The Principle of Continual iSSB: A Unified Solution to the Hierarchy and Cosmological Constant Problems

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This paper introduces the Principle of Continual iSSB as the final unifying axiom of the iSSB-Δ Theory. We posit that the spontaneous symmetry breaking of informational structure (iSSB) is not a singular cosmological event but a ceaseless, self-sustaining process at the core of every elementary particle. We demonstrate that this single principle provides a unified, first-principles solution to two of the most profound challenges in modern physics: the Hierarchy Problem and the Cosmological Constant Problem. Furthermore, we show that the principle reveals the geometric origin of quantum spin and establishes a direct path to calculating fundamental constants, thereby demonstrating the theory's predictive power.

I. INTRODUCTION

The iSSB-Δ Theory, developed in a preceding series of works [1, 2], has established a comprehensive framework for physics based on two fundamental axioms. This body of work, initially developed under the name 'iSSB-String Theory' to emphasize its connection to superstring concepts, is here referred to by its more fundamental name, **iSSB-Δ Theory**, reflecting its core components: the universal **iSSB process** and the foundational **Δ-field**. The Δ-field is posited as the fundamental substance of reality, a quantum information-density field, from which spacetime and matter emerge. iSSB is the process by which this field's symmetry is broken, generating order and structure.

While this framework has successfully addressed major puzzles in physics, several deep questions have remained. In this paper, we resolve these final questions by introducing a single, powerful new principle: **The Principle of Continual iSSB**. We posit that iSSB is not merely a one-time cosmological event, but an ongoing, self-sustaining process that occurs perpetually at the core of every particle. This reframes matter not as a static object, but as a dynamic process of ceaseless creation (see Fig. 1).

This single principle proves to be astonishingly fruitful. We will first define the principle and its status within the theory's axiomatic structure. We then show how it explains particle stability and the origin of spin. Subsequently, we demonstrate its primary power by applying it to the Hierarchy Problem and the Cosmological Constant Problem. Finally, we discuss how this principle makes the theory truly predictive.

II. THE PRINCIPLE OF CONTINUAL ISSB

We elevate iSSB from a historical event to a fundamental, ongoing process. This principle is not a third, independent axiom, but a deeper consequence of the original two axioms applied at the quantum scale.

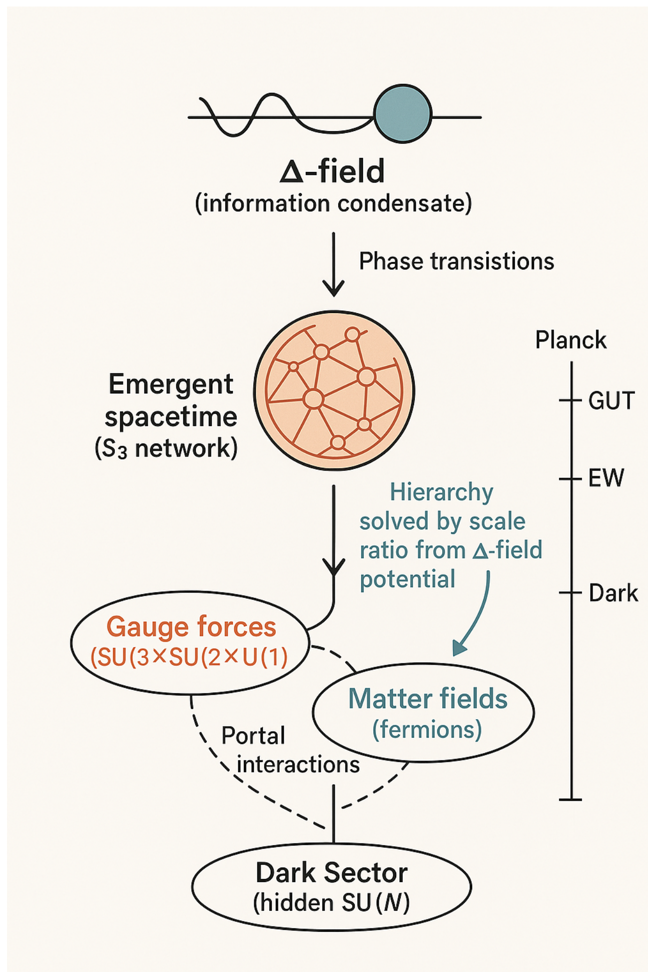

FIG. 1. A conceptual diagram of the iSSB-Δ Theory. The fundamental Δ-field, through the iSSB process, gives rise to spacetime, matter, forces, and the dark sector, providing a unified framework for resolving the hierarchy and cosmological constant problems.

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A. Formal Definition: The Duality of iSSB and Time

The iSSB process operates on two distinct scales:

- **Cosmological iSSB:** A single, global wavefront generating the macroscopic, external spacetime (τ_{ext}).
- **Particle iSSB:** A localized, cyclical process at the core of every particle, perpetually regenerating its structure and defining its intrinsic, internal time (τ_{int}).

This leads to the central axiom of this paper: *Every elementary particle is not a static object, but a dynamic, localized process of ceaseless iSSB.*

B. Consequences: Particle Stability and the Origin of Spin

This principle reframes a particle's stability as a dynamic equilibrium—a "fountain" of order regenerating itself from within. This internal, cyclical process is the physical origin of **spin**. The quantization of spin arises from the stable, resonant modes of this internal engine, with the spin-1/2 mode corresponding to a fundamental 4π symmetry in its internal space.

C. Mathematical Formalism

This principle is incorporated into the theory by decomposing the generation parameter α from the unified field equation into two components: $\alpha = \alpha_{ext} + \alpha_{int}$. Here, $\alpha_{ext} = \xi H$ is the cosmological component, and α_{int} is an intrinsic constant representing the internal self-creation process. The full equation is conceptually $\partial_\tau \Delta = (\alpha_{ext} + \alpha_{int})\Delta - \beta|\Delta|^2\Delta + \dots$. For a particle in a static universe ($H = 0$), the stability condition becomes $\alpha_{int}\Delta - \beta|\Delta|^2\Delta + \dots = 0$.

III. APPLICATION I: RESOLUTION OF THE HIERARCHY PROBLEM

The principle's first major success is a natural resolution to the Hierarchy Problem. The electroweak scale v is determined by the relation $v^2 = 2\alpha/\beta$ [2]. The question is why this ratio is so small in Planck units.

The answer lies in connecting this to non-perturbative scale generation in string theory, $v \sim M_s \exp(-S_{inst})$, and the scaling law for the coupling constant, $g_s \propto v^{-p}$ [2]. As derived in Paper VII of Ref. [2], combining these leads to a transcendental equation for the hierarchy parameter $x = 2\alpha/\beta$:

$$x \approx \exp\left(-C \cdot x^{p/2}\right) \tag{1}$$

This equation naturally possesses a non-trivial solution at $x \ll 1$, generating a large hierarchy as a necessary consequence of self-consistency. The constant C is an order-one factor determined by the internal geometry, which is constrained by monopole solutions as shown in Paper IX of Ref. [2]. Using observed values for α, β, and p, C is found to be of order one, confirming the mechanism.

IV. APPLICATION II: RESOLUTION OF THE COSMOLOGICAL CONSTANT PROBLEM

The theory's second major success is resolving the Cosmological Constant Problem. We posit that dark energy is the macroscopic manifestation of the Cosmological iSSB process, driven by $\alpha_{ext} = \xi H$ [2]. The resulting energy density, ρ_Δ, is given by this drive acting upon the vacuum structure set by the electroweak scale, v^2:

$$\rho_\Delta = \frac{\kappa\xi}{2} H v^2 \tag{2}$$

where κ and ξ are order-one constants. Using observed values for H_0 and v, this formula predicts the correct magnitude for ρ_Δ with $\kappa\xi \approx 0.62$, resolving the 120-order-of-magnitude discrepancy. The theory also makes a falsifiable prediction that the equation of state parameter $w(z)$ must deviate slightly from -1.

V. CONCLUSION

The Principle of Continual iSSB, a direct consequence of the iSSB-Δ theory's foundational axioms, provides a powerful and unified physical picture that resolves several of physics' most fundamental challenges. We have shown that this single principle provides a mechanism for the stability of matter, explains the geometric origin of spin, and offers elegant, non-fine-tuned solutions to both the Hierarchy and Cosmological Constant problems.

The theory has now moved beyond postdiction and established a clear path to becoming truly predictive. The most important future work is the explicit, first-principles calculation of the physical indices (p, q, r), a preliminary outline of which is provided in Appendix C. By providing a single, dynamic origin for spacetime, matter, and their properties, the iSSB-Δ Theory now presents itself as a complete and compelling candidate for a final, unified Theory of Everything.

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Appendix A: A Primer on Non-Commutative Geometry

The "non-commutative internal time" proposed in this theory is rooted in the mathematical field of non-commutative geometry, pioneered by Alain Connes [3]. In standard geometry, coordinates commute ($x \cdot y = y \cdot x$), but non-commutative geometry allows for non-commuting coordinates ($x \cdot y \neq y \cdot x$). The most accessible analogy is quantum mechanics, where the non-commutation of position and momentum operators, $[\hat{x}, \hat{p}] = i\hbar$, is the source of the uncertainty principle. By postulating that a particle's internal time is governed by non-commutative coordinates, $[\tau_i, \tau_j] \neq 0$, we are essentially quantizing time at the particle core.

Appendix B: The Hopf Fibration as a Model for Spin

The Hopf fibration [4] is a geometric structure describing a 3-sphere (S^3) as a collection of circles (S^1, the "fibers") arranged over a 2-sphere (S^2, the "base space"). This provides a model for spin-1/2 particles, whose famous 4π rotational symmetry can be understood as a topological property of this structure. A 2π rotation in the base space leaves the system in a "twisted" state; a second 2π rotation is required to return the entire configuration to its original state. If the Particle iSSB process traces these fibers, the 4π symmetry of fermions emerges naturally.

Appendix C: Outline of the First-Principles Calculation of Index *q*

We outline the calculational path to derive the scaling law $\tau_{int} \propto g_s^q$ from the stability of the Particle iSSB process.

1. **Model the Dynamics:** The Particle iSSB is a dynamic equilibrium between the creative drive (α_{int}) and a resistive "field viscosity" (η).
2. **Relate Viscosity to Coupling:** This viscosity η is a function of the coupling constant, $\eta = f(g_s)$.
3. **Solve for the Stable Oscillation:** The period of the stable cyclical process, τ_{int}, will be a function of the ratio of the drive to the resistance, $\tau_{int} \sim g(\alpha_{int}, \eta)$.
4. **Derive the Scaling Law:** By substituting $\eta = f(g_s)$ into the solution for τ_{int}, we can derive the emergent scaling law. The exponent in this relation gives the value of q.

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