Open quantum systems dynamics

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Every physical system is never completely isolated, as the very same possibility of testing its existence relies on the fact that it interacts with some external world. The Quantum Mechanics itself, understood as a physical theory describing reality, considers necessarily the presence of an observator and this necessarily implies for every physical system to be embedded in some environment (at least theoretical). In any case, today is still obscure the transition from the quantum coherent world to the classical non-coherent world in which we live and that we experience every day. At the heart of this problem there is the need of establishing a dialogue between us, macroscopical objects, and the quantum microscopical objects. However, it is today clear that studying quantum systems and, in particular, the way they can be used and controlled for conveying or extracting information, requires a thorough analysis of how they interact with their, no matter how "big", environment. **Open Quantum Systems** (OQS) are purely quantum physical systems whose behaviour requires being described taking into account their interaction with some properly chosen quantum environment.

Considering issues related with the quantum-to-classical crossover, we notice that it is not necessary for a macroscopic object to behave classically. An exemplary case is that of a system made by a large number N of spin-1/2 particles and such that its total spin S is a conserved quantity: no matter how large N is, such magnet is, in general, a genuinely quantum one, as clearly seen if its total spin is, say, $S = 1/2$ or $S = 1$. In fact, it can be qualitatively understood that what actually matters, as far as the wiping of quantum features is concerned, is the dimension of the portion of Hilbert space effectively explored by the state of the system during its evolution: if this dimension is large, a classical behaviour emerges. Referring to the above magnetic system, the portion of Hilbert space effectively explored has dimension $2S + 1$: a classical-like dynamics is hence expected in the large-S limit, which is indeed the formal classical limit for spin systems.

In the first part of my PhD, we study the case when a magnetic system Ξ, made by N spin-1/2 particles is seen as the environment of some underlying quantum partner. The two systems interact, and the magnet features a global symmetry that guarantees its total spin S to be a constant of motion. As far as one keeps S finite, such magnet is a prototype of a system that has a distinct quantum behaviour despite being macroscopic (N goes to infinity). As for its microscopic companion we choose a quantum mechanical oscillator Γ, with which Ξ exchanges energy according to a Hamiltonian that goes beyond the pure-dephasing interaction. In particular, we analyze the back-action, i.e. the evolution of the environment induced by Γ.

In the future, we would like to analyze, for the above system, possible connections with the phenomenon recently introduced under the name of "quantum darwinism"; moreover, in the framework of studying macroscopic environments, we would like to explore the possible connections between quantum information theory and (quantum?) gravity.