Comment on
"Superfluid Anisotropy in YBCO:
Evidence for Pair Tunneling Superconductivity"

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Comment on "Superfluid Anisotropy in YBCO: Evidence for Pair Tunneling Superconductivity"

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Recently, Xiang and Wheatley [1] extended our proximity coupling SN model [2] of the (S) CuO_2 plane and (N) CuO chain layers in YBCO compounds, using the single particle bands $\epsilon_{1k}^0 = -t(\cos k_a + \cos k_b) - \mu_1$ and $\epsilon_{2k}^0 = -t_{2y} \cos k_b - \mu_2$, respectively. Although we showed [2] that it was possible to fit the penetration depth $\lambda_{ab}(T)$ in twinned YBCO with either s - or d -wave pairing and both bands free-particle-like, they claimed that: (1) It is *impossible* to fit the quasi-linear $\lambda_a(T)$ in untwinned YBCO [3] without order parameter line nodes, such as for $d_{x^2-y^2}$ pairing. (2) Even d -wave SN fits to the $\lambda_{a,b,c}$ data [3] are inferior to those obtained [1] from a model of d -wave interlayer pair tunneling (DIPT) [4]. We remark that their claim (1) is false, and (2) ignores other data [5–9] favoring proximity coupling.

A quasi-linear $\lambda_a(T)$ can arise in the SN model if the chain band is *quasi-one-dimensional*, with $\epsilon_{2k} = \epsilon_{2k}^0 - t_{2x} \cos k_a$ consistent with the local density approximation, which also requires $\epsilon_{1k} = \epsilon_{1k}^0 - t' \cos k_a \cos k_b$. We calculated $\lambda_{a,b,c}(T)$ with these ϵ_{1k} and ϵ_{2k} forms, and $\epsilon_{\perp}(k_z)$ from [2]. In Fig. 1, we show the results for s - and d -wave pairing [2], and list the parameters in the caption. At $T_0 = 0.01T_c$, $\lambda_a/\lambda_b = 1.38(1.30)$ and $c\lambda_c/b\lambda_b = 60(57)$ for s - (d)-wave pairing, respectively, consistent with experiment [3]. The d -wave curves in Fig. 1a are nearly identical to those in Fig. 1 of [1]. However, the s -wave curves in Fig. 1b are *also* quasi-linear at low T , and quite similar to the d -wave curves. Hence, it is *nearly impossible* to distinguish s - from d -wave pairing in the SN model.

Recent $\lambda_{c,ab}(T)$ measurements [5] on twinned YBCO better fit the predictions of the *SN* model than of the DIPT model [1]. More important, in the DIPT model [1], the entire Fermi surface (FS) is gapped except at the nodes, implying the specific heat $C(T) \sim \alpha T^2$ as $T \rightarrow 0$. However, a best fit [6] to the YBCO $C(T)$ data with $\gamma T + \alpha T^2 + \beta T^3$ showed $\beta, \gamma > 0$, but $\alpha \leq 0$, *inconsistent* with line nodes. But, the *SN* model accounts for the γT term, as that part of the chain FS far from the plane FS remains normal. A more realistic model would include the *pairbreaking* chain oxygen vacancies [7]. The resulting local normal chain regions would also lead to proximity coupling [8]. Finally, we remark that Nb/Cu bilayers [9] exhibit $\sigma_{1,2}(T)$ behaviors remarkably similar to those in YBCO.

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FIGURES

FIG. 1. Plots of $\lambda_x^2(T)/\lambda_x^2(T_0)$ versus T/T_c for $x = a, b, c$ (solid curves) with dimensionless parameters $t = 25, t' = 20, \mu_1 = \mu_2 = 15, t_{2x} = 8, t_{2y} = 25, J_1 = 1.5, J_2 = 0.5$, relative to the bare T_{c0} [2]. (a) $d_{x^2-y^2}$ pairing. Dashed curve: standard d -wave model [2]. (b) s -wave pairing. Dashed curve: standard BCS model.