High Field Transport Properties of Anomalous Metallic States

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Introduction

Much attention has been paid to novel type of anomalous metallic states that arises without magnetic criticality. The PI's group has developed new rare-earth metal based compounds such as PrV_2Al_{20} whose quadrupole (orbital) moments of Pr ions are strongly hybridized with conduction electrons [1]. PrV_2Al_{20} exhibits a quadrupolar ordering at 0.6 K. Its field-temperature phase-diagram is expected to have a smooth quantum phase transition at 10-15 T, therefore exotic quantum critical behavior arising from the orbital fluctuation is expected.

In addition, we also focused on other paramagnetic compounds α-$YbAlB_4$ and $Pr_2Ir_2O_7$ which are candidates for other-types of anomalous metallic states. The metallic state of the former compound is expected to be dominated by valence fluctuations of Yb^{2+}-Yb^{3+}. In the latter compound, while the strong spin-orbit interaction of Ir ions is expected to induce a Weyl-semi-metallic state, Pr moments form a chiral spin liquid state at low temperatures [2]. In both compounds, it is of importance to obtain information about the Fermi surface.

Experimental

We have measured the magnetoresistance of PrV_2Al_{20} (three crystals) and α-$YbAlB_4$ (one single-crystal) in addition to magnetic torque in $Pr_2Ir_2O_7$ using the 31 T magnet-system in Cell 9 during the period from 12/16 to 12/20/13. For $YbAlB_4$ and $Pr_2Ir_2O_7$ systems, previous studies at the NHMFL already led to two publications [2,3].

Results and Discussion

As for the PrV_2Al_{20}, we first constructed the phase diagram of the quadrupolar ordered state around the critical field H_c = 11 T for H // [110] and [111]. Near this field, the residual resistivity becomes strongly enhanced (Fig. 1 inset), and the temperature dependence of the resistivity exhibits quantum critical-like behavior with sublinear temperature dependence. These results suggest the emergence of an anomalous metallic state due to quantum critical orbital (or quadrupolar) fluctuations. In addition, at high fields we found new Shubnikov de Haas frequencies in α-$YbAlB_4$ and $Pr_2Ir_2O_7$, which are found strongly anisotropic in character.

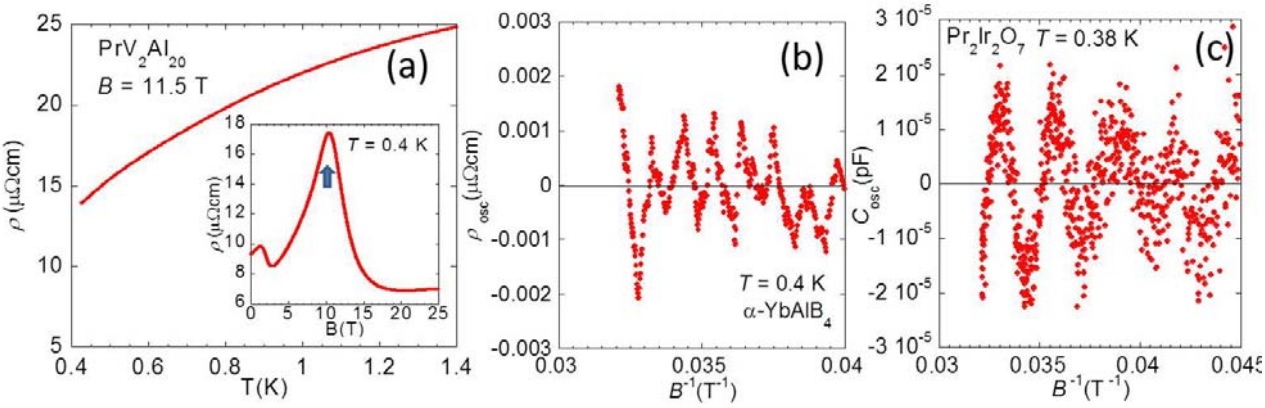

Figure 1 (a) Temperature dependence of the resistivity under fields for PrV_2Al_{20}. Inset: Field dependence of the resistivity at 0.4 K. (b) and (c) Shubnikov de Haas effects seen in α-$YbAlB_4$ and $Pr_2Ir_2O_7$.

Conclusions

We have studied three rare-earth based compounds, i.e. PrV_2Al_{20}, α-$YbAlB_4$ and $Pr_2Ir_2O_7$, respectively. From the temperature dependence of the resistivity around a field-induced quantum critical point and from the observed quantum oscillatory phenomena, we will be able to extract extremely important information about the nature of these anomalous metallic states.

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