Comment on "Violation of Kohler's Rule in the Normal-State Magnetoresistance of $YBa_2Cu_3O_{7-\delta}$ and $La_2Sr_xCuO_4$"

The unusual normal state kinetics of high-T_c cuprates is recognized now as the key to our understanding of the high-T_c phenomenon [1]. In particular, Harris *et al.* [2] found that the normal-state magnetoresistance (MR) $\Delta\rho/\rho$ of several cuprates displays a temperature dependence that strongly violates Kohler's rule. Their conclusion was that the anomalous power laws T^{-n} of the in-plane conductivity, the Hall "constant" R_H, and the weak-field MR ($n = 1$, 1, and 4, respectively) identify two distinct lifetimes $\tau_{\rm tr}$ and τ_H associated with the response to the electric field and the Lorentz force, respectively, hence violating the Boltzmann kinetics.

However, there is no point in abandoning Boltzmann kinetics if the bipolaron theory [3] is applied. A fraction of bipolarons is localized by disorder, so that the number of delocalized carriers is proportional to T while the boson-boson inelastic scattering rate is proportional to T^2. This allows us to explain the linear in-plane resistivity, the Hall density, as well as the semiconductinglike c-axis resistivity [4].

In this Comment, I show that the bipolaron theory provides the most natural microscopic explanation of the anomalous MR observed by Harris *et al.* [2].

The (bi)polaronic nature of carriers in cuprates is now well documented: by many observations of the characteristic polaronic spectral function in the infrared conductivity of both underdoped and optimally doped cuprates (for references see [3]), by the isotope effect on the carrier mass [5], and by the flat bands in the high-resolution photoemission spectra [6]. Normal state magnetic susceptibility is well described by the bipolaron model at any doping [4]. These and many other findings, in particular a semiconductorlike doping dependence of the dc conductivity, allow us to consider cuprates as doped semiconductors with the (bi)polaronic carriers, nondegenerate above T_c. Then the weak-field MR is given by the classical formula [7], $\Delta\rho/\rho = KH^2/\rho^2$, with the slope $K = \beta R_H^2$, where

$$\beta \equiv \frac{\Delta\rho}{\rho\Theta_H^2} = \frac{\langle\tau_{\rm tr}^3\rangle\langle\tau_{\rm tr}\rangle}{\eta\langle\tau_{\rm tr}^2\rangle^2} - 1 \,. \qquad (1)$$

Here $\langle\cdots\rangle$ means an average with the Boltzmann distribution function, for instance $\langle\tau_{\rm tr}\rangle = \int dE N(E) E \tau_{\rm tr}(E) \times \exp(-E/T)$, $N(E)$ the density of states and $\eta = 4m_x m_y/(m_x + m_y)^2$ describes the in-plane anisotropy of the one-particle energy spectrum, observed with the high-resolution photoemission spectroscopy [6] and derived microscopically [8]. For a low amount of disorder we found $\eta = 0.64$, while in strongly disordered cuprates η might be significantly smaller, about 0.1 or less [8]. The inelastic scattering rate of delocalized carriers by localized ones is proportional to the square of the phase volume available for the scattering near the mobility edge, so that $\tau_{\rm tr} \sim (T + E)^{-2}$ [4]. As a result, one obtains $\beta = \{9eEi(-1)/20\eta[1 + 2eEi(-1)]\} - 1$, where $eEi(-1) \simeq -0.596$. This yields the temperature independent constant $\beta \simeq 1.2$ with $\eta = 0.64$ and $\beta \simeq 13.0$ with $\eta = 0.1$ which is fairly close to the observed values [2], $\beta \simeq 1.5$ to 1.7 in $YBa_2Cu_3O_{7-\delta}$ and $\beta \simeq 13.6$ in $La_{2-x}Sr_xCuO_4$. By taking into account the Anderson localization the Hall constant is given by $R_H \sim 1/T$ [4]. Then Eq. (1) provides a parameter-free fit to the experimental data [2], Fig. 1, explaining the violation of Kohler's rule.

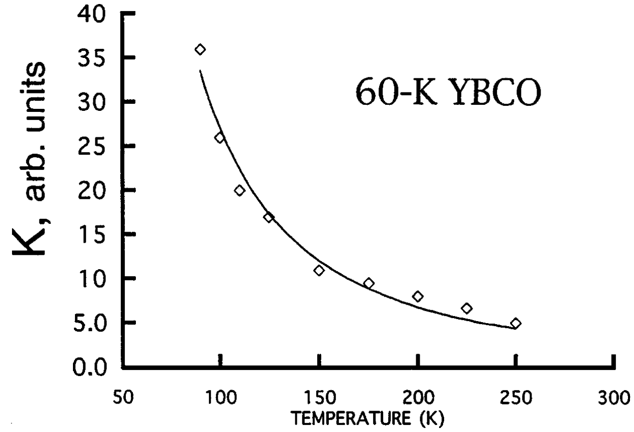

FIG. 1. The temperature dependence of the slope K, violating Kohler's rule as measured experimentally [2] (points) and described by the bipolaron kinetics (line).

In conclusion, the bipolaron kinetics allows us to describe the anomalous power laws of the normal state properties of cuprates including the weak-field MR being at peace with the Boltzmann theory in contrast with the "two different memory times" model hypothesized in Ref. [2].

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