Quantum critical scaling in beta-YbAlB\(_4\) 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 (\(\alpha\)-YbAlB\(_4\)) is a heavy Fermi liquid, its sibling \(\beta\)-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 \(\beta\)-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 \(\beta\)-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 \(\gamma\) 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 theoretical implications of this fragile intrinsic quantum criticality in \(\beta\)-YbAlB\(_4\) and discuss the possibility of a quantum critical phase, rather than a quantum critical point, in this material.