Superconductivity and Quantum Criticality in Heavy Fermions

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Soon after the discovery of heavy-fermion (HF) superconductivity (SC) in $CeCu_2Si_2$ (1979), UBe_{13} [Ott *et al.* (1983)], UPt_3 [Stewart *et al.* (1984)] and URu_2Si_2 [Schlabitz *et al.* (1984)], these materials were considered prime candidates for showing SC mediated by antiferromagnetic (AF) paramagnons [see, e.g., Schmitt-Rink *et al.* (1986), Scalapino *et al.* (1986)]. $CeCu_2Si_2$ was found to have a complex chemical phase diagram that can be transformed into a complex generic physical phase diagram (1996). The latter contains ``phase A", an ordinary incommensurate spin-density wave (SDW) with very small ordered moment (2004). While moderate lattice expansion as achieved by low doping with Ge stabilizes ``phase A", application of a tiny pressure weakens AF order and establishes a quantum critical point (QCP), presumably being of the (3D) SDW-type (1998). In the *T-p* phase diagram of $CeCu_2Si_{1.8}Ge_{0.2}$, a narrow superconducting dome centered around this QCP exists (2003), similar to the one found earlier for $CePd_2Si_2$ at the critical pressure $p_c \sim 2.8$ GPa [Mathur *et al.* (1998)]. Unique to $CeCu_2Si_{1.8}Ge_{0.2}$, however, is the occurrence of a second dome of SC that coincides with a weak valence transition near $p = 5$ GPa (2003).

We discuss evidence for HFSC under the *low-p* dome being mediated by extended AF quantum critical spin fluctuations, as first proposed for $CePd2Si_2$. Interestingly, for the isostructural quantum critical compound $YbRh_2Si_2$ (2000), no superconductivity exists, at least above $T = 10$ mK. For this material, a number of experimental results, e.g., of the thermal (2003) and magnetic (2008) Grüneisen ratios, are presented. They highlight an unconventional nature of the QCP, at which an AF instability seems to coincide with a Mott transition in the subsystem of the 4f electrons.

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