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Modeling Open Systems

S&T Campaign: Computational Sciences
Computing Sciences

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Research Objective

- To develop the most efficient possible models for simulating open quantum systems in regimes in which present master equations fail.

Challenges

- Understanding the dynamics of open systems, through analysis of bath models and exact simulations.
- Distilling this information, quantifying its complexity, and synthesizing reduced models.

Example challenge

Simple thermal master equations take different forms depending on whether transition are degenerate or non-degenerate. At present it is not known how to interpolate between these equations. Below we show two master equations describing the transitions

|1> -> |0> and |2> -> |0>

The first applies when the transitions are degenerate, and the second when they are not:

$$\begin{aligned}\dot{\rho} =& \frac{-i}{\hbar}[H_{\rm sys}, \rho] \\ &- \gamma\left(|3\rangle\langle 3|\rho|3\rangle\langle 3| - |1\rangle\langle 3|\rho|3\rangle\langle 1|\right) \\ &- \gamma\left(|2\rangle\langle 2|\rho|2\rangle\langle 2| - |1\rangle\langle 2|\rho|2\rangle\langle 1|\right) \\ &- \gamma\left[\left(|2\rangle\langle 3| + |3\rangle\langle 2|\right)\rho\left(|2\rangle\langle 3| + |3\rangle\langle 2|\right)\right] \\ &+ \gamma\left[|1\rangle\langle 2|\rho|3\rangle\langle 1| + |1\rangle\langle 3|\rho|2\rangle\langle 1|\right]\end{aligned}$$

$$\begin{aligned}\dot{\rho} =& \frac{-i}{\hbar}[H_{\rm sys}, \rho] \\ &- \gamma\left(|3\rangle\langle 3|\rho|3\rangle\langle 3| - |1\rangle\langle 3|\rho|3\rangle\langle 1|\right) \\ &- \gamma\left(|2\rangle\langle 2|\rho|2\rangle\langle 2| - |1\rangle\langle 2|\rho|2\rangle\langle 1|\right)\end{aligned}$$

ARL Facilities and Capabilities Available to Support Collaborative Research

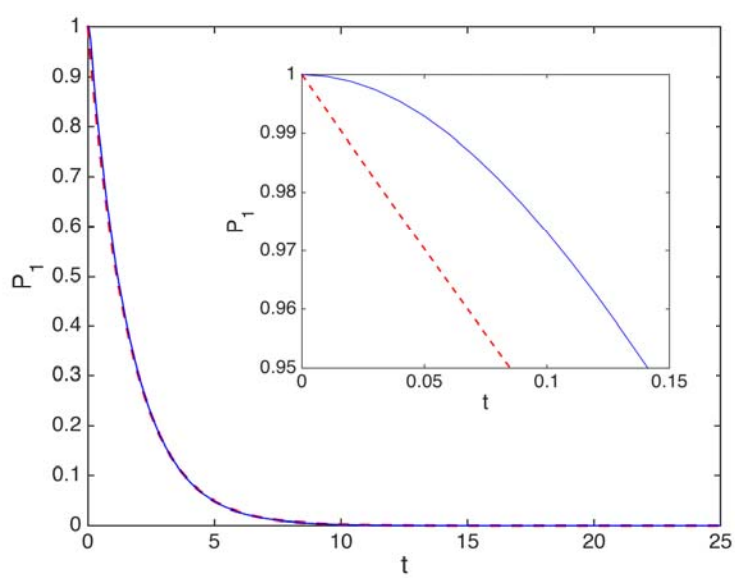
- Theory team with expertise in quantum measurement, open systems, and quantum control, MPI/C++
- Supercomputers and HPC support staff

Expertise/Facilities/Capabilities Sought in Collaboration

- Complementary expertize in open systems, simulation algorithms and methods, and approximation methods.

References

- Breuer and Petruccione, The Theory of Open Quantum Systems (OUP, Oxford, 2007).
- Rivas, Douglas, Plato, Huelga, and Plenio, New J. Phys. 11, 113032 (2010).



Unitary simulation of weakly-coupled atomic decay (blue) verses the Markovian master equation (red-dashed).

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