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Adiabatic elimination approach to the completely positive master equation for open quantum Brownian motion

Recently, Bauer *et al.* [1,2] introduced *open quantum Brownian motion* (OQBM) as a scaling limit of discrete-time open quantum walks [3,4], providing a new mathematical framework for quantum Brownian motion. In this setting, the dynamics of the Brownian particle are governed by dissipative interactions with a thermal bath and depend on the state of internal degrees of freedom. A microscopic derivation of OQBM for a free Brownian particle subject to decoherent interaction with a thermal environment was subsequently proposed [5,6]. In our recent work [7], we extended this framework by deriving OQBM in a generic dissipative scenario using the method of adiabatic elimination of fast variables. However, this approach led to a master equation that is not completely positive, consistent with the limitations of the standard Caldeira-Leggett model [8,9]. To resolve the issue of positivity, we now apply the rotating wave approximation (RWA) to the system-bath interaction Hamiltonian. This leads to a completely positive master equation for OQBM in the case of a weakly driven open Brownian particle confined within a quadratic potential and dissipatively coupled to a thermal bath. From the resulting dynamics, we derive equations for the first, second, and third cumulants of the position distribution of the OQBM walker.

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