High-Energy Magnetic Excitations in $La_{2-x}Ba_xCuO_4$

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Since their discovery in 1986 [1], the cuprate high-temperature (high-T_C) superconductors have been a topic of intense study. In addition to high-temperature superconductivity, these materials display a complex array of magnetic structures and excitations, whose crucial relationship to the superconducting state remains elusive.

In this vein, we have undertaken a systematic study of the nature of magnetic excitations in the prototypical cuprate $La_{2-x}Ba_xCuO_4$. Using the time of flight instrument SEQUOIA at Oak Ridge National Labs we mapped the inelastic scattering over a large region of reciprocal space in the (HHL) plane in single crystals over a range of hole doping, namely x = 0.035, 0.05 and 0.095. Figure 1 shows representative data taken on a single crystal with x = 0.05. Our measurements revealed a relatively dispersionless phonon mode stretching horizontally over many Brillouin zones around 20 meV; a result that repeats for all three doping levels measured. This phonon mode overlaps with the magnetic signal which appears as vertical rods of scattering extending out at the (H,H,L) = (± ½, ± ½ , L) (and crystallographically equivalent positions). In the regions where the phonon mode and magnetic signals overlap, there appears to be an enhancement of the scattering intensity, a phenomenon which has been seen in related systems [2].

To further investigate the nature of this enhancement, we performed an experiment using the triple-axis C5 spectrometer at Chalk River and measured the Q and temperature dependence of the excitations in the overlapping regions for a single crystal with x = 0.035. A vertically focusing PG002 monochromator and a flat PG002 analyzer with fixed final energy E_f = 7.369 THz were used. A PG filter was used at the scattered side to eliminate higher harmonic contamination from the beam. Collimations were set to [none, 0.8°, 0.85°, 2.4°]. We were able to model the data as the superposition of a linear background, which includes the optic phonon mode, plus two identical squared Lorentzians, which are centered at different positions. Figure 2 shows that after phonon and background contributions are removed from the observed scattering, there exists an enhancement of the magnetic scattering centered at 19-21 meV. Were the origin of this enhancement due to the overlap of crystalline and magnetic excitations, there would only be a monotonic decrease in intensity observed by this analysis relative to the low energy scattering. This strongly suggests that this feature is an intrinsic magnetic effect, as is supported by our time of flight measurements.

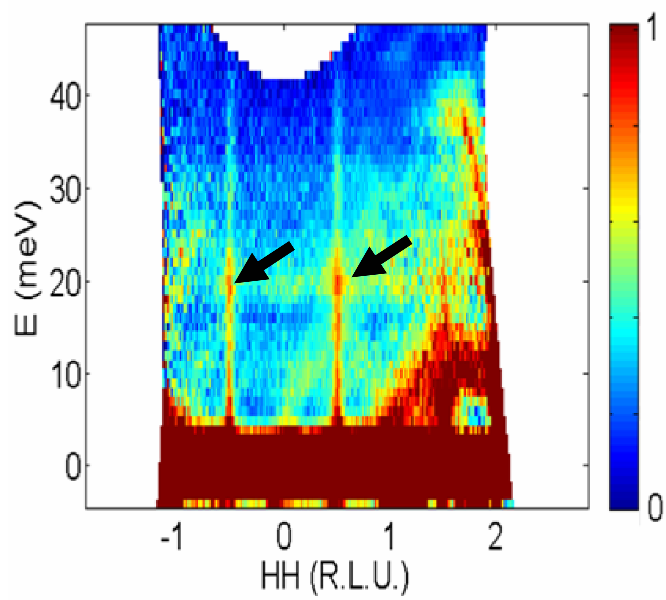

Fig. 1 Inelastic neutron scattering from SEQUOIA on x = 0.05 as seen by the central detector bank. This data was taken at 6 K. Intensity is shown in arbitrary units. All information along L was integrated. The magnetic excitations are seen as rod shaped dispersions emanating from the (H,H,L) = (± ½, ± ½ , L) positions. We are investigating the overlap region of these magnetic features with the nearly dispersionless phonon mode (shown arrows point to this region).

Figure 3 shows the temperature dependence of the dynamic susceptibility of the total scattering, using an empty sample can run to subtract the background. This result, shown as diamond data points, is preliminary as the data contains both magnetic and crystalline effects. The fact that the amplitude of susceptibility decreases at high temperatures suggest the presence of magnetic contributions in the observed scattering at this energy. Further experiment is required to fully determine the magnetic contribution. It is also interesting to consider this result in the context of both the elastic magnetic ordering temperatures of this system at different doping levels. The temperature dependence of the magnetic dynamic susceptibility for two concentrations, x = 0.0125 and 0.035, are shown in circles and squares respectively, for energies <1 meV. The dashed lines indicate the various elastic magnetic ordering temperatures relevant to this system. How these various features relate is not well understood at this point.

Further investigation is required to understand these results in detail, as well as to give insight into the effects of different barium concentrations. With a complete understanding of the results presented here, we will then be in a position to compare our results to related systems [3].

References

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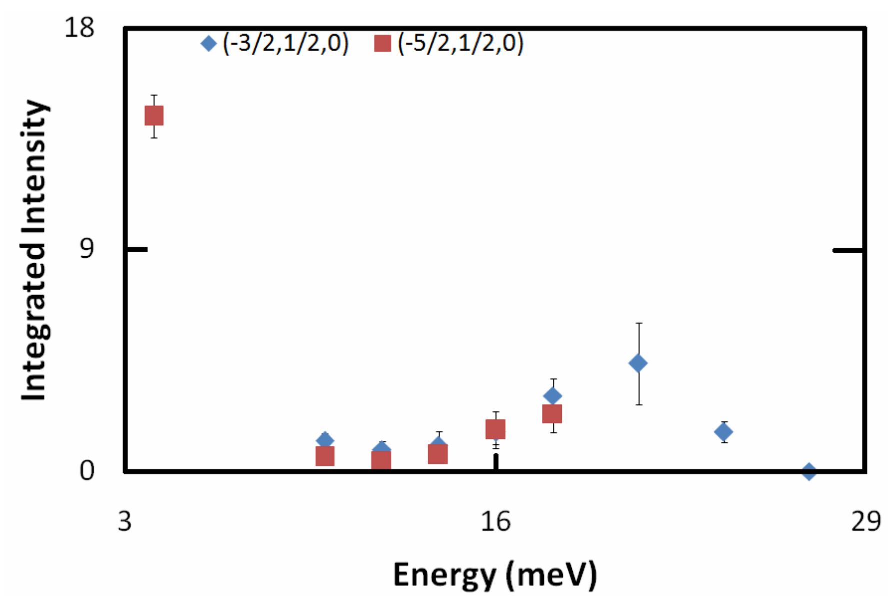

Fig. 2 Magnetic intensity obtained from fits of constant E scans taken at 3 K on a single crystal with x = 0.035 at C5. The data is described well by a linear function, which consists of both phonon and background contributions, plus two Lorentzian squared functions centered at incommensurate magnetic positions.

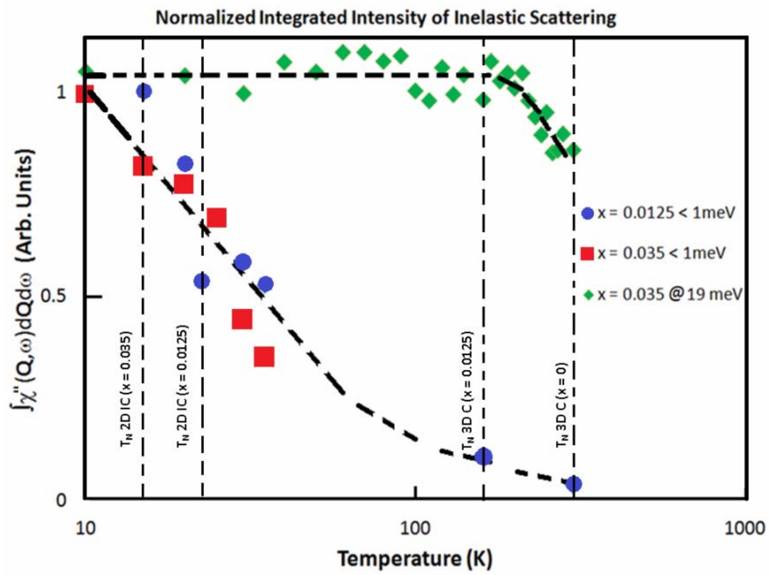

Fig. 2 Temperature dependence of the dynamic susceptibility for energy transfers of < 1 meV (obtained from an experiment at DCS) and 19 meV (from the present experiment) shown on a semi-log scale. The integrated susceptibilities at low energy are obtained from fits of the data, whereas the 19 meV susceptibilities are obtained from empty can subtracted measurements. Dashed lines correspond to three dimensional commensurate (3D C) and two dimensional incommensurate (2D IC) ordering temperatures relevant to this system at various dopings. Dashed lines following the trend of the data are guides to the eye, with one trend representing the data collected at DCS and another for data collected at C5.