Comment on "3D X-Y Scaling of the Specific Heat of $YBa_2Cu_3O_{7-\delta}$ Single Crystals"

In a recent article, Overend, Howson, and Lawrie [1], subsequently referred to as OHL, gave strong evidence that their specific heat data near T_c in a magnetic field were better described by low field critical scaling laws than by the lowest Landau level (LLL) high field approximation, at least up to 8 Tesla. The critical exponents and amplitude ratios were found to be consistent with those observed in the λ transition of ^4He. OHL based their conclusion on the excellent scaling obtained using the 3D X-Y model, and the impossibility of scaling their data using the LLL approximation.

OHL measured the specific heat C of a mg-size single crystal of $YBa_2Cu_3O_{7-\delta}$ (YBCO) in magnetic fields up to 8 T, using an ac technique. Such methods yield only relative values. We have recently measured the specific heat of a much larger crystal (0.29 g) of YBCO up to 16 T, using a high precision adiabatic, continuous heating method.

The weakest part of any scaling attempt is the approximation used for the nonsingular part of the specific heat, since the fluctuation component C_{fl} is but a few percent of the total heat capacity C_{tot}. OHL use a linear baseline (i.e., $C_{tot} - C_{fl} = a + bT$) situated far *above* the specific heat peak. To avoid such an arbitrary baseline subtraction, we suggest another way to scale the data. Since phonons, and more generally nonsingular contributions, are expected to be insensitive to the field, we have $\partial C_{tot}/\partial \ln B = \partial C_{fl}/\partial \ln B$. The quantity $\partial C_{tot}/\partial \ln B$ obeys the same scaling laws as C_{fl} but is not blurred by a large background. The price to be paid for the derivation is a high accuracy of the thermometry versus field. The latter was verified in our case using the triple point of argon.

Using the measured quantity $\partial C_{fl}/\partial \ln B$, we tested both the LLL [3] and 3D X-Y approximations [4], as attempted by OHL using $C_{fl} - C_0$. We define $T_c(B)$ as $\partial(C/T)/\partial B|_{T_c} = \max$.

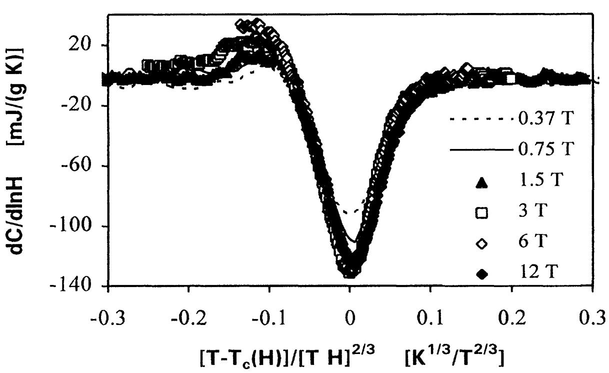

FIG. 1. Scaling plot of $\partial C_{fl}/\partial \ln B$ in the LLL approximation. The scaling variable is $[T - T_c(B)]/(BT)^{2/3}$.

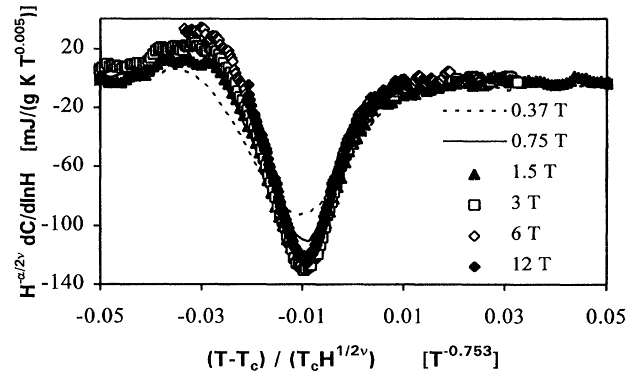

FIG. 2. Scaling plot of $B^{-|\alpha|/2\nu}\partial C_{fl}/\partial \ln B$ in the 3D X-Y model. $\alpha = -0.0066$ and $\nu = 0.664$.

The plot of $\partial C_{fl}/\partial \ln B$ vs the scaling variable $x = [T - T_c(B)]/[BT]^{2/3}$ corresponding to the LLL approximation is given in Fig. 1. The curves collapse on a single one for average fields higher than 1 T. Below 1 T, as could be expected, either higher Landau levels contribute, making the LLL approximation invalid, or finite size and/or inhomogeneity effects limit the sharpness of the transition.

The corresponding 3D X-Y scaling plot is given by $B^{-|\alpha|/2\nu}\partial C_{fl}/\partial \ln B$ vs $[T - T_c]/[T_c B^{1/2\nu}]$ (Fig. 2). The result is somewhat less good but does not differ drastically from that obtained in the LLL scheme. This is due to the negligible variation of the prefactor $B^{-|\alpha|/(2\nu)}$ ($0.986 < [B(\mathrm{T})]^{-|\alpha|/(2\nu)} < 1.007$ for $0.25 < B < 16$ T, which is replaced by 1 in the LLL case, and to the small difference between $1/2\nu \approx 0.753$ and the LLL exponent of $\frac{2}{3}$.

Summarizing, we state that, based on a method that does not depend on an arbitrary baseline subtraction, one cannot decisively rule out either LLL or 3D X-Y scaling. Both give good results, with a small advantage for LLL. We note, however, that LLL scaling is expected to improve at high fields, whereas the opposite is true for 3D X-Y low field scaling. In this respect, experiment would rather be in favor of the high field LLL approximation.

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