The dynamics of open quantum systems

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Aufgabenstellung

"In open quantum systems, one of the established ways to deal with a given problem is to consider its microscopic description, in terms of the degrees of freedom of both the system and the environment and of the interaction between them. In this kind of approach, the environment is usually represented as an infinite collection of quantum harmonic oscillators, and the coupling between them and the system is encoded in a function of their frequencies called the spectral density. The state of the environment, both at equilibrium and as the dynamics progresses, can be averaged over in order to determine the so-called reduced dynamics of the system in contact with it, without carrying along unnecessary information about the dynamics of the harmonic oscillators.

The spectral density of an environment is not usually known from first principles but rather introduced based on observation of experimental data or inference on theoretical grounds, which raises the question of how strongly an error in it will affect the reduced dynamics of the system. In a previous paper (https://arxiv.org/abs/1611.03377), we addressed this issue for the case of a two-level system coupled to a harmonic environment, and derived an error bound on the state of the system given an error in the spectral density.

One crucial factor that made it possible to obtain this result was the finite dimension (2) of the system; even for the simplest infinite-dimensional systems, such as a free particle or a harmonic oscillator, we believe that no such bound can exist in general. However, in the special case of a harmonic oscillator initialized in a Gaussian coherent state and coupled linearly to the harmonic oscillators of the environment, the system becomes effectively two-dimensional again because the state is specified by just two parameters at all times. Therefore, it might be possible to rephrase the problem in such a way that a similar error bound can be derived, extending the uses of our previous result to a different class of systems.

The topic involves basic notions of quantum mechanics such as the quantum harmonic oscillator, multipartite systems, mixed states and partial trace, specific instruments such as coherent states and their properties, and possibly a thorough revision of the connections between the canonical (operator) and path-integral formulations of quantum mechanics and their meaning and foundations.