

Robustness of Qubit Probes for Sensing Quantum Phases of Matter Under Thermal Fluctuations

Presenting author: Sambunath Das

Co-Authors: Sambunath Das¹, Hari Kumar Yadalam², Mark T. Mitchison², Katarzyna Roszak¹

1. Institute of Physics of the Czech Academy of Sciences, 182 00, Prague, Czech Republic

2. King's College London, Strand, London, WC2R 2LS, United Kingdom

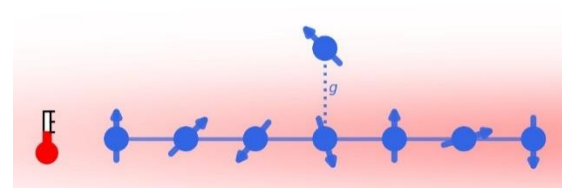
E-mail: sambunath@fzu.cz

Probing complex quantum systems with a mobile qubit has emerged as a powerful technique to explore properties that are otherwise difficult to access with classical measurements [1-3]. By coupling a qubit to a many-body system and analysing its decoherence, one can extract information about the system's correlations, excitations, and critical behaviour. In particular, a qubit interacting via a pure dephasing coupling with a spin-1/2 Heisenberg XXZ chain has been shown to act as a sensitive detector of global features, such as the anisotropy parameter, gapless versus gapped phases, and quantum critical points [4].

While these studies focused on zero-temperature environments, real quantum systems are often subject to thermal fluctuations, which can strongly influence their dynamics. Understanding how finite temperature affects qubit decoherence provides insight into the interplay between thermal excitations and many-body correlations. Here, we extend the qubit-probe approach to finite temperatures, examining the decoherence dynamics of a qubit coupled to a thermal Heisenberg spin-1/2 XXZ chain [Fig.1]. Our results reveal that temperature not

only modifies coherence rates but can qualitatively change the decoherence behaviour [Fig. 2], establishing the qubit as a sensitive probe of thermal effects in strongly correlated spin environments.

Figures



Figures 1. Schematic diagram of a spin-qubit probe interacting with a thermal Heisenberg spin chain. g denotes the qubit-chain coupling.

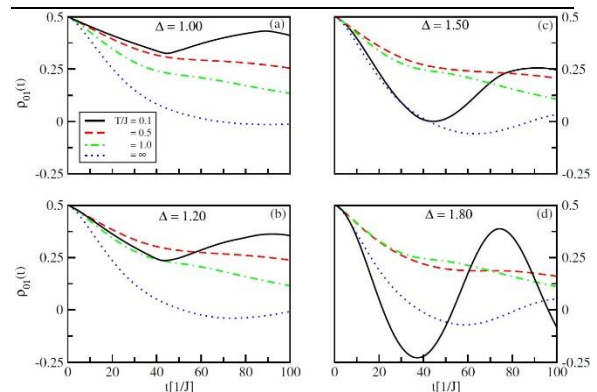


Figure 2. Evolution of qubit coherence for different anisotropy parameters (Δ) of the spin chain at various temperatures.

References:

1. F. Casola, T. van der Sar et al, Nat. Rev. Mat. **3**, 17088 (2018).
2. J. F. Rodriguez-Nieva, K. Agarwal et al, Phys. Rev. B **98**, 195433 (2018).
3. S. Chatterjee, J.F. Rodriguez-Nieva et al, Phys. Rev. B **99**, 104425 (2019).
4. M Płodzień, S. Das et al, Phys. Rev. B **111**, L161115 (2025).