NON-LOCAL QUANTUM CRITICALITY IN HIGH-SYMMETRY SYSTEMS $CeIn_{3-x}Sn_x$

A.V. Silhanek (MST-NHMFL, LANL); T. Ebihara (Shizuoka University, Japan); N. Harrison, M. Jaime (MST-NHMFL, LANL); K. Tezuka (Shizuoka University, Japan); V. Fanelli (MST-NHMFL, LANL); C.D. Batista (T-11, LANL)

When the Neel temperature T_N of an antiferromagnet is tuned to absolute zero at a quantum critical point (QCP), the uncertainty principle leads to a divergence in the characteristic lengthscale of the fluctuations of the staggered-moment order parameter [1]. In itinerant electron antiferromagnets, strong on-site correlations often cause the renormalized Fermi bandwidth T* to become comparable to T_N. A potential locally critical scenario arises in which the extent to which the d- or f-electrons locally contribute charge degrees of freedom to the Fermi liquid becomes subject to fluctuations at the QCP [2,3] and their effective localization is conditional upon the inequality T_N>T* being satisfied necessitating T→0 at the QCP as depicted in Fig. 1(a). Several f-electron antiferromagnets, including $CeCu_{6-x}Au_x$, $YbRh_2Si_{2-x}Ge_x$ and $CeRhIn_5$, appear to provide examples of such behavior as function of pressure p, magnetic field H or chemical substitution x. However, no experiment has yet been able to gauge the extent to which local criticality requires the spin fluctuations to be two-dimensional (2D). Were this an absolute requirement, the unambiguously three-dimensional (3D) spin fluctuation spectrum of cubic $CeIn_3$ should then provide the essential f-electron counterexample to local criticality. In such a case, one might expect a quantum critical spin-density wave (SDW) scenario [4] in which T* remains finite at the QCP (see Fig. 1(b)).

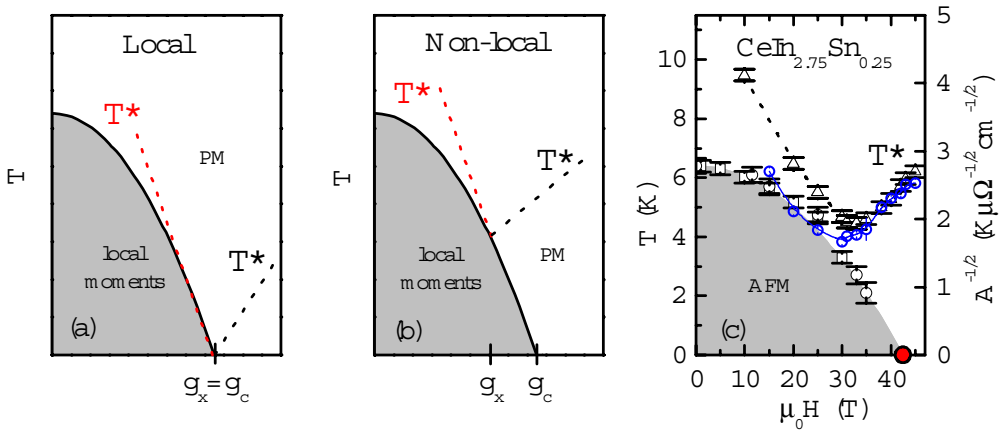

Figure 1. Schematic of antiferromagnetic quantum criticality tuned at $g = g_c$ according to (a) the locally critical scenario and (b) the SDW scenario, where T* represents the Fermi temperature. The parameter g can correspond to p, H or x, depending on the system. (c) T,H phase diagram of $CeIn_{2.75}Sn_{0.25}$ extracted from Cp(T) (○ symbols) and ρ(T) data (□ symbols), with the grey region represents the antiferromagnetic (AFM) phase under the fitted $T_N = T_{N,0}(1 - (H/H_c)^2)$ curve. Δ symbols delineate maxima in ∂ρ/∂T which are approximately representative of the Fermi bandwidth T* in the paramagnetic (PM) region. Blue circles represent $A^{-1/2}$ in the low temperature limit T << T*.

In the present work we utilize the fact that Sn-substitution of only 8 % of the In sites in $CeIn_3$ (yielding $CeIn_{2.75}Sn_{0.25}$) reduces T_N to ~6.4 K so as to enable quantum criticality of the same type II antiferromagnetic phase as in pure $CeIn_3$ to be tuned by a static magnetic field $\mu_0 H_c = 42 \pm 2$ T (see Fig.1(c)). Electrical transport and thermodynamic measurements reveal that m* does not diverge, suggesting that cubic $CeIn_3$ is representative of a critical spin-density wave (SDW) scenario. The existence of a maximum in m* at a lower field $\mu_0 H_x = 30 \pm 1$ T may be interpreted as a field-induced crossover from local moment to SDW behavior as the magnitude of the antiferromagnetic order parameter falls below the Fermi bandwidth.

References

[1] Sachdev, S., Quantum Phase Transitions (Cambridge Univ. Press, Cambridge, 1999).
[2] Coleman, P., *et al.*, J. Phys.: Condens. Matt., **13**, R723 (2001).
[3] Si, Q., *et al.*, Nature, **413**, 804 (2001).
[4] Moriya, T., Phys. Rev. Lett., **24**, 1433 (1970); Hertz, J.A., Phys. Rev. B, **14**, 1165 (1976); Millis, A.J., Phys. Rev. B, **48**, 7183 (1993).