Comparison of Quantum Master Equations for Far-from-Equilibrium Dynamics

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Abstract

We assess the accuracy of two quantum master equations for far-from-equilibrium electron transport through a double quantum dot coupled to two fermionic reservoirs at fixed temperature and chemical potentials [1, 2]: the Born–Markov (BM) and Born–Markov–Secular (BMS) equations. An exact benchmark is constructed by analytically solving matter and energy currents for a single-dot model and mapping it (via an isomorphism) to the double-dot system [3]. We then compare steady-state matter/energy currents, populations, and coherences as functions of the inter-dot tunneling amplitude. BM reproduces the benchmark well across the full tunneling range. In contrast, BMS deviates strongly at small tunneling but becomes accurate at large tunneling. This trend is quantified by the trace distance between the steady-state density matrices predicted by BM and BMS.

References

[1] AE Allahverdyan, R Balian, and Th M Nieuwenhuizen. "Quantum thermo dynamics: thermodynamics at the nanoscale". In: Journal of Modern Optics 51.16-18 (2004), pp. 2703–2711.

[2] Micha Horodecki and Jonathan Oppenheim. "Fundamental limitations for quantum and nanoscale thermodynamics". In: Nature communications 4.1 (2013), pp. 1–6.

[3] Philipp Strasberg, Gernot Schaller, Tobias Brandes, and Massimiliano Esposito. "Quantum and information thermodynamics: a unifying framework based on repeated interactions". In: Physical Review X 7.2 (2017), p. 021003.

Figures

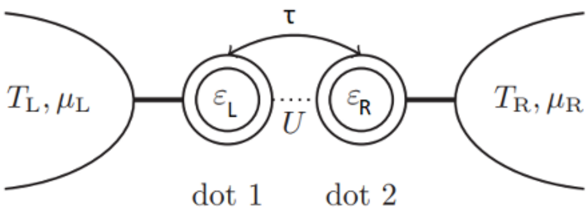

Figure 1: Schematic illustration of a DQD model. Dot 1 is coupled to the left lead with temperature TL and chemical potential μL and dot 2 is connected to the right lead. Electrons can hop between the two quantum dots with an inter-dot tunneling strength τ and there could be a presence of a nonlinear repulsive Coulomb interaction denoted by U.

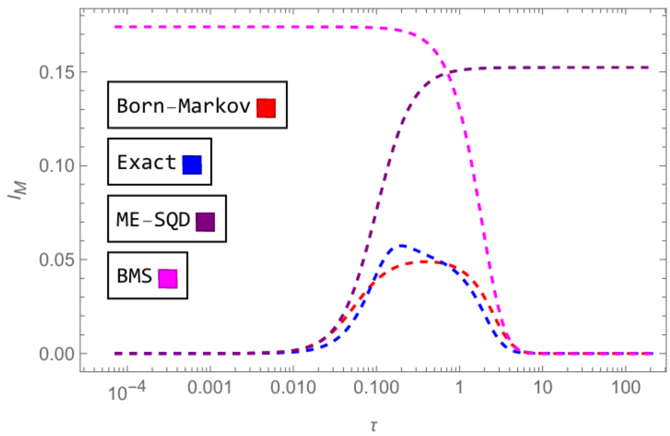

Figure 2: Matter current produced in the DQD plotted as a function of the inter-dot tunneling amplitude τ.