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Summary of the doctoral thesis

"Objectivity in open quantum systems"

Since the birth of quantum mechanics, the macroscopic world has not been consistently explained along with the microscopic world, despite our belief that microscopic objects are fundamental ingredients of the macroscopic world. In recent years, it has been one of the most popular views on a mechanism behind the quantum-to-classical transition that such apparent distinction between the macroscopic and microscopic worlds comes from a collective effect known as decoherence due to a large number of uncontrolled degrees of freedom.

This thesis examines an advanced decoherence mechanism in two simple but important theoretical models of open quantum systems: a harmonic oscillator interacting with either a collection of harmonic oscillators, called quantum Brownian motion (QBM) model, or spins, called a boson-spin model. Our interest is to find signatures of an emergent classicality through environmental interactions in the systems as proposed by the quantum Darwinism idea. More concretely, we look for ``objectivity" emerging from quantum states, based on further development of quantum Darwinism, called spectrum broadcast structures (SBS). These are specific multipartite quantum state structures, encoding an operational notion of objectivity.

In quantum Darwinism, the process of classicalization through environmental interactions is parallel to the information transfer from a central system to the environment. We quantify this information transfer by the distinguishability for the quantum states of the environment. Due to such dualism, our focus in the dynamics are on the situation where the state of a central oscillator is close to a classical state and not much influenced by the environmental interactions, which is not the one usually adopted in open systems theory, e.g. in the master equation approaches such as the Born-Markov approximation. We choose realistic initial conditions of the environment such as the thermal state. In order to identify objectivity in the structure of a quantum state, we analyze the decoherence factor and the generalized overlap, which measure decoherence and the environmental state distinguishability, respectively.

We obtain two different length scales associated with decoherence and distinguishability for both systems. This may come as a surprise because the decoherence scale is usually treated as the classicalization scale. The consequences in both systems for objectivity are the following: i) the bigger the number of environmental subsystems are taken into account, the better objectivity occurs, ii) the decoherence factor and the generalized overlap form a complementary relation and

iii) distinguishability is more difficult to obtain than decoherence. Especially, in the boson-spin model, we find that the initial momentum contribution of a central oscillator and a spin self-Hamiltonian play a crucial role in objectivity. We have also found an interesting application of the Floquet theory in this model.

Finally, we study objectivity from a quantum-information point of view. Working in the boson-spin model, we treat the information transfer to the environment as a quantum channel. We analyze the Holevo quantity, which describes the maximum information transfer into a spin environment. This provides an interesting example of application for the continuous variable version of the Holevo theorem to open quantum systems and the quantum-to-classical transition.

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