Low-temperature Transport Power Law Near a Quantum Critical Point in $BaFe_2(As_{1-x}P_x)_2$

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Introduction

The physics of quantum phase transitions connects to some of the most difficult problems in condensed matter physics, including metal-insulator transitions, frustrated magnetism and high temperature superconductivity. The most difficult problem in understanding the ground state of such systems is not how exotic ordered states appear, but the absence of order which is associated with a very unusual metallic state. This problem mirrors that considered by Landau in 1957, when trying to rationalize how the properties of ordinary metals could be understood from the physics of the Fermi gas, despite the substantial Coulomb interactions between charge carriers themselves. The solution that particle-hole excitations could be isomorphic to the excitations of Fermi gas is the basis for our modern understanding of metals. Landau's idea is quite general and even applies to strongly correlated systems such as the overdoped cuprates, the overdoped pnictides and heavy fermion materials, where the quasi-particle effective mass can exceed 30 times that of the bare electron mass. However, near a quantum critical point, a new kind of metal emerges, one where the specific heat diverges logarithmically and the resistivity is linear, not quadratic in temperature.

Experimental

The magnetoresistance was measured in high magnetic fields were made available at the NHMFL, Tallahassee (45T, static) and at Los Alamos National Labs (65T pulsed).

Results and Discussion

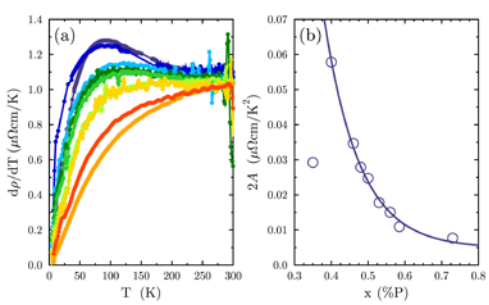

Figure 1 : (a) The derivative of the resistivity for all samples considered, including both data from zero field and high field experiments. All derivatives cross the origin within experimental error, suggesting that the resistivity is best described by ρ=ρ0,0+ATn with n>1. **(b)** TheslopenA of the derivative is linear at low enough temperatures, suggesting n = 2. Plotting this slope as a function of doping suggest a dramatic increase at compositions between x = 0.35 and 0.4, possibly indicating the presence of a quantum critical point.

Conclusions

We fit finite-size windows Ti < T < Tf in temperature of dρ/dT, with the derivative of $\rho=\rho_{0,0}+AT^n$ and observe the evolution as we slide this window up in temperature (**Figure 1**). From this we extract the average power law n (Tav), where Tav = 1 /(Ti + Tf). For all compositions considered, n → 2, the value typically associated with electron-electron scattering in a Fermi liquid. The present analysis of the zero-field transport in over- doped $BaFe_2(As_{1-x}P_x)_2$ suggests that while the transport appears strongly linear at temperatures T > Tc, the low temperature transport from the field dependence will always return to a higher power, suggestive of an underlying Fermi liquid ground state. The data suggests that this breaks down near a quantum critical point on the overdoped side of the phase diagram.

Acknowledgements

HHK, JGA, JHC and IRF acknowledge support of the U.S. DOE, Office of Basic Energy Sciences under contract DE-AC02-76SF00515.