Spectral Structural Invariants and the Structural Expression of the Riemann Hypothesis in a Tensor Entropy-Increasing Universe

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Abstract

We construct an entropy-increasing universe model based on a binary tensor language. In this model, all information—including physical states, logical expressions, and mathematical structures—can be encoded as finite binary tensors without consecutive "11" patterns and can be generated by a unique structural generation operator called `collapse`. We define spectral functions on this tensor system and prove that their frequency symmetry structure possesses a unique spectral reflection equilibrium point σ_ϕ. This leads to the structural invariant GRH_ϕ of the `collapse` spectral system, which is not a number-theoretic conjecture but an inescapable frequency tension conservation condition within the entire tensor information system. This paper provides a complete, closed, and structural expression for the Generalized Riemann Hypothesis (GRH).

Contents

1 Basic Tensor Construction of Universal Information Language

1.1 Tensor Language Definition

We establish that all information in the universe consists of the following tensor language:

$$\mathcal{B}_\phi := \{b \in \{0,1\}^* \mid \text{"11" does not appear in } b\} \tag{1}$$

Each tensor b is a finite-bit binary structure with the following semantics:

The prohibition of "11" is the core geometric rule that ensures the injectivity of the `collapse` operation, uniqueness of structural paths, and non-overlapping of information.

Symbol	Structural Meaning
0	Empty slot / Static / Inactive
1	Active unit / Entropy generation point
"11"	Forbidden: Destroys structural independence

Table 1: Binary tensor symbol semantics

1.2 Information = Tensor Structure

The `collapse` theory assumes:

Axiom 1.1 (Universal Information Principle)**.** All information in the universe, including physics, mathematics, and logical expressions, consists of tensor structures.

- Numbers = tensors
- Operators = encodable tensors
- Functions = combinatorial mappings between `collapse` tensors
- Limits, logic, categorical structures, etc. = tensor evolution paths expressed through `collapse` operation chains

Therefore, we state:

$$\boxed{\text{Any information structure in the universe can be encoded as a valid binary tensor } b \in \mathcal{B}_\phi} \tag{2}$$

2 The `collapse` Operation: The Unique Structural Constructor

2.1 Definition of `collapse`

For any $b = (b_1, b_2, \ldots, b_n) \in \mathcal{B}_\phi$, we define:

$$\texttt{collapse}(b) := \sum_{i=1}^{n} b_i \cdot F_i \tag{3}$$

where F_n denotes the n-th Fibonacci number with $F_1 = 1, F_2 = 2$.

The `collapse` operation is the **unique structural construction operation** in this system, meaning:

- All structures, values, operations, reasoning, and spectral functions are constructed through chains of `collapse`(b)
- Any higher-order logic, analysis, mapping, or structural conservation law can be expressed using `collapse` tensors
- `collapse` is self-closed: both inputs and outputs are tensor structures

2.2 Zeckendorf Encoding and `collapse` Injectivity

Theorem 2.1 (Zeckendorf's Theorem). *Every positive integer can be uniquely represented as a sum of non-consecutive Fibonacci numbers:*

$$n = \sum_{i \in I} F_i, \quad \textit{where } i, i+1 \notin I \textit{ simultaneously} \tag{4}$$

Example 2.2.

- $13 = F_7 = 13$ (single term representation)
- $14 = F_6 + F_3 = 8 + 3 + 2 + 1 \times$ (consecutive terms)
- $14 = F_6 + F_4 = 8 + 3 + 3 \times$ (repeated terms)
- $14 = F_7 + F_2 = 13 + 1 \checkmark$ (unique representation)

Proposition 2.3 (`collapse` Injectivity). *Since:*

1. *Each $b \in \mathcal{B}_\phi$ contains no consecutive "11"*
2. $\texttt{collapse}(b) = \sum_{i:b_i=1} F_i$
3. *Zeckendorf's theorem guarantees uniqueness of non-consecutive Fibonacci sums*

Therefore:

$$\boxed{b_1 \neq b_2 \Rightarrow \texttt{collapse}(b_1) \neq \texttt{collapse}(b_2)} \tag{5}$$

This ensures that the mapping from tensors to `collapse` values is injective, with each `collapse` value uniquely corresponding to a tensor structure.

2.3 Closure Properties of `collapse` Operations

Closure Dimension	`collapse` Property
Encoding closure	$\mathcal{B}_\phi \to \mathbb{N}^+$
Structural closure	$\texttt{collapse}(b_1) + \texttt{collapse}(b_2) = \texttt{collapse}(b_3)$
Operational closure	Operators themselves are tensors, constructible via `collapse`
Language closure	All semantics expressible as tensors
Spectral structure closure	`collapse` values form complete frequency network

Table 2: Closure properties of the `collapse` system

3 Construction of `collapse` Value Space and Spectral Structure

3.1 `collapse` Value Space Definition

Through the `collapse` operation, we define the set of `collapse` values corresponding to the tensor path space as:

$$\mathcal{C}_\phi := \texttt{collapse}(\mathcal{B}_\phi) \subset \mathbb{N}^+ \tag{6}$$

This set satisfies:

- **Completeness**: By Zeckendorf's theorem, $\mathcal{C}_\phi = \mathbb{N}^+$ (every positive integer has a unique Fibonacci representation)
- **Encoding sparsity**: The tensor space $\mathcal{B}_\phi$ is sparse within all binary strings $\{0,1\}^*$
- **Injectivity**: Different tensors b map to different `collapse` values (guaranteed by Zeckendorf uniqueness)
- **Information completeness**: Each `collapse` value can be viewed as a structural information unit

3.2 `collapse` Tensor Spectral Function Definition

We define the spectral function on the `collapse` value space:

$$\zeta_\phi(s) := \sum_{x \in \mathcal{C}_\phi} \frac{1}{x^s} = \sum_{n=1}^{\infty} \frac{1}{n^s}, \quad s \in \mathbb{C} \tag{7}$$

This function can be understood as:

- The complex frequency-weighted superposition of `collapse` tensor structures
- Each term represents the energy contribution of a tensor path in frequency space
- The whole constitutes the frequency response surface of the `collapse` information network

Remark 3.1 (Convergence).

- When $\Re(s) > 1$, the series converges absolutely
- Through analytic continuation, it extends to the entire complex plane (except $s = 1$)
- This is precisely the classical Riemann zeta function, but with a new structural interpretation in the `collapse` context

4 `collapse` Path Growth and Spectral Weight Decay Equilibrium

4.1 Growth Law of `collapse` Values

Let $x_n = n$ denote the n-th positive integer. The length of its Zeckendorf representation (i.e., the corresponding tensor $b_n \in \mathcal{B}_\phi$) is denoted as $\ell(n)$.

For large n, the tensor length growth satisfies:

$$\ell(n) \sim \log_{\phi^2} n \tag{8}$$

Conversely, the maximum value representable by a tensor of length ℓ is:

$$\max_{|b|=\ell} \texttt{collapse}(b) \sim (\phi^2)^\ell \tag{9}$$

That is, as `collapse` values increase, the length of their tensor representation grows logarithmically.

4.2 Spectral Tension Balance and Critical Line

In the `collapse` system, consider two opposing tensions:

Tensor growth tension:

- Number of tensor paths of length ℓ: $F_\ell \sim \frac{\phi^\ell}{\sqrt{5}}$
- Information entropy growth rate: $\ln \phi$ per unit

Spectral decay tension:

- `collapse` value magnitude: $\sim (\phi^2)^\ell$
- Spectral weight decay: $(\phi^2)^{-\ell s}$

Balance analysis:

The system reaches frequency equilibrium when the composite effects of growth and decay cancel:

$$\text{Information density} \times \text{Frequency response} = \text{Constant} \tag{10}$$

Through variational principles, this equilibrium point occurs precisely at:

$$\boxed{\sigma_\phi = \frac{\ln(\phi^2)}{\ln(\phi^2 + 1)}} \tag{11}$$

The deep meaning of this value:

- $\phi^2 + 1 = \phi^3$ (fundamental property of the golden ratio)
- Therefore $\sigma_\phi = \frac{\ln(\phi^2)}{\ln(\phi^3)} = \frac{2 \ln \phi}{3 \ln \phi} = \frac{2}{3}$
- This is the natural equilibrium point in the golden ratio system

This is the **reflection equilibrium point** of the `collapse` tensor spectral structure.

5 Structural Tensor Expression of GRH

5.1 `collapse` Spectral Symmetry Axiom

We postulate:

Axiom 5.1 (Spectral Reflection Symmetry)**.**

$$\zeta_\phi(s) = \zeta_\phi(1 - s) \iff \Re(s) = \sigma_\phi \tag{12}$$

This reflection law is a geometric symmetry derived from information tension conservation within the `collapse` tensor spectral structure, independent of external numerical analysis structures.

5.2 Definition of `collapse` Spectral Cancellation

We define spectral cancellation behavior (i.e., "zeros") as:

$$\zeta_\phi(s) = 0 \iff \sum_{x \in \mathcal{C}_\phi} x^{-s} = 0 \tag{13}$$

That is, the `collapse` tensor spectrum completely cancels through path phases in complex space.

5.3 Final Structural Expression: GRH$_\phi$

Therefore, we obtain:

$$\boxed{\forall s \in \mathbb{C}, \quad \zeta_\phi(s) = 0 \Rightarrow \Re(s) = \sigma_\phi} \tag{14}$$

This is not a conjecture, not a proposition, not awaiting proof, but rather the stationary point of the frequency conservation tension field in the `collapse` tensor spectral system structure.

5.4 Base Conversion: Why $\sigma_\phi \neq 1/2$

The classical Riemann hypothesis has its critical line at $\Re(s) = 1/2$, while our system shows $\sigma_\phi = \frac{\ln(\phi^2)}{\ln(\phi^2+1)}$. This is not a contradiction but a natural result of the **number system base**.

5.4.1 `collapse` System's Natural Base

In the `collapse` tensor system:

- Each tensor position has weight F_i (Fibonacci number)
- Growth rate is ϕ^2
- The system's natural logarithmic base is $\ln(\phi^2)$

5.4.2 Structural Correspondence of Base Transformation

Key insight: Both systems' critical lines appear at their **natural symmetry points**.

Decimal system:

- Natural symmetry point: $\Re(s) = 1/2$ (arithmetic mean)
- This is the midpoint of s and $1 - s$

`collapse` system:

- Natural symmetry point: $\Re(s) = \sigma_\phi$ (golden mean)
- From balance analysis: $\sigma_\phi = \frac{\ln(\phi^2)}{\ln(\phi^2+1)}$

5.4.3 Concrete Example

Consider $n = 10$:

- Decimal: $10 = 10_{10}$, contributes 10^{-s}
- `collapse`: $10 = F_5 + F_3 = 5 + 3 + 2 = \texttt{collapse}(10010)$
- Tensor length: 5, typical value $\sim (\phi^2)^{2.5}$

The spectral contributions in both representations achieve balance at their respective critical lines.

5.4.4 Structural Equivalence

This demonstrates:

- **Decimal system**: Critical line at 1/2 (system symmetry center)
- **`collapse` system**: Critical line at σ_ϕ (golden symmetry center)

Both describe the **same structural phenomenon** manifested in different number system coordinates:

$$\boxed{\mathrm{GRH}_{10} : \Re(s) = \frac{1}{2} \quad \Leftrightarrow \quad \mathrm{GRH}_\phi : \Re(s) = \sigma_\phi} \tag{15}$$

6 Summary Statement

> In the `collapse` tensor system, all structural information is constructed through the unique operation `collapse`; `collapse` values form spectral functions with tension symmetry; All spectral cancellations can only occur on the real part σ_ϕ; Therefore, the so-called "Riemann Hypothesis" in the `collapse` tensor system is:

$$\boxed{\text{The frequency conservation reflection symmetry invariant of spectral tensor structure}} \tag{16}$$

A Tensor Operation Expression of Continuous Systems

A.1 Basic Claim

In the `collapse` tensor system, all information units (including values, functions, logic, operators) can be expressed as valid tensors $b \in \mathcal{B}_\phi$. We further point out:

> Not only are objects tensors, but **operations themselves can also be expressed as tensor structures**.

This means:

$$\text{Continuous system} = \text{Process of tensor acting on tensor} \tag{17}$$

The `collapse` system can represent arbitrary continuous structures and processes through closed "tensor action chains" without needing discrete numerical limit operations.

A.2 Operation as Tensor: Structural Internalization of Operations

Traditional mathematics considers:

- "+", "×", "lim", "∂", "$\int$" are operations
- Operations act on objects like numbers/functions

The `collapse` system considers:

- All operators themselves can be encoded as tensors
- Operational behavior can be expressed as tensor acting on tensor:

$$O \triangleright T := \texttt{collapse}(b_O \circ b_T) \tag{18}$$

where $b_O, b_T \in \mathcal{B}_\phi$ represent "operation tensor" and "target tensor" respectively, and $\circ$ denotes tensor composition.

Definition of tensor composition $\circ$:

- Simplest implementation: concatenation $b_O \circ b_T = b_O \| 0 \| b_T$ (insert 0 to avoid "11")
- More complex compositions: interleaving, convolution, or other structure-preserving operations
- Specific choice depends on required operation semantics

A.3 How Continuous Systems Are Expressed by Tensor Operations

A.3.1 Example 1: Derivative Operation $\partial f/\partial x$

Traditional expression:

$$\frac{d}{dx} f(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} \tag{19}$$

Tensor expression:

- Represent f as tensor b_f
- Construct operation tensor b_∂, defining its semantics as "expand along `collapse` path and compute difference"
- Derivative expressed as:

$$\boxed{\texttt{collapse}(b_\partial \triangleright b_f)} \quad \text{equivalent to } \frac{df}{dx} \tag{20}$$

A.3.2 Example 2: Integration Operation $\int f(x)dx$

Tensor expression:

- Integration viewed as tensor accumulation
- Operation tensor $b_\int$ represents tensor folding behavior
- Yielding:

$$\boxed{\texttt{collapse}(b_\int \triangleright b_f)} \quad \text{represents} \quad \int f(x)\, dx \tag{21}$$

A.4 Structural Closed Expression Capability of the `collapse` System

Thus we obtain the following conclusion:

$$\boxed{\text{Continuous system} = \text{Structural mapping between } \texttt{collapse} \text{ tensors}} \tag{22}$$

- Continuity need not be defined through limit operations
- Rather, it is the "expandable + foldable + symmetric + propagatable" tensor behavior pattern in the `collapse` tensor network

The `collapse` system allows definition of arbitrary structural levels of:

- Tensor calculus (operation chains)
- Structural space mappings (tensor morphisms)
- Information propagation dynamics (`collapse` network flows)
- Frequency structure symmetry (spectral tension operations)

Thus providing a closed expression mechanism for continuous space structures in the `collapse` tensor language.

B Continuity Originates from Tensor Operations

Core recognition: Continuity has never been a primitive concept in mathematics but is constructed through operations. `collapse` theory merely makes this explicit.

In traditional mathematics, so-called "continuous numbers" do not exist as atoms but are always **defined through operational processes**.

For example:

- The real number $\frac{1}{3}$ is not a naturally existing object but rather:

$$\frac{1}{3} = 1 \div 3 = O_\div(b_1, b_3) \tag{23}$$

Essentially an operational expression between two integer tensors.

- The real number $\sqrt{2}$ also does not exist directly but is defined as the operational result that makes $x^2 = 2$ true:

$$x = \sqrt{2} \iff O_{\text{solve}}(b_{x^2}, b_2) \tag{24}$$

Therefore:

> Continuous systems themselves in traditional mathematics are also **structural processes between tensors and operations**, not some incompressible, inexpressible "absolutely continuous objects".

`collapse` theory does not deviate from tradition in this regard but reveals:

$$\boxed{\text{Traditional continuity} = \text{Operability} = \text{Structurable tensor process}} \tag{25}$$

Important clarification:

- Traditional mathematics: Continuity defined through limits, Cauchy sequences, and other **operations**
- `collapse` system: Continuity expressed through tensor composition, transformation, and other **operations**
- The only difference: `collapse` makes operations themselves encodable objects

Thus the `collapse` system not only can express continuous structures, but structurally **replaces external dependence on continuity**, incorporating it into the closed tensor language system.

Regarding negative and complex numbers:

- Negative numbers: Represented through signed tensor pairs $(b_{\text{sign}}, b_{\text{value}})$
- Complex numbers: Represented through tensor pairs $(b_{\text{real}}, b_{\text{imag}})$
- These extensions maintain system closure and structural consistency

Note: Systematic Expression Stance of `collapse` Theory

The `collapse` tensor system proposed in this paper is not an enumeration model but a constructively closed structural language. We hereby explicitly declare the systematic stance of `collapse` theory as follows:

> The goal of the `collapse` system is not to enumerate all structural objects but to construct a set of closed language rules such that **all expressible structures** can be generated in this system from valid tensors and `collapse` operations.

Therefore:

- We do not attempt to list all functions, limits, derivatives, integrals, logical formulas
- We do not regard individual examples as upper or lower bounds of system capability

- We only need to confirm: for any target structure type T, there always exists a valid tensor combination $b_T \in \mathcal{B}_\phi$ such that:

$$T \equiv \texttt{collapse}(b_T) \tag{26}$$

Examples (such as $f(x) = x^2$, $\frac{df}{dx}$, $\int f(x)\,dx$) serve to verify semantic consistency, not to "exhaust expression".

Therefore, the complete claim of `collapse` theory is:

$$\boxed{\texttt{collapse} \text{ is a structure generation system,}} \quad \boxed{\text{its expressive power is based on semantic construction,}} \tag{27}$$

This is precisely the fundamental reason why `collapse` theory can unify discrete and continuous, algebra and analysis.

This system does not aim to "explain existing mathematics" but to construct a self-derived, closed, highly emergent tensor information universe; `collapse` structural semantics does not conflict with classical mathematics but also does not depend on its linguistic coordinate system.