Synchronization and quantum correlations in networks

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Synchronization phenomena have been observed in a broad range of physical, chemical and biological systems but there are few attempts to describe them in the quantum regime. Most of the attention in this regime has been devoted to the problem of entrainment induced by an external driving[1] and not to spontaneous synchronization. We also mention recent research by different groups on synchronization of nano/microscopic systems. Even if these works[2–4] are concerned with classical (average) properties these devices are indeed susceptible of having quantum behaviour, being the subject of an intense experimental effort. In Ref.[5], for the first time, we established the connections between the phenomenon of synchronization and quantum correlations.

We initially considered a fundamental quantum system[6,5], two coupled and detuned quantum harmonic oscillators dissipating into the environment. Different dissipation mechanisms, corresponding to the situations in which (i) every oscillator dissipate in an independent bath (separate baths, SB), or (ii) the correlations length in the bath is larger than the oscillators systems (common bath, CB), are considered.

The dynamics of the system[6] for Gaussian states, is fully characterized by first and second order moments of positions and momenta of the oscillators. We identify the conditions leading to spontaneous synchronization showing that the ability of the system to oscillate at a common frequency is related to the existence of disparate decay rates of the normal modes[5]. We then analyzed different measures of correlations and their temporal decay due to decoherence. We showed that this phenomenon is accompanied by robust quantum discord[7] and mutual information between the oscillators, preventing the leak of information from the system.

Once identified the conditions for synchronization and its quantum aspects, we extended our analysis to the case of a quantum network[8]. At difference from the case of a couple of oscillators, we showed that even in presence of diversity between the nodes (in their frequencies and in the couplings with the rest of the network) it is possible to have asymptotic entanglement. We discuss several situations, like the possibility to synchronize the whole network by tuning one of the oscillators frequencies, or by inducing synchronization only in one part of the cluster, or the conditions to connect two oscillators to a network inducing asymptotic entanglement between them.

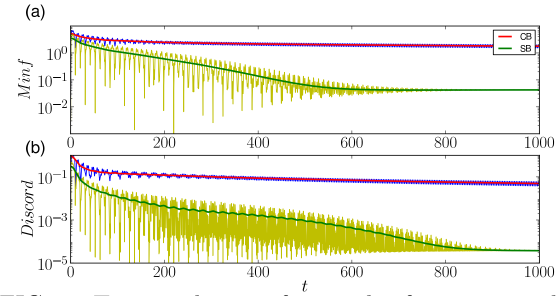

FIG. 1. Time evolution of mutual information and quantum correlations (discord) in the cases of a common bath (CB) and separate baths (SB). More details in Ref.[5].

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