ESRF	**Experiment title:** Magnetic order in the antiferromagnetic ground state of single crystalline $EuRh_2Si_2$ probed by X-ray resonant magnetic scattering	**Experiment number:** HE 3719
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Names and affiliations of applicants (* indicates experimentalists):

Kurt Kummer*, ESRF, F-38043 Grenoble.

Silvia Seiro*, Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden.

Flora Yakhou-Harris*, ESRF, F-38043 Grenoble.

Helen Walker*, DESY, D-22607 Hamburg.

Denis Vyalikh, Dresden University, D-01062 Dresden.

Christoph Geibel, Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden.

Report:

The magnetic order in $EuRh_2Si_2$ single crystals at low temperatures was studied by means of resonant x-ray magnetic scattering. Three anti-ferromagnetic (AFM) phases were found, which we refer to as the low-temperature (low-T), medium-T, and high-T phase, with ordering temperatures T_t = 12.3 K, $T_{N,1}$ = 22.9 K and $T_{N,2}$ = 24.5 K, respectively. These temperatures agree very well with the critical temperatures found in our specific heat and magnetic susceptibility measurements. For the medium- and high-T phase incommensurate magnetic structures with different and temperature-dependent propagation vectors $\boldsymbol{\tau} = (00\tau)$ were found. The magnetic order in the low-T phase is even more complex and cannot be described in terms of a single ordering wave vector. The data analysis is under way. A full understanding of the magnetic ordering in $EuRh_2Si_2$ could now be gained if also the orientation of the Eu 4f magnetic moments in the different phases was known.

The experiment was performed at beamline P09 of the PETRA 3 storage ring at DESY. The energy was set to 7.610 keV, the white line of the Eu L_2 absorption edge, where a maximum resonant enhancement of the magnetic reflections was found. For polarisation analysis a graphite crystal was used to switch between the σ-π' and σ-σ' scattering channel, where one is sensitive to magnetic and charge ordering, respectively.

For all three phases--low-, medium- and high-T—magnetic reflections were found along the 001direction, whereas no reflections could be detected when scanning off-specular along 100. Fig. 1 shows the intensity detected in the σ-π' scattering channel as $\boldsymbol{Q}$ is scanned from the 004 to the 006 Bragg reflection. Below the ordering temperature $T_{N,2}$ magnetic reflections are observed at incommensurate $\boldsymbol{Q}$ vectors 00l with $l = 2n \pm \tau$. For the high-T and medium-T phase a single τ of about 0.79 is found, pointing to a sinusoidal or spiral ordering along 001. Several Kelvin around the transition from high-T to intermediate-T the value of τ becomes temperature dependent. This is better seen in Fig. 2a where the evolution of the magnetic reflections at 0 0 4+τ is plotted against temperature. Upon transition from one magnetic phase to another, abrupt changes

in peak positions and intensities occur which allow to clearly separate the phases. Fig. 2b shows the integrated intensity of the reflection related to each of the phases as a function of temperature.

For the low-T phase no notable temperature dependence of τ values are found but now several additional magnetic reflections emerge (see Fig. 1). The underlying magnetic order cannot any more be described by a single propagation vector and must be considerably more complex. Our magnetic susceptibility data shows a small hysteresis opening up in the low-T phase when H is applied along 001 which could be due to a canting of magnetic moments away from the c axis.

To fully understand the magnetic order in $EuRh_2Si_2$ it is, therefore, necessary to also know the orientation of the magnetic moments in each phase. This could be done by means of x-ray magnetic diffraction at the Eu $M_{4,5}$ edges, in resonance to the Eu 4f shell where the magnetic moments in $EuRh_2Si_2$ reside. Both, the reflections at 0 0 τ and 0 0 2-τ would be accessible with the momentum transfers achievable at these photon energies. In addition, high purity and easy control over the incoming polarisation is possible in the soft X-ray range with Apple-type undulators. A proposal for a respective experiment has been put in for beamline ID08 of the ESRF.

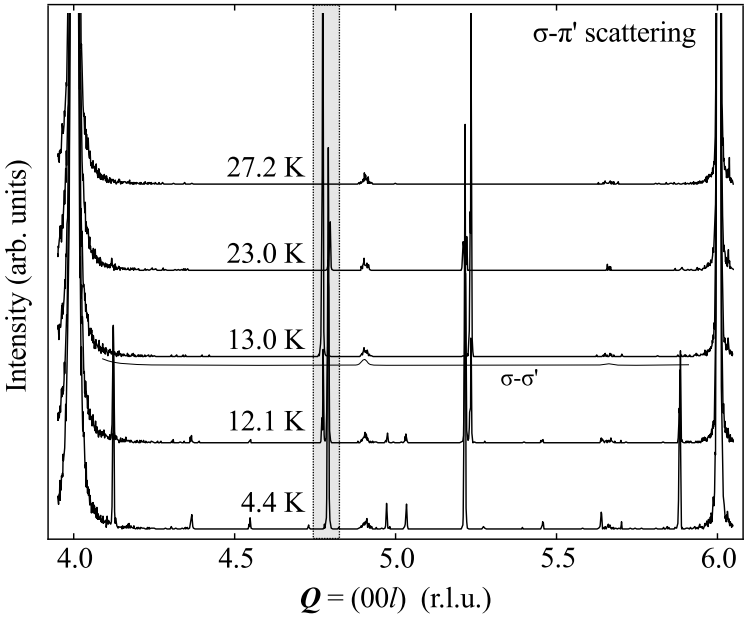

Fig. 1: *Intensity in the σ-π' scattering channel as* ***Q*** *is scanned from 004 to 006 for the three anti-ferromagnetic phases of $EuRh_2Si_2$: the low-T phase (T = 4.4 K), transition from the low-T to medium-T phase (12.1 K), the medium-T phase (13 K), and the high-T phase (23 K). For comparison the same scan is shown for T above the ordering temperature T_N = 24.5 K and, in the medium-T phase, for the σ-σ' channel which is insensitive to magnetic ordering. Details of the temperature dependent evolution in the dashed box around l = 4.79 are shown in Fig. 2.*

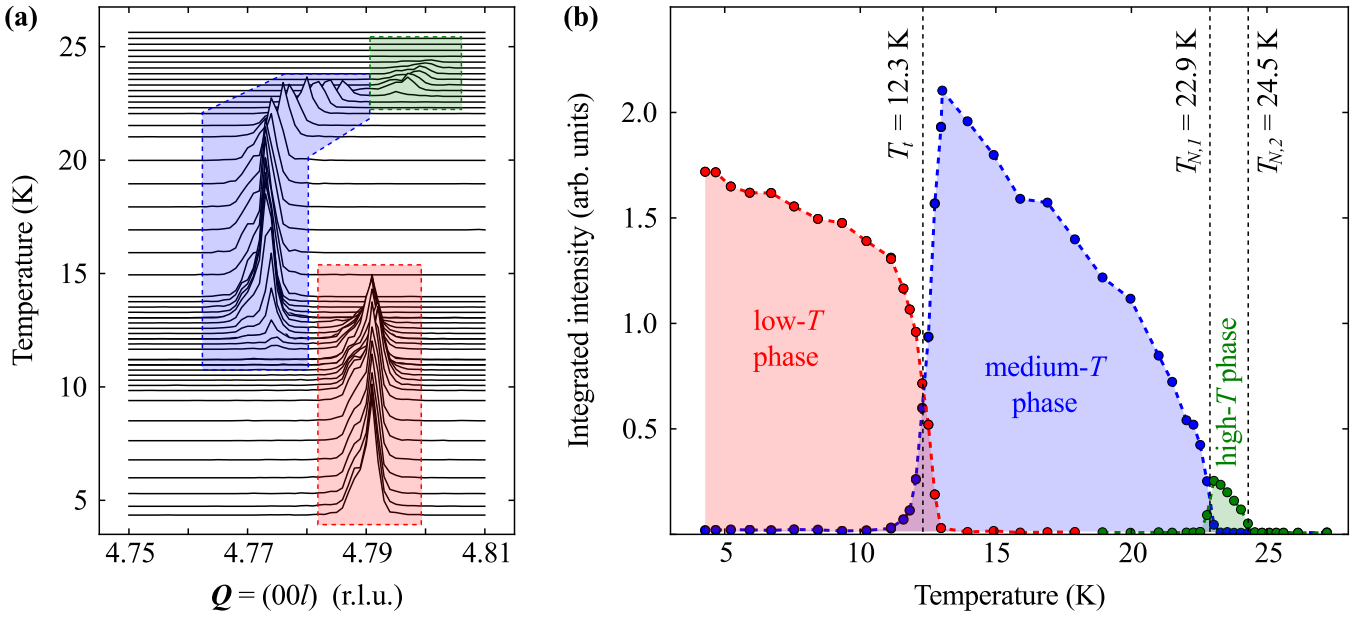

Fig. 2: ***(a)*** *Evolution of the magnetic reflections at* ***Q*** *= 0 0 4+τ with τ ~ 4.79 as a function of temperature.* ***(b)*** *Temperature dependence of the integrated intensity of the magnetic reflections related to each of the AFM phases.*