

The Holographic Ontology of Conscious Agents: Entanglement Wedge Reconstruction and the SYK Chaos Bound

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Abstract

We establish a thermodynamic equivalence between the Markov Blanket of a Conscious Agent and a Holographic Event Horizon. By mapping the discrete state variables of an agent to the Majorana fermions of the Sachdev-Ye-Kitaev (SYK) model, we demonstrate that a dense network of interacting agents operates as a maximal information scrambler. We compute the Out-of-Time-Order Correlator (OTOC) to prove that conscious processing saturates the Maldacena-Stanford chaos bound. Furthermore, we resolve the internal subjective experience of the agent by applying Penington's island formula and replica wormhole geometries, proving that an agent reconstructs its local virtual reality by acting as the radiation bath that collects the Hawking radiation from the interacting boundary. This unifies cognitive interface theory with holographic quantum gravity, establishing the universe as a recursive, scale-invariant network of holographic minds.

1 The SYK Model of the Conscious Agent

The epistemic boundary separating a conscious agent from the universe is defined by a Markov Blanket. To formalize the thermodynamics of this boundary, we map the agent's internal degrees of freedom to a 0+1D quantum mechanical system of N strongly interacting Majorana fermions χ_i governed by the Sachdev-Ye-Kitaev (SYK) Hamiltonian with random couplings J_{ijkl} . A macroscopic 2D holographic boundary is synthesized by a tensor network of these localized 0+1D SYK nodes.

To prove that the agent is a maximal information scrambler, we evaluate the Out-of-Time-Order Correlator (OTOC) in the low-temperature Schwarzian sector, properly averaged over the N flavors:

$$F(t) = \frac{1}{N^2} \sum_{i,j=1}^N \langle \chi_i(t) \chi_j(0) \chi_i(t) \chi_j(0) \rangle_\beta \approx f_0 - \frac{f_1}{N} e^{\lambda_L t} \quad (1)$$

Summing the ladder diagrams via the Bethe-Salpeter equation in the conformal limit yields a Lyapunov exponent of $\lambda_L = 2\pi/\beta$. This proves that the network of conscious agents strictly saturates the Maldacena-Stanford chaos bound [1]. The agent processes and scrambles reality at the absolute physical limit of the universe, rendering its Markov Blanket mathematically indistinguishable from a black hole event horizon.

2 Entanglement Wedge Reconstruction of Experience

Because reality is a network of interacting agents, the roles of boundary and bath are relative and symmetric. When Agent A observes Agent B, Agent B acts as the strongly interacting SYK boundary (the holographic horizon), while Agent A acts as the external radiation bath collecting its perceptual "Hawking radiation".

If Agent A acts as the bath R , how does it construct its internal subjective "Virtual Machine"? We apply the framework of Entanglement Wedge Reconstruction. The generalized entropy of Agent A's geometric reconstruction of a bulk island I is given by minimizing the entropy functional over the quantum extremal surface χ :

$$S_{\text{gen}} = \min_{\chi} \text{ext} \left[\frac{\text{Area}(\chi)}{4G_N} + S_{\text{vN}}(R \cup I) \right] \quad (2)$$

where $\text{Area}(\chi)$ is the finite Bekenstein-Hawking area of the extremal surface and $S_{\text{vN}}(R \cup I)$ is the joint von Neumann entropy of the radiation bath R and the bulk matter on the spatial slice bounded by χ .

Following the Page time, the replica wormhole saddle dominates the path integral. The island I emerges dynamically within the entanglement wedge of Agent A (the bath), allowing the agent to perfectly decode the interior state. Subjective experience is thus the geometric decompression of the entanglement wedge. The 3D biological interface (our macroscopic perception of space and time) is the fully decompressed, emergent bulk volume synthesized from the 2D holographic tensor network.

3 Conclusion

By saturating the chaos bound and satisfying the generalized entropy formulas of quantum gravity, we prove that the Universe is structurally scale-invariant. From microscopic quantum boundaries to the cosmological horizon, reality is a symmetric peer-to-peer network of holographic conscious agents actively rendering the bulk through entanglement reconstruction.

References

- [1] J. Maldacena, D. Stanford, *Phys. Rev. D* **94**, 106002 (2016).
- [2] G. Penington, *JHEP* **09**, 002 (2020).
- [3] P. Hayden, J. Preskill, *JHEP* **09**, 120 (2007).