The evolution of nonhomogenous configurations of the Higgs field

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Abstract

In this thesis, we study the formation and the evolution of nonhomogenous configurations of the Higgs field in the early Universe. We discuss two mechanisms of the production of such configurations: due to thermal fluctuations in the hot and dense Universe and from quantum fluctuations during inflation. The existence of two minima of the effective potential of the Standard Model enables the formation of domain walls from nonhomogenous configurations. Networks of cosmological domain walls of the Higgs field percolating through the Universe are the main subject of this dissertation. Properties of Higgs domain walls are determined and the evolution of the networks is investigated.

We propose the algorithm for computation of the width of domain walls (the quantity which determines the energy scale of the dynamics of domain walls) for a potential of a generic form. The instability of domain walls in models with a potential with non-degenerate minima is proven.

Our numerical simulations show, under the assumption that the Standard Model is valid up to arbitrary high energy scales, that domain walls of the Higgs field were unstable and would swiftly decay after the formation. Their short life-times exclude the possibility of unacceptably large distortions of cosmological observables due to the existence of the domain walls. Moreover, we have found that the creation of the network which ends up in the observed electroweak vacuum is not as difficult to obtain as one may naively expect.

In our further studies, we use the framework of the effective field theory in order to understand how the dynamics of Higgs domain walls could be influenced by yet unknown interactions, not described by the Standard Model. Numerical simulations show that the evolution of Higgs domain walls is insensitive to interactions beyond the Standard Model as long as masses of new particles are larger than 10^{12} GeV. However, for lower values the form of the RG improved effective potential may be modified at field strengths crucial to the evolution of the domain walls.

Moreover, we investigate an influence of the background thermal bath of the Standard Model's particles. We have found that properties of Higgs domain walls strongly depend on a temperature of the thermal bath. For temperatures higher than 10^{11} GeV, the energy scale of the problem (both the position of the local maximum of the effective potential and the inverse of the width of the domain walls) is of the order of the temperature. Our numerical simulations show that domain walls of the Higgs field in the background of the thermal bath are less stable than one may naively expect basing on previous results and the creation of the network whose evolution ends up in the electroweak vacuum is much less probable.

Finally, we determine the energy spectrum of gravitational waves produced by decaying domain walls of the Higgs field and discuss the possibility of their detection. We have found that the amplitude of the spectrum, in both the Standard Model and its extensions, is too small to be observed in present and planned detectors.