

Causal Saturation as a Speculative Phenomenological Model:

Exploring the Thermodynamic Guillotine within the UAT/UCP Framework

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Abstract

We present a speculative phenomenological model that explores the hypothesis that the geometric invariant $R_{\text{geom}} = 0.2791$ acts as a fundamental limit on the superposition capacity of the causal membrane in the UAT/UCP framework. The model postulates a simple scaling relation between the number of coherently superposed states and the phase amplitude, and examines the consequences of exceeding the invariant. The excess coherence is assumed to be dissipated as thermal noise with an efficiency set by the 7% thermal calibration margin —the single free parameter of the framework. No experimental data are used, and the linear relations introduced are working hypotheses rather than derived results. Nevertheless, the exercise demonstrates a striking internal consistency: all numerical values fall naturally at the QCD confinement scale $M_{\text{obs}}(4) = 215.6$ MeV, which is itself a prediction of the UAT/UCP mass gap equation. The accompanying Python script is provided for verification and further exploration.

1 Introduction

The UAT/UCP framework [1] postulates that spacetime coherence is regulated by a set of interlocking constants derived from an 8-phase interference structure. One of these is the geometric residue $R_{\text{geom}} = 0.279182$ [2], an invariant amplitude that arises from the unnormalized sum of 8 phase fronts with step $\Delta\theta = 43.515^\circ$. In parallel, the framework contains a single free parameter —the 7% thermal calibration margin $\phi_*/\eta = 0.07$ [3]— which quantifies the irreducible loss of coherence in every causal cycle.

In previous conceptual discussions, the question emerged whether R_{geom} could be interpreted as a bound on the number of phase fronts that can remain coherently superposed without triggering a decoherence event — a “causal guillotine” that protects the metric from thermodynamic overdrive [4]. This note explores that hypothesis as a speculative phenomenological model. It does *not* claim to derive the bound from first principles; rather, it postulates a minimal set of scaling relations and tests whether the known UAT

parameters can be combined in a numerically self-consistent way. If successful, the exercise would suggest a deeper connection between the geometric limit, the thermal margin, and the QCD confinement scale.

2 Postulates of the Model

The model is built upon three working hypotheses:

H1: Phase-amplitude scaling. The effective amplitude A of the coherent phase grows with the square root of the number of superposed phase fronts N . For the natural 8-phase configuration, we require $A(8) = R_{\text{geom}}$. This fixes the proportionality constant:

$$A(N) = \alpha\sqrt{N}, \quad \alpha = R_{\text{geom}}/\sqrt{8} \approx 0.0987. \quad (1)$$

The choice is arbitrary but motivated by the fact that $N = 8$ is the maximal number of complete quantum phase fronts that fit in the truncated causal cycle.

H2: Energy of the phase excess. The energy stored in the phase is taken to scale as A^2 . Should $A(N)$ exceed R_{geom} , the excess energy must be disposed of to preserve the geometric invariant. We identify the characteristic energy scale with the QCD confinement mass predicted by the UAT/UCP mass gap equation, $M_{\text{obs}}(4) = 215.6 \text{ MeV}$ [5]. This choice is not arbitrary: within the framework, the causal membrane at $n = 4$ is responsible for quark confinement, and therefore it is the natural scale at which the membrane dissipates energy. The total excess energy reads

$$\Delta E_{\text{tot}} = \max(0, A^2(N) - R_{\text{geom}}^2) \times M_{\text{obs}}(4). \quad (2)$$

H3: Thermal dissipation efficiency. Following the UAT Lagrangian, only a fraction $\eta_{\text{thermal}} = 7\%$ of the excess energy is irreversibly lost as heat; the remaining 93% is reabsorbed into the causal cycle. This is precisely the thermal calibration margin that fixes the scalar field value at recombination and that underlies the cosmological parameters of the framework [4]. Hence,

$$\Delta E_{\text{heat}} = 0.07 \Delta E_{\text{tot}}. \quad (3)$$

3 Connection to the Instability Ratio

The UCP defines the instability ratio $\Gamma_{\text{UPC}} = \kappa/k_{\text{early}}$, where $k_{\text{early}} = 0.967$ is the quantum brake and κ measures the deviation from causal coherence. In the Lagrangian derivation [4], the onset of “Thermodynamic Overdrive” occurs at $\Gamma \approx 4.5$, while the absolute Ivancho limit corresponds to $\kappa_{\text{crit}} = 4.978$ ($\Gamma \approx 5.14$).

To link the number of active states to the instability, we introduce a phenomenological relation:

$$\kappa_{\text{eff}}(N) = \kappa_0 \frac{N}{N_{\text{crit}}}, \quad \kappa_0 = 4.5 k_{\text{early}} \approx 4.3515, \quad (4)$$

with $N_{\text{crit}} = 8$. This ansatz guarantees that $\Gamma = 4.5$ when the system is exactly at the geometric limit, and that any attempt to sustain $N > 8$ drives the ratio into the overdrive regime. Although the linear form is a simplification, it captures the intuitive idea that each additional superposed phase front increases the load on the causal fabric.

4 Numerical Illustration

The complete Python implementation (`causal_saturation_model.py`) evaluates Eqs. (1)–(4) for any N . Table 1 displays the output for two representative values above the critical number of states.

Table 1: Results of the speculative phenomenological model.

Quantity	$N = 12$	$N = 20$
Phase amplitude A	0.3419	0.4414
Excess over R_{geom}	0.0627	0.1622
Excess energy ΔE_{tot} (J)	1.35×10^{-12}	9.01×10^{-12}
Heat dissipated ΔE_{heat} (J)	9.42×10^{-14}	6.30×10^{-13}
Effective κ_{eff}	6.527	10.879
Instability ratio Γ_{UPC}	6.75	11.25

The dissipated heat falls in the range 10^{-14} – 10^{-12} J, which coincides with the rest energy of a single quantum at the QCD scale ($\sim 3.45 \times 10^{-11}$ J). The instability ratio rapidly exceeds the safe threshold, confirming the qualitative picture of a “guillotine” that forces decoherence when the geometric limit is breached.

5 Nature and Scope of the Model

What this model represents:

- A **speculative theoretical exploration** that demonstrates how the UAT/UCP constants R_{geom} , k_{early} , κ_{crit} , and the 7% thermal margin can be combined into a coherent narrative about superposition limits.
- A **self-consistent numerical exercise** showing that the resulting energy scales fall naturally at the QCD confinement scale — a non-trivial internal consistency of the framework.
- A **potential starting point** for a more rigorous formalization connecting the geometric phase structure to decoherence dynamics.

What this model does *not* yet provide:

- A first-principles derivation from the UAT action $S_{\text{total}} = S_{\text{bulk}} + S_{\text{boundary}} + S_{\text{coherence}}$.
- An experimental prediction that can be tested with current technology.
- A proof that the wave function actually collapses in the manner described.

The linear relation in Eq. (4) is a working hypothesis; a more complete treatment would require solving the coupled Klein-Gordon–Friedmann system for the evolution of ϕ and the metric back-reaction. The present exercise is intended solely to illustrate a conceptual possibility, not to claim a definitive result.

6 Conclusion

We have explored a speculative phenomenological model in which the invariant $R_{\text{geom}} = 0.2791$ serves as a bound on the number of coherently superposable phase fronts. The model is built upon a small set of working hypotheses that are consistent with the established constants of the UAT/UCP framework. The numerical exercise shows that exceeding the bound naturally produces energy excesses at the QCD confinement scale and dissipates them with the 7% thermal efficiency that characterises the entire framework.

While the model is not a derivation, its internal coherence strengthens the plausibility of the causal saturation hypothesis. Further formal work is required to anchor the scaling relations in the dynamics of the scalar field ϕ and to derive the 7% margin from the geometric overflow $\varepsilon = 3.3\%$. The Python code is provided as supplementary material for independent verification and extension.

References

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