Comment on "Structure and Phase Transition of Josephson Vortices in Anisotropic High-T_c Superconductors"

For cuprate superconductors in fields parallel to the planes, it has been found that the temperature dependence of the resistivity suggests a continuous transition [1], instead of the expected first order transition. The often accepted theoretical picture is that the system undergoes a continuous transition analogous to the nematic to smectic transformation in liquid crystals [2,3].

In a recent Letter [4] Hu and Tachiki examined the transition in this geometry by Monte Carlo simulations on an anisotropic frustrated 3D *XY* model and argued that the behavior of both the helicity modulus and the specific heat suggests a continuous transition. However, we will argue below that the observed behavior rather is characteristic of a two-dimensional system and may not be used to deduce the character of the 3D transition.

Hu and Tachiki plotted the temperature dependence of the specific heat C in their Fig. 2. The data show that the specific heat in this 3D system has a peak around $T = 1.05$ and that the maximum value of the plotted quantity is $24 \times C \approx 36$. This was found to hold for three different system sizes, of which the smallest was $48 \times 40 \times 48$. To compare with the specific heat for a single 2D layer, we have made simulations with $L = 44$ which is chosen to have close to the same area as 48×40. Recall that the peak of the specific heat in the 2D model is a nonsingular feature well separated from the Kosterlitz-Thouless temperature $T_{\mathrm{KT}} \approx 0.89$.

Our results for $24 \times C$ for the 2D system are shown by the filled circles in Fig. 1. The similarity to the data of Hu and Tachiki (symbols in the same figure) is striking. We therefore conclude that the data for the anisotropy $\Gamma = 10$ of Ref. [4] are dominated by 2D fluctuations. The peak does not correspond to any transition in the 3D model and the absence of any sharp features in this data cannot be taken as evidence for a continuous transition in the 3D model.

To understand the relation to the 2D *XY* model we note that it is possible to choose a gauge with $A_{ix} = A_{iy} = 0$, and the frustration included in the A_{iz} only. Considered in this way, the system consists of some stacked unfrustrated 2D *XY* planes with a weak interplane coupling that at some positions between the planes is ferromagnetic ($A_{iz} = 0$), at some positions is antiferromagnetic ($A_{iz} = \pi$), and otherwise is something between. The interplane interactions therefore tend to cancel each other out and this results in a very weak effective interplane interaction. To see the true 3D behavior one would therefore need very large planes.

Based on their more recent simulations Hu and Tachiki [5] suggest the existence of a critical value of $f\Gamma$ related to the difficulty for the lattice to fit into the layered system. Even though one can not exclude the possibility of a new behavior for large $f\Gamma$, we have three remarks relevant to their new results: (1) To resolve the first order transition one needs system sizes much larger than the correlation length right above the transition. What the recent results suggest is therefore only that this length grows with Γ—but not that it has become infinite for $\Gamma = 10$ as in a continuous transition. (2) The evidence for a second order transition is based only on the absence of features in the specific heat. This is a very weak argument since the large fluctuations associated with the diverging correlation length certainly should affect the free energy and thereby the specific heat. (3) For large $f\Gamma$ Hu and Tachiki find that all layers will be occupied by vortices. This is in marked contrast to the suggested smectic phase [2] with vortices only at certain layers.

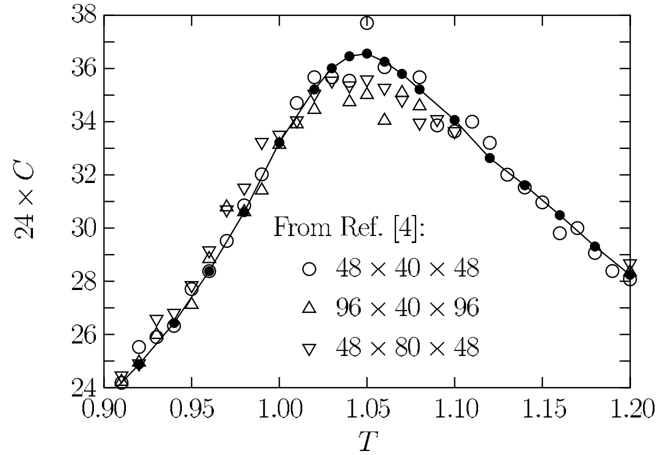

FIG. 1. Filled circles: Specific heat for a two-dimensional *XY* model with $L = 44$. Open symbols: data points from the inset of Fig. 2 in Ref. [4].

However, the main message of the present Comment is that the specific heat data in Ref. [4] (see Fig. 1) give strong evidence for 2D fluctuations and nothing else.

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