Experimental Report

04/02/2014

Proposal: **5-31-2288** **Council:** 10/2012

Title: Magnetic order of MnGe under pressure

This proposal is a new proposal

Researh Area: Physics

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Samples: MnGe

Instrument	Req. Days	All. Days	From	To
D20	4	6	18/03/2013	22/03/2013
			22/07/2013	24/07/2013

Abstract:

MnGe is an helical magnet of the same B20 structure as MnSi, but much less studied due to its difficult synthesis. Recent measurements show that it combines a higher value of the Neel temperature (170K) and ordered moment (2.5 μB) to a very small helical period (38 A at low temperature), yielding the larger Topological Hall effect of the B20 family. In contrast with MnSi, recent band calculations on MnGe suggest a stability of the Mn moment up to high pressures, then a transition towards a semi metallic state. We propose to study evolution of the magnetic structure of MnGe under pressure.

Helical magnets with B20 cubic structure attract a lot of interest due to their unusual magnetic and electric properties. They also show strong instabilities versus pressure and or applied field. The most well-known is MnSi, where helical order is stabilized below TN=29.5K. Under pressure, MnSi shows a quantum critical transition (QCP) towards a non-Fermi liquid state, stabilized above a critical pressure where the Néel transition vanishes [1]. Under a moderate magnetic field, it also shows a peculiar spin texture just below the Neel transition, the so-called A phase with skyrmion lattice [2]. This non colinearity and non coplanarity of the spin structure is the source of a Topological Hall Effect (THE). In the cubic B20 family, the helical order is mostly due to a competition between ferromagnetic exchange and the Dzyaloshinskii-Moryia (DM) anisotropy, which is non zero because of the lack of centro-symmetry of the structure [3,4]. With respect to MnSi, MnGe offers the possibility of decreasing the helical period. It has been much less studied than MnSi, since the synthesis of the metastable cubic MnGe phase is complex and only powdered samples are available. Recent neutron and susceptibility data [5,6] show a Néel transition at T_N= 170(5)K. Above T_N, a Curie-Weiss behavior is observed up to 300K, with an effective Mn moment of 3.68 μB close that expected for Mn^{4+} ion (3.87 μB), and a ferromagnetic Curie Weiss constant of +231K. MnGe also shows the largest THE response of all cubic magnets [5]. This large electric response is directly connected with the very short period of the helical modulation: about 30 Å, to be compared with ~180 Å in MnSi and up to 500 to 1000Å in FeGe and FeCoSi for instance.

To understand better the original magnetic behavior of MnGe, we investigated its crystal structure and magnetic order under pressure on D20. At low temperature (5-10K), well below T_N, we measured concomitantly the evolution of the crystal and of the magnetic structure giving us access to a good estimation of the long range ordered magnetic moment. Four sets of diffraction patterns and there thermal evolutions were measured at 1.9±0.1 GPa; 4.3±0.1 GPa; 8.5±0.4 GPa and 10.1±0.5 GPa obtained thanks to the Paris-Edinburg pressure cell. For each pressure, we measured at least 5 temperatures (1 to 2 hours counting each) in the range of 10K-150K, to check the ground state and the T_N value. To observe the first satellite (situated at 2θ= 3.5-4° for λ=2.4 Å), we needed a well collimated beam, and a careful adjustment of the beam stop (see figure 1). About 10 hours were necessary to decrease the temperature and increase it again above 200K to change the pressure in a hydrostatic way, when the ethanol/methanol transmitting medium is liquid. We also measured the EOS at 300K to compare with that predicted by band structure calculations [8].

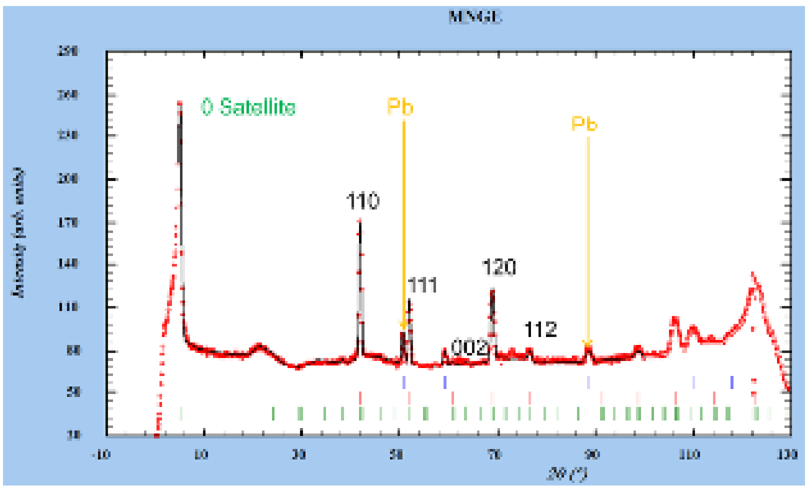

Figure 1 Diffraction pattern obtained with D20 diffractometer at 30K and 1.9GPa. A small shaving of lead was put in the MnGe powder in order to probe the pressure inside the anvil. Solid line is a Fullprof refinement.

Due to the weakness of the signal measured under high pressure, only the magnetic satellite of the (000) reflection can be observed, other satellites are too small to be seen. This magnetic reflection has been indexed with an incommensurate wave vector **k**= (0,0,ζ) in reciprocal lattice unit, with ζ varying from 0.137 to 0.223.

Three important results were obtained thanks to this experiment:

- The transition temperature decreases with increasing pressure. This decrease is linear and close to the MnSi behavior with one order of magnitude more in the pressure value to suppress the helical phase for MnGe.
- the Mn magnetic moment varies with pressure in two steps: it decreases linearly below 6 GPa then saturates to a small value around 1 μ_B above.
- The EOS at ambient temperature was accurate enough to be compared with *ab initio* model.

Following these measurements, a collaboration started with a German theoretician, and macroscopic measurements under pressure were also performed in collaboration with a Russian team. The neutron results (evolutions of T_N, Mn Magnetic moment, EOS) were used to constraint new *ab initio* band calculations, allowing us to build a new model to interpret them. A common paper has been selected by the Editor of Nature Communications and is currently under review [7].

References:

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