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Fractional magnetization plateau and spinon quantum spin Hall state in kagome antiferromagnets

Abstract:
The kagome lattice is an exceptional platform for exploring novel many-body states, owing to its distinctive lattice and electron structures. Motivated by very recent experimental observations of the 1/9-magnetization plateaus in YCu3(OH)$_{6+x}$Br$_{3-x}$ and YCu3(OD)$_{6+x}$Br$_{3-x}$, our study delves into the magnetic-field-induced phase transitions in the nearest-neighbor antiferromagnetic Heisenberg model on the kagome lattice using the variational Monte Carlo technique. We uncover a phase transition from a zero-field Dirac spin liquid to a field-induced magnetically disordered phase that exhibits the 1/9-magnetization plateau. Through a comprehensive analysis encompassing the magnetization distribution, spin correlations, chiral order parameter, topological entanglement entropy, ground-state degeneracy, Chern number, and excitation spectrum, we pinpoint the phase associated with this magnetization plateau as a chiral $\mathbb{Z}_3$ topological quantum spin liquid and elucidate its diverse physical properties. As the magnetic field increases further, we also obtain a 1/3-magnetization VBS state.

Besides, we construct a spinon quantum spin Hall state in kagome antiferromagnets with an additional Dzyaloshinskii-Moriya interaction. This state is a gapped QSL sharing the analogous physical properties with quantum spin Hall state. In term of the category of topological order, it is an Abelian double-semion topological order (doubled Chern-Simons state or CSL$_+$CSL$_-$) described by a sum of two topological quantum field theories with opposite chiralities, which is suggested in string-net model.

References:
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[2] Li-Wei He and Jian-Xin Li, Spinon quantum spin Hall state in the kagome antiferromagnet with a Dzyaloshinskii-Moriya interaction, Phys. Rev. B 110, 035131 (2024).

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