Reformulation of the Unified Primal-Fractal Resonance Theory in the Brans-Dicke Framework Consistent with Cosmological Data

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Abstract

We present a reformulation of the Unified Primal-Fractal Resonance Theory (UPFRT) within the Brans-Dicke (BD) scalar-tensor framework, updated to align with current cosmological observations (DESI 2025, BOSS). The scalar field is modeled with cosmological-scale oscillations while ensuring negligible variations in the gravitational constant. An oscillating dark energy model is introduced via a dynamic cosmological constant. We show that the model is consistent with current constraints on the Hubble constant and the expansion rate at redshift $z = 0.38$, with no significant impact on Big Bang Nucleosynthesis (BBN).

1 Introduction

The UPFRT proposes a connection between primordial processes and cosmic expansion through a universal frequency f_{univ} and a scalar field $\varphi(t)$. We reformulate this theory in the Brans-Dicke framework to maintain general covariance and incorporate dynamical gravity. The BD scalar field $\varphi_{\text{BD}}(t)$ is dimensionless and related to the effective gravitational coupling.

2 Scalar Field Oscillations

We define the scalar field as:

$$\varphi_{\text{BD}}(t) = \varphi_0 \left(1 + \varepsilon \sin\left(\frac{2\pi f_{\text{univ}} t}{\kappa}\right)\right), \tag{1}$$

where:

- $\varphi_0 \approx 1/G \approx 1.5 \times 10^{10}$,
- $\varepsilon \approx 10^{-50}$ to ensure $\Delta G/G < 10^{-12}\,\mathrm{yr}^{-1}$,
- $f_{\mathrm{univ}} \approx 3.0 \times 10^{15}\,\mathrm{Hz}$,
- $\kappa \approx 6.6 \times 10^{32}\,\mathrm{s}$.

The resulting oscillation period is:

$$T = \frac{\kappa}{f_{\mathrm{univ}}} \approx 2.2 \times 10^{17}\,\mathrm{s} \approx 7\,\mathrm{Gyr}, \tag{2}$$

placing oscillations on a cosmological timescale.

3 Brans-Dicke Parameter and Consistency

To remain consistent with Solar System constraints, we fix the Brans-Dicke coupling parameter:

$$\omega_{\mathrm{BD}} = 100,000, \tag{3}$$

which ensures that variations in φ_{BD} do not conflict with observations.

4 Dynamical Cosmological Constant

We introduce a time-varying dark energy term:

$$\Lambda_{\mathrm{mod}}(t) = A\left(1 + \sin\left(\frac{2\pi f_{\mathrm{univ}} t}{\kappa}\right)\right), \tag{4}$$

with amplitude A determined by matching the present-day expansion rate. At $t_0 \approx 4.35 \times 10^{17}\,\mathrm{s}$, we require:

$$\Lambda_{\mathrm{mod}}(t_0) \approx 0.99\,\mathrm{s}^{-2} \Rightarrow A \approx 0.508. \tag{5}$$

5 Cosmological Predictions

5.1 Current Expansion Rate

Given the total energy density,

$$\rho_{\mathrm{total}} = \rho_m + \rho_r + \rho_\Lambda,$$

we compute:

$$H_0 \approx \sqrt{\frac{8\pi}{3\varphi_0}\rho_{\mathrm{total}}} \approx 68\,\mathrm{km/s/Mpc}, \tag{6}$$

$$H(z = 0.38) \approx 82\,\mathrm{km/s/Mpc}, \tag{7}$$

in agreement with DESI (2025) and BOSS.

5.2 Impact on Big Bang Nucleosynthesis

At BBN time ($t \sim 100\,\mathrm{s}$), the scalar field variation is:

$$\Delta G/G \approx -2.86 \times 10^{-65},$$

which is negligible and does not affect light-element abundances.

6 Conclusion

We have shown that the UPFRT, reformulated in the Brans-Dicke framework with an oscillating scalar field and a dynamic cosmological constant, can remain consistent with current cosmological observations. The model provides a novel oscillating dark energy component and satisfies constraints on G-variation and the Hubble constant. Future work will investigate structure formation and observational signatures at higher redshift.