Popular summary of the research project

One of the most important challenges faced by theoretical physics is to construct the quantum theory of all fundamental interactions, which would combine properly the known quantum structures describing elementary particle physics with quantum gravity, the unknown quantized version of General Relativity. At present our knowledge is far from complete; in particular the application of standard quantization methods to gravity, which were very successful in quantum electrodynamics and high energy particle physics have failed. On the other hand, we need the theory of quantum gravity in order to describe, among others, the early moments of existence of our Universe, to clarify what is hidden behind the horizon of black holes and, presumably, to discover the nature of dark matter and dark energy, comprising most of the matter in the Universe.

The search for quantum gravity has proved to be a formidable task, and none of the attempts to find this theory was sufficiently successful. Despite this, in the last several decades we learned a lot about the structures of this future theory; in particular most of the approaches to quantum gravity point out to the fact that in this theory a minimal accessible length scale should exist, and space-time points make only sense in a macroscopic approximation. The existence of the minimal length has its very important consequence in the property that the spacetime in quantum gravity cannot be smooth and classical anymore. The Einsteinian paradigm about continuous commutative space-time, so successful in the construction of classical general relativity, in the domain of quantum gravity should be changed. In the presence of gravitational fields there is a limit of accuracy for the space-time localization measurements, with new uncertainty relations characterized by Planck length 10^{-35} m, which plays the role of the minimal length. As in quantum mechanics, we implement the algebraic consequences of these measurement limitations by postulating that quantum space-times are not commutative and transform under new type of transformations, called quantum symmetries.

The aim of our project is to investigate the consequences of the non-commutative spacetime hypothesis by studying several classes of quantum space-time models which can be linked with quantum gravity. In the project we will examine the properties of such models of non-commutative quantum space-times, consider their quantum symmetries and further pass to noncommutative field-theoretic models which will be applied e.g. in quantum cosmology and the search for quantum space-time symmetries in loop quantum gravity.

The project will be realized by the project leader (J. Lukierski), two senior investigators (A. Borowiec and J. Kowalski-Glikman), and four junior investigators, in collaboration with several foreign partners of the project participants. The research results will be published in very well-known international journals as well as presented at international symposia and conferences.