Heavy fermions: Interplay between
Kondo entanglement, quantum criticality and unconventional superconductivity

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Heavy-fermion (HF) metals, i.e., intermetallic compounds of certain lanthanide and actinide elements, have been subject of intensive investigations over the last three to four decades. These research activities have furnished important discoveries, e.g., of unconventional superconductivity ("beyond BCS") and unconventional quantum criticality ("beyond Landau"). Almost fifty HF superconductors are currently known, more than half of which exhibiting a quantum critical point (QCP) where antiferromagnetic (AF) order is smoothly suppressed by tuning a non-thermal control parameter, like pressure or magnetic field. Two variants of HF AF-QCPs have yet been established, i.e., a conventional ("3D SDW") and an unconventional ("Kondo destroying") QCP [1, 2]. To get rid of the huge entropy accumulated at such an AF QCP in a clean, stoichiometric HF metal unconventional superconductivity develops in its vicinity.

To illustrate the validity of this *quantum critical paradigm*, we address exemplary materials for the two afore-mentioned different QCP scenarios, i.e., the isostructural compounds $CeCu_2Si_2$ and $YbRh_2Si_2$. $CeCu_2Si_2$, the first HF superconductor [3], exhibits SC at a 3D SDW-QCP and was considered a (one-band) *d*-wave superconductor until recently, when its specific heat was found to exhibit exponential temperature dependence at very low temperatures [4], typical for a conventional BCS superconductor. However, based on atomic substitution [5], inelastic neutron - scattering [6] and penetration - depth [7] results we shall argue that $CeCu_2Si_2$ most likely is a fully-gapped two-band *d*-wave superconductor [7].

$YbRh_2Si_2$ exhibits an unconventional ("Mott-type") QCP as reflected by, e.g., an abrupt jump of the Fermi-surface volume [8-10] and a violation of the Wiedemann-Franz law [11]. For this material, no SC has been detected down to 10 mK, the lowest temperature accessible for resistivity measurements in a ^{3}He-^{4}He dilution refrigerator [12]. However, recent magnetic and specific-heat measurements performed in a nuclear demagnetization cryostat down to about 1 mK revealed HF, i.e., unconventional, SC below T_c = 2 mK [13]. This supports the relevance of the *quantum critical paradigm*, regardless of the microscopic nature of the AF QCP.

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