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HALL EFFECT IN THE HEAVY FERMION COMPOUND CePtSi

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Abstract. – We present Hall effect measurements on the heavy fermion compound CePtSi. Above the neel temperature the behavior of the Hall effect is that generally observed in heavy fermion compounds and ascribed to skew scattering. Below T_N the Hall effect is enhanced and its strongly non-linear field dependence evidences the existence of a field-induced phase transtion. We discuss the origin of the enhancement of the Hall effect below T_N .

The Hall effect of many heavy fermion compounds has been studied for several years. For systems which do not present a magnetically ordered phase at low temperature (CeAl₃, CeCu₆... etc., see Ref. [1-6]), its behavior is well known: large and generally positive Hall constant with a pronounced maximum at low temperature (around the onset temperature for coherence effects). This behavior is ascribed to skew scattering [7-8]. Anomalous velocity contributions have been also proposed to be important at low temperatures [9]. In systems with magnetically ordered phase at low temperatures, such as U₂Zn₁₇ [10] or URu₂Si₂ [11], the Hall effect increases strongly in the ordered phase, which is not yet well understood. In URu₂Si₂ the enhancement of the Hall constant below the Neel temperature has been ascribed to an increase of the ordinary Hall effect induced by a reconstruction of the Fermi surface. In this communication we present Hall effect data on the CePtSi compound (polycrystalline samples). CePtSi is a heavy fermion system with a temperature coefficient of the electronic specific heat of about 800 mJ/mol K² [12, 13]. Slight anomalies in the temperature dependence of the resistivity and magnetic susceptibility have suggested the existence of antiferromagnetism below about 2.5 K [13].

Figure 1 shows the temperature dependence of the initial Hall constant *above the neel temperature*. As in most heavy fermion compounds, R_H is large, positive and exhibits a pronounced maximum in the temperature range where the resistivity drops towards its residual value. We have tested the theoretical expression [8]:

$$R_H = R_H^{\text{ord}} + \gamma \rho \tilde{\chi} \quad (1)$$

where R_H^{ord} is the ordinary Hall constant, ρ is the magnetic resistivity, $\tilde{\chi}$ is the reduced susceptibility ($\tilde{\chi} = \chi/C$ where C is the Curie constant), and γ is a constant ($\gamma \tilde{\chi} \rho$ is the contribution from skew scattering by the cerium lattice; in equation (1) we neglect the residual skew scattering by defects or impurities). To test equation (1) we have used:

- values of ρ derived by Lee and Shelton [12], $\rho = \rho(\text{CePtSi}) - \rho(\text{LaPtSi})$;
- three different sets of data for χ from reference [12] and 13] and from our own measurements on the sample used for the Hall effect;

Fig. 1. – Temperature dependence of the initial Hall constant of CePtSi above the Neel temperature, $T_N = 2.8$ K. Inset: Temperature dependence of the initial Hall constant at low temperatures above and below T_N . Note the different scales for the main figure and the inset. To compare with typically metallic values, the Hall constant of Cu is about $0.5 \times 10^{-12} \Omega \text{cm/G}$ ($1 \Omega \text{cm/G} = 10^2 \text{m}^3/\text{A} \cdot \text{sec}$).

– the ordinary Hall constant, $R_H^{\text{ord}} = 2.3 \times 10^{-12} \Omega \text{cm/G}$, derived by plotting the values of R_H at high temperatures *versus* $\rho \chi$ and extrapolating to $\rho \chi = 0$ (high temperature limit) [14]. In first approximation R_H^{ord} is assumed to be temperature independent.

As shown in figure 2, and in agreement with equation (1), $(R_H - R_H^{\text{ord}})/\rho \chi$ is approximately constant in the major part of the temperature range. The deviations observed below about 25 K depend on the values of χ used for the fit, so that it is hard to establish whether these deviations are intrinsic (due, for

Fig. 2. – $(R_H - R_H^{\text{ord}})/\rho \chi$ versus T in the temperature range above T_N . The magnetic resistivity is derived from reference [12], $\rho = \rho(\text{CePtSi}) - \rho(\text{LaPtSi})$. (a): χ from reference [13]; (b): χ from reference [12]; (c): χ from our own measurements on the sample used for the hall effect. The values of $(R_H - R_H^{\text{ord}})/\rho \chi$ are normalized to 1 at 175 K.

example, to anomalous velocity contributions at low temperatures) or arise from impurity effects in χ .

Below T_N , the initial Hall constant increases sharply, as shown in the inset of figure 1. However it is not sufficient to consider only the initial Hall constant, as this appears in figure 3 where the Hall resistivity ρ_{xy} [15] is plotted as a function of H . Whereas ρ_{xy} is a quasi-linear function of H above T_N (see curve at 2.8 K), below T_N $\rho_{xy}(H)$ begins by a steep increase and, at a well defined threshold field, becomes almost field independent. The shape of the curves indicates the existence of a field-induced phase transition. By plotting the threshold field as a function of T , see inset of figure 3, one obtains a well defined transition line with $T_N(H=0) = 2.8$ K. It thus turns out that CePtSi presents a good example of the extreme sensitivity of the Hall effect to small changes of the electronic structure in heavy fermions systems: the initial Hall constant increases by a factor of about 15 between 28 K, just above T_N , and 2.7 K, just below; as a function of the field, at 2.7 K for example, the slope of $\rho_{xy}(H)$ decreases by two orders of magnitude at the field induced transition. In contrast the existence of antiferromagnetic ordering and of a field-induced phase transition appears much less clearly in the magnetization, resistivity and magnetoresistance [13, 15].

Fig. 3. — Hall resistivity versus applied field at several temperatures (indicated on the curves). Inset: Phase diagram of CePtSi derived from the sharp turn of the $\rho_{xy}(H)$ curves.

In contrast to what has been proposed for URu₂Si₂ [11], the change of the Hall effect below T_N in CePtSi cannot be explained in terms of ordinary Hall effect and ascribed to a reconstruction of the Fermi surface in AF state. Below T_N the Hall constant increases abruptly to about $100 R_H^{\text{ord}}$ and it is hard to believe that the effective number of carriers decreases by a factor of 100, whereas the resistivity remains practically constant around T_N [13]. In addition an antiferromagnetic-like gap would appear progressively below T_N and 0 K, whereas the Hall constant of CePtSi is high just below T_N and decreases rapidly when T decreases. We rather believe that the change of the Hall effect below T_N arises from a change of the anomalous contributions (skew scattering [7, 8] or anomalous velocity [9]). The anomalous terms are very sensitive to

the phase shifts of the resonant scattering and should be strongly affected by the formation of any fine structure of the density of states associated to cooperative effects and by any field dependence of this fine structure.

In conclusion CePtSi shows interesting aspects of the Hall effect in heavy fermion compounds. Above T_N the Hall constant exhibits the usual behavior of the heavy fermion compounds and, at least above 25 K, fits well with the predictions of skew scattering models. Below T_N , the initial Hall constant is strongly enhanced and the non-linear dependence of the Hall resistivity evidences the existence of a field induced phase transition. Our results suggest that the important change of the Hall effect below T_N is due to changes of the extraordinary contributions rather than to a reconstruction of the Fermi surface.

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