

Electro-nuclear quantum phase transition in TmVO_4



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Funding Grants: K. M. Amm (NSF DMR-2128556); M. P. Zic (NSF DGE-1656518); I. R. Fisher (AROSR FA9550-20-1-0252, FA9550-24-1-0357, FA 9550-22-1-084)

Investigations of metals close to an electronic nematic quantum critical point are driven by the prospect of uncovering fundamental insights into the behavior of iron-based superconductors. Thulium vanadate, TmVO_4 , an insulator possessing ferroquadrupolar ordering at low temperatures, offers an excellent platform for exploring nematic quantum criticality because its ordered state can be suppressed by an applied magnetic field.

Magnetic susceptibility measurements were extended to ultralow temperatures, and signatures in the signal were used to identify the ferroquadrupolar transition. These measurements were performed with the Bay 2 cryogenic instrument in the MagLab High B/T Facility, where adiabatic demagnetization of a copper nuclear-refrigerator stage from high magnetic fields, combined with immersion of the single-crystal sample in isotopically pure liquid ^3He , enabled cooling more than an order of magnitude below previously accessible temperatures.

The resulting phase diagram revealed a pronounced back-bending of the phase boundary toward lower magnetic fields at the lowest temperatures. Incorporating hyperfine coupling between the Tm nuclear moments and the 4f electronic degrees of freedom into a single-ion semi-classical mean-field model accounts for this back-bending, demonstrating that the quantum phase transition can be tuned not only by the applied magnetic field but also by nuclear degrees of freedom. This outcome provides important insight about the influence that often neglected, subtle interactions have on the properties of quantum materials and devices.

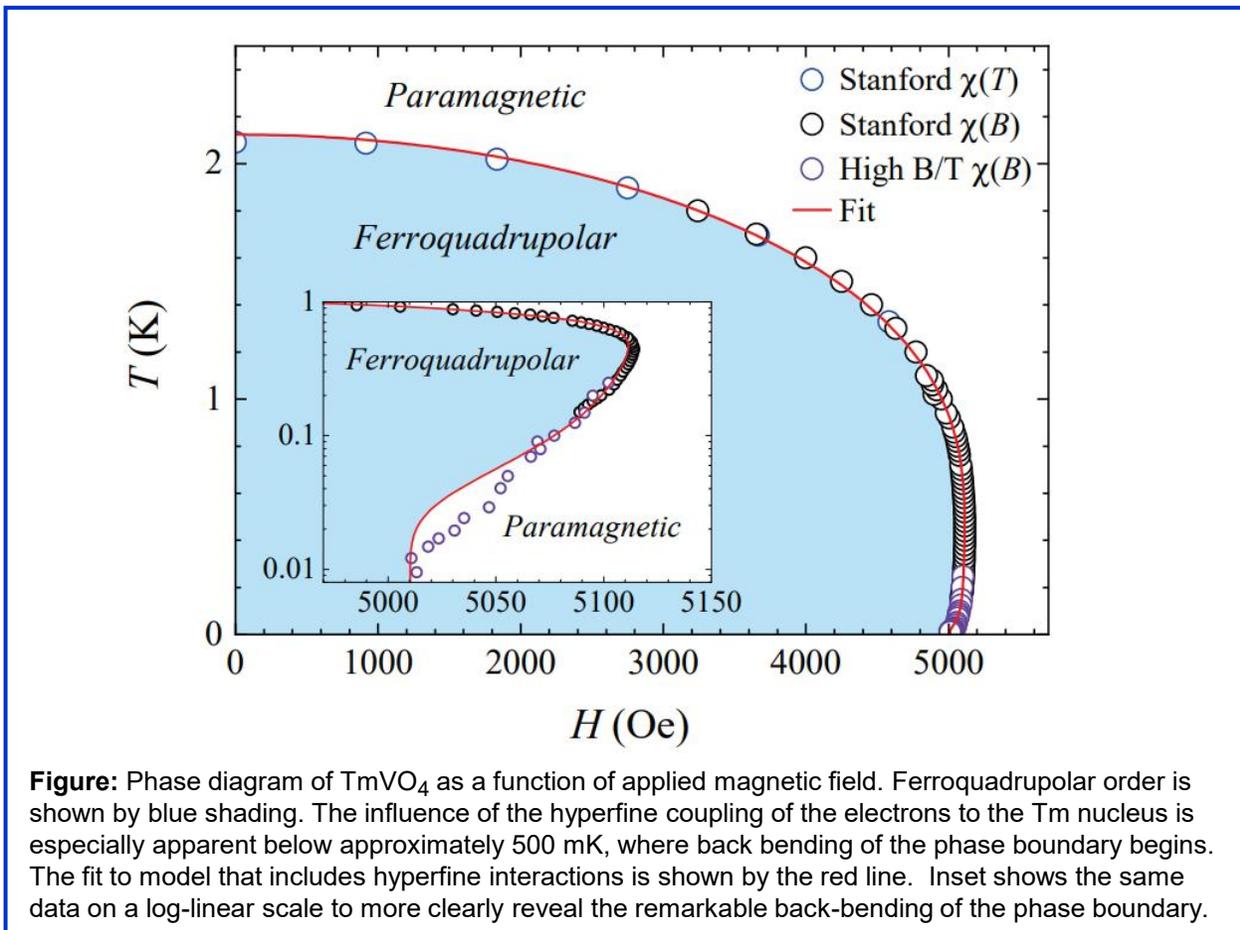


Figure: Phase diagram of TmVO_4 as a function of applied magnetic field. Ferroquadrupolar order is shown by blue shading. The influence of the hyperfine coupling of the electrons to the Tm nucleus is especially apparent below approximately 500 mK, where back bending of the phase boundary begins. The fit to model that includes hyperfine interactions is shown by the red line. Inset shows the same data on a log-linear scale to more clearly reveal the remarkable back-bending of the phase boundary.

Facilities and instrumentation used: High B/T Facility (University of Florida): Bay 2 dilution refrigerator and nuclear demagnetization refrigerator system

Citation: "Electro-nuclear quantum phase transition in TmVO_4 ", Mark P. Zic, Chao Huan, Nicolas Silva, Yuntian Li, Mark W. Meisel, and Ian R. Fisher, arXiv:2509.11489, doi:10.48550/arXiv.2509.11489; <https://arxiv.org/abs/2509.11489>