

“Microscopics of Quantum Annealing in the Disordered Dipolar Ising Ferromagnet $\text{LiHo}_{0.45}\text{Y}_{0.55}\text{F}_4$ ”

The technique of “quantum annealing” (QA) involves using quantum fluctuations to find the global minimum of a rugged energy landscape. For some problems it has been shown to produce faster optimization than thermal annealing (TA), and it has been adopted as one technique used for quantum computing (adiabatic quantum computing). Conceptually, QA is often framed in the context of the disordered transverse field Ising model, where a magnetic field applied perpendicular to the Ising axis tunes the quantum fluctuations and enables a “better” (lower energy) spin configuration to be obtained via quantum tunneling. A celebrated material example of this model, $\text{LiHo}_{0.45}\text{Y}_{0.55}\text{F}_4$, was shown decades ago to exhibit faster dynamics after a QA protocol, compared to a TA protocol. However, little is known about the actual process of optimization involved and ultimately what the optimal spin configurations are like.

We have set out to understand the microscopics of QA in $\text{LiHo}_{0.45}\text{Y}_{0.55}\text{F}_4$ using diffuse magnetic neutron scattering. We performed the same protocols as initially used to demonstrate QA in this material, and find that the QA protocol results in what appears to be the equilibrium state, whereas TA results in a state that continues to evolve over time. This is as expected if QA indeed provides an optimization “speed up” compared to TA. However, we also clearly observe evidence that the transverse field does more than just introduce quantum fluctuations; namely, it produces random longitudinal fields, which had been previously studied theoretically and experimentally. Thus, while the material does respond to QA differently than TA, it is not a simple annealing problem; the energy landscape being optimized is changing as the optimization proceeds. Understanding this version of quantum annealing could be of interest in the context of adiabatic quantum computing, possibly for designing new algorithms, or for accounting for unwanted experimental effects.

Bio: Kate joined the faculty of the Department of Physics at Colorado State University in 2015. Her research focus is on synthesis and characterization of frustrated and quantum magnetic materials, in particular using neutron scattering. She earned her PhD from McMaster University in 2012 and was a postdoctoral fellow at NIST/Johns Hopkins University, as well as in the Chemistry Department at Colorado State University, before taking up her current position. In her spare time she loves hanging out with her 3 year old son, and is currently studying Bayesian statistics and machine learning.