High-Temperature Optical Spectral Weight and Fermi-liquid Renormalization in Bi-Based Cuprate Superconductors

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Since their discovery in 1986, the research on superconducting cuprates has been focused on their “low-temperature” properties, like the superconductivity and the so-called pseudogap, while the high-T properties of the cuprates have been scarcely investigated up to now. The present work is, to our knowledge, the first optical study of two Bi-based cuprates at optimum doping, from their critical temperature $T_c$ to 500 K. We have measured their optical conductivity $\sigma(\omega)$ and their spectral weight $W(\Omega, T)$ up to a cut-off frequency $\Omega$. The $T$-dependence of the carrier kinetic energy (which is proportional to $W(T)$) is described in terms of the Sommerfeld expansion, which is usually limited to the first term in $T^2$. We have found that, above 300 K, $W(T)$ deviates from the $T^2$ behavior in both compounds, even though the extrapolation to a dc conductivity $\sigma(\omega \to 0)$ remains well far from the Ioffe-Regel limit. As shown in the Figure, the deviation is well described by the second term of the Sommerfeld expansion, namely that in $T^4$. This shows that, despite all the anomalies encountered in the behavior of high-Tc superconductors, a Fermi-liquid picture works well up to such a high $T$. However, the coefficients of both the $T^2$ and the $T^4$ term are much enhanced by strong correlations, as shown by our dynamical mean field theory (DMFT) calculations. All measurements have been done by CNR-SPIN and CNR-IOM personnel, using the apparatus of the CNR-SPIN laboratory at University La Sapienza.

Figure caption. Temperature-dependent optical spectral weight $W(T)$ of optimally doped (a) Bi$_2$Sr$_1.6$La$_0.4$CuO$_6$ and (b) Bi$_2$Sr$_2$CaCu$_2$O$_8$, normalized to the (extrapolated) value at $T = 0$. The IR data (red dots) are compared with DMFT calculations for the restricted sum rule (blue diamonds) of the single-band Hubbard model. Also shown are theoretical calculations for the non-interacting system (U = 0) and the lowest-order Sommerfeld expansion, where the coefficient $B$ is simply rescaled by the DMFT quasi-particle weight ($Z$-scaled). In panel (a) DMFT calculations for the total sum rule are displayed for comparison (green squares). In the inset the dotted (dashed) line indicates the fit performed on $W(T)$ data using the Sommerfeld expansion up to the second (fourth) order.