Investigating nonlinear spin dynamics in the hexagonal manganites

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Geometrical magnetic frustration, such as that inherent in the triangular lattice of Mn^{3+} spins in the hexagonal manganites, can lead to many interesting phenomena. In the case of (Y,Lu)MnO_3, the frustrated magnetic interactions lead to a non-collinear magnetic structure, called a 120° order. This allows the possibility for magnon decay and magnon-magnon interactions which would be forbidden by symmetry in a collinear structure [1], and observations by our group using unpolarised neutron scattering indicated that this might be the case in $LuMnO_3$ [2].

In order to investigate this behaviour in more detail, we performed polarised inelastic neutron scattering measurements using the C5 triple-axis spectrometer at CNBC. In $LuMnO_3$ we only investigated the lowest energy 'roton-like' minimum mode in detail and found that its polarisation dependence showed the moments to be polarised perpendicular to the triangular plane, as expected by both linear spin wave theory and the 1/S expansion [3]. In $YMnO_3$, we were able to measure both the low and higher energy mode, as these lay closer together than in $LuMnO_3$. We found that at the magnetic Brillouin zone boundary $\boldsymbol{Q}$=(1.5,0,1), the lower energy mode is polarised perpendicular to, and the higher energy mode is polarised within the triangular plane, as expected by the theory. However, slightly away from this, at $\boldsymbol{Q}$=(1.3,0,1), some intensity was observed at the lower energy in the I_v^{SF} channel which indicates that some in-plane polarisation component has mixed in (figure 1). The integrated intensity of this peak is some 15% of the out-of-plane component, which is significantly larger than predicted by theory (<1%) and may be an indication of the magnon-phonon coupling which we have observed in recent time-of-flight (ToF) neutron scattering measurements [4].

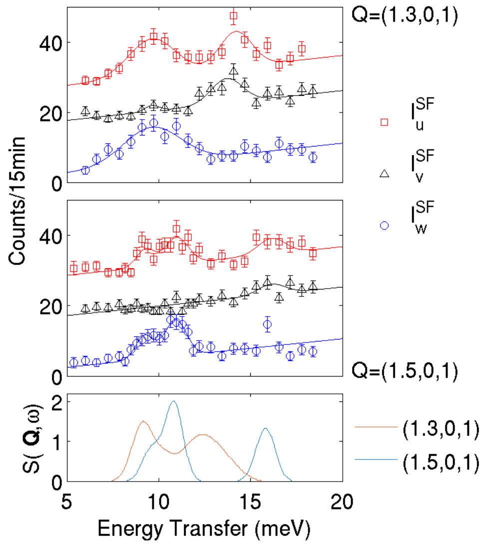

Figure 1: Measured polarised inelastic neutron scattering intensity (top) in $YMnO_3$. u, v, w, indicate the guide field directions which are, respectively, parallel to, horizontally perpendicular to, and vertically perpendicular to the momentum transfer Q. The spin-flip (SF) channel measures the magnetic component perpendicular to Q ***and*** *to the field direction. Thus, I_v^{SF} measures the vertical component, and I_w^{SF} indicates the horizontal component perpendicular to Q. The horizontal plane is (H0L), so I_v^{SF} is mostly proportional to the magnetic moment in the triangular (HK0) plane. The bottom panel shows the calculated structure factor including a linear magnon-phonon coupling term.*

In these measurements, we found that the broad band of scattering around 20 meV previously attributed to magnon decay are actually optic phonons given intensity at low $\boldsymbol{Q}$ from a linear magnon-phonon coupling which is only possible in non-collinear magnetic structures such as found in the $RMnO_3$ compounds. This magnon-phonon coupling also explains another puzzling observation in this measurement: the appearance of two peaks around 10meV at $\boldsymbol{Q}$=(1.5,0,1), where only one is expected by linear spin wave or 1/S theory, as shown in figure 1.

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[2] J. Oh et al., *Phys. Rev. Lett.* **111** 257202 (2013)
[3] M. Mourigal et al., *Phys. Rev. B* **88** 094407 (2013)
[4] J. Oh et al., in preparation.