Experimental report

05/02/2016

Proposal: **5-41-806** **Council:** 10/2014

Title: Magnetic field inducing co-existing antiferromagnetic phases in $SrYb_2O_4$

Research area: Physics

This proposal is a continuation of 4-01-880

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Samples: $SrYb_2O_4$

Instrument	Requested days	Allocated days	From	To
D10	8	8	11/05/2015	19/05/2015

Abstract:

$SrYb_2O_4$ is an insulating magnet, consisting of two types of zigzag chains running along the c-axis and forming a honeycomb structure in the ab-plane. The similar first and second-neighbor distances suggest high geometrically frustrated magnetic interactions. This frustration sums up to strong single ion anisotropy to produce a highly degenerate ground state manifold reflected by a very complex and anisotropic magnetic phase diagram. Despite of $SrYb_2O_4$ having a CurieWeiss temperature of −110K, the compound only orders at 0.9K at zero field, the magnetic structure is found to be noncollinear with a reduction of the ordered magnetic moment from the full ionic moment. Due the competition between frustration and high single ion anisotropy, $SrYb_2O_4$ has very rich and complex magnetic phase diagram. New magnetic Bragg peaks appear at 5T, when the field is applied along the c axis, suggesting a formation of a new magnetic structure. Here we propose to study these different phases using single crystal neutron diffraction on D10.

Magnetic field inducing co-existing antiferromagnetic phases in $SrYb_2O_4$

$SrYb_2O_4$ is an insulating magnet, consisting of two types of zigzag chains running along the c-axis and forming a honeycomb structure in the ab-plane. The similar first and second-neighbor distances suggest high geometrically frustrated magnetic interactions. This frustration sums up to strong single ion anisotropy to produce a highly degenerate ground state manifold reflected by a very complex and anisotropic magnetic phase diagram (see Fig. 1). Despite of $SrYb_2O_4$ having a CurieWeiss temperature of −110K, the compound only orders at 0.9K at zero field, the magnetic structure is found to be non-collinear with a reduction of the ordered magnetic moment from the full ionic moment [1]. The different magnetic phases formed when applying a field along the c-axis have been investigated by neutron diffraction on D10.

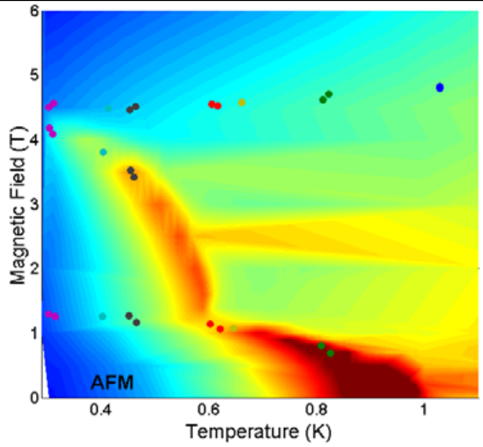

Figure 1. Magnetic phase diagram with magnetic field along the c-axis. The colors indicate the heat capacity in units of J/K. The circles indicate the critical fields extracted from magnetocaloric effect measurements.

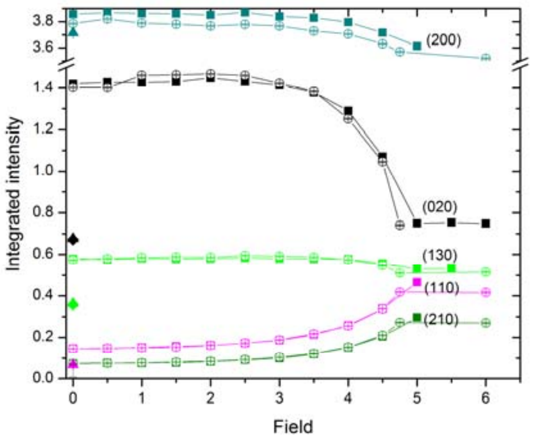

Figure 2. Fitted integrated intensity of the most relevant magnetic plus nuclear Bragg peaks measured on D10. The circles indicate measurements at 30mK, while the squares were taken at 60mK and triangles and rhombohedra are above the Neel temperature.

For the experiment at D10 a 3.2g $SrYb_2O_4$ single crystal has been mounted in a cupper holder, aligned to have the c-axis vertical and mounted in a dilution stick. A vertical magnet was used to reach fields of up to 6T. Three different magnetic phases were investigated by measuring the temperature and magnetic field dependence of key magnetic reflections. Additionally, incommensurate positions where new Bragg peaks appear on previously measured E2-HZB data were checked, but no intensity was found at those positions.

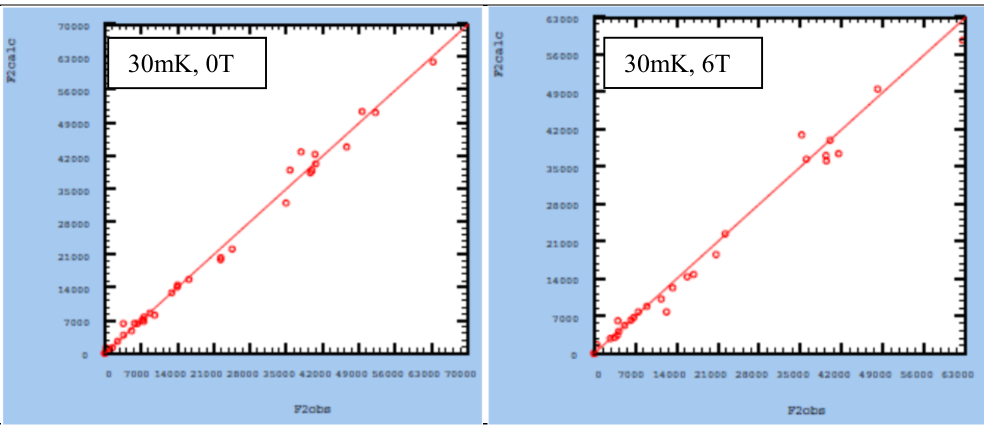

Figure 3. Observed vs. calculated integrated Bragg intensity of SrYb2O4 nuclear plus magnetic reflections measured on D10 at T = 30mK and 0T and 6T.

The measured data set were refined using Fullprof, the obtained structures and refinements are shown in Figures 3, 4 and 5. In table 1 all results from the refinements are listed. The zero field results are in agreement with published results [1], however total ordered moment is smaller than previously found. When a magnetic field is applied along the c-axis a ferromagnetic mode is formed along the field.

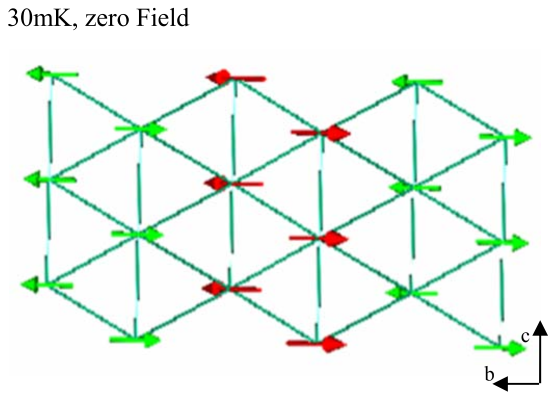

Figure 4. Magnetic structure of SrYb2O4 where the arrows represent the Yb3+ ions spins (Yb1 green, Yb2 red) projected onto the bc plane.

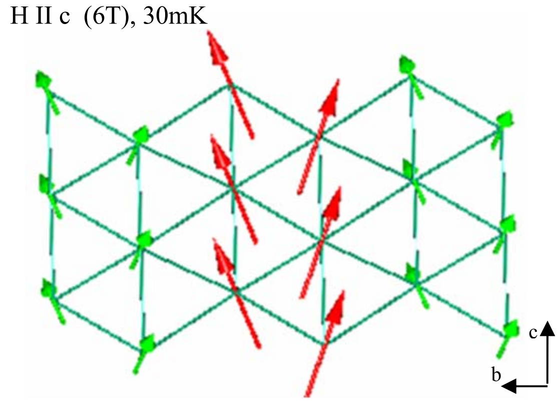

Figure 5. Magnetic structure of SrYb2O4 when applying a magnetic field of 6T along the c-axis. Arrows represent the Yb3+ ions spins (Yb1 green, Yb2 red) projected onto the bc plane.

Table 1: Results of the magnetic structure refinement assuming $\Gamma4(A_xG_y)$ as the magnetic mode for the magnetic structure at zero field and $\Gamma4(A_xG_y)+\Gamma6(F_z)$ for the 6T. The table shows the comparison of the refinement of the polarized data from D7 and the simultaneous refinement of nuclear and magnetic component of the data from D10, at zero field and at 6T applied along the c-axis.

	30mK, 0T (D7 + E4 refinement)			**30mK, 0T (D10 refinement)**			**30mK, H II c 6T**			
Name	μ_x (μ_B)	μ_y (μ_B)	μ (μ_B)	μ_x (μ_B)	μ_y (μ_B)	μ (μ_B)	μ_x (μ_B)	μ_y (μ_B)	μ_z (μ_B)	μ (μ_B)
Yb11	3.37(5)	-1.9(1)	3.90(8)	1.231	-0.589	1.3648	-0.077	-0.617	1.571	1.6894
Yb12	-3.37(5)	1.9(1)	3.90(8)	-1.231	0.589	1.3648	0.077	0.617	1.571	1.6894
Yb13	-3.37(5)	-1.9(1)	3.90(8)	-1.231	-0.589	1.3648	0.077	-0.617	1.571	1.6894
Yb14	3.37(5)	1.9(1)	3.90(8)	1.231	0.589	1.3648	-0.077	0.617	1.571	1.6894
Yb21	0.81(5)	-2.0(1)	2.2(1)	0.280	-0.679	0.7347	0.593	-0.175	0.578	0.8463
Yb22	-0.81(5)	2.0(1)	2.2(1)	-0.280	0.679	0.7347	-0.593	0.175	0.578	0.8463
Yb23	-0.81(5)	-2.0(1)	2.2(1)	-0.280	-0.679	0.7347	-0.593	-0.175	0.578	0.8463
Yb24	0.81(5)	2.0(1)	2.2(1)	0.280	0.679	0.7347	0.593	0.175	0.578	0.8463
	Rexp=5.76			Rexp=3.7			Rexp=4.73			

Although the acquired data has been enough to identify the magnetic modes of the 0T and 6T phases, technical problems with the dilution refrigerator in addition to a shorter beamtime due to unexpected reactor shut down did not allowed us to acquire a completed dataset to get a proper refinement of the magnetic phases. A continuation experiment will be necessary to complete the project.

References:
[1] D. L Quintero-Castro, et al., Phys. Rev. B 86, 064203 (2012)