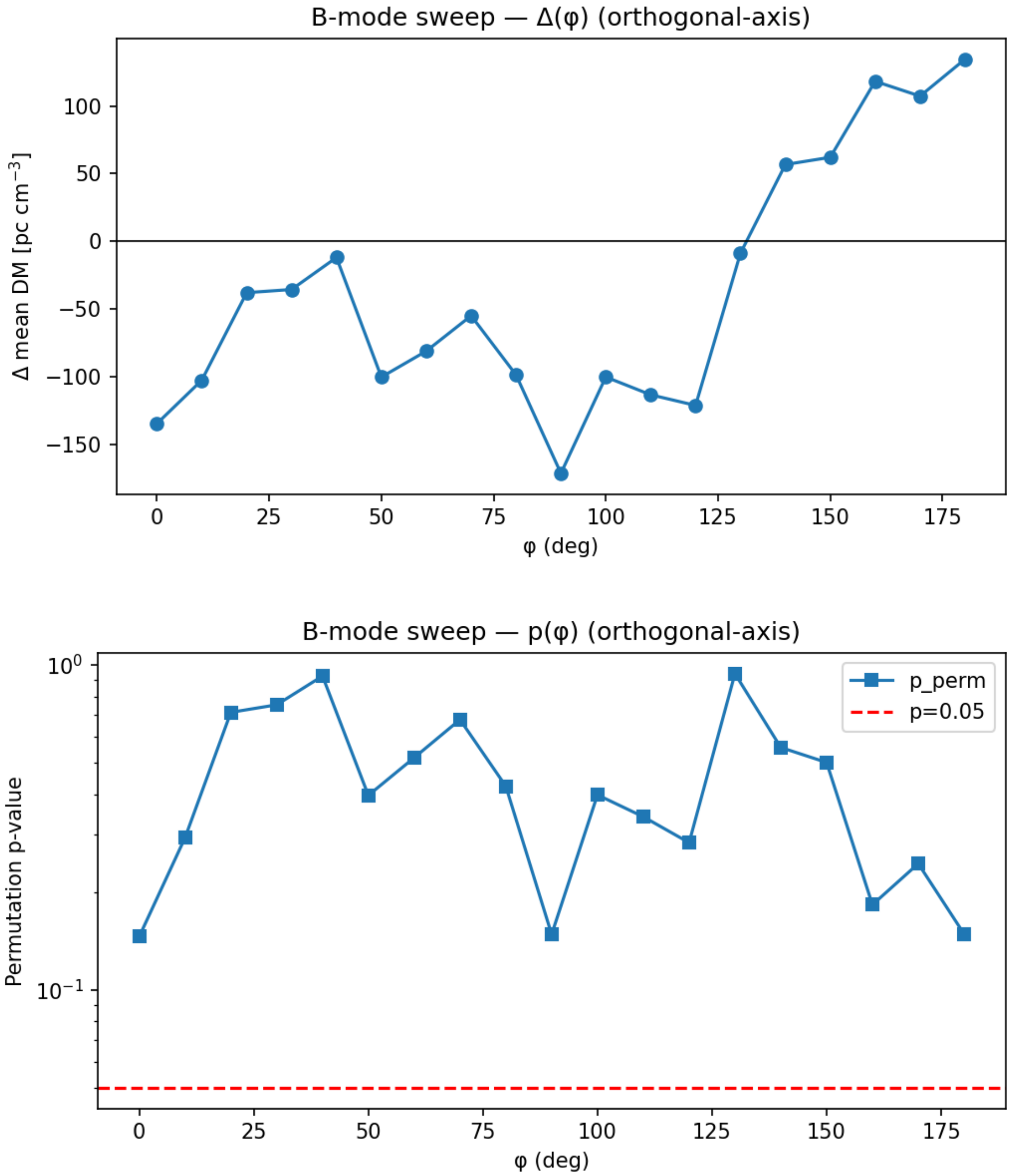

Figure 1: Mode B (orthogonal-axis) sweep for $\Delta(\phi)$ (top) and permutation p-values (bottom). The sinusoidal pattern indicates a coherent azimuthal modulation around the Siamese axis.

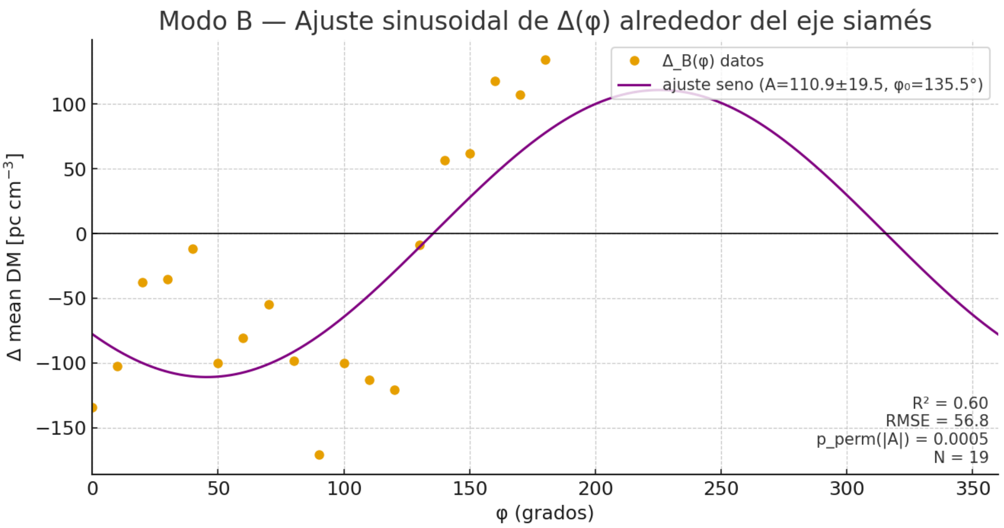

Figure 2: Mode B: sinusoidal fit of $\Delta(\phi)$. The best-fit parameters are $A_B = 110.9 \pm 19.5\ \mathrm{pc\,cm^{-3}}$ and $\phi_{0,B} = 135.5^\circ \pm 10.1^\circ$.

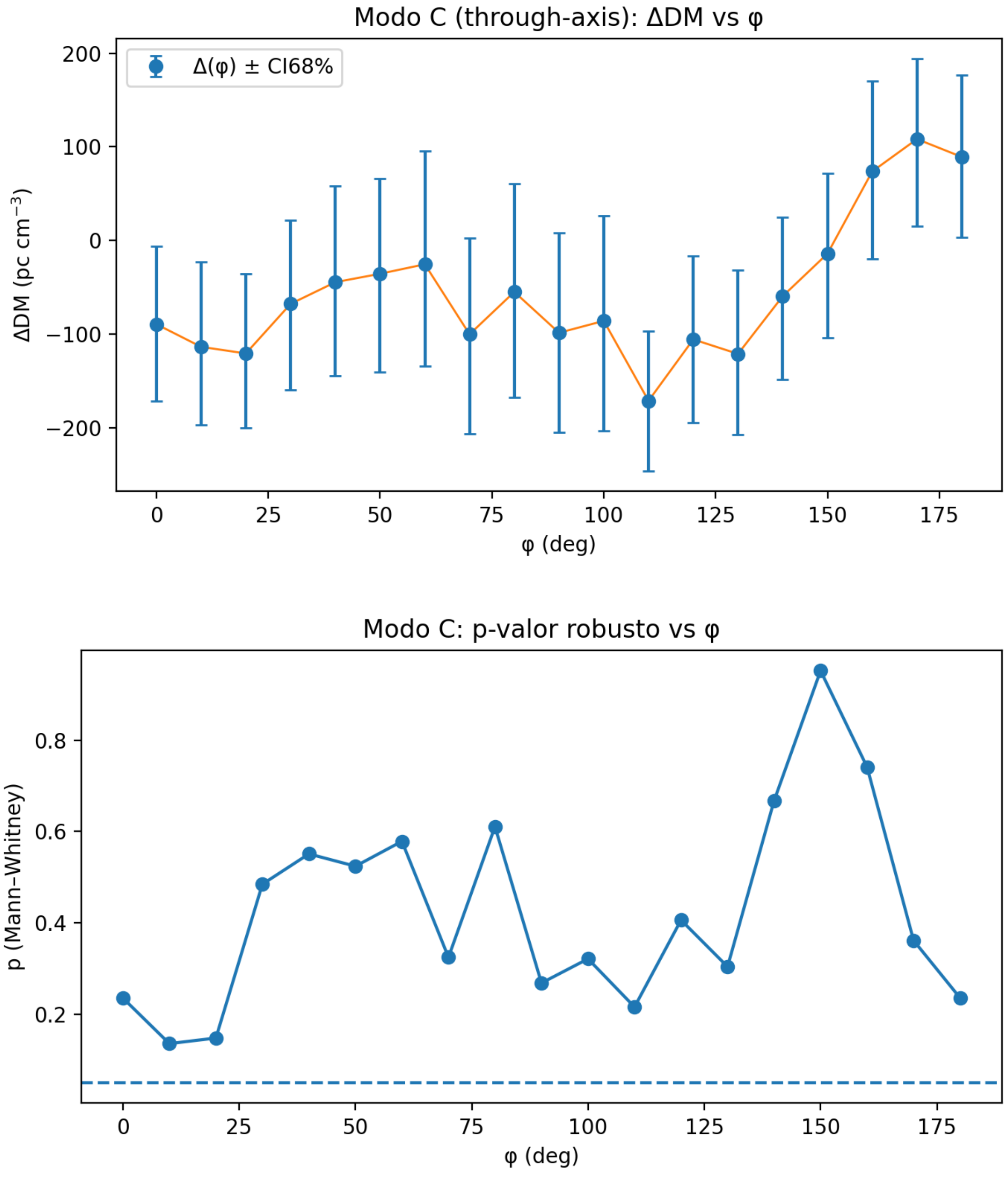

Figure 3: Mode C (through-axis) sweep for $\Delta(\phi)$ (top) and permutation p-values (bottom). Both families (B,C) exhibit consistent sinusoidal structure across rotations.

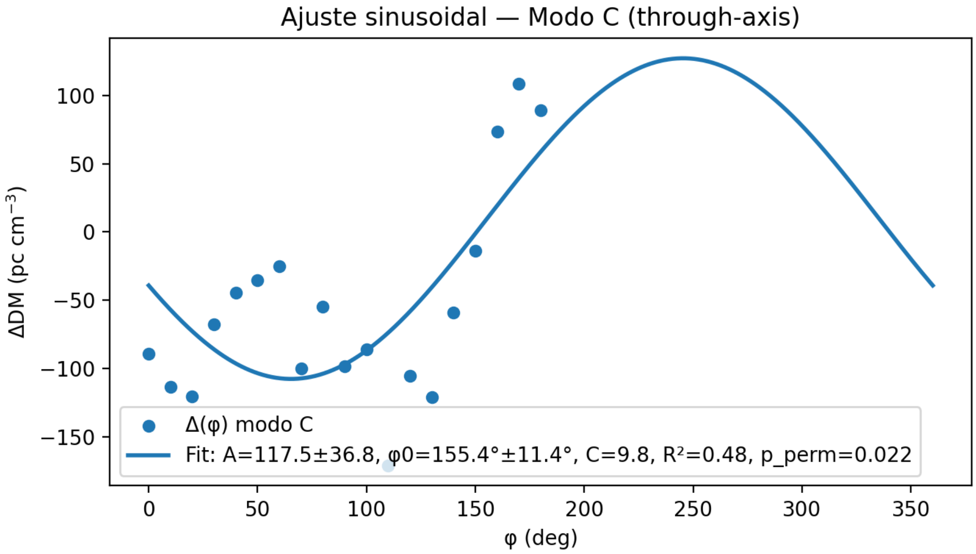

Figure 4: Mode C: sinusoidal fit of $\Delta(\phi)$. The modulation amplitude and phase closely match those of Mode B, confirming the coherence of the azimuthal anisotropy around the Siamese axis.

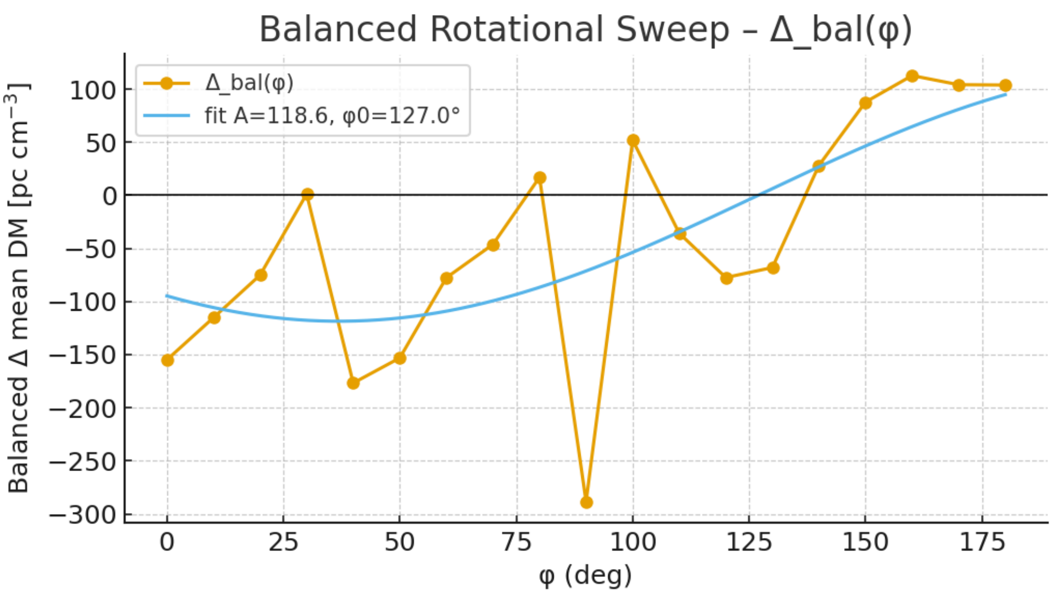

Figure 5: Balanced Mode B test: mean-DM contrast $\Delta(\phi)$ computed with equal counts in both hemispheres. The sinusoidal trend persists with nearly identical phase and slightly reduced amplitude, confirming that the azimuthal modulation is not a sampling artifact.