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HALL EFFECT IN KONDO ALLOYS $CeCu_{5-x}Al_x$

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Abstract. – We present Hall effect measurements on disordered Kondo alloys $CeCu_{5-x}Al_x$ ($x = 1$ and $x = 2$). Our results at low temperatures cannot be accounted for by only skew scattering terms and support the existence of an additional contribution from anomalous velocity effects.

The $CeCu_{5-x}Al_x$ alloy series includes heavy fermion (HF) system such as $CeCu_4Al$ and $CeCu_3Al_2$ in which the temperature coefficient of the electronics specific heat respectively amounts to about 1.5 J/mol K^2 and 0.5 J/mol K^2 [1]. However, in contrast with the case of classical HF compounds, the disordered substitution of Al for Cu prevents the development of coherence effects at low temperatures and the behavior of the $CeCu_4Al$ and $CeCu_3Al_2$ alloys is that of a collection of independent Kondo impurities. This is shown in figure 1 by the continuous increase of the resistivity for decreasing temperatures.

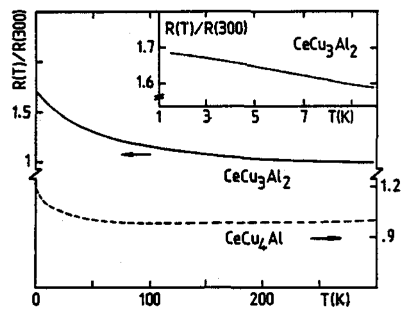

Fig. 1. – Resistivity *vs.* temperature for $CeCu_4Al$ and $CeCu_3Al_2$.

In this communication, we present Hall effect measurements on $CeCu_4Al$ and $CuCu_3Al_2$ alloys. The large anomalous Hall effect of the HF systems is generally ascribed to skew scattering and interpreted in the existing single impurity skew scattering models [2, 3]. As shown recently, anomalous velocity contributions could also be significant below the Kondo temperature [6]. In ordered compounds such as $CeAl_3$ [4], $CeCu_6$ [5], UPt_3 [4], etc..., the single impurity skew scattering models accounts fairly well for the experimental data at high and intermediate temperatures and very poorly at low temperatures. But it is hard to establish whether this discrepancy arises from the onset of coherence effects – not taken into account in the models – or from the onset of anomalous velocity contributions. The $CeCu_{5-x}Al_x$ alloys – without coherence effects – are of interest to shed some light on this problem.

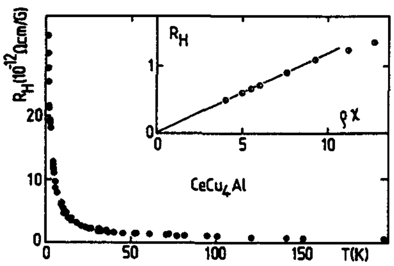

Fig. 2. – Initial Hall constant *vs.* temperature for $CeCu_4Al$. Inset: determination of the ordinary Hall constant from the high temperature data. We find $R_H^{ord} \approx 0$.

Figures 2 and 3 display the temperature dependence of the initial Hall constant for $CeCu_4Al$ and $CeCu_3Al_2$ respectively. We do not find the usual behavior of coherent HF compounds in which R_H presents a pronounced maximum at about the onset temperature for coherence and drops rapidly at lower temperatures. This can be understood from the expression [3]:

$$R_H = R_H^{ord} + \gamma\tilde{\chi}\rho$$

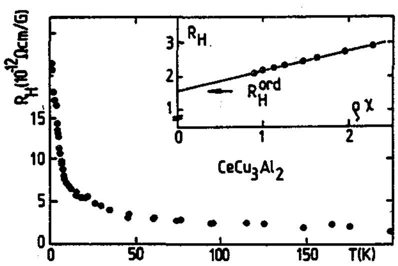

Fig. 3. – Initial Hall constant *vs.* temperatures for $CeCu_3Al_2$. Inset: Determination of R_H^{ord} from the high temperature data. We find: $R_H^{ord} \approx 1.55 \times 10^{-12}$ Ωcm/G.

where R_H^{ord} is the ordinary Hall constant, $\gamma\tilde{\chi}\rho$ is the skew scattering contribution, $\tilde{\chi}$ is the reduced suscep-

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tibility (i.e. susceptibility over Curie constant) and ρ is the magnetic resistivity. In our $CeCu_{5-x}Al_x$ alloys not only χ but also ρ continue to increase down to 1 K, so that R_H is not expected to present the low temperature drop of the coherent compounds. This has also been found in other incoherent systems [7-9]. To test equation (1) we assume a temperature independent value of R_H^{ord} (derived as shown in the inset of Fig. 2 and 3) and we plot the ratio $r = \left(R_H - R_H^{ord}\right) / \chi\rho$ as a function of T in figure 4 and 5. Down to about 20 K, for both $CeCu_4Al$ and $CeCu_3Al_2$, the ratio r is approximately temperature independent, which is in agreement with equation (1) and an approximately constant value of

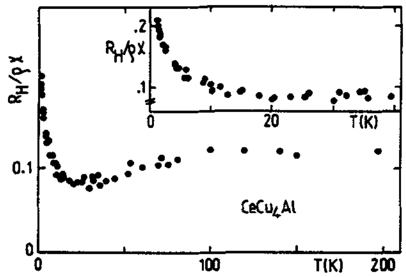

Fig. 4. – $\left(R_H - R_H^{ord}\right) / \rho\chi$ *vs.* temperature for $CeCu_4Al$ ($R_H^{ord} \approx 0$ for $CeCu_4Al$; ρ and χ measured on the same sample).

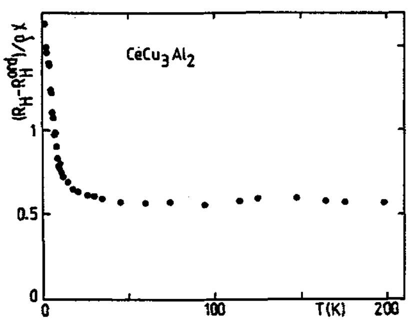

Fig. 5. – $(R_H - R_H^{ord})/\rho\chi$ *vs.* temperature for $CeCu_3Al_2$($R_H^{ord} \approx 1.55 \times 10^{-12}$ Ωcm/G; ρ and χ measured on the same sample).

the coefficient γ [10]. Below about 20 K, in both systems, the ratio r increases steeply. This enhancement of the Hall effect appears too strong to be merely explained by a change of the relatively small ordinary Hall effect or by impurity effects. As a matter of fact, we have also found systematic similar enhancements in other incoherent HF systems ($Ce_{1-x}La_xCu_6$ [8], irradiated $CeCu_2Si_2$ [9], ...). Such enhancements can be due to a change of the coefficient of the skew scattering term γ below the Kondo temperature T_K (γ is expected to change by T_K) or by the onset of an anomalous velocity contribution below T_K. As γ is expected to change very progressively around T_K [11], we rather believe that the experimental data of figure 4 and 5 indicate the existence of anomalous velocity contributions to the Hall effect of HF systems at low temperatures.

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[10] In $CeCu_4Al$ the ratio r decreases by about 30 % between 100 K and 20 K. This could reflect a decrease of the prefactor γ at the approach of the Kondo temperature.

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