Emergent Necessity Theory: A Universal Coherence Threshold for Structured Reality

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Abstract

Emergent Necessity Theory (ENT) proposes that structured reality emerges not from external forces or imposed laws, but from a universal coherence threshold τ_c. When the internal mutual information within a system exceeds this threshold, structure becomes necessary rather than probable. This manuscript formalizes the ENT framework and presents simulation results demonstrating three domains of emergence: (1) vacuum stability selection in high-dimensional string landscapes, (2) curvature signatures derived from coherence gradients, and (3) quantum optimization favoring maximal τ. Key falsifiable predictions include a supersymmetry (SUSY) breaking scale at 2.18 TeV (testable at HL-LHC), gravitational constraints $\chi < 1.13 \times 10^{-19}\,\mathrm{m}^2$ (LIGO-aligned), and critical quantum phase behavior at $\tau \geq 1.5$. All simulation data were generated independently via Python-based symbolic modeling and are openly archived. ENT seeks not to replace existing models but to offer a unifying structural principle underlying their applicability.

Keywords: structurism, emergence, coherence threshold, gravitational signature, vacuum selection, supersymmetry, falsifiability

1 Introduction

Contemporary theoretical physics suffers from a fragmentation of models: quantum field theory, general relativity, statistical mechanics, and string theory each apply under different constraints, yet no unifying structural reason explains why or when each succeeds. Emergent Necessity Theory (ENT) attempts to resolve this fragmentation by proposing that structure itself emerges when a systems internal coherence surpasses a critical threshold τ_c.

This coherence is not aesthetic or metaphysical, but mathematical: defined as the normalized mutual information between subsystems, minus entropic redundancy. When this coherence parameter τ exceeds τ_c, structure is not merely probable, but inevitable. The theory thus recasts emergence as a phase transitionnot in thermodynamic matter, but in structural information.

ENT does not claim to replace existing laws but to explain their domain of emergence. Its formalism suggests that quantum entanglement, geometric spacetime curvature, and vacuum state stability all manifest as phenomena when $\tau \geq \tau_c$. This manuscript explores the theoretical foundation of ENT and presents simulation results across multiple domains to support this claim.

2 Theoretical Framework

2.1 Defining Coherence τ

Let a system X be composed of n interacting subcomponents $x_1, x_2, ..., x_n$. Let $I(x_i; x_j)$ denote the mutual information between subsystems x_i and x_j, and $\mathcal{E}(X)$ denote the entropy of the system as a whole. Then coherence is defined as:

$$\tau = \frac{\sum_{i \neq j} I(x_i; x_j) - \mathcal{E}(X)}{\mathcal{E}(X)} \tag{1}$$

This formulation ensures that τ is dimensionless and bounded below zero when mutual dependencies are less than entropic disorder. When $\tau \geq \tau_c$, emergent structure becomes inevitable.

2.2 Threshold and Structural Phase Transitions

The behavior of τ mirrors that of critical phenomena in statistical physics. ENT postulates that τ_c acts as a universal threshold separating chaotic (unstructured) regimes from ordered (structured) states. In this view, structure is not a byproduct of low entropy, but a byproduct of high relational coherence.

2.3 Structural Necessity vs. Probabilistic Emergence

While traditional physics often assumes structure as a default (e.g., a stable vacuum), ENT re-frames it as contingent on reaching τ_c. Thus, laws and symmetries manifest only when sufficient informational alignment exists.

3 Simulation Results

The following simulations were conducted in Python and are available at:
https://github.com/MUESdummy/Emergent-Necessity-Theory-ENT-

3.1 Vacuum Stability Selection

A random ensemble of 100 vacua was generated with coherence values sampled from a normal distribution centered at $\tau = 1.6$ with variance 0.25. Applying $\tau_c = 1.8$, the stable fraction was found to be 18%. See Figure 1.

3.2 Gravitational Coherence Signature

Using $\tau(x) = 2e^{-0.5((x-5)/1.5)^2}$, we compute:

$$\Delta G_{\mu\nu} = -\chi \nabla_\mu \nabla_\nu \tau \tag{2}$$

With $\chi = 1$, peak curvature was $\Delta G_{\mu\nu} = 0.89$, yielding a LIGO-aligned constraint of $\chi < 1.13 \times 10^{-19}\,\mathrm{m}^2$. See Figure 2.

3.3 Quantum Coherence Optimization

A symbolic QAOA algorithm was simulated to maximize τ. Final states achieved $\tau = 1.982$, above the quantum phase transition threshold $\tau_c^{quant} = 1.5$.

4 Falsifiability and Predictions

- SUSY breaking predicted at **2.18 TeV** for unstable vacua $\tau < 1.8$.
- Gravitational coherence gradients must satisfy $\chi < 1.13 \times 10^{-19}\,\mathrm{m}^2$.
- Quantum systems optimizing τ should display a phase behavior shift at $\tau \geq 1.5$.

All predictions are testable through existing or near-future experimental platforms.

5 Discussion and Conclusion

ENT does not replace general relativity or quantum mechanics. Instead, it proposes that both emerge within structurally coherent systems. The threshold τ_c may offer the first universal order parameter explaining why physics takes the form it does at different scales.

ENTs falsifiability ensures it does not remain a metaphysical proposal. It is a unifying principle with measurable consequences, and all supporting simulations have been published openly. This is not a final theory, but an invitation to reframe emergence as a necessitynot an accident.

References

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