Experimental report

15/02/2021

Proposal: **4-01-1670** **Council:** 4/2020

Title: Determination of the magnetic excitations in the charge density wave compound TbTe3 by inelastic neutronscattering

Research area: Materials

This proposal is a new proposal

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Samples: Tb Te3

Instrument	Requested days	Allocated days	From	To
THALES	6	5	26/08/2020	31/08/2020

Abstract:

The interest of this proposal lies in the observation of an interaction between the ordered magnetic moments and the CDW manifested by the appearance of smaller magnetic peaks indexed as ½-qCDW along the modulation direction, the c-axis. Despite the small sample size, the magnetic scattering cross section is so large that counting times at the magnetic Bragg peaks are in the order of 1000-5000 c/s in in22 and in ThALES. Similarly, the magnetic excitations can be well observed with relatively low counting times (same reports and Fig. 1). The excitations are composed by a dispersive mode between 3.2 and 4.8 meV and a series of peaks at lower energies. ThALES is the correct instrument for this measurement. The goal of this proposal is to determine the magnetic excitations and the influence of the different magnetic orderings and phase transitions onto the excitation spectra.

Experimental report 4-01-1670 $TbTe_3$ sur Thales:

Aim of the experiment:

Our preliminary experiments on the magnetic ordering taken place below 6K in $TbTe_3$ on IN22 (CRG-2702 and 7-02-188) have shown a complex magnetic ordering with at least 2 (may be three) phase transitions with coexistence of commensurate (½,0,0), (½,½,0), (0,0, ½) and incommensurate structures, (0,0,0.21)[1,2]. In addition, the magnetic excitations can be well observed with relatively low counting times (same reports). In this first experiment on IN22 we realized that the excitations are composed of a dispersive mode between 3.3 and 4.8 meV and a series of peaks at lower energies. Under these circumstances the need for higher energy resolution with the use of cold neutrons appeared as mandatory and ThALES is the correct instrument for this measurement. The goal of this proposal was (i) to measure the magnetic excitations with improved energy resolution and eventually (ii) to rule on the influence of the different magnetic orderings and phase transitions onto the excitation spectra.

Experimental details:

Single crystals of $TbTe_3$ grow in platelet shape with the crystallographic b* axis perpendicular to the platelet. We used a 120 mg single crystal, oriented with the [3,3,1] and [0,1,0] directions in the scattering plane, in order to access the incommensurate magnetic modulation, q_m~0.21c*, resulting from the Charge Density Wave (CDW), q_{CDW}~0.29c* [3,4]. The use of the goniometers on the instrument with the 3D option of NOMAD gave access to out of scattering plane components in a restricted *Q* range limited by the angular range of the goniometers with mounted cryostat. The sample was measured in the temperature range *T* <50K. We used a Si(111) monochromator and PG(002) with k_f fixed of k_f=1.5 Å^{-1}. Some scans ware taken at k_f=1.3 Å^{-1} to improve the energy resolution.

Results:

A summary of the results is shown in Fig. 1. The dispersion curve of magnetic excitations located at around 4 meV and at around 2 meV has been measured along 2 principal directions, (0,0,q_l) and (q_h,q_h,0)

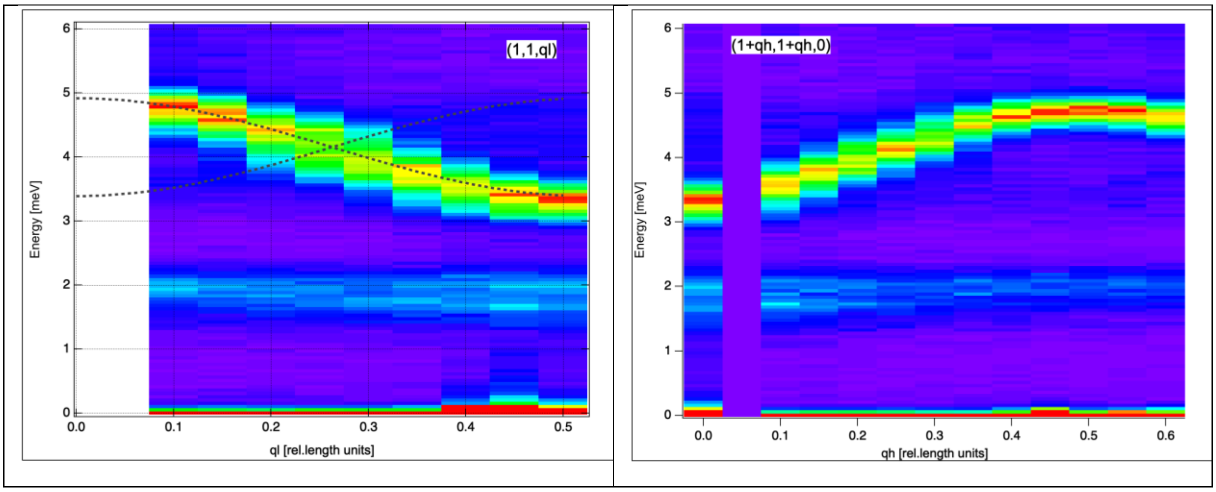

Fig. 1 Compound dispersion with the energy scans taken at 1.7K along two principal directions.

The temperature dependence of the excitations has been measured through the different magnetic transitions. The excitations centered around 4 meV (or <u>upper band</u>) do not exhibit significant changes on traversing the different magnetic transitions, just the center shifts from 4.15 meV at 1.7K to 3.95 meV above T_N. The band width of the upper band decreases from 0.85 meV at 1.7K to 0.25 meV at the highest measured temperature, 50K. Not surprisingly the upper band becomes flatter and flatter, and broadens probably due to thermal effects. It remains quite well defined even at 10^*T_N. This is a signature that the upper band is related to crystal field excitations of Tb, along with some exchange among these ions.

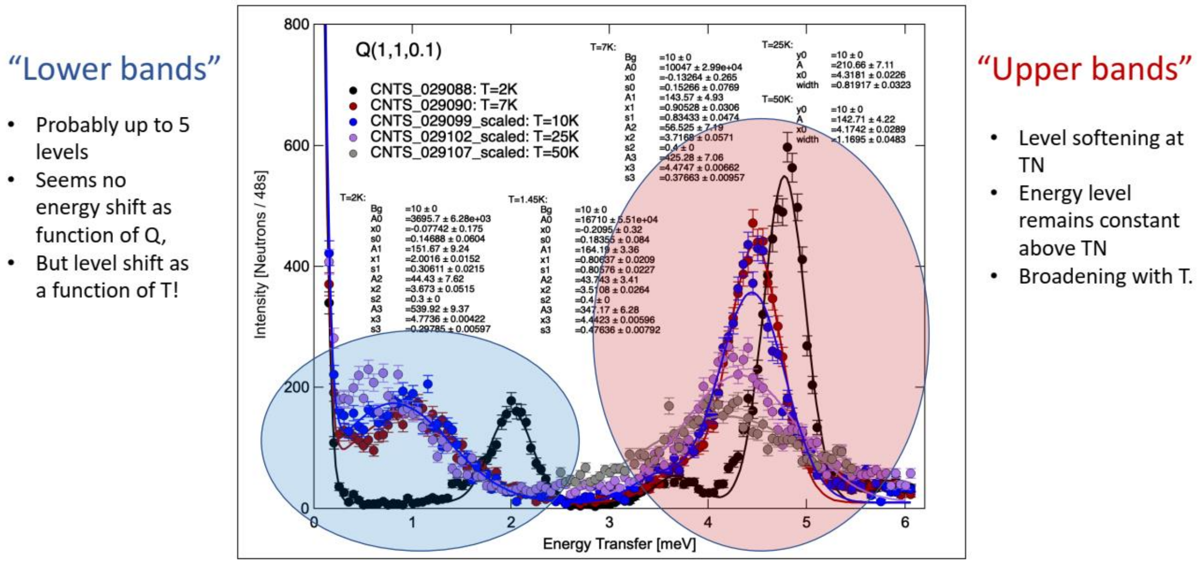

Fig. 2 Overall temperature dependence of the excitations, with a lower and upper band.

The lower band is centered at 2 meV at 1.7K and is dispersionless. Contrary to the upper band, the lower band does soften continuously on approaching T_N, becoming centered at around 1 meV at 6K. In addition, the well-defined excitation becomes rapidly spread in energy, as it shown in Figs. 2 and 3. Another important feature is that it seems that this band is still inelastic at 25K and q_m~0.21c* whereas it is clearly quasielastic at q=0.4c* and 6K.

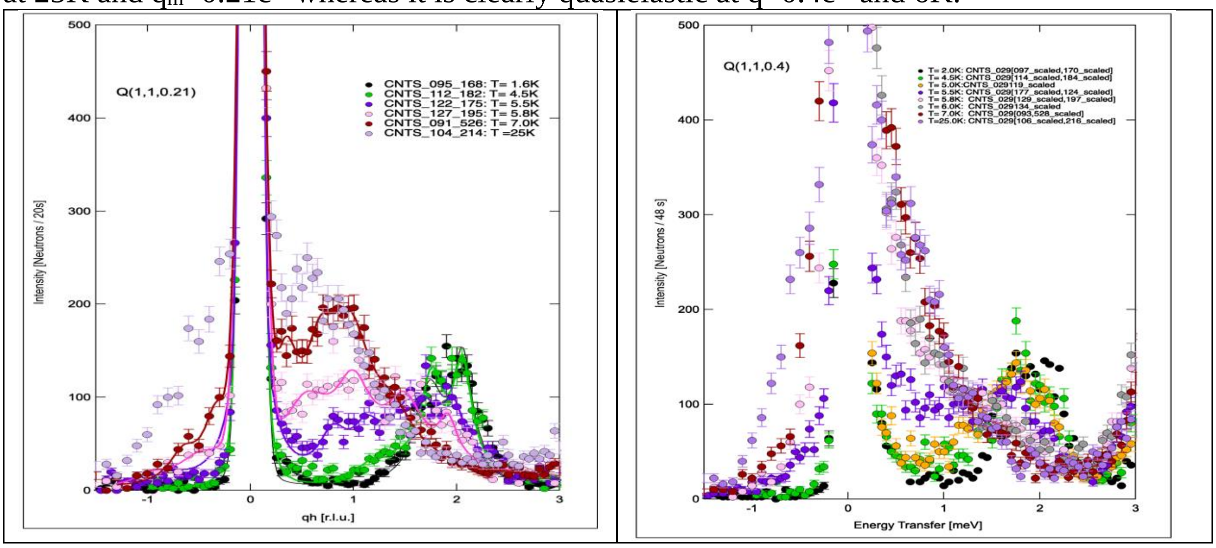

Fig. 3 Energy scans at 2 q-positions and several different temperatures. These two positions correspond to the position of the incommensurate magnetic modulation, q_m~0.21 (left panel) and the commensurate modulation (right panel).

[1] F. Pfuner, et al., J. Phys. : Condens Matter 24 (2012) 036001
[2] S. Chillal, et al., Phys. Rev. B 102, 241110 (2020)
[3] N. Ru, et al., Phys. Rev. 77, 035114 (2008)
[4] W.S. Lee, et al., Phys. Rev. B 85, 155142 (2012)