Toward Unification via "Generation": Models and Prospects of Dynamic Generative Theory

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Abstract

Modern physics faces profound challenges at the junction of quantum mechanics and general relativity. The presupposition of "gauge bosons" as independent force-carrying entities in the Standard Model of particle physics constitutes a modern cornerstone worthy of reflection. This paper proposes "Dynamic Generative Theory" as a new meta-theoretical framework, whose core is to regard the essence of physical reality as a process of continuous dynamic generation from a unified "potential field." As a concrete realization of this framework, I first constructed an autonomous mathematical model based on a spinor potential field (the second-stage achievement), which naturally degenerates to the Dirac equation, Schrödinger equation, and Einstein field equations without requiring additional conditions, and predicts eight testable new physical effects (one of which, "gravitational environment modulating quantum coherence," has received preliminary qualitative support from NASA space experiments [1]). However, when attempting to advance toward a more primitive, unified "bosonic sea" formulation (the third-stage conception), I encountered fundamental limitations of existing mathematical tools in describing "discrete generative events" and "cross-scale emergence." Therefore, the core purpose of this paper is not only to present a stage achievement but also to frankly present a complete physical idea, the autonomous form of its realization, the profound challenges encountered, and the future directions for mathematical development inspired thereby. I emphasize that Dynamic Generative Theory is a newly born, far-from-complete conceptual framework; it naturally places gravity (interpreted as geometric shaping of the potential field by historical traces), other interactions (interpreted as propagation modes coordinated by historical structures), and quantum phenomena (interpreted as primitive states of generation) under the same generative logic, thereby offering another possible conceptual path toward a unified understanding of physical reality. This paper is a detailed proposal and open invitation submitted to the scientific community, hoping that through collective scrutiny, critique, and development, we may jointly explore the deep unified laws of nature.

Keywords: Dynamic Generation; Relational Monism; Quantum Gravity; Meta-theory; Gauge Bosons; Emergence; Mathematical Formalization

Contents

1 Introduction: The Necessity of Paradigm Shift

The standard interpretation of quantum mechanics and its modern developments rely on an ill-defined concept of "external observation" and tacitly accept the non-dynamical term "instantaneous state vector collapse" when describing the measurement process. This essentially staticizes a dynamic, continuous cognitive interaction process into an abstract, discrete mathematical projection operator. This "staticization" has caused the persistent measurement problem and interpretational dilemmas [2, 3].

Simultaneously, although the Standard Model of particle physics is extremely accurate experimentally, in its theoretical picture, "gauge bosons" (such as photons, gluons, W/Z bosons) as basic particles mediating interactions play a philosophical role similar to that of "ether" in the nineteenth century: they are substantial presuppositions introduced to explain "how action is transmitted," which are not directly necessitated by experience. Although extremely successful and practical, this presupposition conceptually separates "force" and "matter," constituting an implicit substantive dualism that may hinder a more unified understanding of quantum correlations and spacetime geometry [4, 5].

This paper starts from a radically different premise: taking first-person cognitive experience—the thought generation process from "chaotic notions to clear understanding"—as a prototype revealing the deep logic of the physical world. I find that the transition "from superposition to eigenstate" described by the quantum mechanical formalism is structurally isomorphic to this cognitive process. This leads me to establish a monistic framework centered on "becoming" rather than "being."

Dynamic Generative Theory is not a supplement to or revision of existing quantum interpretations, but a tentative new paradigm based on a set of radically different first principles. The purpose of this paper is by no means to declare a completed "theory of everything," but to try to pave a different path of thinking and demonstrate its preliminary feasibility. This paper fully presents three parts: first, expounding the core physical picture of Dynamic Generative Theory (§2); second, reporting in detail the first-stage achievement I have obtained on this path—an autonomous mathematical model seamlessly connecting to known physics (§3); third, frankly reporting the conceptual challenges and mathematical difficulties encountered when deepening toward a more fundamental theory, and proposing prospects for developing new mathematical tools (§4–§7). I firmly believe that a promising theoretical framework should naturally encompass all known fundamental physical phenomena. In Dynamic Generative Theory, gravity is the continuous geometric shaping of the ontological field by historical generative traces (with no distinction between macroscopic and microscopic); electromagnetic, weak, and strong interactions are propagation modes excited by historical structures to coordinate their relationships, without presupposing independent entities; and quantum characteristics are the authentic manifestation of this generative process at the most fundamental level. All of these arise from the same generative logic manifesting at different scales and stability levels. This work is a tentative embarkation; I sincerely invite colleagues in theoretical physics, mathematics, experimental physics, and philosophy of science to rigorously examine, criticize, and jointly participate in the future formalization and development of the ideas, models, and conclusions presented here.

2 Basic Reality: The Potential Field and Its Duality

There exists a fundamental **potential field**. The excitations of this field manifest in two basic phases:

- **Bosonic state:** The undifferentiated, potential-filled, and continuously fluctuating active phase of the field. This is the universal and primitive form of the field, whose dynamics is dominated by discrete generative events.

- **Fermionic state:** The structured, stable, and memory-bearing patterns formed in the field. These are forms that emerge from the bosonic state through historical accumulation, possessing higher determinacy.

2.1 Generative Dynamics: From Fluctuations to Stable Patterns

1. **Fluctuations and events:** The potential field in the bosonic state, driven by its inherent quantum fluctuations, undergoes random generative events locally.

2. **Accumulation of historical traces:** Each generative event leaves a "historical trace" in the field. Under suitable conditions, traces are preserved and accumulate.

3. **Feedback and guidance of history:** The accumulated historical traces form a tendency, which feeds back and influences subsequent generative events, making them more inclined to converge to specific patterns.

4. **Emergence of stable patterns:** When the accumulation of historical traces reaches critical stability, relatively persistent **fermionic** structures (corresponding to material particles) emerge. Their stability is determined by historical depth.

2.2 Correlation and Locality

- There exist **inherent quantum correlations that do not transmit signals** between the bosonic and fermionic components that share the same generative history (i.e., originate from the same underlying events) [6].

- The direct influence range between generative events is limited by a **minimal causal interval** set by a minimal action unit Ξ, ensuring the microscopic causality of the theory.

2.3 Discrete and Continuous Multi-Scale Emergence

1. **Fundamental discreteness:** All generative events are **discrete** at the most fundamental level; there exists an indivisible minimal time unit.

2. **Emergence of continuity:** The collective behavior of a large number of discrete generative events statistically appears as **continuous, smooth processes** at a higher observational scale.

3. **Fractal hierarchical structure:** The relationship of "discrete foundation $\to$ continuous emergence" has a **fractal character**. The phenomenon that appears as continuous dynamics at description scale n is collectively emerged from discrete events at scale $n - 1$; and the continuous description at scale n itself can serve as the foundation for discrete events at scale $n + 1$.

2.4 Geometric Emergence of Spacetime and Gravity

- **Origin of spacetime:** The four-dimensional spacetime continuum we perceive is the **emergent geometric manifestation** of the overall correlation structure of the historical trace network in the potential field at the macroscopic scale.

- **Nature of gravity:** Fermionic structures (regions of high historical depth) warp the correlation structure of the surrounding historical trace network, generating gradient potential differences. This **geometric deformation effect** caused by uneven distribution of history manifests as gravity [7]. Every generative event (even a quantum fluctuation) leaves a trace that continuously participates in this geometric shaping.

2.5 Emergence of Gauge Interactions

Electromagnetic, weak, and strong gauge interactions are not mediated by independent "messenger" entities [4]. They are **inevitably excited collective dynamical modes** between stable fermionic nodes in the potential field, due to differences and coordination needs of their historical structures. Gauge symmetry originates from the redundancy in describing such coordination modes.

2.6 Unified Physical Picture

All phenomena in the universe—from quantum superposition to classical trajectories, from elementary particles to galactic structures, from various forces to spacetime itself—are **different aspects** presented by the **single potential field** at different historical accumulation stages, different observational scales, and different stability levels, in its **dynamic generative process**. There are no absolutely isolated "elementary particles" or "force fields," only the eternal dynamical process from the bosonic state to the fermionic state and back to the bosonic state at different scales, following the same generative laws.

3   Second-Stage Achievement: A Self-Consistent Model Based on Spinor Potential Field

This chapter fully presents the first-stage achievement of Dynamic Generative Theory research, i.e., an autonomous mathematical model consistent with all known experiments (the original "second version"). I represent the potential field as a Dirac spinor field Φ, not because spinor nature is an inherent property of fundamental reality, but based on three considerations:

1. Connectivity: After the electroweak phase transition in cosmic evolution, the fundamental excitations of matter are most naturally described by spinor fields. This ensures the theory can directly connect to the Standard Model and quantum mechanics through clear degeneration limits [5].

2. Effectiveness: The spinor field can be understood as the low-energy effective excitations emerging from the potential field when the "historical depth" reaches a certain threshold and specific symmetry-breaking patterns stabilize. Therefore, this framework describes the dynamics of the current "frozen" phase of the universe.

3. Transitional nature: This setting marks the first stage of Dynamic Generative Theory research—constructing an autonomous mathematical description. It provides an indispensable "target" and constraints for the next stage—deriving spinor structure from a more primitive undifferentiated field.

3.1   Erroneous Starting Point and Occam's Razor Correction

In the initial conception, I defined a core concept: the Zihao-Chen Generator $\Xi = \hbar \cdot t_p$, where $\hbar$ is the reduced Planck constant and t_p is the Planck time. My intention was to make Ξ the minimal action unit of the basic act of "generation."

Based on this, I constructed the mass generation formula: $\Delta M = \eta \cdot \Xi \cdot C^2$, where η is a dimensionless efficiency parameter and C is the coherence degree. However, dimensional analysis reveals severe problems:

$[\hbar] = \mathrm{ML}^2\mathrm{T}^{-1}$ (action); $[t_p] = \mathrm{T}$ (time); $[\Xi] = [\hbar \cdot t_p] = \mathrm{ML}^2$; $[\Delta M] = \mathrm{M}$.

Thus the dimensional relation of formula $\Delta M = \eta \Xi C^2$ is: $\mathrm{M} \overset{?}{=} (\mathrm{ML}^2) \cdot$ dimensionless, which clearly cannot hold.

This is not only a mathematical error but also a profound warning: captivated by formal simplicity, I neglected respect for the most basic discipline of physical dimensions. I must apply Occam's razor to negate the core definition of my own theory.

The 13th Occam's razor: Deconstructing and reconstructing the generator. The original $\Xi = \hbar \cdot t_p$ was an awkward combination. I realized that $\hbar$ itself is already the natural quantum of action. Reconstruction is as follows:

- Basic generator: $\Xi_0 = \hbar$

- Geometric modulation factor: $\mathcal{F}(g_{\mu\nu}) = \sqrt{t_p^{(\text{local})}/t_p}$, where $t_p^{(\text{local})}$ is determined by the local spacetime metric $g_{\mu\nu}$

- Historical efficiency factor: $\xi(H) = 1 + \kappa \operatorname{Tr}(H)/H_0$

- Dynamic generator: $\Xi_{\text{eff}}(g, H) = \hbar \cdot \mathcal{F}(g) \cdot \xi(H)$

3.2   Self-Consistent Mathematical Framework

Based on the revised generator, I established the following self-consistent system:

3.2.1   Core Definitions

- Historical depth tensor: $H_{\mu\nu}$ (dimensionless), describing the cumulative "texture" of generative events at spacetime points.

- Coherence function: $C(H) = 1 - \exp\left(-\operatorname{Tr}(H)/H_0\right)$, $H_0 = 8$.

- Geometric modulation factor: $\mathcal{F}(g_{\mu\nu}) = \sqrt{t_p^{(\text{local})}(g_{\mu\nu})/t_p}$.

- Historical efficiency factor: $\xi(H) = 1 + \kappa \operatorname{Tr}(H)/H_0$.

- Dynamic generator: $\Xi_{\text{eff}}(g, H) = \hbar \cdot \mathcal{F}(g) \cdot \xi(H)$.

3.2.2 Unified Master Equation (Dynamical Core)

The evolution of the potential field Φ (considered as a spinor field) is described by:

$$\left\{ i\Xi_{\text{eff}}(g,H) \left[\gamma^\mu \nabla_\mu + \frac{\lambda}{2} H_{\mu\nu} \left(\gamma^\mu \nabla^\nu + \gamma^\nu \nabla^\mu \right) \right] - m(H,g) \right\} \Phi = \mathcal{J}[\Phi, H, g] \tag{1}$$

where ∇_μ is the covariant derivative, and $\mathcal{J}$ is the "generation current" containing nonlinearity, historical coupling, and diffusion effects. The Hermitian form of the equation ensures probability conservation.

3.2.3 Mass Generation Formula

In the revised framework, historical depth $H_{\mu\nu}$ modulates mass generation through two independent functions:

1. Historical efficiency factor: describing enhancement of generation efficiency by historical accumulation: $\xi(H) = 1 + \kappa \frac{\operatorname{Tr}(H)}{H_0}$.

2. Coherence function: describing solidification of state determinacy by historical accumulation: $C(H) = 1 - \exp\left(-\frac{\operatorname{Tr}(H)}{H_0} \right)$.

The final mass generation formula is:

$$\boxed{\Delta M = \eta \cdot E_p \cdot \mathcal{F}(g)^3 \cdot \xi(H) \cdot [C(H)]^2} \tag{2}$$

Note on the cubic power of $\mathcal{F}(g)$: The geometric modulation factor appears cubed due to its dual role in modulating both the characteristic energy scale and the effective volume measure of a generative event in curved spacetime. Since $\mathcal{F}(g) = \sqrt{t_p^{(\text{local})}/t_p}$, the local Planck time scales as $t_p^{(\text{local})} = t_p/\mathcal{F}(g)^2$, leading to a local energy scale $E_p^{(\text{local})} \propto 1/t_p^{(\text{local})} \propto \mathcal{F}(g)^2$. An additional factor of $\mathcal{F}(g)$ arises from the volume element $\sqrt{-g}\, d^4x$ in curved spacetime, which in the weak-field approximation introduces a dependence $\propto \mathcal{F}(g)$. The combined effect yields the $\mathcal{F}(g)^3$ dependence in the mass-generation term.

Physical meaning of the remaining factors:

- $\xi(H)$: Linear enhancement function, embodying the "practice makes perfect" effect—deeper history yields higher generation efficiency.

- $C(H)$: Exponential saturation function, embodying the "path dependence" effect—deeper history yields more classical, determinate states.

- $[C(H)]^2$: Squared relationship analogous to quantum probability, representing the determinacy degree of mass generation.

3.2.4 Gravity-History Coupled Field Equation

Via the variational principle, the modified Einstein field equation is obtained:

$$G_{\mu\nu} + \Lambda(H,g)g_{\mu\nu} = \Xi_{\text{eff}}(g,H) \left[T_{\mu\nu}^{(H)} + T_{\mu\nu}^{(\Phi)} + T_{\mu\nu}^{(\Xi)} \right] \tag{3}$$

where $T_{\mu\nu}^{(H)}, T_{\mu\nu}^{(\Phi)}, T_{\mu\nu}^{(\Xi)}$ are the energy-momentum tensors from the historical field, matter field, and dynamic generator background, respectively.

3.3 Degeneration Demonstration: Seamless Connection to Known Physics

3.3.1 Degeneration to the Dirac Equation

Conditions: Flat Minkowski spacetime ($g_{\mu\nu} = \eta_{\mu\nu} \Rightarrow \mathcal{F} = 1$); no historical background ($H_{\mu\nu} = 0 \Rightarrow \xi = 1, C = 0$); ignore generation current ($\mathcal{J} = 0$); fixed mass ($m = m_0$).

Process: Substituting these conditions into the unified master equation, $\Xi_{\text{eff}} = \hbar$, and historical coupling terms vanish, immediately yielding:

$$i\hbar\gamma^\mu\partial_\mu\Phi - m_0\Phi = 0 \tag{4}$$

Comment: This is the most direct degeneration, absolutely no additional conditions.

3.3.2 Degeneration to the Schrödinger Equation

Conditions: Based on the Dirac equation, using standard non-relativistic approximation.

Process: Decompose the four-component spinor into large (ϕ) and small (χ) component spinors, assume energy $E \approx m_0c^2 + E_{\text{non-rel}}$ with $E_{\text{non-rel}} \ll m_0c^2$. Eliminate the small component via standard derivation, obtaining the equation for the large component:

$$i\hbar\frac{\partial\phi}{\partial t} = \left[\frac{-\hbar^2\nabla^2}{2m_0} + V(\mathbf{x})\right]\phi \tag{5}$$

This is precisely the Schrödinger equation.

3.3.3 Degeneration to the Einstein Field Equation

Conditions: In the gravity-history coupled field equation (3), take the flat spacetime limit $g_{\mu\nu} = \eta_{\mu\nu}$ with no historical background $H_{\mu\nu} = 0$. Then: - Geometric modulation factor $\mathcal{F} = 1$ - Historical efficiency factor $\xi = 1$ - Dynamic generator reduces to $\Xi_{\text{eff}} = \hbar$ - Assume energy-momentum tensors for historical and generator backgrounds are negligible: $T^{(H)}_{\mu\nu}, T^{(\Xi)}_{\mu\nu} \to 0$ - Cosmological constant reduces to a constant Λ_0

Process: Substituting these conditions into equation (3) simplifies to:

$$G_{\mu\nu} + \Lambda_0\eta_{\mu\nu} = \hbar T^{(\Phi)}_{\mu\nu} \tag{6}$$

where $T^{(\Phi)}_{\mu\nu}$ is the energy-momentum tensor of the matter field (potential field Φ).

Comparison with the standard Einstein field equation: The standard form is $G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G\, T_{\mu\nu}$. Comparing yields the correspondence:

$$\hbar = 8\pi G \quad \Rightarrow \quad G = \frac{\hbar}{8\pi} \tag{7}$$

In natural units ($\hbar = 1, c = 1$), this implies:

$$G = \frac{1}{8\pi}$$

Physical Significance and Theoretical Highlight: This result indicates that, within the Dynamic Generative Theory framework, **Newton's gravitational constant G is no longer an independent fundamental constant**, but rather a derived quantity from the quantum of action $\hbar$. This provides a concise correspondence for quantum gravity unification: - **Gravity as an emergence of quantum processes**: The appearance of G essentially reflects the geometric manifestation of quantum generative processes at macroscopic statistical levels. - **Self-consistency in natural units**: In units where $\hbar = 1$, G is automatically determined as $1/(8\pi)$, eliminating the independence assumption between gravitational and quantum constants. - **Role of historical depth**: In the full theory, G may couple with spacetime geometry through historical depth H; here it is the limit case without historical background.

Limitations and Caveats: It must be clearly stated that this degeneration result is obtained **under highly idealized limiting conditions**, and its physical interpretation requires caution: 1. **Idealization of limiting conditions**: - Assumes completely flat spacetime and uniform historical background, neglecting spacetime curvature and historical structure fluctuations on cosmological scales. - Ignores contributions from $T^{(H)}_{\mu\nu}$ and $T^{(\Xi)}_{\mu\nu}$, which may be non-negligible in regions with significant

historical depth or strong spacetime curvature (e.g., near black holes, early universe). 2. **Physical meaning of the constant correspondence**: - The relation $G = \hbar/(8\pi)$ holds in natural units, but **does not imply that the gravitational constant is dimensionally eliminable**. In conventional units, it represents a dimensional conversion relation between $\hbar$ and G. - This correspondence is currently obtained at the level of classical field equations and has not been derived from the complete quantum generative dynamics; thus, it should be regarded as a **low-energy effective correspondence**, not a rigorous first-principles derivation. 3. **Connection with existing theories**: - This relation bears formal resemblance to certain quantum gravity models (e.g., the natural unit choice $G\hbar = 1$ in loop quantum gravity), but its physical origin differs—here it stems from the degeneration of the generator Ξ in the absence of historical background. - The stability of this relation needs to be tested in more general spacetime backgrounds, particularly when historical depth H is dynamically evolving.

3.4 Eight Testable Predictions and Preliminary Support from NASA Experiments

Dynamic Generative Theory logically derives eight specific, falsifiable physical predictions. These eight predictions form a tight logical network, from microscopic events to cosmic fate. Particularly emphasized is the seventh prediction—**"dynamic spacetime locality,"** i.e., the gravitational environment modulates the fundamental scale of quantum processes (Ξ_{eff} modulated by local geometry).

3.4.1 Prediction 1: Historical Imprint

The outcome of a single quantum measurement can be biased by the system's extremely weak "pre-history." Through carefully designed statistical experiments, reproducible anomalous distributions may be discovered.

Expanded Explanation: This prediction challenges the standard assumption that repeated measurements under identical conditions are independent and identically distributed (I.I.D.) samplings from a static probability distribution. Dynamic Generative Theory posits that each measurement is an irreversible *generative event* that increases the local **historical depth** H in the system's background potential field, thereby subtly altering the probability landscape for subsequent events $P(n) = G(H(n-1))$.

The Experimental Test: A proposed protocol involves performing a long sequence N of identical projective measurements *without resetting the system*, recording the outcome sequence $\{X_1, X_2, ..., X_N\}$ in strict order. The analysis then focuses on the sequential structure: - **Sequence Correlation Analysis**: Testing for non-zero autocorrelation $C(\tau \geq 1)$ which would violate the I.I.D. assumption. - **Trend Analysis**: Detecting systematic drifts in cumulative sums or moving averages beyond random fluctuation. - **Noise Stripping**: A key innovation is to model unavoidable device instabilities as known "classical constraint noise" $\Delta P_{\text{device}}(n)$. By synchronously monitoring environmental parameters and subtracting this modeled influence, the residual perturbation $\Delta P_{\text{residual}}(n)$ that correlates systematically with the measurement index n becomes the candidate signal for the Historical Imprint effect. This provides a clear, feasible pathway for direct verification using existing high-stability quantum systems (e.g., ion traps, NV centers) and their historical data, requiring no new equipment.

3.4.2 Prediction 2: Convergence Dynamics

Quantum state preparation or measurement-induced wave packet collapse has a characteristic lower-bound time set by the generative cost Ξ_{eff}, satisfying $\Delta E \cdot \Delta \tau \geq \Xi$. This time signal can be detected using ultrafast optics or superconducting circuits.

3.4.3 Prediction 3: Entanglement Programming

By carefully designing spatiotemporally distributed constraint sequences (e.g., complex laser pulses), customized non-trivial entangled state structures can be "programmed."

3.4.4 Prediction 4: Breaking of the Classical Lock

Applying carefully designed strong reverse dynamical constraints to macroscopic classical objects may briefly break their "classical lock," inducing observable quantum behavior (e.g., macroscopic tunneling or coherent oscillations).

3.4.5 Prediction 5: Field Structure Mapping

By systematically measuring statistical deviations (e.g., correlation functions) of quantum systems under different boundary conditions, one can inversely reconstruct the effective potential landscape of the underlying potential field and the correlational structure of the historical texture H.

3.4.6 Prediction 6: Spacetime Generation Imprint

The non-Gaussianity in the universe's large-scale structure (e.g., galaxy distribution) and cosmic microwave background radiation may contain unique imprints related to the power spectrum of the early universe's historical depth field H [8].

3.4.7 Prediction 7: Gravitational Modulation of Quantum Coherence (Dynamic Spacetime Locality)

A quantum system's ability to exhibit wave-like behavior (coherence) is modulated by the local gravitational potential Φ. Specifically, the visibility V of interference fringes (e.g., in a double-slit or matter-wave interferometer) varies with Φ.

Expanded Explanation from *Gravity as a Constraint*: This prediction stems from dynamizing the generator to Ξ_{eff}, which is modulated by local spacetime geometry. In this framework, gravity is a gradient-like constraint on the background potential field. A stronger gravitational potential acts as a stronger "background constraint," promoting the generative transition from superposition (wave) to a determinate state (particle), thus reducing coherence.

Quantitative Relation & Experimental Support: - **Prediction:** $V(\Phi) \propto \exp(-\alpha|\Delta\Phi|/\Xi_{\text{eff}})$, where $\Delta\Phi$ is the gravitational potential difference. - **Preliminary Evidence:** Data from NASA's Cold Atom Lab (CAL) on the International Space Station shows coherence times for Bose-Einstein condensates extended by two orders of magnitude in microgravity ($\Delta\Phi \sim -10^{-10}c^2$) compared to ground. This is reinterpreted as a direct manifestation of a weakened Ξ_{eff} effect [1]. - **Table-Top Test:** A decisive ground-based experiment is proposed. Using a standard cold-atom interferometer and vertically displacing it by a known height (e.g., 1 m, yielding $\Delta\Phi \sim 10^{-16}c^2$), a statistically significant difference in interference visibility V should be measurable after long integration. This isolates the gravitational potential variable and is feasible with existing technology.

3.4.8 Prediction 8: Cosmic Generative Total Lifetime and Cyclic Evolution

Based on generative dynamics logic, this theory predicts the universe will undergo a complete dynamic cycle, including generation-driven expansion, materialization saturation, gravity-dominated collapse, historical reset, and potential restart stages. The current universe is in the generation-driven expansion stage. The qualitative feature of this prediction—dark energy density decays with the cosmic materialization process—can be tested by future high-precision observations of dark energy equation of state $w(z)$ evolution [8].

3.4.9 Preliminary Support from NASA Cold Atom Experiment

In 2020, NASA's cold atom experiment on the International Space Station (ISS) (results published in Nature 582, 193-197 (2020)) provided strong preliminary evidence for Prediction 7 [1]. The experiment compared coherence properties of Bose-Einstein condensate (BEC) in microgravity (space station) and ground gravity environments. It found that in the space station microgravity environment, atomic clouds expanded larger and maintained coherence significantly longer ($T_{\text{coh}} > 1$ second, compared to millisecond scale typical on ground).

In the Dynamic Generative Theory framework, this phenomenon can be naturally explained: Earth's surface gravitational potential ϕ is stronger (more negative) than the space station environment. According to the geometric modulation factor definition $\mathcal{F}(g) \approx 1 + \phi/(2c^2)$, the ground environment has slightly smaller $\mathcal{F}(g)$ than the space station. Since the dynamic generator $\Xi_{\text{eff}} \propto \mathcal{F}(g)$, and characteristic times of quantum processes may relate to Ξ_{eff}, the effective "quantum rhythm" on ground is slightly slower, leading to faster decoherence and shorter coherence time. This qualitatively matches the observed "longer coherence time on the space station."

3.5   Paradigm Terminology Conversion Table

The following table outlines the radically different world picture provided by Dynamic Generative Theory:

Table 1: Paradigm Terminology Conversion Table (Part 1.1)

Traditional Concept	Dynamic Generative Theory Interpretation (Second-Stage Model)	Brief Explanation
Vacuum	Potential field, full of net correlation potential differences.	Not empty, but a field with driving potential containing all possibilities.
Fermions (matter)	Solidified history: topological nodes stabilized in the potential field because historical depth H reached a critical value.	Not fundamental "building blocks," but products of the generative process reaching a stable stage. Their mass originates from coherent bosonic forces absorbed and condensed.
Gauge bosons (forces)	Flowing relations: propagation modes excited by the potential field rebalancing due to correlation potential differences caused by historical structure differences among stable nodes (fermions).	Not independent entities, but dynamical manifestations of the fermion relational network. Gauge symmetry arises from redundancy in shared historical description [4].
Quantum entanglement	Shared history: two or more stable nodes originate from the same generative event, thus intrinsically sharing a common historical inscription.	The root of nonlocal correlation is the holism of history, not signal transmission in space. Bell inequality violation is a natural consequence of this intrinsic holism [6].
Wavefunction collapse	Finite-time generative event: measurement is a new generation guided by the measuring instrument (as a strong historical node), requiring payment of Ξ, hence a minimal time $\Delta\tau \geq \Xi_{\text{eff}}/\Delta E$.	A dynamical process, not instantaneous magic.
Probability	Posterior statistics from ignorance of historical details: generation itself is deterministic, but macroscopic observers cannot know all details of microscopic historical inscriptions, leading to statistical predictions.	Randomness is apparent; the root is incomplete information.
Measurement	Constraint-guided generation: macroscopic instruments provide strong constraint patterns, forcing the measured system to pay Ξ within finite time, generating a new stable node resonant with the instrument pattern.	Solves the "measurement" privilege problem; measurement is part of the universe's own dynamics.
Decoherence	Complication and dilution of the historical network: interaction between system and environment is essentially coupling with a larger historical network. Specific information of the system is encoded in nonlocal correlations of this large network; from the system subspace, its "pure" historical pattern is diluted, manifesting as decoherence.	The environment does not "destroy" coherence but "dilutes" it through shared history.

Table 2: Paradigm Terminology Conversion Table (Part 1.2)

Classicality	Stable network under high historical depth: constituted by a massive number of stable nodes connected via dense shared historical networks; its enormous H makes $C(H) \to 1$, behavior highly determinate.	Quantum and classical are two ends of the same spectrum, continuously characterized by $C(H)$.
Mass	Measure of node stability, equal to the total energy of coherent bosonic forces condensed within the node.	Einstein's mass-energy relation here is a conservation relation of generation.
Spacetime	Macroscopic geometric manifestation of historical depth: the metric $g_{\mu\nu}$ is determined by historical depth H.	Spacetime is not a stage but the sediment of the performance [7, 9].
Dark energy	Net correlation potential difference: the background potential difference driving generation, not balanced by local stable nodes in the potential field itself.	The root of cosmic accelerated expansion, to be gradually consumed during materialization [8].

This conversion table reveals a radically different world picture: there are no pre-existing particles, only constantly generating structures; no independently transmitting forces, only constantly adjusting relations; spacetime and matter share the same origin; quantum and classical are one.

4   Advancing Toward a More Fundamental Theory: Third-Stage Exploration and Its Implications

After successfully constructing the self-consistent model based on the spinor field Φ, I was not satisfied but troubled by a more fundamental question: if "generation" is primary, then the most basic field in the theory should be the most primitive, most undifferentiated "potential," and should not pre-implant structures like "spinor nature" representing specific stable material forms. This prompted me to reflect on the deep imagery of the current Standard Model of particle physics: it presupposes "gauge bosons" (like photons, gluons) as independent fundamental entities. From the perspective of Dynamic Generative Theory, although this presupposition is extremely successful and practical, it is in philosophical tension with the generative view that "force is the manifestation of relations among entities." It reminded me of the "ether" concept introduced in the nineteenth century to explain light propagation—a substantial background posited to explain "how action is transmitted," not directly necessitated by experience. I realized that, if adhering to "generation" as the ontological core, one must attempt a more radical starting point: a pure potential field not pre-containing any stable particle or mediator imagery, and let all structures and "forces" cooperatively emerge therefrom. This is the fundamental motivation driving me to explore the third-stage framework starting from a "bosonic sea" $B(x)$.

4.1   Core Conception of the Third Stage: Minimalist Equation and Its Advantages

The core of the third-stage framework is attempting to describe the most primitive generative process with an extremely concise equation:

$$\boxed{\Box_g B - HB = 0} \tag{6}$$

where $B(x)$ is the undifferentiated scalar potential field ("bosonic sea"), $H(x)$ is the historical depth, and $\Box_g$ is the curved spacetime d'Alembertian.

Its conceptual advantages are prominent:

1. Starting point more primitive, more unified: the only primitive entity is a single, undifferentiated scalar field, truly embodying the pursuit of "monism."

2. Form extremely concise: the equation itself possesses astonishing mathematical beauty, as if directly inscribing the balance between "fluctuation" and "coagulation" tendencies.

3. Naturally contains self-referential idea: historical depth H itself should be determined by past generative events of the potential field B (e.g., via some time average $H \sim \langle B^2 \rangle$), and it in turn acts as a "mass term" in the equation back-acting on the future evolution of B, perfectly capturing the core intuition of "history guiding generation."

4.2 Fundamental Difficulties and Limitations Encountered

Despite conceptual elegance, when trying to develop this equation into a complete theory, I encountered fundamental difficulties that existing mathematical tools can hardly overcome:

1. Locality problem: The equation $\Box_g B - HB = 0$ describes a field continuously fluctuating in spacetime. How can local, stable "islands" (i.e., fundamental particles) naturally and necessarily emerge from this global, uniform "sea"? The equation itself lacks an intrinsic mechanism leading to localization and stabilization. I could only introduce additional assumptions from other theories, like "existence of topological soliton solutions," but this is not a logical necessity derived from the equation [10, 11].

2. Lack of formalization for emergence mechanism: Even assuming soliton solutions exist, how to make these classical solutions exhibit Fermi statistics? This requires another independent, technically complex "soliton fermionization" procedure. Similarly, how do gauge interactions emerge? These questions have no intrinsic, dynamical answers in the third-stage framework; they need to "graft" known mathematical structures (like gauge groups, spinor representations) from outside. This makes the third stage more like a conceptual framework sketch, not a self-sufficient computational engine [12].

3. Deep contradiction between discrete and continuous: The equation itself is still a continuous partial differential equation, its variables defined on a continuous spacetime manifold. This has inherent tension with the core idea in the principles of "fundamental discreteness" (generative events are discrete at the deepest level). I cannot use this continuous equation to describe or derive that deepest-level discrete generative process.

4.3 Summary: A Precious "Failure"

The third-stage exploration is a precious "failure." It shows: our existing toolbox, centered on continuous mathematics (differential geometry, partial differential equations), may fundamentally be incompatible with the core picture of physical reality as "discrete generative events" and their "cross-scale emergence." That elegant equation $\Box_g B - HB = 0$, perhaps precisely because it is locked in the paradigm of continuous mathematics, cannot give birth to the discrete particles and quantum characteristics we desire. This setback clearly points to a conclusion: to realize the full program of Dynamic Generative Theory, a new mathematical language must be developed, one that can start from generative events and naturally describe the dialectical unity of discrete and continuous.

5 Mathematical Formalization Outlook: Towards a New Mathematical Language Based on Generative Dynamics

There exists a profound descriptive gap between the core physical picture of Dynamic Generation Theory and traditional mathematical tools that presuppose "being" and "background spacetime." To rigorously formulate this theory, it is urgent to develop a new mathematical language that can naturally embed "generation," "history," and "hierarchical emergence." The following design principles are directly derived from the core physical picture elaborated in Section 2 of this paper.

5.1 Design Principles: Mathematical Requirements Derived from Core Tenets

Principle 1 (corresponding to Tenets §2 and §2.1): Duality of the Fundamental Field. The mathematical framework must describe a **single fundamental potential field**. It must be mathematically compatible with two phases:

- **Bosonic phase**: The undifferentiated, active phase of the field, whose fundamental activities are discrete, local **generation events**, denoted by $\{\bullet_i^{(n)}\}$.

- **Fermionic phase**: **Topological structures** or **condensed patterns** within the field that have stabilized through the accumulation of history in specific modes. Known fermions (matter particles) should be interpretable as quantized manifestations of such structures.

Principle 2 (corresponding to Tenets §2.1 and §2.2): Intrinsic Recording and Guidance of Historical Traces. The system must intrinsically contain a **"historical trace field"** $h^{(n)}(x)$, which encodes the cumulative effects of past generation events. This field is not a passive record but must be able to feed back as a parameter into the field's own dynamics; that is, the propensity or mode of future events $\bullet_{\text{new}}$ should be modulated by the gradient or distribution of $h^{(n)}$, realizing "history-guided generation."

Principle 3 (corresponding to Tenet §2.2): Intrinsic Correlation and Causal Locality. The mathematical description should naturally lead to the existence of **non-signaling intrinsic correlations** between various stable structures (fermionic phase) that originate from the same underlying cluster of generation events (shared history). Simultaneously, the direct influence range of new events must be limited by a **minimum causal interval** set by the generation unit Ξ, ensuring microscopic causality [6].

Principle 4 (corresponding to Tenet §2.3): Multi-scale Hierarchical Emergence of Discrete and Continuous. The system must naturally define **hierarchies** of description. At level n, physics is described by a set of discrete events $\{\bullet_i^{(n)}\}$. There must exist a well-defined **"emergence map"** $\uparrow^{(n)}$ such that the collective patterns of events at level n can generate a **continuous field** $\mathbb{A}^{(n+1)}(x)$ at level $n+1$. The "continuous" field $\mathbb{A}^{(n)}$ at level n itself forms the discrete basis for phenomena at level $n+1$. This recursive structure of "discrete $\rightarrow$ continuous $\rightarrow$ higher-level discrete ..." is central to the formalization.

Principle 5 (corresponding to Tenet §2.4): Geometric Emergence of Spacetime and Gravity. Ultimately, the mathematical system must demonstrate that the **four-dimensional spacetime continuum and its metric geometry** are the inevitable manifestation of the macroscopic-scale correlation structure of the historical trace network $h(x)$ within the potential field. Gravitational effects should emerge from the underlying dynamics as the geometric expression of "correlation potential gradients" caused by uneven distribution of historical depth [7, 13].

Principle 6 (corresponding to Tenet §2.6): Collapse of Structures and Information Preservation. The formalization must be able to describe: when the potential in a local bosonic phase is exhausted, its enormous historical gradient will cause the structure to **dynamically collapse** into a "deep well." Mathematically, this requires characterizing the **"decompilation"** process from a continuous field $\mathbb{A}^{(n)}$ to a set of discrete events $\{\bullet_i^{(n-1)}\}$. Due to historical sharedness (Principle 3), the informational pattern inside the collapse should be preserved through non-local correlations of the external field.

Principle 7 (corresponding to Tenet §2.6): Unified Descriptive Framework. All the above principles must be integrated into a **self-consistent mathematical framework**. The goal of this framework is to show that quantum uncertainty, classical determinism, particles, interactions, and even spacetime itself are different aspects of the same potential field at different historical stages and different observational scales.

5.2 A Suggestive Symbolic Framework Sketch

To concretize the seven design principles outlined above and demonstrate a possible direction for formalization, we build upon the physical concepts already introduced to outline a highly simplified symbolic framework. This framework aims to show that the properties required by Principles 1-7—"single primitive field, historical feedback, multi-scale emergence," etc.—can be attempted to be realized through carefully defined mathematical objects and mappings. Below is a conceptual example for this purpose:

To illustrate the idea, I attempt to sketch a set of symbols (please note, this is not a complete system but a suggestive example):

- **Basic Activity Units of the Potential Field:** At scale n, the **bosonic phase (active phase)** activity of the field is represented as a set of discrete generation events $\{\bullet_i^{(n)}\}$, each with attributes like position, intensity, time, etc.

- **Stable Structures of the Potential Field:** At scale n, the **fermionic phase (stable phase)** of the field is represented as a continuous field $\blacksquare^{(n)}(x)$, which emerges statistically from the discrete events at the lower level $(n-1)$.

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- **Emergence Map:** $\Uparrow^{(n)}$ denotes the coarse-graining emergence map from the set of discrete events at scale n to the continuous field at scale $n+1$. **This directly corresponds to Design Principle 4 (multi-scale hierarchical emergence).**

- **Projection Map:** $\Downarrow^{(n)}$ denotes the map that identifies potential discrete structures at scale n from the continuous field (e.g., topological defect detection).

- **Historical Trace Field:** $h^{(n)}(x)$ represents the cumulative influence of historical generation events at scale n. It is a continuous field but shaped by discrete events. **This is precisely the intrinsic historical record required by Principle 2**.

Based on these symbols, we can attempt to express some core physical processes:

- **Hierarchical Emergence (embodies Principles 4 and 1):**

$$\blacksquare^{(n+1)}(x) = \Uparrow^{(n)}\left(\{\bullet_i^{(n)}\}\right) \tag{7}$$

This equation indicates that the continuous structure (higher-order fermionic phase) at scale $n+1$ emerges from the discrete events (lower-order bosonic phase activity) at scale n through specific rules.

- **Historical Feedback (embodies Principle 2):**

$$P(\text{new event } \bullet_j^{(n)} \text{ occurs at } x) \propto \exp\left[-\beta\left(\nabla h^{(n)}(x)\right)^2\right] \tag{8}$$

This indicates that new events are more likely to occur where the historical gradient is gentle (the h field is "flat"), reflecting the guidance of historical traces on subsequent generation events, leading to self-organization.

- **Phase Transition Condition (from bosonic to fermionic phase, embodies Principles 1 and 2):**

$$\text{When } \frac{\delta h^{(n)}}{\delta t} < \epsilon \text{ and } \int_V h^{(n)}(x)d^3x > H_{\text{crit}}, \text{ then } \{\bullet_i^{(n)}\} \xrightarrow{\Uparrow} \blacksquare^{(n+1)} \tag{9}$$

That is, when historical accumulation in a region is substantial (H is large) and its variation slows, the cluster of discrete events will undergo a phase transition into a higher-level continuous stable structure.

- **Information Preservation and Decompilation (during structural collapse, embodies Principle 6):**

$$\text{If } \blacksquare^{(n)} \text{ collapses, there exists an operator } \mathcal{R} \text{ such that } \mathcal{R}\left(\partial\blacksquare^{(n)}\right) \approx \{\bullet_i^{(n-1)}\} \tag{10}$$

That is, the boundary information of the continuous structure, under the premise of historical correlation (Principle 3), is sufficient to decompile and reconstruct its internal discrete structure. This provides an alternative perspective on black holes and information puzzles [14].

5.3 Open Challenges and Invitation

This sketch faces profound mathematical challenges, including but not limited to:

1. **Rigorous Definition of the Emergence Map:** How can a continuous field be uniquely and reasonably defined from a discrete, stochastic set of events? This may require combining non-standard analysis, measure theory, or sheaf theory in category theory [15].

2. **Axiomatization of Historical Field Dynamics:** How can the accumulation of historical traces and their feedback effects be mathematically characterized? This may necessitate developing new types of integro-differential equations or stochastic process theories.

3. **Natural Emergence of Topological Structures:** How can topologically non-trivial stable structures (e.g., solitons) emerge from pure generation events? This involves the intersection of algebraic topology and dynamical systems [14].

4. **Compatibility with Existing Physical Mathematics:** How can standard structures such as differentiable manifolds and fiber bundles be naturally derived from this system under appropriate limits? Establishing a rigorous "correspondence principle" is needed.

I emphasize that the above symbolic system is merely a conceptual sketch among many possible paths of formalization. Its value lies in demonstrating the potential feasibility of constructing a mathematical description starting from "generation events" and "historical feedback." We eagerly invite colleagues in mathematics and theoretical physics to propose more rigorous and complete formalization schemes based on this, or to forge entirely new paths, to collectively tackle the fundamental challenge of **"how to build a mathematical language for physics based on generation."**

6 Dynamic Generative Theory as Meta-Theory: Dialogue with Existing Theories

This framework does not deny or overturn existing, well-tested theories but is an exploration of possibilities from a more primitive, fundamental angle inspired by the above theories. The stage achievement presented in this paper aims to establish connections with these profound theories and explore the possibility of a more inclusive conceptual framework.

6.1 Connection to Quantum Mechanics (QM)

In the limit of flat spacetime and no non-trivial historical structure, the unified master equation of Dynamic Generative Theory directly degenerates to the Dirac equation; further non-relativistic approximation gives the Schrödinger equation. Probability interpretation, superposition states, and entanglement in quantum mechanics are interpreted in this theory as the undifferentiated nature of the potential field and the nonlocality of historical correlations [2, 6]. The measurement process corresponds to strong constraint and guided generation of the potential field by specific historical depth patterns (instruments).

6.2 Connection to Quantum Field Theory (QFT)

When ignoring the dynamics of spacetime itself (fixed metric) and taking the historical depth field H as a uniform background, the nonlinear terms and historical coupling terms in the generation current $\mathcal{J}$ of Dynamic Generative Theory can be organized into gauge-invariant interaction forms. Then the theory degenerates to quantum field theory on a fixed background spacetime [5]. Gauge symmetry is here regarded as a low-energy effective symmetry emerging among different excitation modes of the potential field to maintain historical consistency, not a fundamental postulate [4].

6.3 Connection to General Relativity (GR)

In the long-wavelength, macroscopic limit, the statistical average of historical depth H directly couples with spacetime curvature. Via the variational principle, the Einstein field equations naturally emerge from the action of Dynamic Generative Theory [7, 9]. Gravity is interpreted as the flow tendency of the potential field caused by gradients of historical traces. General relativity is the inevitable manifestation of Dynamic Generative Theory in the classical approximation where historical traces are smooth and quantum fluctuations are averaged out.

6.4 Resonance with String Theory

The one-dimensional extended vibrating objects in string theory can be interpreted in Dynamic Generative Theory as stable topological defects (solidified phases) formed by specific historical correlation patterns in the potential field. The vibrational spectrum of strings corresponds to different resonance modes of historical inscriptions. In the limit of ignoring short-range fluctuations of historical depth and assuming excitations of the potential field are confined to topological structures of specific dimensions, the dynamics of Dynamic Generative Theory may coincide with the low-energy effective action of string theory [16]. The "landscape" of string theory may correspond to different branching paths of historical evolution of the potential field.

6.5 Resonance with Loop Quantum Gravity (LQG)

The core of loop quantum gravity—spin networks and quantization of spacetime—naturally resonates with the discrete generation idea of Dynamic Generative Theory. Spin networks can be interpreted as discrete "skeletons" of historical trace networks in the potential field, their nodes and edges recording generative events and causal correlations. The area-volume quantization in loop quantum gravity is precisely the geometric manifestation of the existence of a minimal action interval (Ξ_{eff}) for generative processes [13]. In a simplification focusing only on the quantum discrete structure of spacetime geometry and temporarily ignoring detailed history of matter fields, the descriptions of spacetime foundations by the two theories may converge.

6.6 Resonance with Causal Set Theory

Causal set theory reduces the essence of spacetime to a partially ordered set of discrete events. This highly aligns with the idea of Dynamic Generative Theory taking generative events as basic units [17]. The difference is that Dynamic Generative Theory endows each event with rich internal structure (cause spectrum and effect pattern) and specifies dynamical rules for event generation (guided by historical traces). Therefore, causal sets can be seen as a "simplified projection" of the causal skeleton of Dynamic Generative Theory.

6.7 Unified Meta-Theoretical Picture

The above theories, each with its unique and profound mathematical language, explore the foundation of physical reality that is not directly perceivable from different angles, akin to using different (co)homology groups to probe the "hole" structure of a complex topological space—string theory focuses on its vibration modes [16], loop quantum gravity depicts its discrete skeleton [13], causal sets sort its event order [17], and quantum field theory establishes extremely precise dynamics on its smooth level [5]. I highly praise and admire the extraordinary wisdom and brilliant achievements shown by these explorations. It is precisely these diverse, profound attempts that constitute the core scientific motivation inspiring me to develop Dynamic Generative Theory to seek a more comprehensive description. This framework hopes to provide a conceptual "complex" in which these different "homology groups" can find the topological space they commonly originate from—namely, the ontological reality whose sole process is "generation." All known theories are effective descriptions of this fundamental process under different approximations, scales, and foci.

7 Conclusion and Future Work: A Three-Stage Research Program

The core vitality of Dynamic Generative Theory lies in its attempt to use a simple generative logic to unify all aspects of nature. In this picture, gravity, other interactions, the quantum-classical dichotomy, all dissolve into different phenomena presented by the same generative process, as the system's historical accumulation depth and observational scale differ. There are no absolute fundamental particles, nor absolutely independent forces; there is only the eternal dance from fluid to solidification and back to fluid, following the same generative laws at different scales.

However, I must soberly realize that this grand picture is still mainly a philosophical conception and preliminary mathematical proposal. The work in this paper can be clearly divided into three stages, which together outline a future research path:

7.1 Three-Stage Development Roadmap

1. **First Stage (Deepening and Testing Phase):** Based on the second-stage model (§3), fully advance experimental verification of its eight testable predictions. Focus is on designing ground-based high-precision atom interferometer experiments to quantitatively test "gravitational environment modulating quantum coherence" (Prediction 7); simultaneously, use astronomical observational data (like dark energy equation of state evolution, CMB non-Gaussianity) to test cosmological predictions [8]. The goal of this stage is to subject Dynamic Generative Theory to the strictest experimental interrogation in the existing physical context and possibly discover new phenomena.

2. **Second Stage (Mathematical Tool Exploration Phase):** Face the mathematical difficulties revealed by the third-stage exploration (§4) and engage in deep collaboration with mathematicians and logicians. Based on the symbolic system conception proposed in Chapter 5, develop a new mathematical language that can rigorously formalize "discrete generative events," "historical trace feedback," and "multi-scale emergence." This stage may produce entirely new mathematical structures; its success will determine whether the theory can break through the constraints of existing paradigms [15, 14].

3. **Third Stage (Rebuilding Foundation Phase):** Using the new mathematical tools developed in the second stage, rebuild a true first-principles theory centered on the "fluid phase/solidified phase" binary phase transition. The goal is to strictly derive the emergence of continuous spacetime, various matter particles (fermions and bosons), and their interactions, starting from the most primitive discrete generative events, ultimately completing the full logical closure from the "generative sea" to the universe we observe [18, 19].

7.2 Invitation to the Scientific Community

This paper is by no means a completion declaration but a detailed proposal, stage model, and call for future collaboration constructed by an independent researcher. I clearly realize that the second-stage model is a powerful "proxy," but it is not the ultimate answer; the setback of the third stage points to the mathematical fortress that must be overcome on the path forward; and the conception in Chapter 5 is a brave attempt to solicit better ideas.

I firmly believe that only through rigorous scrutiny, intellectual collision, and concerted collaboration of the scientific community can this framework possibly grow from an inspiring idea to a scientific theory that withstands testing. Therefore, here, as an independent researcher, I issue this sincere invitation:

- **To theoretical physicists:** Please examine the mathematical autonomy of the second-stage model, seek possible loopholes or counterexamples; contemplate its deep connections with your field (string theory [16], loop quantum gravity [13], condensed matter theory [20, 21], etc.).

- **To experimental physicists:** Please review the experimental feasibility of the eight predictions, design more ingenious experimental schemes, and use data to provide verdicts for the theory [1].

- **To mathematicians and logicians:** Please challenge and develop the rudimentary symbolic conception in Chapter 5; I need your power to build the new mathematical edifice describing "generation" itself [15, 14].

- **To all colleagues who love contemplating nature's mysteries:** Whether you are a senior scholar or a young student, if you are touched by the core intuition of "generation," welcome to join this exploration. Regardless of the ultimate fate of Dynamic Generative Theory, the process of pursuing deeper unity itself is the most precious embodiment of the scientific spirit.

Science is not about pursuing personal immortal monuments but the eternal journey of humanity collectively exploring truth. Dynamic Generative Theory is a new signpost on this journey—it may be correct or wrong, but it sincerely invites all of us to look toward that "generative sea" and bravely sail into the unknown.

8 Appendix

A Complete Mathematical Derivation Process (Second-Stage Model)

This appendix provides the complete process from dimensional analysis to reconstruction of the generator system, derivation of the unified master equation, and variational derivation of the gravity-history coupled field equation.

A.1 From Dimensional Analysis to Reconstruction of the Generator System

Goal: Construct a dimensionally autonomous mass generation formula.
Known: In natural units ($\hbar = c = 1$), the dimension of mass (or energy) is 1.
Steps:

1. Basic unit: The minimal action consumed by a generative event is $\Xi_0 = \hbar = 1$.

2. Time scale: The characteristic time of event occurrence is the local Planck time $t_p^{(\text{local})}$, whose relation to the background spacetime Planck time t_p is determined by the metric. Define the geometric modulation factor:

$$\mathcal{F}(g) = \sqrt{\frac{t_p^{(\text{local})}(g)}{t_p}} \tag{11}$$

   In weak field approximation, $t_p^{(\text{local})} \approx t_p(1 + \phi/c^2)$, so $\mathcal{F}(g) \approx 1 + \phi/(2c^2)$.

3. Historical modulation: Historical depth $H_{\mu\nu}$ (now a dimensionless tensor) enhances the "efficiency" of generation. Introduce the historical efficiency factor:

$$\xi(H) = 1 + \kappa \frac{\text{Tr}(H)}{H_0} \tag{12}$$

   where κ is a dimensionless coupling constant, $H_0 = 8$ is the characteristic scale.

4. Dynamic generator: Integrating geometric and historical modulation, define:

$$\Xi_{\text{eff}}(g, H) = \hbar \cdot \mathcal{F}(g) \cdot \xi(H) = \mathcal{F}(g) \cdot \xi(H) \tag{13}$$

5. Energy release: The energy released in one generative event should be proportional to the Planck energy E_p, modulated by the above factors. Considering dimensions and powers of modulation factors (derived from $t_p^{(\text{local})} = t_p/\mathcal{F}^2$), the released energy is:

$$\Delta E = E_p \cdot \mathcal{F}(g)^3 \cdot \xi(H) \tag{14}$$

6. Mass generation: Part of the released energy converts to rest mass, the conversion rate determined by dimensionless efficiency η and system coherence $C(H)$. Coherence defined as $C(H) = 1 - \exp(-\text{Tr}(H)/H_0)$, quantifying system determinacy. Final formula:

$$\Delta M = \eta \cdot \Delta E \cdot [C(H)]^2 = \eta \cdot E_p \cdot \mathcal{F}(g)^3 \cdot \xi(H) \cdot [C(H)]^2 \tag{15}$$

   Dimensional check: $[E_p] = M$, other factors dimensionless, so $[\Delta M] = M$, self-consistent.

A.2 Derivation of the Unified Master Equation (From Action Principle)

Attempt to construct a Dirac-type action containing historical coupling. Action construction:

$$S[\Phi, \bar{\Phi}, g, H] = \int d^4x \sqrt{-g}\mathcal{L} \tag{16}$$

where the Lagrangian density is:

$$\mathcal{L} = \frac{i}{2}\Xi_{\text{eff}} \left[\bar{\Phi}\gamma^\mu \nabla_\mu \Phi - (\nabla_\mu \bar{\Phi})\gamma^\mu \Phi\right] \tag{17}$$

$$+ \frac{i}{2}\Xi_{\text{eff}}\lambda H_{\mu\nu} \left[\bar{\Phi}\gamma^\mu \nabla^\nu \Phi - (\nabla^\nu \bar{\Phi})\gamma^\mu \Phi\right] \tag{18}$$

$$- m(H, g)\bar{\Phi}\Phi - V(\Phi, \bar{\Phi}, H, g) \tag{19}$$

Here the first term is the standard Dirac term but with Ξ_{eff} replacing $\hbar$; the second term is coupling between historical tensor $H_{\mu\nu}$ and the spinor field derivative; the third term is the mass term dependent on history and geometry; the fourth term V is the potential term, possibly containing self-interactions.

Equation of motion derivation: Vary with respect to $\bar{\Phi}$, $\delta S/\delta\bar{\Phi} = 0$. Note Ξ_{eff} depends on g and H but not directly on Φ or $\bar{\Phi}$. After calculation:

$$i\Xi_{\text{eff}}\gamma^\mu \nabla_\mu \Phi + i\Xi_{\text{eff}}\lambda H_{\mu\nu}\gamma^\mu \nabla^\nu \Phi - m(H, g)\Phi = \frac{\delta V}{\delta\bar{\Phi}} \tag{20}$$

To ensure operator Hermiticity (thus probability current conservation), symmetrize the historical coupling term, obtaining the final unified master equation:

$$\left\{ i\Xi_{\text{eff}}(g, H) \left[\gamma^\mu \nabla_\mu + \frac{\lambda}{2}H_{\mu\nu} \left(\gamma^\mu \nabla^\nu + \gamma^\nu \nabla^\mu\right)\right] - m(H, g) \right\} \Phi = \mathcal{J}[\Phi, H, g] \tag{21}$$

where $\mathcal{J} = \delta V/\delta\bar{\Phi}$ is generically called the generation current.

A.3 Derivation of Gravity-History Coupled Field Equation

The total action consists of geometric-historical part and matter part:

$$S_{\text{total}}[g, H, \Phi] = S_{GH}[g, H] + S_{MH}[\Phi, g, H] \tag{22}$$

1. Geometric-historical action S_{GH}:

$$S_{GH} = \int d^4x \sqrt{-g} \left\{ \frac{1}{2\Xi_{\text{eff}}(g, H)} [R(g) + \Lambda(H, g)] + \mathcal{L}_{\text{kin}}[H, \nabla H] \right\} \tag{23}$$

where R is the Ricci scalar, $\Lambda(H, g)$ is the history-dependent cosmological constant, $\mathcal{L}_{\text{kin}}$ is the kinetic term of the historical tensor (e.g., $\propto \nabla_\alpha H_{\mu\nu} \nabla^\alpha H^{\mu\nu}$).

2. Matter-historical action S_{MH}:

$$S_{MH} = \int d^4x \sqrt{-g} \, \Xi_{\text{eff}}(g, H) \cdot \mathcal{L}_M[\Phi, \nabla\Phi, g, H] \tag{24}$$

$\mathcal{L}_M$ is the standard Lagrangian density form of matter fields (including the potential field Φ).

Varying the metric $g^{\mu\nu}$: Apply variational principle $\delta S_{\text{total}}/\delta g^{\mu\nu} = 0$. This is tedious but standard. Key point: Ξ_{eff} itself depends on $g^{\mu\nu}$ (through $\mathcal{F}(g)$), so its variation contributes additional terms. The final result can be organized as the modified Einstein equation:

$$G_{\mu\nu} + \Lambda(H, g)g_{\mu\nu} = \Xi_{\text{eff}}(g, H) \left[T_{\mu\nu}^{(H)} + T_{\mu\nu}^{(M)} + T_{\mu\nu}^{(\Xi)} \right] \tag{25}$$

where:

$$T_{\mu\nu}^{(H)} = -\frac{2}{\sqrt{-g}} \frac{\delta(\sqrt{-g}\mathcal{L}_{\text{kin}})}{\delta g^{\mu\nu}} \quad \text{(energy-momentum tensor of historical field)} \tag{26}$$

$$T_{\mu\nu}^{(M)} = -\frac{2}{\sqrt{-g}} \frac{\delta(\sqrt{-g}\mathcal{L}_M)}{\delta g^{\mu\nu}} \quad \text{(energy-momentum tensor of matter field)} \tag{27}$$

$$T_{\mu\nu}^{(\Xi)} = -\frac{2}{\sqrt{-g}} \frac{\delta(1/\Xi_{\text{eff}})}{\delta g^{\mu\nu}} \quad \text{(new term from variation of } 1/\Xi_{\text{eff}}) \tag{28}$$

interpretable as the energy-momentum tensor of the "generator background," encoding the back-reaction of quantum generative processes on spacetime geometry.

In the flat spacetime no-history limit, $T_{\mu\nu}^{(H)}$ and $T_{\mu\nu}^{(\Xi)}$ vanish, $\Xi_{\text{eff}} \to \hbar$, the equation simplifies to $G_{\mu\nu} = \hbar T_{\mu\nu}^{(M)}$; comparing with the standard equation gives $G = \hbar/(8\pi)$.

B Cosmological Simulation Code and Results (Second-Stage Model)

This appendix provides adjustment notes, core algorithms, and key results of cosmological simulation based on revised formulas.

B.1 Simulation Parameters and Formula Adjustments

The original cosmological simulation was based on old formulas with dimensional problems. In the revised framework, the simulation's core formulas need updating, but the overall algorithm structure (discrete lattice, iterative generation) remains unchanged.

- Lattice: Use a two-dimensional $N \times N$ grid (e.g., 100×100) to simplify the simulated universe.

- State variables: Each lattice point (i, j) stores potential value P_{ij}, historical depth trace $h_{ij} \equiv \text{Tr}(H_{ij})$, coherence $C_{ij} = 1 - \exp(-h_{ij}/8)$, mass M_{ij}.

- Mass generation: When a generative event occurs at lattice point (i, j) and $C_{ij} > C_{\text{th}}$ (e.g., 0.4), generate mass according to the new formula:

$$\Delta M_{ij} = \eta_{\text{sim}} \cdot E_p^{(\text{sim})} \cdot \mathcal{F}_{\text{sim}}^3 \cdot \xi(h_{ij}) \cdot C_{ij}^2 \tag{29}$$

where:

- $E_p^{(\text{sim})}$ is the Planck energy unit set in simulation (usually 1).
- $\mathcal{F}_{\text{sim}}$ in homogeneous cosmological simulation can be first set to 1 (ignore spatial curvature variation), or try a simple scale-factor related model.
- $\xi(h_{ij}) = 1 + \kappa_{\text{sim}} \cdot h_{ij}/8$.
- $\eta_{\text{sim}}, \kappa_{\text{sim}}$ are simulation parameters to be calibrated.

B.2 Recalibration and Expected Results

1. Calibration method: Run simulation, adjust parameters η_{sim} and κ_{sim} so that when simulation "time" reaches step S_{now} corresponding to the current universe age (13.8 Gyr), the calculated matter fraction $\Omega_m = \frac{\sum M_{ij}}{\sum M_{ij} + \sum P_{ij}}$ equals the observed value 0.315 [8].

2. Expected changes: Since the baseline changed from tiny $\hbar t_p$ to huge E_p, the efficiency parameter η_{sim} will be many orders of magnitude smaller than the old simulation's $\eta \approx 75$ (possibly around 10^{-86} order). But this is just a proportionality constant in simulation, not affecting evolution patterns.

3. Key output: The simulation outputs total generative steps S_{total} (when $\Omega_m > 0.999$). The universe's total lifespan is given by the step-time scaling law:

$$T_{\text{total}} = t_{\text{now}} \times \frac{S_{\text{total}}}{S_{\text{now}}} \tag{30}$$

We expect that as long as the revised dynamics maintains similar scaling behavior, the key prediction values 131.5 billion years and 118 billion years will remain robust.

B.3 Open Source Code and Data

The updated simulation code is open-sourced to ensure transparency and reproducibility:

- Zenodo archive: `https://zenodo.org/records/18233378`

The repository contains complete simulation code (Python), parameter files, initialization scripts, and data analysis scripts (Jupyter Notebook) for generating figures and tables in the paper. All data are reproducible.

C Third-Stage (Bosonic Sea) Framework Details

This appendix provides a detailed description of the third-stage (bosonic sea) framework, archived as a record of the exploration process. Its core idea is to construct a more primitive theory with an undifferentiated scalar field as the sole entity.

C.1 First-Principle Concept Definitions

Potential Field (Bosonic Sea)
Denoted $B(x)$. This is the only primitive entity of the theory, an undifferentiated "sea of possibilities," called "bosonic sea." It is a scalar field on spacetime (for simplicity, internal degrees of freedom not considered for now), representing the undifferentiated background of all possible structures in the universe.

Historical Depth H
Denoted $H(x)$ (dimensionless). This is the "memory" of the potential field, describing the cumulative imprint of generative events. Macroscopically manifests as spacetime curvature; microscopically as stability of material structures. It is a dimensionless scalar field on spacetime.

Dynamic Generator Ξ
The generation cost Ξ is the minimal action required to perform a deterministic generative event:

$$\Xi(x) = \hbar \left[1 - \frac{H(x)}{H_{\text{max}}(T)} \right] \tag{31}$$

where $H_{\text{max}}(T)$ is the maximum historical depth achievable at current temperature. This embodies "historical inertia": the deeper the history, the lower the cost for further generation.

Coherence Function

Historical depth H enhances system determinacy. Introduce coherence function $C(H)$ to quantify this effect; its specific form will be determined in future statistical physics derivations. In current work, it suffices to clarify that $C(H)$ increases monotonically with H, and $C(0) = 0$, $C(H_{\max}) = 1$.

C.2 First-Principle Assumption: Potential Field–Historical Depth Self-Referential Equation

Based on three meta-physical principles (generation principle, historical record principle, self-referential guidance principle), propose the basic equation of this theory. Introduce two basic field variables:

- Potential field $B(x)$: describing the undifferentiated background of all possible structures in the universe, the "bosonic sea."

- Historical depth $H(x)$: describing the cumulative imprint of generative events.

The interaction between potential field and historical depth is described by:

$$\boxed{\Box_g B - HB = 0} \tag{32}$$

where $\Box_g = \frac{1}{\sqrt{-g}} \partial_\mu (\sqrt{-g} g^{\mu\nu} \partial_\nu)$ is the d'Alembertian in curved spacetime, $g_{\mu\nu}$ is the spacetime metric tensor.

Physical Interpretation of the Equation

The left-hand side contains two terms, corresponding to two competing tendencies:

1. Wave diffusion term $\Box_g B$: describes propagation and diffusion of the potential field in spacetime. In flat spacetime limit, it degenerates to the standard wave equation, indicating the potential field tends to propagate as waves and fill entire space, maintaining its uniformity and symmetry.

2. Historical coagulation term $-HB$: describes the modulating effect of historical depth on the potential field. When historical depth $H > 0$, this term acts like a negative mass-squared term, tending to give the potential field a non-zero expectation value where history is deep, thereby breaking symmetry and forming local coagulation.

The competition between the two terms embodies the dynamic balance between "generation" and "memory": the wave diffusion term tends to maintain the uniformity and possibility of the potential field, while the historical coagulation term tends to solidify possibilities into reality and leave historical imprints.

Relation Between Metric $g_{\mu\nu}$ and Historical Depth H

In the complete theory, spacetime metric $g_{\mu\nu}$ is not an independent background structure but an emergent quantity determined by historical depth H. In this work, adopt the following assumed relation as preliminary closure:

$$g_{\mu\nu}(x) = \eta_{\mu\nu} + \frac{8\pi G}{c^4} H(x) \eta_{\mu\nu} + \mathcal{O}(H^2) \tag{33}$$

where $\eta_{\mu\nu}$ is the Minkowski metric. This linear relation reflects the core intuition: "historical depth is curvature."

C.3 Topological Soliton Solutions and Fermionization Conjecture

As the universe cools, historical depth H begins to accumulate in some regions. Consider static case ($\partial_t B = 0$) and assume flat metric, the equation simplifies to:

$$-\nabla^2 B - HB = 0 \tag{34}$$

This is an eigenvalue problem, but note H itself depends on the stable part of B, so it is actually a nonlinear equation. Assume under appropriate self-consistent conditions, this equation allows localized, stable solutions, i.e., topological solitons [10, 11].

Physical picture: If H has a local distribution in space (e.g., Gaussian type), then the equation may allow bound state solutions, i.e., B takes larger values where H is large, decaying exponentially far away. These solutions have locality, stability, and topological charge, similar to particles.

Soliton Fermionization Conjecture

When quantizing classical soliton solutions, quantum excitations of their zero modes (like position, orientation) may satisfy anticommutation relations, thus behaving as fermions [10, 21]. This requires rigorous proof via semi-classical quantization methods (like Faddeev–Popov path integral) and is a core mathematical challenge for the future.

C.4 Mathematical Challenge List

1. Challenge 4.1: Prove that equation $\Box_g B - HB = 0$ under self-consistent conditions (H defined by B) allows stable topological soliton solutions [10, 11].

2. Challenge 4.2: Determine topological invariants of solitons and establish correspondence with known particle quantum numbers (spin, charge, etc.).

3. Challenge 4.3: Derive spinor structure (emergence of Dirac matrices) from soliton solutions of scalar field B.

4. Challenge 4.4: Rigorously prove that quantized zero modes satisfy anticommutation algebra (Fermi statistics) [21].

5. Challenge 4.5: Derive mass formula: $m = E_{\text{soliton}}/c^2$, and establish connection with known fermion mass spectrum.

6. Challenge 4.6: Define historical depth tensor $\mathbf{H}$ so it contains directional information.

7. Challenge 4.7: Establish constitutive relation between historical depth tensor and Ricci curvature tensor [7, 9].

8. Challenge 4.8: Derive metric emergence equation from variational principle.

9. Challenge 4.9: Derive Yang–Mills action from B field dynamics [4].

10. Challenge 4.10: Explain why the gauge group is $SU(3) \times SU(2) \times U(1)$, and derive corresponding representations [5].

11. Challenge 4.11: Derive relation between gauge coupling constants and potential field parameters.

This appendix aims to record the original conception of the third-stage framework and the profound mathematical difficulties faced, providing a clear "problem map" for future exploration.

Acknowledgments

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