ESRF

Experiment title: Search for quadrupolar ordering in PrB_6	Experiment number: BM-28-01-889

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Report:

When the orbital angular momentum of electrons around an ion is not quenched by a large crystal field, one has the possibility that the higher order multipole moments of those electrons at each ionic site may align, because whilst the spin angular momentum may only be expanded up to dipolar terms, the orbital moment may be expanded up to $2l$ multipolar moments.

This multipolar ordering has been postulated to occur in PrB_6 and to be responsible for stabilising the double-q magnetic structure which is observed below 4.2 K [1]. In particular it is believed that the Q_{xy} quadrupoles are aligned in anti-phase through a nearest neighbour quadrupole-quadrupole interaction which causes a doubling of the cubic unit cell in all directions, such that the ordering wavevector is $(\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2})$.

In a previous XMaS experiment [2] we observed a superlattice reflection at such a wavevector which is present in the $\sigma\sigma$ but not in the $\sigma\pi$ channel. This indicates that it is not of magnetic origin. Time pressures meant, however, that we could not further investigate the azimuth dependence of the intensity of this peak, and hence deduce its order parameter.

The aim of this experiment was to accomplish this task. We found however, that due to sample degradation in the intervening period, that the structural Bragg intensities are an order of magnitude less than what we had observed previously. As the $(\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2})$ peaks were previously seen to have intensities over three orders of magnitude less than the structural Bragg peaks, and were just above background, they were undetectable in this experiment.

In addition to this we observed a splitting of the magnetic peaks at 5K in the incommensurate phase. However, this occurred most at an azimuth angle $\psi = 82^o$ ($\phi = 0^o$ in this setup), whilst no splitting was observed at $\psi = 175^o$ ($\phi = -90^o$). In addition, the (110) peak at $\psi = 170^o$ was also observed to split at 10 K. We thus attribute the second peak to another crystallite in the sample with a slightly different orientation. This may also be another sign that the sample had degraded between the present experiment and our last measurements in 2007. Figure 1 shows the temperature dependence of the Bragg peaks (222) at $\psi = 170^o$, (110) ($\psi = 80^o$) and the magnetic peaks which is at $(\frac{5}{4}\ \frac{5}{4}\ \frac{1}{2})$ at 2 K and at $(\frac{5}{4}\ 1.2\ \frac{1}{2})$ ($\psi = 80^o$) at 5K.

References

[1] M.D. Le, *Magnetism and Quadrupolar Order in f-electron systems*, PhD Thesis, University of London 2009.

[2] H.C. Walker, K.A. McEwen, D.F. McMorrow, M. Beckmann, J-G. Park, S. Lee, F. Iga and D. Mannix, *Phys. Rev. B* **79** (2009) 054402

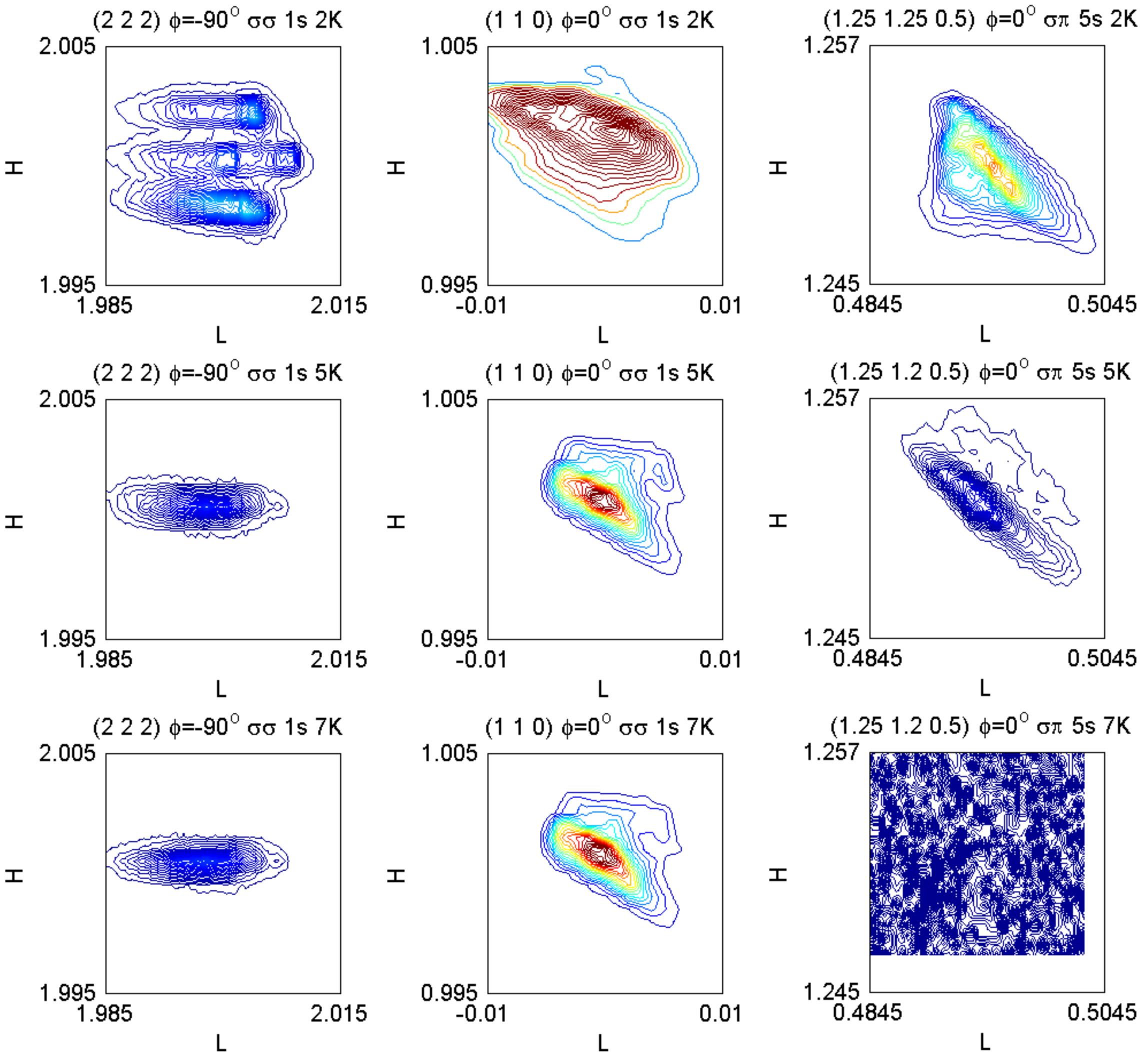

Figure 1. Temperature dependence of the (222), (110) and magnetic peaks. At 2 K in the commensurate phase the (222) peaks is seen to be clearly split due to a structural transition, as is the magnetic peaks. The splitting of the (110) peak at 5K persists above T_N, and is thus probably due to another crystallite.