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Experiment title: Resonant magnetic X-ray scattering in $Nd_{2-x}Ce_xCuO_4$ with x=0 and 0.15		**Experiment number:** he593
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Report:

We have performed an X-Ray Resonant Magnetic Scattering experiment at the $L_{2,3}$ edge of the neodymium on a Nd_2CuO_4 single crystal, in the different *anti-ferromagnetic* phases.
In Nd_2CuO_4, the Cu^{2+} spins order antiferromagnetically below the Néel temperature $T_N^{Cu} = 242\,K$[**1**]. Two spin reorientation transitions are observed at $T_1 = 76\,K$ and $T = 29\,K$ [**2,3**] (see also [**4**] and references therein for further details). The three ordered phases called I ($T_1 < T < T_N$), II ($T_2 < T < T_1$), and III ($T < T_2$) have an *anti-ferromagnetic* order in the planes, with a *non-colinear* structure between planes. The *non-colinear* spins form an angle $\phi = -\pi/2$ in the phase I and III, while they form an angle $\phi = \pi/2$ in the phase II. It is know from neutron diffraction data that the Nd^{3+} magnetic moments are strongly enhanced around $T^{Nd} \approx 1.5 - 3\,K$[**3**].

q dependence:

In order to clarify the nature of the resonant spectrum, we have performed a polarization analysis of the scattered light. We have measured the resonant magnetic scattering signal for different *anti-ferromagnetic* reciprocal lattice vectors $(\frac{1}{2}, \frac{1}{2}, q_\ell)$ has shown in **figure 1**.
In the $\pi \to \sigma$ channel, the scattered intensity is proportional to the spin component perpendicular to the scattering plane $\mathcal{S}_\perp(q)$, while in the $\pi \to \pi$ channel it is proportional to the parallel component $\mathcal{S}_\parallel(q)$. Due to the non-colinear magnetic structure of Nd_2CuO_4, each Bragg reflection depends either on the $\mathcal{S}_\parallel(q)$ spin component or on the $\mathcal{S}_\perp(q)$ spin component as given by the following table:

q_ℓ	Phase III $T < 29\ K$	Phase II $29 < T < 76\ K$	Phase I $78 < T < 242\ K$
even	$\mathcal{S}_\perp(q)$ $\pi \to \sigma$ channel	$\mathcal{S}_\parallel(q)$ $\pi \to \pi$ channel	$\mathcal{S}_\perp(q)$ $\pi \to \sigma$ channel
odd	$\mathcal{S}_\parallel(q)$ $\pi \to \pi$ channel	$\mathcal{S}_\perp(q)$ $\pi \to \sigma$ channel	$\mathcal{S}_\parallel(q)$ $\pi \to \pi$ channel

We have therefore a fairly good understanding of the q dependence for both resonant and non-resonant signals. On the other hand the energy dependence, which is changing as a function of q, is still puzzling.

Finally we did not observe so far the signature of a quadrupolar contribution. Nevetheless, a measurement in the $\sigma \to \sigma$ and $\sigma \to \pi$ polarization channels is still required to conclude on this issue.

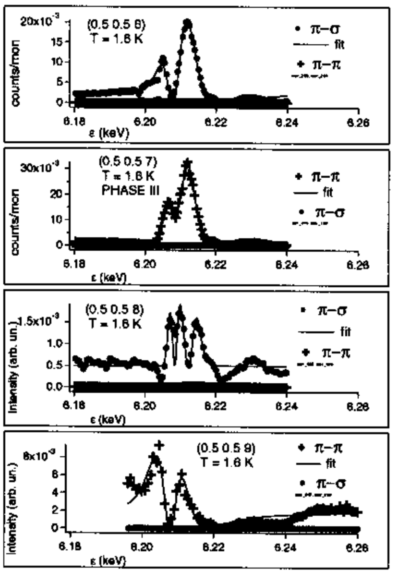
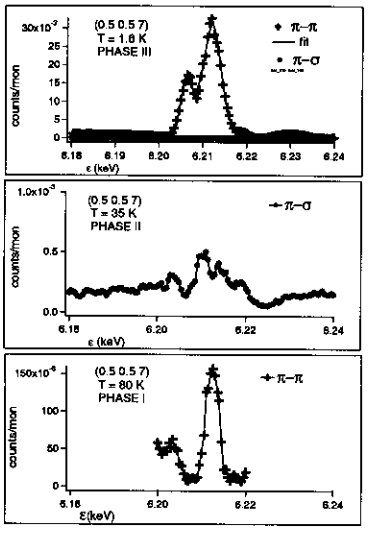


figure 1: Energy and polarisation dependence of the resonant magnetic scattering signal for different *anti-ferromagnetic* reciprocal lattice vectors $(\frac{1}{2}, \frac{1}{2}, q_\ell)$.

Temperature dependence:

The selection rules described above is observed up to T_N^{Cu} (see **figure 2** and **3**). The persistence of the resonant signal up to T_N^{Cu}, suggests that the Nd 5d electrons magnetism is driven by the exchange with the copper magnetic moments *even* at high temperature.
As clearly evidenced in **figure 2**, we found that the resonant spectra shape changes completely from phase to phase. This is an un-expected result, for which an interpretation still needs to be found.
We would like to mention that out of six days of experiment, two took place during the *4 GeV machine mode* to the detriment of the experiment.



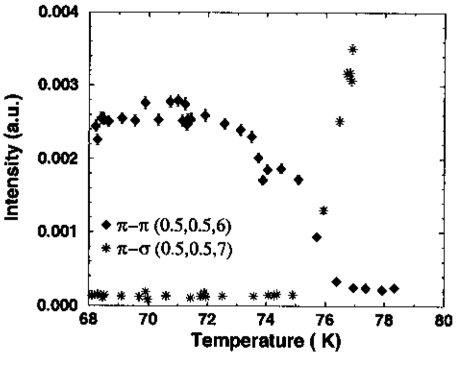


figure 2: A complete set of resonant spectra at $(\frac{1}{2}, \frac{1}{2}, 7)$ in the 3 different magnetic phase.

figure 3: The transition from the phase II to the phase I are shown for the resonant signal at $(\frac{1}{2}, \frac{1}{2}, 6)$ and $(\frac{1}{2}, \frac{1}{2}, 7)$.

References:

[1] G.M. Luke et al., *Nature* **338**, 49 (1989)
[2] J. Akimitsu et al., *J. Phys. Soc. Japan* **58**, 2646 (1989); S. Skanthakumar et al., *Physica C* **160**, 124 (1989)
[3] M. Matsuda et al., *Phys. Rev. B* **42**, 10098 (1990)
[4] H. Casalta et al., *Phys. Rev. B* **57**, 471 (1998)