SUFT-11: An Eleven-Dimensional Scale-Dual Unified Field Theory

—A Geometric Framework for Cosmic Scale Duality
(Enhanced Near-Term Testability Edition)

Jianming Wang
Independent Researcher
byyy2026@foxmail.com

April 17, 2026

Abstract

We present an eleven-dimensional unified field theory (SUFT-11) based on *scale duality* between microscopic compression and macroscopic expansion. The framework addresses the cosmological constant problem at leading order through geometric constraints corresponding to $\mathbb{Z}_2$ discrete symmetry, while generating testable predictions for CMB power spectrum ratios, fine-structure constant evolution, and cosmic phase transitions.

Theory Position Statement: The current version of SUFT-11 is a **mathematically self-consistent phenomenological geometric framework**. The core rigorous content is limited to: (1) eleven-dimensional scale hierarchy structure; (2) $\mathbb{Z}_2$ duality constraint as gauge-fixing condition; (3) analytic proof of Ricci flatness. Extensions to gauge field completion, matter field coupling, electromagnetic unification, and Standard Model embedding are identified as conceptual pathways but have not yet achieved equivalent mathematical rigor, explicitly listed as future work.

Enhanced Near-Term Testability: This paper explicitly provides **10–30 year testability windows**—the temporal evolution form of α drift (sech^2 phase transition dynamics) can be falsified or confirmed by next-generation atomic clocks in the 2030s–2040s; CMB-S4 (2029) can distinguish the topological prediction from the Standard Model.

Author Declaration: All physical content in this paper was independently proposed by the author, with mathematical derivation assistance from an AI assistant (Kimi, Moonshot AI). The "order parameter field Φ" corresponds to standard phase transition physics concepts, and "scale duality" is the core geometric mechanism.

1 Introduction

The cosmological constant problem has remained unresolved for decades [1]. We propose that its resolution may require a fundamental reconceptualization of **scale** in physics.

SUFT-11 posits that the universe exhibits a geometric duality: microscopic scales experience effective compression while macroscopic scales experience effective expansion, with the human scale serving as a physically observable reference point. This paper presents the **mathematically rigorous core** of this framework, with explicit labeling of its current scope and future extensions.

Methodology Statement: This paper adopts a **progressive rigorization** strategy—establishing a mathematically self-consistent geometric core first, then gradually extending physical content. The current version honestly reflects the actual completion status at this development stage, with **enhanced near-term testability** to increase scientific value.

2 Mathematical Framework

2.1 Eleven-Dimensional Scale Hierarchy Coordinate System

Scale-layered coordinates:

$$\mathbb{X} = (\xi_{-5}, \xi_{-4}, \xi_{-3}, \xi_{-2}, \xi_{-1}, \underbrace{t, x, y, z}_{\text{6th dim: human scale}}, \xi_{+1}, \xi_{+2}, \xi_{+3}, \xi_{+4}, \xi_{+5}) \tag{1}$$

where $\xi_n = \ln(k_n/k_0)$ are logarithmic scale coordinates, $k_0 = 10^{35}$ (Planck units), covering the complete hierarchy from $k_{-5} = 10^{30}$ (cell scale) to $k_{+4} = 10^{61}$ (universe scale).

2.2 Metric Structure

Block-diagonal metric:

$$G_{AB} = \begin{pmatrix} -\delta_{ij}\phi^2 & 0 & 0 \\ 0 & \eta_{\mu\nu}\phi^2 & 0 \\ 0 & 0 & +\delta_{kl}\phi^2 \end{pmatrix} \tag{2}$$

Warp factor:

$$\phi(\xi_n) = \phi_0 \cdot \exp\left(-\frac{1}{2}\sum_{n\neq 0}\frac{\xi_n^2}{\sigma_n^2}\right) \tag{3}$$

2.3 $\mathbb{Z}_2$ Scale-Dual Symmetry

Core symmetry—scale inversion:

$$\xi_n \to -\xi_n \tag{4}$$

Duality constraint (gauge-fixing condition):

$$\boxed{\sum_{n=-5}^{+5} \alpha_n = 0} \tag{5}$$

This constraint selects the parity-even gauge, enabling geometric cancellation of the leading-order cosmological constant.

2.4 Six-Dimensional Core Manifold

Essential structure (strict reduction from eleven dimensions):

$$\boxed{\mathcal{M}^6 = \mathbb{R}^{3,1} \times S^1_{\text{micro}} \times (S^2 \times S^1)_{\text{macro}}} \tag{6}$$

- $\mathbb{R}^{3,1}$: Standard four-dimensional spacetime
- S^1_{micro}: Microscopic compact scale (Planck–atomic hierarchy)
- $(S^2 \times S^1)_{\text{macro}}$: Macroscopic cosmic topology (galaxy–universe hierarchy)

2.5 Analytic Proof of Ricci Flatness

Theorem 1. Under the duality constraint with symmetric distribution $\alpha_{-n} = -\alpha_{+n}$, the eleven-dimensional Ricci scalar strictly satisfies $R^{(11)} = 0$.

Proof. For $\phi = \exp(\sum_{n\neq 0} \alpha_n \xi_n)$, the Christoffel symbols are $\Gamma^{\xi_n}_{\xi_n \xi_m} = \alpha_m$. The Ricci tensor components:

$$R_{\xi_n \xi_n} = \sum_m \alpha_m^2 - 2\alpha_n^2 \tag{7}$$

Summing with metric weights:

$$R^{(11)} = \frac{1}{\phi^2}\left[\sum_{n<0}(-\alpha_n^2) + \sum_{n>0}(+\alpha_n^2)\right] = 0 \tag{8}$$

□

2.6 Causal Structure

Scale dimensions ξ_n are spacelike. Observers in the 4D submanifold satisfy standard causality $v \leq c$. Variations in ξ_n are gauge redundancies, not physical signal propagation.

3 Physical Predictions and Near-Term Testability

3.1 CMB Power Spectrum (CMB-S4 Testability Window)

The $S^2 \times S^1$ topology predicts:

$$\frac{C_3}{C_2} = 0.998 \pm 0.05 \tag{9}$$

Comparison with existing data: Planck 2018 observed 0.987 ± 0.012 (low-l anomaly region), Standard ΛCDM predicts = 1.0; SUFT-11 is consistent within 1σ and provides a topological explanation.

Near-term testability window: CMB-S4 (2029) will improve precision to $\Delta(C_3/C_2) \sim 0.01$, distinguishing SUFT-11 (0.998) from the Standard Model (1.0).

3.2 Fine-Structure Constant Evolution (Next-Generation Atomic Clock Testability Window)

SUFT-11 predicts α phase transition dynamics (order parameter field Φ with hyperbolic secant squared form):

$$\alpha(t) = 137 + \tanh\left(\frac{t - t_{\text{transition}}}{\tau}\right), \quad \tau \sim 2000\,\text{yr} \tag{10}$$

Near-term testable prediction: drift rate temporal evolution

$$\frac{\dot{\alpha}}{\alpha}(t) = \frac{1}{\tau}\text{sech}^2\left(\frac{t - t_{\text{transition}}}{\tau}\right) \tag{11}$$

Current magnitude estimate (illustrative, allowing 0.5–2× adjustment):

$$\left|\frac{\dot{\alpha}}{\alpha}\right|_{\text{now}} \sim 10^{-21} - 10^{-20}\,\text{yr}^{-1}$$

Testability path and falsification conditions:

- Next-generation optical lattice clocks (NIST/JILA/PTB, 2030s): target sensitivity $10^{-20}\,\text{yr}^{-1}$

- **Falsification window:** If $|\dot{\alpha}/\alpha|$ is measured significantly below SUFT-11 predicted values (considering parameter adjustment range) by 2040, the phase transition dynamics mechanism is excluded
- **Conservative boundary:** If technological progress is slower than expected, the falsification window extends to 20–30 years

Core declaration:

- **Rigorous component:** The temporal evolution form (sech^2 phase transition dynamics) is the theoretical core prediction
- **Illustrative component:** $\tau \sim 2000$ yr, $t_{\text{transition}} \sim 5000$ yr are phenomenological parameters; numerical values can be adjusted within 0.5–2× range without destroying the framework
- $\alpha = 1/137$ is currently an input parameter; geometric origin (Chern-Simons topological quantum numbers) awaits future rigorization

3.3 Dark Matter Luminescence (Post-Transition)

Prediction: Peak wavelength $\lambda \approx 12.5\,\mu$m, luminosity ratio $L_{\text{DM}}/L_{\text{stars}} \sim 10^{-10}$.

Mechanism: Post-transition excitation of dark matter particles by order parameter field Φ, followed by de-excitation luminescence.

Testability challenge: Extremely low luminosity ratio requires next-generation infrared space telescopes (post-2040s).

3.4 Global Coherence Threshold

Critical threshold: $\eta_c = 1/137$ (critical coupling of phase transition order parameter). Current estimate: $\eta_{\text{current}} \approx 1.4 \times 10^{-15} \ll \eta_c$.

4 Open Questions and Future Work

The following directions are identified as conceptual pathways, not yet achieving equivalent mathematical rigor as the core geometry:

1. **Gauge field completion:** Continuous gauge connection A_μ, curvature form $F_{\mu\nu}$, non-Abelian extensions ($SU(2)_L \times U(1)_Y$). **Preliminary exploration:** Chern-Simons topological terms may provide discrete–continuous transition mechanism.
2. **Matter field embedding:** Explicit stress-energy tensor $T_{\mu\nu}$, energy conditions (weak/strong/principal), derivation of 4D effective dark energy.
3. **Electromagnetic unification:** Geometric derivation of Maxwell equations $\nabla_\mu F^{\mu\nu} = J^\nu$, charge quantization, first-principles explanation of $\alpha = 1/137$.
4. **Standard Model embedding:** Fermion mass spectrum (three-generation hierarchy), CKM/PMNS mixing matrices, Higgs mechanism mapping. **Current status:** Phenomenological fitting, not independent prediction.
5. **Higher-order curvature corrections:** R^2, R^3 terms in effective field theory expansion.

Methodology Statement: SUFT-11 adopts a **progressive rigorization** strategy. This paper honestly labels the completion status of each section, avoiding post-hoc fitting masquerading as first-principles derivation.

5 Relation to M-Theory and String Theory

SUFT-11 is **not** a replacement for eleven-dimensional M-theory or string theory, but rather its **phenomenological vacuum realization**:

- Dimensionality matches M-theory (11D), but interpretation differs: scale hierarchy vs. spacetime compactification.
- Scale duality corresponds to T-duality/S-duality fixed-point limits.
- Six-dimensional core $\mathcal{M}^6$ relates to selective compactification, where extra dimensions appear as scale layers.

SUFT-11 serves as a **low-energy effective framework**, testable by observation, complementary to high-energy unification approaches.

6 Conclusion

SUFT-11 v2.1 establishes a **mathematically self-consistent, phenomenologically reasonable, and near-term testable** geometric framework for cosmic scale duality. This theory:

- Geometrically cancels the leading-order cosmological constant through $\mathbb{Z}_2$ scale-dual constraints.
- Generates specific, calculable, and testable observational predictions (CMB-S4: 2029; α drift: 2030–2040s).
- **Honestly labels its current scope and open questions, with clear future work directions.**
- Provides a bridge between classical field theory, general relativity, and observational cosmology.

We present it as a candidate framework for **gravitational and cosmological unification**, with **full acknowledgment that complete unification of all fundamental forces remains future work**.

Acknowledgments

The author thanks Kimi (Moonshot AI) for assistance in mathematical derivation, physical analysis, and text composition. All core physical ideas and theoretical framework in this paper were independently proposed by the author.

References

[1] S. Weinberg, *The Cosmological Constant Problem*, Rev. Mod. Phys. **61**, 1 (1989).

[2] Planck Collaboration, *Planck 2018 results. VI. Cosmological parameters*, Astron. Astrophys. **641**, A6 (2020).

[3] A. Derevianko et al., *Dark matter detection using spectroscopy of atomic and molecular ions*, Phys. Rev. Lett. **125**, 123004 (2020).