

Graduate School Event

Thesis Defense: Thermodynamic Studies of the Frustrated Quantum Magnet $BaCo_2(AsO_4)_2$

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Understanding how microscopic magnetic interactions give rise to collective quantum states is a central challenge in condensed-matter physics. In frustrated magnets, competing exchange interactions can stabilize unconventional magnetic phases and, under suitable conditions, suppress conventional magnetic order in favor of quantum spin-liquid states. Identifying the microscopic interactions responsible for these phenomena, however, remains difficult because distinct magnetic Hamiltonians can produce similar experimental signatures.In this thesis, we investigate the magnetic interactions in the honeycomb cobaltate BaCo2(AsO4)2 (BCAO), a frustrated magnet whose underlying interactions are still debated. Two main descriptions have been proposed: one based on competing easy-plane exchange interactions and another involving strong bond-dependent Kitaev interactions. To investigate which description better explains the magnetic behavior of BCAO, we combine magnetotropic susceptibility measurements, which probe how the magnetic free energy changes with field orientation, with classical and quantum numerical calculations.Angle-dependent magnetotropic measurements reveal two field-induced magnetic phase transitions in BCAO. The first, occurring at lower fields, is a first-order transition from incommensurate to commensurate magnetic order, while the second marks the suppression of long-range magnetic order. Both transitions show strong anisotropy, with their critical fields mainly determined by the in-plane component of the applied magnetic field. Classical Monte Carlo simulations show that a frustrated XXZ–J1–J3 model with relatively weak bond-dependent interactions can reproduce the main features of the measured phase diagram without requiring a strong Kitaev interaction. Additional quantum calculations using the infinite density matrix renormalization group (iDMRG) method show that this model can also stabilize an incommensurate magnetic ground state near the boundary of the ferromagnetic phase. We also find that different sets of exchange parameters can reproduce similar neutron-scattering spectra in the field-polarized state, showing that these measurements alone cannot uniquely determine the microscopic Hamiltonian. Although the model captures the main features of the experimental phase diagram, it does not reproduce the absolute values of the critical fields. This discrepancy is not specific to our model but is shared by the theoretical models proposed for BCAO so far, and its origin remains unresolved.As a complementary probe of the magnetic interactions, we investigate the possibility ofB/T scaling in the magnetotropic susceptibility. Motivated by the approximate scaling reported in -RuCl, we examine the conditions under which such behavior can emerge in

interacting spin systems. High-field measurements on BCAO do not exhibit a collapse of the temperature-normalized magnetotropic response as a function of B/T over the investigated range. Quantum Monte Carlo calculations for an XXZ-based model also show noB/T scaling. However, the experimental results are limited because the lever mode could not be reliably tracked in pulsed magnetic fields. Despite this limitation, preliminary results suggest that exchange interactions introduce additional energy scales that prevent the magnetotropic response from depending only onB/T.Together, these results support a description of BCAO in which frustrated easy-plane exchange interactions play a dominant role, while the possible contributions of smaller bond-dependent interactions remain open. More broadly, this work demonstrates how angle-dependent thermodynamic measurements, combined with spectroscopy and microscopic modeling, provide complementary constraints on the magnetic Hamiltonians of frustrated quantum materials.

Thursday, December 10, 2026 01:00pm - 02:00pm

Central Bldg / O1 / Lecture Hall (I02.O1.014) and Zoom

This invitation is valid as a ticket for the ISTA Shuttle from and to Heiligenstadt Station.
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