Resonant Scattering from $La_{0.5}Sr_{1.5}MnO_4$ at the Manganese K-Edge

T.A.W. Beale[1], P.D. Spencer[1], S.B. Wilkins[2], P.D. Hatton[1],
S.D. Brown[3], D. Prabakaharan[4] and A.T. Boothroyd[4]

[1]Department of Physics, University of Durham, Rochester Building, South Road, Durham, DH1 3LE, UK.
[2]European Commission, Joint Research Center, Institute for Transuranium Elements, Hermann von Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany *and* ESRF.
[3]XMaS CRG, ESRF, Boîte Postal 220, F-38043 Grenoble Cedex, France.
[4]Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, UK

In the $La_{0.5}Sr_{1.5}MnO_4$ system there are two competing orderings. The first is a Jahn-Teller structural distortion present on the MnO_6 octahedra. In addtion there is a direct ordering of the Mn 3*d* orbitals. The effect of the components of orbital ordering and Jahn-Teller distortion of the *K*-edge electrons can be separated by looking in the σ-π, and σ-σ channels respectively. Our results show that both components are present. In addition there is a charge modulation which enables the above orderings - only present on Mn^{3+} ions to occur. We show the energy resonance of the induced effect on the *K*-edge electrons,and the temperature dependence of these individual orderings.

Introduction:

We present high resolution resonant x-ray scattering data from the layered manganite system $La_{0.5}Sr_{1.5}MnO_4$ [1]. This system has generated considerable interest in the last 18 months, principally through the development of soft energy resonant scattering [2]. Although *L*-edge resonant scattering provides a direct method of probing the magnetic data of the system, there are a number of techniques - principally polarization analysis (fig. 1) - that are not yet possible, and have to be done at the *K*-edge.

Experimental Method

Single crystal diffraction was performed at the XMaS beamline, ESRF, on a high quality sample grown by the floating-zone method at the University of Oxford. The crystals was pre-aligned and then cut and polished with the <110> surface normal.

The sample was mounted on the cold finger of a closed cycle He cryostat in a four circle Huber diffractometer. Single channel diffraction was achieved using a polarisation analyser (PA) with a Cu(220) crystal. At the Mn *K*-edge energy this reflection is very close to 90° so there is very little leak through. This PA was coupled with a high resolution analyser, a setup that enabled both high spatial resolution with polarization separation.

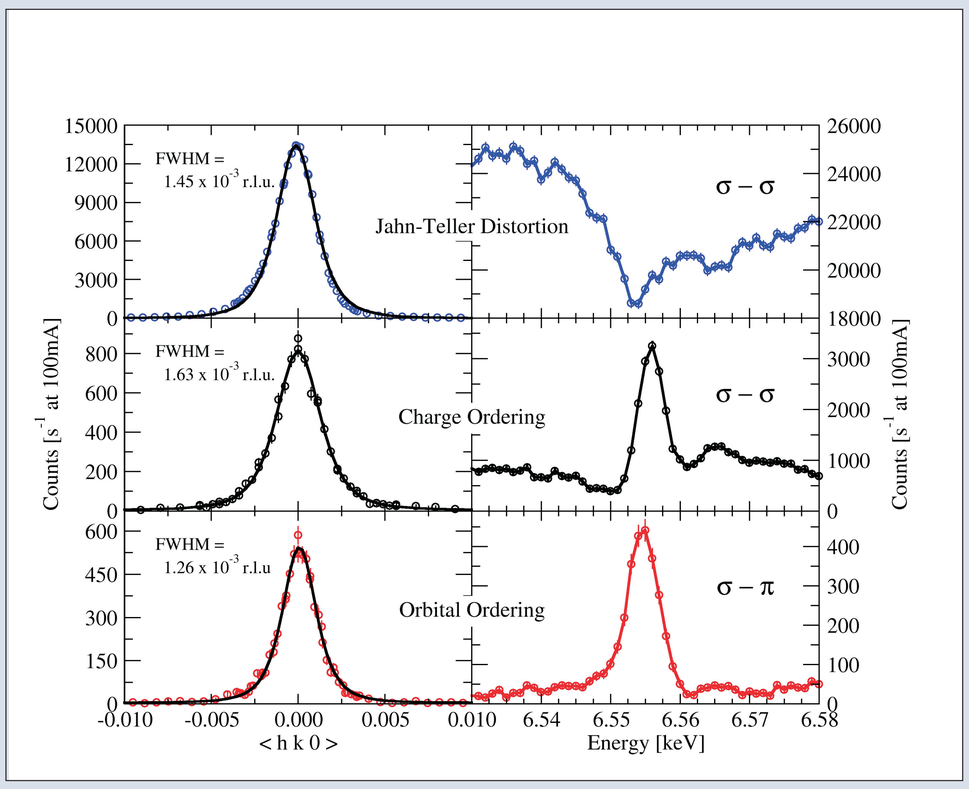

Figure 1. Width and energy resonances of the Jahn-Teller, charge order, and orbital order reflections.

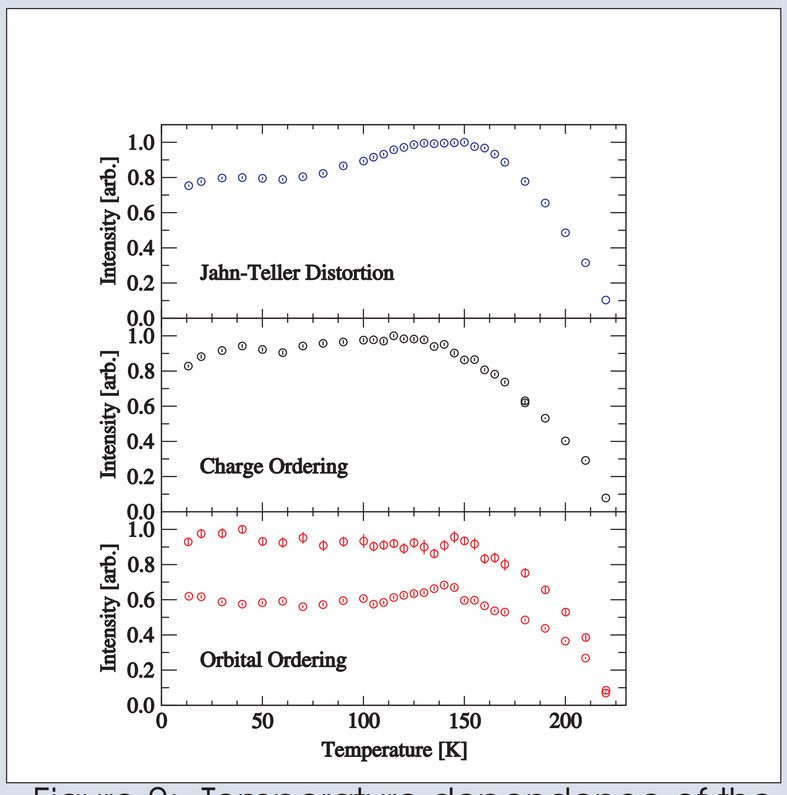

Figure 2: Temperature dependence of the long range ordering in $La_{0.5}Sr_{1.5}MnO_4$.

Results:

The Jahn-Teller and orbital order signals lie at the same wavevector (h±1/4,k±1/4,l) and so to distinguish between the two a PA is used [3]. The Jahn-Teller reflection is a purely structural effect and so can only appear in the σ-σ channel . At the resonant edge it shows a dip in intensity (fig 1). The orbital order by comparison is a dipole transition and so appears in the σ-π channel and shows a resonant peak at the Mn *K*-edge. The charge order signal, also shows a peak in energy, but is found in the σ-σ channel.

The temperature dependence for the three ordering signals is found to be identical (fig. 2). They appear at 220 K, and increase in intensity to 150 K before showing a slight decrease down to 10 K.

The width of these superlattice peaks are fairly comparable, suggesting that no ordering is significantly more correlated than another. These peak widths also stayed constant throughout the temperature range.
Resonant diffraction at the Mn *K*-edge can be compared to that at the *L*-edge [2]. The resonant shape is significantly different, as *K*-edge resonance is only looking at an induced magnetic moment, rather than probing the 3*d* electrons directly.

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[2] S.B.Wilkins, P.D. Spencer *et al*., Phys. Rev. Lett. **91** 167205 (2003)
[3] J.P. Hill and D.F. McMorrow Acta Crystallographica **52** 236 (1996)