Experimental report

07/09/2021

Proposal: **5-31-2660** **Council:** 10/2018

Title: Tuning incommensurate spin textures in a Weyl semimetal

Research area: Physics

This proposal is a new proposal

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Samples: Ce1-xPrxAlGe

Instrument	Requested days	Allocated days	From	To
D1B	0	1	11/07/2019	12/07/2019
D2B	2	0		
D11	4	2	04/09/2019	06/09/2019

Abstract:

This study aims at the investigation of a Weyl semimetal with tunable ferromagnetic exchange couplings in the series of Ce1-xPrxAlGe. The end members CeAlGe and PrAlGe offer remarkable new physics in terms of being rare examples of magnetic Weyl semimetals, while the solid solutions of Ce and Pr allow a tuning between an easy-plane spin texture with an incommensurate component (CeAlGe) and an easy-axis ferromagnet (PrAlGe). Here we propose to study the various solid solutions first by powder diffraction, and then by small-angle neutron scattering (SANS) to determine the composition-dependence of the magnetic ground state in detail. These data are needed for the full understanding of the interplay between magnetism and magnetotransport pheneomena arising from the topologically non-trivial features of the electronic structures in semimetals.

Experimental Report 5-31-2660: Tuning incommensurate spin textures in a Weyl semimetal

Abstract

This study aims at the investigation of a Weyl semimetal with tunable ferromagnetic exchange couplings in the series of $Ce_{1-x}Pr_xAlGe$. The end members CeAlGe and PrAlGe offer remarkable new physics in terms of being rare examples of magnetic Weyl semimetals, while the solid solutions of Ce and Pr allow a tuning between an easy-plane spin texture with an incommensurate component (CeAlGe) and an easy-axis ferromagnet (PrAlGe). Here we propose to study the various solid solutions first by powder diffraction, and then by small-angle neutron scattering (SANS) to determine the composition-dependence of the magnetic ground state in detail. These data are needed for a full understanding of the interplay between magnetism and magnetotransport phenomena arising from the topologically non-trivial features of the electronic structures in semimetals.

Together with the data of the EASY proposals 450 and 451 we could obtain a good understanding of the magnetic and structural properties of the solid solution series of $Ce_{1-x}Pr_xAlGe$ and published our results in Ref. [1]. For the magnetic ground state, the first obvious result is that the magnetic difference pattern strongly changes from x = 0.2 to x = 0.4 (see Figure 1). Starting from x = 0.4 the moments align ferromagnetically as in the pure PrAlGe case, with Γ^1 as the irreproducible solution. We find an increasing moment of 1.25711 μ_B (x = 0.4) to 1.77025 μ_B (x = 0.6) compared to 2.25 μ_B for PrAlGe. As apparent from Figure 3 the x = 0.2 sample has a similar behavior as the pure CeAlGe sample with an incommensurate satellite ring. The resulting q value of $Ce_{0.8}Pr_{0.2}AlGe$ seen in the SANS data of 0.117 Å with a k vector of k = a·q/(2π) = 0.079 shows a shift compared to our results of x = 0. For x = 0.2, the magnetic structure refines well with the multi-k model from the x = 0 sample as shown in Figure 1. We obtain a moment oscillating from 0 to 0.674 μ_B compared to 1.02 for x = 0. In Figure 3 we extrapolate the moment development and find with x = 0.3 the realization of an induced ferromagnetic field of similar size to the one we found experimentally for CeAlGe necessary to induce a Q = 1 state. In Figure 3 we show the q and temperature dependence of the SANS measurement on a x = 0.2 and 0.3 polycrystalline ingot that confirms a peculiar behavior as we find a crossover region of an incommensurate Ce ordering and a diffuse scattering at low q from the spin freezing of the Γ^1 Pr solution.

x	**0.2**	**0.4**	**0.6**
a	4.26003 (9)	4.26290(7)	4.25638(9)
c	14.65517 (39)	14.66125(32)	14.64836(38)
z_R	0.59483(38)	0.59140(29)	0.59308(35)
z_{Al}	0.17432(36)	0.17127(27)	0.17738(32)
z_{Ge}	0.01319(0)	0.00642(0)	0.01246(0)
$x_{refined}$	0.04	0.064	0.32
R	4.46	3.52	3.47

Table 2: Rietveld refinement results of the same three powder samples of $Ce_{1-x}Pr_xAlGe$ measured at 15 K with a wavelength of 2.52 Å on D1B.

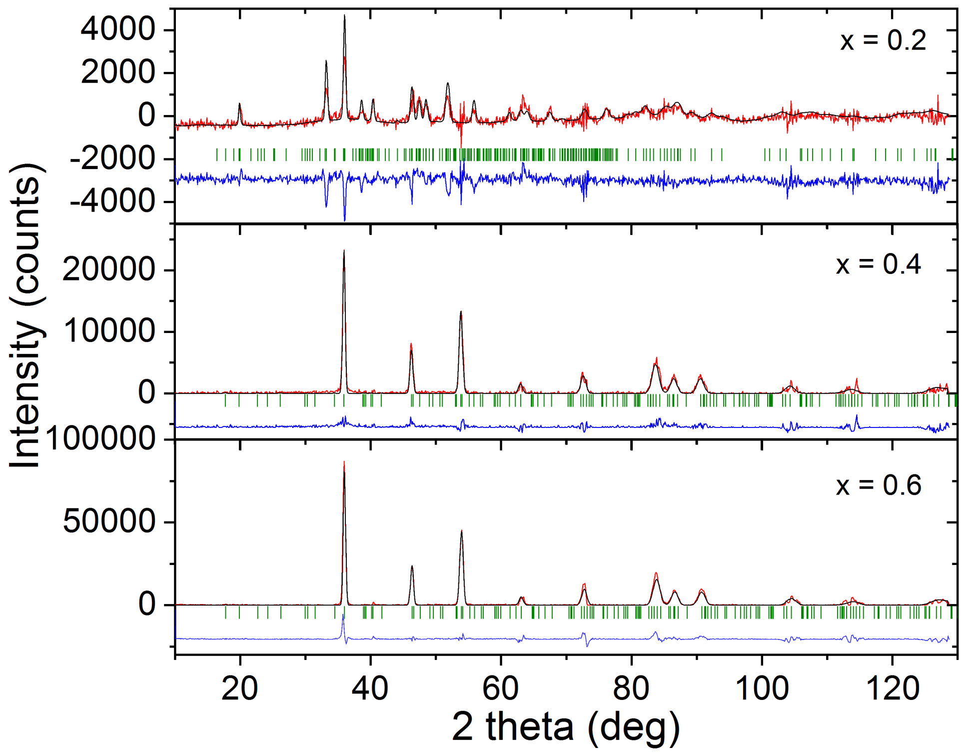

Figure 1: NPD difference pattern of the 1.5 K and 15 K, 2.52 Å data of D1B and the resulting magnetic refinement.

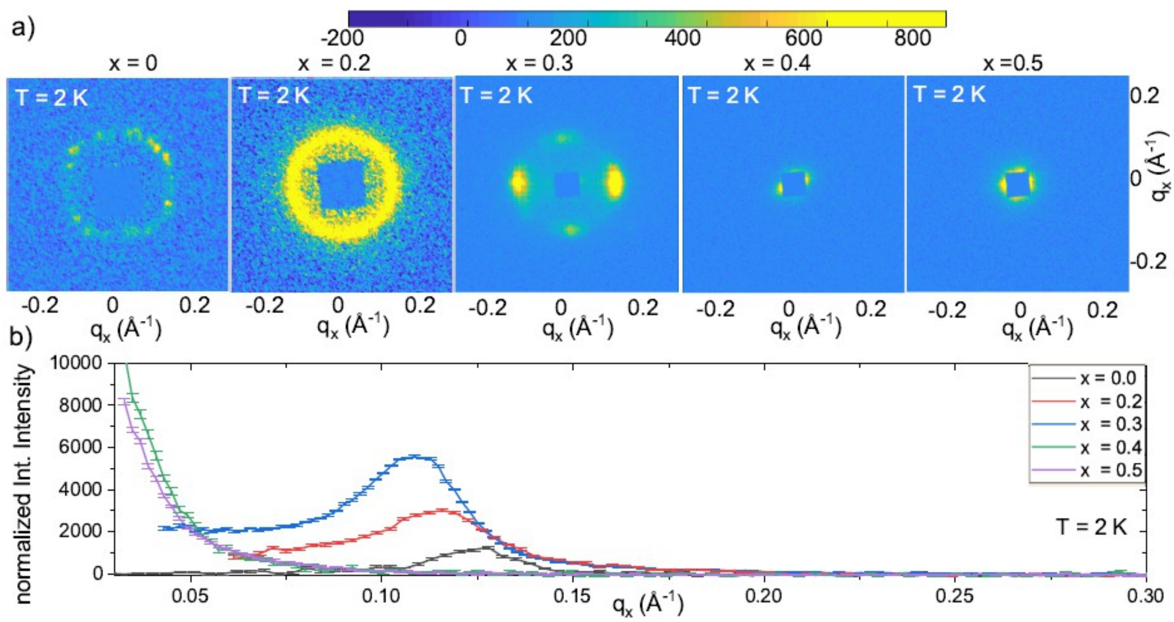

Figure 2: a) SANS magnetic scattering shown for the polycrystalline ingots in q space, where the scaling was set to the same range for comparison. b) Integrated intensities of the SANS patterns plotted versus the wave vector q normalized to the sample size that intensities can be compared.

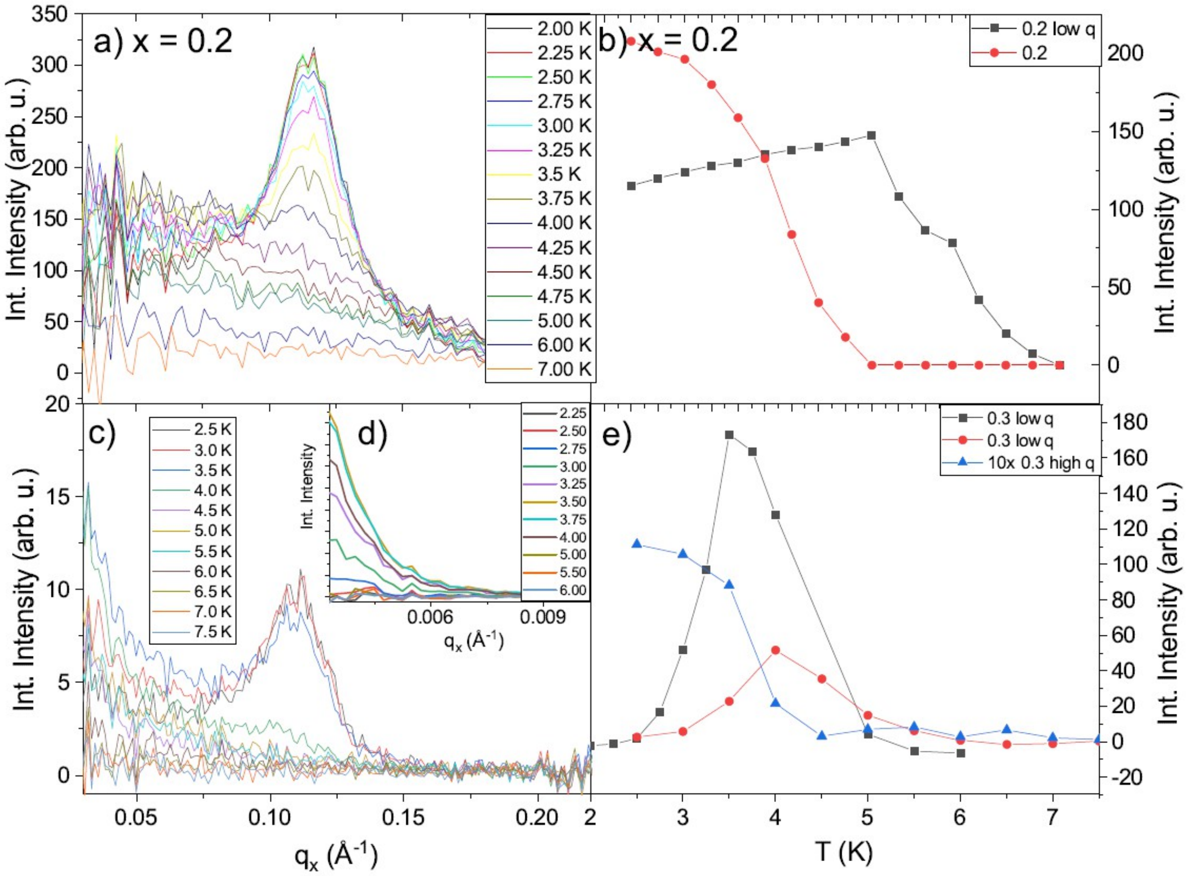

Figure 3: Integrated intensities of the SANS patterns of a,b) x = 0.2 and c,d,e) x = 0.3 plotted first versus the wave vector in a,c,d) and second versus the temperature in b,e).

References

[1] Pascal Puphal et al. Phys. Rev. B 101, 214416 (2020).