Experimental report

09/02/2016

Proposal: **DIR-132** **Council:** 4/2014

Title: Test of models for charge order ina doped layered cobaltate

Research area: Physics

This proposal is a new proposal

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Samples: La1.67Sr0.33CoO4

Instrument	Requested days	Allocated days	From	To
IN20	3	3	11/12/2014	15/12/2014

Abstract:

Charge Order Dimensionality and the Hourglass Magnetic Excitation Spectrum.

In many doped Mott insulators the charges doped into the materials are found to align in one dimensional density wave orders, called charge-stripes. These charge stripes may be full and insulating with one hole per charge ordered site such as in $La_{2-x}Sr_xNiO_4$, or half-full and metallic like such as in La-based cuprate superconductors [1]. In the cuprates, static charge order has been observed to compete with superconductivity in both La-based cuprates [2], and Y-based cuprates [3]. In the case of the Y-based cuprates there is evidence that charge order is not striped but has a 2 dimensional checkerboard pattern[4]. There is heightened interest in understanding what stabilizes the two types of charge order, and whether charge-stripes or checkerboard charge correlations drive the formation of the universal hourglass-shaped magnetic excitation spectrum in the hole doped cuprates[2,5].

Better understanding of charge ordering processes can be gained by studying the insulating charge ordered materials such as manganates, nickelates and cobaltates[6]. In $La_{2-x}Sr_xCoO_4$ incommensurate magnetic order consistent with spin and charge stripes has been found in the doping range $0.25 < x < 0.5$ [7], but so far there has been no direct evidence for any charge stripe 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 ($x = 0.5$) [8]. 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 $La_{2-x}Sr_xCoO_4$ [9].

In proposal 5-53-247 we used polarized neutron scattering to separate the magnetic and structural diffraction signals in the (HHL) scattering plane of $La_{5/3}Sr_{x1/3}CoO_4$. Longitudinal polarization analysis was employed with the neutron polarization, **P**, parallel to the scattering wavevector, **Q**, so that elastic spin-flip scattering is from magnetic order and non-spin flip scattering from structural order (after corrections for imperfect neutron polarization are applied). Consistent with published results on the charge ordered structure of $La_{1.6}Sr_{0.4}CoO_4$, we observed checkerboard charge order at 300 K [8]. We repeated the same scans of the charge order structure at 2 K, then performed a data subtraction of the 300 K data from the 2 K data, and this revealed two incommensurate structural peaks. The two structural peaks have wavevectors that are consistent with the charge-stripes expected from the incommensurate magnetic order observed in $La_{5/3}Sr_{x1/3}CoO_4$. Our initial results were indicative of charge-stripe order but the need to observe the charge order at $l \neq 0$ positions limited our scattering plane to (HHL). We were therefore unable to show that this non-magnetic diffuse signal has the fourfold anisotropy expected for charge stripes running parallel to [110] and [-110], or whether the signal was an isotropic change in the checkerboard charge order peak shape.

In this latest experiment we studied the additional low temperature structure within the (HK0) plane through scans around (1.5, 1.5, 4.5) in reciprocal space performed by tilting the sample cryostat. In this way we created pseudoscans from single-point measurements in the (HK0) plane. One of the most informative scans is shown in figure 1. We performed a circular scan around the (1.5, 1.5, 4.5) at l = 4.5 to scan the symmetry of both the **b** magnetism and **c** the additional low temperature structure (after subtraction of the 300 K signal). Both the magnetism and observed structural Bragg reflections have fourfold symmetry. The fourfold symmetry of the structural diffuse scattering is consistent with the fourfold anisotropy expected for charge stripes running parallel to [110] and [-110].

In our polarized neutron diffraction experiments on IN20 we have found evidence for the existence of charge-stripe order in $La_{5/3}Sr_{x1/3}CoO_4$ co-existing with checkerboard charge order. We are considering the implications of this finding for the origin of the hourglass shaped magnetic excitation spectrum in $La_{2-x}Sr_xCoO_4$, and are working on a paper based on these results.

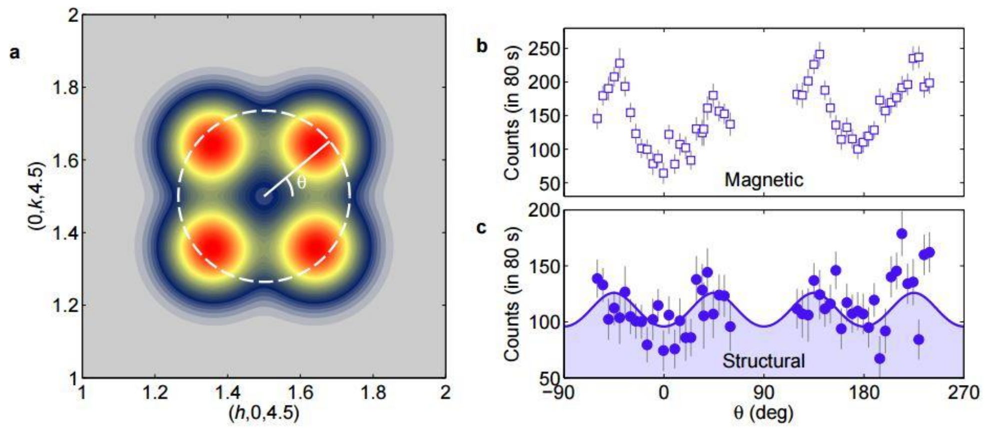

Figure 1: **a.** A pictorial representation of the fourfold symmetry of Bragg reflections from short range charge-stripe order in $La_{5/3}Sr_{1/3}CoO_4$ measured around (h,k,4.5). The path of a novel θ scan is indicated, this scan was achieved by performing an out-of-scattering plane scan by tilting the cryostat. The θ scan was performed using polarized neutron diffraction so that the structure of the **b**. magnetic Bragg reflections, and **c.** additional charge-stripe order Bragg peaks are separated. Both the magnetic and charge peaks have a fourfold symmetry consistent with charge-stripe order.

References:
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