Experimental report

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Proposal: **CRG-3023** **Council:** 4/2023

Title: Magnetic field dependence of the q=1/2 magnetic response in detwinnedYBa2Cu3O6.6

Research area: Physics

This proposal is a new proposal

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Samples: YBa2Cu3O6.6

Instrument	Requested days	Allocated days	From	To
IN12	5	5	26/09/2023	01/10/2023
ORIENTEXPRESS	1	1		

Abstract:

The abstract is in the scientific case pdf file.

Magnetic field dependence of the q=1/2 magnetic response in twin-free $YBa_2Cu_3O_{6.6}$.

Scientific case: In superconducting cuprates, the intrinsic nature of the pseudogap (PG) state has been a longstanding mystery. According to thermodynamic measurements, this state could be a true symmetry breaking phase and superconductivity could develop around its quantum critical point, suggesting a strong interplay between these two states of matter. Using polarized neutron diffraction (PND) technique, a complex magnetism has been highlighted when entering the PG state. It is made of a q=0 magnetism, that develops at rather long range, and of a bi-axial q=1/2 magnetism at much shorter range. Both types of magnetisms seem tightly bound to each other and attached to the PG state. Put together these magnetisms could form an extended magnetic pattern originating from a long-ranged loop current magnetic texture. Such a texture could play a key role in the opening of the pseudogap (i.e partial gap) at the Fermi surface.

The bi-axial q=1/2 magnetism is observed at wave vectors of the form (0.5,0,L) and (0,0.5,L). The different PND studies in $YBa_2Cu_3O_{6+x}$ (x=0.6, 0.9,1) using both twined and twin-free single crystals show that the magnetic component along **c** contributes to the magnetic scattering at integer L values, while the planar magnetic component gives a response at half-integer values. At variance with the leading out-of-plane magnetic response (parallel to **c**), which increases gradually upon cooling in the PG state, the planar response is likely to change owing to its interaction with other electronic instabilities (charge density wave and/or superconductivity) or due to a magnetic rearrangement yielding an net a-b anisotropy in spin space.

In order to get a better understanding of the q=1/2 magnetism, we performed a PND experiment using the 3.5T-horizontal cryomagnet on IN12 Exp CRG-3023.

Experimental details: We used a twin-free $YBa_2Cu_3O_{6.6}$ sample (T_c=63 K), made of a few tenths of single crystals co-aligned and glued on an Al-plate. The sample was installed inside the 3.5T-horizontal magnet. We used the standard polarized neutron set-up of IN12: incoming neutron polarized with a cavity and scattered neutron analyzed with a Heusler analyzer. We used a focusing PG monochromator but a flat Heusler analyser. The Be filter was inserted in the scattered beam to remove higher harmonics. The guide effect, the velocity selector and the Be Filter make $\lambda/2$ contaminations of our data rather unlikely. The sample was aligned in a scattering plane defined as: (-1,0,-l) / (h,0,-1), with $h=(c/a)^2l$. The horizontal magnet was set to be always parallel to the first axis of the scattering plane. With such a configuration, one could study the scattered intensity across wave vectors (0.5,0,0) and (0.5,0,0,5) using longitudinal scans in both spin flip (SF) and non-spin-flip (NSF) channels, keeping the neutron spin polarization **P** always parallel to **Q**. Under these conditions, the full magnetic response shows up in the SF channel only. The flipping FR was measured with a value of 18 on the nuclear Bragg reflection (1,0,0) and 25 on (1,0,1).

Data analysis. For the analysis of longitudinal scans across (0.5,0,0) or (0.5,0,0.5), we performed a first measurement in the NSF channel, where the nuclear response shows the modulated intensity coming from the specific arrangement of the CuO chain in our sample, appearing on top of a sloping background. The chain signal divided by the flipping ratio was added to a sloping background to give the line shape of the SF background (**Fig.1**). In the SF channel, the magnetic signal shows up as a signal centered on H=0.5, with a Gaussian profile. The same procedure was applied for the analysis of the longitudinal scans performed at different magnetic fields (0.01 T, 1T and 2T).

Outcome of Exp. CRG-3023. Fig. 1.a-d report a set of longitudinal scan across (0.5,0,L) at 80 K in both the NSF and SF channels, for an applied magnetic field of 0.01 T. In the NSF channel, the scattering from the CuO chains controls the line shape of the background, while a magnetic signal, located near H=0.5, appears in the SF channel. The magnetic signal seems narrower and sharper at L=0 than at L=0.5. The observation of a magnetic signal at L=0.5 and T=80 K in twin-free $YBa_2Cu_3O_{6.6}$ is an important observation. Indeed such a signal at (0.5,0,0.5) was reported in a twined $YBa_2Cu_3O_{6.6}$ sample at 80 K, but was absent in our twin-free sample at 1.5 K. Complementary PND measurement were performed on THALES on our twin-free sample (Fig. 1.e). They indicated that the signal could be actually recovered: (i) by moving from (0.5,0,0.5) to (0,0.5,0.5) at 1.5 K, or (ii) by increasing the temperature above the superconducting ordering temperature or the onset temperature of an incipient charge density wave instability. Fig. 1.d confirms the presence of the magnetic signal at 80 K, i.e. above the superconducting temperature.

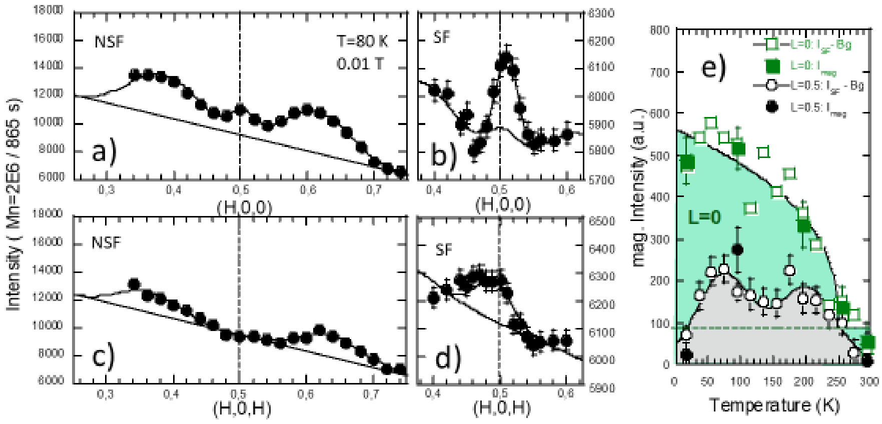

Figure 1 Longitudinal scans across (0.5,0,L) in the NSF and SF channels at 80 K and under 0.01 T: a-b) L=0, c-d) L=0.5. e) Temperature dependence of magnetic intensities at (0.5,0,L) with L=0 (green squares) and L=0.5 (black symbols). Data reported in e) were measured on THALES.

Then, we performed a magnetic field study of the magnetic responses at (0.5,0,L) for L=0 and L=0.5. At L=0, the magnetic intensity displays a net increase for an applied magnetic field of 1 Tesla (Fig. 2.a). At larger field (2 T), the magnetic intensity saturates within error bars or weakly decrease (Fig. 2.b). For the first time, our study highlights a magnetic field effect on the q=1/2 magnetism. Concerning the magnetic signal at L=0.5, it seems to slightly decrease (Fig. 2.c). Such an effect could indicate either (i) a reorientation of the planar magnetic component with a weakening of the magnetic component along **b** with respect to that along **a** or ii) a loss of the doubling of the unit cell along **c**, yielding a transfer of intensity from (0.5,0.5) to (0.5,0,0). The differential scans reported in Fig. 2.d go along the second interpretation.

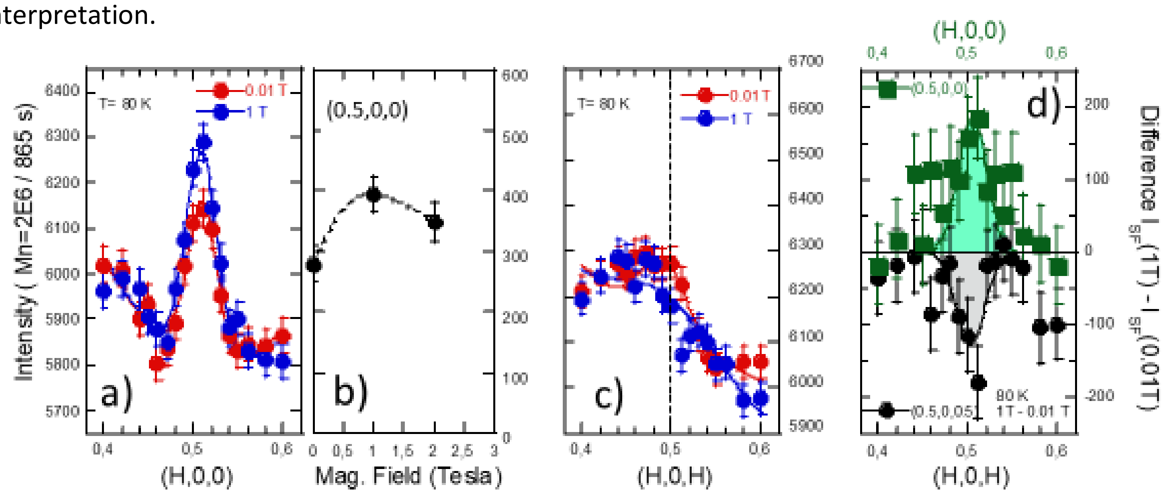

Figure 2 Longitudinal scans across (0.5,0,L) at 80 K for 0.01 T (blue bullet) and 1 T (red bullet) : a) L=0, c) L=0.5. b) Magnetic field dependence of the magnetic intensity measured at (0.5,0,0). d) Difference between longitudinal scans at 1 T and 0.01 T around (0.5,0,L) : L) 0 (green squares), L=0.5 (black symbols.