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Suppression of the Grüneisen parameter of CeCu_6 by a magnetic field[†]

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Abstract

In order to investigate the suppression of the heavy-fermion state of CeCu_6 by a magnetic field ($B \parallel c$) we have measured the coefficients of thermal expansion of a single-crystalline sample ($\alpha_a, \alpha_b, \alpha_c$) in the temperature range 0.3–10 K in fields up to 8 T. The electronic Grüneisen parameter ($\Gamma_{\text{hf}} = V_m a_v / \kappa \gamma$), which amounts to 80 in zero field ($T \rightarrow 0$), is reduced by a factor 10 in a field of 8 T. This enormous drop of Γ is attributed to a rapid suppression of the magnetic inter-site correlations.

The heavy-electron compound CeCu_6 exhibits an unusually large quasiparticle mass as is inferred from the large Sommerfeld coefficient in the specific heat ($\gamma \simeq 1600 \text{ mJ/mol K}^2$) [1]. In general, the strong mass renormalization in heavy-fermion (HF) compounds is attributed to the presence of competing electronic interactions: the on-site Kondo screening and inter-site antiferromagnetic (RKKY-type) interactions. In the case of CeCu_6 this picture has been confirmed by inelastic neutron-scattering experiments [2].

Under influence of a magnetic field the HF state is suppressed albeit at a moderate rate and in a strongly anisotropic way [1]. Specific-heat measurements reveal that the largest effects are found for a field along the orthorhombic c -axis, with the

γ -value reduced to $\sim 500 \text{ mJ/mol K}^2$ for $B = 7.5 \text{ T}$ [3]. It has been demonstrated by inelastic neutron-scattering experiments ($B \parallel c$, $B < 5 \text{ T}$) that the effect of a magnetic field on the microscopic level is to suppress primarily the inter-site interactions, whereas the on-site fluctuations persist [2]. The threshold field, B^* , for suppression of the inter-site interactions (metamagnetism) amounts to 2.5 T.

The formation of the Kondo-lattice state in CeCu_6 is accompanied by a pronounced maximum in the coefficient of volume expansion (α_v) at $T^* = 2.5 \text{ K}$ [4]. The Grüneisen parameter for the heavy-electron contribution $\Gamma_{\text{hf}} = V_m a_v / \kappa \gamma$ (where $a_v = \alpha_v / T$ is the coefficient of the linear term in the volume expansion) attains the enormous value of 80 [4, 5], implying a strong volume dependence of the width of the HF resonance ($\Gamma_{\text{hf}} = -\partial \ln T^* / \partial \ln V$). In Ref. [6] we reported a large field effect on the coefficient of linear thermal

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Fig. 1. Coefficient of linear thermal expansion of CeCu_6 versus temperature in a magnetic field along the c -axis. Upper frame α_a , middle frame α_b and lower frame α_c . (●) 0 T, (Δ) 2 T, ($\blacktriangle$) 4 T, (+) 6 T and ($\circ$) 8 T. In the lower frame additional curves are given at fields of 3, 4.5, 5 and 7 T, as indicated.

expansion along the c -axis ($\alpha_c(T)$) at very low temperatures (0.1–0.5 K). In this paper we present a complete data set (including data for the a - and the b -axis), which enabled us to investigate $\alpha_v(B)$ and $\Gamma_{\text{hf}}(B)$ in relation to the suppression of the HF state by a magnetic field.

The linear coefficient of thermal expansion ($\alpha = L^{-1}dL/dT$) along the three principal orthorhombic axes (α_a , α_b , α_c) have been measured in a magnetic field ($B \parallel c$) in the temperature interval 0.3 K $< T < 10$ K using a sensitive capacitance dilatometer mounted in a ^3He cryostat. The experimental results (obtained on the same specimen as used in Ref. [4–6]) for α_a , α_b and α_c are shown in Fig. 1, while the calculated coefficient of volume expansion $\alpha_v = \alpha_a + \alpha_b + \alpha_c$ is shown in Fig. 2. The field dependence of $\alpha_a(T)$, $\alpha_b(T)$ and $\alpha_c(T)$ is rather complex. The largest effect is observed for α_c : the

Fig. 2. Coefficient of volume expansion of CeCu_6 divided by 3 ($\alpha_v/3$) vs temperature at fields ($B \parallel c$) as indicated.

Fig. 3. The effective Grüneisen parameter of CeCu_6 vs temperature at fields ($B \parallel c$) as indicated.

positive contribution centered at 1.8 K in zero field is strongly suppressed and becomes of the order of α_a in a field of 8 T. Simultaneously, α_b becomes dominant. As a result α_v is strongly suppressed at low temperatures, while T^* ($= 2.5$ K for $B = 0$ T) shifts towards higher temperatures.

In Fig. 3 we show the effective Grüneisen parameter $\Gamma_{\text{eff}}(T) = \alpha_v(T)V_m/kc(T)$ in applied fields, where we used the specific-heat data obtained for the same sample [2]. The Grüneisen parameter for the HF contribution ($\Gamma_{\text{hf}} = \Gamma_{\text{eff}}$ for $T \rightarrow 0$), which amounts to ~ 80 in zero field, is reduced by a factor 10 in a field of 8 T. This signifies that α_v is suppressed at a much faster rate than the specific

heat. More precisely, in a field of 8 T the coefficient a_v is reduced by a factor 30, whereas γ is reduced by a factor 3 only. This implies that the density of states remains fairly high in a field of 8 T, whereas its pressure dependence becomes much weaker. The enormous drop of Γ_{hf} with field is primarily attributed to a rapid suppression of the inter-site correlations. Magnetostriction measurements at very low temperature ($T < 0.4$ K) have revealed that this might occur in a two-step process [6]. Further measurements are underway in order to elucidate this point [7].

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References

- [1] Y. Onuki and T. Komatsubara, *J. Magn. Magn. Mater.* 63&64 (1987) 281.
- [2] J. Rossat-Mignod, L.P. Regnault, J.L. Jacoud, C. Vettier, P. Lejay, J. Flouquet, E. Walker, D. Jaccard and A. Amato, *J. Magn. Magn. Mater.* 76&77 (1988) 403.
- [3] A. Amato, D. Jaccard, J. Flouquet, F. Lapierre, J.L. Tholence, R.A. Fisher, S.E. Lacy, J.A. Olsen and N.E. Phillips, *J. Low Temp. Phys.* 68 (1987) 371.
- [4] A. de Visser, A. Lacerda, P. Haen, J. Flouquet, F.E. Kayzel and J.J.M. Franse, *Phys. Rev. B* 39 (1989) 11301.
- [5] A. de Visser, J.J.M. Franse, A. Lacerda, P. Haen and J. Flouquet, *Physica B* 163 (1990) 49.
- [6] A. Lacerda, P. Haen, A. de Visser, J. Flouquet and E. Walker, *Phys. Lett. A* 164 (1992) 93.
- [7] S. Holtmeier et al., to be published.