凝縮系物理学ゼミナール
Condensed Matter Theory Seminar

Date: 13:30-15:00, Wednesday, 17 April 2024

Title: Quantum skyrmion dynamics studied by neural network quantum states

Speaker: Mr. Ashish Joshi

Abstract:

Skyrmions are vortex-like magnetic structures that are topologically protected. These quasiparticles are important in the field of spintronics because of their potential use in memory storage devices. With the experimental discovery of skyrmions with sizes a few times the atomic lattice spacing [1], the importance of quantum effects in these systems cannot be neglected. The dynamical properties of magnetic skyrmions are mainly analyzed classically, which may only be relevant for large skyrmions.

For example, while classically, the dynamics of skyrmions are described by the Landau-Lifshitz-Gilbert equation, small-sized skyrmions cannot be described using classical spins as quantum effects can play an important role. However, a quantum mechanical analysis is exactly possible only for small systems due to memory limitations and numerical methods are needed to approximate [2,3].

In this work, we study the dynamics of quantum skyrmions under a magnetic field gradient using neural network quantum states [4]. First, we obtain a quantum skyrmion lattice ground state using variational Monte Carlo with a restricted Boltzmann machine as the variational ansatz for a quantum Heisenberg model with Dzyaloshinskii-Moriya interaction. Then, using the time-dependent variational principle, we study the real-time evolution of quantum skyrmions after a Hamiltonian quench with an inhomogeneous external magnetic field. We show that field gradients are an effective way of manipulating and moving quantum skyrmions. Furthermore, we demonstrate that quantum skyrmions can decay when interacting with each other. This work shows that neural network quantum states offer a promising way of studying the real-time evolution of quantum magnetic systems that are outside the realm of exact diagonalization.

References :

[1] N. Nagaosa and Y. Tokura, Nature Nanotechnology **8**, 899 (2013).

[2] A. Joshi, R. Peters, and T. Posske, Physical Review B **108**, 094410 (2023).

[3] A. Haller et al., Physical Review Research **4**, 043113 (2022).

[4] A. Joshi, R. Peters, and T. Posske, arXiv:2403.08184.