One of the biggest challenges in modern physics is full understanding of phenomena related to systems of strongly correlated particles. Exact solution of quantum mechanical many-body problem is possible only in some particular cases. The problem is exponential growth of computational complexity with system sizes, which are not tractable by best computers and probably it won't be possible in the future, in any case not using classical computers – the ones we use every day. Alternative solution, proposed by Richard Feynman in '80, is construction of isolated quantum system in order to study its thermodynamic properties, which can be also modified at will to design more exotic quantum state. Indeed, Feynman's idea has been realized for many years on ultracold gases in optical lattices, however currently only a limited number of quantum systems can be modelled, in particular only with short-range interaction. A disadvantageous factor are costs of extreme laboratorial environment, e. g. to construct an appropriate set of lasers and equipment to reach temperatures close to absolute zero.

In recent years an alternative concept to quantum simulations has been proposed in twisted atomic layers forming, so called, moire superlattices. Atomic layers deposited on top of each other and rotated by a given angle, form effective periodic potential with a lattice constant ranging from 1 to 100 nm, controlled by a twist angle. Appropriate choice of atomic layers forming a heterostructure with a fixed twist angle, simple change of carrier concentration by external potential, control of Coulomb interaction strength by a distance to nearby metallic gates, or additional change of electronic properties by applying external fields, electric and magnetic, assure that these systems satisfy all criteria of good quantum simulators. Indeed in recent years (2018-2021), a few leading experimental groups confirmed appearance of exotic phases in twisted atomic layers: correlated insulating and superconducting states in twisted bilayer graphene and Mott insulators or Wigner crystalls in transition metal dichalcogenides. In view of huge amount of possibilities of modelling strongly correlated systems, it seems a new field in condensed matter physics has appeared that will be dominant in next few years.

Relatively new character of this field causes that there are many open problems that need to be clarified in order to help directing appropriate experimental research, in twisted bilayer graphene: the nature and stability of insulating states and the origin of superconductivity, and how one can increase a transition temperature to a superconducting phase, or in twisted transition metal dichalcogenides what is the relation between modelled quantum system and a twist angle, type od heterostructure or external factors. Theoretical research within this project are aimed at derivation of appropriate effective many-body models depending on mentioned controlled parameters in order to propose given quantum simulators that can be realized experimentally. Additionally, the aim of the project is to create theoretical foundations explaining latest experimental results and deeper understanding of the nature of systems of strongly correlated particles.