Suppression of the Shastry-Sutherland phase in Ce_2Pd_2Sn at a field induced critical point

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(Dated: November 19, 2018)

The magnetic phase diagram of Ce_2Pd_2Sn is investigated through the field dependence of thermal, transport and magnetic measurements performed at low temperature. The upper transition, $T_M = 4.8\,K$ is practically not affected by magnetic field up to $B = 1\,T$, whereas the lower one $T_C(B)$ rapidly increases from 2.1 K joining T_M in a critical point at $T_{cr} = (4.2 \pm 0.3)K$ for $B_{cr} = (0.12 \pm 0.03)$ T. At that point the intermediate phase, previously described as an unstable Shastry-Sutherland phase, is suppressed. A detailed analysis around the critical point reveals a structure in the maximum of the $\partial M/\partial B(B)$ derivative which could be related to the formation of a novel phase in that critical region.

PACS numbers: 75.20.Hr, 71.27.+a, 75.30.Kz, 75.10.-b

I. INTRODUCTION

Complex or metastable phases are favored in the proximity of magnetic transitions since, within the Landau theory, the change of sign of the first term of the free energy $G(\psi)$ broadens its minimum as a function of the order parameter ψ as $T \to T_C$. In these critical conditions the 'roughness' of $G(\psi)$, occurring in real systems, may present relative minima which may become relevant in the formation of novel phases [1]. In recent years an increasing number of magnetic systems exhibiting non trivial types of order parameters have been reported. Those complex phases may correspond to metastable ground states, such as frustrated or 'spin ice' [2] systems, Shastry-Sutherland phases [3, 4] or other exotic phases. Those phases can be tuned by non-thermal control parameters like pressure (e.g. in non conventional superconductors [5]) or by magnetic field (e.g. in $Sr_3Ru_2O_7$ [6]) and driven to a quantum critical points at $T = 0$ [7]. Alternatively, some of those phases become unstable under moderate variation of the external parameters and are suppressed in a critical point at finite temperature.

Recently, the formation of an unstable Shastry-Sutherland ShSu phase was reported to form in Ce_2Pd_2Sn [8]. That phase is observed within a limited range of temperature, between $T_M = 4.8 > T > T_C = 2.1\,K$, having as the upper limit a correlated paramagnetic phase and a ferromagnetic FM one as ground state GS. This exotic phase builds up from FM-dimers formed by Ce nearest-neighbor atoms, and shows the onset of magnetic correlations at $T \leq 20\,K$. An antiferromagnetic AF exchange interaction between those dimers drives the formation of the ShSu phase, realized in this compound as a quasi 2D square lattice of effective spin $S_{eff} = 1$ below $T_M = 4.8\,K$ [8].

Stable ShSu phases are predicted for AF-dimers and AF inter-dimer interactions by theoretical calculations [4]. This scenario was recently observed in Yb_2Pt_2Pb single crystals [9], which undergoes a slight shift of part of Pt atoms that results in two types of Yb-Pt tetrahedral sublattices. On the contrary, Ce_2Pd_2Sn presents a unique crystalline Ce-lattice where the mentioned exotic phase becomes unstable at $T_C = 2.1\,K$, undergoing a first order to its FM-GS. Neutron diffraction experiments [10] revealed a modulated character of this phase, with the local moments pointing in the 'c' crystallographic direction. The incommensurate propagation vector $[qx]$ changes from 0.11 (at 4.2 K) to 0.077 (at 2.8 K) where it suddenly drops to $[qx = 0]$ once the long range FM order parameter sets on.

Since the mentioned magnetic phase is unstable and only holds within a short range of temperature, the application of external field is expected to produce significant effects including its eventual suppression in a critical point. To our knowledge there are no systematic investigations of magnetic phase diagrams for Ce_2T_2X compounds (with T = Ni, Cu, Pd, Rh, Pt and X = Sn and In) performed yet. This is not a minor point since in the last years a big effort was done searching for critical points at very low temperature and magnetic field may fine tune the critical conditions. Furthermore, the scarce examples for FM critical points places the Ce_2T_2Sn family of compounds as good candidates for that current topic since it builds up from Ce atoms disposed in triangular prims mimiking those of CeT [11] FM compounds.

Preliminary studies on the effect of the magnetic field [12] on Ce_2Pd_2Sn showed that the upper transition is overcome by the lower one by applying moderate magnetic filed. In order to investigate the characteristics of that critical region, we have performed a detailed investigation of the magnetic field effects on the low temperature thermal, magnetic and transport properties of this compound. Such a study allows to assemble a magnetic phase diagram including the critical point where the intermediate phase is suppressed.