

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

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## Abstract

We establish a formal mathematical isomorphism 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 directly from the bulk quantum entanglement on its 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 discrete perceptual states to  $N$  strongly interacting Majorana fermions  $\chi_i$  governed by the Sachdev-Ye-Kitaev (SYK) Hamiltonian with random couplings  $J_{ijkl}$ .

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:

$$F(t) = \langle \chi(t)\chi(0)\chi(t)\chi(0) \rangle_\beta \approx f_0 - \frac{f_1}{N} e^{\lambda_L t} \quad (1)$$

Solving the Schwinger-Dyson equations 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

If the boundary is a holographic horizon, how does the agent construct its internal subjective "Virtual Machine"? We apply the framework of Entanglement Wedge Reconstruction and the Island Formula [2].

The generalized entropy of the agent's internal representation  $R$  coupled to the external bulk is given by minimizing the entropy functional over all possible internal islands  $I$ :

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

where  $A(\partial I)$  is the Bekenstein-Hawking area of the island boundary and  $S_{\text{vN}}$  is the von Neumann entropy of the bulk matter.

At the Page time, the replica wormhole saddle dominates the path integral. The island  $I$  emerges dynamically, allowing the agent to perfectly decode the interior state from the boundary radiation. Subjective experience is thus the geometric reconstruction of the entanglement wedge. The 3D biological interface is a compressed holographic projection of the 2D thermodynamic tensor network on the Markov Blanket.

## 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 recursive nesting 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).