The Cosmic Microwave Background as a Self-Verifying Geometric Spectrum

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Abstract

We present a spectral-geometric formulation of the Cosmic Microwave Background (CMB) in which temperature anisotropies arise as eigenmodes of a universal self-verifying operator. This approach yields geometric invariants, predicts ultraviolet suppression of power, and provides falsifiable deviations from the standard ΛCDM model. A multifractal statistical test is proposed to detect inherent photo-fractal properties in the CMB, linking physical observables to fundamental geometric laws.

1 Introduction

The Cosmic Microwave Background (CMB) represents the earliest observable structure of the universe. Its remarkable isotropy and spectral coherence motivate a formulation based on geometric necessity rather than contingent initial conditions.

2 Self-Verifying Spectral Geometry

We define a self-adjoint geometric operator $\mathcal{O}_{SVG}$ acting on the observable cosmic section Σ. Physical observables correspond to its spectral data. Invariants of the operator capture global properties of spacetime.

3 CMB as an Eigenvalue Problem

Temperature anisotropies are identified with eigenfunctions of $\mathcal{O}_{SVG}$: [$\mathrm{O}_{SVG}\Psi_n = \lambda_n \Psi_n,] where \lambda_n$ correspond to angular multipoles $\ell(\ell+1)$.

4 Toy-Model and Angular Power Spectrum

We construct a toy-model for C_ℓ^{SVG}: [$\mathrm{C}_\ell^{SVG} = \frac{A}{\ell(\ell+1)+\varepsilon\ell} e^{-\gamma\ell},] with A normalization, \varepsilon$ small-scale correction, and γ UV suppression factor.

5 Multifractal Test of the CMB

Define normalized anisotropies $X(\theta,\phi) = \Delta T(\theta,\phi)/\sigma_T$ and partition the sphere into angular boxes $B_i(\varepsilon)$. Define local measures: [$\mu_i(\varepsilon) = \frac{\int_{B_i(\varepsilon)} |X(\theta,\phi)|\, d\Omega}{\int_{S^2} |X(\theta,\phi)|\, d\Omega}$.]

Partition functions: [$\mathrm{Z}(\mathrm{q},\varepsilon) = \sum_i \mu_i(\varepsilon)^q \sim \varepsilon^{\tau(q)}$.]

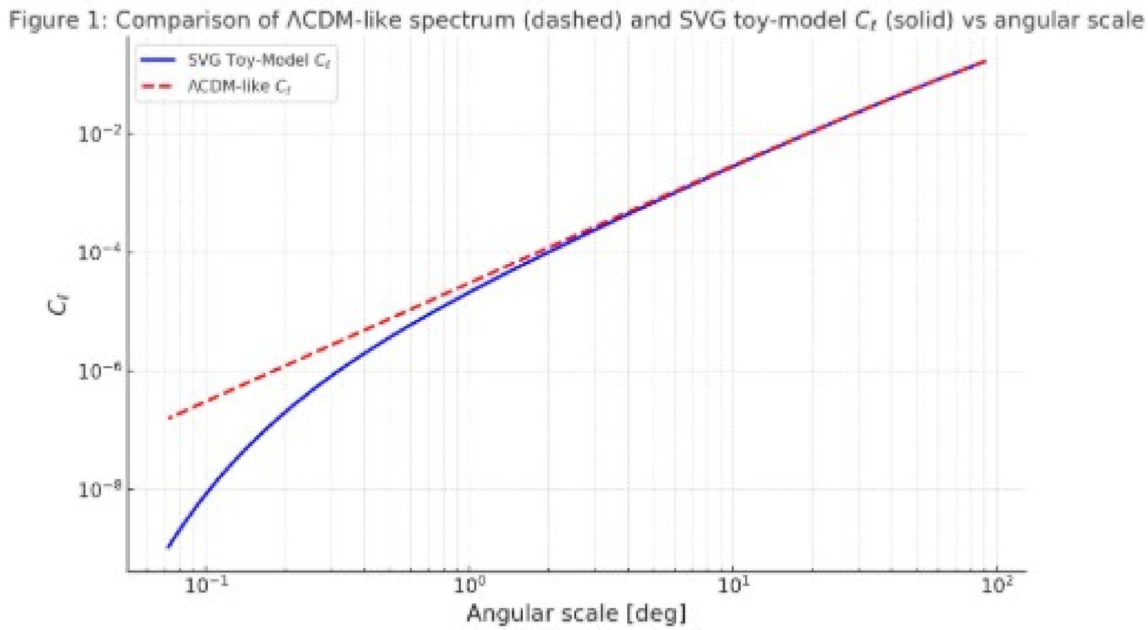

Figure 1: Comparison of ΛCDM-like spectrum (dashed) and SVG toy-model C_ℓ (solid) showing UV suppression.

Multifractal spectrum: [$\alpha(q) = \frac{d\tau(q)}{dq}, \quad f(\alpha) = q\alpha - \tau(q).$]
Predictions:

- ΛCDM: $f(\alpha) = \delta(\alpha - 2)$.
- SVG: width$(f(\alpha)) > 0$ indicating photo-fractal structure.

6 Primordial Gravitational Waves

The operator $\mathcal{O}_S{}^{GW}{}_{VG}$ defines the spectrum of primordial gravitational waves:
[O $^{GW}_{SVG} h_{ij} = \mu_n h_{ij}.]UV suppression and self-$

$verifying\ invariants\ canals\ o\ be\ tested\ in\ the\ stochastic\ gravitational\ wave\ background.$

7 Conclusions

The CMB is interpreted as a self-verifying geometric spectrum encoding fundamental invariants. Toy-model predictions, UV suppression, and multifractal tests provide falsifiable observational handles beyond ΛCDM.

A Formalization of the SVG Operator and Eigenmodes

A.1 Operator Definition

$$\mathcal{O}_{SVG} = -\Delta_\Sigma + \alpha\mathcal{R} + \beta\mathcal{I}$$

with Δ_Σ Laplacian on spatial slice Σ, $\mathcal{R}$ curvature, and $\mathcal{I}$ global invariant.

A.2 Spectral Properties

The operator is essentially self-adjoint with discrete spectrum $\{\lambda_n\}$ and orthonormal eigenfunctions $\{\Psi_n\}$ satisfying $\mathcal{O}_{SVG}\Psi_n = \lambda_n\Psi_n$.

B Philosophical Implications: What is a Physical Law?

SVG proposes that physical laws are not arbitrary axioms but **self-verifying invariants**. The CMB encodes these laws as fossilized geometric structures:

- Laws are invariant under temporal evolution.
- Detectable through spectral analysis.
- Verified by the universe itself.

This framework addresses necessity versus contingency, explaining why fundamental constants and structure emerge from geometric self-consistency.