Research

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Inflation

The theory of cosmic inflation provides a link between the physics of the early universe and particle physics. What makes the theory so attractive is that it simultaneously solves certain conceptual problems of the standard hot big bang picture in cosmology as well as presenting predictions that fit very well with observations. Although inflation helps with explaining many features in our universe such as homogeneity and flatness, there are still many questions about how inflation fits into a fundamental framework.

Eternal Inflation and Types of Vacua: One possible framework for inflation involves an eternally inflating background. There are claims in the literature that an eternally inflating multiverse with a collection of vacuum types can remove Boltzmann Brain problems and gives the multiverse a natural arrow of time without additional assumptions. To achieve this, authors use what are called terminal vacua which are Anti de-Sitter type vacua that crunch towards a singularity whose evolution is no longer followed. In my first [1] paper, we introduce what we call "arrival terminal" vacua. Transitioning from these arrival terminals is the time reverse of a transition to an anti de-Sitter type vacuum. We note that not including these types of transitions gives a description that is either non-unitary or uses specially tuned initial conditions. We show in a toy model, how claims made in the literature depend on special assumptions.

Initial Quantum State: In ongoing work, I am exploring the initial quantum state of inflation and how it affects observables today. Quantum fluctuations generated during inflation produce a nearly scale invariant power spectrum for the scalar perturbations by the end of inflation. This prediction fits very well to what is observed in the cosmic microwave background. Various authors have suggested inflation could be short. If inflation was just enough to produce a universe consistent with what we observe today, then differences in the initial quantum state of the inflaton could be observable.

Entanglement, Gravity and Black Holes

The black hole information paradox presents an apparent contradiction between quantum mechanics and general relativity. It is unclear how the causal structure inherent to black holes and the unitarity built into quantum field theory fit together in the context of an evaporating black hole. In recent years the concept of a "firewall" was presented in the literature which has changed the understanding of this long standing puzzle and could lead to deep insight into the true nature of quantum gravity. The firewall prevents infalling objects and information from entering the black hole and is claimed by some to be the least radical solution which would resolve the contradiction of physical principles.

Cosmological Horizon: I've investigated circumventing the firewall conclusions in the context of de Sitter space [2], where the nature of the information problem is altered by the presence of a second horizon. Using a qubit toy model, we examine the entanglement properties of evaporating black hole states and present a construction with no information problem and no firewalls.

Multipartite Entanglement for Black Holes: My paper in preparation [3], "Multipartite entanglement and firewalls" challenges assumptions regarding the type of entanglement critical to the firewall argument. Utilizing multipartite entanglement, we consider a more intricate entanglement structure which allows a level of entanglement sharing. We construct a toy model which exhibits a history of time states that explicitly differ in their entanglement properties. If a similar entanglement structure is present in actual black holes, this type of entanglement could alter or even undo the firewall argument.

References

[1] Henry Stoltenberg and Andreas Albrecht. Eternal Inflation with Arrival Terminals. *Phys. Rev.*, D91(2):023503, 2015.

[2] Henry Stoltenberg and Andreas Albrecht. No Firewalls or Information Problem for Black Holes Entangled with Large Systems. *Phys. Rev.*, D91(2):024004, 2015.

[3] Shengqiao Luo, Henry Stoltenberg, and Andreas Albrecht. Multipartite Entanglement and Firewalls. 2016. arXiv:1408.5179[gr-qc].