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Field-tuned quantum criticality of heavy fermion systems

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Intensive study of strongly correlated electronic systems has revealed the existence of quantum phase transitions from ordered states to disordered states driven by non-thermal control parameters such as chemical doping, pressure, and magnetic field. In this presentation I will discuss a recent progress of magnetic field-tuned quantum criticality with particular emphasis on the Fermi liquid instabilities of conduction electrons in heavy fermion metals and emergent phases around quantum critical points. In particular, a wide range of strange metallic behavior has been observed beyond the quantum critical point in Yb-based materials; YbAgGe, Ge-doped YbRh2Si2, YbPtBi. In the H-T phase diagram of YbPtBi, for example, three regimes of its low temperature states emerges: (I) antiferromagnetic state, characterized by spin density wave like feature, which can be suppressed to T = 0 by the relatively small magnetic field of Hc ˜ 4 kOe, (II) field induced anomalous state in which the electrical resistivity follows r(T) ˜ T1.5 between Hc and ˜ 8 kOe, and (III) Fermi liquid state in which r(T) ˜ T2 for H > 8 kOe. Regions I and II are separated at T = 0 by what appears to be a quantum critical point. Whereas region III appears to be a Fermi liquid associated with the hybridized 4f states of Yb, region II may be a manifestation of a spin liquid state. The observation of a separation between the antiferromagnetic phase boundary and the small to large Fermi surface transition in recent experiments has led to the new perspective on the mechanism for quantum criticality. In this new approach, the global phase diagram includes the effects of magnetic frustration, which is an important additional tuning parameter in the Kondo lattice model of heavy fermion materials. Frustration leads to the enhanced quantum fluctuations, as the system tunnels between different competing magnetic states.

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