## Comment on "Anomalous Spectral Weight Transfer at the Superconducting Transition of $Bi_2Sr_2CaCu_2O_{8+\delta}$"

In a recent paper [1], I suggested that careful analysis of the comparison of the sum rule on angle-resolved-photoemission-spectroscopy (ARPES) intensity between normal and superconducting states would be a crucial test of central features of the theory of high-$T_c$ superconductors. The Letter by Dessau *et al.* [2] has carried out this test beautifully and, in addition, gives unexpected and remarkably clear evidence for the "interlayer" mechanism for superconductivity.

First, let us comment on the $\Gamma$-$X$ curves. Here the best theoretical normalization is to normalize to equal total areas rather than to equal intensity in the tail, because of the sum rule referred to in the Letter; if this is done, it is clear that, as predicted [1], the intensity in the superconducting peak comes to a great extent from the *entire* region of energies up to a cutoff of order of several $J$ (i.e., a few tenths of eV). This *lowering* of the excitation energies for one-electron and one-hole states is the source of the superconducting condensation energy in the "interlayer" theory. In BCS, as demonstrated long ago by Chester [3], it is the phonon frequencies which are lowered, and this accounts for the condensation energy.

More exciting is the result along $\Gamma$-$M$. Here we must point out that there is a doubling of the *calculated* energy bands at general points in the two-dimensional zone (see, for instance, Ref. [13] of the Letter) [4] because of the hopping matrix element connecting the two close Cu-O layers in Bi-Sr-Ca-Cu-O. Basically, odd and even combinations of the two layers,

$$\varphi_k^{\pm} = \varphi_k^{(1)} \pm \varphi_k^{(2)} ,$$

where (1) and (2) refer to the layers, are separated by an energy splitting $2t_k$, where

$$t_k = (\varphi_k^{(1)} | \mathcal{H} | \varphi_k^{(2)}) .$$

This splitting nearly vanishes along the symmetry direction $\Gamma$-$X$ because the hopping is primarily via the intervening Ca ion, which sits at a node in the wave function for these $k$ values. However, at general points the splitting is of order 0.1 eV or greater, and it is a strong support for the two-dimensionally correlated, non-Fermi liquid theory of the normal state that this splitting is *not* seen in ARPES of the normal state, even though the feature resolution is much better than the splitting. (Also, incidentally, the corresponding peak of ir conductivity is missing.)

In the superconducting state, as pointed out in Ref. [1], the quasiparticle, fermionlike nature of the electronic excitations is partially restored. Therefore, at a general $k$, such as along $\Gamma$-$M$, we expect to see a *return of the odd-even band splitting in the superconducting state.* 90 meV is a reasonable value for the somewhat diminished splitting one might expect to see. We ascribe the two features, then, to quasiparticle poles belonging to odd and even linear combinations of states at the same transverse $k$. This can be confirmed by checking whether they track the predicted band splitting.

Unfortunately the complete theory of the spectrum well below $T_c$ is not available. The arguments one has are purely perturbative and serve only to roughly locate $T_c$ and indicate that the quasiparticle pole reappears just below $T_c$. The ARPES data should stimulate redoubled efforts. As the data stand, however, they demonstrate the large energy effects of restoring the interlayer coupling, which would be ample to explain the observed $T_c$'s, even if they are not the only coupling mechanism. In summary, if the experimental data given in the Letter can be quantified, in principle they can solve the problem of the microscopic nature of high-$T_c$ superconductivity.

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[1] P. W. Anderson, Phys. Rev. B **42**, 2624 (1990).
[2] D. S. Dessau *et al.*, Phys. Rev. Lett. **66**, 2160 (1991).
[3] G. F. Chester, Phys. Rev. **103**, 1693 (1956).
[4] The band structure given in Ref. [13] of the Letter does not show the splitting well along $\Gamma$-$M$ because of mixing with a Bi band whose position is at best controversial. Band structures calculated by other groups or for Y-Ba-Cu-O show it more clearly. On the other hand, if the structure is due to mixing with the Bi layer, as the authors think is possible, that does not diminish the point that three-dimensional band structure is reappearing below $T_c$.

 