GENERAL DESCRIPTION OF OUR PROJECT

Quantum gravity is important for realistic reasons. It stands for the unification of the most robust physical laws known to us, which are written in the form of the two most precisely tested theories: (modified) general relativity about gravity in the large distances, and the standard model of elementary particles about the microscopic quantum structure of matter. The theory of quantum gravity we choose to study, loop quantum gravity, is the “minimal” theory that takes this unification as the only starting point for all physical laws. Therefore, our project of completing this theory is a pursuit of a microscopic theory of gravity, through a unified extension of the robust physical laws beyond their current domains of scales.

Quantum gravity is notoriously difficult, due to the clash between the principles of quantum theories and the notion of gravity being mediated by dynamical spacetime in general relativity. In our project, this problem manifests as the frontiers of loop quantum gravity, which take the form of concrete physical problems. This theory is based on a well formulated quantum description of gravity in terms of the absolute-microscopic (Plank-scale) building blocks of spacetime, in a similar manner of the standard model in which the states of matter can be built from the elementary particle excitations.

To show that the mentioned robust laws, applicable in their scales much larger than the Plank-scale, can emerge from loop quantum gravity, we will pursuit: (1) the proper descriptions of the elementary particles living among the Plank-scale building blocks of spacetime; (2) the construction of the quantum observables in the dynamical quantum spacetime, for the description of the measurable dynamics; (3) using the obtained Planck-scale dynamics to extract the emergent physical laws in the much larger scales.

The joint expertise of the members from the two group covers a wide range of perspectives and approaches in loop quantum gravity, useful for our stated goals. We will thus tackle the above through the various approaches, in search of the consistency and complements between the individual results. This way, the Plank-scale structures of the physical states may be obtained in a more stringent way with a deeper level of understanding. Also, we will adhere to the minimal nature of loop quantum gravity, such that our results may be formulated as testable predictions on the phenomenon addressed by the large-scale theories. As for the concrete results, we expect to obtain from loop quantum gravity: (1) emergent dynamical laws of the quantum matter in the large scales when the spacetime appears as a smooth continuum, and the possible corrections to the standard model resulting from the quantum nature of spacetime; (2) more precise ways of constructing meaningful quantum observables, with which loop quantum gravity may be formulated as a theory of deterministic evolution; (3) progress in the derivation of the emergent dynamics of various interesting gravity-matter coupling system, including the quantum cosmological spacetime, the quantum black holes, with various matter contents.

From these results, we expect to deduce the signature predictions of loop quantum gravity, in the form of crucial corrections to the robust laws. These corrections would provide observational signals to be tested by the ever advancing observations and experiments in cosmology and particle physics, when they reach toward the unexplored scales of the large and the small.