Quantum thermodynamic insights and their use for atomistic spin dynamics simulations and cold atom thermometry

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I will give an introductory talk to quantum thermodynamics, reporting on a selection of my group's results. First, it is known that the coupling of nanoscale and quantum systems with their environment can be relatively strong. This coupling changes the dynamics as well as the equilibrium state [1]. To describe the dissipative dynamics of a spin, we set up a system+bath Hamiltonian and derive a generalised Landau Lifshitz Gilbert (LLG) equation [2], a phenomenological equation widely used in magnetism. We also provide an efficient method to numerically solve the non-Markovian dynamics and obtain the bath-modified equilibrium state. The utility of these concepts is demonstrated by predicting the equilibrium state's magnetisation of a magnetic material (e.g. nickel). Including environment-induced quantum effects gives a much improved match with experimental data, also in the low temperature regime which has resisted accurate atomistic modelling [3].

In the second part of my talk, I will report on our recent results on optimal (global) quantum thermometry [4]. This new framework is most relevant for small data sets, such as those in cold atom experiments where taking data series can be a lengthy process. Our theoretical framework, based on Bayesian principles, has successfully been used to reduce estimation errors in release-recapture experiments [5].

[1] Open quantum system dynamics and the mean force Gibbs state, A. Trushechkin, M. Merkli, J. D. Cresser, J. Anders, AVS Quantum Sci. 4, 012301 (2022)

[2] Quantum Brownian motion for magnets, J. Anders, C. Sait, S. Horsley, New J. Phys. 24, 033020 (2022)

[3] Accounting for Quantum Effects in Atomistic Spin Dynamics, M. Berritta, S. Scali, F. Cerisola, J. Anders, arXiv:2305.17082 (2023)

[4] Global Quantum Thermometry, J. Rubio, J. Anders, L. A. Correa, PRL 127, 190402 (2021)

[5] Optimal cold atom thermometry using adaptive Bayesian strategies, J. Glatthard, et al., PRX Quantum 3, 040330 (2022)