

Zero-Temperature Magnetic Transition in an Easy-Axis Kondo Lattice Model

Jian-Xin Zhu, T-11; S. Kirchner, Rice University; R. Bulla, Universitat Augsburg;
Qimiao Si, Rice University

Over the past decade or so, a sizable number of (nearly) stoichiometric heavy fermions have been discovered in which the antiferromagnetic transition temperature can be continuously suppressed to zero. These quantum critical materials have not only elucidated the heavy fermion physics but also provided a concrete setting to address the larger question on the nature of quantum criticality. The application of the Landau-Ginzburg-Wilson paradigm considers the fluctuations of the magnetic order parameter as the primary critical modes. The resulting $T=0$ K spin-density-wave (SDW) quantum critical point (QCP) is Gaussian. However, a host of dynamical, transport, and thermodynamic data suggest that the observed QCPs are non-Gaussian, indicating the existence of additional quantum critical modes. Since there is not yet a universal prescription for the identification of such emergent critical modes, microscopic considerations have been playing an important role.

One theoretical idea invokes the breakdown of the Kondo screening effect at the magnetic QCP to characterize the new critical modes. In the form of local quantum criticality, the destruction of the Kondo effect arises through the decoherence by the magnetic order parameter fluctuations. Microscopically, this picture has been studied through the extended dynamical mean field theory (EDMFT) approach to the Kondo lattice systems.

This approach describes the Kondo lattice in terms of a Bose-Fermi Kondo (BFK) model, with the spectra of its fermionic and bosonic baths self-consistently determined. The EDMFT approach goes beyond the conventional methods. It treats such competition dynamically. An important question is whether the actual zero temperature transition is second order.

We have used the EDMFT to address this issue in a spin-1/2 antiferromagnetic Kondo lattice model with an easy-axis anisotropy [1,2]. We have derived results in real frequency using the bosonic numerical renormalization group (bNRG) method and compare them with Quantum Monte Carlo results in Matsubara frequency. The bNRG results show a logarithmic divergence in the critical local spin susceptibility, signaling a destruction of Kondo screening. The $T=0$ K transition is nearly second order, with any jump in the magnetic order parameter not exceeding a few percent of the full moment. Our results are important for experiments, not only because the numerical studies play an important role in the understanding of the unusual magnetic dynamics (which itself was the primary initial experimental indication for the non-SDW nature of the QCP), but also because the theoretical picture has crucial predictions for other experiments (such as a jump of Fermi volume and fractional exponent in the Grüneisen ratio) that are actively being examined by ongoing experiments.

More generally, whether unconventional QCPs would be stable and relevant to realistic models/materials or tend to be preempted by first-order transitions are broadly important and also arises in, e.g., the case of deconfined quantum criticality in spin/boson lattice systems.

For more information contact Jian-Xin Zhu at jxzhu@lanl.gov.

[1] Jian-Xin Zhu, et al., <http://arxiv.org/abs/cond-mat/0607567>.

[2] Jian-Xin Zhu, et al., *Phys. Rev. Lett.* **91**, 156404 (2003).

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