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Cosmological Perturbations and Complexity in Bianchi I Spacetime

The study of cosmological perturbations and quantization during inflation has predominantly focused on the Friedmann-Lemaitre-Robertson-Walker (FLRW) spacetime. Still, there are very few non-FLRW spacetime cosmological perturbation studies. Among these, the Bianchi I model is one of the simplest anisotropic spacetime models, featuring varying scale factors (a(t)) in orthogonal directions. This characteristic renders Bianchi I a more encompassing representation of spacetime than the FLRW model. Recent studies have discussed cosmological perturbations and quantization in Bianchi I spacetime and have shown shear coupling between scalar-vector-tensor perturbation, which is absent in the FLRW case. The primordial universe has shown signs of chaos, and studying this can help in understanding the anisotropic nature of the universe. The evolution of out-of-time-ordered correlators (OTOC) has emerged as a valuable tool for quantifying quantum chaos. In recent years, the study of OTOCs and quantum chaos has gained interest in various fields, including condensed matter and cosmology. OTOCs were initially devised to calculate vertex correction of current in superconductors but have evolved into a method of measuring quantum chaos and growth of complexity in quantum information theory. OTOC calculations have been used to measure complexity in the squeezed state of cosmological perturbations of FLRW metric and have shown that quantum chaos manifests during the inflationary epoch but gradually diminishes during the radiation-dominated era. Here, we use the OTOC calculation to study the same in anisotropic spacetime models, namely the Bianchi I model, and compare it with FLRW and show the intricate interplay between quantum effects and the evolving structure of the universe, particularly during the critical epochs of cosmic inflation and radiation domination.

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