Experimental report

17/01/2018

Proposal: **5-41-893** **Council:** 4/2016

Title: Uniaxial pressure dependence of magnetic order in partially frustrated CePdAl

Research area: Physics

This proposal is a new proposal

Main proposer: **Stefan LUCAS**

Experimental team: Oliver STOCKERT
Stefan LUCAS

Local contacts: Karin SCHMALZL

Samples: CePdAl

Instrument	Requested days	Allocated days	From	To
D23	6	0		
D10	0	5	06/10/2016	12/10/2016

Abstract:

The metallic heavy-fermion compound CePdAl might be a model system to investigate the influence of magnetic frustration on quantum criticality. The antiferromagnetic order below 2.7K can be suppressed to 0 by applying hydrostatic or chemical pressure. Due to the arrangement of Ce ions on a distorted Kagomé lattice in the basal plane, geometric magnetic frustration is present. Neutron scattering experiments reveal, that only two thirds of the Ce ions participate in long-range magnetic order whereas the other third remains mainly disordered.

Applying uniaxial pressure within the basal plane modifies the exchange interactions and thus might lift the frustration. Moreover, effects of different magnetic domain population are expected. In a previous measurement under constant uniaxial stress, remarkable changes in magnetic intensity were observed. It shall be investigated, how uniaxial pressure can tune the degree of frustration and how it influences the stability of magnetic order in CePdAl.

Uniaxial pressure dependence of magnetic order in partially frustrated CePdAl (Proposal 5-41-893)

In the research field of strongly correlated electron systems, magnetic frustration is an interesting topic since several decades. By preventing magnetic systems from long-range ordering, new quantum states of matter and interesting quantum mechanical effects have been discovered [1]. Recently the influence of magnetic frustration on quantum phase transitions, i.e. continuous $T = 0$ phase transitions, was theoretically described [2]. These kind of phase transitions are driven by a non-thermal tuning parameter, e.g. pressure, magnetic field or chemical substitution. Magnetic frustration can also act as a tuning parameter and span a new axis in the phase diagram [2]. In order to change the degree of frustration and influence the magnetic order, uniaxial pressure is an ideal tool, which we used in this experiment to study its effect on the partially frustrated system CePdAl.

The intermetallic compound CePdAl is a rare example of a heavy-fermion metal, which shows effects of magnetic frustration. Below $T_\mathrm{N} = 2.7\,\mathrm{K}$ two thirds of the magnetic Ce^{3+} ions order antiferromagnetically, whereas the other third does not participate in long-range magnetic order [3]. This is due to the arrangement of the moments on a distorted kagome lattice in the hexagonal basal plane leading to geometric frustration. Because of the hexagonal symmetry, three magnetic domains exist, which are described by the following propagation vectors: $\vec{q}_1 = (0.5\;0\;0.35)$, $\vec{q}_2 = (0\;0.5\;0.35)$ and $\vec{q}_3 = (0.5\;-0.5\;0.35)$ [3]. Using a horizontal $(h\;0\;l)$ scattering plane and a neutron wave length of 2.36 Å, we were able to investigate all 3 domains at D10 by tilting the detector. A constant uniaxial pressure of about 0.8 kbar was applied along the k-direction, i.e. within the frustrated basal plane using our homemade uniaxial pressure cell. As a reference, we measured the sample again after releasing the uniaxial pressure to zero.

Fig. 1 shows the effect of uniaxial pressure for the three different magnetic domains at base temperature of about $T = 1.6\,\mathrm{K}$. One can clearly see, that the intensity of domain $\vec{q}_1$ is decreased by about 80 %, wheras the other 2 domains are stabilized by about 50 % each. Thus, a moderate uniaxial pressure already leads to a clear change in the magnetic domain population, indicating that the initial magnetic order is very sensitive to weak perturbations. We also observed, that the correlation length or domain size increased along the c-direction, whereas it seemed to be decreased in the basal plane. If this is a true effect is difficult to say, because also the slightly different alignment of the sample might cause some slight deviations. However, it might also indicate a crucial role of the interactions along the c-direction, which were not taken into account in more detail so far.

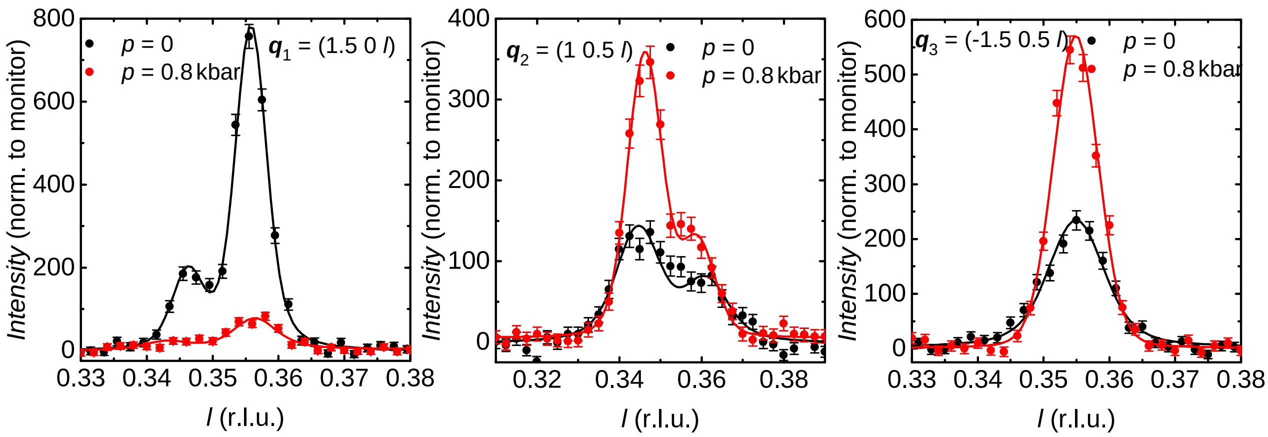

Figure 1: Normalized magnetic intensity of the 3 different magnetic domains at $T = 1.6\,\mathrm{K}$ at ambient (black dots) and uniaxial pressure of 0.8 kbar (red dots). Due to a twinning of the single crystal, a double-peak structure occurs at some Bragg peaks. Solid lines are guides to the eye.

Looking at the temperature dependence of the normalized integrated magnetic intensity of the $\vec{q}_2$ domain as an example in Fig. 2, one can see, that the intensity around 2.7 K is slightly enhanced under uniaxial pressure. Most striking however is, that there is a difference of about 100 mK in the onset of short-range order between the data under uniaxial pressure and zero pressure (see Fig. 2). This is a clear indication, that the magnetic order is stabilized under uniaxial pressure and that the long-range magnetic order persists to about 2.8 K instead of only 2.7 K. The corresponding Néel temperatures marked in Fig. 2 are estimated by the inflection point in the temperature dependence of the line width. Above T_N there is still a remarkable amount of short-range order present due to the presence of magnetic frustration.

With this uniaxial pressure measurement, we could nicely show, that the magnetic order of CePdAl is very sensitive to uniaxial pressure. Applying only 0.8 kbar within the frustrated basal plane leads to strong effects in the magnetic domain population and a stabilization of the magnetic order. The Néel temperature could be increased by about 100 mK, which is a remarkable effect and shows, that uniaxial pressure might be a powerful tool to tune magnetic frustration. Further measurements under even higher uniaxial pressures or along the c-direction would be very interesting to learn more about the magnetic anisotropy and stability of the partially frustrated state in CePdAl.

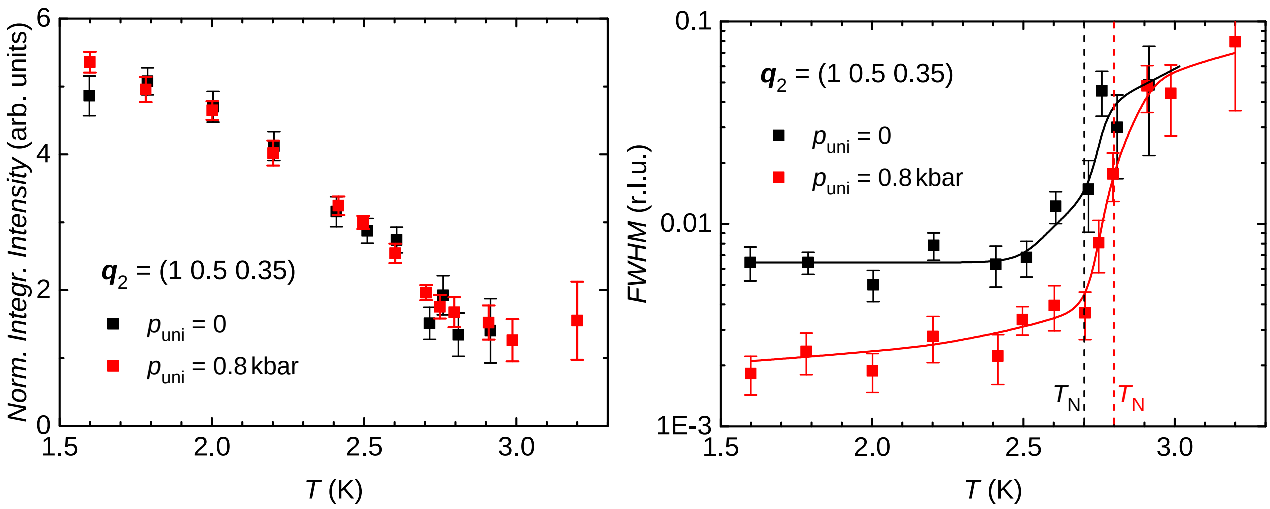

Figure 2: Temperature dependence of the integrated intensity (normalized to low temperature data) and peak width (FWHM) of l-scans of the $\vec{q}_2$ domain. Lines are guides to the eye.

[1] L. Balents, Nature **464**, 199 (2010); [2] Q. Si, Phys. Status Solidi B **247**, No. 3, 476-484 (2010); [3] A. Dönni et al., J.Phys.: Cond. Mat., 11213 **8** (1996);