Experimental report

09/02/2016

Proposal: 5-31-2452 **Council:** 4/2015

Title: Evolution of magnetic structure in MnP as pressure tunes it towards superconductivity

Research area: Physics

This proposal is a new proposal

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Samples: MnP

Instrument	Requested days	Allocated days	From	To
D20	5	4	03/12/2015	07/12/2015
D23	5	5	07/12/2015	12/12/2015

Abstract:

Manganese phosphide MnP has been investigated for decades because of its rich magnetic phase diagram. The magnetic structure of MnP is ferromagnetic below 291K. It transforms into a helimagnetic structure at 47K with a propagation vector q = 0.117a*. Very recently Superconductivity was reported under pressures of 8 GPa. Since this finding might make MnP the first Mn-based superconductor, and superconductivity occur in the vicinity of FM, AFM and helical phases, there is a need to understand how the magnetism evolve upon doping as the system approaches the superconducting state. Our objective is to complete the phase diagram of magnetic structure with temperature and pressure by neutron diffraction experiments. Combining powder and single crystal diffraction we aim to: 1) Identify the magnetic phases up to 8GPa, 2) track pressure dependence of ordered moment and ordering vector, 3) refine the detailed magnetic structure in each of the identified phases.

The goal of this experiment was three-fold. The first was to identify the magnetic phases of MnP and their transitions in the ~2GPa range and up to 4GPa using powder diffraction on D20. The second was to solve the potential « AFM ? » phase discovered with bulk susceptibility measurements, using D20 and D23. Finally, the goal was to track the evolution of magnetic propagation vector and order parameter as a function of pressure up to 8 GPa using powder diffraction on D20

Manganese phosphide MnP has a rich magnetic phase diagram. It has a slightly distorted NiAs structure with the spacegroup of Pbnm (No.62). The magnetic structure of MnP is ferromagnetic below TC =291 K. It transforms into a helimagnetic structure at TS = 47 K with a propagation vector q = 0.117a*. Recently, a canted antiferromagnetic structure with weak ferromagnetic magnetization along the b* axis in the ferromagnetic phase, an alternatively tilted helimagnetic phase structure below Ts was found by neutronscattering experiment.Most importantly, in december 2014, the discovery of superconductivity in MnP was reported under pressures of 8 GPa and with TSC ~1 K.

Two experiments were performed with the Paris Edinburgh pressure cell, one with a 50mg powder sample on D20, and the other with a single crystal (of 4mm diameter and 1mm height) aligned with a and b in the scattering plane, on the single crystal diffractometer D23.

D20

We obtained powder patterns for λ =2.41 Å for a wide range of temperatures and for 6 different applied pressure loads, 300, 390, 470, 620 , 870 and 1120 bar. For each increase in pressure load, the sample was warmed up above a minimum temperature (200-250K for low applied pressure and 300K for the highest pressures). The sample was cooled back down to base using liquid Nitrogen to about 80K and then using the cryostat. Most of the powder patterns above 80K were obtained while warming up.
The actual applied pressure as a function of applied load and temperature. was obtained from calibrations with the (111) and (200) Pb Bragg peaks. Figure 1 shows the area of the pressure-temperature phase diagram access during this experiment. In addition, it shows the already known helimagnetic phase as well as the new magnetic phases discovered during this experiment.

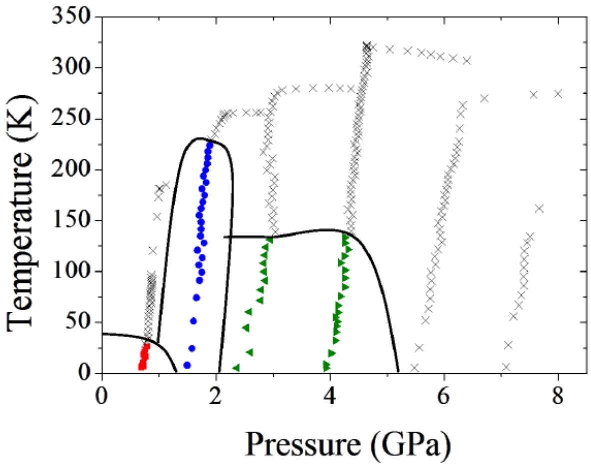

Figure 1 Points of the Pressure Temperature for which a powder pattern was obtained on D20. Red dots correspond to the helimagnetic phase. Blue and Green dots corrrespond to the new observed magnetic phases

D23

For the single crystal diffractometer experiment, three samples were prepared inside a lead capsule, and the two first attempts were not successful. The final sample was aligned with a and b in the scattering plane, with less than a degree of tilt. The sample was oriented so that the pillars of the Paris-Edinburgh pressure cell would not block the scattering from the 110 Bragg peaks. Each pillar correspond to approximatly 50° of blind area.

We measured at an incident wavelength of λ =2.38 Å, and the D20 results were used in order to calibrate the pressure and to choose which scans to perform. The applied pressure loads were : 300, 390 and 620 bar. The pressure cell failed due to an unidentified error and we could not apply 870 bar. As for D20, pressure was applied close to room temperature, and the sample was cooled down first via an nitrogen bath to 80K, and then using the cryostat. From nuclear Bragg peaks, we obtained the pressure-temperature dependance of the lattice parameters a and b. For the helimagnetic phase, we obtained the temperature dependance of the magnetic intensity from reciprocal scans.

Concerning the investigation of the new magnetic phases (at 1.5 and 3.9 GPa), the reciprocal space that we searched at 5.5 K is shown in Figure 2. We did not find the magnetic peaks expected from the D20 experiments, even when adding a small out of plane component by 1, 3 and 5 degrees tilting. Fom this we conclude that the propagation vector of the new phases should have a c component. The small vertical divergence of the Paris- Edinburgh cell does not allow for a study of the c component for the alignement of our ample. We plan to apply for beamtime to measure the first magnetic phase using a 15kbar clamp cell, allowing us to explore the reciprocal space along c.

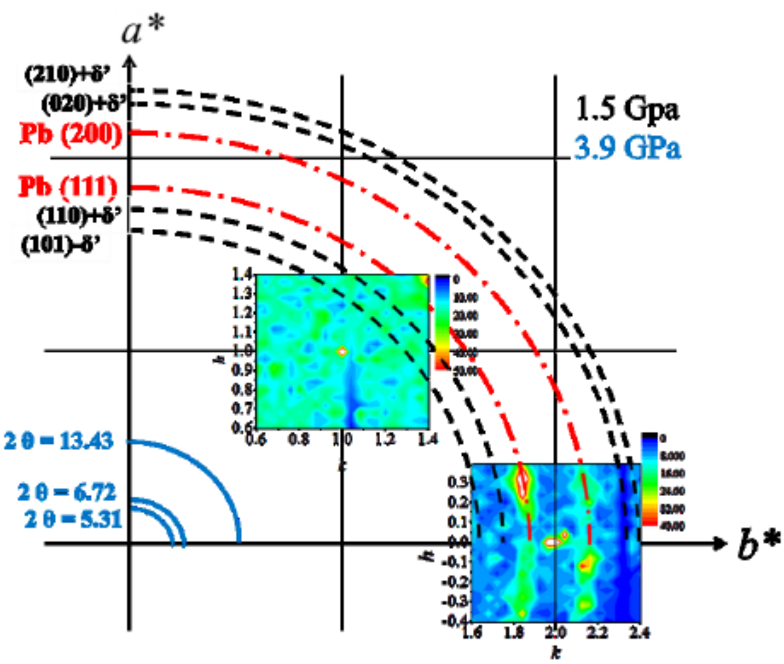

Figure 2 : Area of the reciprocal space investigated on D23. No trace of the magnetic peaks observed peaks on D20 at 1.5 and 3.9 GPa were found on D23.