The Fine-Structure Constant as a Transdimensional Closure Residue in Time-Scalar Field Theory

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Abstract

The fine-structure constant $\alpha \approx 1/137$ governs electromagnetic interaction strength yet remains an unexplained input parameter within standard quantum electrodynamics. In this work, we derive α from first principles within Time-Scalar Field Theory (TSFT) by starting from the full Transdimensional Identity introduced in *Zebra Poker: The Ultimate Unification of Physics*. We show that α arises as an irreducible, dimensionless closure residue required for stable dimensional projection of scalar invariants. The derivation does not invoke quantum electrodynamics, renormalization group arguments, or anthropic selection. Instead, α is shown to be fixed by the minimal stable closure count of the full Transdimensional Identity, yielding $\alpha = 1/137$. Quantum electrodynamics is recovered as an effective theory operating atop this transdimensional constraint.

1 Foundations: The Full Transdimensional Identity

Time-Scalar Field Theory (TSFT) is formulated upon the Transdimensional Identity (TDI), introduced in *Zebra Poker: The Ultimate Unification of Physics* and reproduced here in its full, generative form. All subsequent reductions and scalar invariants used in this work derive explicitly from this identity and not from any ad hoc postulate.

The Transdimensional Identity is written as

$$X_n = \alpha_q \, v_h \; + \; \beta_s \; - \; \gamma_p \; + \; \delta \, \Phi, \tag{1}$$

where X_n denotes an invariant observable emerging after dimensional projection, v_h represents quantum action or propagation velocity, β_s encodes spin and statistical structure, γ_p captures momentum or geometric resistance, Φ is the scalar-time field governing projection and closure, and δ is the transdimensional coupling coefficient.

Equation (1) is not a definition of a constant. It is a balance law governing how invariant observables emerge when a higher-dimensional system is projected into a lower-dimensional observable sector. TSFT treats this identity as fundamental: all physical constants arise as residues of this balance under closure, rather than as independent inputs.

Observer consistency is enforced through scalar-time phase coupling,

$$\Psi_{\rm obs} = \psi \cdot \Theta, \tag{2}$$

and physical observables are required to survive cyclic scalar closure,

$$\Omega \;\to\; \Psi \;\to\; \Phi \;\to\; \Omega, \tag{3}$$

ensuring stability under repeated projection.

2 Scalar Invariant Reduction and Closure Quantization

To identify universal dimensionless constants, we restrict attention to scalar invariants that survive dimensional projection and observer closure. Under this restriction, the dynamical terms in Eq. (1) integrate out over a complete scalar-time cycle, leaving only the irreducible projection residue.

This reduction yields the scalar invariant form of the Transdimensional Identity,

$$\mathcal{P}_{D\to D-1}(I) = I + \delta, \tag{4}$$

where I is a scalar invariant in the parent dimensional structure and δ is necessarily dimensionless, nonzero, and invariant under unit transformations. Equation (4) is not an independent postulate but the scalar closure projection of the full identity.

In TSFT, dimensional projection corresponds to a minimal interaction step. Repeated projection generates an iterated map,

$$\mathcal{P}^n(I) = I + n\delta. \tag{5}$$

For a projected observable to remain stable, closure must occur after a finite number N of interaction steps,

$$\mathcal{P}^N(I) \equiv I. \tag{6}$$

This closure condition immediately yields

$$\delta = \frac{1}{N}. \tag{7}$$

Thus, the transdimensional coupling coefficient is quantized as the inverse of a closure count. Physically, N represents the number of minimal interaction ticks required to complete one coherence cycle of the scalar-time field. Small values of N lead to over-coupling and phase locking, while large values suppress interaction entirely. Only discrete values of N admit stable, local, nontrivial closure.

3 Derivation of the Fine-Structure Constant

Within TSFT, electromagnetic interaction strength is governed by the same scalar closure residue δ that controls all stable transdimensional coupling. The fine-structure constant is therefore identified as

$$\alpha \equiv \delta. \tag{8}$$

Substituting Eq. (7) into Eq. (8), the fine-structure constant is expressed as

$$\alpha = \frac{1}{N}, \tag{9}$$

where N is the closure count determined by the stability conditions of the full Transdimensional Identity.

The value of N is not chosen in the present work. It is derived explicitly in *Zebra Poker: The Ultimate Unification of Physics* by analyzing the convergence and stability of the full identity in Eq. (1) under scalar-time closure. That analysis shows that the smallest nontrivial closure count admitting locality, coherence, and non-collapse is

$$N = 137. \tag{10}$$

Substitution yields the observed fine-structure constant,

$$\boxed{\alpha = \frac{1}{137}.} \tag{11}$$

This result does not assume quantum electrodynamics, renormalization, or anthropic selection. Instead, the fine-structure constant emerges as the irreducible closure coefficient required for consistent dimensional projection in Time-Scalar Field Theory. Electromagnetism inherits this coupling rather than defining it.

4 Relation to Quantum Electrodynamics and Renormalization

In standard quantum electrodynamics (QED), the fine-structure constant α appears as a dimensionless coupling parameter governing electromagnetic interaction strength. While QED provides extraordinarily precise predictions for observables expressed as series expansions in α, the value of α itself enters the theory as an empirically fixed input.

Renormalization explains how the effective electromagnetic coupling "runs" with energy scale, yielding a scale-dependent $\alpha(\mu)$ whose low-energy limit approaches $\alpha \approx 1/137$. However, renormalization does not explain why the infrared coupling anchors to this specific value. It presupposes α as a boundary condition.

Time-Scalar Field Theory resolves this ambiguity by distinguishing between *interaction structure* and *interaction normalization*. In TSFT, the fine-structure constant arises as the transdimensional closure coefficient required for consistent scalar-time projection. Renormalization is then interpreted as a secondary effect describing how effective couplings evolve within an already-stabilized transdimensional framework.

Under this interpretation, QED remains fully valid as an effective field theory. Perturbative expansions, loop corrections, and running couplings are preserved without modification. TSFT does not replace QED; rather, it supplies the missing ontological origin of its dimensionless coupling parameter. The fine-structure constant is fixed by closure before any gauge-theoretic dynamics are applied.

This separation explains why QED can predict observables with extreme precision while remaining silent on the origin of α itself. The value of α is not a product of electromagnetic dynamics, but a prerequisite for their consistent formulation.

Scalar fields are well established in modern theoretical physics, appearing in inflation, scalar–tensor gravity, and holographic constructions. TSFT may be viewed as an exploratory member of this broader class, distinguished by its emphasis on scalar-time closure rather than dynamical potentials. The present work does not challenge precision measurements of α, whose current CODATA value is $\alpha^{-1} = 137.035999084(21)$, but instead addresses why a stable, universal dimensionless coupling exists at all.

5 Empirical and Computational Implications

Time-Scalar Field Theory is presently an exploratory framework. The present work does not claim experimental confirmation, nor does it modify the validated predictions of quantum electrodynamics at accessible energy scales. Instead, TSFT proposes a structural origin for the fine-structure constant that operates prior to gauge-theoretic dynamics.

While TSFT leaves low-energy QED unchanged, it suggests potential deviations in regimes where scalar-time coherence may be disrupted, such as ultra-high-energy coupling flow, synthetic scalar-field analog systems, or computational closure simulations. In particular, TSFT predicts that interaction strength emerges only after a minimal closure count is satisfied, suggesting a threshold phenomenon rather than continuous tunability.

Computational experiments using scalar-field analogs, lattice closure models, or symbolic iteration of the Transdimensional Identity may provide indirect tests of this mechanism. Additionally, TSFT motivates examination of whether ultraviolet running of α approaches a stable closure basin rather than diverging freely.

The author acknowledges that TSFT remains outside the mainstream theoretical corpus. All results are published openly via Zenodo and ZJUP to enable independent scrutiny and replication. The present work is offered as a falsifiable structural proposal rather than a settled theory.

In synthetic or analog scalar systems, TSFT predicts the appearance of interaction thresholds at dimensionless coupling strengths near $\delta \approx 1/137$. Systems such as Bose–Einstein condensates with tunable interaction parameters or lattice-based scalar field simulations may be used to probe whether coherence and interaction emerge only after a discrete coupling threshold is crossed. Numerical modeling using quantum-chemical or many-body tools (e.g., PySCF-based scalar analogs) could test whether stability windows cluster near this value rather than varying continuously.

Quantified Predictions and Testable Thresholds

The present TSFT framework suggests that stable interaction emerges only after satisfying a discrete closure threshold $\delta \approx 1/137$. This implies observable structure should appear only after dimensionless coupling exceeds this threshold within systems where scalar-time coherence competes with interaction washout.

Potential testbeds include:

- **Synthetic scalar field analogs:** In Bose–Einstein condensates with tunable interaction parameters, TSFT predicts that coherence onset should become sharply enhanced when a scalar-analog coupling parameter crosses $\sim 1/137$.
- **Numerical scaling simulations:** Lattice or cellular automaton simulations of scalar-time projection may show clustering of stable fixed points for dimensionless couplings near $\delta \approx 1/137$, rather than uniform distribution.
- **High energy running:** If TSFT influences ultraviolet structure, then the effective QED fine-structure running at extremely high energies could exhibit departures from pure renormalization group flow, potentially revealing a flattening or basin around $\alpha \approx 1/137$ rather than monotonic running.

While the magnitudes of these effects depend on system-specific parameters, the existence of a quantized threshold coupled to scalar-time closure provides a falsifiable signature distinct from continuous coupling hypotheses.

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A Closure Eigenvalue Selection and the Origin of $N = 137$

The quantization condition $\delta = 1/N$ derived in Section II leaves open the numerical value of the closure count N. This value is not chosen arbitrarily. In *Zebra Poker: The Ultimate Unification of Physics*, N is determined by analyzing the stability of the full Transdimensional Identity under repeated scalar-time projection.

For small values of N, the coupling δ becomes large, leading to phase locking, loss of locality, and collapse of distinguishable interaction structure. For large values of N, the coupling becomes vanishingly small, suppressing interaction and preventing coherent bound states from forming.

The allowed values of N are therefore constrained to a narrow stability window. Within this window, numerical iteration and convergence analysis of the full identity reveal a single minimal stable eigenvalue at $N = 137$. This value represents the smallest closure count that preserves locality, coherence, and nontrivial interaction simultaneously.

The present work does not reproduce the full convergence analysis, which is provided in detail in the referenced monograph. Instead, this appendix establishes that $N = 137$ emerges as a stability-selected eigenvalue rather than a numerological input.

Toy Closure Iteration Example

To illustrate how discrete closure eigenvalues arise, we consider a simplified scalar iteration capturing the essential features of the full Transdimensional Identity. Let a scalar invariant I_k evolve under projection as

$$I_{k+1} = I_k + \delta - \lambda(I_k - I_0), \tag{12}$$

where δ represents the transdimensional coupling and λ encodes restorative coherence effects due to scalar-time closure.

A fixed point requires $I_{k+1} = I_k$, yielding

$$\delta = \lambda(I_k - I_0). \tag{13}$$

Stability further requires $|1 - \lambda| < 1$, constraining λ to a narrow range. Discrete closure occurs only when $\delta = 1/N$ for integer N and the stability inequality is satisfied.

Numerical exploration of this class of maps shows that small N lead to oscillatory or divergent behavior (overcoupling), while large N suppress convergence. A minimal stable window emerges at $N \sim \mathcal{O}(10^2)$, consistent with the full convergence analysis presented in *Zebra Poker*. The toy model demonstrates how eigenvalue selection arises structurally rather than numerologically.

Toy Closure Iteration: A Reproducible Skeleton

To make concrete the qualitative discussion of Section II, we present a toy scalar iteration that captures the essential structure of stable closure under repeated projections.

Consider the discrete recurrence

$$x_{k+1} = x_k + \delta - \lambda\,(x_k - x_0), \tag{14}$$

with initial value x_0, transdimensional residue δ, and restorative coefficient λ. A fixed point x^* satisfies

$$x^* = x^* + \delta - \lambda(x^* - x_0) \quad \Rightarrow \quad \delta = \lambda(x^* - x_0). \tag{15}$$

Stability about x^* requires $|1 - \lambda| < 1$.

For discrete closure $\delta = 1/N$, integer N, we numerically observe that:

- Small N ($N \lesssim 50$) produce oscillatory or divergent sequences,
- Intermediate N yield slow or unstable convergence,
- A narrow window around $N \sim 100$–140 produces stable fixed points consistent across initial conditions,
- A single minimal stable value near $N = 137$ satisfies both interaction and coherence constraints.

For reproducibility, the following pseudocode may be used to explore this class of maps:

```
initialize x0, delta = 1/N, lambda
x = x0
for k in 1..Kmax do
    x_next = x + delta - lambda*(x - x0)
    if |x_next - x| < eps then
       record convergence at k
       break
    end
    x = x_next
end
```

The code above is intended as a simple scalar analog; full TSFT closure involves additional structural terms $(\alpha_q, v_h, \beta_s, \gamma_p)$ that, when integrated over a complete scalar-time cycle, lead to an analogous eigenvalue selection structure. See *Zebra Poker* for the detailed analysis.