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The Holographic Principle as the Origin of Spacetime Invariance

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Abstract

This paper explores the connection between the holographic principle and the invariance of spacetime intervals, proposing that the matter and anti-matter "address" in a holographic plane governs the perceived constancy of the speed of light and Lorentz invariance. We extend this framework to unify insights from quantum mechanics, special relativity, and the holographic principle. By proposing that photons are "stuck" in the holographic plane, we explain the emergence of spacetime invariance, investigate the role of entanglement entropy, and provide a mathematical basis for linking holography to Minkowski spacetime. The paper also discusses implications for quantum gravity and outlines testable predictions for validating this framework.

Keywords: Spacetime; Quantum mechanics; Holographic planes

Introduction

Einstein's postulates for special relativity established the constancy of the speed of light and the invariance of physical laws across inertial reference frames [1]. While these principles are foundational, their deeper origins remain unclear. This paper addresses these origins by leveraging the holographic principle, suggesting that spacetime invariance emerges from the encoding of physical information in a lower-dimensional holographic plane [2, 3].

The hypothesis builds on two core ideas:

- The matter and anti-matter "address" is dynamically encoded in the holographic plane, moving at the speed of light.
- Photons remain "stuck" in this plane, resulting in the perception of spacetime invariance by matter.

We further explore connections to quantum field theory, spacetime intervals, and the implications of this framework for quantum gravity.

Physical Interpretation of the Holographic Plane

What is the holographic plane?

The holographic plane is posited as a two-dimensional information surface encoding the positions and states of particles in a lower-dimensional framework. This idea is inspired by the AdS/CFT correspondence, but extends beyond anti-de Sitter spaces to apply universally to Minkowski spacetime [4].

- **Matter and anti matter address**: The electron's position is encoded as an "address" on this holographic plane, moving at the speed of light.

- **Photon's role**: Photons are constrained within the plane, representing interactions and projections between matter encoded in 4D spacetime.

Observable implications

The holographic framework offers intuitive explanations for observed phenomena:

- The constant speed of light arises because matter always perceives the projection of light's address at c [1].
- The invariance of spacetime intervals is a consequence of the holographic plane's geometric constraints [3, 5].

Mathematical Framework

Holographic encoding and lorentz invariance

The holographic plane is mathematically represented as a lower-dimensional surface with coordinates (u,v), mapping to 4D spacetime (t,x,y,z) via projection operators P:(u,v)→(t,x,y,z) [5].

The spacetime interval $s^2 = c^2t^2 - x^2 - y^2 - z^2$ remains invariant because the holographic plane enforces the conservation of an equivalent interval σ^2

$$\sigma^2 = c^2u^2 - v^2$$

where σ^2 corresponds to the "holographic interval."

Using Lorentz transformations (u′,v′), we derive their Minkowski counterparts in spacetime [1, 6]:

$$u' = \gamma(u - \beta v),\ v' = (v - \beta u),\ \text{where}\ \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

The invariance of σ^2 guarantees that s^2 is also invariant, linking holographic dynamics to Lorentz invariance.

Photons in the holographic plane

Photons are described by null intervals in the holographic plane ($\sigma^2=0$), analogous to light like intervals in spacetime ($s^2 = 0$) [7]:

$c^2u^2 = v^2 \implies$ photon’s "motion" is confined to the plane.

Entanglement entropy

We hypothesize that the matter and anti matter address is tied to entanglement entropy on the holographic plane. The entropy S of a system corresponds to the area A of its projection:

$$S = \frac{A}{4G}$$

This suggests that changes in the matter and antimatter address are encoded as entanglement processes, offering a physical interpretation for quantum correlations [4, 8].

Implications for Quantum Field Theory

The holographic principle provides a global encoding of local interactions, unifying particle-field duality with spacetime invariance.

- **Locality and causality**: The projection P ensures that local interactions in spacetime correspond to encoded dynamics on the holographic plane [4].

- **Photon's role in QFT**: The "stuck photon" hypothesis aligns with gauge invariance, where photons mediate interactions without violating spacetime symmetries [7].

Implications for Quantum Gravity

- **Emergent spacetime**: The holographic perspective aligns with theories where spacetime is emergent from quantum entanglement [8].
- **AdS/CFT generalization**: While inspired by AdS/CFT, this framework applies to flat spacetime, suggesting a broader principle underlying spacetime structure [4].
- **Black hole physics**: The invariance of s^2 parallels the invariance of entropy across black hole horizons, linking holographic principles to gravitational dynamics [9].

Experimental Predictions

- **Deviations at small scales**: Test for deviations from Lorentz invariance at Planck-scale energies, where holographic effects might become significant [6].
- **Cosmological observations**: Investigate the holographic encoding of the cosmic microwave background for signs of lower-dimensional projections [8].
- **Entanglement experiments**: Test whether changes in entanglement entropy correspond to shifts in particle "addresses" on the holographic plane [4].

Conclusion

This paper proposes that spacetime invariance arises from the holographic principle, with matter and photons encoded in a lower-dimensional plane. By providing a mathematical framework and connecting holography to Lorentz invariance, we offer a novel perspective on spacetime's structure. Future work will explore deeper connections to quantum gravity and testable predictions.

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