

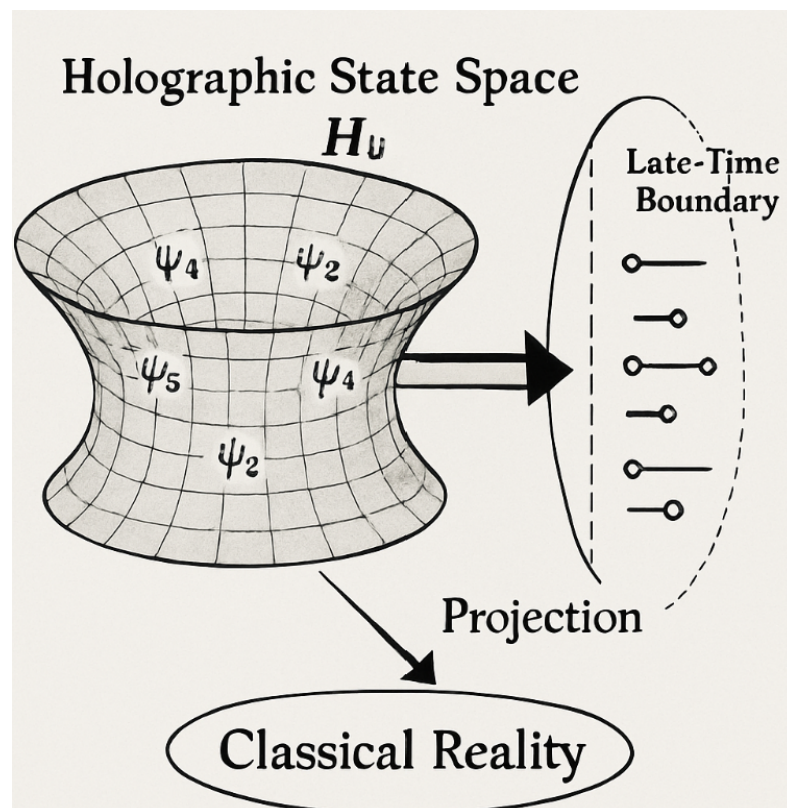
The Holographic State Space: A Mathematical Formalism for the Cosmic Storehouse: Proto-theory

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Experimental Abstract

Inspired by the top-down cosmological framework proposed by Hertog and Hartle, this paper introduces a mathematical formalism to describe the "cosmic storehouse"—the primordial state of potentiality from which all observable forms emerge, in the form of a proto-theory. We posit the existence of a universal Hilbert space, termed the **Holographic State Space** (\mathcal{H}_U), which contains all possible quantum histories of the universe as basis states. The emergence of a specific, classical reality is modeled as a projection event, where an observation at a late-time boundary condition collapses the universal state vector into a consistent family of histories. This work provides a rigorous mathematical structure for the concept that the universe selects itself from a vast library of potential forms, governed by the principle of holographic information.



1. Introduction

The holographic principle, originating from black hole thermodynamics ('t Hooft, Susskind) and given a precise formulation in the AdS/CFT correspondence

suggests that the information content of a volume of space can be encoded on its boundary. Thomas Hertog, in his collaboration with Stephen Hawking, extended this idea into a "top-down" cosmology. In this view, there is no unique bottom-up evolutionary path for the universe. Instead, our present-day observations select a privileged class of histories from a superposition of all possible ones. This concept implies a pre-physical reality, a "cosmic storehouse" of forms existing in potential. The goal of this paper is to move beyond metaphor and describe this storehouse in precise mathematical terms. We propose a model where this storehouse is a complex Hilbert space, and physical reality is a projection from it.

2. The Mathematical Framework: Holographic State Space

We begin by postulating the foundational entity of our model:

Postulate 1: The Holographic State Space (\mathcal{H}_U).

There exists a complex, separable Hilbert space \mathcal{H}_U , the Holographic State Space, whose orthonormal basis vectors $\{|\phi_n\rangle\}$ correspond to all possible, complete histories of a universe. Each $|\phi_n\rangle$ represents a distinct potential form, a unique configuration of spacetime geometry and quantum fields from beginning to end. The entire potential of the cosmos, prior to any observation, is described by a single state vector in this space, the **Universal State Vector** $|\Psi_U\rangle$. This vector is a superposition of all potential forms:

$$|\Psi_U\rangle = \sum_n c_n |\phi_n\rangle$$

where $c_n \in \mathbb{C}$ are complex coefficients satisfying the normalization condition $\sum_n |c_n|^2 = 1$. In the absence of any information, we might assume a state of maximal potentiality where all coefficients have equal magnitude, $|c_n| = 1/\sqrt{N}$, where N is the total number of possible histories (potentially infinite).

Postulate 2: The Projection Postulate of Cosmic Observation: an experiment.

The emergence of a classical, observable universe is triggered by a late-time observation \mathcal{O} . This observation is represented by a projection operator $\hat{P}_{\mathcal{O}}$ that acts on the Universal State Vector $|\Psi_U\rangle$. This operator projects $|\Psi_U\rangle$ onto the subspace of \mathcal{H}_U spanned by all histories that are consistent with the observation \mathcal{O} .

If an observer measures a set of parameters corresponding to \mathcal{O} , the state of the universe collapses:

$$|\Psi_{\text{observed}}\rangle = \frac{\hat{P}_{\mathcal{O}} |\Psi_U\rangle}{\|\hat{P}_{\mathcal{O}} |\Psi_U\rangle\|}$$

The probability of observing a reality consistent with \mathcal{O} is given by the Born rule on a cosmic scale:

$$\text{Prob}(\mathcal{O}) = \langle \Psi_U | \hat{P}_{\mathcal{O}} | \Psi_U \rangle = \|\hat{P}_{\mathcal{O}} |\Psi_U\rangle\|^2$$

This model encapsulates Hertog's top-down approach. We don't have a single history evolving forward in time. Instead, we have a static "library" of all possible histories, \mathcal{H}_U , and our present existence acts as a filter, selecting a coherent volume from this library. The fundamental equation governing the universe is not one of temporal evolution, but the timeless Wheeler-DeWitt equation, whose solutions form the basis states $|\phi_n\rangle$:

$$\hat{H}_{\text{total}}|\phi_n\rangle = 0$$

This equation states that the total energy of a universe-history is zero, reinforcing the idea of the universe as a self-contained quantum fluctuation from nothing.

3. Challenges

We have proposed a mathematical framework that gives structure to the concept of a cosmic storehouse of potential forms. By defining the Holographic StateSpace \mathcal{H}_U and modeling observation as a projection operator, we can describe the emergence of our specific reality from a vast superposition of possibilities. This formalism aligns with the top-down cosmology of Hertog and provides a tangible mathematical object for studying the foundational principles of quantum gravity and the nature of existence itself, further investigation involving the standard model and the higgs field are of essence. For now any conclusion is postponed and the theory is kept open. The author could not achieve a proper conclusion.

4. References

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- Hertog, T. (2023). *On the Origin of Time*.
- Maldacena, J. M. (1998). *The Large N Limit of Superconformal Field Theories and Supergravity*.
- Susskind, L. (1995). *The World as a Hologram*.

Commentary on Hertog and Further Mathematical Connections

the Holographic State Space:

Hertog argues that we must abandon the idea of a single, linear timeline that started with a Big Bang and move towards a "top-down" view. What hertog actually points out is our need to develop quantum mechanics.

a **Hilbert Space** (\mathcal{H}_U) is the fundamental arena of quantum theory.

The "**Selection**" of our reality is modeled as a **quantum measurement**, using a projection operator (\hat{P}_O). This is the standard mechanism in quantum mechanics for how a definite outcome arises from a cloud of probabilities.

This model elevates the **observer** to a cosmologically significant role, which is a key, and controversial, element of Hertog's thesis. Our existence and the universe we see are not an accident at the end of a long chain of events, but rather the very condition that gives shape and meaning to the entire chain.

Mathematical Connections and theoretical problem statement. We appeal to the science community, to help us solve this problem.

Negative Effective Mass

In solid-state physics, the effective mass (m^*) of an electron in a crystal lattice is not its intrinsic mass but a parameter that describes its response to a force. It depends on the curvature of the energy-momentum ($E - k$) dispersion relation:

$$m^* = \hbar^2 \left(\frac{d^2 E}{dk^2} \right)^{-1}$$

Theoretical problem: how does negative effective mass relate to the higgs?

A **negative effective mass** occurs when the energy band is concave down ($d^2 E / dk^2 < 0$). This means the particle paradoxically accelerates in the opposite direction of the applied force.

Context: In the context of the cosmic storehouse, certain "exotic" universal histories ($|\phi_n\rangle$) could be described by fields that exhibit negative effective mass. Such fields would be representing highly unusual but potential realities within \mathcal{H}_U .

Cédric Villani and Optimal Transport

The core idea, the Monge-Kantorovich problem, is finding the most efficient way to transform one distribution of "mass" into another. The cost of a transport plan

$\gamma(x, y)$ is given by:

$$C(\gamma) = \int_{X \times Y} c(x, y) d\gamma(x, y)$$

where $c(x, y)$ is the cost of moving a unit of mass from point x to point y .

Villani his work could be key: Imagine the Universal State Vector $|\Psi_U\rangle$ representing an initial distribution of "potentiality." The collapse to our observed universe

$|\Psi_{\text{observed}}\rangle$ could be seen as an optimal transport problem: What is the most "efficient" or "probable" way for the universe to rearrange its potential to satisfy our observational constraints? Villani's mathematics could provide a framework for calculating the "cost" or likelihood of different cosmic outcomes.

Martin Hairer's Fields Medal work on regularity structures provides a way to make sense of stochastic partial differential equations (SPDEs) that are otherwise ill-defined due to extreme randomness. A classic example is the Kardar-Parisi-Zhang (KPZ) equation, which describes the growth of interfaces:

$$\frac{\partial h}{\partial t} = \nu \nabla^2 h + \frac{\lambda}{2} (\nabla h)^2 + \eta(t, x)$$

The noise term $\eta(t, x)$ is so "rough" that standard calculus fails. Hairer's work provides the mathematical tools to handle it.

It's about structures: The initial state of the universe, the cosmic storehouse, would be subject to violent quantum fluctuations—a form of cosmic "noise." Hairer's structures could be the mathematical tool needed to rigorously describe the state $|\Psi_U\rangle$ itself, treating the Wheeler-DeWitt equation as a kind of SPDE on the space of all geometries, properly accounting for the foundational quantum randomness.

Maryam Mirzakhani and Moduli Spaces

Maryam Mirzakhani, worked on the geometry and dynamics of Riemann surfaces, specifically their "moduli spaces." A moduli space is a geometric space whose points represent different complex structures on a surface. She calculated the volumes of these spaces. Her work often involved integrals over the moduli space $\mathcal{M}_{g,n}$ of genus g surfaces with n marked points.

String theory inspiration: In string theory, a fundamental pillar of quantum gravity, the fundamental particles are tiny vibrating strings. The history of a string moving through spacetime traces out a 2D surface called a worldsheet, which is a Riemann surface. The properties of string interactions depend on the geometry of these surfaces. Mirzakhani's work on moduli spaces is therefore fundamental to calculating probabilities in string theory. Each $|\phi_n\rangle$ in our Holographic State Space could correspond to a universe governed by a different string theory vacuum, and her mathematics would be essential for understanding the structure of that "storehouse of string theories."

Our open theory and problem statement: The holographic principle itself is an optical metaphor: a 2D surface (like a photographic film) encoding a 3D image. Information in our universe is primarily transmitted by photons. Photonic technologies, like **photonic crystals** that can trap and guide light in intricate ways, serve as a perfect physical analogy for how the "cosmic boundary" might store and structure the information of the bulk spacetime. Advanced concepts in photonics, such as structured light and quantum optics, provide tangible models for how information (potential forms) could be encoded and processed on a cosmic holographic plate. Through photonics we can investigate further. However, our current knowledge surrounding negative effective mass is premature.

Since the author could not comprehend the relationship between negative effective mass and the higgs field, we leave our proto-theory open for now. If anyone can solve the relationship between the higgs field and negative effective mass, and help us achieve a deeper understanding regarding our Holographic State Space, please email peterdeceuster5@gmail.com