MAR12-2011-004116

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Quantum critical scaling in beta-YbAlB4 and theoretical implications

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Emergent phenomena in quantum materials are subject of intense experimental and theoretical research at present. A wonderful example thereof are the sister phases of $YbAlB_4$ - a newly discovered heavy fermion material [1]. While one phase (α-$YbAlB_4$) is a heavy Fermi liquid, its sibling β-$YbAlB_4$ is quantum critical, supporting an unconventional superconductivity with a tiny transition temperature of $\sim$ 80 mK. Latest experiments [2] uncover the quantum critical T/B-scaling in β-$YbAlB_4$ and prove that superconductivity emerges from a strange metal governed by an extremely fragile quantum criticality, which apparently occurs at zero field, without any external tuning.

Here, we will present a theoretical perspective on the quantum critical scaling in β-$YbAlB_4$ and will show that the critical exponents can be derived from the nodal structure of the hybridization matrix between Yb f-band and the conduction electrons. It follows that the free energy at low temperatures can be written in a scaling form $F \propto [(k_B T)^2 + (g\mu_B B)^2]^{3/4}$, which predicts the divergent Sommerfeld coefficient γ and quasi-particle effective mass as $B \to 0$: $\gamma \sim m^*/m \propto B^{-1/2}$. This is indeed observed in the experiment [1,2], which places a tiny upper bound on the critical magnetic field $B_c < 0.2$ mT. We will discuss theoritical implications of this fragile intrinsic quantum criticality in β-$YbAlB_4$ and discuss the possibility of a quantum critical phase, rather than a quantum critical point, in this material.

[1] S. Nakatsuji *et al.*, Nature Physics **4**, 603 (2008).

[2] Y. Matsumoto, S. Nakatsuji, K. Kuga, Y. Karaki, Y. Shimura, T. Sakakibara, A. H. Nevidomskyy, and P. Coleman, Science **331**, 316 (2011).