



HAL
open science

Ce₃Pt₂₃Si₁₁ ferromagnet: unusual magnetic behavior brought to light by neutron studies

Christine Opagiste, Rose-Marie Galéra, Mehdi Amara, Carley Paulsen, S. Rols, B. Ouladdiaf

► To cite this version:

Christine Opagiste, Rose-Marie Galéra, Mehdi Amara, Carley Paulsen, S. Rols, et al.. Ce₃Pt₂₃Si₁₁ ferromagnet: unusual magnetic behavior brought to light by neutron studies. 2011. ⟨hal-00677837⟩

HAL Id: hal-00677837

<https://hal.science/hal-00677837v1>

Submitted on 9 Mar 2012

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Ce₃Pt₂₃Si₁₁ ferromagnet: unusual magnetic behavior brought to light by neutron studies

C. Opagiste, R.-M. Galéra, M. Amara and C. Paulsen (Institut Néel - CNRS-UJF, Grenoble, France)
S. Rols and B. Ouladdiaf (ILL)

Instruments : Four-circle diffractometer D10
Time-of-flight spectrometer IN4

Introduction :

The ternary system R-Pt-Si (R = rare earth element) triggers a lot of interest, due to peculiar physical behaviors of some compounds: unconventional superconductivity, heavy-fermion properties, coexistence of superconductivity and magnetic ordering..., such as CePt₃Si, reported as the first non-centro symmetric heavy fermion superconductor. Actually, several studies let suppose a sample dependence of the superconductivity and for instance, in Ce deficient samples, the coexistence of a new phase, Ce₃Pt₂₃Si₁₁, was suspected to interfere with superconducting properties. We have undertaken an extended investigation on this new phase.

Ce₃Pt₂₃Si₁₁ crystallizes in a face-centered cubic structure (Fm-3m space group). Recently, we have synthesized very high quality single crystals. Magnetic measurements have shown that Ce₃Pt₂₃Si₁₁ orders ferromagnetically at $T_c = 0.44$ K with a spontaneous magnetic moment far smaller than the theoretical value of $2.14 \mu_B/\text{Ce}$ expected for Ce³⁺ ion [1]. Such a reduction may arise from crystal electric field (CEF) effect and / or from magnetic arrangements more complex than the collinear ferromagnetic one.

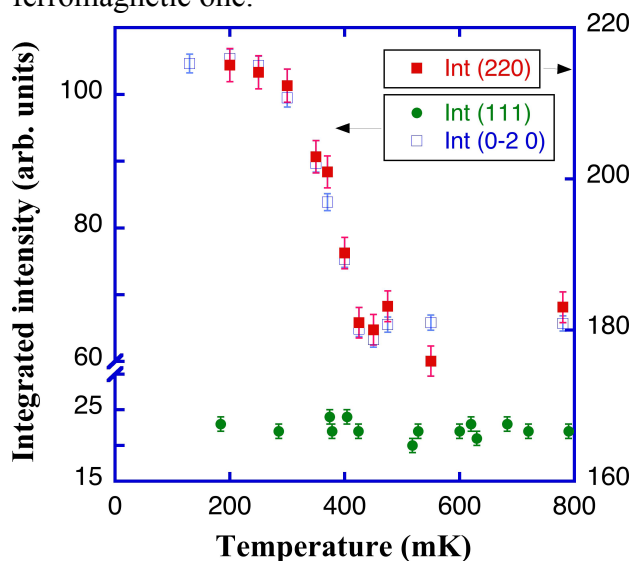


Figure 1: Thermal variation of the integrated intensity of the (220), (0-20) and (111) reflections (error bars are represented for each data point).

Neutron diffraction experiments performed on a single crystal using the unique four-circle dilution cryostat available on the D10 diffractometer, confirmed the transition at T_c . Below T_c , as illustrated by the temperature dependence of the (220), (0-20) and (111) reflections (figure 1), the magnetic contribution is only observed on top of nuclear reflections with hkl all even. The non-observation of a magnetic contribution for odd reflections indices is a strong constraint. This leads to ferromagnetic couplings between pairs of Ce ions within the 6 Ce ions in the unit cell. Group theory analysis shows that the only non-zero basis vectors, consistent with a ferromagnetic arrangement on the Ce sites are those of the Γ_{10} irreducible representation. These vectors describe a ferromagnetic arrangement along [100], [010] and [001] axis respectively, while a combination of the three basis vectors leads to a ferromagnetic arrangement along the [111] direction. This is in very good agreement with the magnetization process, shown in figure 2a. The refined value of the magnetic moment, $1.2(2)\mu_B$ per Ce ion, is close to that deduced from the magnetization measurements (figure 2a). Both determinations strongly indicate a doublet CEF ground state.

The CEF excitations were studied by inelastic

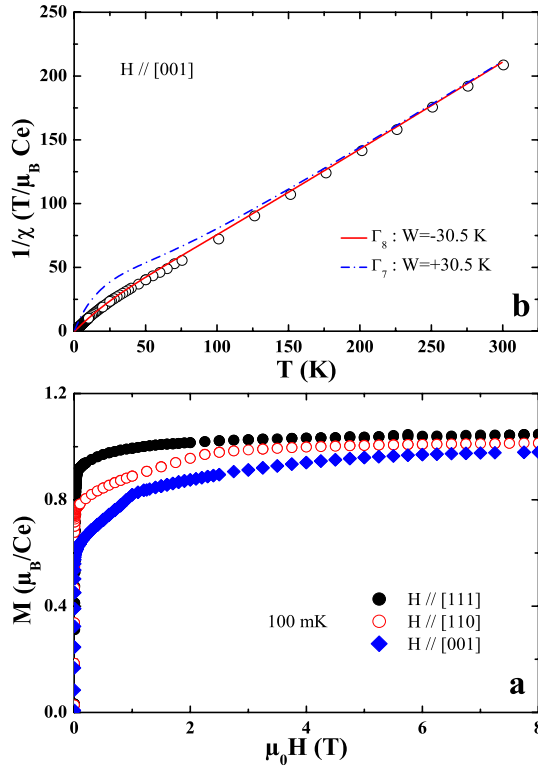


Figure 2: a) Magnetization curves along the three principle axes of the cube in the ferromagnetic phase at 100mK. b) Thermal variation of the inverse of the magnetic susceptibility ($\mu_0 H // [001]$). The lines represent the calculated curves using the values of the CEF parameter W reported in the figure.

neutron scattering on the IN4 time-of-flight spectrometer. For Ce^{3+} ions in cubic symmetry, only fourth degree terms are effective in the CEF Hamiltonian and thus only one parameter, $W = \pm E_{\text{CEF}}/6$ has to be considered [2]. A positive (negative) W selects a doublet (quadruplet) as CEF ground state. Unexpectedly, two magnetic excitations are observed at $E_1=12 \text{ meV}$ and $E_2=19.6 \text{ meV}$ on the spectra (figure 3), while neutron diffraction experiments shows that the structure remains cubic down to 800 mK. Observation of two CEF excitations in a cubic Ce compound was earlier reported in CeAl_2 . It was interpreted in terms of an unusual magneto-elastic coupling that gives rise to a bounding state between the excited CEF quadruplet level and low-lying vibronic states [3-5].

Calculations of the magnetic susceptibility within the CEF formalism show that experimental data are in better agreement with

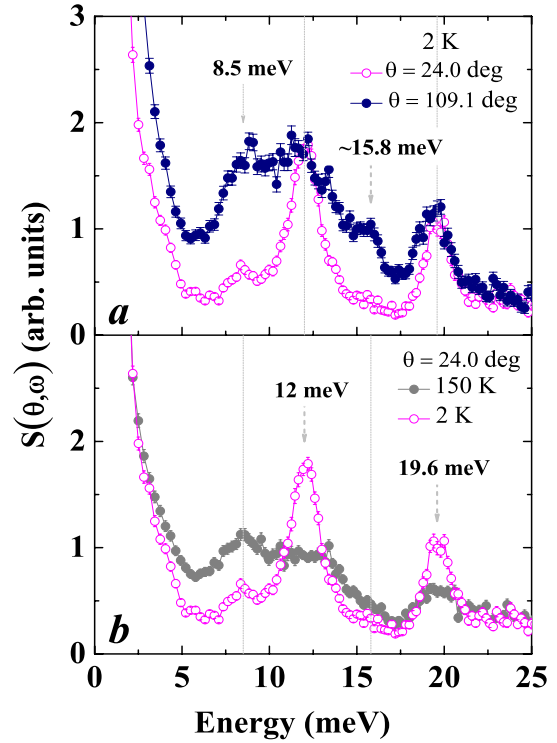


Figure 3: a) Inelastic intensities for two scattering angles at 2 K. b) Inelastic intensities for $T = 2 \text{ K}$ and 150 K at low angle detector averaging.

a quadruplet CEF ground state (figure 2b). In this case an interpretation similar to that of CeAl_2 should not apply, as the excited doublet cannot be split. The discrepancy between the different experimental observations in $\text{Ce}_3\text{Pt}_{23}\text{Si}_{11}$ together with an apparent crystal symmetry that remains cubic can be tentatively explained by the splitting of the quadruplet ground state via a dynamical Jahn-Teller effect [6]. This hypothesis will need further exploring.

References:

- [1] C. Opagiste, C. Paulsen, E. Lhotel, P. Rodière, R.-M. Galéra, P. Bordet, and P. Lejay, *J. Magn. Magn. Mater.*, 321, 613 (2009)
- [2] K. Lea, M. Leask, and W. Wolf, *J. Phys. Chem. Solids*, 23, 1381 (1962)
- [3] M. Loewenhaupt, B. D. Rainford, and F. Steglich, *Phys. Rev. Lett.*, 42, 1709 (1979)
- [4] P. Thalmeier and P. Fulde, *Phys. Rev. Lett.*, 49, 1588 (1982)
- [5] P. Thalmeier, *J. Phys. C: Solid State Phys.*, 17, 4153 (1984)
- [6] C. Opagiste, R.-M. Galéra, M. Amara, C. Paulsen, S. Rols and B. Ouladdiaf, *Phys. Rev. B*, 84, 134401 (2011)