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場所：大阪大学理学部宇宙地球科学科棟（Ｆ棟）5 階 F524
講師：小野田　繁樹　氏
（（独）理化学研究所）
題目：Unified theory of anomalous Hall transport phenomena:
intrinsic versus extrinsic mechanisms

概要：The anomalous Hall effect (AHE) in ferromagnets has been a fundamental and intriguing issue in condensed-matter physics. However, the controversy on the mechanism has continued to this date.

In this talk, a unified theory of the AHE is presented for ferromagnetic metals with dilute impurities at the zero temperature [1], using the Keldysh technique in the gauge-covariant Wigner space [2]. In the superclean case, the AHE is mostly due to the extrinsic skew-scattering contribution. When the Fermi level is located around an avoided-crossing of band dispersions split by the *spin-orbit interaction* and/or the *scalar spin chirality*, the intrinsic AHE is resonantly enhanced by the topological non-perturbative nature to the order of e^2/h in 2D and $e^2/ha \sim 10^3 \Omega^{-1}\mathrm{cm}^{-1}$ in 3D with the lattice constant a. Then, an extrinsic-to-intrinsic crossover occurs when the relaxation rate γ becomes comparable to the spin-orbit interaction energy. Further increasing γ, a scaling relation $\sigma_{xy} \propto \sigma_{xy}^{1.6}$ appears in the dirty regime. The present work reveals the two crossovers, which explains wide experimental results [3] beyond the conventional perturbation theory in the spin-orbit coupling [4].

The anomalous Nernst and thermal Hall effects are also studied [5]. The thermal Hall conductivity follows the electric Hall conductivity and the same crossovers occur. However, the thermoelectric Hall conductivity suffers from an appreciable skew-scattering contribution, which masks the Berry curvature of the Bloch wavefunction near the Fermi surface even in the intrinsic regime.

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[3] T. Miyasato *et al.*, Phys. Rev. Lett. **99**, 086602 (2007).
[4] J.M. Luttinger, Phys. Rev. **112**, 739 (1958).
[5] S. Onoda *et al.*, unpublished.

（担当：川村研）