Experimental Report

05/03/2015

Proposal:	**5-41-765**	**Council:**	4/2014	
Title:	Magnetic phases in La2-xSrxCoO4, x= 0.67 and 0.75			

This proposal is a new proposal

Research Area: Physics

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Samples: La2-xSrxCoO4, x = 0.67 and 0.75

Instrument	Req. Days	All. Days	From	To
D10	7	6	29/09/2014	05/10/2014

Abstract:

We propose to explore the nature of the ordered phases in La2-xSrxCoO4 for x = 0.67 and 0.75. At lower x values this system condenses into short-range incommensurate magnetic phases consistent with spin and charge stripes. We will search for diffraction peaks from magnetic order and map out out the distribution of diffuse scattering. We will also measure the temperature evolution of the magnetic order.

Magnetic phases in $La_{2-x}Sr_xCoO_4$ x = 0.67 and 0.75

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]. More recently, interest has turned to the $La_{2-x}Sr_xCoO_4$ family. The AFM order is formed from Co^{2+} ions with S = 3/2, and the holes are located on Co^{3+} which has spin S = 0. The advantage of this system over the manganates and nickelates, therefore, is that the doped holes do not carry a magnetic moment. This simplification has enabled us to obtain a good understanding of the excitation spectrum of several members of the $La_{2-x}Sr_xCoO_4$ family [4].

The magnetic order has been studied in $La_{2-x}Sr_xCoO_4$ for x < 0.60 [4–5]. Like the cuprates and nickelates, there is a region in the phase diagram which is characterized by incommensurate AFM order consistent with spin and charge stripes. For ideal spin and charge stripe order, the incommensurability is proportional to the hole concentration, and this is what is found for 0.33 < x < 0.5. For x = 0.60 the incommensurability is found to be smaller than what would be expected for charge stripes, suggesting that the ideal charge stripe model might break down for x > 0.5.

Up to now there had been no reports of measurements on $La_{2-x}Sr_xCoO_4$ with x > 0.60. The aim of this experiment was to study the nature of the magnetic order in this high hole-doping region. We prepared large single crystals of $La_{2-x}Sr_xCoO_4$ with x = 0.67 and 0.75 by the floating-zone method. The masses of the crystals were 3.2 g and 2.2 g. Both crystals were of high quality with sharp mosaics.

D10 was set up with the 4-circle goniometer and multidetector. The incident neutron wave vector was 2.662 $Å^{-1}$. Measurements were made at T = 2 K and at several temperatures between 2 K and 100 K. The scans performed at 2 K revealed for both compositions a four-fold pattern of diffuse magnetic peaks at positions (0.5, 0.5, L) ± (ε, ε, 0) with L = odd integer, and (0.5, 0.5, L) ± (ε, $-\varepsilon$, 0) with L = even integer. Figure 1 shows an example of a diagonal scan through two magnetic peaks. The values of the incommensurability parameter ε were found to be ε = 0.32 ± 0.01 (x = 0.67) and ε = 0.30 ± 0.01 (x = 0.75). The widths of the peaks in scans parallel to (h,h,0) correspond to in-plane correlation lengths of approximately 1 nm.

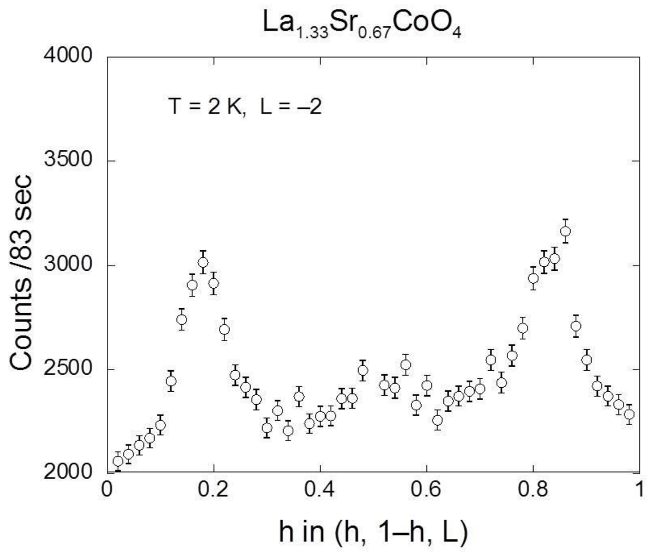

Figure 1. Q scan through the magnetic peaks centred at (0.5, 0.5, L) ± (ε, $-\varepsilon$, 0).

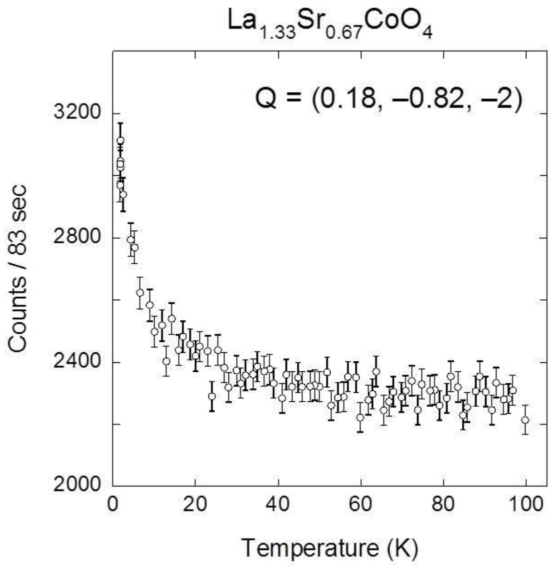

Figure 2. Temperature dependence of the counts at the maximum of the magnetic peak in the sample with x = 0.67.

Figure 2 shows the temperature dependence of the magnetic short-range order in the x = 0.67 crystal obtained by counting at the maximum of the magnetic peak while cooling the sample. The figure shows a gradual increase in intensity starting around 50 K, with a more rapid rise below about 20 K. It is clear from this that the magnetic correlations develop slowly with decreasing temperature, consistent with a significant amount of disorder. The results for the x = 0.75 crystal were similar.

For ideal stripes, the incommensurability is proportional to the hole doping level: $\varepsilon = n_h/2$, where $n_h = x+2\delta$ with δ is the oxygen excess in the formula $La_{2-x}Sr_xCoO_{4+\delta}$. Assuming $\delta = 0$, the observed value $\varepsilon = 0.32$ for x = 0.67 lies close to the value 0.335 expected for ideal stripes. However, for x = 0.75 the the observed value $\varepsilon = 0.30$ is significantly below the ideal stripe value $\varepsilon = 0.375$. These results indicate that the picture of short-range stripe order holds for cobaltates with x = 0.67. For x = 0.75, either the stripe picture breaks down, or the crystal is oxygen-deficient ($\delta < 0$) so that the hole doping level is not as high as $n_h = 0.75$. Diffraction measurements to determine the oxygen content of the crystals are required to distinguish these two possibilities.

References

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