Abstract

In this thesis, we investigate the cosmological model of non-minimal Higgs inflation. The basic idea is to unify the "low-energy" sector of the Standard Model with the high-energy phase of inflation during the early universe. Both sectors rely on the existence of a fundamental scalar field. The scalar Higgs boson is an integral part of the Standard Model in order to maintain gauge invariance while explaining the origin of the masses of the elementary particles. Similar, in cosmology the scalar inflaton is necessary in order to drive inflation, the rapid accelerated phase of expansion. The basic assumption of the Higgs inflation scenario is that the two scalar particles are only the manifestations of one and the same particle, the "Higgs-inflaton". The consistency with observational data of the cosmic background radiation requires the assumption of a strong non-minimal coupling of the Higgs-inflaton to gravity. It turns out that quantum corrections mainly determine the cosmological parameters of the model and are crucial for the predictions. Moreover, we resort to the renormalization group flow in order to connect the energy scale of the electroweak vacuum with the inflationary energy scale, separated by many orders of magnitude. We derive a range of possible values for the mass of the Higgs-inflaton. These predictions can be be tested by future experiments at the Large Hadron Collider (LHC) and the satellite PLANCK.

We further investigate an application of the non-minimal Higgs inflation model in the context of quantum cosmology. Via the path integral approach, we calculate the cosmological probability distribution for the universe to tunnel "from nothing to existence". A sharp peak in this distribution - selecting a specific value of the inflaton field - can be interpreted as the initial conditions for inflation. The predicted value can be tested by the detection of primordial gravitational waves that leave their imprints in the B-polarization of the cosmic background radiation.

In order to realize these models technically, we have calculated the divergent part of the one-loop off-shell effective action of a $O(N)$-symmetric multiplet of scalar fields non-minimally coupled to gravity in a closed form. Due to the functional nature of the couplings, the result is very general and can be used as a reference for many different cosmological applications.

In cosmology, it is convenient to transform between two specific field parametrizations, denoted "Jordan frame" and "Einstein frame". It is an ongoing discussion whether these two frames are physically equivalent. Mathematically, both frames are equivalent at the classical level. We explicitly show that this does not hold anymore at the quantum level. Moreover, we identify this failure of equivalence to be part of a more general problem: the parametrization dependence of the conventional off-shell effective action. This reduces the cosmological debate between Jordan frame and Einstein frame to the lack of covariance of the formalism.