

Quantum physics is the branch of science relating to the very small. The non-intuitive properties of quantum physics come from the fact that we cannot just take the laws of nature describing the every-day, macroscopic world and apply directly to atoms or light. The reason of that is that in the quantum realm the principle of locality is violated. This principle states that an object is only directly influenced by its immediate surroundings. However, quanta exist in a haze of probability and cannot be assigned a definite position. Their position is spread over two or more places at once. Moreover, particles can become entangled, which means that actions on one entity can affect its partners across the cosmos.

This proposal is intended to study some consequences of many-particles entanglement and resulting, fascinating phenomena coming from the quantum world. One of the key achievements in these studies was the shift from reductionistic paradigm to a new one based on collective phenomena. This is the so-called principle of emergence. Emergence is a process whereby larger entities, patterns, and regularities arise through interactions among smaller or simpler entities that themselves do not exhibit such properties. The principle of emergence is central in the quantum world and often connected to the phenomenon of quantum entanglement. The basic idea of quantum entanglement is that two particles can be intimately linked to each other even if separated by millions of kilometers. A change induced in one will affect the other. If many quantum particles are entangled the emergent behavior can be really complex and counterintuitive. The non-trivial patterns of entanglement is the root of many highly novel phenomena and new phases of matter unparalleled in our usual experience. The goal of this project is to develop a theoretical framework to study complex, emergent behavior of quantum systems and to lay the ground for technologies of the future such as quantum computers.