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Abstract

Classical and quantum aspects of perturbations in Primordial Universe

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The quest for a comprehensive description of the initial stages of our Universe leads through the understanding of quantum gravity. In this work, our aim is to obtain a Hamiltonian formulation suitable for canonical quantization. Moreover, we assume that the early Universe can be described with fewer initial symmetries, thus we abandon the isotropy assumption and instead explore anisotropic universes, beginning with the simplest one, namely Bianchi I.

The presence of small initial fluctuations in the early universe can be well described by perturbations around a homogeneous background. General relativity (GR) is a constrained system, and we apply the so-called Dirac procedure for constrained systems to derive a gauge-invariant Hamiltonian formulation suitable for quantization. In this work, we present how this procedure can be extended to a generic background and its relation to the Kuchař decomposition. Subsequently, we apply this formulation to a Bianchi I universe, obtaining new and interesting results on the gauge-invariant representation of matter and geometry perturbations. Contrary to the Friedman-Lemaître-Robertson-Walker (FLRW) case, in which all the modes decouple, in Bianchi I we see that scalar and tensor modes do not decouple.

We show that new types of gauge-fixing conditions exit in this case. For instance, a gravitational wave can be encoded into scalar modes, by introducing a new gauge which is not valid in FLRW.

Furthermore, we make a first step towards a consistent and unified quantization of the composite system made of a background mode and perturbation modes. Specifically, we study tensor modes in a FLRW universe. We focus on the relation between the choice of internal time of the universe and the quantum evolution it undergoes. Our results indicate that the time reparametrization invariance in general relativity affects the quantum evolution of the background and perturbation modes. However, in the classical limit, i.e. for a large universe, the dynamics becomes unique. Thus, the predictive power of the theory is maintained.