Transport theory of conduction electron systems coupled with spin ice

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Itinerant electrons sometimes exhibit unusual properties through the interaction with peculiar spatial structures brought about by geometrical frustration. In this talk, we consider itinerant electrons coupled with spin-ice-type localized Ising moments. This setting is relevant to several metallic Ir pyrochlore oxides, such as $Ln_2Ir_2O_7$ (Ln=Pr, Nd), where Ir 5d conduction electrons interact with Ln 4f localized moments. In these compounds, anomalous transport phenomena have been reported, such as non-monotonic magnetic field dependence of Hall conductivity[1] and resistivity minimum, which does not follow the canonical scenario of Kondo effect [2]. To address these issues, we adopt a spin-ice-type Ising Kondo lattice model on a pyrochlore lattice. We solve this model by applying the cluster dynamical mean-field theory and the perturbation expansion in terms of the spin-electron coupling J, and obtain longitudinal and transverse conductivities by the Kubo formula.

As a result, we found that (i) the resistivity shows a minimum at a characteristic temperature below which spin ice correlation sets in (Fig. 1 (a), (b)) [3], and that (ii) the Hall conductivity shows anisotropic and non-monotonic magnetic field dependence due to the scattering from the spatially extended spin scalar chirality (Fig. 1 (c)) [4]. These results well explain various aspects of the experimental data of $Ln_2Ir_2O_7$ (Ln=Pr, Nd), and give new insights into the role of geometrical frustration in itinerant systems.

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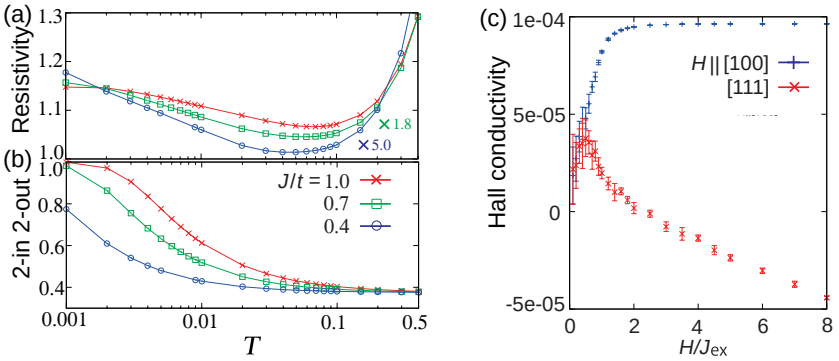

Fig. 1 Temperature dependence of (a) resistivity and (b) the probability that a tetrahedron is occupied by 2-in 2-out spin configuration. (c) Magnetic field dependence of Hall conductivity for $H \parallel [100]$ and [111] directions.

[1] Y. Machida et al., Phys. Rev. Lett. **98**, 057203 (2007).
[2] S. Nakatsuji et al., Phys. Rev. Lett. **96**, 087204 (2006).
[3] M. Udagawa, H. Ishizuka and Y. Motome, Phys. Rev. Lett. **108**, 066406 (2012).
[4] M. Udagawa and R. Moessner, submitted.