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Names and affiliations of applicants (* indicates experimentalists):

SEVERING, Andrea*; SUNDERMANN, Martin*

Institute of Physics II, University of Cologne,Zülpicher Straße 77, D-50937 Cologne, Germany

KRISCH, Michael*; MORETTI, Marco*

European Synchrotron Radiation Facility (ESRF), B.P. 220, 38043 Grenoble C´edex, France

AGRESTINI, Stefano*; TJENG, L. Hao; HAVERKORT, Maurits W, THALMEIER, Peter

Max Planck Institute for Chemical Physics of Solids, Nöthnizer Straße 40, 01187 Dresden, Germany

GOLDEN, Mark

Laboratory University of Amsterdam Van der Waals-Zeeman Institute Valckenierstraat 65 NL - 1018 XE Amsterdam

REPORT

The heavy fermion superconductor URu_2Si_2 undergoes a mysterious phase transition into a so-called *hidden order* (HO) phase at T_{HO}=17.5 K [1]. Order parameters of higher rank, e.g. quadrupole (rank 2), octupole (rank 3) etc. do not exhibit Bragg reflections, so that these types of order are often referred to as *hidden order* and more advanced methods are required to identify the HO. So far, despite intense research over the last two decades, the nature of the HO in URu_2Si_2 has remained unknown. Nevertheless, there are two hot multipole candidates for the HO phase in URu_2Si_2, the hexadecapole, rank 4 or dotriacontapole, rank 5-type order, each having a different impact on the azimuthal spatial distribution of the local 5*f* wave function in the HO order phase [2-4]. We therefore want to measure the spatial distribution the 5*f* ground state wave function above and below the HO transition, thus obtaining insight into which theory is applicable for explaining the HO in URu_2Si_2. Our method of choice is non-resonant inelastic x-ray scattering (NIXS), a new method, which gives an undisguised view onto the wave function without the need to make assumptions about, for example, the symmetries of intermediate states in resonant x-ray techniques.

We have measured the uranium $O_{4,5}$ edge of URu_2Si_2 with NIXS above (25K) and below (5K) the hidden order transition at several points in reciprocal space in order to a) detect possible changes as function of temperature and b) map out the spatial distribution of the 5*f* ground state wave function. Both monochromators (Si(111) and Si(311)) were in the beam, resulting in a resolution of ~0.7eV at the elastic position for an incident energy of 9.68 keV. Data were collected in horizontal geometry and the data of the analyzer column at 2θ=153° were added up (sum of three analyzers). This high angle corresponds to a momentum transfer of $|\mathbf{q}|$ = 9.5 $Å^{-1}$ and the scattering intensity contains already an important amount of higher multipole scattering. The single crystals with polished surfaces were mounted in the cryostat which had an inner capton and outer aluminum dome.

Fig. 1 a) to c) shows the $O_{4,5}$-edges of URu_2Si_2 for several directions of **q** with respect to the crystal lattice. The O-edges are on top of the rising Compton contribution and are normalized to the background before and above the O-edges. No background has been subtracted. In the present set-up the O-edge signal is almost as large as the Compton scattering. Possible energy shifts have been corrected for by means of the elastic line.

The data of both temperatures are summed up because we could not detect any changes across the hidden order transition within our data statistics.

Fig. 1a) compares the scattering intensity of **q**||100 and **q**||001 (||a and ||c). The former corresponds to the angles {w(xy)=0° & w(xz)=0°} and the latter to {w(xy)=0° & w(xz)=90°}. The directions are symbolized by the coloured crosses in the fictitious orbital which was taken from Ref. [2]. There is a clear direction dependence between 100 and 001. This is confirmed by measuring some interim directions (not shown).

Fig. 1b) compares the in-plane directions **q**||100 and **q**||110 and a direction in between. We did not find any direction dependence within the plane.

Fig. 1c) compares two directions at the same out-of-plane angle. There is a small change with direction visible at ≈105 eV, however. This might be a true effect! However, we cannot rule out that the two directions were measured at slightly different latitudes and that some more 001 contribution in the {w(xy)=0° & w(xz)=30°}–direction (blue) could yield such an increase in intensity at ≈105 eV. In addition there was some Bragg contribution between 90 and 92 eV in the {w(xy)=22.5° & w(xz)=30°}-direction (orange and see inset).

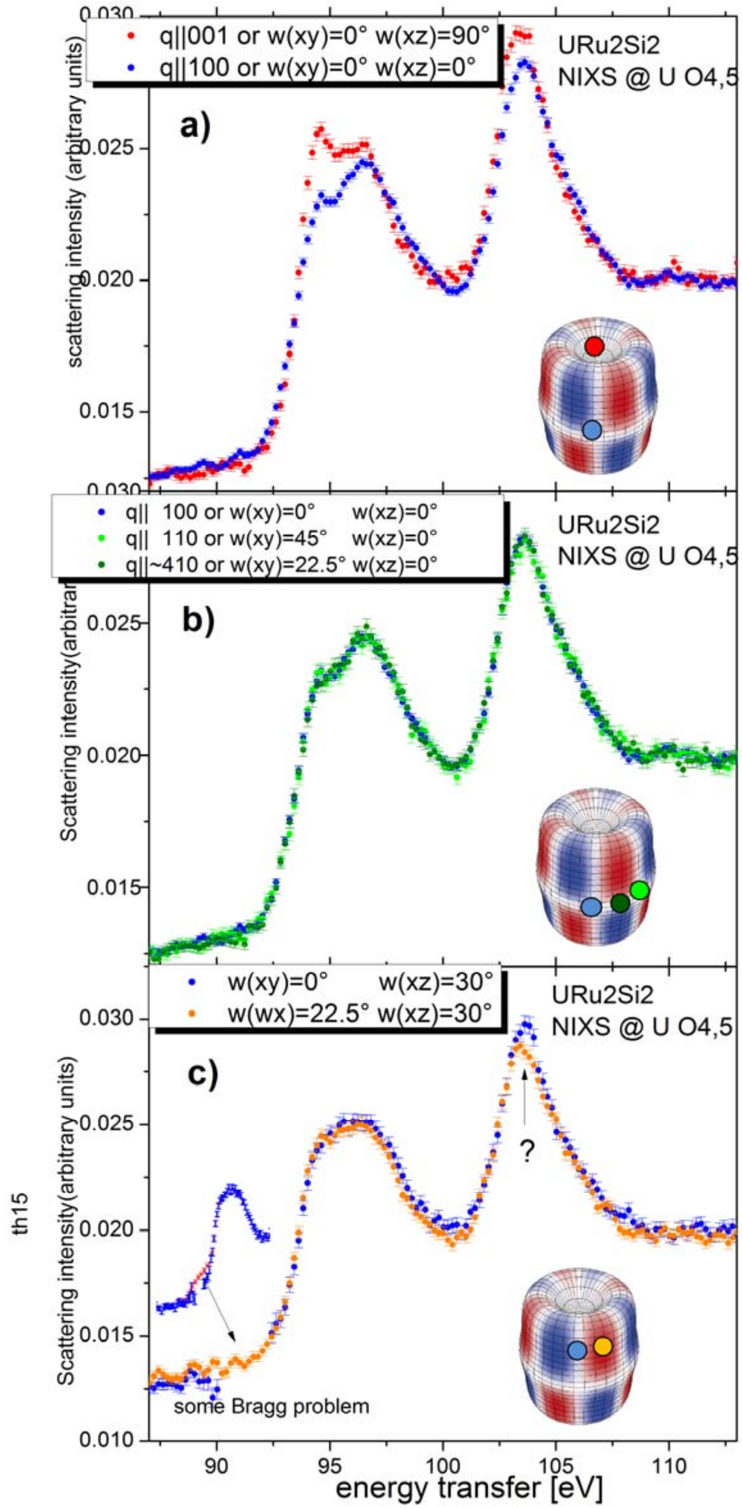

Fig. 1) URu_2Si_2 $O_{4,5}$ edge for several **q** direction directions. The directions are indicated in the panels.

References:

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