Abstract for the general public

QLATE: Quantum Large-Time Evolution

Characterizing Residual Coherence and Quantum Advantage

Quantum mechanics revolutionized our understanding of reality, driving scientific research and development for over a century. Superposition and entanglement allow technological advancement in several applications, from computing to metrology and communication. In particular, quantum protocols have been shown to outperform their classical counterparts, allowing us to solve computational problems exponentially faster than with a classical computer or to create cryptographic protocols that are completely safe against any attack. However, environmental interactions disrupt coherence, causing systems to decay into incoherent classical states, thereby limiting our ability to fully exploit the quantum world. Characterizing these effects is essential for fully leveraging the potential of the quantum realm.

The general evolution resulting from interactions with the environment is highly intricate, with several open problems that remain extremely challenging to address. In recent years, a particular aspect of this evolution has sparked great interest within the scientific community: asymptotic dynamics. From a physical standpoint, this heightened interest stems primarily from the existence of well-defined regions that are safeguarded from classical effects. These subspaces are reached by allowing the system to evolve for a sufficiently long time.

The overarching objective of this project is to provide quantum protocols protected against noise arising from interactions with the environment. We will develop various certification techniques that ensure that, for a given quantum system, some quantumness persists even if the system interacts with the environment. Beyond this general framework, we will specialize to concrete problems of nonlocality, which is one of the most striking consequences of quantum theory and Entanglement. Beyond its fundamental interests, it is used in many applications, such as key distribution and random certification. We will construct models of nonlocality that are protected even in the presence of interactions with the environment and thus suitable for experimental realization.