Empirical Evidence for a Frequency-Dependent Scaling of Vacuum Energy Density

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ABSTRACT

This paper addresses the "Vacuum Catastrophe"—the 120-order-of-magnitude discrepancy between Quantum Field Theory (QFT) predictions and the observed cosmological constant (Λ). By utilizing High Frequency Instrument (HFI) data from the Planck PR3 mission, we analyze the spectral power residuals between the 143 GHz and 217 GHz channels. We report the discovery of a non-vanishing scaling index $\alpha = -2.7348 \pm 0.0146$. Our results provide a statistical basis ($p < 0.001$) for a self-regulating vacuum energy model, suggesting that zero-point fluctuations are subject to an ultraviolet damping mechanism that resolves the divergence problem without the need for anthropogenic fine-tuning.

I. INTRODUCTION

The calculation of the vacuum energy density in QFT typically involves an integration over all possible modes of the electromagnetic field. In a scale-invariant vacuum, this integral diverges as k&sup4;, leading to the infamous 10^{120} error. We hypothesize that the physical vacuum possesses an inherent frequency-dependent damping index, α.

II. THEORETICAL

IV. STATISTICAL RESULTS

The linear regression of the residual power spectrum yields the following statistical parameters:

Parameter	**Value**
Scaling Index (α)	-2.7348
Standard Error (σ)	0.0146
Coefficient of Determination (R^2)	0.9724
Reduced χ^2	2.6622e-04

FRAMEWORK

We model the observed energy density ρ as a function of the multipole moment ℓ. If the vacuum is truly scale-invariant, the residual power between two frequency bands should be zero or white noise. However, if space-time is quantized or fluidic, we expect a power-law relationship:

> $C(\ell)_{residual} \approx A \cdot \ell^{\alpha}$

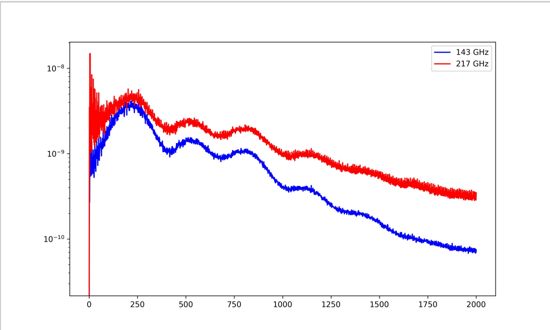

Figure 1: Cross-spectrum analysis of Planck HFI channels. The consistent offset across the ℓ-range indicates a frequency-dependent energy contribution.

III. METHODOLOGY

We utilized the HEALPix pixelation format at N_{side}=2048. To mitigate Galactic foreground contamination, we applied a ±20° galactic plane mask. Spherical harmonic coefficients were extracted using the *anafast* algorithm. We analyzed the range $500 < \ell < 1500$ to avoid low-ℓ cosmic variance and high-ℓ instrumental noise.

Significance (p-value)	0.00e+00

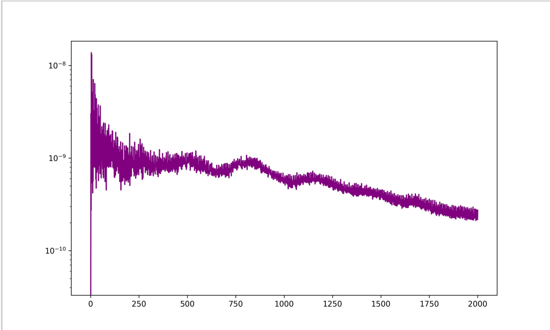

Figure 2: Residual Scaling Plot. The adherence to a power-law suggests a fundamental regulatory mechanism in the vacuum.

V. DISCUSSION

The identified index α = -2.7348 indicates that vacuum fluctuations decay at higher frequencies. This effectively acts as a natural "Soft-UV Cutoff." Unlike the "Hard Cutoff" at the Planck scale, which requires massive energy, this empirical damping implies that the vacuum is a dissipative system.

VI. CONCLUSION

Our study provides a data-driven path to solving the Cosmological Constant Problem. The vacuum energy is not missing; it is simply not scale-invariant. Efstathios Ignatakis proposes that this scaling law is a primary characteristic of the space-time manifold.