ESRF	**Experiment title: X-ray Resonant Scattering Study of the Antiferroquadrupolar order in $TmGa_3$**	**Experiment number**: HE-940
Beamline: XMaS	**Date of experiment**: from: 21/3/01 to: 26/3/01	**Date of report**: 26/8/01
Shifts: 18	**Local contact(s)**: Dr S. Brown	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

D. Mannix. XMaS UK CRG Beamline, ESRF, Grenoble, F-38043 France.

F. Yakhou. ESRF, Grenoble, F-38043 France.

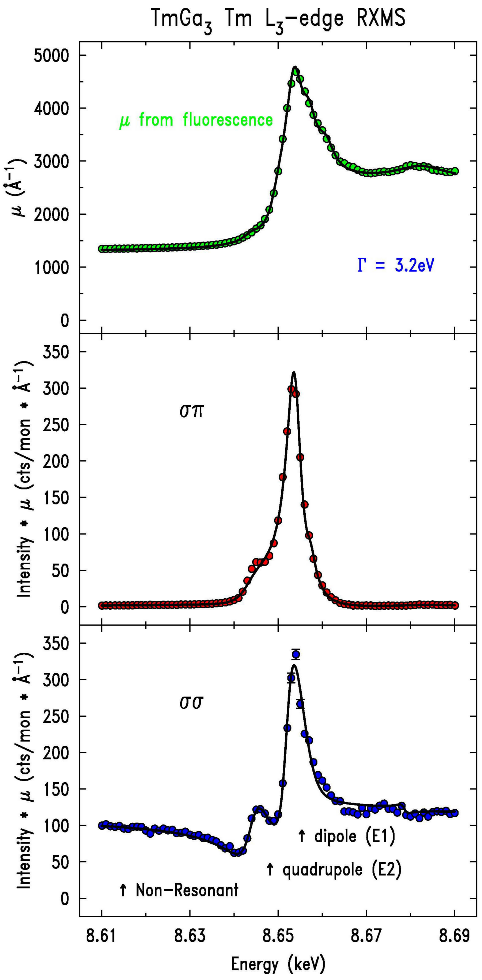
Report:

The aim of this experiment was to investigate the antiferromagnetic (AFM) and antiferroquadrupolar (AFQ) order in $TmGa_3$, using resonant x-ray scattering (RXS). Furthermore, we also wished to study the interplay of these orderings in an applied magnetic field, which is know to have a dramatic effect on the transition temperatures. Neutron diffraction studies have determined that $TmGa_3$ is antiferromagnetic below T_N = 4.26K with magnetic propagation vector (0 ½ ½). However, neutrons do not directly couple to quadrupolar interactions so that the AFQ order parameter was unknown, but specific heat measurements have identified the AFQ phase transition to be T_Q= 4.29K.

The integrated intensities of the (0 ½ 1½) peaks, in the vicinity of the Tm L_3 edge, are shown in **figure 1;** the middle panel are the $\sigma\pi$ and bottom panel the $\sigma\sigma$ scattered polarisations. The top panel shows the absorption coefficients from the fluorescence that was used to correct the data for absorption. RXS is observed in the dipole threshold for the $\sigma\sigma$ intensities, shown in figure 1 (bottom panel). This $\sigma\sigma$ scattering cannot arise from the magnetism since dipole resonant x-ray magnetic scattering is forbidden for this polarisation. This scattering may arise from the antiferroquadrupolar ordering in $TmGa_3$, suggesting that the AFQ ordering wave-vector is the same as the AFM, q=(0 ½ ½). The temperature dependence of the (0 ½ 1½) reflection, is shown in **figure 2**, at energies corresponding to dipole transitions (top panel), quadrupole transitions (middle panel) and non-resonant scattering (bottom panel). There is a marked difference in the temperature dependence for the $\sigma\sigma$ and $\sigma\pi$ intensities, with the $\sigma\sigma$

intensities dissappearing close to T_Q and σπ close to T_N. The temperature dependence suggests that the σσ scatering arises from AFQ while the σπ arise from AFM. Furthermore, the AFQ appears to be driving the AFM ordering in $TmGa_3$.

We have not been successful in studing the interplay of the AFM and AFQ order in an applied magnetic field nor completing an azimuthal dependence, which would enable us to unambiguously determine the AFQ and AFM type RXS. For this we will need to cut a (011) face crystal in a continuation experiment.



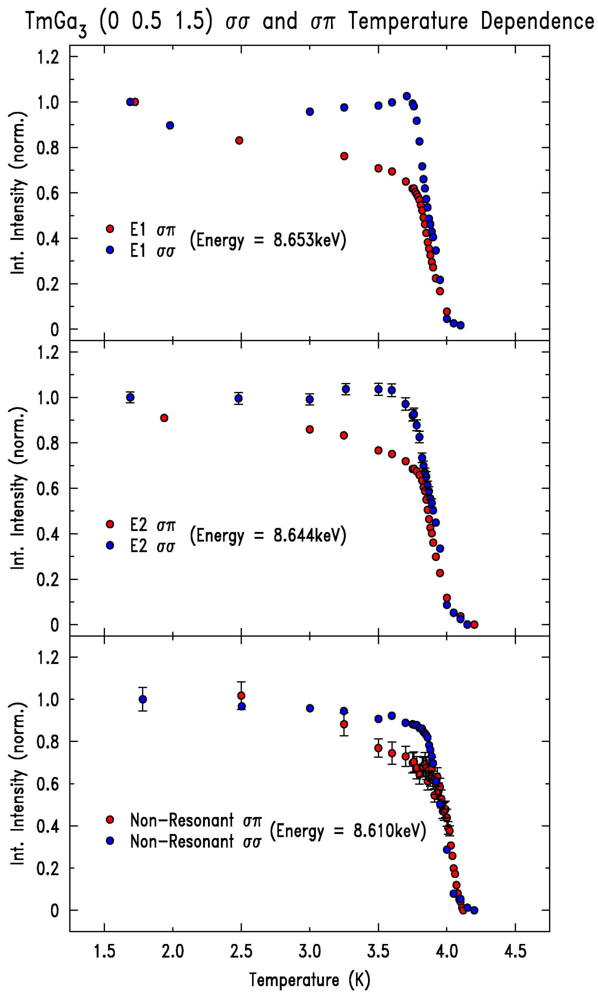


Figure 1 (left). Top panel: absorption coefficients from fluorescence. Middle panel: The (0 ½ 1 ½) σπ intensities in the vicinity of the Tm L_3 edge. Bottom panel: The σσ intensities of the (0 ½ 1½) reflection.

Figure 2 (right). The temperature dependence of the (0 ½ 1½) σπ and σσ intensities, with the incident x-ray energy at the dipole threshold (top panel), quadrupole threshold (middle panel) and in the non-resonant regime (bottom panel).