More than 80% of matter in the Universe is made of dark matter of unknown origin. The existence of dark matter is an undeniable proof for the existence of New Physics beyond the Standard Model of fundamental interactions and the identity of dark matter is one of the greatest mysteries of nature. For many years experimental program of dark matter searches has been driven by a theoretical prejudice that dark matter possesses the charge of weak interactions. That approach has failed to bring a discovery of dark matter. This strongly motivates existence of the Dark Sector defined as a collection of particles, including the dark matter particles, that are not charged under the Standard Model interactions i.e. neutral with respect to strong, electromagnetic and weak interactions. Particles in the Dark Sector may, however, have charges of some unknown interactions.

In this project we propose and systematically explore a hypothesis that the physics of the Dark Sector is responsible for the solution of not only the dark matter puzzle but also other problems of the Standard Model. One of the problems is an unknown mechanism generating an excess of matter over antimatter in the Universe called baryogenesis. Moreover, the Standard Model suffers from a problem related to incomprehensible huge hierarchy between the electroweak scale, at which unification of electromagnetic and weak interactions occurs, of the order of 100 GeV and the Planck scale, at which effects of quantum gravity are expected to appear, of the order of 10^{19} GeV.

In this project many new dark matter candidates will be investigated in existing and new models of the Dark Sector which aim to solve also other problems of the Standard Model mentioned above. Among the dark matter particle candidates that will be studied there are also particles charged under new long-range interactions which may have impact on various interesting astrophysical observations.

The possibility of a strong first-order phase transition leading to successful baryogenesis in a cosmological history of models of the Dark Sector will be also investigated. In particular, it will be studied whether effects of the Dark Sector on the electroweak phase transition, which is known to be second-order in the Standard Model, may lead to the electroweak phase transition of the first order. Moreover, phase transitions originating from broken symmetries of the Dark Sector and their possible link to baryogenesis will be also investigated. A special attention will be given to the analysis whether phase transitions under consideration may lead to strong enough signal of gravitational waves to be observed in planned experiments searching for these waves.

The project overlaps in time with a very reach and diverse experimental program including new Cosmic Microwave Background experiments, dedicated searches for dark matter and the Run 3 of the LHC. This will drive our efforts to construct new theories of the Dark Sector which, in turn, will allow us to identify novel signatures of the Dark Sector. Possible experimental signals that cannot be explained in the Standard Model will be interpreted in models of the Dark Sector and will be used to develop new theoretical ideas.

The ultimate goal of the project is to shed new light on the structure of the Dark Sector which will bring us closer to its discovery.