Cuprate Quantum Oscillations up to 85 Teslas

Gregory S. Boebinger, National High Magnetic Field Laboratory

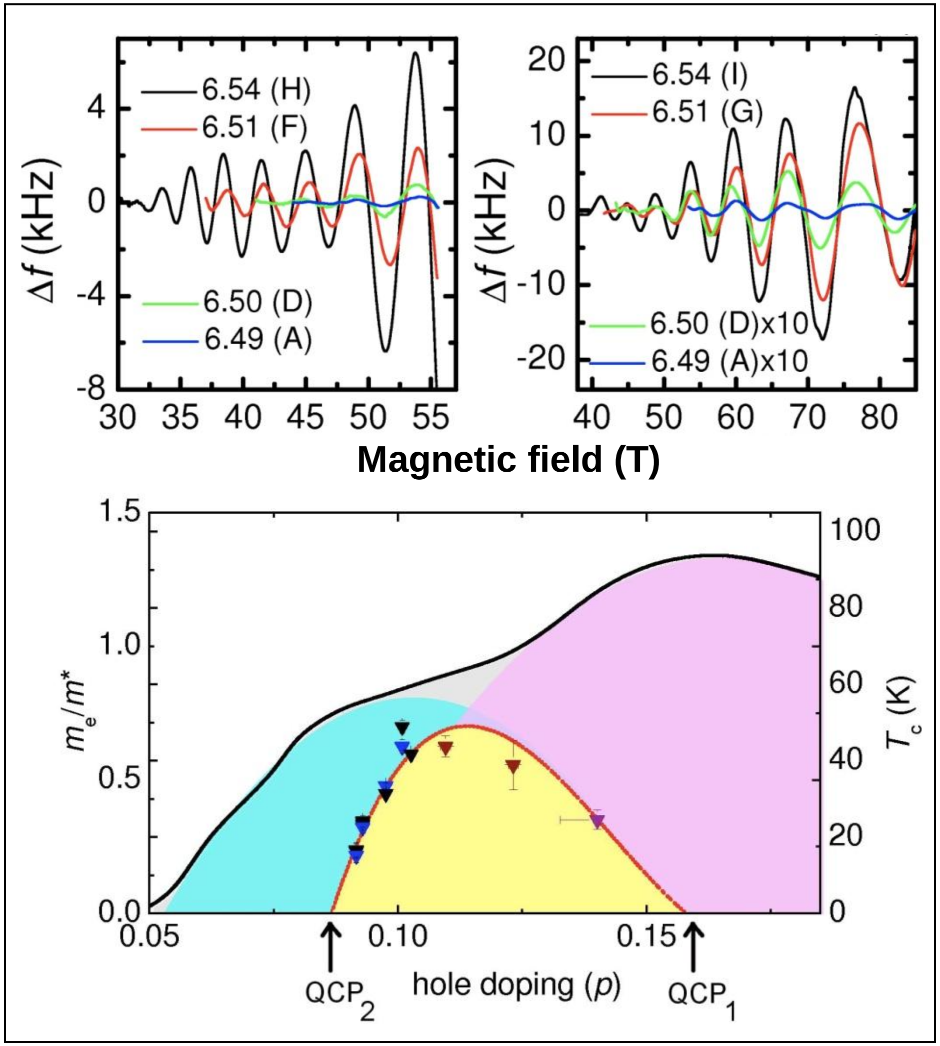
DMR-Award 0654118

Pulsed Field Facility User Program, LANL

The 85 T multi-shot (MS) magnet is a world-unique and indispensable tool for studying magnetic quantum oscillations (QO) on high-temperature cuprate superconductors.

The 85T MS magnet recently enabled a detailed doping dependent study of QO data (top figures) for compositions of YBCO from $YBa_2Cu_3O_{6.49}$ to $YBa_2Cu_3O_{6.69}$ [1,2]. The oxygen concentration is given for each sample in the figures.

The high magnetic fields allow disordered samples to still exhibit QOs *and* give a very large magnetic field window over which the QO's are observed. This enables researchers to resolve multiple QO frequencies in a sample [2]. The QO data also allow doping-dependent trends - for example, in effective mass *m** (lower figure) - to be tracked in detail for the first time over a large range of the phase diagram [1,2].



[1] S.E. Sebastian, N. Harrison, M.M. Altarawneh, C.H. Mielke, R. Liang, D.A. Bonn, W.A. Hardy and G.G. Lonzarich PNAS 107 (14) 6175-6179 (2010).
[2] J.Singleton, C. de la Cruz, R. D. McDonald, S. Li, M. Altarawneh, P. Goddard, I. Franke, D. Rickel, C. H. Mielke, X. Yao and P. Dai, Phys. Rev. Lett. 104, 086403 (2010).

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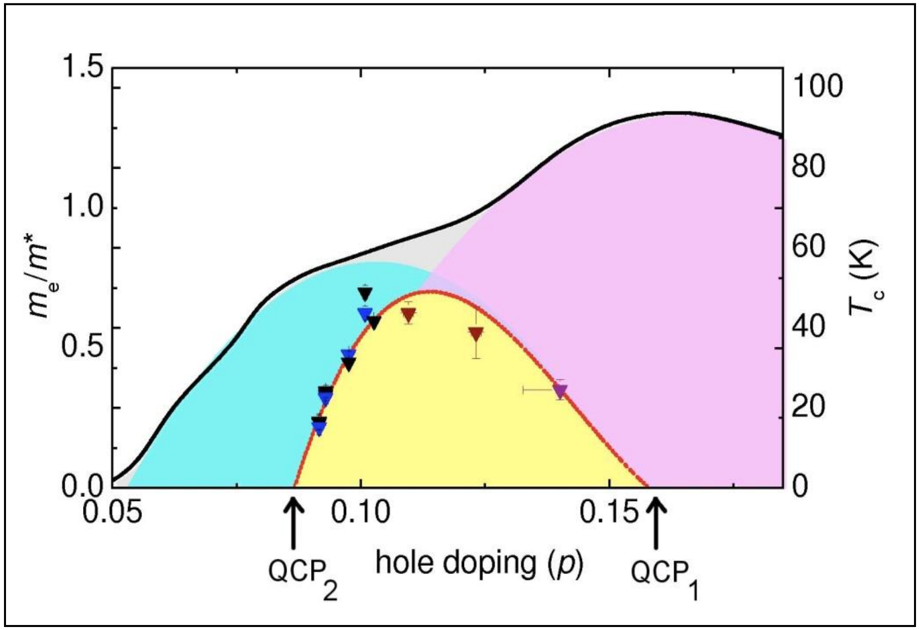

The 85 T pulsed magnet at the Magnet Lab offers a unique platform for probing the phase diagram of high-temperature superconductors. In YBCO, experiments at 85 T reveal a dramatic upturn in the effective mass *m** at lower hole doping [1]. Plotted at left is the inferred collapse in the inverse mass m_e/m^* (or Fermi temperature) approaching the metal-insulator crossover at a quantum critical point QCP_2 — the very first thermodynamic evidence for a global divergent susceptibility beneath the superconducting dome.

The experiments also extended the hole doping range further towards optimal doping [2]— linking up with previous 85 T data on $YBa_2Cu_4O_8$ (also taken at the NHMFL and published in 2008). The doping dependence of the effective mass strongly suggests a second quantum critical point (QCP_1) close to optimal doping [1,2]. There are therefore likely to be two thermodynamic quantum critical points beneath the high-temperature superconducting dome, suggestive of the possible involvement of quantum criticality in two superconducting subdomes (blue and pink in the figure).

[1] S.E. Sebastian, N. Harrison, M.M. Altarawneh, C.H. Mielke, R. Liang, D.A. Bonn, W.A. Hardy and G.G. Lonzarich PNAS 107 (14) 6175-6179 (2010).

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