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Short Communication

The Mystery of Space: A Way to Bring Together Quantum Mechanics and General Relativity

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Abstract

Quantum mechanics and general relativity are two important theories that make up modern physics. These theories do not function cohesively under extreme cosmic conditions, such as black holes or the universe's origin. This paper examines the enigma of space at its most fundamental level, where existing models fail. This paper delineates the conceptual trajectory towards a unified theory of space by scrutinizing the constraints of existing theories and evaluating proposed frameworks such as string theory, loop quantum gravity, and emergent spacetime. Solving this puzzle could change how we think about black holes, the Big Bang, and even lead to new technologies.

More Information

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Introduction

Space, time, matter, and energy make up the universe, but space is the most mysterious of these. When you look at space from a human perspective, it looks smooth and continuous. But what happens at the smallest scales, around the so-called Planck length (about 10^{-35} meters)? Is space made up of tiny particles? Is it made up of quantum bits? Physicists still don't know.

General relativity explains how mass and energy change the shape of space, while quantum mechanics explains how subatomic particles behave in ways that are hard to predict. But these two ideas are fundamentally at odds with each other. Each theory has a different idea of how space works, which causes math problems at very large scales, like black holes and the early universe. This tension has led to one of the biggest unanswered questions in physics: quantum gravity [1-5].

Why we need quantum gravity

Black hole physics: Spacetime inside black holes is bent infinitely, but quantum mechanics can't deal with this.

The big bang: A theory that combines quantum uncertainty with gravitational collapse is needed to explain how space and time began.

Planck scale: At very small distances, changes in quantum fields could change space itself.

A comprehensive theory must elucidate the behavior of space under the influence of both gravitational and quantum effects.

Difficulties in comprehending space

No experimental data: Current experiments can't directly see the Planck scale because it is too small.

Mathematical conflicts: Quantum mechanics needs a fixed background of space, but gravity bends space.

No unique prediction: Various models forecast divergent spatial behaviors, none of which have been validated.

Current theoretical approaches

Several theories try to explain how space works at the quantum level:

- **String theory**

It says that particles are not points, but tiny strings that vibrate. The existence of these strings in higher-dimensional space remains unverified.

- **Quantum gravity in a loop**

It says that space is made up of separate loops or "chunks." It eliminates the necessity for a continuous background and quantizes space itself.

- **Spacetime that is coming into being**

In this perspective, space is not fundamental but arises from more fundamental quantum information processes, potentially linked to quantum entanglement.

Why it's important to solve this problem

If we knew what space really is, we could:

Talk about the black hole information paradoxes.

Recreate the first few seconds after the Big Bang

Use the principles of quantum gravity to make new technologies

Bring all physical laws together into one theoretical framework

Conclusion

The idea of space is still a new area of study in physics. Even though general relativity and quantum mechanics have been very successful, neither can fully explain how space works when things get really extreme. Quantum gravity, which combines these theories, could change the way we think about the universe forever. Even though there are still a lot of questions that need to be answered, research into the quantum nature of space may soon lead to discoveries about the very nature of reality.

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