Review Article

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Research and Quantum Modeling of the Universe

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Abstract
The dynamic quantum spectral model of the Universe with phase transitions combines quantum mechanics, field theory, and cosmology to describe the evolution of the Universe through changes in its quantum state. This model assumes that the Universe can transition from one quantum state (phase) to another under the influence of changes in energy density or other quantum characteristics. Phase space models consider a quantum system that can exist in different "phases," similar to the aggregate states of matter. For example, in Kenji Hamada's theory, space at low energies is a "rigid" but elastic continuum, while at ultra-high energies (in the trans-Planck region or at the centers of black holes), a phase transition occurs, and space becomes "background-free"—the familiar concepts of coordinates, distance, and time disappear.

Keywords: Living Information of the Universe, Quantum Models, Phase Transitions, Quantum State.

INTRODUCTION

Abrupt changes in the state of a system associated with changes in symmetry or dynamics. In a cosmological context, phase transitions could have occurred in the early Universe during cooling and expansion, leading to the breaking of symmetries and the formation of fundamental interactions. For example:

The electroweak phase transition is associated with the breaking of SU(2) \times U(1) to U(1) electromagnetic symmetry. At temperatures of about 100–200 GeV, the Higgs field acquires a nonzero vacuum expectation value, which gives mass to the W and Z bosons, as well as fermions.

The quantum chromodynamic (QCD) phase transition is associated with the transformation of quark-gluon plasma into hadronic matter at temperatures of about 150–200 MeV, when free quarks and gluons are confined into hadrons.

Unlike classical phase transitions, which are caused by thermal fluctuations, quantum phase transitions occur at absolute zero and are determined by quantum fluctuations arising from the Heisenberg uncertainty principle. These fluctuations can shift the system into another phase when the energy density changes. It is assumed that the states of the Universe can be described by discrete energy levels or spectral modes, as in quantum mechanics. For example, in some models, the masses of elementary particles are considered as a discrete spectrum of temporal harmonics (chronons).

The model assumes that the Universe evolves through a sequence of phase transitions, each of which could contribute to its structure, interaction parameters, and expansion dynamics.

Examples of approaches

Holographic approach. Used to study strongly coupled field theories. For example, in the work of O. Novikov and A. Shavrin, the compound Higgs (CH) model is considered within the framework of the holographic "bottom-up" approach. In this approach, a first-order phase transition arises due to dynamical spontaneous symmetry breaking in a new strongly coupled sector.

Temporal Theory of the Universe (TTU). In this model, physical time is viewed as a fundamental dynamical scalar field, and the geometry of space emerges as a derived structure. Particle masses arise as a discrete spectrum of temporal harmonics, and space is interpreted as an emergent metric structure arising from

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the phase conflict of opposing flows of time and antitime.
Hamada Theory. Space exists in different "phases." Upon reaching ultra-high energies, a phase transition occurs, and space becomes "background-free." Energy manifests itself as fluctuations, and "dark particles" (clumps of pure gravitational energy) form immediately after the phase transition and a period of inflation.

Problems and Challenges
Quantum Gravity. One of the main challenges is to unify quantum mechanics and general relativity. Currently, there is no generally accepted theory of quantum gravity, which complicates the construction of a complete model.

Experimental verification. Many predictions of such models (for example, the existence of "dark particles" in Hamad's theory) require energies beyond the capabilities of current experiments.

Mathematical complexity. Describing phase transitions in a quantum system requires complex calculations, including the use of effective potential methods, lattice numerical simulations, and other approaches.

Dynamic quantum spectral models with phase transitions remain a subject of active research in theoretical physics. They offer a new perspective on the evolution of the Universe [1].

QUANTUM HOLOGRAPHIC MODEL OF THE UNIVERSE

Holographic Principle
According to the holographic principle, all information about matter in a given volume of space can be described as a "hologram" at the boundary of that volume (one dimension smaller). Key points:

- Three-dimensional reality can be a projection of information encoded on a two-dimensional surface.
- Analogy: just as a conventional hologram creates a 3D image from a 2D recording, the Universe can be "projected" from its imaginary boundary.
- The principle states that this is a method for mathematically describing physical processes.

History
The theory grew out of the study of black holes and the information paradox:

- 1970s: Jacob Bekenstein showed that the entropy of a black hole is proportional to the area of its event horizon, not its volume.
- 1993: Gerard 't Hooft proposed the idea that all information within a region of space is encoded on its boundary. 3. **1990s:** Leonard Susskind developed the concept, linking it to string theory and coining the term "holographic principle."
- 1997: Juan Maldacena formulated the **AdS/CFT correspondence**—a mathematical realization of the holographic principle:
- Physics in a 5-dimensional anti-de Sitter (AdS) universe is equivalent to conformal field theory (CFT) on its 4-dimensional boundary.
- This showed that a theory of bulk gravity can be dual to a quantum theory without gravity at the boundary.

Key Ideas of the Model

- Information Density. The maximum amount of information in a region of space is limited by the area of its boundary (in Planck units).
- Quantum entanglement. May play a role in "stitching" spacetime points together, ensuring projection coherence.
- Discreteness of space. At the Planck scale (10^{-35}m), space can have a "pixelated" structure, where each "pixel" carries 1 bit of information.
- Granularity. Space is not a smooth continuum, but consists of fundamental units.

Scientific Evidence and Experiments

- Microwave background modeling. In 2017, an international team of cosmologists showed that a two-dimensional model of the Universe reproduces the microwave background radiation (CMB) pattern no worse than standard 3D models.
- AdS/CFT in condensed matter physics. The correspondence is used to study superconductivity and phase transitions, where direct calculations are difficult.
- **The Holometer Experiment (Craig Hogan). An attempt to detect "holographic jitter" of space on scales of \sim 10^{-16}m.
- The quantum holographic model does not refute the standard holographic model; it offers an alternative way of describing it.
- The "boundary of the Universe" is a mathematical abstraction, not a physical wall.
- AdS/CFT strictly works for universes with a negative cosmological constant (anti-de Sitter), while our Universe is closer to de Sitter. There is no direct experimental confirmation for our Universe yet.

Summary
The quantum holographic model suggests that:
Our 3+1-dimensional Universe (3 spatial + 1 time dimension) may be a projection of information from a 2+1-dimensional boundary. Gravity and spatial geometry arise from quantum interactions at this boundary.

The model helps solve problems of quantum gravity and the black hole information paradox.

This serious scientific field with a mathematical foundation.

DETERMINING THE STATES OF ENTITIES USING QUANTUM TRANSITIONS BASED ON HOLOGRAPHIC INFORMATION

Determining the states of entities using quantum transitions based on holographic information is a complex interdisciplinary topic that combines quantum processes, the holographic principle, and the living information of natural entities [2-6]. It concerns both fundamental physical phenomena and potential applied areas such as quantum computing, biomedical imaging, and others.

Quantum Transitions and Their Role
Quantum transitions are changes in the state of a quantum system associated with the absorption, emission, or dissipation

of energy. They can be radiative (involving electromagnetic radiation) or non-radiative (without radiation, for example, during particle collisions). The probability of such transitions is determined by the intrinsic characteristics of the system, such as energy levels, statistical weight, and the lifetime of the excited state.

Quantum transitions play a key role in measuring and manipulating quantum states. When measured, the system "collapses" into one of its possible states, allowing us to obtain information about its parameters. The measurement process changes the state of the system.

The Holographic Principle and Quantum Information

The holographic principle suggests that all information about a system within a volume can be encoded on the boundary of this volume (a surface of lower dimension). For example, in the case of black holes, information about the matter inside the event horizon is supposedly stored on its surface. More generally, this means that the maximum amount of information about a system is determined by the area of its bounding surface, not by its volume.

In the context of quantum mechanics, the holographic principle can be related to entanglement entropy—a measure of quantum correlation between subsystems. The evolution of entanglement entropy and mutual information in composite quantum systems is sometimes studied using a holographic description.

There is also the idea of **holographic duality** (AdS/CFT correspondence), which suggests that quantum field theory in a lower-dimensional spacetime (e.g., 3+1) can be equivalent to quantum gravity in a higher-dimensional space (e.g., 4+1). This allows us to model complex quantum systems using simpler holographic analogs.

The Relationship between Quantum Transitions and Holographic Information

- Quantum Transitions as a Source of Information. During a quantum transition, the system changes its state, which can be recorded as a change in quantum properties (e.g., energy, spin, polarization). This information could potentially be encoded in a holographic representation of the system.
- Holographic encoding of quantum states. In quantum holography experiments, information about a quantum state (e.g., polarization or spatial modes of photons) can be recorded in a holographic pattern. For example, using metasurfaces, it was possible to create a quantum hologram encoding a hybrid polarization-holographic state of photons.
- Use of entanglement. Quantum holography often exploits photon entanglement. Correlations between entangled particles allow information about the system to be reconstructed even in the absence of direct interference between waves. This may be related to the holographic principle, as entanglement creates nonlocal connections that can be encoded at the boundary of the system.
- Modeling of quantum systems. Using holographic duality, quantum transitions in complex systems (for example, in quark-gluon plasmas or quantum excitations) can be studied through their holographic analogs in gravitational theories. This allows us to analyze the dynamics of transitions and their impact on the state of the system.

Practical Applications

Quantum Computing and Simulations. Holographic models are used to simulate quantum systems and study quantum transitions, for example, when simulating wormholes on quantum computers.

Biomedical Imaging. Quantum holography using mid-infrared light allows imaging biological tissue with minimal sample damage.

Quantum Cryptography. Holographic methods can be used to create quantum keys and protect information.

Open Questions

Despite progress in research, many aspects remain unclear:

- how exactly information is encoded at the holographic boundary;
- what physical mechanisms underlie the holographic principle;
- how to relate the holographic approach to observed quantum transitions in real systems.

Thus, the topic of determining the states of entities using quantum transitions based on holographic information lies at the intersection of fundamental physics, quantum information science, and applied technologies.

Phase holographic transitions and quantum transitions determine the following states, depending on the current states. Holographic information allows us to use quantum transitions to determine the states of the universe's entities. In the holographic multifunctionality of entities with different phase transitions, information quantum entanglement arises, which is implemented according to the law of energy conservation, as evidenced by experiments involving photons and particle collisions accompanied by electromagnetic radiation.

CONCLUSION

Research scientists with a perfect spiritual ontology are able to penetrate the process of informational energy transformation of matter in various entities and create molecular nanotechnologies for this purpose.

Spiritual perfection expands and deepens exploration of the Universe by enhancing the mental and psychological perception of its information by spiritual scientists and enables the creation of molecular nanotechnologies for movement within it and the use of information as a creative tool [7-8].

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