TAMING THE BLOCH-REDFIELD EQUATION: RECOVERING AN ACCURATE LINDBLAD EQUATION FOR GENERAL OPEN QUANTUM SYSTEMS

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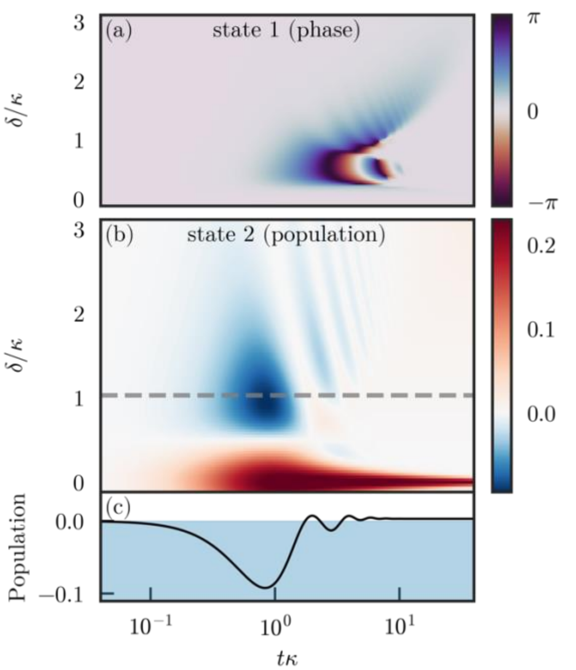
Master equations play a pivotal role in investigating open quantum systems. In particular, the Bloch-Redfield equation stands out due to its relation to a concrete physical environment [1]. However, without further approximations it does not lead to a Lindblad master equation that guarantees that the density matrix stays completely positive, which has raised some concerns regarding its use. This study builds on previous efforts to transform the Bloch-Redfield framework into a mathematically robust Lindblad equation [2, 3], while fully preserving the effects that are lost within the secular approximation that is commonly used to guarantee positivity. These previous approaches introduce two potential deficiencies: the environment-induced energy shift can be non-Hermitian and some decay rates can be negative, violating the assumptions of Lindblad's theorem. Here, we propose and evaluate straightforward solutions to both problems. Our approach [4] offers an effective and general procedure for obtaining a Lindblad equation, derived from a concrete physical environment, while mitigating the unphysical dynamics present in the Bloch-Redfield equation.



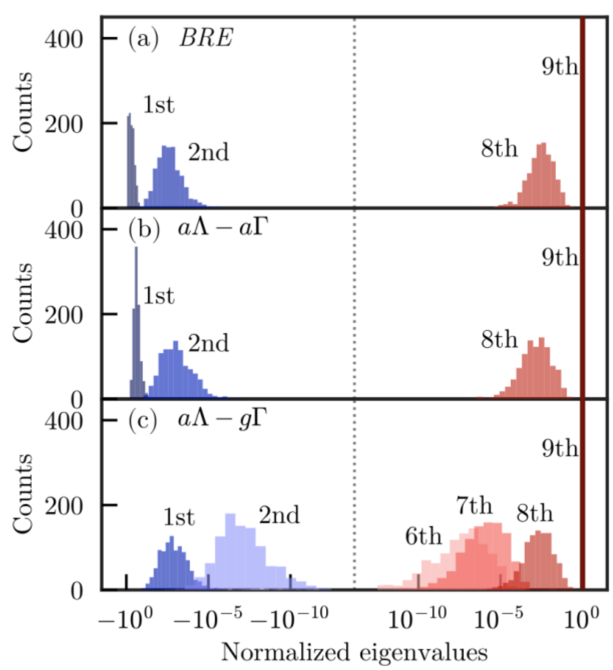


Figure 1 – Left: (a) complex and (b, c) negative populations arising from the master equation derived in [2]. Right: normalized eigenvalues of the Kossakowski matrix. The negative ones prevent these equations from yielding physical results. The last row (c) showcases much smaller negative values, which are negligible [4].

References:

[1] Jeske, J. et al., *J. Chem. Phys.*, **142**, 064104 (2015).
[2] McCauley, G. et al., *npj Quantum Information*, **6**, 74 (2020).
[3] Fernández de la Pradilla, D., Moreno, E., Feist, J., *SciPost Phys.*, **15**, 252 (2023).
[4] Fernández de la Pradilla, D., Moreno, E., Feist, J., *arXiv:2402.0635 [quant-ph]* (2024).