Reg. No: 2019/32/C/ST2/00248; Principal Investigator: dr Tomasz Krzysztof Krajewski

Inhomogeneous configurations of fields in the early Universe

Description for the general public

Detection of the Cosmic Microwaves Background Radiation in 1964-1965 was as unexpected by they discoverers Arno Allan Penzias and Robert Woodraw Wilson (Nobel prize in physics in 1978) as it was significant for modern cosmology. The existence of radiation filling the whole Universe which is a relic of the Big Bang was postulated in the mid 40. by the George Gamow, Ralph Alpher and Robert Herman, however these early works were not known to its discoverers. Observation of the Cosmic Microwave Background Radiation have been a crucial argument for the Big Bang hypothesis and its present measurements are one of the most important sources of knowledge about the structure of the Universe.

Even thought, the discovery of the Cosmic Microwave Background Radiation confirmed the Big Bang theory, some of features of the observed radiation, especially its isotropy, are challenging to be explained in the standard cosmological scenario. The most popular solution to problems of this scenario is an inflationary hypothesis. It states that the early Universe go through the phase of accelerating expansion called inflationary epoch. If this period was long enough, one causally connected patch of the Universe blow up as much to became a source of the isotropic Cosmic Microwaves Background Radiation later on. During the accelerating expansion the curvature of the Universe decreases, so inflation explains why the present Universe is so flat, too. Moreover, detailed studies have shown that primordial perturbations which became seeds for formation of presently observed structures, might be produced during inflation. Many inflationary models which share same universal predictions and in the same time differ in quantitative details, were proposed so far.

Recently published results of measurements of the Cosmic Microwave Background Radiation performed by the Planck satellite combined with BICEP and KEK experiments have stared the new era in the phenomenology of inflationary models. Obtained value of the spectral index and bound on the tensor to scalar ratio of fluctuations excluded, for the first time in the history, the wide class of inflationary models. Planned, future measurements of anisotropies of the Cosmic Microwave Background Radiation will be more precise and will allow for further reduction of the space of compatible models.

However, majority of presently in use methods of estimation of anisotropies of this radiation generated by perturbations produced during inflation are only approximate. Significant contribution to uncertainties of quantities obtained from inflationary models comes from weak understating of the reheating process.

During inflationary epoch, the Universe is dominated by a hypothetical, inflation causing inflaton field. In order to form the present Universe, filled with Standard Model particles, the process of their production, connected with transfer of the energy from the inflaton field to other degrees of freedom, had to took place. This process is called reaheating. It proceeds in different ways in various inflationary models and its dynamics is still not fully understood. The number of approximated methods of estimation of the influence of the reheating process on present cosmological observables exist, however they base on various, not always satisfied, assumptions.

The most universal method of studying of reheating is numerical lattice simulations which take advantage of the computational power of (super)computers. These simulations enable for reliable investigation of the reheating process in many models, even those for which analytic methods break down. Moreover, analogical simulations can be used to study, so called topological defects: cosmological domain walls, cosmic strings and monopoles; structures formed from primordial fluctuations which due to their stability could significantly influence the evolution of the Universe.

Even though their undoubted advantages, numerical lattice simulations have not been popular among cosmologists so far. Tedious preparation and interpretation of results of lattice numerical simulations is reason for that.

The aim of this project is studying of the reheating process in the most promising inflationary models. In order to achieve this goal lattice simulations and other methods will be used. Due to modern numerical methods cosmological observables will be determined with extraordinary precision. Moreover, the further exploration of the physics of topological defects is assumed.