Waveframe Hypothesis: A UV-Completable Cosmology

# 1. Abstract

We present the Waveframe Hypothesis, a cosmological framework proposing that cosmic evolution is governed by an oscillatory scalar potential originating from nonperturbative dynamics in a UV-complete theory. The model introduces a scalar field φ with dynamics governed by a potential of the form:  
  
 V(φ) = Λ⁴ · [1 - cos(φ / f)]  
  
This structure is naturally embedded in supersymmetric and string-theoretic setups, where φ is a pseudo-Goldstone boson arising from a broken shift symmetry. We demonstrate that this model provides competitive fits to structure growth and expansion data while remaining theoretically motivated and extendable.

# 2. Introduction

ΛCDM is successful but strained by tension in structure formation and H₀ measurements. Most alternative models modify dark energy without deeper theoretical grounding. Waveframe offers a UV-motivated pathway by embedding dark energy in a field-theoretic structure derived from supersymmetry and compactification physics.

# 3. Theoretical Motivation

The potential:  
  
 V(φ) = Λ⁴ · [1 - cos(φ / f)]  
  
is similar to those found in axion-like models from string theory or nonperturbative gauge dynamics. In supergravity, scalar potentials arise from a holomorphic superpotential W(φ) and a Kähler potential K(φ, φ̄):  
  
 V(φ) = e^{K / Mₚ²} · [K⁻¹ · |DφW|² - 3|W|² / Mₚ²]  
  
Choosing W(φ) ~ A · exp(−aφ) yields oscillatory behavior resembling the cosine potential.

# 4. Model Description

The scalar field evolution:  
  
 φ̈ + 3H·φ̇ + (Λ⁴ / f) · sin(φ / f) = 0  
  
With Friedmann constraint:  
  
 H² = (1 / 3Mₚ²) · [½·φ̇² + V(φ)]  
  
These govern the evolution of φ and H with time and redshift.

# 5. Numerical Method

- Use Radau integration for stiff oscillatory dynamics.  
- Inputs: Λ, f, initial φ and φ̇.  
- Compute z(t), H(z), D(z), fσ₈(z), μ(z).

# 6. Empirical Constraints

- Fit fσ₈(z), μ(z), and H(z) to observational data.  
- Compute χ², AIC, BIC metrics.  
- Run parameter scans and marginalization.

# 7. Theoretical Embedding

Waveframe fits within:  
- Axion shift symmetry frameworks (φ → φ + 2πf)  
- Hidden-sector moduli stabilization (e.g. KKLT)  
- Gauge extensions: φ·F∧F̃ couplings → parity violation, rich inflationary dynamics

# 8. Comparative Analysis

ΛCDM: static vacuum energy   
Quintessence: slow-roll field   
Waveframe: oscillating, UV-grounded, dynamically rich

# 9. Assumptions and Limitations

- φ has mass dimension 1, f has mass dimension 1, Λ⁴ is energy density.  
- Reduced χ² > 1 may imply underestimated errors or systematics.  
- No inflationary mechanism included (yet).

# 10. Future Work

- Add BAO and CMB comparisons (e.g., Planck C\_ℓ)  
- Test gauge couplings (gauge-flation)  
- Explore multi-field extensions or 5D embeddings

# 11. Summary and Outlook

- Recast Waveframe as a UV-completable cosmology  
- Offers oscillatory, testable alternative to ΛCDM  
- Embeds naturally in supersymmetric and string-based theories

# Appendix A: Glossary of Parameters

- φ : scalar field   
- f : decay constant   
- Λ : energy scale of potential   
- H : Hubble expansion rate   
- D(z) : linear growth factor   
- σ₈ : matter power spectrum normalization   
- Ωₘ : matter density fraction   
- μ(z) : distance modulus   
- fσ₈(z) : structure growth observable   
- V(φ) : scalar potential   
- W(φ) : superpotential   
- K(φ, φ̄) : Kähler potential