DESCRIPTION FOR THE GENERAL PUBLIC (IN ENGLISH)

The physics system of our interest is a hot and dense, strongly interacting matter, consisting of quarks and gluons. This type of matter existed in the Early Universe but at about 10 microseconds after the Big Bang, due to the expansion of the Universe and cooling, it transformed itself into hadrons, i.e., particles which are bound states of quarks and gluons. In this context, we talk usually about the phase transition from the quark-gluon plasma to a hadron gas.

Similar physics conditions are now realized in Earth laboratories by colliding heavy atomic nuclei at the highest possible energies (for example, at the Large Hadron Collider at CERN and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory). This branch of physics is known as the field of ultra-relativistic heavy-ion collisions. To large extent, this activity has interdisciplinary character combining nuclear physics and high-energy physics with other fields of theoretical physics, such as statistical physics, kinetic theory, and relativistic viscous hydrodynamics.

As the matter of fact, the latter forms the basis of our understanding of the processes of heavy-ion collisions. Starting from the initial conditions which reflect the initial geometry of colliding nuclei, the hydrodynamic equations determine the space-time evolution of matter, including the phase transition from the quark-gluon plasma to a hadron gas.

A great accomplishment of the applications of relativistic hydrodynamics to describe heavy-ion collisions is an estimate of the shear viscosity of the plasma. It is characterized by the ratio of the shear viscosity η to the entropy density s. The hydrodynamic calculations indicate that this ratio is close to the value $\hbar/(4\pi k_B)$, which follows from the use of the string-theory methods to analyze strongly coupled systems (here $\hbar$ is the Planck constant divided by 2π and k_B is the Boltzmann constant). This result shows again that the physics of heavy-ion collisions connects different fields of physics, which may seem completely unrelated at the first sight.

The success of relativistic hydrodynamics poses new questions and problems, mainly about its applicability range and theoretical foundations that refer often to more microscopic theories. The aim of this project is an attempt to answer these questions and to develop existing formalism of viscous hydrodynamics in such a way that it is better suited for description of the dynamics of strongly interacting matter produced in heavy-ion collisions. Within the proposed project, one plans to extend the hydrodynamic approach, so it better describes out-of-equilibrium situations, includes the new degrees of freedom (that have been neglected in the past), and is closer to microscopic theories (for which it should be a good approximation). The studies will be based on the application of kinetic theory and direct generalizations of hydrodynamic equations. An important result of the investigations will be numerical codes that may be used in direct analyses of the new experimental data.

The project has a potential to contribute to the rapidly developing field of relativistic hydrodynamics, which has entered now its Golden Age.