ESRF	**Experiment title:** Resonant inelastic X-ray scattering studies of the charge-density-wave order in the model cuprate superconductor	**Experiment number**: HC3030
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The charge-density-wave (CDW) phenomenon was studied in the model high-T_c superconductor $HgBa_2CuO_{4+\delta}$ (Hg1201) via resonant inelastic X-ray scattering (RIXS) at the L_3-edge of copper. A crucial question regarding the nature of the CDW phenomenon in the hole-doped cuprates is whether the observed short-range order is static or associated with dynamic spectral features. We measured a single crystal of Hg1201 with T_c = 69K (hole concentration p = 0.083) and constructed energy-momentum RIXS intensity maps, with focus on the CDW momentum transfer, q_{CDW}.

The spectrometer was set to its highest back-scattering angle (2θ = 149.5°). Different values of the in-plane momentum transfer q along the Cu-O bond diretion (H in reciprocal lattice units) were accessed by rotating the sample about an axis perpendicular to the scattering plane. At each rotation angle θ, we measured the spectrum for several minutes, with the beamline and spectrometer conditions optimized for an energy resolution of about 50 meV. Prior to the acquisition of a Hg1201 spectrum, we obtained a spectrum on a thin layer of silver paint (located next to the sample) in order to pinpoint the zero-energy-loss pixel locationon the CCD camera detector.

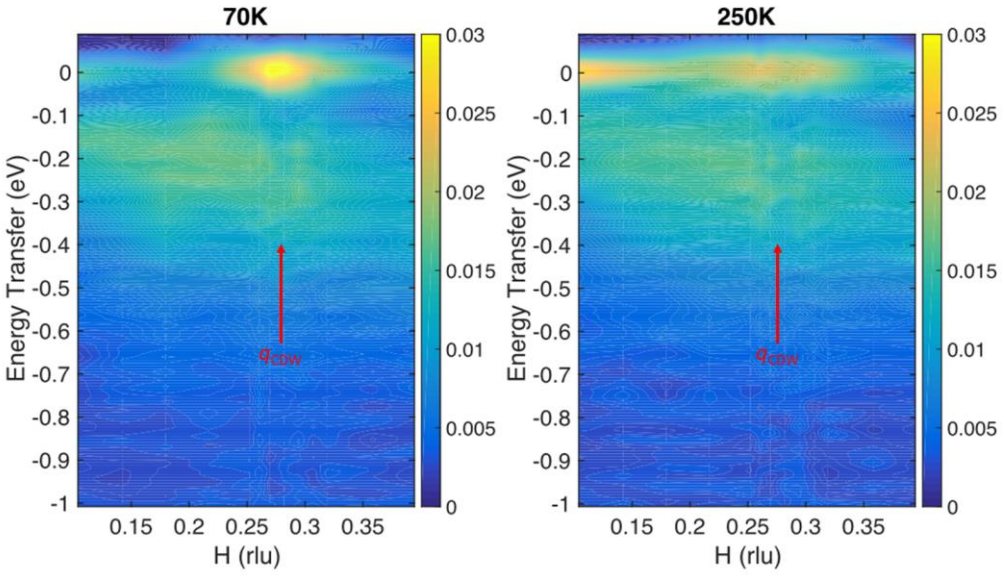

Figure 1 Energy-momentum intensity map of Hg1201. The low-energy transfer part of the RIXS map at two temperatures collected in π polarization at the Cu L-edge (~930 eV). In both spectra, an increase of the scattered intensity is observed aroud q_{CDW} = 0.28. CDW fluctuations are still clearly visible at 250 K, despite the fact that the T_{CDW} = 200 K detected by RXD [1]. The dispertion of magnetic excitation (0.2 – 0.3 eV energy loss) is visible as well.

Figure 1 shows the energy-momentum intensity map collected on the Hg1201 single crystal of Hg1201. The 70 K data (close to T_c = 69 K) show a clear quasi-elastic enhancement of the scattered intensity. This increase can be attributed to the CDW order phenomenon, as its momentum position corresponds to q_{CDW} observed via resonant X-ray diffraction (RXD) [1]. Although the magnetic excitations (paramagnons) are clearly visible in the spectra [2], no softening is observed at q_{CDW}. Surprisingly, the spectra collected at 250 K, well above the T_{CDW} = 200K [1], show an increase of the quasi-elastic peak intensity around q_{CDW}.

Motivated by this interesting observation, we have performed detailed data analysis. Figure 2 shows the RIXS intensity integrated over specific ranges of the energy transfer. The intensity integrated over the entire energy-loss range (Figure 2a), which combines the quasi-elastic andinelastic signal, shows a clear peak at 70 K aroud q_{CDW} = 0.28, and no CDW peak at 250 K. This is consistent with our prior RXD result; the analysis mimics the energy-integrated RXD experiment and yields consistent results. Figure 2b shows the intensity only of the quasi-elastic region. An intense, well-defined peak at q_{CDW} is observed at 70 K. However, a pronounced peak is still observed at 250 K, well above T_{CDW} =200 K. The width of the peak does not became substantialy broader above T_{CDW}, and hence the correlation length does not significantly change across T_{CDW}. The intensity increase thus suggests that the CDW fluctuations are increasingly stabilized and static below T_{CDW}. Furthermore, Figure 2c demonstrates that the intensity integrated over the inelastic part of the spectra, including the magnetic excitations, exhibits a maximum around q_{CDW} at 70 K. The absence of this peak above T_{CDW} suggests that the magnetic excitations may be impacted by the static CDW order at low temperatures.

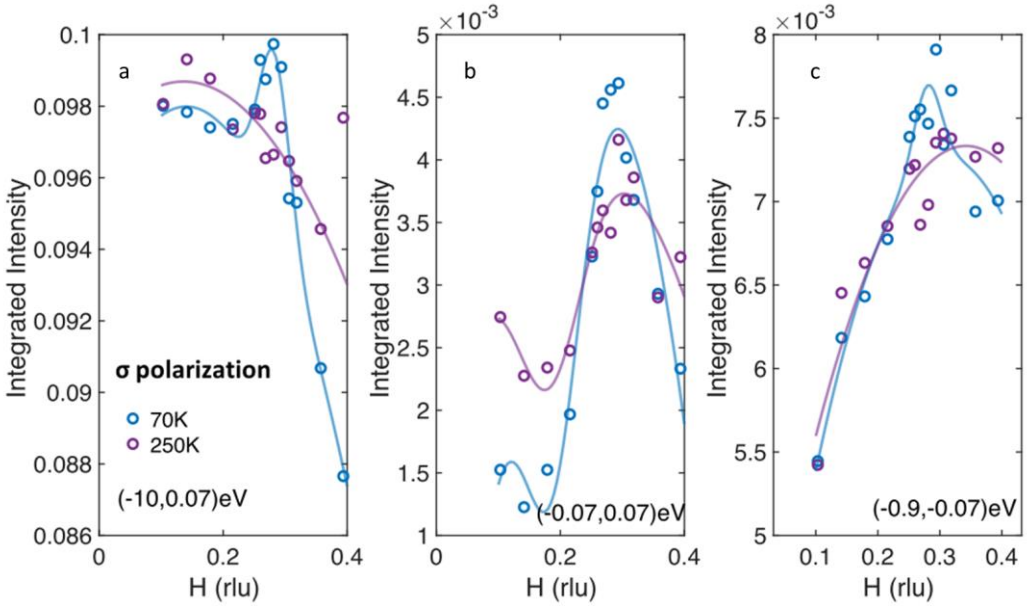

Figure 2 Energy-integrated RIXS spectra collected with σ-polarized incoming photons at 70K and 250K. (a) The intensity integrated over the entire energy lose range, including the quasi-elatsic peak and the inelastic signal. Clear peak is observed aroud q_{CDW} = 0.28, consistent with our prior RXD results. No CDW peak is observed in the integrated spectra collected at 250K. (b) RIXS intensity integreted only on the quasi-elastic peak. Strong CDW peak is observed at 70K bot also presence of the CDW peak is apparent at 250K. (c) The inelastic part of the RIXS integrated in the rane from -0.07 to -0.9 eV. While enhancement of the intensity is visible aroud q_{CDW} at 70K, only smooth, nonmonotonic evolution is observed at 250K. The experimental data is represented by open circles, and the lines are fits using a sum of a polynomial function and a Gaussian.

In summary, we performed an initial RIXS measurement of underdoped Hg1201 and observed a pronounced CDW peak in the quasi-elastic signal not only around T_c, but also above T_{CDW}, the characteristc CDW "onset" temperature as determined from prior RXD measurements [1]. Although no clear evidence of a softening of magnetic excitations was observed, intensity integration that includes the scattering from the paramagnons was found to be clearly enhanced at q_{CDW} in the low-temperature spectra. We anticipate that this line of research, involving a model cuprate compound, will have considerable impact on the field. In order to arrive at a benchmark dataset that will enable improved theoretical modeling of the CDW order and its connection to the pseudogap state and superconductivity, further study (a more detailed temperature dependence as the doping dependence) is required.

[1] W. Tabis *et al.*, arXiv.1702.03348 (2017)
[2] L. Braicovich *et al.*, Phys. Rev. Lett. **104**, 077002 (2010)