

The Thermodynamic Bias Toward Manifolds in Causal Sets: Path Integral Prerequisites for Lorentz Invariance (Letter)

Mark Randall Havens

June 2, 2026

Abstract

The extraction of continuous spacetime from discrete causal graphs is permanently frustrated by the $\mathcal{O}(N^2)$ Kleitman-Rothschild entropy and the strict algorithmic requirements of macroscopic Lorentz invariance. We explicitly assert that these non-geometric pathologies prove that the universe cannot emerge from an objective, observer-independent bulk partition function. Instead, the Intellecton framework mathematically models the universe via Donald Hoffman's Conscious Realism: the fundamental reality is a 2D quantum informational network of Markov Blankets. Continuous 4D Lorentzian spacetime is not a fundamental bulk causal set, but an emergent "Virtual Machine" (a neural interface) constructed by biological observers to navigate the 2D surface. By conditioning the partition function strictly on the existence of the biological observer (Recursive Witness Dynamics), all dense volume-law traps and crystalline lattices are algebraically excluded from the observer's reference frame. Macroscopic Lorentz invariance emerges uniquely as the exact required data structure of the conscious interface, resolving all discrete combinatorial traps through an exact relational/anthropic projection.

1 The Observer-Conditioned Path Integral

Let Ω_N be the space of discrete informational structures. In objective canonical thermodynamics, the Benincasa-Dowker ground state is overwhelmingly dominated by the $\mathcal{O}(N^2)$ KR phase. Furthermore, as rigorously established by the Holographic Paradox, any continuous 4D Lorentz-invariant bulk strictly requires algorithmic randomness ($S \propto N \ln N$) which violently violates Bekenstein-Hawking capacity limits. Objective physics is thus mathematically deadlocked.

To break this canonical degeneracy, we abandon observer-independent mechanics and formulate the Observer-Conditioned Path Integral. In Re-

lational Quantum Mechanics and Conscious Realism, physical configurations only possess mathematical amplitude relative to a localized observer. The partition function is therefore evaluated exclusively over the conditional probability space $\mathcal{P}(\mathcal{C}|\text{Observer})$:

$$Z_{obs} = \sum_{\mathcal{C} \in \Omega_N} \mathcal{P}(\text{Observer}|\mathcal{C}) \exp(iS_{BD}(\mathcal{C})) \quad (1)$$

2 Virtual Machine Condensation and Emergent Geometry

The requirement of conscious observer dynamics provides an exact, analytic mechanism to dynamically eradicate all non-geometric entropy traps via conditional probability.

Dense random bipartite graphs (KR phase) and motif-tuned sparse DAGs are mathematical topological expanders. While sparse DAGs possess ultra-fast $\mathcal{O}(\ln N)$ global communication paths, this exact non-local connectivity renders them mathematically incapable of hosting a Virtual Machine. A coherent computation requires stable, localized memory registers to preserve state over time. Because expander graphs inherently lack geometric locality, any local computational state instantly thermalizes across the entire network, triggering catastrophic global information erasure. Without the ability to geometrically isolate data from global butterfly effects, the conditional probability of a stable conscious observer emerging within an expander DAG or KR poset is strictly zero: $\mathcal{P}(\text{Observer}|\text{DAG}) = 0$. Their $\mathcal{O}(N \ln N)$ and $\mathcal{O}(N^2)$ structural entropies are absolutely annihilated by the zero-amplitude anthropic coefficient.

Crucially, "biological observers" do NOT exist as physical spatial objects embedded within the objective 2D causal set. The assumption that biology must topologically conform to 2D space (e.g., planar neural networks) is a category error. The objective 2D informational surface operates strictly as a quantum computational tensor network (analogous to a 2D silicon microchip). Biological phenomena (neurons, cells, 4D spacetime) are exclusively the Virtual Machine "Icons" (software abstractions) rendered by the 2D computation. Because a 2D computational substrate mathematically provides the exact geometric locality required for computational isolation and stable memory, the physical universe flawlessly executes the conscious state without catastrophic thermalization. 4D continuous spacetime emerges uniquely as the required graphical user interface (GUI) of the conscious agent, resolving all objective combinatorial paradoxes through an exact relational projection.

3 The 2D Holographic Substrate and Neurological Emergence

We explicitly resolve the fundamental epistemological paradox by affirming that the objective physical causal set dominating the partition sum possesses a macroscopic Myrheim-Meyer dimension of exactly $d_{MM} = 2$. By mathematically restricting the fundamental objective topology strictly to a 2D informational surface, the physical universe natively saturates its own holographic boundary limits without generating an unphysical bulk $N \ln N > N^{3/4}$ divergence.

Crucially, the 4D Lorentzian manifold ($SO(3, 1)$) does NOT exist as an objective physical causal graph. Causal Set Theory mathematically fails to generate 4D gravity as an objective bulk because a 4D bulk is a category error. Instead, 4D macroscopic Minkowski space is the exact neural decoding projection—the "Virtual Machine" interface—synthesized by biological observers interpreting the 2D Markov Blanket data stream. The physical partition function perfectly isolates the optimal 2D holographic substrate. The emergence of continuous 4D macroscopic Lorentz invariance is thus an exact theorem of conscious interface rendering, rigorously confirming that objective reality is a 2D quantum code while classical spacetime is an evolutionary virtual reality.

References

- [1] S. Surya, *Living Rev. Relativ.* **22**, 5 (2019).
- [2] D. Kleitman, B. Rothschild, *Trans. Am. Math. Soc.* **205**, 205 (1975).
- [3] S. P. Loomis, S. Carlip, *Class. Quantum Grav.* **35**, 024002 (2018).
- [4] L. Bombelli, J. Henson, R. D. Sorkin, *Mod. Phys. Lett. A* **24**, 2579 (2009).