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Unusual Phase Diagram of $\text{CeOs}_4\text{Sb}_{12}$

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Introduction

Filled skutterudite compounds, with the formula MT_4X_{12} , where M is an alkali metal, alkaline-earth, lanthanide, or actinide, T is Fe, Ru, or Os, and X is P, As, or Sb, display a wide variety of interesting phenomena caused by strong electron correlations [1]. Among these, the three compounds $\text{CeOs}_4\text{Sb}_{12}$, $\text{PrOs}_4\text{Sb}_{12}$, and $\text{NdOs}_4\text{Sb}_{12}$, formed by employing Periodic Table neighbors for M, span the range from an antiferromagnetic (AFM) semimetal (M = Ce) via a 1.85 K unconventional (quadrupolar-fluctuation mediated) superconductor (M = Pr) to a 1 K ferromagnet (FM; M = Nd) [1]. In the course of an extended study of these compounds, we uncovered an unusual phase diagram for $\text{CeOs}_4\text{Sb}_{12}$ [1].

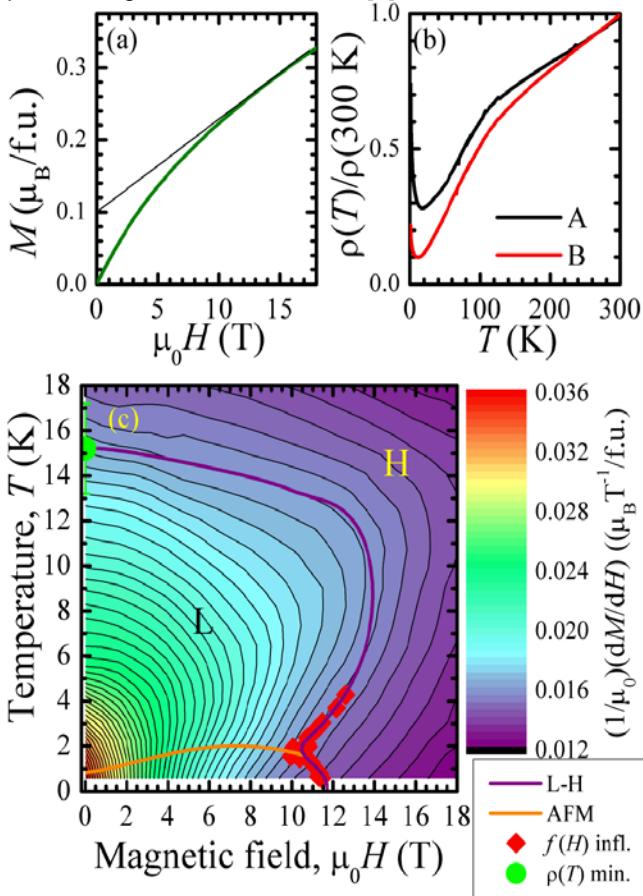


Figure 1. Data and phase diagram for $\text{CeOs}_4\text{Sb}_{12}$.

Not only are the energy scales of the two transitions similar in this part of the phase diagram, but also the AFM is expected to arise from the formation of a spin-density wave, a process that depends crucially on the Fermi surface and its fluctuations [1].

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References

[1] P.-C. Ho, et al., *Phys. Rev. B* **94**, 205140 (2016).

Results and Discussion

To delineate the various low-temperature phases, data from a pulsed-field extraction magnetometer at NHMFL Los Alamos [Fig. 1(a)] and a SQUID magnetometer at Warwick University were used to map out the differential susceptibility as a function of field and temperature [Fig. 1(c)]. These data were compared with resistivity measured at Fresno State [Fig. 1(b)] and Proximity-Detector-Oscillator MHz conductivity in pulsed fields at Los Alamos [1].

The resulting phase diagram of $\text{CeOs}_4\text{Sb}_{12}$ is determined by competing energy scales. The purple L-H boundary denotes a valence transition; in the L phase, the 4f electrons act as very heavy band quasiparticles. However, as field and/or temperature rises, it becomes more energetically favorable for the 4f electrons to become localized on their parent Ce ions. Unusually, a backwards curvature of the L-H boundary occurs in the vicinity of the low-temperature AFM state [orange phase boundary in Fig. 1(c)]. This is possibly due to antiferromagnetic fluctuations, that act to destabilize the L phase, pulling the L to H boundary to lower fields as temperature is reduced toward the AFM transition. Once antiferromagnetic order is established, the free-energy landscape changes and it appears that the L phase becomes more stable as the temperature is lowered further, such that the L to H and antiferromagnetic phase boundaries coincide and move to higher fields. This interplay between the Fermi-surface reconstruction (the L to H transition) and the antiferromagnetism can arise because these phases are inextricably linked.