ESRF	**Experiment title:** Study of the $TbMnO_3$ local distortions by x-ray resonant scattering at the Mn K-edge and Tb L_3-edge	**Experiment number**: HE 2761
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Names and affiliations of applicants (* indicates experimentalists):

Dr. Joaquín García*, Dra. Gloria Subías*, Dr. Javier Blasco* and Vera Cuartero*

Instituto de Ciencia de Materiales de Aragón, CSIC – Univ. de Zaragoza, Zaragoza (Spain).

Report:

$TbMnO_3$ perovskite is the representative of materials where antiferromagnetism (AFM) and ferroelectricity coexist at low temperatures. Neutron diffraction experiments have shown that Mn^{3+} magnetic moments go through an incommensurate AFM sine order below 40 K, described by a wave vector $\boldsymbol{k}_{Mn}$ = (0, 0.29, 0) in the ortorrombic unit cell *Pbnm*. The $\boldsymbol{k}_{Mn}$ vector decreases with temperature down to a *quench* at $\boldsymbol{k}_{Mn}$ = (0, 0.28, 0) with a $T_{quenching}$ ~ 28K. At this temperature a magnetization component caused by Mn sublattice along **c** axis is developed. $TbMnO_3$ shows then a ferroelectric order at T_C ~ $T_{quenching}$ ~ 28K. [1] In this phase, the Tb moments also order with the same wave vector as the Mn, but they are transversally polarized along the **a** axis. [2] Moreover, below 7 K there is an AFM order of Tb^{3+} magnetic moments, showing a magnetization component along **a** axis, with a wave vector $\boldsymbol{k}_{Tb}$ = (0, 0.415, 0). However, the microscopic origin of the magnetically induced ferroelectricity is still unknown.

A resonant x-ray scattering study at the Mn K-edge and Tb L_3-edge of $TbMnO_3$ was performed to investigate the local distortions responsible for the ferroelectricity. Forbidden reflections (0 k 0), (0 0 l) with *k, l* = 3, 5 were measured in single-crystals cut with [010] and [001] surfaces normal at room temperature. The dependence of the intensity for these reflections on temperature and azimuthal angle was investigated in detail. A Cu (220) crystal was used to analyze the polarization of the scattered beam: perpendicular (σ‘) or parallel (π’) to the scattering plane. We also observed some incommensurate reflections of the type: (0, 2+q_{Mn}, 0), (0, 4-q_{Mn}, 0), (0, 4-q_{Mn}, 1) in both edges and (0, 3-q_{Mn}, 0), (0, 1-q_{Mn}, 3) and (0, ±q_{Mn}, 3) reflections only in Tb L_3 edge, being q_{Mn} =0.28.

We can see in figure 1 (a) the intensity of (030) forbidden reflection as a function of the photon energy at different azimuthal angles in the σ-π’ channel, at room temperature. A strong resonance is observed at 6552 eV, just at the Mn K-absorption edge. Scattering intensity is only observed in the σ–π’ polarization channel for all forbidden refections studied and when the crystal is rotated around its scattering vector, the σ–π’ intensity of these reflections show a $\cos^2\phi$ dependence. There is a π/2 periodicity of the resonant intensity on the azimuthal angle ϕ for (0,k,0) and (0,0,l) reflections.

We have also measured the temperature evolution so that in figure 1 (b) we can see the integrated intensity of the forbidden reflections evolving with temperature. Here, we could not find any significant intensity variation either around the Nèel temperature, $T_N \sim 40$ K, or at $T_C \sim 28$ K.

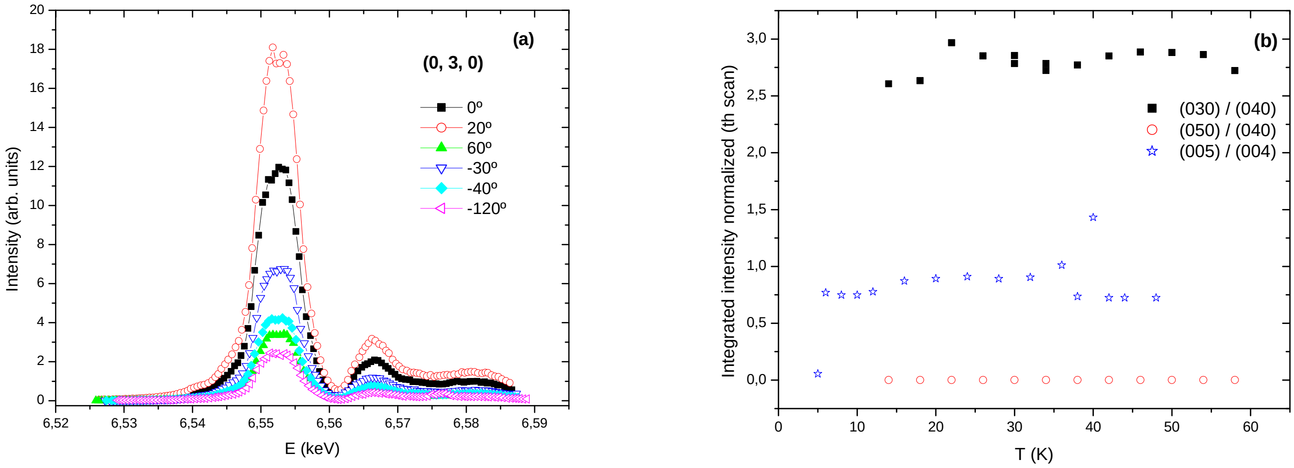

Figure 1. (a) Energy dependence of the forbidden (0, 3, 0) reflection measured at different azimuth angles, in the σ→ π' channel at the Mn K absorption edge. **(b)** Integrated intensity of the (0k0) and (00l) (θ scan) of forbidden reflections as a function of temperature.

On the other hand, figure 2 shows the energy dependence of the observed incommensurate reflections in the σ-π' channel at the Mn K edge. It is worth noting that the resonance observed at the (0, 4-q_{Mn}, 1) reflection is slightly shifted to lower energies with respect to the (0, 2+q_{Mn}, 0) and (0, 4-q_{Mn}, 0) reflections. This indicates that the resonant signal at these (0, 2+q_{Mn}, 0) and (0, 4-q_{Mn}, 0) reflections could have a different origin, taking into account that the (0, 4-q_{Mn}, 1) reflection has the hallmarks of a resonant x-ray magnetic scattering (A-type AFM).

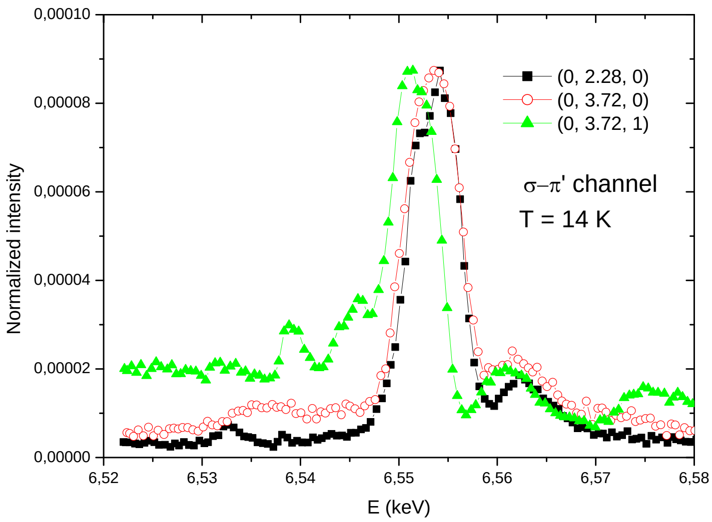

Figure 2. Energy dependence of the incommensurate reflections, polarization-resolved (σ→π') at the Mn K absorption edge at T= 14 K. The first two are normalized to th maximum of intensity of the third.

Finally, the behavior of the studied forbidden reflections closely resembles to $LaMnO_3$ [3], which suggests that in this case they are also originated by anisotropic tensor scattering.

[1] S. Quezel *et al.* Physica B+C **86-88**, (1977), 916-918
[2] M. Kenzelmann *et al.* Phys. Rev. Lett. **95**, 087206 (2005).
[3] G. Subías *et al.* Phys. Rev. B **75**, 235101 (2007)