Experimental report

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Proposal: 5-11-412 **Council:** 4/2015

Title: High-temperature study of charge correlations in layered cobalt oxides

Research area: Physics

This proposal is a continuation of 5-14-257

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Samples: La1.667Sr0.333CoO4
La1.6Sr0.4CoO4
La1.333Sr0.667CoO4
La1.2Sr0.8CoO4

Instrument	Requested days	Allocated days	From	To
IN12	0	0		
IN8	6	6	08/09/2015	14/09/2015

Abstract:

The observation of hour-glass magnetic spectra in layered Cobalt oxides La2-xSrxCoO4 which are isostructural to the prototypical HTSC cuprate materials La2-xSrxCuO4 attracted enormous attention. Due to the missing knowledge about the nature of charge ordering within the La2-xSrxCoO4 phase diagram it was difficult to understand the true origin of the hour-glass spectra in these cobaltates in the past. Within the entire La2-xSrxCoO4 phase diagram there is not a single known point of any charge correlations (including charge ordering onset temperatures) apart from the half-doped sample. In order to change this situation, we would like to study the charge correlations systematically as a function of hole-doping and temperature for x=1/3, 0.4, 2/3 and 0.8. A thermal triple-axis spectrometer turns out to be essential for measuring weak superstructure reflections not only in cuprates but also in these cobaltates. Especially away from half-doping the situation will worsen drastically since the already weak reflections get continuously broader and weaker away from x=1/2. For all these purposes, we ask for 6 days at the IN8 spectrometer.

High temperature study of charge correlations in layered cobalt oxides

The hourglass shaped magnetic excitation spectrum was found to be a ubiquitous property of the high temperature superconducting cuprates [1]. Considerable attention has been re-attracted due to the observation of such hourglass shaped magnetic excitations in the non-copper containing cobalt oxide materials [2]. These cobaltates are isostructural to the prototypical cuprates materials $La_{2-x}Sr_xCuO_4$ and exhibit incommensurate magnetic correlations with a wavevector similar to that found in the isostructural nickelate compounds [3, 4]. Hence, it was proposed that the hourglass feature in the cobaltates originates from diagonal charge stripe phases [2]. However, in our recent two comprehensive investigations of $La_{2-x}Sr_xCoO_4$ with x=1/3 and 0.4, we identified an entirely different origin of the hourglass spectrum in these materials, i.e. *nano phase separation* [5, 6].

Within our novel *nano phase separation* model, checkerboard charge order plays an important role. These checkerboard charge ordered regions have a domain size in the nanometer scale and they are interspersed with nanoscopic undoped islands. Interestingly, we have found that these checkerboard charge ordered regions have a transition temperature far above room temperature [5]. However, apart from just one single charge ordering temperature in the phase diagram is known for the half doped sample, no other charge ordering temperatures for other doping levels are yet known.

Therefore, we have studied the hitherto unknown charge ordering part of the phase diagram. We have measured three single crystal samples of $La_{2-x}Sr_xCoO_4$ with x = 0.36, 1/2, and 0.6 that were grown by optical floating zone furnace following the same procedure as reported in our earlier work [5, 6]. Each sample has been oriented with [100]/[010] in the scattering plane. Two PG filters were used at IN8 to suppress higher order contaminations. In order to measure the transition temperature, the samples were heated from room temperature up to 1200 K in a vanadium furnace with a vacuum better than 10^{-4} mbar. PG monochromator and analyzer were used with double focusing mode to enhance the flux of the neutron beam.

Typical elastic scans along the (H 3-H 0) direction are shown for $La_{1.4}Sr_{0.6}CoO_4$ in Figure 1. The half interger peak that originates from checkerboard charge ordering can be seen. (The larger peak on the left side is from the vanadium furnace.) The temperature dependence of the integrated peak intensities of the half integer peak is shown in Figure 2 for all three samples. The transition temperature is determined by fitting our data to the critical power law. Surprisingly, the transition temperatures for all three samples are almost the same, in other words, they do not depend on the Sr doping level, in contrast with that found in isostructural nickelates [3, 4]. We attribute this to the huge difference in the ionic sizes of Co^{2+} and Co^{3+} ions.

References:

[1] J. M. Tranquada et al., Nature 429, 534 (2004).
[2] A. T. Boothroyd et al., Nature 471, 341 (2010).
[3] M. Cwik et al., Phys. Rev. Lett. 102, 057201 (2009).
[4] H. Ulbrich and M. Braden, Physica C: Superconductivity 481, 31 (2012).
[5] Y. Drees, et al., Nature Commun. 4, 2449 (2013).
[6] Y. Drees, et al., Nature Commun. 5, 5731 (2014).

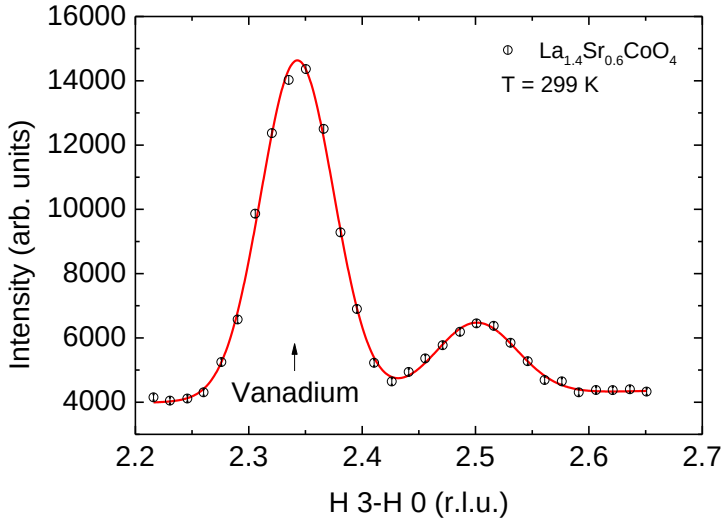

Figure 1 Neutron scattering intensities observed at 299 K in an (H 3-H 0) scan for sample $La_{1.4}Sr_{0.6}CoO_4$. The bigger peak on the left side originates from the vanadium of the furnace.

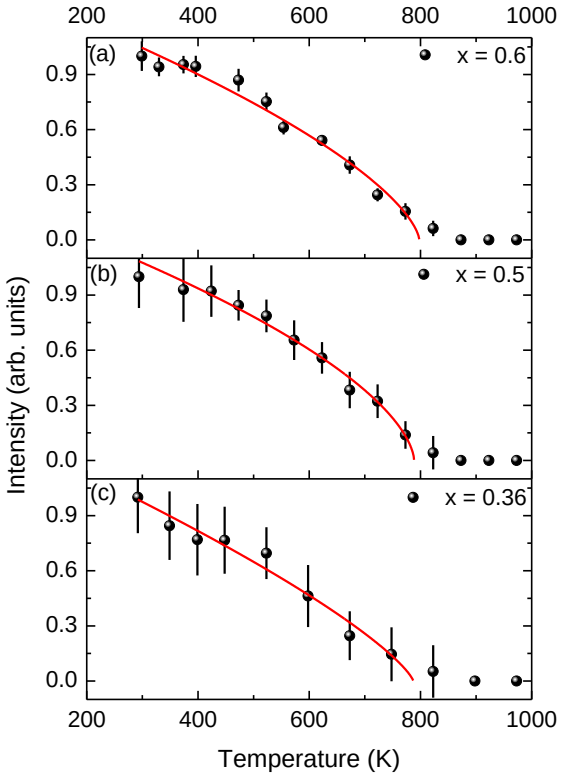

Figure 2 Temperature dependence of the integrated intensity of the checkerboard charge order signal for samples $La_{1.4}Sr_{0.}6CoO4$ with x = 0.36, 0.5 and 0.6 observed at half-integer peak positions (2.5 0.5 0) and normalized to the value at room-temperature.