Behavior of Ising spins at a quantum phase transition

IRG1: Princeton Center for Complex Materials (DMR-1420541)

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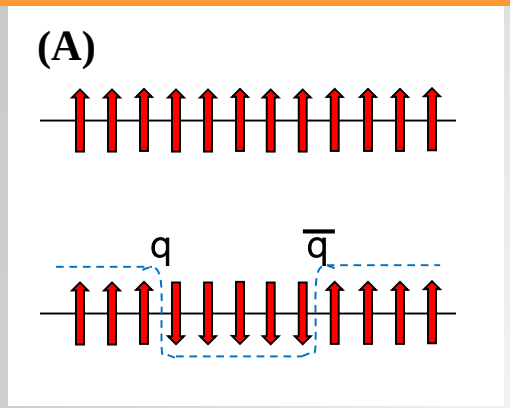
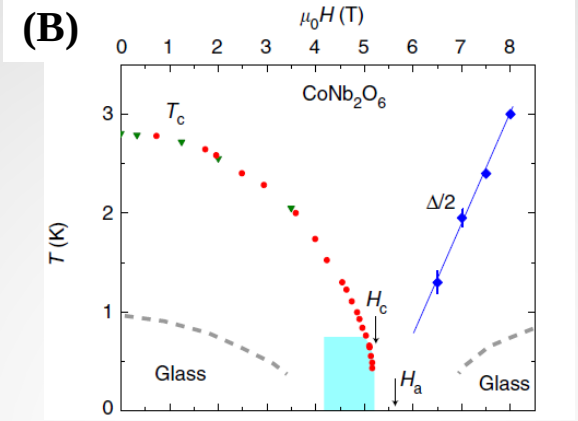
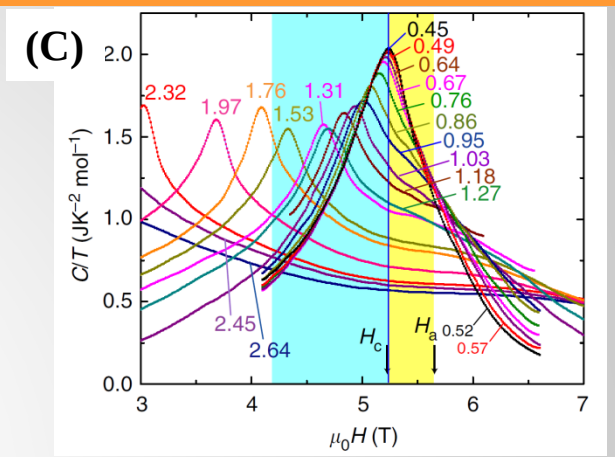


A) The Ising spin chain without defects (top), and one with 2 domain walls, q and $\overline{q}$.



B) Measured phase diagram of $CoNb_2O_6$. The QCP occurs at the field H_c.



C) Heat capacity vs. H at fixed T showing a peak at the QCP.

In a magnet, the phase transition to the ferromagnetic state occurs as the temperature T is decreased below the Curie temperature. To study the "quantum" phase transition, we fix T at zero Kelvin while varying, instead, the magnetic field H. The archetypal model is the transverse Ising magnet comprised of chains of spins (see Fig. A). A field, transverse to the chains, induces a transition from the ferromagnetic to the disordered state at the quantum critical point (QCP). This model is of great interest because domain walls (which separate spin-up from spin-down domains) mimic the quark-antiquark string $(q, \bar{q})$ (Fig. A). The material that best matches the theoretical Ising model is $CoNb_2O_6$. Its QCP occurs at a transverse field H of 5.2 Tesla (Fig. B). Recently, Liang *et al*. [1] reported a detailed low-temperature heat capacity experiment that uncovered several unusual features. At the QCP, the heat capacity rises to a prominent peak that accounts for ~1/3 of all the spin degrees of freedom (Fig. C). Most interestingly, they find that the heat capacity of the spin excitations close to the QCP are fermion-like, reminiscent of the exact results obtained for an isolated chain (Jordan-Wigner fermion).

1. T. Liang *et al*. "Heat capacity peak at the quantum critical point of the transverse Ising magnet $CoNb_2O_6$," *Nat. Commun*. 6:7611 doi: 10.1038/ncomms8611 (2015).

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