Diffusion and Dissipation in Quantum Maps and Algorithms: Spectral Quantum-Classical Correspondence and Noise Models

Abstract

The issue of quantum-classical correspondence is key to understanding the emergence of the classical world from systems governed by quantum laws. The fast loss of correspondence in classically chaotic quantum systems is reestablished in the presence of decoherence caused by an environment. To the usual approach to the study of correspondence in short time scales through the time evolution of mean values of observables we opose a long time approach. We study the spectrum of the propagator of density matricies in the presence of noise, in the $\hbar \to 0$ and negligible noise strength limits.

The systems studied are quantum maps on the torus because they provide simple examples where all the main features of chaotic systems appear. To model open systems we use the superoperator formalism and their operator sum or Kraus representations. These superoperators introduce decoherence (and also dissipation). We show that the spectrum of the propagator resulting of the composition of a unitary map and a difusive noise channel is closely related to the classical quantities that determine the correlation function decay: the Ruelle-Pollicott resonances. To do so we introduce two ways of eficiently computing the relevant part of the spectrum. Moreover we show how time dependent quantities like the linear entropy and the Loschmidt echo, of interest in issueas related to foundations of physics, exhibit a long time behavior with a universal regime determined by the largest classical resonance.

Finally, we study different models of noise which are relevant in quantum computation and quantum information. We relate quantum algorithms with quantum maps and use phase space techniques. We also find fundamental differences between identity preserving channels with respect to identity non-preserving ones. The latter correspond to dissipative processe while the former correspond to diffusion and decoherence.

Keywords: Quantum-classical correspondence, open quantum systems, asymptotic decay, quantum dynamical semigroups.