Magnetic order in a new multiferroic, samarium-based manganite

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Research in the field of multiferroics has intensified since the discovery in 2003 of a novel class of materials, the so called "type-II" multiferroics, in which the nature of the magnetic order *causes* ferroelectricity [1]. Resonant x-ray scattering (RXS) has featured in this work, perhaps most notably to study the archetypal type-II multiferroic $TbMnO_3$, where it has served as a complementary probe to neutron diffraction [2]. However, when manganites are formed with rare earths which, in their naturally occurring isotopic forms, are strongly neutron absorbing isotopes (e.g. Sm or Gd), RXS can be the most convenient method to the determine the *full* details of the magnetic structure, beginning with the determination of the magnetic wavevector(s) and domains, a task usually undertaken with neutrons.

Here we report results from our recent *XMaS* experiment on $Sm_{0.5}Y_{0.5}MnO_3$, a concentration from the $Sm_{1-x}Y_xMnO_3$ family we have recently found (from bulk studies) to be multiferroic [3]. Like $TbMnO_3$, the multiferroic state appearing in $Sm_{0.5}Y_{0.5}MnO_3$ is signalled by a second antiferromagnetic phase transition seen in magnetization measurements. The temperature for the transition, $T_{N2} \approx 20$ K, is some 7 K below T_{N2} in $TbMnO_3$ [1,2]. In fact, it is the onset of a *cycloidal* antiferromagnetic phase at T_{N2} in $TbMnO_3$ which is responsible for the ferroelectricity [1]. Confirmation that such a phase occurs in $Sm_{0.5}Y_{0.5}MnO_3$ has been beyond the scope of the present experiment. Rather our aim has been a modest one: to determine the wavevector and domains present in $Sm_{0.5}Y_{0.5}MnO_3$ in its $T < T_{N2}$ magnetic phase.

A high quality single crystal of $Sm_{0.5}Y_{0.5}MnO_3$, prepared, orientated and polished at Warwick, was used in the study. The sample had its orthorhombic b-axis normal to its polished surface. The study concentrated on the Sm L_2 edge (~ 7.32 keV), where the strongest magnetic scattering (over the x-ray energy range accessible at *XMaS*) would be expected in the system. Guided by information from scattering studies on $TbMnO_3$ [2], we have been successful in finding magnetic satellite reflections in $Sm_{0.5}Y_{0.5}MnO_3$. Indeed, we have observed (resonant) satellites corresponding to the four domain types, A-, F-, C- and G-type, reported from RXS studies on $TbMnO_3$ [2], and we show their temperature dependences in **Figure 1**. The wavevector corresponding to these four reflections is q ≈ 0.32 b*, which is close to the value ($q_{Mn} \approx 0.28$-0.29 b*) associated with the ordering of the Mn 3d moments in $TbMnO_3$ [2].

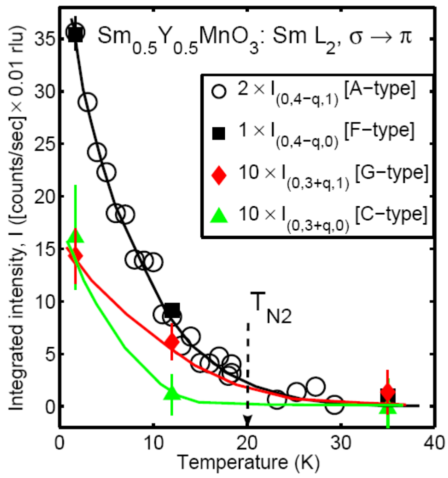

Figure 1: Temperature dependence of the integrated intensities of the different magnetic satellite reflections observed in $Sm_{0.5}Y_{0.5}MnO_3$, recorded at the Sm L_2 absorption edge in the rotated polarization channel (σ→π). The labels A, C, F and G follow a convention used in studies of $TbMnO_3$ (see Ref. 2). Solid lines are guides to the eye. The vertical dashed line indicates the temperature at which a second magnetic transition and an anomaly in the dielectric constant are found coincident with each other in bulk studies (Ref. 3).

By inference from the RXS, non-RXS and neutron diffraction results on $TbMnO_3$ [2], we believe that that the scattering we have observed here (**Figure 1**) is an indirect response from the ordering of the Mn 3d moments, seen via their polarization of Sm 5d band. That is, we infer that $q_{Mn} \approx 0.32$ b* in $Sm_{0.5}Y_{0.5}MnO_3$. Like the Tb 4f moments in $TbMnO_3$, it is possible that the Sm 4f moments order at a much lower temperature with their own (distinct from Mn order) wavevector, and it will be our goal in future *XMaS* studies to hunt out for such ordering.

[1] D. Khomskii, Physics **2**, 20 (2009).

[2] D. Mannix *et al.*, Phys. Rev. B **76**, 184420 (2007) and O. Prokhnenko *et al.*, Phys. Rev. Lett. **99**, 177206 (2007). (Both of these articles include data from *XMaS*.)

[3] D. O'Flynn *et al.*, J. Phys: *Proceedings of ICM, 2009*.