Experimental Report

21/11/2014

Proposal: **5-53-247** **Council:** 4/2014

Title: Search for charge order accompanying magnetic order in La2-xSrxCoO4

This proposal is a new proposal

Research Area: Physics

Main proposer: **BOOTHROYD ANDREW TIMOTHY**

Experimental Team: BABKEVICH Peter
FREEMAN Paul
BOOTHROYD ANDREW TIMOTHY
PRINCEP Andrew
RAHN Marein

Local Contact: WHEELER Elisa
ENDERLE Mechthild

Samples: La2-xSrxCoO4 (x = 1/3)

Instrument	Req. Days	All. Days	From	To
IN20	5	8	02/10/2014	10/10/2014

Abstract:

We will search for diffuse scattering associated with Co2+/Co3+ charge-ordered superstructures in La5/3Sr1/3CoO4. The charge-order diffuse scattering is expected to occur at the same positions in reciprocal space as the magnetic diffuse scattering, which we have already characterised. Therefore, we will use longitudinal polarisation analysis to separate the structural and magnetic diffuse scattering.

Search for charge order accompanying magnetic order in $La_{2-x}Sr_xCoO_4$

Charge stripes are a type of density wave order found in many doped Mott insulators. They have particular relevance for the copper-oxide superconductors, since stripe order has been found to compete with high temperature superconductivity in the 214 family, e.g. $La_{2-x}Ba_xCuO_4$ [1], and very recently also in the 123 compounds $YBa_2Cu_3O_{6+x}$ [2]. In the 214 system charge stripe order is accompanied by spin stripe order, whereas in the 123 system charge order found without coexisting spin order. There is heightened interest in understanding what stabilizes stripe order and how it relates to superconductivity.

Evidence for spin and charge stripe order has also been found in 214 manganates, nickelates and cobaltates [3]. In the $La_{2-x}Sr_xCoO_4$ cobaltates, incommensurate magnetic order consistent with spin and charge stripes has been found in the doping range $0.25 < x < 0.5$ [4], but so far there has been no direct evidence for any charge component to the order. Moreover, a sample with $x = 0.4$ with incommensurate magnetic order was found to have commensurate checkerboard charge order characteristic of the half-doped composition ($x = 0.5$) [5]. This result calls into question whether charge stripes really exist in the cobaltates, and challenges our interpretation of the hour-glass magnetic spectrum found in $La_{2-x}Sr_xCoO_4$ [6].

The aim of this experiment was to use polarized neutron diffraction on IN20 to search for charge order in a sample of $La_{5/3}Sr_{1/3}CoO_4$. This composition has short-range incommensurate magnetic order with ordering vector $\mathbf{q}_m = (0.33, 0.33, 0)$. In the stripe model we expect charge stripe order with ordering vector $\mathbf{q}_c = \mathbf{q}_m$. Hence, polarized neutrons are essential to separate the magnetic signal from the structural scattering associated with any charge order.

The sample was a high quality single crystal in the form of a rod of mass 11 g. It was aligned with the [1,1,0] and [0,0,1] directions in the horizontal scattering plane. IN20 was set up for longitudinal polarization analysis, with Heuser as monochromator and analyser. The incident neutron wave vector was 2.662 $Å^{-1}$, and two PG filters were placed in the incident beam to suppress high orders. Measurements were made at several temperatures between 2 K and 300 K.

Surprisingly, at room temperature we observed diffuse nuclear scattering peaks at (0.5+H, 0.5+H, L), where H and L are integers, consistent with checkerboard charge order. Checkerboard charge order is characteristic of the half-doped composition x = 0.5. An example is shown in Fig. 1. However, on cooling we observed a broadening of the checkerboard peaks without change in their amplitude — see Fig. 1(a). In Fig. 1(c) we plot the difference $\Delta I_{NSF} = I_{NSF}(2K) - I_{NSF}(300K)$ to highlight the additional non-spin-flip (NSF) scattering, which exhibits two incommensurate diffuse peaks either side of (1.5, 1.5, L). This diffuse nuclear scattering is consistent with the four-fold pattern of incommensurate peaks that would arise for short-range charge stripes with wave vector $\mathbf{q}_c = (0.33, 0.33, 0)$ accompanying the observed magnetic order. However, the observed nuclear diffuse scattering could also be explained by the effect of a condensation of holes into a checkerboard pattern with increasing disorder as temperature is lowered.

In a future measurement we hope to distinguish these possibilities by performing scans in other directions which would give very different intensities for the two cases.

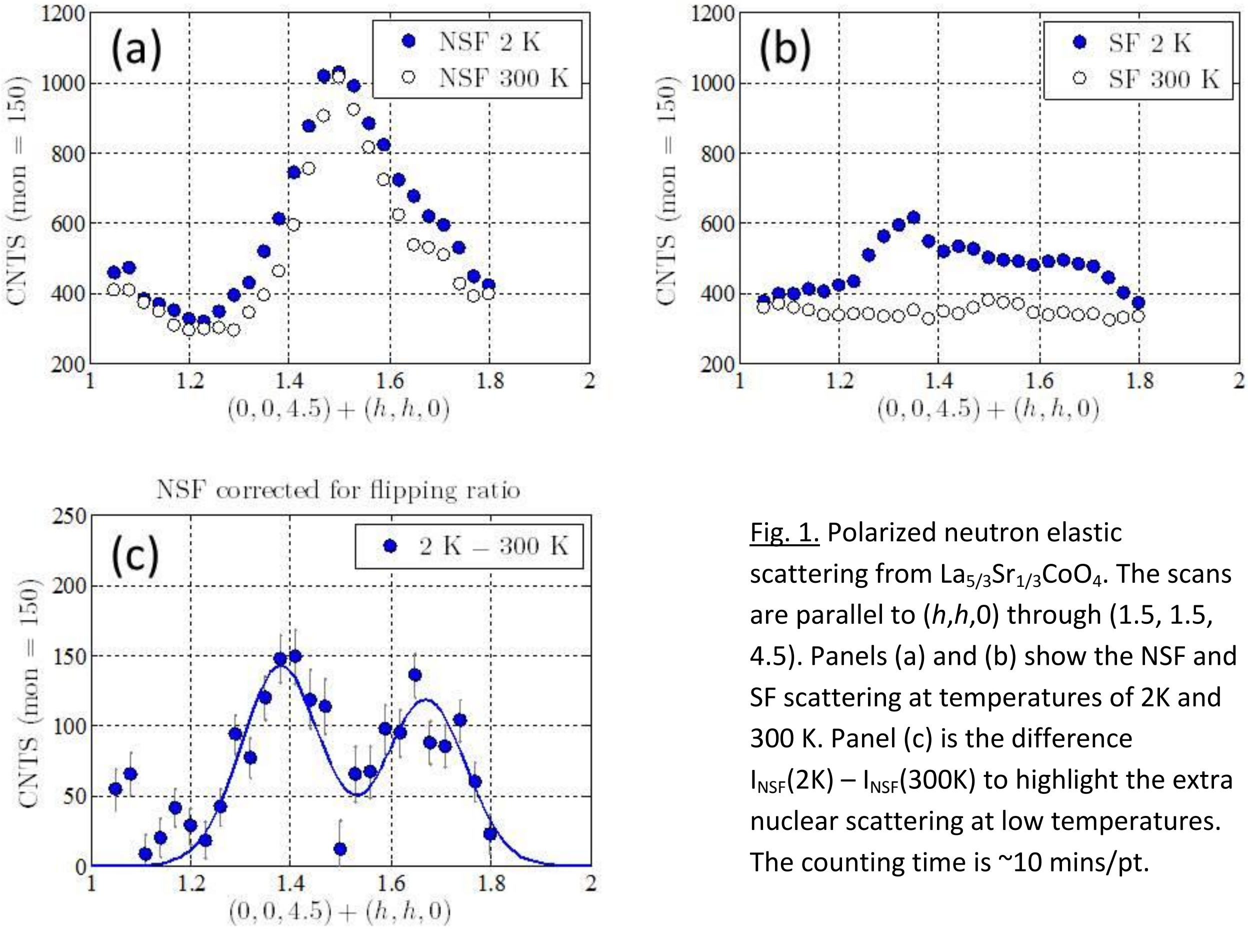

Fig. 1. Polarized neutron elastic scattering from $La_{5/3}Sr_{1/3}CoO_4$. The scans are parallel to (*h*,*h*,0) through (1.5, 1.5, 4.5). Panels (a) and (b) show the NSF and SF scattering at temperatures of 2K and 300 K. Panel (c) is the difference I_{NSF}(2K) – I_{NSF}(300K) to highlight the extra nuclear scattering at low temperatures. The counting time is ~10 mins/pt.

References

[1] J. M. Tranquada, *et al.*, Nature **429**, 534 (2004)
[2] M. Vojta, Adv. Phys. **58**, 699 (2009).
[3] H. Ulbrich & M. Braden, Physica C**481**, 31 (2012)
[4] M. Cwik *et al*., Phys. Rev. Lett. **102**, 057201 (2009); S. M. Gaw *et al.*, Phys. Rev. B **88**, 165121 (2013)
[5] Y. Drees *et al.*, Nature Commun. **4**, 2449 (2013)
[6] A. T. Boothroyd *et al.*, Nature **471**, 341 (2011).