Reg. No: 2021/42/E/ST2/00009; Principal Investigator: dr Andrzej Hryczuk

Dark matter and baryogenesis within multicomponent dark sectors and non-standard cosmological models

Popular project description

The creation of baryon-antibaryon asymmetry and the nature of dark matter are one of the largest mysteries of cosmology and particle physics.

The visible Universe is made of particles with only tiny admixture of antiparticles. The mechanism that causes this asymmetry is called baryogenesis and is necessary for the possibility of any form of matter to create stable structures and as a consequence stars, planets and life. Another indispensable ingredient for structures to form is the dark matter – an unknown matter component constituting about 80% of the total matter of the Universe. Despite the fact that it has been many decades since the discovery of its existence it is still 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 interconnections between these two processes: dark matter production and baryogenesis. Moreover, it will explore effects arising in more realistic, multicomponent scenarios for the theory of dark matter and study non-equilibrium in the Early Universe. It will help in deepening our knowledge about its history and properties.

A recently developed 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.

The physics of elementary particles and fundamental 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 continuously gives us further evidence for the Standard Model. On the other hand, however, the LHC has not given any lasting clues how to improve the theory - and there can be no doubts that it requires to be extended, as it does not include some of the observed phenomena, like the existence of dark matter. It cannot also explain baryogenesis, i.e. how the observable matter came to be. This is one of the reasons why particle physicists stare at the starts with growing hope, that some answers can be found among them.