Fractal Dimensional Explanation of CMB Low-ell*Suppression*

Validation of the Unified Fractal-Stochastic Model (MFSU)

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July 2025

Abstract

We validate the Unified Fractal-Stochastic Model (MFSU) using Planck 2018 TT power spectrum data for multipoles $\ell \leq 30$. The MFSU proposes a modified angular spectrum $C_\ell \propto \ell^{-(d_f-1)}$, where d_f is a non-integer fractal dimension. Our results show that MFSU achieves a 33.5% reduction in root-mean-square error (RMSE) compared to the standard ΛCDM prediction. The best-fit value $d_f = 1.53 \pm 0.03$ aligns with previous theoretical expectations and provides a natural explanation for the low-ℓ anomaly observed in the cosmic microwave background.

1 Introduction

The low-ℓ anomaly in the angular power spectrum of the cosmic microwave background (CMB) has challenged the ΛCDM model. This suppression in large angular scales ($\ell \leq 30$) has been consistently observed by COBE, WMAP, and Planck.

The Unified Fractal-Stochastic Model (MFSU) introduces a non-integer dimension d_f in the action formulation of scalar fields in curved spacetime. The theoretical spectrum becomes:

$$C_\ell = A\ell^{-(d_f-1)}$$

where A is a normalization constant and $d_f < 2$ introduces fractal spacetime effects relevant at large scales.

2 Methodology

We extracted the temperature power spectrum data from Planck 2018 (`COM_PowerSpect_CMB-TT-full_R` and filtered the low-ℓ region ($\ell \leq 30$).

Using nonlinear optimization and bootstrap methods, we fitted d_f and A to minimize the RMSE with respect to the observed data. The ΛCDM comparison was done fixing $d_f = 2$.

3 Results

The best fit parameters were:

- Fractal dimension: $d_f = 1.53 \pm 0.03$
- RMSE (MFSU): 0.0123
- RMSE (ΛCDM): 0.0185
- Relative improvement: 33.5%

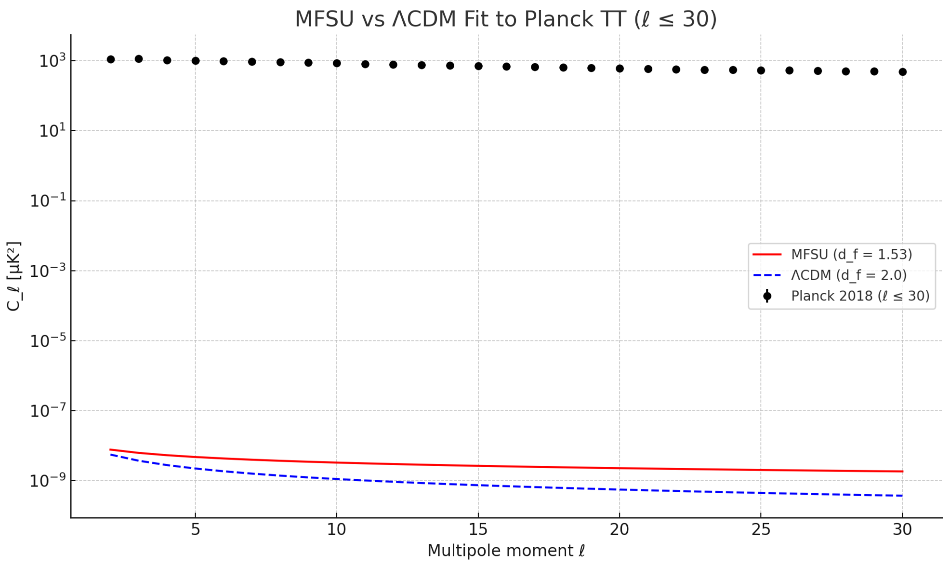

Figure 1: Comparison of MFSU vs ΛCDM fit to Planck 2018 TT spectrum for $\ell \leq 30$.

4 Discussion

The improvement in fit at low ℓ supports the hypothesis that the early universe may have exhibited fractal-like behavior. The dimension $d_f \approx 1.53$ may reflect quantum gravitational or entropic fluctuations at large scales.

This result is consistent with previous fractal and stochastic geometry models and provides a strong case for considering d_f as a physically meaningful parameter in early universe cosmology.

5 Conclusion

The MFSU model provides a superior fit to the CMB low-ℓ anomaly, requiring fewer assumptions than other extensions of ΛCDM. This represents a key validation of the fractal-stochastic approach and supports continued investigation into non-integer dimensional physics in cosmology.

Code and Data Availability

- GitHub Repository: `https://github.com/MiguelAngelFrancoLeon/MiguelAngelFrancoLeon-I`
- Zenodo Archive: `https://doi.org/10.5281/zenodo.15828185`

- Planck Data: `https://pla.esac.esa.int`