

The impact of non-equilibrium and thermal effects on the evolution of Dark Matter in the Early Universe plasma

Popular project description

Despite the fact that it has been many decades since the existence of the Dark Matter - we know now constituting about 80% of the total matter of the Universe - was first discovered, its nature still remains a mystery. In fact, it is one of the biggest puzzles of modern physics. And a very important one, as the understanding of the nature of Dark Matter can open a new window on the physics of fundamental particles and interactions.

Furthermore, Dark Matter played a crucial role in the history of the Universe. It is because of it and the gravitational potential it generates, our ordinary baryonic matter had enough time to collapse and form larger structures: galaxies, stars and planets. Also now the Milky Way is embedded in a halo much larger than itself - the clump of Dark Matter inside of which the galaxy was created. Astronomical observations give us only handful of details regarding halo structure. However, thanks to mathematical models and specialized computer simulations we have very good reasons to believe that we do have some understanding the halo. Nevertheless, a vast number of questions still remain unanswered.

The project aims at development of theoretical and numerical methods needed for improving the understanding of these open questions. In particular, by studying in detail the impact of non-equilibrium and thermal effects on the evolution of Dark Matter in the Early Universe. It will help in deepening our knowledge about its history and properties. Furthermore, in the project it is envisioned to study the impact of the self-interactions between the Dark Matter particles, both on its evolution and structure formation in the Universe.

A new approach based on full numerical solution of the Boltzmann equation for the Dark Matter phase space distribution function is going to be used. With it one is equipped to thoroughly study the departure from local thermal equilibrium and its impact for various types of interactions of Dark Matter and the surrounding plasma of the Early Universe. Additionally, an approach based on non-equilibrium finite-temperature quantum field theory will be studied and further developed. In a hot and dense medium quantum thermal effects modify the cross sections for various processes, e.g., bound state formation and dissociation or thermal broadening of particles' widths.

The physics of fundamental particles and interactions finds itself at the moment in a curious situation. The Standard Model is the most precise and most accurate theory ever written. It describes perfectly all the interactions measured in experiments within broad range of energies. The Large Hadron Collider (LHC) at CERN gives us further evidence of the theory every day. On the other hand, however, the LHC has not given any lasting clues how to improve the Standard Model - and there can be no doubts that it requires to be extended, as it does not include some of the observed phenomena (e.g. neutrino masses or existence of Dark Matter). This is one of the reasons why particle physicists stare at the starts with growing hope, that some answers can be found among them.