Department of Physics
Condensed Matter Physics
Clarendon Laboratory, Parks Road, Oxford OX1 3PU

UNIVERSITY OF OXFORD

CONDENSED MATTER SEMINAR

Thursday 10 November at 14.30

"New insights at ultra-low temperatures: superconductivity and a closer look at quantum criticality"

Alix McCollam
High Field Magnet Laboratory (HFML-EMFL), Radboud University, The Netherlands

Many strongly correlated electron systems develop ordered phases at low temperatures that can be well understood in terms of an electronic order parameter. At ultra-low temperatures, however, the hyperfine interaction between nuclei and electrons becomes increasingly important, and we have to consider how this affects ordered phases and phase transitions close to zero temperature.
$PrOs_4Sb_{12}$ is a superconductor below T_C = 1.85 K and H_{C2} = 2.2 T, and develops antiferroquadrupolar (AFQ) order in magnetic fields between ~4 T and 14 T. The hyperfine constant of Pr is relatively large at 52 mK and the Pr crystal electric field levels are closely involved in both the superconducting and AFQ phases. Previous results suggest that the hyperfine interaction plays a significant role in the low temperature properties of this material [1].

To explore this role, we performed magnetic susceptibility measurements as a function of temperature and magnetic field to temperatures as low as 1 mK. We find that the phase boundaries in $PrOs_4Sb_{12}$ anomalously develop down to ~5 mK: AFQ order is enhanced at low temperature, whereas superconductivity is suppressed.
We explain our results in terms of a ground state composed of hybrid nuclear-electronic states with novel low energy excitations. That is, strong hyperfine interactions mean that the low temperature Pr energy levels can no longer be considered as purely electronic entities, but must be described in terms of both electron and nuclear quantum numbers. The low temperature quadrupole excitations develop from these nuclear-electronic states, and are considerably modified compared to their higher temperature counterparts. I will discuss how this leads to a novel type of nuclear-electronic quantum critical point at the AFQ transition, with a strongly damped region of criticality. I will also explain how the hyperfine induced suppression of superconductivity gives insight into a highly unconventional superconducting pairing mechanism.

[1] A. McCollam *et al.*, Physical Review B, **88**, 075102 (2013).

Host: Prof Amalia Coldea
Simpkins Lee room