How to map a pseudogap?

A pseudogap (PG) is believed to be responsible for the non Fermi-liquid normal state of cuprate superconductors. In particular, field induced PG collapse causes negative longitudinal magnetoresistance (MR) \(^1\). The PG collapses because of spin-splitting of the polaron band while the orbital effects are irrelevant \(^1\). Recently these conclusions, including the Zeeman relation, \(k_B T^* = gB_{pg}\), which couples the PG temperature, \(T^*\), and the PG closing field, \(B_{pg}\), were reaffirmed by the authors of Ref.\(^2\). It will be demonstrated below that \(^2\) lacks consistency and its conclusions are based on fallacious propositions and unsupported by the authors’ own experimental results. For these reasons, \(^2\) does not represent reliable independent evidence in support of the original findings by \(^1\).

Unlike \(^1\), Ref.\(^2\) mistakenly assumes that it is not the conductance but the net resistance, \(\rho_c = \rho^n + \Delta \rho_c\), that is the sum of two channels: the ‘ungapped’ \(\rho^n \propto T\), measured with intrinsic tunnelling at the highest overheating \(^3\), and \(\Delta \rho_c\), the excess resistivity due to DOS depletion \(^4\), obtained by the subtraction of that poorly defined \(\rho^n\) from the net \(\rho_c(T, B)\). Ref.\(^2\) further claims that \(\Delta \rho_c(B)\) extrapolation beyond 60 T gives a reliable \(B_{pg}\) estimate that is insensitive to the functional form of the fit, so that other approximations give the same estimates. I will show below that, in addition to the inconsistency \(^4\) and the lack of theoretical support, the entirely empirical \(B_{pg}\) evaluation procedure of \(^2\) lacks both reliability and accuracy.

Providing the data from \(^2\) are reliable, these should allow for a cross-check of the authors’ conclusions. However, even a brief look at the insert to Fig.1c reveals several inconsistencies. First, contrary to \(^2\), the power-law fit here appears to be a 3rd order polynomial. Second, unlike \(^2\), which claims \(B_{pg} = 300\pm50\)T, I found that extrapolations of data-compatible fits give \(B_{pg}\) in the range 200-\(\infty\) for the same crystal, UD\((T_c=90\)K\). Thus, the accuracy claimed by \(^2\) is seriously overestimated.

Moreover, the data of the most overdoped sample, central to \(^2\), are even more dubious. Let us consider the insert to Fig.2 from \(^2\) (reproduced in Fig.1) which allegedly justifies both the power-law dependence, \(\Delta \rho_c(B) - \Delta \rho_c(0) \propto B^\alpha\), and the accuracy of \(B_{pg}\) estimate. As is clear from Fig.1, the experimental curves favour an exponential dependence (solid lines) that provides a reasonable T-dependent parameter \(B_0\) (see Table in Fig.1) in drastic contrast to the unphysical scatter of \(\alpha\) and \(\Delta \rho_c(0)\), the parameters of the fit by \(^2\). Importantly, Fig.1 suggests a dramatically higher uncertainty in the extrapolation procedure by \(^2\). Even if this procedure is adequate, a realistic \(B_{pg}\) estimate from Fig.1 gives 100-1000T rather than 86-89 as in \(^2\). Thus, the experimental data of \(^2\) do not support their conclusions.

To conclude, the \(B_{pg}\) evaluation procedure by \(^2\) is theoretically unjustified and could only be used as an empirical exercise. Moreover, the experimental data by \(^2\) do not provide the accuracy claimed for the \(B_{pg}\) estimate, thus rendering irrelevant their phase diagrams. Hence the conclusions of \(^2\) lack reliable grounds beyond those of Ref.\(^1\). Additional inconsistencies in \(^2\) carried over from prior articles \(^4\) cast further doubts on the reliability of \(^2\). However, as far as the raw data are concerned, these may not necessarily be incorrect. In particular, the estimates of resistive upper critical field correlate reasonably with \(^1\). Interestingly, \(H_{c2}\) for crystals of vastly different doping \(^2\) follow the single dependence, \(H_{c2} = H_0(t-1/2)^{1/2} (1 = T/T_c)\), with the doping dependent \(H_0=4-12\)T, see \(^2\) for details.

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V.N.Zavaritsky

Department of Physics, Loughborough University, Loughborough LE11 3TU, United Kingdom.

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[4] Thus, the assumptions of \(^2\) drastically contradict the principal conclusion of Ref.\(^1\) from \(^2\), which attributed the negative MR to the superconducting state and, moreover claimed \(\rho(B)\) to exhibit strong current dependence up to 4-5\(H_{sc}\), \(H_{sc}\) is the field of \(\rho(B)\) maximum.
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