凝縮系物理学ゼミナール

Condensed Matter Seminar

Date: 13:30-15:00, Wednesday, 31 May 2023

Title: Neural Network Quantum States and Quantum Skyrmions
Speaker: Mr. Ashish Joshi (Condensed Matter Theory Group)

Abstract:

Classical magnetic skyrmions are magnetic structures with vortex-like configurations and a quantized skyrmion number. The observation of skyrmions with sizes a few times the atomic lattice spacing raises the question about the importance of quantum effects in these systems. However, the exact solutions exist only when the number of particles is small and one has to resort to numerical methods. These methods aim to approximate this 'quantum many body problem' efficiently and accurately. In recent years, machine learning techniques have been increasingly used with the existing numerical methods to tackle the quantum many body problem [1].

In this work we investigate the ground state properties of quantum skyrmions [2,3] in a ferromagnet using variational Monte Carlo with the neural network quantum state as variational ansatz. We study the ground states of a two-dimensional quantum Heisenberg model in the presence of the Dzyaloshinskii-Moriya interaction (DMI). We show that the ground state accommodates a quantum skyrmion for a large range of parameters, especially at large DMI. The spins in these quantum skyrmions are weakly entangled, and the entanglement increases with decreasing DMI. We also find that the central spin is completely disentangled from the rest of the lattice, establishing a non-destructive way of detecting this type of skyrmion by local magnetization measurements. While neural networks are well suited to detect weakly entangled skyrmions with large DMI, they struggle to describe skyrmions in the small DMI regime due to nearly degenerate ground states and strong entanglement. We propose a method to identify this regime and a technique to alleviate the problem. Finally, we analyze the workings of the neural network and explore its limits by pruning. Our work shows that neural network quantum states can be efficiently used to describe the quantum magnetism of large systems exceeding the size manageable in exact diagonalization by far [4].

References:

[1] Dawid, A., Arnold, J., Requena, B., Gresch, A., ... & Dauphin, A. (2022) arXiv:2204.04198.
[2] Siegl, P., Vedmedenko, E. Y., Stier, M., Thorwart, M., & Posske, T. (2022).
[3] Haller, A., Groenendijk, S., Habibi, A., Michels, A., & Schmidt, T. L. (2022).
[4] Joshi, A., Peters, R., & Posske, T. (2023) arXiv:2304.09504.