Experimental report

04/02/2016

Proposal: **5-31-2381**

Council: 10/2014

Title: Pressure induced quantum critical point in Mn1-xCoxGe chiral magnet

Research area: Physics

This proposal is a new proposal

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Samples: Mn1-XCoXGe , X=0.11

Instrument	Requested days	Allocated days	From	To
D20	5	5	26/06/2015	01/07/2015

Abstract:

MnGe chiral magnet shows giant Topological Hall Effect associated with small helical pitch. In MnGe we have observed a pressure induced Quantum Critical Point (QCP) associated with a High Spin- Low Spin transition, quite unique in the B20 family. At ambient pressure, substitution of Mn for Co strongly weakens Mn magnetism and suppresses the chiral order at low Co content (x=0.3). We propose to study the influence of pressure on a Mn1-XCoxGe sample (x=0.11) just above the Co-induced QCP. This experiment will allow us to see if the HS –LS transition is robust under Co substitution, to study the high pressure phase in details, and find the value of second QCP which marks the transition from the LS to a non-magnetic state. It will be an important step in the understanding of this unusual QCP.

ILL 5-31-2381: 26/06 - 01/07/2015

Pressure induced quantum critical point in $Mn_{1-x}Co_xGe$ chiral magnet

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Modern research on quantum criticality (QC) in itinerant magnets involves a great deal of experimental and theoretical efforts. Mechanical pressure or stress applied on chemically clean systems can drive them towards non-magnetic states as a result of an increasing delocalization of the electronic wave functions, implying the existence of a quantum critical point (QCP) at $T \rightarrow 0$. In some cases, *e.g.* notorious invar alloys, intermediate states can be stabilized between the ambient pressure "high spin" (HS) state and the non-magnetic "zero spin" (ZS) state reached at highest compression. Recent theoretical[1] and experimental[2,3] studies of the cubic chiral magnet MnGe revealed that such an intermediate "low spin" (LS) state was stabilized in a large pressure ($5 \leq p \leq 23$ GPa) and temperature (from base up to –at least- room T) range. On the other hand, long-range magnetic order (LRMO) is found to collapse at $p_0 \approx 13$ GPa, as extrapolated from the linear dependence of $T_N(p)$. A complementary route to QC can be paved by means of chemical doping of the pure system. For instance, Co-doping of MnGe ultimately leads to diamagnetic CoGe[4]. As a natural consequence, one should be able to reach a QCP in $Mn_{1-x}Co_xGe$ by optimizing its Co content. In this spirit, we have selected $Mn_{0.85}Co_{0.15}Ge$ which displays a sizeable ordered moment at ambient pressure but reduced Néel temperature and unit cell volume with respect to MnGe. These characteristics imply that the system must be closer to a magnetic instability and QCP as compared with the pure system. The goal of our experiment was thus twofold: *(i)* checking whether the HS-LS scenario would still hold in $Mn_{0.85}Co_{0.15}Ge$ and *(ii)* approaching the pressure-induced QCP while observing and quantifying gradual changes in its magnetic structure.

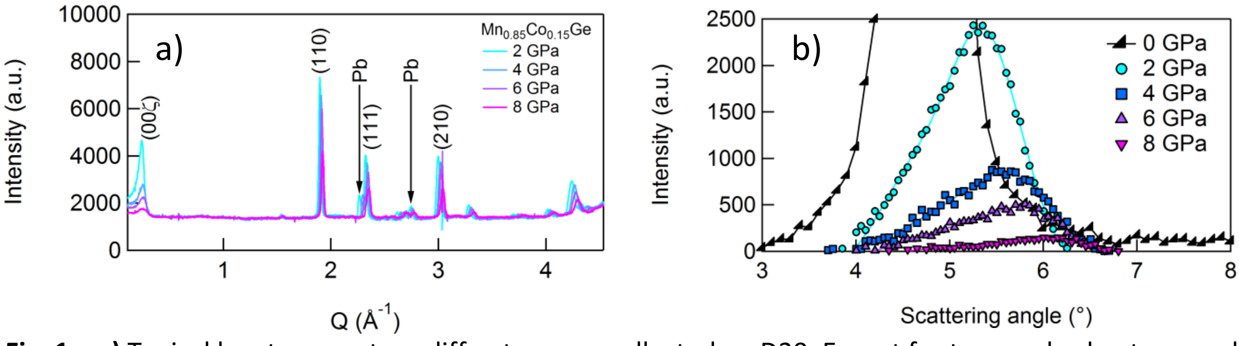

Fig. 1 – a) Typical low temperature diffractograms collected on D20. Except for two peaks due to a small slice of Pb used as pressure marker, the crystal structure and 0th–order helimagnetic satellite are well resolved. **b)** Pressure dependence of the 0th–order helimagnetic satellite at Q = (00ζ). Data at ambient pressure, recorded on the G4.1 diffractometer (LLB, Saclay) is shown for comparison.

[1] U.K. Rössler, J. Phys.: Conf. Series **391** (2012) 012104
[2] M. Deutsch *et al.*, Phys. Rev. B **89**, 180407(R) (2014)
[3] N. Martin *et al.*, arXiv:1601.05332 (2016)
[4] J.F. DiTusa et *al.*, Phys. Rev. B **90**, 144404 (2014)

We have recorded series of diffractograms as a function of pressure applied by means of a Paris-Edinburgh cell (2-10 GPa) and temperature (5-300 K). Since pressure can only be changed in a hydrostatic way close to room temperature (where the methanol/ethanol mixture used as transmitting medium is in liquid state), we could work at one pressure value per day as ≈ 10 hours were required to heat up and cool the sample back to 5 K.

A selection of low temperature diffractograms is displayed in Fig. 1a. The pressure evolution of the helimagnetic structure was followed through the 0^{th}-order satellite as shown in Fig. 1b (higher order satellites are not visible due to their low intensity). It allows determining the ordered moment and periodicity of the spin spirals. As opposed to pure MnGe, we find no trace of an intermediate low spin state in $Mn_{0.85}Co_{0.15}Ge$. Instead, the ordered magnetic moment appears to decay almost linearly as a function of pressure (Fig. 2a). From this evolution, we can estimate a critical pressure for the collapse of LRMO of about 10.3(6) GPa (against 13 GPa in MnGe). A naïve evaluation of the critical concentration x_C is then obtained using $\Delta p_0(x) \approx (10.3\text{-}13)/0.15 \approx -0.18$ GPa/[at % Co] via $x_C = p_0(0)/\Delta p_0(x) = 0.7(1)$. Note that $x_C < 1$, in agreement with the fact that CoGe shows no LRMO. Similar to MnGe, wavelength of the helical magnetic structure decreases with increasing pressure, but shows not saturation in the explored pressure range (Fig. 2b).

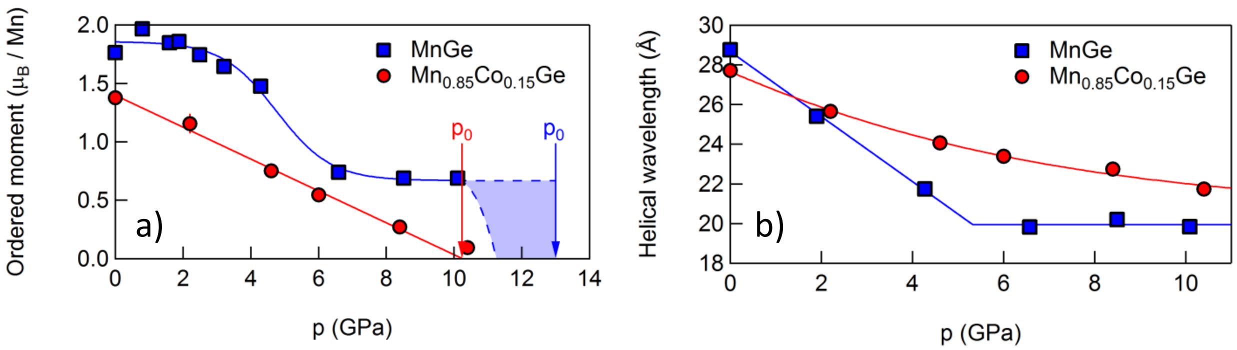

Fig. 2 – a) Pressure dependence of the ordered magnetic moment towards its collapse at $p_c \approx 10.5$ GPa. **b)** Evolution of the wavelength of the helical structure. Published high pressure data (partly obtained on D20) for pure MnGe is shown for comparison in both panels.

Apart from an unexpected electric shutdown on the experimental area, the instrument and sample environment worked remarkably well. The experiment was indeed successful since we could determine the *locus* of the QCP in $Mn_{0.85}Co_{0.15}Ge$ at $p_C = 10.3(6)$ GPa. Moreover, the obtained data allows us excluding a two-step disappearance of LMRO.

Our observations put additional constraints on the band model of MnGe and motivate further studies of quantum criticality in this system. These data will soon be published, along with macroscopic and complementary neutron measurements.