FIELD-DEPENDENT ANISOTROPIC HALL EFFECT IN SINGLE CRYSTAL HEAVY FERMION YbAgGe

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YbAgGe was recently recognized to be one of the few stoichiometric Yb-based heavy-fermion (HF) compounds that demonstrate field-induced evolution from (small moment) antiferromagnetism to non-Fermi-liquid (NFL) behavior and further to a heavy Fermi-liquid state. The critical field needed to induce the quantum critical point (QCP) in YbAgGe is moderate and anisotropic (H_c^{ab} ~ 45 kOe, H_c^{c} ~ 80 kOe) [1]. Recently, Hall effect measurements through the QCP were suggested [2] to be one of the key experiments to get insight into the nature of an antiferromagnetic QCP. Here we report evolution of the temperature- and field-dependent Hall coefficient in YbAgGe with more attention to the low temperature/high field, close to QCP, domain that was probed down to T/T_N ~ 0.05 and up to H/H_{QCP}~ 2 - 4.

YbAgGe single crystals were grown from Ag- and Ge-rich high temperature ternary solutions. AC Hall resistivity measurements were taken utilizing ^{3}He-^{4}He Oxford dilution refrigerator (DR) with a superconducting magnet at NHMFL - Los Alamos (T_{min} = 0.05 K, H_{max} = 180 kOe).

The most conspicuous feature in the $\rho_H(H)$ curves (upper panels of the Fig. 1) is a pronounced local extremum (maximum for H || ab and minimum for H || c) that occurs at fields close to the respective critical H_{QCP} [1]. For both directions of the field the feature shifts slightly to higher fields and broadens with increase of temperature. The field-dependent Hall coefficient (lower panels of the Fig. 1) reveals more features: extrema in the Hall coefficient (indicated by lines) represent the width of the key anomaly in $\rho_H(H)$; a high field break in the slope (marked by arrows) possibly indicates a crossover to the FL regime (serving as an alternative definition of the coherence temperature, T*), since the Hall coefficient is in essence field-independent in higher fields; further studies are required to understand the origin of an additional, intermediate-field feature seen for H || ab (asterisk in Fig. 1). Based on the data and salient features discussed above, considered together with our earlier measurements and recent magnetotransport data down to 70 mK [3] we can propose a composite low temperature H - T phase diagram for YbAgGe (Fig. 2). The Hall line defined from the extremum of $\rho_H(H)$ at low temperatures approaches the QCP. With temperature increase this feature can be followed up to 2 - 3 K, far beyond T_N in zero field. The width of the Hall anomaly related to the QCP decreases on cooling and narrows to ~ 0.2 H_{crit} at T = 50 mK, being much narrower, in relative units, than for $YbRh_2Si_2$. Whereas the general features of the phase diagram are similar for both orientation of the applied field, the functional form of $R_H(H)$ (Fig. 1), differs between H || ab and H || c, and is disparate to the theoretically suggested options [2] and the observations in $YbRh_2Si_2$. Since R_H in general has a complex dependence on the details of the electronic structure, the differences in functional behavior of the $R_H(H)$ for different field orientations in YbAgGe is probably due to the details of the Fermi surface of this material, while the distinct feature for each H direction is due to the field-induced QCP.

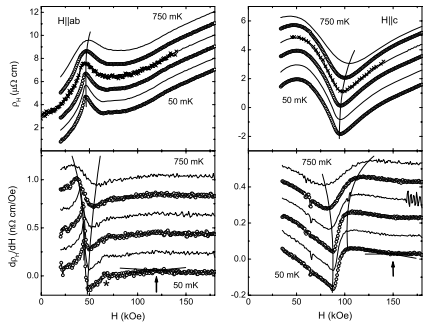

Fig. 1. Representative data (taken at 50, 100, 200, 400, 500 and 750 mK) for anisotropic field-dependent Hall resistivity and Hall coefficient of YbAgGe.

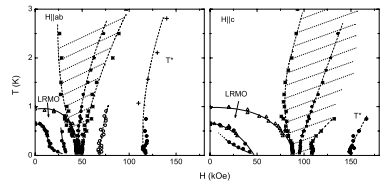

Fig. 2. Composite anisotropic H - T phase diagrams of YbAgGe. triangles, + - from Ref. 1, dots - from Ref. 3. On each panel: stars - Hall line, hatched area marks the width of the Hall anomaly.

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References

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