Glenn T. Seaborg Center Seminar

Quantum Criticality in $PuMX_5$ (M=Co, Rh; X=Ga, In) Superconductors Evidence for an Antiferromagnetic Quantum Critical Point and Valence (Quantum) Critical End-Point in $PuMX_5$ (M=Co, Rh; X=Ga, In) Superconductors

Eric D. Bauer

Los Alamos National Laboratory, Los Alamos, NM

December 3, 2014
4:00 pm – 5:00 pm
Bldg. 70A, Room 3377

The discovery of superconductivity in $PuCoGa_5$ with a transition temperature of T_c = 18.5 K [1] has generated renewed interest in Pu-based intermetallic compounds. $PuCoGa_5$, and its superconducting cousin $PuRhGa_5$ (T_c = 8.7 K) [2], have the same crystal structure as a growing class of tetragonal $CeMIn_5$ (M=Co, Rh, Ir) heavy fermion superconductors, suggesting that the structure plays a key role in generating superconductivity in these materials. While a variety of measurements have firmly established that the $CeMIn_5$ compounds are unconventional d-wave superconductors, most probably mediated by antiferromagnetic spin fluctuations, it is less clear what drives the high transition temperature in $PuCoGa_5$, which is an order of magnitude larger than all other know Ce- or U-based heavy fermion superconductors. The physical properties of two new members of this "115" family of superconductors, $PuRhIn_5$ and $PuCoIn_5$ [3], along with the observation of long-range antiferromagnetic order in $PuRh(In,Cd)_5$, indicates that these $PuMIn_5$ (M=Co, Rh) reside close to an antiferromagnetic quantum critical point [4]. Recent measurements [5] of all of the elastic moduli of $PuCoGa_5$ delineate the temperature evolution of each symmetry channel; in contrast with the ordinary behavior of the shear moduli, the compressional moduli exhibit anomalous softening upon cooling and over a broad temperature range, which is truncated at the superconducting transition. The scalar (A_{1g}) symmetry of the compressional moduli in which the softening is observed requires a non-magnetic scalar order parameter η. This result, concomitant with its temperature dependence of the form $\eta=1/(T-T_V)$, where T_V = 9(1) K, provides strong evidence for a valence transition at T_V that is avoided by the superconducting state. The low temperature scale of this avoided valence transition suggests that $PuCoGa_5$ is near a critical-end point, whose slow fluctuations are intimately involved in the unconventional superconductivity. The nature of the quantum criticality in the $PuMX_5$ materials and its connection to the unconventional superconductivity will be discussed.

[1] J. L. Sarrao et al., Nature 420, 297 (2002).
[2] F. Wastin et al., J. Phys.: Condens. Matter 15 S2279 (2003).
[3] E.D. Bauer et al., J. Phys.: Condens. Matter 24 052206 (2012).
[4] G. Koutroulakis et al., (unpublished).
[5] B. Ramshaw et al., (submitted to Nature PhysicsProc. Nat. Acad. Sci.).

Host: Stefan Minasian (510) 486-5352 SGMinasian@lbl.gov | Admin. Asst: Catherine Mendez (510) 486-5587
Ernest Orlando Lawrence Berkeley National Laboratory One Cyclotron Road, Berkeley, California 94720