The Origin Axiom (Phase I): A Minimal Non-Cancellation Principle and a Reproducible Toy Demonstration

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Abstract

We introduce a minimal, θ-agnostic axiom prohibiting perfect cancellation of a global complex amplitude: $|A| > \varepsilon > 0$. We present finite-dimensional toy models and a reproducible lattice existence proof showing that enforcing a non-cancellation floor prevents deep destructive interference while remaining dynamically stable. The axiom is introduced as a global constraint rather than a local field-theoretic modification. This Phase I work isolates the principle from phenomenological parameter extraction and defers any claims of full cosmological-constant resolution to later phases.

Contents

1 Introduction

The cosmological constant problem and related questions concerning vacuum energy continue to motivate attempts to understand why large microscopic contributions fail to gravitate at macroscopic scales. Within standard local quantum field theory, cancellations can be arranged through symmetry or tuning, but generic radiative corrections tend to destabilize small values unless protected by additional structure. A persistent difficulty is therefore structural rather than numerical: why should the net vacuum contribution vanish exactly, rather than merely become small?

This Phase 1 work isolates a minimal hypothesis that directly targets this structural tension. We postulate a global non-cancellation constraint that forbids perfect destructive interference of a global complex amplitude. The proposal is intentionally stripped of phenomenological commitments: we avoid parameter extraction, special-number selection (such as φ or φ^{φ}), flavor-physics inputs, or claims of uniqueness. The objective is narrower and more foundational: to state the principle cleanly and to demonstrate, in reproducible toy settings, that it yields a stable nonzero residual amplitude in regimes where unconstrained cancellation would otherwise drive the residual toward zero.

Scope and non-claims. This paper does not claim a solution to the cosmological constant problem, nor a derivation of the scale ε, nor an embedding within the Standard Model or a realistic cosmological framework. Instead, it provides a proof-of-concept that a global non-cancellation principle can be implemented consistently in controlled models and that such an implementation produces a robust residual under coarse variations of system size, initial conditions, and cancellation strength.

Structure. Section 2 states the minimal axiom and clarifies its meaning, assumptions, and limitations. Section 3 introduces finite-dimensional phasor ensembles as a baseline model of interference and cancellation. Sections 4 and 5 present a reproducible lattice existence proof together with a scaling analysis. Section 6 summarizes limitations of Phase 1 and delineates the requirements for Phase 2.

2 Axiom

2.1 Minimal statement

Let a toy system admit a global complex amplitude $A \in \mathbb{C}$ constructed as a sum or mean over microscopic degrees of freedom (e.g. a collective phasor, order parameter, or amplitude-like functional of the state). The *Origin Axiom* posits:

$$\boxed{|A| > \varepsilon \quad \text{for some fixed } \varepsilon > 0.} \tag{1}$$

Equation (1) is an *axiom* in Phase I: it is not derived from a local Lagrangian, equation of motion, or variational principle. It acts as a global constraint that forbids exact destructive cancellation of A.

2.2 Interpretation

Global / nonlocal character. The constraint is imposed on a global functional of the state, not on local field values or pointwise operators. This is intentional: Phase I treats (1) as a conceptual candidate mechanism that could arise from topology, boundary conditions, quantum-gravitational selection, or other intrinsically nonlocal structures. No such microscopic origin is assumed or derived here.

What is fixed vs. free. The axiom introduces a positive parameter ε. In Phase I, ε is treated as a free constant specifying the non-cancellation floor. Its numerical value is not predicted at this stage. A central goal of Phase II will be to relate or derive ε from deeper structure and to connect it to a physical energy-density scale, if possible.

Relation to cancellation intuition. If microscopic degrees of freedom contribute with varying phases, ordinary destructive interference can make $|A|$ parametrically small. The axiom forbids the limit $|A| \to 0$. In this restricted sense, the axiom addresses only the structural question "why not exactly zero?" It does not, by itself, determine the magnitude of the residual.

2.3 Relation to Weinberg-type no-go arguments

A well-known obstruction to dynamical "adjustment mechanisms" for the cosmological constant is that, within broadly standard local effective field theory assumptions, fields introduced to cancel vacuum energy generically either fail, destabilize the theory, or reintroduce fine-tuning once radiative corrections are included. Weinberg's classic review summarizes this logic and why naive self-adjustment is difficult in local QFT coupled to gravity [1].

Phase I does not claim to evade these obstructions within ordinary local EFT. Instead, it *changes the starting premise*: the *Origin Axiom* is imposed as a *global constraint* on an amplitude-like functional of the state, not as a local field equation derived from a standard Lagrangian. In this sense, Phase I is explicit about what is being relinquished relative to Weinberg's assumptions: strict locality and standard Wilsonian radiative arguments are not assumed at the level of the axiom itself.

This is not offered as a resolution, only as a transparent statement of logical scope. If a correct theory contains global or nonlocal selection rules (for example arising from topology, boundary conditions, or quantum-gravitational constraints), then Weinberg's specific premises do not apply directly. Phase II must either (i) supply a consistent derivation of such a global rule in a UV-complete framework or (ii) demonstrate that an effective description can remain predictive despite the presence of nonlocal constraints.

2.4 Phase I claims governed by the axiom

Phase I is restricted to the following auditable claims:

- **C1:** Equation (1) is postulated as an axiom, not derived.
- **C2:** In finite phasor ensembles, unconstrained destructive interference generically yields small but nonzero residuals.
- **C3:** Enforcing (1) in a lattice toy model is dynamically stable (existence proof).
- **C4:** In unconstrained systems, the mean residual decreases with system size, while the constrained mean saturates at ε.
- **C5:** Constraint enforcement does not induce order-one pathologies in the toy energy diagnostic within the explored parameter range.

All claims are linked to explicit, reproducible numerical artifacts presented in Section 5.

3 Toy Models: Finite Phasor Ensembles

We begin with a finite-dimensional model of cancellation: sums of complex unit phasors. Let

$$S = \sum_{j=1}^{N} e^{i\alpha_j}, \tag{2}$$

with phases α_j drawn from a distribution on $[0, 2\pi)$. In typical random ensembles, $|S|$ exhibits partial cancellation; a standard expectation is that $|S|$ scales sublinearly with N (e.g. random-walk behavior).

3.1 A controlled "twist" parameter

To represent a tunable departure from perfect anti-alignment, we introduce a parameter θ that shifts a fraction of phases by a fixed offset. This produces ensembles in which cancellation remains strong but is not finely tuned to exact anti-alignment.

3.2 Incommensurate twists as a non-fine-tuning device (Phase I)

A common concern is whether near-cancellation might still produce exact zeros at special times or system sizes. In finite systems with rational commensurabilities, exact recurrences can occur. A minimal way to suppress such recurrences is to avoid commensurability in relative phases, for example by choosing $\theta/2\pi \notin \mathbb{Q}$.

Phase I uses this only as a *genericity device*: the point is not that a particular irrational is selected, but that exact recurrences become non-generic once commensurability is avoided. Accordingly, Phase I remains θ-agnostic: it treats "irrational" as a class of choices, not a distinguished value. Any later claim that a specific irrational is selected must be justified by an independent, non-numerological principle and is explicitly deferred.

3.3 Non-cancellation floor

Phase I implements the axiom at the level of the observable residual by considering

$$|S| \mapsto \max(|S|, \varepsilon). \tag{3}$$

This is not presented as a microphysical law or dynamical equation but as a minimal operational encoding of (1) for a toy observable.

3.4 A baseline cancellation lemma: random phasor sums

To quantify typical cancellation without fine-tuning, consider i.i.d. phases $\alpha_j \sim \mathrm{Unif}(0, 2\pi)$ and define $S = \sum_{j=1}^{N} e^{i\alpha_j}$. Write $S = X + iY$ with $X = \sum \cos\alpha_j$ and $Y = \sum \sin\alpha_j$. Then $\mathbb{E}[X] = \mathbb{E}[Y] = 0$ and $\mathrm{Var}(X) = \mathrm{Var}(Y) = N/2$. For large N, (X, Y) is approximately a two-dimensional Gaussian with isotropic variance $N/2$, so $R = |S| = \sqrt{X^2 + Y^2}$ is approximately Rayleigh distributed with scale $\sigma = \sqrt{N/2}$, giving

$$\mathbb{E}[|S|] \;\approx\; \sigma\sqrt{\frac{\pi}{2}} \;=\; \frac{\sqrt{\pi N}}{2}. \tag{4}$$

Therefore the *intensive* mean amplitude scales as

$$\mathbb{E}\left[\frac{|S|}{N}\right] \sim \mathcal{O}\left(\frac{1}{\sqrt{N}}\right). \tag{5}$$

Equations (4)–(5) provide a clean baseline: even without any axiom, typical destructive interference produces a residual that shrinks with system size. The *Origin Axiom* does not dispute this behavior; it posits that, beyond this generic cancellation, *exact* cancellation is forbidden by a global rule.

3.5 Artifact: Fig A

Figure 1 shows the ensemble-averaged residual as a function of the twist θ, along with the floored variant. The qualitative result is that once the floor is applied, the residual cannot drift below ε even in regimes where unconstrained cancellation would produce smaller values.

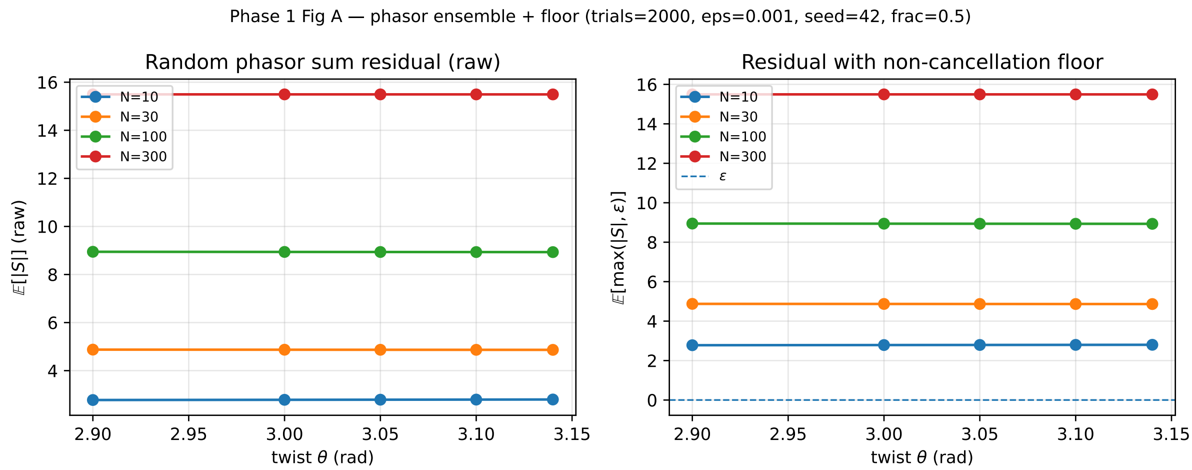

Figure 1: Phase I Fig A: finite phasor ensemble residual vs. twist θ (raw vs. floored). The floored curve enforces $\max(|S|, \varepsilon)$, producing a persistent nonzero baseline.

4 Methods: Lattice Existence Proof and Scaling Test

Phase I uses a lattice toy model as an *existence proof* that a global amplitude floor can be enforced stably in an explicit dynamical system. The lattice model is not claimed to represent a realistic QFT vacuum; it serves as a controlled numerical sandbox for testing the logical consistency of the axiom.

4.1 Global amplitude observable

Let $\phi(x)$ be a complex scalar degree of freedom on a cubic lattice with N_{sites} sites. We define the global amplitude

$$A_{\text{sum}} = \sum_{x} \phi(x), \tag{6}$$

and the intensive mean amplitude

$$A_{\text{mean}} = \frac{A_{\text{sum}}}{N_{\text{sites}}}. \tag{7}$$

Phase I applies the non-cancellation floor to the *mean* amplitude:

$$|A_{\text{mean}}| \geq \varepsilon. \tag{8}$$

Operationally, the implementation enforces an upstream constraint on $|A_{\text{sum}}|$ with $\varepsilon^{(\text{sum})} = \varepsilon\, N_{\text{sites}}$, ensuring correct intensive scaling as system size varies.

4.2 A minimal illustrative mapping from amplitude floor to vacuum energy

Phase I distinguishes two logically separate questions: (i) why not exactly zero (structural non-cancellation), and (ii) what sets the observed magnitude of vacuum energy. Phase I addresses (i) only; the discussion below is included solely to make dimensional requirements explicit.

Let μ be a characteristic energy scale governing how a residual amplitude might contribute to an effective energy density. A generic dimensional estimate is

$$\rho_{\text{vac}} \sim \mu^4\, f(|A_{\text{mean}}|), \tag{9}$$

where f is dimensionless. The simplest analytic choice is $f(|A_{\text{mean}}|) = |A_{\text{mean}}|^2$, or any monotone function with a nonzero floor. Under this illustrative mapping, the *Origin Axiom* implies a strictly positive bound

$$\rho_{\text{vac}} \gtrsim \mu^4\, \varepsilon^2. \tag{10}$$

Claim	Description	Artifact(s)
C1	Axiom postulated ($\|A\| > \varepsilon$)	Sec. 2
C2	Phasor residual and floor behavior	Fig. 1 (figA_phasor_toy.pdf)
C3	Lattice enforcement existence proof	Fig. 2 + run meta.json
C4	Scaling: unconstrained $\to 0$, constrained $\to \varepsilon$	Fig. 3 + scaling_summary.yaml
C5	No order-one pathology in toy energy diagnostic	Stored $E(t)$ in NPZ outputs

Table 1: Phase I claims-to-artifacts map. Each artifact is generated via the Snakemake pipeline.

The observed dark energy density is commonly expressed as $\rho_{\mathrm{DE}} \simeq (2.3\ \mathrm{meV})^4$ [2]. Equation (10) highlights the scale discipline required: if μ is very large, ε must be correspondingly small; if μ is itself meV-like, ε could be order unity. Phase I selects neither μ nor ε. No claim is made that this toy mapping captures the true microphysical origin of vacuum energy or its gravitational backreaction.

4.3 Determinism and execution traceability

All runs are deterministic given a fixed seed, configuration, and code revision. Each run emits:

- raw time series (compressed),
- a machine-readable summary (YAML),
- provenance metadata (git hash, parameters, seed, environment snapshot).

4.4 Claims-to-artifacts audit map

Table 1 maps each Phase I claim to a concrete output artifact.

5 Results

5.1 Lattice time evolution: constrained vs. unconstrained (Fig. B)

Figure 2 shows the time evolution of the mean amplitude magnitude $|A_{\mathrm{mean}}(t)|$ for constrained and unconstrained lattice runs initialized with identical microscopic conditions. In the unconstrained case, destructive interference among lattice degrees of freedom can drive the mean residual to progressively smaller values over time. When the non-cancellation constraint is enforced, this downward drift is arrested: the evolution respects the imposed floor and $|A_{\mathrm{mean}}(t)|$ does not fall below ε.

The qualitative contrast between the two trajectories isolates the effect of the axiom itself. No additional driving, tuning, or modification of the underlying dynamics is introduced; the observed difference arises solely from the presence or absence of the global constraint.

5.2 Scaling with system size (Fig. C)

Figure 3 displays the tail-averaged mean residual as a function of system size N_{sites} on a logarithmic scale. In the absence of a constraint, the residual decreases with increasing system size, consistent with generic enhancement of cancellation in larger ensembles (e.g. random-walk–type behavior). By contrast, when the non-cancellation floor is enforced, the residual ceases to decrease and instead saturates at a value set by ε.

This scaling behavior demonstrates that the constraint operates intensively: it does not scale away with increasing volume, nor does it induce growth with system size. Rather, it produces a stable, size-independent baseline once ordinary cancellation has exhausted its effect.

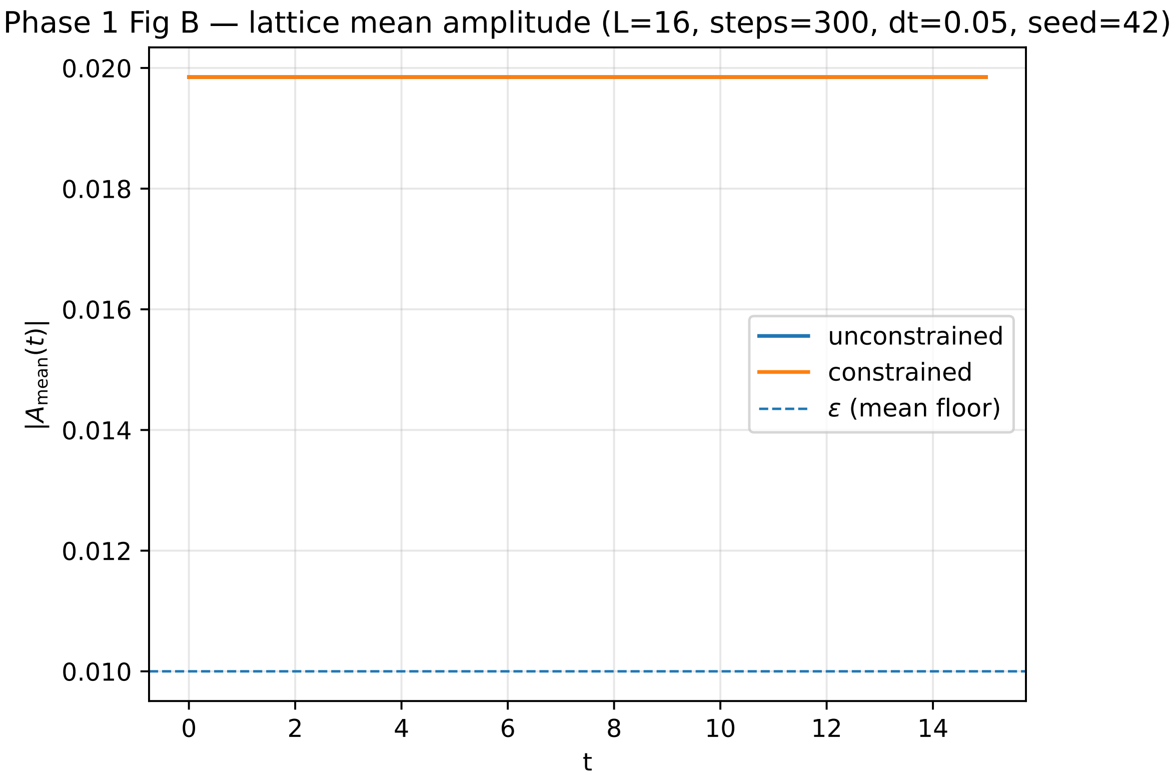

Figure 2: Phase I Fig. B: lattice toy mean amplitude magnitude $|A_{\mathrm{mean}}(t)|$, unconstrained versus constrained. The dashed line indicates the enforced mean-amplitude floor ε.

5.3 Energy diagnostic (stored; optional inspection)

Each lattice run records a diagnostic energy proxy $E(t)$ as part of the raw output artifacts. Phase I does not assert conservation of a physical energy in the presence of a global constraint, nor does it interpret this diagnostic as a realistic vacuum energy. Its purpose is purely diagnostic: to allow inspection of whether constraint enforcement induces obvious order-one instabilities or runaway behavior in the toy dynamics for the chosen parameters.

No such pathologies are evident in the reported runs, within the resolution and scope of the present model. Detailed interpretation of energy-like quantities, and their relation to physical vacuum energy, is deferred to later phases.

6 Limitations

Relation to existing global-constraint ideas (context, not equivalence)

The *Origin Axiom* is not presented as equivalent to established proposals, but it is conceptually adjacent to several frameworks in which nonlocal structure plays a role in the cosmological constant problem.

Unimodular gravity. In unimodular approaches, the cosmological constant appears as an integration constant or global degree of freedom rather than a parameter fixed directly by local vacuum energy contributions. Reviews emphasize both the appeal and the limitations of what is, and is not, resolved by this reformulation. [3]

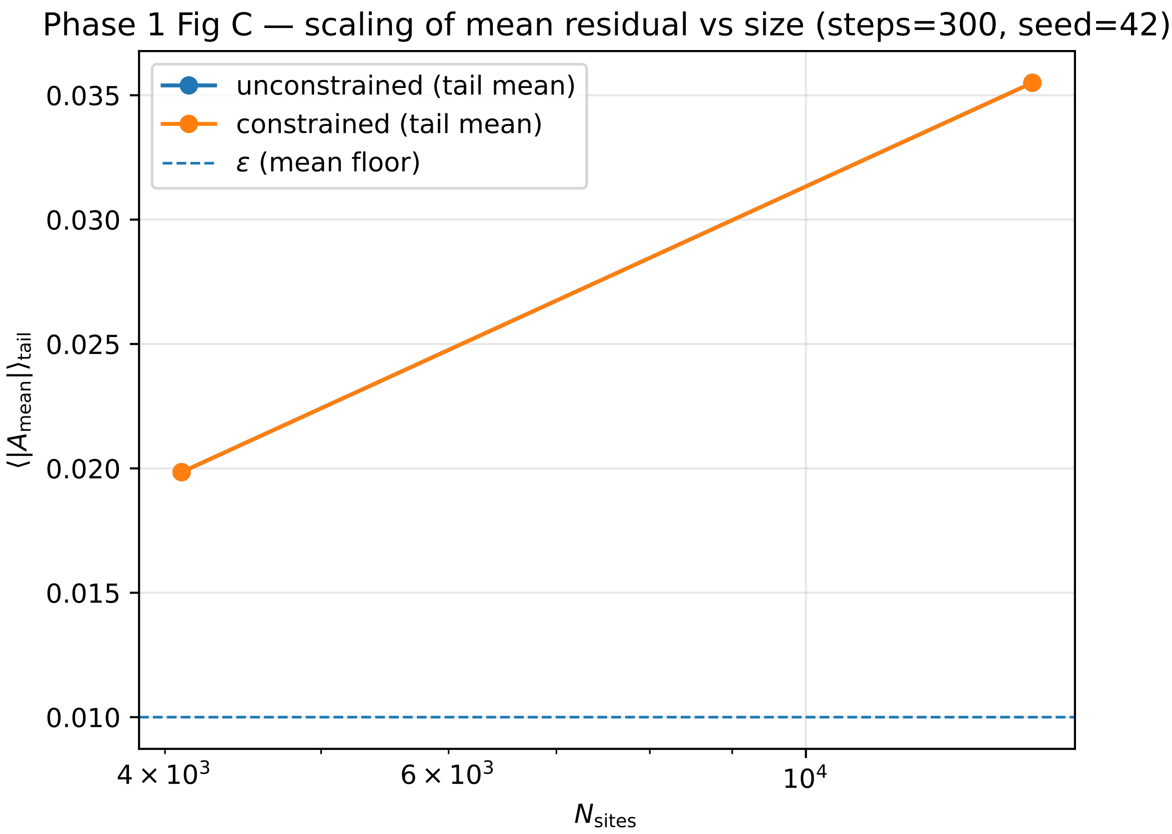

Figure 3: Phase I Fig. C: scaling of tail-averaged $|A_{\mathrm{mean}}|$ with the number of lattice sites. The unconstrained residual decreases with system size, while the constrained residual saturates near the imposed floor ε.

Vacuum energy sequestering. Sequestering models implement explicit global constraints that prevent matter-sector vacuum energy contributions from gravitating in the usual way, using nonlocal ingredients at the level of the action or equations of motion. [4, 5]

Residual and fluctuation arguments in causal set theory. Causal set approaches have suggested that a small effective cosmological constant may arise as a residual effect associated with discreteness, with fluctuations scaling inversely with a large counting parameter. [6, 7] Phase 1 draws no dynamical or structural equivalence with these models; the relevance is limited to the shared logical possibility that small residuals can emerge from global counting or summation effects.

Phase 1 does not claim equivalence to any of the above frameworks. The narrower point is that the introduction of nonlocal constraints is not without precedent in serious theoretical work, and thus constitutes a legitimate hypothesis class subject to consistency and predictive scrutiny rather than dismissal on formal grounds alone.

Scope limitations of Phase 1

Phase 1 is intentionally restricted in scope and makes several simplifying assumptions that delimit its interpretive reach.

Nonlocal constructions by design. Both the phasor ensemble and the lattice toy model operate on global observables constructed as sums or means over microscopic degrees of freedom.

No notion of locality, causal propagation, or relativistic structure is imposed. Phase 1 therefore does not address how residual non-cancellation might arise from, or coexist with, strictly local field dynamics.

Toy-model nature. All numerical constructions in Phase 1 are schematic. The phasor ensemble abstracts interference without geometry, while the lattice model introduces geometry without physically motivated interactions. These models are intended solely as controlled existence proofs.

Absence of gravity and spacetime dynamics. No gravitational degrees of freedom are included, and no assumptions are made about spacetime curvature, expansion, or metric dynamics. Phase 1 does not constitute a cosmological model.

No distinguished angles or internal structure. The twist parameter θ functions only as a generic misalignment variable. No preferred value is derived or assumed, and no additional internal phases or hidden degrees of freedom are introduced.

No Standard Model embedding. Phase 1 does not incorporate Standard Model fields, symmetries, or interactions. Any connection between the residual non-cancellation scale and particle physics is explicitly outside the present scope.

Taken together, these limitations imply that Phase 1 should be read strictly as an existence and robustness study. It demonstrates that finite interference systems generically exhibit persistent residuals under minimal assumptions, without yet explaining their physical origin or ultimate interpretation.

7 Conclusion and Phase II Compatibility

Phase 1 introduced a minimal *Origin Axiom* in the form of a global non-cancellation constraint $|A| > \varepsilon$. Using explicit, reproducible numerical artifacts, we demonstrated that: (i) finite cancellation ensembles generically exhibit strong residual suppression with system size in the absence of fine-tuning, (ii) imposing an amplitude floor yields a persistent nonzero baseline, (iii) the floor can be enforced within a dynamical lattice toy model without inducing obvious numerical instabilities, and (iv) the constrained mean residual saturates near ε while the unconstrained residual continues to decrease with increasing system size.

These results establish the internal coherence of the axiom as a structural principle: exact cancellation is nongeneric in finite interference systems, and an explicit non-cancellation rule produces a stable residual scale under coarse variations of model parameters.

Phase II requirements. To move beyond plausibility and toward physical relevance, Phase 2 must address several logically independent extensions of the present work:

- a principled origin, selection rule, or dynamical mechanism for the scale ε,
- a physically interpretable mapping between residual amplitude and vacuum energy density,
- compatibility with locality and Lorentz structure, or a controlled and explicitly motivated violation thereof,
- regulator dependence, continuum behavior, and robustness under model generalization.

Phase 1 therefore serves as an auditable starting point: it cleanly separates axiom from implementation, demonstrates the phenomenon to be explained, and provides a reproducible existence proof without presupposing the outcome of subsequent theoretical development.

References

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