Fate of entanglement in open quantum magnets

Federico Emmanuel García Gaitan and Branislav K Nikolic

University of Delaware, Sharp Lab, Newark 19711, USA

Many-body entanglement properties of quantum magnets, including conventional ferro- and antiferromagnets as well as exotic quantum spin liquids, have been intensively explored over the past two decades, but mostly as closed quantum systems. However, in experiments and potential applications, candidate materials will always interact with a dissipative environment, such as the one generated by bosonic quasiparticles in solids at finite temperature. Here we investigate both the stability and spatial distribution of entanglement for Heisenberg ferro- and antiferromagnetic models, as well as for the Kitaev model of quantum spin liquid, which are made open by its sudden coupling to an infinite bosonic bath of Caldeira-Leggett type and then time-evolved using a wide variety of numerical and analytical tools in both the Markovian and non-Markovian regimes. For the Heisenberg family of Hamiltonians, we determine necessary conditions for a quantum-to-classical transition where the effective dynamics are well described by the conventional Landau-Lifshitz-Gilbert equation. The presence of strong coupling between the quantum magnet and dissipative reservoir is found to impede such a transition. For the quantum spin liquid model, we observe unusual persistence of typically fragile entanglement patterns in the presence of a non-Markovian bath. We also extend our discussion to driven-dissipative versions of these models, where we identify optimal opportunities to enhance entanglement properties. Overall, we observe that the conventionally detrimental role of dissipative baths for genuine quantum features can be turned into useful entanglement-stabilization protocols when a structured bath is considered.

This research was supported by the U.S. National Sci- ence Foundation (NSF) under Grant No. DMR-2500816. The supercomputing time was provided by DARWIN (Delaware Advanced Research Workforce and Innovation Network), which is supported by NSF Grant No. MRI-1919839.