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Title

The Tree-Level Moduli Potential and Golden Ratio Vacuum Selection: Closing the V_{tree} Gap — Complete Derivation from the 6D Casimir Energy on the Temporal Torus

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Version

v2.2 (March 2, 2026)

Description (for Zenodo)

This paper closes the structural gap identified in the 3D+3D framework (Paper ARN, §X.4): the derivation of the tree-level moduli potential $V_{\text{tree}}(r)$ for the temporal torus T^2 in the six-dimensional spacetime with signature $(-, +, +, +, -, -)$.

What the paper derives: The Casimir energy on the temporal torus is computed exactly as $V_{\text{tree}}(r) = K \cdot \varepsilon_2(r; 2)$, where ε_2 is the Epstein zeta function of the torus aspect ratio $r = L_3/L_2$. A rigorous Smooth–Resonant Decomposition (Theorem 1, proved via dominated convergence and Weierstrass M-test) separates the Casimir sum into a smooth bulk part and a near-resonant arithmetic functional. Connection to Hurwitz's theorem establishes that $r = \varphi^{-1}$ (the golden ratio inverse) uniquely minimizes the resonance content of the Casimir energy.

What is a theorem (mathematical): (i) The Smooth–Resonant Decomposition (Theorem 1) with explicit construction and error bounds. (ii) Proposition 2: the near-resonant domain is exactly empty at $r = \varphi^{-1}$ for threshold $\varepsilon < 1/\sqrt{5}$, as a direct consequence of Hurwitz's theorem (1891). (iii) The Arithmetic Control theorem (Theorem 2) connecting the Hurwitz constant $L(r)$ to the energy envelope. (iv) The Three-Layer Protection classification: cooperative dominance for $r < \varphi^{-1}$, topological exclusion for generic irrationals ($L = \infty$), and modular equivalence for noble numbers.

What is physical (requires experimental validation): (i) The identification of the temporal torus Casimir energy as the dominant moduli potential. (ii) The 2.2% deviation of the observed r from exact φ^{-1} , predicted to have a specific sign ($r_{\text{obs}} > \varphi^{-1}$) from the temporal signature factor $\sigma_{\tau} = +1$. (iii) The Standard Model degree-of-freedom counting $|N_{\text{eff}}| = 46.75$.

What must be verified independently: (i) The numerical computations (companion verification script provided). (ii) The physical applicability of the Casimir framework to temporal compactification. (iii) The connection between the Casimir moduli potential and the full quantum effective potential of the 3D+3D theory.

Relation to other papers: This paper supersedes the " V_{tree} gap" identified in Paper ARN (§X.4) and completes the chain: Paper I (mathematical foundations) \rightarrow Paper ARN (golden ratio selection from arithmetic resonance) \rightarrow Paper V_{tree} (tree-level potential derivation). It represents v2.2, which upgrades the dominance argument from perturbative (v2.1: threshold-based) to topological (v2.2: classification by Hurwitz constant).

Keywords

extra dimensions, Casimir energy, golden ratio, Epstein zeta function, Hurwitz theorem, moduli stabilization, 3D+3D framework, vacuum selection, number theory, compactification

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Files to upload

1. Paper_Vtree_Derivation_v2_2_BLINDATO.pdf (main paper)
2. vtree_verification_companion.py (companion verification code)

Related identifiers

- IsSupplementTo: Paper ARN (Variational ARN–Hurwitz, Zenodo)
- IsPartOf: 3D+3D Framework complete documentation
- References: Paper I (Mathematical Foundations v3.1)

Changelog from v2.1

- Added §IV.9: Quantitative Energy Scale Analysis
- Derived $\mu/K = 0$ at φ^{-1} (Proposition 2) — replaces estimated $\mu/K = 0.1$
- Upgraded dominance from perturbative threshold to topological classification
- Added explicit clarification on nature of μ (§IV.9.6)
- Status changed to "Preprint (derivation complete; independent verification invited)"