Here we report first results from our x-ray diffraction experiment at beamline P02.2 on the charge stripe order in La$_{1.67}$Sr$_{0.33}$NiO$_4$ at high pressure and low temperature. The nickelate La$_{2-x}$Sr$_x$NiO$_4$ is the most valuable non-cuprate reference system to the high-T$_c$ superconductors La$_{2-x}$Sr$_x$CuO$_4$ and La$_{2-x}$Ba$_x$CuO$_4$ [1]. Although at ambient pressure La$_{1.67}$Sr$_{0.33}$NiO$_4$ is insulating, at very high pressure it should become either metallic or assume a different exotic ground state [2,3].

The phase diagram of La$_{2-x}$Sr$_x$NiO$_4$ in Fig. 1 shows many similarities with the cuprates, such as the antiferromagnetic phase, a metal-insulator (MI) transition, and the charge and spin stripe phase. The physics of stripe phases is of tremendous interest, because fluctuating stripes may play an important role in the pairing mechanism of the cuprates [4-7]. Charge and spin stripes form when the CuO$_2$ (cuprates) or NiO$_2$ (nickelates) planes are doped with hole charge carriers by e.g. substituting Sr for La. Eventually the holes segregate into quasi 1D charge stripes, separating intermediate spin stripes. In the nickelates the MI transition occurs at much higher doping than in the cuprates. Consequently, the stripe phase of the nickelates falls into the insulating phase, while in the cuprates it falls into the superconducting phase. Resistivity data on the nickelates have shown that at high pressure the MI transition moves to lower x. However, the pressure needed to push it all the way down to the stripe phase has been unknown.

Using a high quality La$_{1.67}$Sr$_{0.33}$NiO$_4$ single crystal (25µm x 25µm x 15µm), we were able to detect several charge stripe satellite reflections at predicted angle positions. The reflections have excellent resolution and signal to background. The diffraction images in Fig. 1 (right) show data taken at 190K. One can see that at low p (4 GPa) charge order satellite reflections are still there, while at very high p (35 GPa) the satellites are gone. Additional data at 150K, 100K and 45K indicate a critical pressure of ~20 GPa.

It is worth noting that the charge stripe satellites are about 5 orders of magnitude weaker than a strong Bragg peak, so that it was uncertain if we will be able to detect them at P02.2, given the fact that the sample thickness (15µm) was one order of magnitude below the preferred thickness of one absorption length. Our results show that P02.2 is perfectly capable of detecting these weak satellites. However, the membrane driven megabar DAC we have used for this study were not suited for in-situ pressure changes at low T, and the available cryostat did not have the necessary stability to perform wide angular sweeps. These were the main obstacles that prevented a more detailed study as a function of pressure and temperature. We have ordered new diamond anvil cells with a less tight fit that will allow in-situ pressure changes at cryogenic temperatures in future experiments.

**Figure 1:** Left: Electronic phase diagram of La$_{2-x}$Sr$_x$NiO$_4$, showing antiferro-magnetic (AFM) phase, stripe phase, checkerboard phase, and metal-insulator transition (MI). Red dots indicate studied temperatures. Right: Diffraction images at T=190K of stripe ordered La$_{1.67}$Sr$_{0.33}$NiO$_4$ at p=4 GPa and p=35 GPa. At p = 4 GPa the positions of several satellite reflections are indicated, such as (0, 4-2e, 3). Two Bragg reflections are indicated as well. At p = 35 GPa all charge stripe satellite reflections are suppressed.
References: