QUANTUM CRITICAL POINT OF $CePd_2Si_2$: A NEUTRON DIFFRACTION STUDY UNDER PRESSURE*

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Neutron diffraction experiments performed on single crystal of the antiferromagnetic compound $CePd_2Si_2$ under applied pressure up to 18 kbar are reported. The magnetic structure and the temperature line-shape of the order parameter do not change with pressure. Anomalous suppression of the magnetic moment is found at high pressure.

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1. Introduction

Pressure induced superconductivity ($T_c \approx 350$ mK) is now well established for $CePd_2Si_2$ [1–6]. It occurs at its quantum critical point (QCP) where the antiferromagnetic order is suppressed at $T = 0$ K by a critical pressure P_c of approximately 27–29 kbar. At the QCP, a non Fermi-liquid ground state is inferred from transport measurements ($\rho = AT^n$ with $n \approx 1.2$–1.3 at P_c). While the $P = 0$ behavior was precisely studied by elastic, inelastic neutron scattering and NMR [7, 8], no microscopic measurements were up to now undertaken under pressure. The present neutron diffraction study of $CePd_2Si_2$ performed up to 18 kbar is aiming to fill this gap. It provides

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a unique microscopic measurement of the pressure dependence of both the Néel temperature, T_N, and the staggered magnetic moment, m_0, on going towards the QCP.

2. Experimental details and results

The magnetic structure was studied on the CEA/CRG D23 lifting arm diffractometer at the ILL-Grenoble with an incident wavelength $\lambda = 1.28$ Å from a Cu (200) monochromator. The single crystal sample obtained by the Czochralski method was cut (typically $3 \times 3 \times 3$ mm^3) and put in two different piston-cylinder pressure cells reaching respectively 10 and 25 kbar with fluorinert as the transmitting pressure medium. The pressure was measured via an refinement of the lattice parameter of a NaCl single crystal located just above the sample in the cell.

At $P = 0$, an refinement of the antiferromagnetic structure gives a magnetic moment of 0.498 (19) μ_B, a value smaller than the one found in previous diffraction studies (0.62–0.66μ_B) [9, 10]. The propagation vector is $(1/2, 1/2, 0)$ with the magnetic moment along the [110] direction. Note that the Néel temperature at ambient pressure, $T_N = 9.0$ (0.1) K, is lower than the one measured on microsized samples [3]. The different behaviors between the large single crystals and the microsized ones are still to be understood.

No change of the magnetic structure is found under pressure. The temperature variation of the magnetic intensity measured at the (1/2, −1/2, 1) Bragg reflection is shown in Fig. 1 for several pressures. In order to study

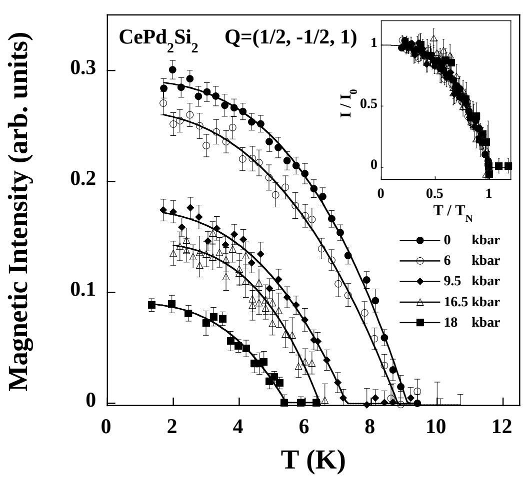

Fig. 1. Intensity of the magnetic (1/2, −1/2, 1) reflection as a function of temperature for several pressures. The inset shows the collapse of the same data plotted in reduced variables: I/I_0 as a function of T/T_N. Lines correspond to fit as indicated in the text.

the evolution with P of the temperature line-shape of the order parameter, normalized data (I/I_0 as a function of $T/T_{\rm N}$) are shown in the inset of Fig. 1. A collapse of the data on a single curve described by the phenomenological expression $I/I_0 = 1 - (T/T_{\rm N})^{\alpha}$ is obtained with the anomalously high value $\alpha = 3$. Although the critical region was not studied in details, the overall behavior of the order parameter is unchanged with pressure. Fig. 2 shows the variation of the staggered magnetic moment ($m_0 \propto \sqrt{I_0}$) as a function of $T_{\rm N}$ with P being an implicit parameter. The staggered moment drops faster than the Néel temperature as the QCP is approached. The individual variations of $T_{\rm N}$ and m_0 as a function of pressure are shown in the inset of Fig. 2. The fit corresponds to power laws in $(P - P_{\rm c})$ with $P_{\rm c}$ being fixed to 29 kbar. The large error bars on the data prevent from commenting further these power laws in the viewpoint of theoretical predictions.

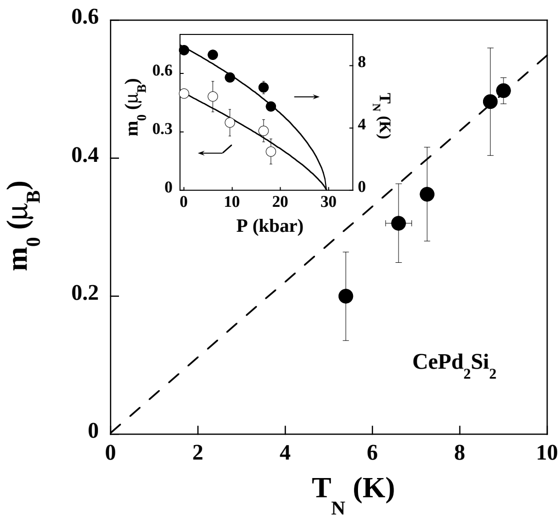

Fig. 2. Variation of the staggered magnetic moment m_0 with respect to the Néel temperature $T_{\rm N}$. The inset shows the pressure variation of m_0 and $T_{\rm N}$. Lines are guides for the eyes.

3. Discussion

The most important result of our study is the anomalous strong depreciation of the magnetic moment with P as compared to the Néel temperature. For local magnetism (Heisenberg model), the relation $m_0 \propto T_{\rm N}^{1/2}$ is expected for a pressure invariant exchange. In spin fluctuation theory, the magnetic moment is reduced and follows $m_0 \propto T_{\rm N}^{3/4}$ [11]. Our data show a line which lies even below the linear relation $m_0 \propto T_{\rm N}$. This linear relation was observed for the archetypal spin density wave structure of doped Cr and explained by Fermi surface properties [12]. The relatively weak moment measured at high pressure points toward a possible occurrence of a so-called small moment antiferromagnetic (SMA) phase in the vicinity of P_c. This kind of evolution of the staggered magnetic moment with pressure was also found in $CeRh_2Si_2$ and its alloys [13, 14], and in URu_2Si_2 (but with the inverse pressure effect) [15]. Reduction of the magnetic moment implies the existence of enhanced spin fluctuations in order to satisfy sum rules. This may favor the emergence of superconductivity at the QCP of $CePd_2Si_2$. To tighten our conclusion concerning the interplay between magnetism and superconductivity, similar experiments on microsized superconducting samples are to be performed using magnetic X ray scattering.

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