	Experiment title: Probing the low-energy orbital texture of Mott insulating Ca2RuO4	**Experiment number**: HC-4422
Beamline:	**Date of experiment**: from: 15 Sep 2021 to: 20 Sep 2021	**Date of report**: 15 Sep 2022
Shifts:	**Local contact(s)**: Davide Betto, Nick B. Brookes	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Karin von Arx, University of Zurich

Qisi Wang, University of Zurich

Julia Küspert, University of Zurich

Johan Chang, University of Zurich

Thorsten Schmitt, Paul Scherrer Institute, Swiss Light Source

Raymond Fan, Diamond Light Source Ltd

Paul Olalde Velasco, Diamond Light Source Ltd

Report:

A) Overview

The original propsal was to study the Mott insulator ruthenate Ca_2RuO_4, where spin-orbit coupling has a comparable energy scale to the crystal field splitting. Neutron scattering study on this system has revealed dispersive single magnon excitations [1], but does not provide information on the orbital characters. It is widely believed that interactions responsible for the Mott insulating state are encoded into this orbital texture [2]. We therefore proposed to study the low-energy spin-orbital excitation spectrum of Ca_2RuO_4 using the high-resolution oxygen *K*-edge RIXS at ID32. However, during another O *K*-edge RIXS experiment at ID32, we did some test measurements on Ca_2RuO_4 and realized that signal yield is overall weak at O *K*-edge. Based on the discussions with the local contacts, we have therefore instead switched to the Cu *L*-edge and carried out a study on the charge-stripe order in the La-based cuprates. A manuscript reporting the results is currently under review at npj Quantum Materials, with a preprint available on the arXiv (arXiv:2206.06695) [3]. Local contacts Davide Betto and Nick B. Brookes are included as coauthors for their substaintial contributions to this work.

B) Experimental results

We perfomed a comprehensive study on the doping evolution of charge correlations in $La_{2-x}Sr_xCuO_4$ (LSCO) and $La_{1.8-x}Eu_{0.2}Sr_xCuO_4$ (LESCO). Linear vertical incident light polarization was used to ehnace the scattering from charge correlations. Due to the two-dimensional nature of the system, the scattering angle was fixed at 149.5°. The ultrahigh energy resolution (FWHM = 33 meV) allows us to separate elastic from the inelastic

processes. As is shown in Fig. 1(a), a phonon mode at ~70 meV would significantly influence the analysis of charge correlations if lower energy resolution is applied. Focusing on the elastic channel, we find that the long-range temperature dependent charge order is replaced by short-range temperature independent charge correlations at a critical doping $x_c \approx 0.15$, which is close to the optimal doping for superconductivity (see Fig. 1(c-f)). The fact that this critical doping of long-range charge order is well below that of the pseudogap suggests no obvious link between the two phenomena. The observation of a charge order quantum critical point at optimally doped LSCO sheds new light on the mechanism of charge order and its relationship with superconductivity.

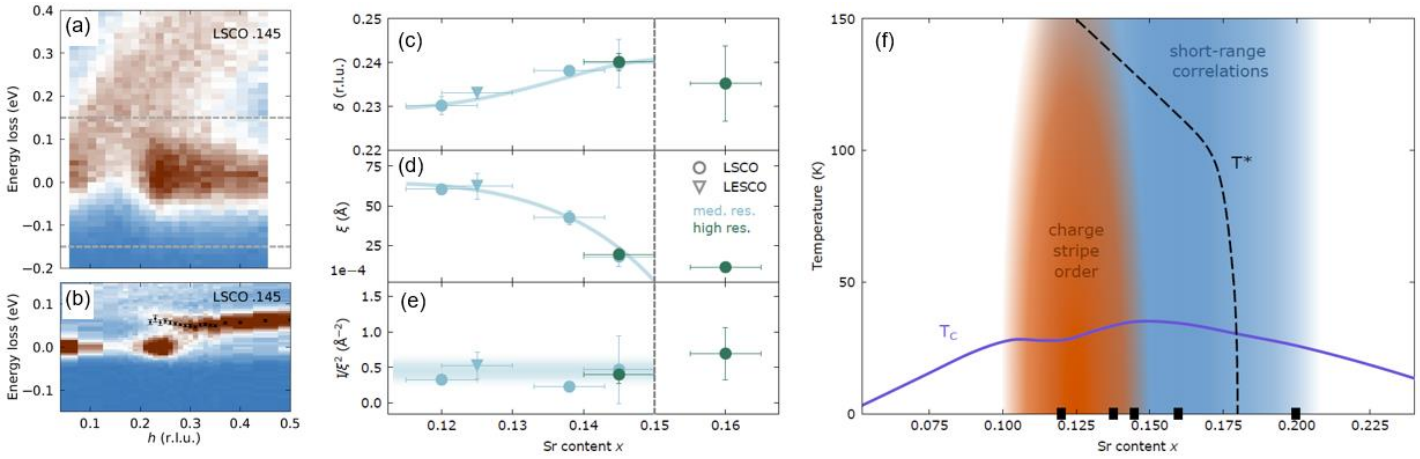

Fig. 1. (a,b) Comparision of RIXS spectra across the charge ordering wav vector probed with (a) medium (129 meV) and (b) high (33 meV) energy resoltuions. Charge order incommensurability (a), correlation length (b), integrated diffraction intensity and its schematic doping-temperate phase diagram (d) summarized from the RIXS measurements on LSCO and LESCO [3].

C) Publication

Data obtained from this beamtime have been included in a manuscript that is currently under review at npj Quamtum Materials. A preprint has been submitted to the arXiv (K. von Arx, Q. Wang *et al.*, arXiv: 2206.06695). The abstract of this manuscript is attached below.

In high-temperature cuprate superconductors, stripe order refers broadly to a coupled spin and charge modulation with a commensuration of eight and four lattice units, respectively. How this stripe order evolves across optimal doping remains a controversial question. Here we present a systematic resonant inelastic x-ray scattering study of weak charge correlations in $La_{2-x}Sr_xCuO_4$ and $La_{1.8-x}Eu_{0.2}Sr_xCuO_4$. Ultrahigh energy resolution experiments demonstrate the importance of the separation of inelastic and elastic scattering processes. Upon increasing doping x, the long-range temperature dependent stripe order is found to be replaced by short range temperature independent correlations at a critical point $x_c \approx 0.15$ distinct from the pseudogap critical doping. We argue that the doping and temperature independent short range correlations originate from unresolved electron-phonon coupling that broadly peaks a the stripe ordering vector. In $La_{2-x}Sr_xCuO_4$, long-range static stripe order vanishes around optimal doping and we discuss both quantum critical and crossover scenarios [3].

References

[1] A. Jain *et al.*, Nature Physics **13**, 633 (2017).

[3] L. Das *et al.*, Physical Review X **8**, 011048 (2018).

[2] K. von Arx, Q. Wang *et al.*, arXiv: 2206.06695.