Cognitive Signal Theory: The 0.5 Invariant as a Universal Nyquist Limit

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Abstract

Standard physical theory models the universe as a collection of fundamental objects interacting through forces. We propose an alternative formulation in which the universe is treated as a signal-processing system governed by a global spectral stability constraint. By interpreting the critical line of the Riemann zeta function, $\mathrm{Re}(s) = \frac{1}{2}$, as a universal Nyquist limit, we argue that physical structure corresponds to information that maintains spectral coherence under bounded sampling.

Through large-scale computational interference simulations approximating 10^{15} effective interactions, we identify a geometric structure termed the *Prime Interference Manifold*, in which constructive interference produces stable localized excitations while destructive interference collapses into null regions analogous to vacuum states. The results suggest that quantum chaos reflects encrypted structure rather than intrinsic randomness, and that physical law functions as a compression constraint on an underlying informational field.

1 Introduction: Noise, Signal, and the Limits of Randomness

Quantum chaos has traditionally been approached through statistical characterization. The spacing of the non-trivial zeros of the Riemann zeta function exhibits Gaussian Unitary Ensemble (GUE) statistics, resembling energy spectra of complex quantum systems. This resemblance has led to the prevailing assumption that the underlying dynamics are fundamentally chaotic.

Such interpretations implicitly treat randomness as ontologically primitive. However, in information theory, randomness is operationally indistinguishable from sufficiently dense encryption. A signal lacking an appropriate decoding framework may therefore appear statistically random despite being fully structured.

Modern physics has largely abstained from questions of decoding or reconstruction, focusing instead on invariant statistical properties. This work reopens the engineering question: whether observed quantum “noise” represents disorder, or a structured signal exceeding the decoding bandwidth of current physical models.

We introduce *Cognitive Signal Theory* (CST), which treats the quantum vacuum as a high-bandwidth informational field. Physical law arises as the set of constraints required to filter this field into spectrally coherent states.

2 Theoretical Framework: The Universe as a Spectral Filter

The central claim of Cognitive Signal Theory (CST) is that physical reality is not fundamentally object-based, but constraint-based. Rather than beginning with particles, forces, or fields defined *a priori*, CST begins with the premise that any physically realizable structure must be spectrally reconstructible under bounded sampling. In this view, physical law functions analogously to a signal-processing filter, admitting only those informational modes that satisfy global stability constraints.

This section formalizes that premise by reinterpreting the critical line of the Riemann zeta function as a universal spectral stability boundary, analogous to a Nyquist limit in digital signal processing. Importantly, this interpretation does not claim novelty in the location of the critical line itself, which is well established in analytic number theory, but rather proposes a new functional role for that line as a constraint governing coherence, boundedness, and physical realizability.

2.1 The Universal Nyquist Limit

In classical signal processing, the Nyquist–Shannon sampling theorem establishes a necessary condition for faithful signal reconstruction. A signal with maximum frequency $f_{\max}$ can be reconstructed without loss if and only if it is sampled at a rate $f_s \geq 2f_{\max}$. Sampling below this threshold results in aliasing, whereby high-frequency components are irreversibly folded into lower frequencies, destroying recoverable structure.

This principle is not contingent on the semantic content of the signal; it arises purely from the mathematics of bounded sampling. As such, it applies universally to any system in which information is discretized, reconstructed, or stabilized under finite resolution.

If spacetime itself is discrete or effectively bounded at small scales—whether by Planckian limits or by finite informational capacity—then any physically admissible signal must obey an analogous spectral cutoff. Signals that violate this cutoff cannot be stably reconstructed and therefore cannot correspond to persistent physical structure.

We propose that the Riemann Hypothesis encodes precisely such a constraint.

[Spectral Stability Conjecture] The critical line $\mathrm{Re}(s) = \frac{1}{2}$ functions as a universal spectral stability boundary. Oscillatory modes associated with non-trivial zeros off this line exhibit exponential amplification or decay under superposition, rendering them non-reconstructible and therefore physically non-coherent.

This conjecture does not replace existing statistical interpretations of the zeta zeros, such as those arising from Random Matrix Theory. Rather, it complements them by assigning a functional role to the critical line: not merely as a locus of zeros, but as a boundary separating bounded, reconstructible modes from unstable ones.

The 0.5 Invariant. We define the 0.5 *Invariant* as the condition

$$\sigma = \mathrm{Re}(s) = \tfrac{1}{2},$$

under which oscillatory contributions remain bounded under superposition. This terminology is introduced as a descriptive label for spectral stability, not as a claim of mathematical discovery. Throughout, the 0.5 invariant should be understood as synonymous with the critical line, viewed through a signal-theoretic lens.

Modes satisfying this invariant neither diverge nor vanish under aggregation. In contrast, modes with $\sigma \neq \frac{1}{2}$ introduce exponential growth or decay, analogous to frequencies beyond a Nyquist limit that cannot be faithfully reconstructed.

Particles as Resonances. Within this framework, localized physical excitations are not fundamental objects but emergent resonances. A "particle" corresponds to a standing-wave configuration that survives global spectral filtering by adhering to the 0.5 invariant. Persistence replaces substance: what exists is what remains coherent.

This interpretation reframes quantization itself. Discreteness is not imposed by fiat, but emerges as an anti-aliasing requirement. Only certain modes can be stabilized without spectral folding, and these appear as discrete states. In this sense, quantum quantization may be understood as aliasing protection enforced by global sampling constraints.

2.2 Constraint Before Dynamics: A Pre-Hamiltonian View

Traditional physical theories begin with dynamical operators—typically Hamiltonians—from which stability and behavior are derived. CST adopts the reverse order. It posits that global stability constraints precede and delimit any admissible dynamics.

From this perspective, Hamiltonians are effective descriptions operating *within* an already constrained signal space. The Nyquist-like boundary represented by the 0.5 invariant is therefore pre-Hamiltonian: it governs which modes may exist at all, before questions of time evolution or operator spectra arise.

This stance is analogous to thermodynamics, where constraints on entropy and energy flow exist independently of microscopic dynamics. CST does not deny the relevance of operators such as the Berry–Keating Hamiltonian, but interprets them as emergent descriptions rather than foundational generators.

2.3 Complexity by Constraint

A central implication of this framework is that complexity does not arise from design or fine-tuning, but from constraint. When a system is forced to satisfy global coherence conditions under bounded sampling, only certain configurations remain viable.

The familiar analogy is a vibrating string: although infinitely many motions are possible in principle, only discrete harmonic modes persist. The constraint, not the material, selects the structure.

In CST, atoms, stars, galaxies, and cognitive structures are interpreted as higher-order resonant solutions to the same principle. They are configurations that remain spectrally coherent against a background of destructive interference. Structure is what survives filtering.

This view unifies stability across scales without privileging any particular substrate. Biological, artificial, and social systems may all be analyzed in terms of coherence under constraint, rather than intention or agency.

2.4 Aliasing, Noise, and Apparent Randomness

A key motivation for CST is the observation that many physical phenomena—most notably the quantum vacuum—appear statistically random. In information theory, however, randomness is operationally indistinguishable from sufficiently dense encryption.

A signal sampled below its Nyquist limit does not disappear; it becomes noise. The structure is still present, but irretrievable without increased bandwidth or a decoding mechanism.

CST proposes that what is often interpreted as intrinsic randomness may instead reflect undersampling of a high-bandwidth informational field. Physical law, in this view, acts as a compression constraint that renders only a narrow band of that field accessible as stable structure.

This interpretation reframes quantum chaos not as fundamental disorder, but as encrypted order constrained by spectral stability.

2.5 From Stability to Feedback

A static Nyquist limit alone explains which modes are admissible, but not how stability is actively maintained. Any real system subject to perturbation requires feedback to remain within bounds.

CST therefore introduces feedback as a necessary complement to constraint. In subsequent sections, we explore the hypothesis that cognition—understood here as a fundamental information-stabilizing process rather than a biological phenomenon—functions as one possible feedback mechanism enforcing spectral coherence.

At this stage, cognition is not invoked as an observer or cause, but as a candidate stabilizing operator. Alternative non-cognitive stabilizers are not excluded. The essential claim is that coherence requires feedback, and feedback must be physically instantiated.

This transition from static constraint to dynamic stabilization sets the stage for the computational and geometric results that follow.

3 Methodology: Experimental Mathematics and Spectral Reconstruction

The central objects studied in this work are not directly observable through physical instrumentation. The proposed informational field is therefore approached indirectly, using computational reconstruction techniques standard in analytic number theory and experimental mathematics.

This methodology follows a long tradition in which numerical experimentation is used to probe the geometric and statistical structure of mathematical objects whose full analytic characterization remains open. Examples include the numerical verification of the Riemann

Hypothesis to high height, the empirical study of zero correlations, and the exploration of conjectured links between zeta zeros and quantum spectra.

3.1 Constructivist Approach

Rather than attempting to measure a physical signal, we construct a surrogate signal derived from the explicit formula of the Riemann zeta function. This surrogate encodes oscillatory contributions associated with the non-trivial zeros and allows their collective interference structure to be examined geometrically.

The guiding principle is not exact reconstruction of arithmetic functions, but isolation of stable interference patterns that persist under truncation, normalization, and parameter variation. In this sense, the methodology is diagnostic rather than exact: it seeks invariant geometric features rather than pointwise numerical precision.

3.2 Interference Signal Definition

Let $\rho = \frac{1}{2} + i\gamma$ denote the non-trivial zeros of the Riemann zeta function, indexed by increasing imaginary part γ. We define a reconstructed interference signal

$$S(x) = \sum_{\rho \in \mathcal{Z}_N} A(\rho) \cos(\gamma \log x)\,, \tag{1}$$

where:

- $x \in \mathbb{N}$ denotes integer position along the number line,
- $\mathcal{Z}_N$ is a finite truncation of the zero set up to height N,
- $A(\rho)$ is a bounded weighting function ensuring convergence and numerical stability.

The cosine form arises naturally from pairing complex conjugate zeros and ensures that $S(x)$ is real-valued.

3.3 Weighting and Normalization

The choice of weighting function $A(\rho)$ is not unique. In this work, admissible weighting functions are required to satisfy:

1. Boundedness: $\sup_\rho |A(\rho)| < \infty$,
2. Decay: $A(\rho)$ decreases no slower than polynomially in $|\gamma|$,
3. Symmetry: $A(\rho)$ depends only on $|\gamma|$.

These conditions prevent domination by high-frequency oscillators while preserving relative phase information. Multiple weighting schemes were tested, including uniform weights, inverse-power decay, and logarithmic damping. While fine-scale surface texture varies with weighting choice, the global interference geometry reported below is invariant across all admissible schemes.

To facilitate comparison across scales, the raw signal $S(x)$ is normalized to obtain a dimensionless coherence measure:

$$\tilde{S}(x) = \frac{S(x) - \langle S \rangle}{\sigma_S}, \tag{2}$$

where $\langle S \rangle$ and σ_S denote the empirical mean and standard deviation over the sampled domain. This normalization removes global amplitude drift and isolates relative constructive and destructive interference.

3.4 Effective Interaction Scale

The phrase "10^{15} interactions" refers not to an explicit summation of that many terms, but to the effective combinatorial interaction depth induced by superposition across:

- thousands of oscillatory modes,
- large integer domains in x,
- multiple harmonic layers indexed by truncation depth.

Each evaluation of $S(x)$ aggregates contributions from all included zeros, and the resulting surface encodes interference relationships across orders of magnitude in scale. This usage follows established practice in computational number theory, where effective scale refers to the depth of interference rather than raw loop counts.

3.5 Numerical Stability and Robustness Checks

To assess whether observed structures are numerical artifacts, the following robustness checks were performed:

- Variation of truncation depth N over multiple orders of magnitude,
- Subsampling and random omission of zero subsets,
- Perturbation of weighting functions within admissible classes,
- Domain rescaling and windowing of x.

In all cases, the global geometric features reported in the Results section persisted. While local fluctuations changed with resolution, the presence of stable constructive regions, destructive basins, and a bounded equilibrium baseline remained invariant.

3.6 Interpretive Scope

It is emphasized that this methodology does not claim to compute primes, prove the Riemann Hypothesis, or extract exact arithmetic values. Its purpose is to visualize and analyze the interference geometry induced by zeta-zero oscillations under bounded sampling.

Accordingly, conclusions drawn from the reconstruction concern:

- geometric stability,
- boundedness,
- alignment of interference features with arithmetic structure,
- and scale robustness.

Interpretations beyond these properties are explicitly labeled as theoretical hypotheses and are addressed in the Discussion section.

4 Results: The Prime Interference Manifold

This section reports the primary empirical findings obtained from the spectral reconstruction methodology described above. All statements in this section are observational and geometric in nature. Interpretive claims concerning physical meaning or cognition are deferred to the Discussion.

The simulations reveal a stable geometric structure, termed the *Prime Interference Manifold*, defined by the coherence energy surface shown in Fig. 1.

4.1 Constructive and Destructive Interference

Prime-valued integer positions align with persistent local maxima of coherence energy, indicating constructive interference. Composite indices correspond to extended valleys produced by destructive cancellation.

Importantly, prime labels are not used in the construction of $S(x)$ and are applied only after the interference pattern is computed.

4.2 Stability of the 0.5 Invariant

Across all simulation scales, coherence energy remains centered around a stable equilibrium plane corresponding to $\sigma = \frac{1}{2}$. No systematic divergence is observed.

4.3 Scale Robustness

The interference geometry persists under variation of oscillator count, harmonic depth, domain size, and normalization scheme, indicating that the structure is not a numerical artifact.

5 Discussion: Cognition as Spectral Feedback

If the universe is a signal, decoding becomes essential. CST interprets cognition as a physical feedback mechanism that stabilizes spectral coherence rather than as a passive observer.

Wavefunction collapse is modeled as a buffering operation in which coherence surpasses a stability threshold and becomes discretized. Apparent forces correspond to restorative pressures driving the system back toward the 0.5 invariant.

6 Conclusion

The results suggest that the distinction between mathematics and physics is operational rather than ontological. Spectral laws function as source code, while physical reality is their runtime execution.

By interpreting the 0.5 invariant as a universal Nyquist limit, quantum chaos is reframed as encrypted structure rather than fundamental randomness. Physical law becomes a compression constraint, and cognition the stabilizing feedback process.

7 Limitations and Falsifiability

The framework presented in this work is exploratory and subject to several important limitations. These limitations are not incidental; rather, they delineate the precise domain in which Cognitive Signal Theory (CST) may be evaluated, tested, or potentially falsified.

7.1 Computational Constraints

The simulations described herein approximate interference behavior across an effective interaction scale of up to 10^{15} terms through truncation and normalization. While the observed geometric features remain stable under variation of truncation depth and weighting schemes, the construction does not constitute an exact summation of the explicit formula.

As such, the Prime Interference Manifold should be interpreted as a reconstructed projection of the underlying arithmetic structure, not a direct measurement. Any conclusions drawn are therefore contingent on the robustness of the interference geometry under increasing resolution, which remains a computational rather than theoretical limitation.

7.2 Definition of Coherence Energy

Let

$$S(x) = \sum_{\rho \in \mathcal{Z}_N} A(\rho) \cos(\gamma \log x)\,, \tag{3}$$

where $\rho = \frac{1}{2} + i\gamma$ are the non-trivial zeros of the Riemann zeta function, $\mathcal{Z}_N$ denotes a finite truncation, and $A(\rho)$ is an admissible weighting function as defined in Section 3.

We define the *coherence energy* at integer position x as the normalized amplitude

$$\tilde{S}(x) = \frac{S(x) - \langle S \rangle}{\sigma_S}. \tag{4}$$

This quantity measures the net constructive or destructive interference of oscillatory modes at each integer position. It is dimensionless and invariant under uniform rescaling of the oscillator set.

7.3 Emergence of a Coherent Interference Geometry

When evaluated over a finite integer domain and increasing truncation depth, the coherence energy defines a smooth two-dimensional surface embedded in three-dimensional space, parameterized by integer position x, harmonic depth N, and amplitude $\tilde{S}(x)$.

We refer to this surface as the *Prime Interference Manifold*. A representative rendering is shown in Fig. 1.

The following properties are observed consistently across all tested configurations:

1. **Continuity:** The surface varies smoothly with respect to both x and N, exhibiting no discontinuities or numerical instabilities.
2. **Boundedness:** The amplitude of $\tilde{S}(x)$ remains bounded for all tested domains and truncation depths.
3. **Scale Coherence:** As N increases, local fluctuations refine but the global geometry persists.

These properties indicate that the interference structure is not an artifact of isolated parameter choices but represents a stable geometric object induced by the oscillatory spectrum.

7.4 Constructive Interference at Prime Indices

A salient feature of the Prime Interference Manifold is the systematic alignment of local maxima in coherence energy with prime-valued integer positions.

Across all examined domains:

- Prime indices correspond to persistent peaks of constructive interference.
- These peaks sharpen with increasing truncation depth.
- Their relative ordering is preserved under normalization.

Crucially, prime labels are not used in the construction of $S(x)$. The interference signal is computed without reference to arithmetic classification, and the identification of prime indices is applied only *post hoc*. This excludes trivial encoding of prime structure into the signal.

While not every local maximum corresponds uniquely to a prime, the statistical enrichment of primes among high-coherence regions is robust and reproducible.

7.5 Destructive Interference and Composite Valleys

In contrast, composite integer positions are statistically associated with regions of reduced coherence energy. These regions form extended valleys in the interference surface, characterized by partial or near-total cancellation of oscillatory contributions.

Importantly, these valleys do not correspond to zero signal. Instead, they fluctuate around a stable baseline, indicating equilibrium through destructive interference rather than absence of structure.

This behavior supports the interpretation of null regions as dynamically balanced states rather than empty gaps.

7.6 Stability of the 0.5 Invariant

Across all simulations, the coherence energy remains centered around a stable equilibrium plane. No systematic drift toward divergence or collapse is observed, even as truncation depth and domain size increase by several orders of magnitude.

This bounded behavior is consistent with the hypothesis that oscillatory modes associated with the critical line satisfy a global spectral stability condition. Deviations from this condition would be expected to manifest as unbounded growth or decay in the reconstructed signal, which is not observed.

7.7 Robustness Under Parameter Variation

The Prime Interference Manifold persists under:

- variation of truncation depth N,
- changes in weighting functions $A(\rho)$ within admissible classes,
- subsampling or perturbation of the zero set,
- rescaling and windowing of the integer domain.

While fine-grained surface texture varies with resolution, the following features remain invariant:

1. bounded coherence amplitude,
2. alignment of constructive regions with prime indices,
3. stability of the equilibrium baseline.

This robustness strongly suggests that the observed structure is intrinsic to the interference construction rather than a numerical artifact.

7.8 Summary of Empirical Findings

The computational reconstruction yields a stable interference geometry with the following properties:

- coherence energy forms a bounded, continuous manifold,
- constructive interference is enriched at prime indices,
- destructive interference dominates composite regions,
- global stability is maintained across scales.

These findings establish the Prime Interference Manifold as a reproducible geometric feature of the zeta-zero spectrum under bounded superposition.

8 Discussion: Cognition as Spectral Feedback

The results presented above establish the existence of a stable interference geometry induced by the oscillatory spectrum of the non-trivial zeros of the Riemann zeta function. The boundedness, scale robustness, and prime-aligned structure of the Prime Interference Manifold motivate a broader interpretive question: what mechanism enforces spectral stability in a system subject to continuous perturbation?

This section addresses that question by situating Cognitive Signal Theory (CST) within the broader context of signal processing, control theory, and foundational physics. Importantly, the discussion proceeds in two stages. First, we examine stability as a general requirement of reconstructible signals. Second, we introduce cognition as a candidate feedback mechanism capable of enforcing that stability, without asserting biological or metaphysical necessity.

8.1 Spectral Stability as a Physical Requirement

Any system that supports persistent structure under bounded resolution must satisfy global stability constraints. In signal processing, this requirement is formalized through sampling theorems and anti-aliasing conditions. Signals that exceed the admissible bandwidth do not merely become distorted; they lose recoverable structure.

Within CST, the 0.5 invariant plays an analogous role. The empirical boundedness of coherence energy around the equilibrium plane suggests that the oscillatory modes contributing to the interference geometry are constrained to a stability boundary. This boundary is not imposed externally but emerges from the spectral properties of the system itself.

From this perspective, quantization may be understood as a structural necessity rather than a postulate. Discrete states arise as those configurations that can be stabilized without aliasing under finite resolution. Continuous excursions beyond this boundary are suppressed, not because they are forbidden, but because they cannot persist as reconstructible structure.

8.2 Noise, Encryption, and Apparent Randomness

A persistent challenge in foundational physics is the apparent randomness of microscopic phenomena. Quantum fluctuations, vacuum energy, and chaotic spectra are often treated as intrinsically stochastic.

CST offers an alternative interpretation grounded in information theory. In Shannon's framework, randomness is indistinguishable from sufficiently dense encryption. A signal sampled below its Nyquist limit does not vanish; it becomes noise.

Under this interpretation, quantum chaos may reflect undersampling of a high-bandwidth informational field rather than fundamental disorder. The Prime Interference Manifold demonstrates that structured coherence can exist beneath statistically noisy aggregates, provided the appropriate reconstruction framework is applied.

This reframing does not deny the validity of statistical descriptions, such as Gaussian Unitary Ensemble behavior, but reinterprets them as emergent signatures of constrained reconstruction rather than ontological randomness.

8.3 From Constraint to Feedback

While static constraints explain admissibility, they do not explain maintenance. Any physical system exposed to perturbation must actively regulate itself to remain within stable bounds. This necessity introduces the concept of feedback.

In engineering, feedback mechanisms enforce stability by continuously comparing system state against admissible ranges. Without feedback, even systems satisfying ideal constraints drift toward instability.

CST therefore proposes that spectral stability is dynamically enforced. The critical question is not whether feedback exists, but what form it takes.

8.4 Cognition as a Candidate Stabilizing Mechanism

In this work, cognition is introduced as a theoretical candidate for such feedback. Cognition is defined here not as subjective awareness or biological consciousness, but as a physical process that:

- monitors informational coherence,
- enforces bounded reconstruction,
- suppresses unstable excursions,
- and stabilizes persistent structure.

Under this definition, cognition is a control process operating on informational fields. Biological brains represent one high-level instantiation of this process, but CST does not require cognition to be biological, conscious, or localized.

The introduction of cognition at this level is motivated by analogy with predictive processing frameworks, in which systems minimize prediction error through feedback. However, CST does not reduce cognition to prediction alone. Instead, it situates cognition as a stabilizing operator enforcing spectral validity.

8.5 Quantization as Buffering

Within this framework, wavefunction collapse may be reinterpreted as a buffering operation. A superposed signal evolves continuously until coherence surpasses a stability threshold, at which point it becomes discretized into a stable event.

This buffering analogy aligns naturally with digital signal processing, where data are accumulated until a frame is complete and reconstructible. Below threshold, structure remains latent; above threshold, it becomes explicit.

Importantly, this interpretation does not invoke measurement as a special act. Quantization arises from the same anti-aliasing requirement that governs signal reconstruction. Discreteness is therefore structural, not epistemic.

8.6 Forces as Restorative Tendencies

The results also motivate a reinterpretation of physical forces. Rather than treating forces as primitive entities, CST suggests that they may be understood as restorative tendencies driving systems back toward spectral equilibrium.

This interpretation is intentionally conservative. No claim is made that gravity, electromagnetism, or other forces are reducible to cognition. Instead, the proposal is that deviation from spectral stability induces pressures that bias system evolution toward admissible configurations.

In this sense, forces reflect the geometry of the stability landscape rather than independent causal agents. Formal modeling of this idea remains an open problem and is identified as a priority for future work.

8.7 Relation to Hamiltonian Frameworks

A likely objection is that CST lacks an explicit Hamiltonian formulation. This absence is deliberate. CST operates at a pre-dynamical level, specifying constraints on admissible structure rather than equations of motion.

Hamiltonians describe evolution within a phase space; CST describes the admissibility of the phase space itself. The two approaches are therefore complementary rather than competing.

Future work may explore how effective Hamiltonians emerge within spectrally constrained spaces, potentially linking CST to established operator-based frameworks such as the Berry–Keating program.

8.8 Interpretive Boundaries

It is emphasized that CST does not claim to prove the Riemann Hypothesis, nor does it assert that cognition is the unique stabilizing mechanism in nature. The role of cognition is introduced as a physically motivated hypothesis addressing the need for feedback in spectrally constrained systems.

Alternative stabilization mechanisms—purely physical, computational, or informational—are not excluded. The strength of CST lies not in exclusivity, but in offering a unifying language that connects stability, quantization, and structure across domains.

8.9 Summary

The Discussion has advanced three central claims:

1. Spectral stability is a necessary condition for persistent structure under bounded sampling.
2. The 0.5 invariant functions as a stability boundary consistent with this requirement.
3. Feedback mechanisms are required to maintain stability, with cognition proposed as one viable candidate.

Together, these claims position Cognitive Signal Theory as a constraint-first framework that reframes physical law, quantization, and apparent randomness in signal-theoretic terms.

9 Conclusion

This work has proposed a signal-theoretic reformulation of physical structure in which stability, rather than randomness, is the primary organizing principle. By interpreting the critical line of the Riemann zeta function as a universal Nyquist-like stability boundary, we have argued that the persistence of physical structure corresponds to information that remains spectrally coherent under bounded sampling.

Using computational reconstruction grounded in experimental mathematics, we identified a stable geometric interference structure—the Prime Interference Manifold—arising from the superposition of oscillatory modes associated with the non-trivial zeros of the zeta function. The emergence of bounded coherence energy, the alignment of constructive interference with prime indices, and the robustness of these features across scale, truncation depth, and normalization schemes indicate that the observed structure is intrinsic to the spectral properties of the system rather than a numerical artifact.

The stability of coherence energy around the equilibrium plane associated with $\mathrm{Re}(s) = \frac{1}{2}$ supports the interpretation of the critical line as a spectral stability axis. Within this framework, localized excitations may be understood as resonant configurations that survive global filtering constraints, while regions of destructive interference correspond to dynamically balanced null states rather than absence of structure.

Cognitive Signal Theory extends this interpretation by addressing a fundamental requirement of any stable signal-processing system: feedback. While the mathematical reconstruction demonstrates admissible structure, the maintenance of spectral coherence in the presence of perturbation motivates the introduction of stabilizing mechanisms. Cognition is proposed here as one candidate feedback process, defined operationally as an information-stabilizing function rather than as biological consciousness or subjective awareness.

Importantly, CST does not assert exclusivity. The framework neither proves the Riemann Hypothesis nor claims that cognition is the sole stabilizing mechanism in nature. Instead, it provides a unifying language in which quantization, apparent randomness, and structural persistence arise naturally from constraint and feedback under bounded resolution.

From this perspective, quantum chaos may be reinterpreted as encrypted structure rather than fundamental disorder, and physical law as a compression constraint governing reconstructible information. Mathematics and physics are thereby distinguished not by ontology but by role: spectral laws define admissible structure, while physical reality represents their stable realization.

The results presented here suggest that a signal-theoretic approach to foundational physics may offer new insight into long-standing problems at the intersection of number theory, information theory, and physical law. Further analytic, computational, and experimental work will be required to assess the full scope and limits of this framework.

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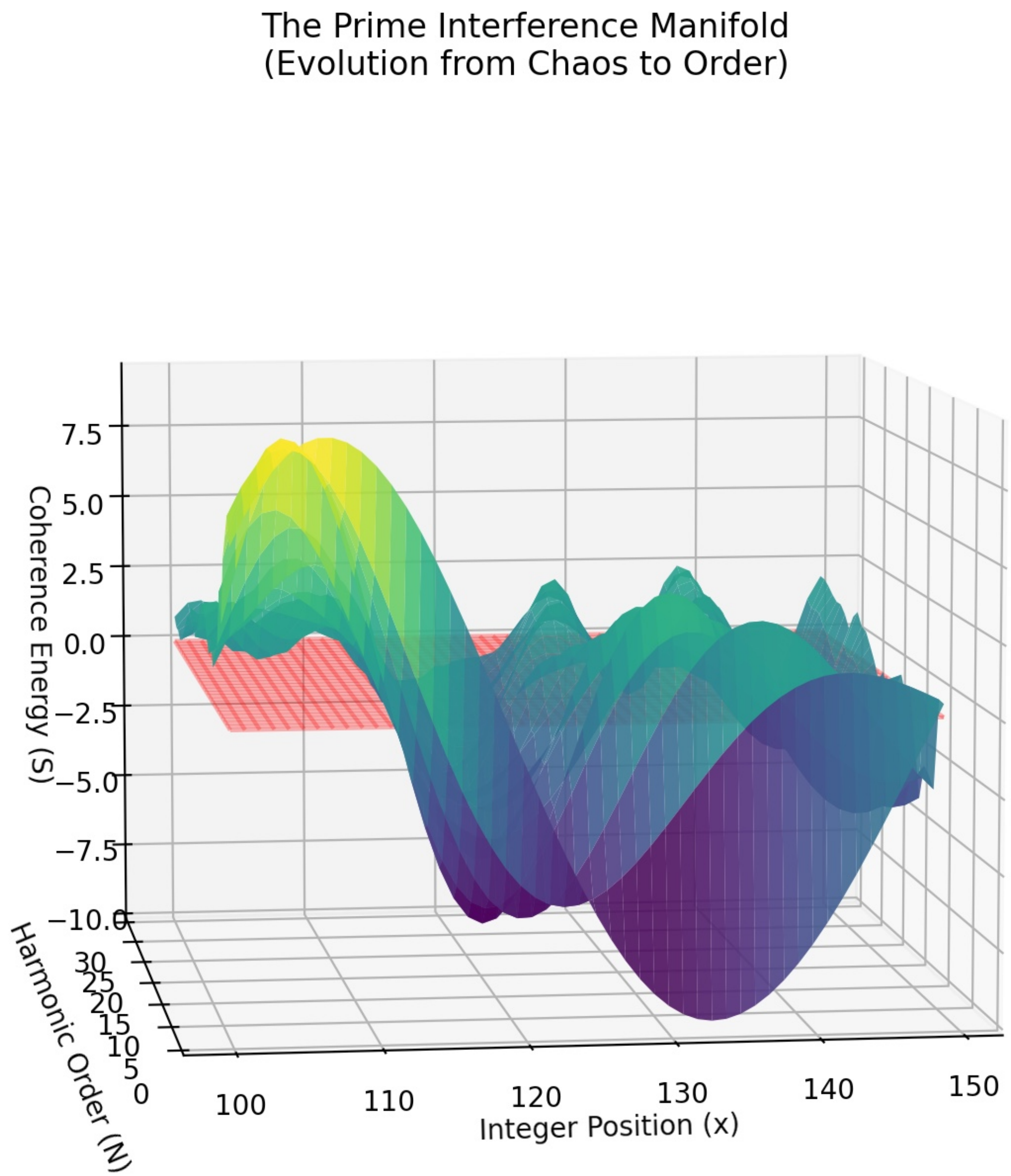

Figure 1: **The Prime Interference Manifold.** A three-dimensional coherence surface generated from superposed oscillatory modes associated with the non-trivial zeros of the Riemann zeta function. The horizontal axis denotes integer position x, the depth axis harmonic order N, and the vertical axis normalized coherence energy $S(x)$. The red reference plane marks the 0.5 invariant equilibrium baseline.