$CeCu_2Ge_2$: Challenging our Understanding of Quantum Criticality

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Introduction

In the zero temperature limit, quantum criticality may appear by suppressing a second-order phase transition. One example is the f -electron heavy-fermions, where quantum criticality (QC) is ascribed to either the suppression of a spin-density wave (SDW) ground state or the Kondo effect. Here, we unveil evidence for magnetic field-induced quantum criticality in $CeCu_2Ge_2$. In all directions, the field suppresses the second order transition from SDW state to paramagnetic state, and leads to some small Fermi surfaces (FSs). For the H//c axis, no evidence for QC is observed, and the effective mass (μ) of these small FSs is very small. But as H is rotated towards the a-axis, the effective mass increases considerably, and becomes undetectable for $\theta > 56^o$. Along a-axis, and at $H \sim 30$T, the resistivity becomes ∝T which, coupled to the divergence of μ, indicates the existence of a field-induced QC point. We also show that the complexity of its magnetic phase diagram(s) makes $CeCu_2Ge_2$ an ideal system to explore field-induced quantum tricritical and QC end points.

Experimental

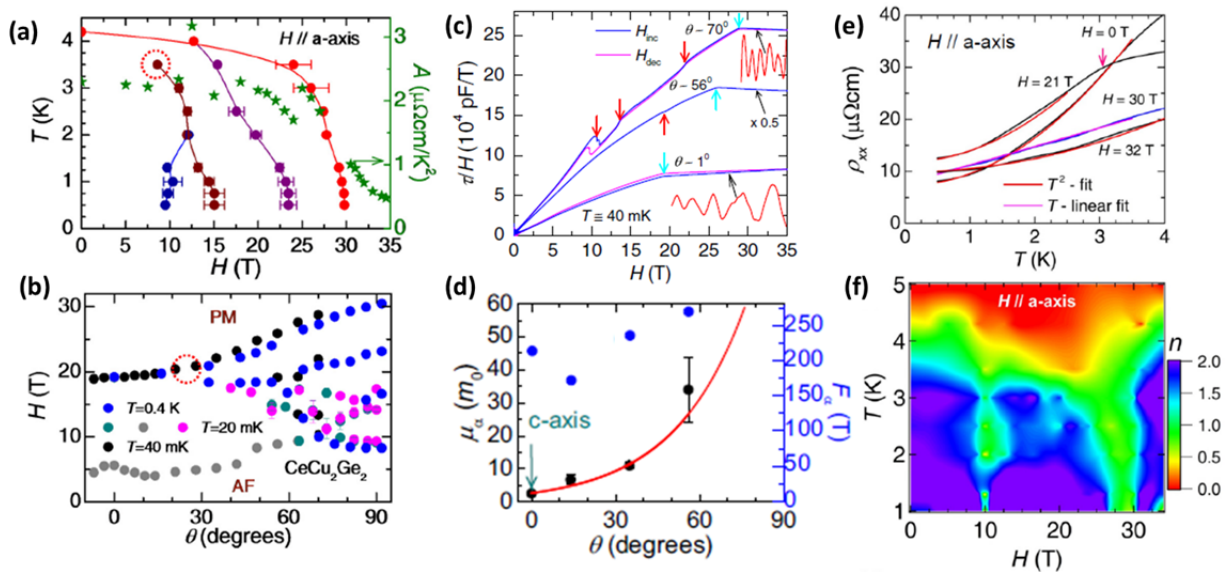

Figure (**a**) T-H phase diagram along a-axis. There are several transitions in the phase diagram. The red line indicates the phase boundary between SDW and paramagnetic state. All the others are first-order metamagnetic transitions. (**b**) *H-θ* phase diagram near the base temperatures. θ is the angle between magnetic field and c-axis. The upper most line indicates the phase boundary between SDW and PM state. All the others are first-order metamagnetic transitions. Note that the red circle indicates an area where first-order transition meets the second-order one. A tricritical point should exist here. (**c**) The torque data measured by a capacitive cantilever at different angles. The oscillatory components are extracted in the PM state. Blue and magenta lines indicates field up and down, respectively. (**d**) Effective masses extracted from the quantum oscillations for different angles. When the field rotates from c-axis to a-axis, the effective mass increases considerably. When $\theta > 56^o$, the effective mass is so heavy that it becomes undetectable. The divergence of effective mass indicates quantum critical point along a-axis. (**e**) T-dependent resistivity at different field along H//a-axis. The red and pink lines are T-square and T-linear fit, respectively. One can see that at 30T, the T-dependence becomes linear, indicating quantum critical point here. (**f**) Contour plot of the exponent $n = \partial ln[\rho(T) - \rho_0]/\partial ln(T)$ built from a complete set of ρ(T,H) curves.

Conclusions

$CeCu_2Ge_2$ shows a complicated phase diagram as a function of temperature, field, and angle. The quantum critical point appears along the a-axis, where the second order transition from SDW to PM state is suppress by magnetic field. It also shows several first-order metamagnetic transitions. A tricritical point should exist in the phase diagram, where the first- and second-order transitions meet.

Acknowledgements

This work is supported by the National Science Foundation Cooperative Agreement No. DMR-1157490.

References:

B. Zeng, Q. R. Zhang, D. Rhodes, Y. Shimura, D. Watanabe, R. E. Baumbach, P. Schlottmann, T. Ebihara and L. Balicas. Phys. Rev. B **90**, 155101 (2014).