Experimental report

17/10/2018

Proposal:	**5-41-932**	**Council:**	4/2017
Title:	Incommensurate magnetic order in underdoped LSCO close to the insulator-superconductor boundary		
Research area:	Physics		

This proposal is a new proposal

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Samples: La_(1.94)Sr_(0.06)CuO_(4)
La_(1.93)Sr_(0.07)CuO_(4)
La_(1.95)Sr_(0.05)CuO_(4)
La_(1.93)Sr_(0.07)CuO_(4) (annealed)

Instrument	Requested days	Allocated days	From	To
THALES	6	5	23/05/2018	28/05/2018
IN12	6	0		

Abstract:

The interplay between magnetism and superconductivity in the copper oxide high Tc superconductors remains a subject for intense study. In recent experiments on underdoped LSCO (x=0.06 and x=0.07) a strong peak at the forbidden (100) position together with a quartet of incommensurate peaks at (±delta; 1±delta; 0) were observed. These peaks are usually ascribed to AFM order and stripes that disappear around TN ~ Tc < 40 K, respectively. Surprisingly, both sets of peaks were present up to room temperature. Unlike previous studies, that found the incommensurability (delta) to be constant and identical to the doping (x) up to x=0.12, we find that the incommensurability in our samples is approximately half the doping at base temperature and even smaller at increased T. We aim to resolve the origin of these structures, magnetic or nuclear, with polarized diffraction using the same LSCO samples.

A study of elastic and dynamic stripes in superconducting LSCO with x = 0.07, at Thales

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The purpose of the experiment was to resolve the origin of the unexpected temperature dependent incommensurate elastic signal previously observed in our LSCO samples of strontium doping x = 0.07. The overall aim of the project was to study the magnetic stripes in this compound. However, when first measurements were attempted at the expected incommensurate position for the static stripes another type of signal was observed which was visible up to room temperature. Thus, we proposed to use polarization analysis in order to determine the origin, magnetic or nuclear, of this signal.

Some preliminary measurements performed at PSI on Rita II prior to this experiment revealed the origin of the signal to be multiple scattering. This meant that by choosing specific values of incoming and outgoing wavevectors we were able to avoid this spurious scattering. So we were able to focus on studying the genuine signal originating from the static and dynamic stripes in different conditions of temperature and applied magnetic field.

The sample

The sample is a LSCO single crystal with doping value x = 0.07. The dimensions of the crystal are as follows: cylindrical shape with length 1.7 cm, diameter 0.6 cm and mass ~3.4 g. The sample has been previously aligned at Orient Express such that the a-b plane is the scattering plane.

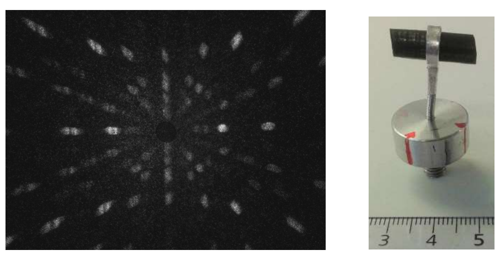

Figure 1: (left) Laue pattern taken along the a or b axis. **(right)** Sample inside the aluminium sample holder aligned in the a-b plane.

Results

Elastic signal

As temperature independent spurious scattering was still present around the (0 1 0) reflection, we defined the signal originating from the static stripes as the difference between low and high (80 K) temperature data (Figure 2). As expected from literature, we were able to confirm the presence of the static stripes only within the superconducting dome at temperature below $T_c \sim$ 11 K for this sample. The field dependence of the elastic signal points to a competition between magnetic order and superconductivity. This is supported by the effect of the applied magnetic field, namely an enhancement of the magnetic signal (Figure 4) simultaneous with a suppression of superconductivity as known from the literature.

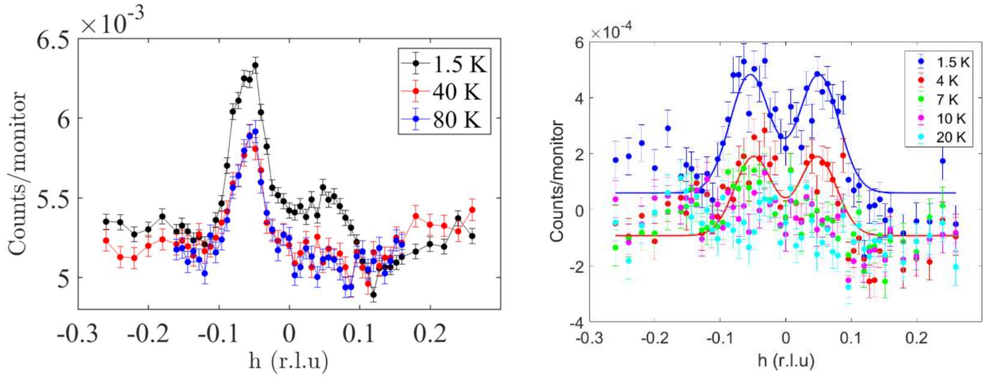

Figure 2: Temperature dependence of the elastic signal around the (0 1 0) reflection taken in zero applied magnetic field. **(left)** Raw diffraction data shown a temperature independent spurious peak at (-0.07 1 0) position. **(right)** Static stripes signal obtained as the subtraction of the low temperature scans of the scan at 80 K.

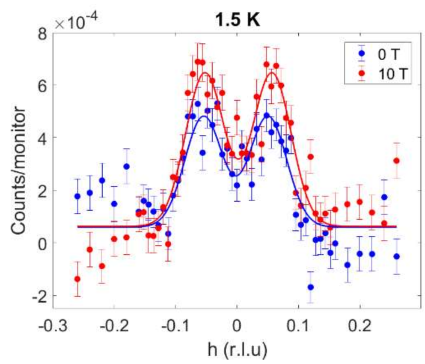

Figure 3: Magnetic field dependence of the elastic signal taken at base temperature 1.5 K around the (0 1 0) reflection.

Inelastic signal

Similar to other underdoped samples presented in the literature, our highly underdoped LSCO crystal shows an incomplete spin gap at low energy transfers (Figure 4). However, contrary to literature, the effect of an applied magnetic field, in this energy transfer regime, is to suppress the inelastic signal.

We can now argue that the overall effect of the applied magnetic field is to move spectral weight, of low energy transfer fluctuations, towards even lower energies, which we pick up in the elastic channel in our neutron scattering experiments.

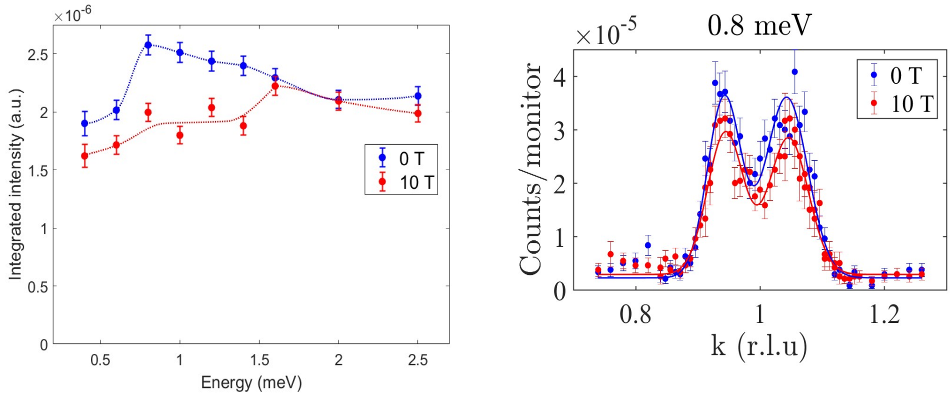

Figure 4: (left) Magnetic field dependence of the incommensurate inelastic signal taken at base temperature 1.5 K. **(right)** Representative raw data scan and fits taken with and without applied magnetic field at 0.8 meV energy transfer. The integrated intensity is defined as the amplitude of the Gaussian fit.