Classical and quantum scalar fields in cosmology

Carsten Gundlach
Clare College

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Abstract

1. The standard Brans-Dicke theory is extended by postulating different coupling constants for the coupling of the dilaton to ordinary and to cosmological dark matter. The two free parameters are constrained from experimental and cosmological evidence, in particular primordial nucleosynthesis. The dilaton coupling to dark matter can be quite large without observable effects today. This is interesting for a range of inflationary models.

2. The quantum theory of cosmological perturbations is rederived, for a general class of backgrounds including Friedmann-Robertson-Walker spacetimes, from quantum cosmology. The only tractable ansatz for the wave function is one which factorizes in the "Fourier components" of the perturbations. New results are: (a) For this ansatz to be self-consistent, the background dependence of the wave function must be semiclassical. (b) When this is the case, the semiclassical backreaction is numerically irrelevant. It is proposed for further reasons that it is never a relevant concept.

3. Given a classical background, and assuming again that the perturbation wave function factorizes in generalized Fourier components, it is possible and natural to solve the linearized gauge-constraints by a canonical transformation. In this way one obtains a generalization of the gauge-invariant quantum theory of Mukhanov (1988), as well as its justification as the first consistent quantization of cosmological perturbations.

4. The perturbations of extended inflationary models, where a scalar field is coupled to the Jordan-Brans-Dicke theory of gravity, are quantized using the new formalism. The resulting density fluctuations in old extended inflation are found to be precisely the same as in a previous approximate calculation where the inflaton was modeled by a cosmological constant. The primordial density fluctuation spectrum is also calculated for the first time for extended chaotic inflation. It is a superposition of two non-flat power law spectra arising from the dilaton and inflaton perturbations.