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Names and affiliations of applicants (* indicates experimentalists):

D. Preziosi*[1], L. Martinelli*[2], G. Krieger*[1], F. Rosa*[2], N. Viart*[3], D. Dentelski[1], M. Salluzzo*[4], G. Ghiringhelli*[2]

[1]*Université de Strasbourg, CNRS, IPCMS UMR 7504, F-67034 Strasbourg, France*
[2]*Politecnico di Milano Dipartimento di Fisica Piazza Leonardo da Vinci 32 IT - 20133 MILANO*
[3]*Institut de Physique et Chimie des Materiaux Groupe des Matériaux Métalliques, STRASBOURG*
[4]*CNR-SPIN Complesso Universitario di Monte Sant Angelo, NAPOLI*

Report:

The recent discovery of superconductivity in infinite-layer nickelates has generated much enthusiasm in the condensed matter physics community. Last year, the first observation of a dispersive feature in the low-energy spectrum was reported by Resonant Inelastic X-ray Scattering (RIXS) measurements. Due to the similarity with cuprates, it was interpreted as a spin wave. However, the evolution over doping of this excitation is different from the one of cuprates, and it is substantially characterized by a decrease of its energy and intensity values. Moreover, very recent RIXS experiments performed on both capped and uncapped infinite-layer nickelate thin films reported about a self-exclusive presence of charge order and magnetic excitations[1,2,3], and the presence of both in capped $LaNiO_2$ thin films[4]. In our experiment, we investigated the low enegy magnetic excitations in infinite-layer nickelates using polarization-resolved RIXS at the Ni L_3-edge. We had two aims: i) clarify the nature of the low-energy dispersive excitations in capped samples, studying their properties as a function of doping, and ii) shed light on the significant discrepancy between capped-uncapped samples by proposing to compare the spectra of capped and uncapped $Nd_xSr_{1-x}NiO_2$ (NSNO) films, exploiting the unique polarization selectivity of ERIXS at ID32.

As we will explain, our experiment has been a great success and we have acquired a large and high-quality set of data. The first part of the experiment has been devoted to study the doping dependence of magnons in capped-NSNO films. **Fig. 1a** shows polarized-resolved RIXS scans at q = (0.36, 0) for undoped and 20%-doped thin films. The clear dispersive magnetic excitations characterizing the capped undoped parent compound NSNO(0) is still present in the 20% doped compound, although strongly damped, and with reduced intensity.
Indeed, it can be observed that the spin-flip intensity (πσ’) in **Fig. 1(b)** is more intense, and at higher energy for the undoped thin film. We note that this phenomenology is at odds with the one observed in cuprate superconductors.

The second part of the experiment was devoted to investigate the differences between capped and uncapped samples, and also the effect of a different substrate. We were able to experimentally confirm by polarization-resolved RIXS measurements that the magnetic excitations are still present in capped NSNO(20) superconducting samples, hence, reproducing the result already presented in literature[1]. Moreover, we also studied the influence of the capping-layer on the magnetic nature of the low-energy feature of our RIXS spectra. In particular, we measured capping-free (uncapped) NSNO(0) samples. **Fig. 2(a)** shows the result of our polarized-resolved RIXS scan from which we could demonstrate that the magnetic excitations are not totally suppressed by the absence of the capping-layer. By comparing the spin-flip intensities of capped and uncapped NSNO(0) thin films in **Fig. 2(b)**, we note that the intensity of the magnon is similar for both samples, and that for the uncapped sample (in orange) appears at lower energies than the one observed for capped samples.

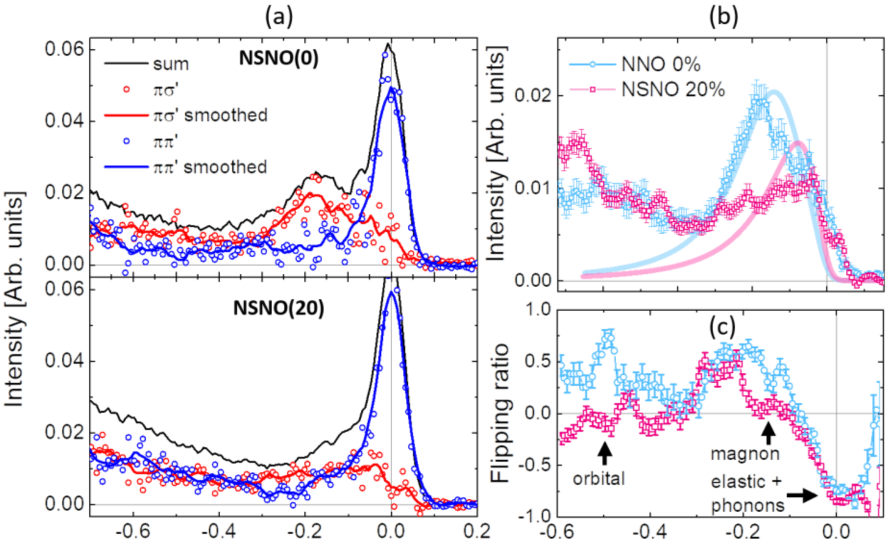

Figure 1 (a): Polarimeter scan for NSNO2(0) (top) and NSNO2(20) (bottom) (b) Comparison of the spin-flop intensity for NSNO2(0) and NSNO2(20) where the solid lines in the top panel represent the fit with an asymmetric Lorentzian function

It has been shown that the use of LSAT single crystal as substrate leads to an increase of the critical temperature onset from 20 K to nearly 40 K[5,6], due to an improved crystalline quality of the precursor phase akin to a reduced tensile strain state. Therefore, we wanted to observe the difference at the low-energy excitations in our samples grown onto LSAT. We show in **Figs. 3(a,c)** in read the X-ray diffraction patterns of the perovskite NSNO(0) phases grown onto STO with an LSAT layer as capping-layer and an uncapped NSNO(0) grown onto LSAT. In blue the related θ-2θ pattern after the topotactic reduction. From our momentum-resolved maps we could firstly observe [**Fig. 3(b)**] that the choice of LSAT as capping-layer leads to a large decrease of the intensity of the magnon which appears now extremely damped. Also, for the uncapped NSNO(0) grown onto LSAT, we could not observe the simultaneous presence of both magnetic excitations and/or CO, as for the NSNO(0) grown onto STO. Further investigations are necessary to understand if those results stem from the precise sample preparation or are intrinsic to the material prepared with different capping layer or undergoing a different strain state from the one of STO.

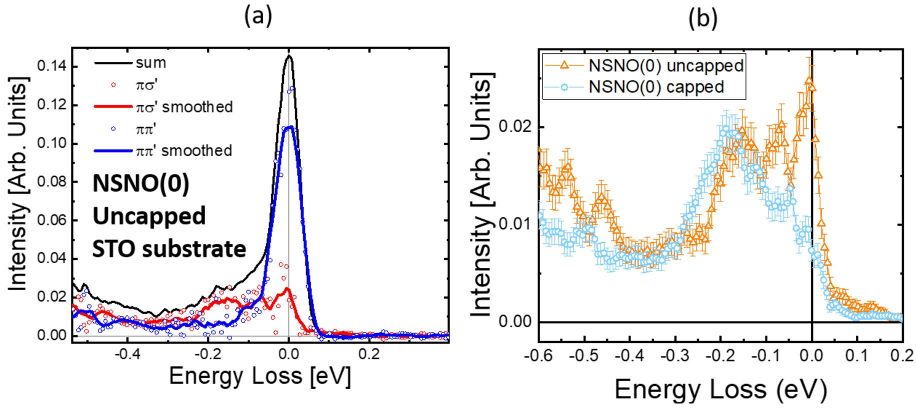

Figure 2: (a) Polarimeter scan for uncapped NSNO2(0) (b) Comparison of the spin-flip intensity for NSNO2(0) capped (blue) and uncapped (orange) thin films.

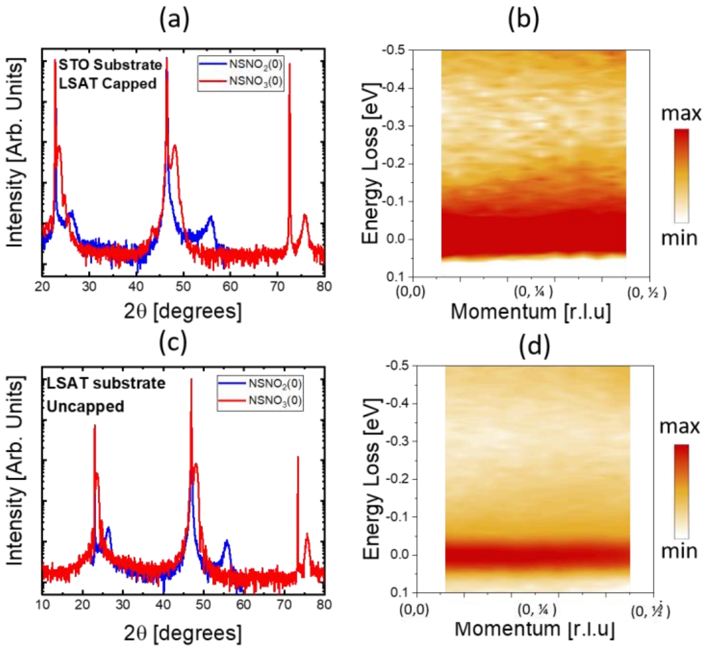

Figure 3 (a,c) XRD and (b,d) in-plane momentum RIXS map along the (10) direction of NSNO(0) with a LSAT capping-layer grown on STO (top) and a NSNO(0) uncapped grown on LSAT (bottom).

Finally, we have been able to demonstrate the also for our uncapped samples the low-energy tail observed in a previous beamtime at ID32 are of magnetic origin. The observed magnons for uncapped samples show a smaller dispersion than the one observed in the case of the capped samples. This might be linked to the precise sample preparation, and the way in which the topotactic reduction take place. Further High-Resolution Transmission Electron Microscopy measurements are planned to shed light on this particular point.

Overall, the experiment has been a great success. At present, we are complementing our experimental analysis with theoretical calculations, in order to provide a microscopic explanation of the observed doping dependence.