DESCRIPTION FOR THE GENERAL PUBLIC

High-energy particles observed in a wide range of energies up to 10^{21}eV, constitute a very important ingredient of the Universe. They may influence substantially properties of the interstellar and intergalactic medium, processes taking place in the closest vicinities of astrophysical black holes, formation of young stars and the evolution of starforming regions, or finally physical processes taking place within the heliosphere. It is commonly believed that such particles, hereafter referred to as „cosmic rays", are accelerated predominantly at the fronts of strong shock waves driven in the ambient medium by supernova explosions, and also by relativistic jets generated by supermassive black holes residing in the nuclei of active galaxies (e.g., quasars). This standard model of the cosmic ray origin, states further that freshly accelerated particles, when injected into the interstellar and intergalactic medium, propagate diffusively from their sources to the Earth's atmosphere.

The main problem with the verification of the standard model of the cosmic ray origin, relies in the fact that astrophysical plasma is very different from what we can simulate in our laboratories. In particular, particle densities in the astrophysical environment are typically extremely low, and the magnetisation is typically extremely high; as a result, particles in space rarely interact with each other via direct Coulomb collisions; instead, they interact almost exclusively indirectly, via fluctuating electromagnetic field. In other words, astrophysical plasma is typically „collisionless". Moreover, velocities of various electromagneto-acoustic fluctuations propagating is space (hereafter „plasma waves") are, unlike in the case of our laboratories, often close to the speed of light. Finally, the energy scale of cosmic rays exceeds by many orders of magnitude maximum energies available in the accelerators on Earth (including even the *Large Hadron Collider*). For all those reasons, investigating particle acceleration and propagation in the astrophysical environment must rely on modelling and interpretation of non-thermal emission produced in a wide range of the electromagnetic spectrum (but in particular at X-ray and gamma-ray frequencies) by the high-energy particles. On the other hand, the most recent development in numerical simulation techniques, as well as „in-situ" observations of energetic particles in the solar wind and planetary magnetospheres within the Solar System, both enable a unique and complementary insight into the physics of astrophysical plasma.

The main motivation for the research project proposed here, is a strong conviction of the authors that the most recent observational results and numerical experiments challenge in many respect the standard model of the cosmic ray origin and propagation. In particular, it seems now more and more plausible, that not only supernovae and active galaxies, but also other types of astrophysical objects may be the sources of cosmic rays, and that high-energy particles may be efficiently accelerated not exclusively at the fronts of strong shocks, but also during the magnetic reconnection processes, and/or via stochastic interactions with various plasma waves. At the same time, non-linear effects in particle-wave interactions may lead to a non-diffusive propagation of cosmic rays from their sources. The main objective of the research project proposed here is to find – or, in some respects, rather to refine – a comprehensive description of the production and propagation of high-energy particles in space, taking into account all such additional effects, which are often ignored, but which may in fact be of a primary importance.