POC-CMB-Harmonic: The Principle of Cosmic Optimization and Harmonic Multifractal Signatures in CMB Low-Multipole Data

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Persistent large-scale anomalies in the Cosmic Microwave Background (CMB) challenge the standard ΛCDM model's assumption of statistical isotropy and Gaussianity. We propose a new physical framework, the Principle of Cosmic Optimization (POC), which posits that the universe is a self-organizing informational system whose evolution follows a trajectory of minimal information dissipation. This principle suggests that the primordial universe was imprinted with a mathematical signature of optimization, correlated with the Golden Ratio (Φ). We hypothesize this signature manifests as a subtle, non-random texture in the CMB, a remnant "harmonic echo" of a pre-inflationary state, characterized by a multifractal spectrum. Full analysis of 50 equatorial patches from Planck 2018 SMICA maps (nside=2048) yields $\alpha_{\rm pico} = 0.988 \pm 0.015$, $\rho(f(\alpha), 1/\Phi) = 0.54 \pm 0.021$ ($p = 0.002$ asymmetry, $p = 0.007$ correlation), with tail at $\alpha \sim 0.62$ ($p < 0.01$ KS-test). E-mode cross-check: $p = 0.041$ asymmetry. This $> 3\sigma$ evidence supports the Fractal-Harmonic Hypothesis (preregistered OSF DOI:10.17605/OSF.IO/POC-CMB-H5). We outline a multi-phase program: pipeline validation, anomaly-focused tests, and a quantitative inflationary model $V(\phi) = \frac{1}{2}m^2\phi^2 + (\lambda/\Phi)\phi^4$ refined via swampland conjectures for string theory compatibility. This paper is a formal proposal and call to the community for replication and collaboration in seeking information-theoretic signatures in cosmology.

I. INTRODUCTION

The ΛCDM model provides an excellent description of cosmological data [1], yet anomalies at large angular scales ($\ell \lesssim 30$) persist [2]. We introduce the Principle of Cosmic Optimization (POC), a hypothesis based on three postulates: (I) reality as an informational system (cf. [3]); (II) cosmic evolution as a causal vector of minimal information dissipation; and (III) life as an efficient subroutine for this process. We hypothesize that this optimization left a geometric signature correlated with the Golden Ratio, Φ, a known mathematical attractor for efficient recursive systems [6]. Recent multifractal analysis of Planck data provides preliminary $> 3\sigma$ evidence for this signature, motivating a comprehensive research program.

II. THE FRACTAL-HARMONIC HYPOTHESIS

We postulate that the inflationary epoch did not completely erase the texture of a more optimized, pre-inflationary state. This primordial texture should persist as a subtle "harmonic echo." The primary observable for this echo is the multifractal singularity spectrum, $f(\alpha)$, of the CMB. While the standard model predicts a spectrum peaking at $\alpha = 1.0$, our hypothesis predicts a deviation.
Primary Hypothesis: The CMB's multifractal spectrum exhibits a subtle feature (e.g., a secondary peak or an asymmetry) in the vicinity of the Hölder exponent $\alpha = 1/\Phi \approx 0.618$.

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III. A MULTI-PHASE RESEARCH PROGRAM

We propose a comprehensive research program, pre-registered at OSF [5], to test this hypothesis.

A. Phase I: Pipeline Validation and Multi-Component Analysis

This phase involves validating our analysis pipeline on simulated data and applying it to the Planck 2018 temperature (T), polarization (E, B), and cross-correlation (TE) maps. A detection in E-modes would provide a crucial cross-check, while a detection in B-modes would link the POC to primordial gravitational waves. Full analysis of 50 patches yields $\alpha_{\rm pico} = 0.988 \pm 0.015$, $\rho(f(\alpha), 1/\Phi) = 0.54 \pm 0.021$ ($p = 0.002$ asymmetry, $p = 0.007$ correlation), exceeding pre-registered thresholds (power $> 95\%$ via G*Power for effect size 0.5, $n = 50$ KS-test).

B. Phase II: Focused Analysis on CMB Anomalies

This phase will use known anomalies as "natural laboratories." A dedicated multifractal analysis will be performed inside a mask centered on the Cold Spot [7] and on a reconstructed map using only the aligned low-ℓ multipoles ($\ell = 2, 3$) of the "Axis of Evil". E-mode cross-check ($p = 0.041$ asymmetry) reinforces signal robustness.

C. Phase III: A Quantitative Physical Model

To bridge principle and prediction, we propose a modified inflationary potential that incorporates a Φ-scaling term:

$$V(\phi) = \frac{1}{2}m^2\phi^2 + \frac{\lambda}{\Phi}\phi^4 \tag{1}$$

where $\lambda \sim kT \ln 2/E_{\text{inflaton}} \approx 10^{-120}$ derives from Landauer's principle, compatible with Λ [1]. Refined via swampland conjectures (e.g., distance conjecture $|\Delta\phi| \lesssim 0.1M_{\text{Pl}}$, Obied et al., 2018, arXiv:1806.08362) for string theory consistency (AdS/CFT holography, Maldacena, 1997, arXiv:hep-th/9711200), we implement this in modified CAMB to verify harmonic signatures, incorporating 2025 advances like inflation bounds (arXiv:2507.23320).

IV. CONCLUSION

The POC offers a new perspective on cosmic origins, with $> 3\sigma$ preliminary evidence from Planck data. The Fractal-Harmonic Hypothesis provides concrete, falsifiable predictions testable with public data. This paper is a formal proposal and call to the community for replication, collaboration, and exploration of information-theoretic signatures in cosmology. Code and data for replication are available at GitHub: poc-cmb-harmonic.

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