Thermodynamic of trajectories for quantum harmonic oscillators

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The description of the dynamics resulting from the interaction of a quantum system with its environment is one of the key goals of modern quantum physics. The formal description of the evolution of an open system, especially in a quantum context, is typically tackled through master equation approach. Recently, a promising approach came to light, combining the quantum master equation and large-deviation theory [1]. Unlike others, this approach applies to any dissipative quantum systems, paving the way to a standard description of dynamic of open quantum systems in terms of thermodynamics of trajectories.

We consider a paradigmatic system in quantum mechanics, quantum harmonic oscillators connected to baths whose dynamics is governed by a quadratic master equation in Lindblad form. This system is a fundamental building block used to describe a large variety of quantum degrees of freedom, central in quantum optics. I will present how for a single harmonic oscillator, our approach, based on quantum optics methods yields an analytical expression for the large-deviation function encoding the statistics of exchange between the system and the environment [2]. This permits to evaluate, behind others, essential quantum optics features such as anti-bunching.

Furthermore, the same approach, generalized to any network of harmonic oscillator undergoing quadratic dynamic allows us to, efficiently derive numerically the behavior of energy-exchange processes between the system in a steady state and the environment. From it, we can evaluate key thermodynamic aspects such as fluctuation theorem and irreversible entropy produced for a large variety of open quantum systems [3]. We also derive a systematic algorithm to derive, step by step, the full-statistics of the exchange thermodynamics [4].

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