Experimental report

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Proposal: **4-02-464** **Council:** 4/2015

Title: Magnetic excitations of oxygen-doped La2CoO4+d

Research area: Physics

This proposal is a new proposal

Main proposer: **ALEXANDER CHRISTOPH KOMAREK**

Experimental team: Zhiwei LI

Local contacts: Andrea PIOVANO

Samples: La2CoO4.2

Instrument	Requested days	Allocated days	From	To
IN3	2	2	10/11/2015	12/11/2015
IN8	3	3	12/11/2015	16/11/2015

Abstract:

Very recently, we were able to develop a new explanation for the emergence of hour-glass magentic spectra in cobalt oxides and to discard an alternative charge stripe scenario. In our nano phase separation scenario, the hour-glass dispersion arises from strongly decoupled excitations within the undoped and within the hole-rich regions of nanometer size. Whereas Co ions within the nanometer-sized hole-rich regions are coupled with weak exchange interactions J', the Co ions within the nanoscopic undoped islands are coupled with much stronger exchange interactions J>>J' such that the hole-rich islands are not able to follow the magnetic excitations of the undoped islands to higher henergies.

In order to get more quantitative experimental input for our entire nano phase separation model, we propose to study oxygen-doped cobaltates now. Compared to La2-xSrxCoO4 smaller exchange interactions can be expected in the La2CoO4+delta system at same hole-doping. Due to an altered size of the exchange interactions this proposed experiment will give complementary information that will help to understand the nature of the crossing of hour-glass spectrum in cobalates.

Magnetic excitations of oxygen-doped $La_2CoO_{4+\delta}$

A magnetic excitation spectrum with an 'hourglass' shape was found to be an ubiquitous property of high-temperature superconducting cuprates [1]. Therefore, the recent observation of such hour-glass shaped magnetic excitation spectra in non-copper containing cobalt oxide materials $La_{2-x}Sr_xCoO_4$ has attracted considerable attention [2]. Recently, we found out that there are no charge stripes in these cobalt oxides [3-6]. Instead, we propose a novel *nanpo phase separation* scenario for the hour-glass spectrum in $La_{2-x}Sr_xCoO_4$ [3-6]. In this scenario, the upper part of the hour-glass dispersion originates from excitations that are basically hosted within undoped La_2CoO_4-like islands and where strong exchange interactions *J* appear (in contrast to the weak exchange interactions *J'* within the hole-doped regions). The interpretation in our original publication [4] additionally proposed that these excitations are separated from the low-energy part of the hour-glass spectrum by an spin anisotropy gap that is well known to exist also in La_2CoO_4 [7], and, therefore, might also persist in the undoped islands within our *nano phase separation* scenario. However, our *new nano phase separation* scenario would also work fine if this is not the case and the crossing of the hour-glass dispersion is simply a crossing of dispersions emanating from the incommensurate magnetic peaks at lower energies – just that the undoped islands contribute mainly to the high energy excitations whereas the contribution of the hole-doped regions simply fades out with increasing energy. Summarizing, there are still two possibilities left – either the crossing of the hour-glass arises from a crossing of dispersion or from an in-plane spin anisotropy gap Δ.

It would be possible to distinguish between these possibilities if one could either increase Δ or decrease *J'* such that the upper and lower part of the Hour-glass spectrum become well separated if the crossing of the hour-glass arises from an in-plane spin anisotropy gap Δ. Otherwise, if the hour-glass spectrum is just shifted to lower energies this might indicate that the crossing of the hour-glass arises from a crossing of dispersions.

Our approach to decrease *J'* is to study the effect of oxygen-doping instead of Sr-doping. Therefore, we studied $La_2CoO_{4+\delta}$ instead of $La_{2-x}Sr_xCoO_4$.

This experiment on IN8 was done with PG monochromator and analyzer working in double focusing mode with k_f = 2.662. Two PG filters were used to suppress higher order contaminations. All measured samples were aligned with [100]/[010] in the scattering plane.

For two samples $La_2CoO_{4+\delta1}$ and $La_2CoO_{4+\delta2}$ (with $\delta1$~0.1 and $\delta2$~0.2) we measured Q-E maps at 10 K as shown in **Fig. 1 & 2**. As a first result, we were really able to diminish the exchange interaction *J'* significantly by oxygen doping compared to the Sr-doped material $La_{1.5}Sr_{0.5}CoO_4$, see **Fig. 1**.

However, we did not observe hour-glass magnetic spectra $La_2CoO_{4.2}$ which is very unlike to our observations in the Sr-doped counterpart $La_{1.6}Sr_{0.4}CoO_4$ [3]. It seems, that for the $La_2CoO_{4+\delta}$ system the checkerboard charge correlations are able to "lock in" within a broader range of hole doping around half-doping than in the $La_{2-x}Sr_xCoO_4$ system. Hence, it will be important to study further samples with intermediate oxygen-doping. Especially our observations in a lower oxygen-doped sample are very promising since we were able to observe the desired separation of upper and lower dispersions for this sample, see **Fig. 2**.

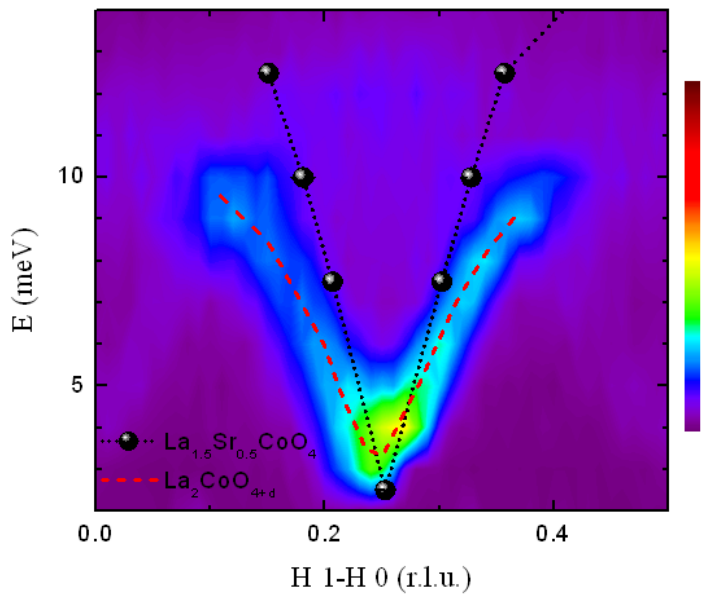

Fig. 1 Magnetic excitations in $La_2CoO_{4+\delta 2}$ with $\delta 2$~0.2.
The black dots denote the values for a Sr-doped reference sample $La_{1.5}Sr_{0.5}CoO_4$.

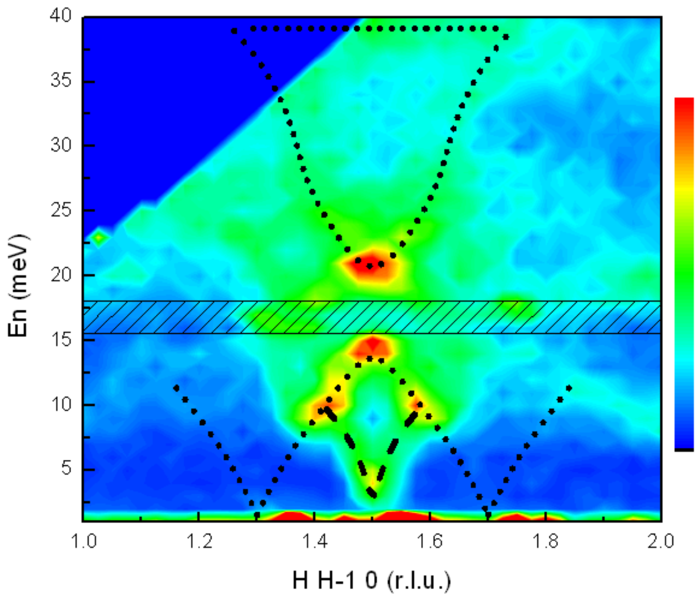

Fig. 2 Magnetic excitations in $La_2CoO_{4+\delta 1}$ with $\delta 1$~0.1. Apparently, upper and lower excitations seem to be separated by a gap. The other features arise from spurious peaks (a very strong one has been subtracted from the data) or from phonons which are much stronger for larger Q-values.

References:

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