Breakdown of Universal Transport in Correlated *d*-wave Superconductors

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Introduction

The low-temperature ``universal" thermal conductivity in cuprates has been extremely important to theoretical approaches to the superconducting state. For example the slope of the d-wave gap near the node v_2 is often extracted from it using the relation $\kappa_0 \sim v_F/v_2$ but recent measurements on underdoped samples show strong violations of this apparently fundamental property of *d*-wave nodal quasiparticles[1]. Using analytical arguments and Bogoliubov-de Gennes simulations, we showed that the breakdown of universality is a consequence of disorder-induced magnetic states in the presence of increasing antiferromagnetic correlations in the underdoped state[2]. These same correlations protect the low energy density of states [2,3].

Results and Discussion

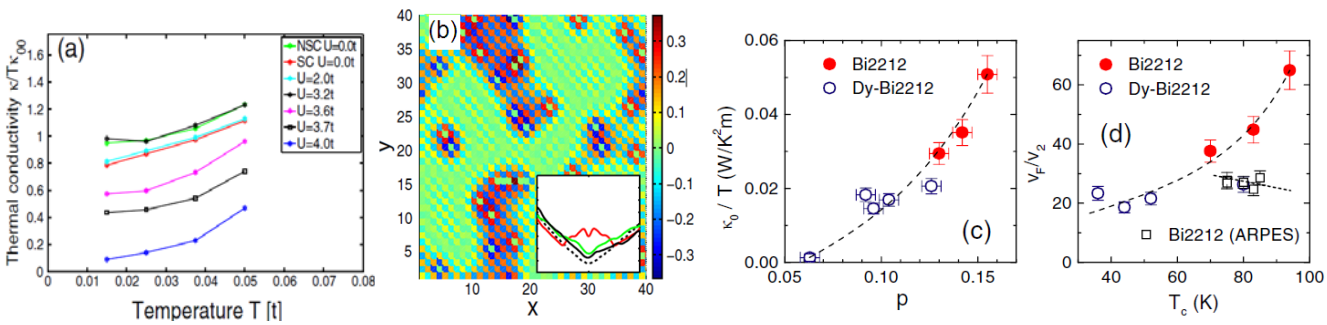

Figure 1 (a) Results of Bogoliubov-de Gennes calculations for *d*-wave superconductor with Hubbard-type correlations indicating that κ is suppressed by the growth of magnetic droplets, as shown in (b). Also shown in insert to (b) is suppression of plateau in DOS by magnetic correlations. (c) Experimental dependence of low-T thermal conductivity on doping in Bi-2212 [2]. (d) Conflict with results of photoemission studies if naïve universal κ formula is assumed [2].

In an earlier paper [4], we showed that magnetic correlations in the superconducting state lead to the formation of antiferromagnetic around dopant impurities in the intrinsically doped cuprates like LSCO and BSCCO. These droplets then overlap, leading to quasi-long range order. An interesting aspect of these additional correlations, which become stronger in underdoped materials, is that the low-energy DOS is suppressed (Fig 1b), leading to the notion of nodal states being "protected" from disorder by interactions[3]. Nevertheless the interactions have a dramatic effect on transport, leading to a violation of the cancellations between scattering lifetime and DOS in the thermal conductivity.

Conclusions

This work strongly suggests that the physics of underdoped, intrinsically doped cuprates is dominated by magnetic fluctuations pinned by dopant disorder. Such tendencies are strongly enhanced in both the superconducting and pseudogap states due to incipient bound state formation around nonmagnetic impurities. This magnetic order scatters low-energy quasiparticles strongly, and leads to a breakdown of universal transport predicted for *d*-wave systems in the presence of ordinary disorder. The universal thermal conductivity expression may therefore not be used to determine the doping dependence of the gap velocity in the underdoped regime of the phase diagram.

Acknowledgements

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References

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