Theory of decoherence for non-equilibrium quantum systems

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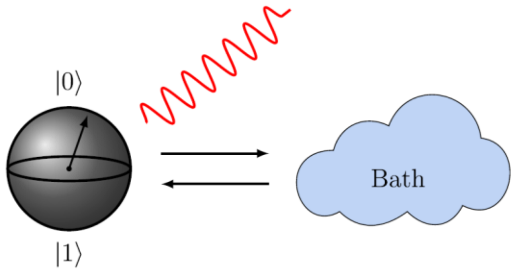
Abstract

We investigate in parallel two common pictures used to describe quantum systems interacting with their surrounding environment, i.e., the stochastic Hamiltonian description, where the environment is implicitly included in the fluctuating internal parameters of the system, and the explicit inclusion of the environment via the time-convolutionless projection operator method. Utilizing these two different frameworks, we show that the dissipator characterizing the dynamics of the reduced system, determined up to second order in the noise strength or bath-system coupling, is universal [1]. That is, it keeps the same form regardless of the drive term, as long as the drive is weak. By considering the first non-vanishing higher-order term in our expansion, we also derive the linear response correction due to memory-mediated environmental effects in driven-dissipative quantum systems [1]. We demonstrate this technique to be highly accurate for the problems of dephasing in a driven qubit [1] and for the theory of pseudomodes for quantum environments [1,2]. Notably, this extends the Redfield equation to the fully-quantum regime. In the final part of the talk, we complement our theory by including non-gaussian fluctuations and by discussing the application of this formalism to the quantum control of Bosonic modes [3].

References

[1] L. Bernazzani, B. Gulácsi, G. Burkard, Quantum Sci. Technol. 10, 045050 (2025).
[2] G. Pleasance, B. M. Garraway, F. Petruccione, Phys. Rev. Res. 2, 043058 (2020).
[3] L. Bernazzani et al., manuscript in preparation (2026).

Figures



$$\dot{\rho} = -i[\mathrm{H} + \mathrm{V}(t), \rho] + \left[\mathbb{K}^{\mathrm{II}}(t) + \mathbb{K}^{\mathrm{III}}(t)\right]\rho$$