Memory kernel and Divisibility of Gaussian Collisional Models [1]

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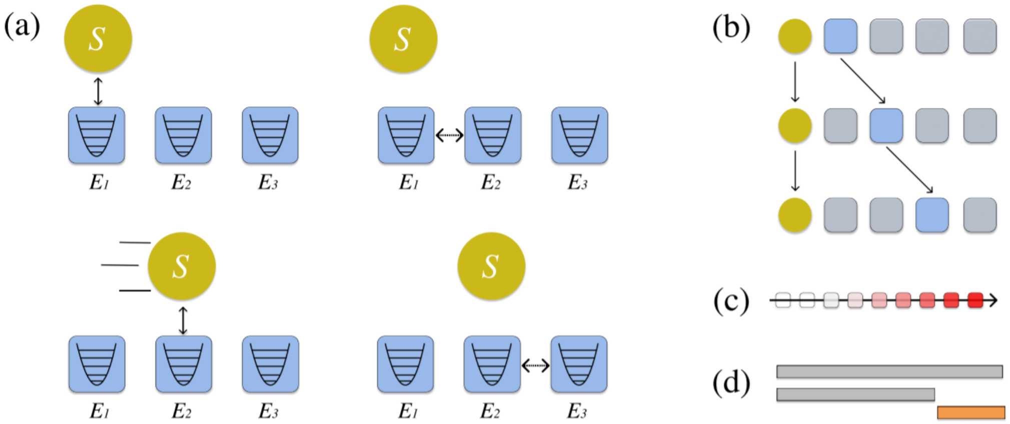

Figure 1: Non-Markovian collisional models. **(a)** First few steps of the dynamics. The system-ancilla interactions SE_n are interspersed by ancilla-ancilla interactions E_nE_{n+1}, which propagate information forward **(b)** Basic structure of the Markovian embedding, a map from the Hilbert space of $S\,E_n$ to that of $S\,E_{n+1}$. **(c)** The memory kernel quantifies how different instants of the past affect the evolution at present times. **(d)** CP-divisibility. Maps in gray, from time 0 to t_n or t_m are by construction CPTP but the intermediate from t_n to $t_m > t_n$ may not be.

The growing interest in quantum information processing applications has highlighted the need for furthering our knowledge on the notion of information flow. Unlike classical systems, in the quantum realm information leaks are much more efficient, i.e. when a system interacts with an environment, information about the former is inevitably transferred to the latter. When the environment is very large and complex, this information may never return. In this case, the dynamics is called Markovian. In general, however, there may be a backflow of information, which characterizes a non-Markovian evolution [2]. From the point of view of causality, this backflow quantifies the ability of the dynamics to communicate past information to the future [3]. Non-Markovianity therefore touches at the core of information processing, which justifies the need for detailed studies. Analyzing non-Markovianity, nevertheless, for general environments is an extremely difficult task. First, the calculations quickly become impractical when the size of the bath is large. Second, realistic baths often have many additional features that tend to mask the effects one is interested in. This motivates the search for controllable models, where the degree of non-Markovianity can be finely tuned. One way to accomplish this, which has seen an enormous surge in popularity in recent years, are through the so-called collisional models [4–15]. The basic idea is to replace the open dynamics of a system by a series of sequential interactions between the system S and small environmental units E_1, E_2, E_3, … (henceforth referred as ancillas). All ancillas are prepared in the same state and each interaction only lasts for a fixed time, after which they never interact again. This therefore leads to a stroboscopic dynamics for the system. The advantage of collisional models is that non-Markovianity can be introduced in a fully controllable manner. There are two main ways to do so. The first is to consider that the ancillas already start correlated [16–20]. The other one is to assume information is transmitted between them during the process [21–28]. Here we shall focus on the second case, that is, we consider a scenario where neighbouring ancillas E_nE_{n+1} interact with each other in between the interactions SE_n and SE_{n+1} (see Fig. 1(a)). This additional interaction signals information from the past to the future, so that when the SE_{n+1} interaction arrives, the ancilla E_{n+1} will already contain some information about the system. We overcome these difficulties by focusing on continuous-variable collisional models, undergoing Gaussian-preserving dynamics. The advantages that come with the Gaussian toolbox allows us to construct a complete framework for the study of non-Markovianity, which: **(i)** encompass a broad range of scenarios; **(ii)** allows for the explicit construction and computation of the memory kernel and **(iii)** provides easy access to a CP-divisibility monotone, which can be directly compared with the memory kernel. The framework is also amenable to analytical calculations and extremely efficient from a numerical perspective. Thus, despite being restricted to Gaussian interactions, it offers multiple advantages over more general maps.

References

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