MAR14-2013-020375

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Itinerant spin ice[1]

MASAFUMI UDAGAWA, University of Tokyo

Spin ice is a prototypical frustrated magnet defined on a pyrochlore lattice. The ground state of spin ice is described by a simple rule called "ice rule": out of four spins on a tetrahedron, two spins point inward, while the other two outward. This simple rule is not sufficient to determine the spin configuration uniquely, but it leaves macroscopic degeneracy in the ground state. Despite the macroscopic degeneracy, however, the ground state is not completely disordered, but it exhibits algebraic spatial correlation, which characterizes this state as "Coulomb phase" where various exotic properties, such as monopole excitations and unusual magnetic responses are observed. Given the peculiar spatial correlation, it is interesting to ask what happens if itinerant electrons coexist and interact with spin ice. Indeed, this setting is relevant to several metallic Ir pyrochlore oxides, such as $Ln_2Ir_2O_7$ (Ln=Pr, Nd), where Ir 5d itinerant 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 low-temperature resistivity upturn [2]. To address these issues, we adopt a spin-ice-type Ising Kondo lattice model on a pyrochlore lattice, and solve this model by applying the cluster dynamical mean-field theory and the perturbation expansion in terms of the spin-electron coupling. As a result, we found that (i) the resistivity shows a minimum at a characteristic temperature below which spin ice correlation sets in [3]. Moreover, (ii) the Hall conductivity shows anisotropic and non-monotonic magnetic field dependence due to the scattering from the spatially extended spin scalar chirality incorporated in spin ice manifold [4]. These results give unified understanding to the thermodynamic and transport properties of $Ln_2Ir_2O_7$ (Ln=Pr, Nd), and give new insights into the role of geometrical frustration in itinerant systems. This work has been done in collaboration with H. Ishizuka, Y. Motome and R. Moessner.

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[4] M. Udagawa and R. Moessner, Phys. Rev. Lett., 111, 036602 (2013).

[1]This work was supported by Grant-in-Aid for Young Scientists (B) (No. 24740221) funded by Japan Society for the Promotion of Science.