Quantum Criticality in Kondo Lattice Model: A Renormalization Group Study Via Quantum non-Linear Sigma Model

Yiming Wang[1], Shouvik Sur[1], Chia-Chuan Liu[2], and Qimiao Si[1]

1. Rice University 2. University of Montreal

When quasiparticles in a metal interact by exchanging soft collective modes, their dynamics tend to develop singularities which, if sufficiently strong, may even destroy the quasiparticle-coherence. Since heavy-fermion metals naturally possess the two necessary components, itinerant electrons and fluctuating local moments, they have played a key role in shaping our understanding of quantum critical metals [1]. The corresponding Kondo lattice model is also emerging as an effective description of d-electron-based flat band systems [2]. Here, we study the Kondo lattice model in terms of a quantum nonlinear sigma model representation. Within the global phase diagram of heavy fermion systems [1,3], we focus on the antiferromagnet(AFs)- to-paramagnet(Ps) transition in the parameter regime where the Fermi surface is “small”. We assess the effect of Kondo coupling and classify different metallic states along the AFs-to-Ps transition through a renormalization group analysis. Our results shed new light on the global phase diagram [1,3] and, especially, the behavior of frustrated Kondo lattices [4,5]. Implications for quantum criticality and the associated Fermi-surface transformation of flat-band systems [2] will be discussed.

[1] S. Paschen & Q. Si, Nat. Rev. Phys. 3, 9-26 (2021); S. Kirchner et al, Rev. Mod. Phys. 92, 011002 (2020); Q. Si et al., Nature 413, 804 (2001)

[2] L. Chen et al, arXiv:2212.08017. H. Hu et al., arXiv:2209.10396.

[3] Q. Si, Physica B378, 23 (2006); Phys. Status Solidi B 247, 476 (2010).

[4] H. Zhao et al, Nat. Phys. 15, 1261 (2019).

[5] M. Kavai et al, Nat. Commun. 12, 1377 (2021).