Quantum Criticality in Cuprate and Iron based Superconductors

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Quantum critical fluctuations between an ordered and disordered state have been suggested to be an important factor in boosting T_c. The iron based superconductor, $BaFe_2(As_{1-x}P_x)_2$, provides perhaps the best example to date where a high T_c is coincident with a region of the phase diagram where many physical properties show the hallmarks of a quantum criticality. In particular, the quasi-particle mass, as measured by dHvA oscillations, specific heat and magnetic penetration depth, increases by up to a factor 10 over a narrow range of x close to the extrapolated end point of the antiferromagnetic transition [1]. Interestingly though, this increase in mass does not seem to have any significant influence on either the lower or upper critical fields – in disagreement with theory [2].

The applicability of a quantum critical scenario to the cuprates is debatable as T_c is zero close the quantum critical point (QCP) of the antiferromagnetic phase. The end point of two competing phases: the pseudogap phase and a charge density wave phase do both occur close to the maximum T_c, however, it is unclear whether either of these phases are quantum critical close to their end points. Recent experiments [3] have shown a strong increase in quasiparticle mass m^* in the cuprate $YBa_2Cu_3O_{7-\delta}$ as optimal doping is approached suggesting that quantum fluctuations of the charge ordered phase may be responsible for the high T_c superconductivity. We have tested the robustness of this correlation between m^* and T_c by performing quantum oscillation studies on the stoichiometric compound $YBa_2Cu_4O_8$ (T_c=79K) under hydrostatic pressure up to 8.7 kbar [4], which increases T_c by ~ 5 K. In contrast to the results for $YBa_2Cu_3O_{7-\delta}$ where T_c is increased by changing δ, we find that in $YBa_2Cu_4O_8$ as T_c is increased by pressure the mass *decreases*. This inverse correlation between m^* and T_c suggests that quantum fluctuations of the charge order enhance m^* but do not enhance T_c. Our results suggest that the proximity of the CDW end point to the maximum in T_c with doping is coincidental and that therefore quantum fluctuations of the CDW order do not boost T_c in the cuprates.

[1] P. Walmsley *et al.* Phys. Rev. Lett. **110**, 257002, (2013).
[2] C. Putzke *et al.* Nature Communications **5**, 5679, (2014).
[3] B.J. Ramshaw *et al. Science* **348**, 317-320, (2015)
[4] C. Putzke, L. Malone, S. Badoux, B. Vignolle, D. Vignolles, W. Tabis, P. Walmsley, M. Bird, N.E. Hussey, C. Proust and A. Carrington (unpublished).

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