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What is Markovian and non-Markovian in Quantum Mechanics: new approaches and viewpoints

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While in classical physics the notion of what is Markovian or not is well defined, this is not the case when it comes to open quantum systems. What makes a quantum dynamics Markovian or non-Markovian (NM)? Traditional answers to this question involve the celebrated Lindblad master equation (ME) and/or the ability of an open dynamics to be governed by a time-local ME. The last few years, yet, witnessed a thorough revision of such concepts with the aim to establish in a rigorous way exact criteria for assessing whether or not a dynamics is NM and even quantifying its degree of quantum “non-Markovianity”. This resulted in a number of “non-Markovianity measures” that have been put forward. Based on these and a number of theoretical advancements, the lack of a Lindblad ME or time-local ME turns out not to be a reliable criterion. For instance, there are Markovian dynamics that are not described by a Lindblad ME, while, on the other hand, many open dynamics that are strongly NM can be shown to effectively obey a time-local ME.

After reviewing these new concepts, in the last part of the talk I discuss a problem where they are used to tackle the question as to whether or not the dynamics of a qubit undergoing single-photon scattering in a waveguide is Markovian. It turns out that, in the infinite-waveguide case, the dynamics is NM when the photon-wavepacket width is comparable with the qubit-field coupling rate. In the semi-infinite waveguide case (mirror-like boundary condition), this source of non-Markovianity adds to that due to the photon delay time (owing to the finite qubit-mirror distance).



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