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Topological correlated phases in frustrated magnets

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Anomalous Hall effect (AHE) is one of the most fundamental transport properties of solid. Since its discovery, the effect is known to be proportional to magnetization and thus the zero field AHE has been observed only in ferromagnets. Hypothetically, however, since intrinsic AHE arises owing to fictitious fields due to Berry curvature, it may appear in spin liquids and antiferromagnets without spin-magnetization in certain conditions. Indeed, a spontaneous Hall effect has been observed in recent experiments in the spin liquid $Pr_2Ir_2O_7$ [1]. In this talk, we will present our experimental observation of a large Hall effects in spin liquids and antiferromagnets and show experimental evidence that they represent novel topological phases in frustrated magnets.

First part of the talk will focus on Pr based pyrochlore compounds. Various interesting phenomena have been found in the spin liquid compound $Pr_2Ir_2O_7$, a metallic spin ice with two electronic sectors [1,2]. One is Pr based spin ice, where strong quantum effects are expected for ferromagnetic exchange coupling and many similarities are found to the quantum spin ice candidate $Pr_2Zr_2O_7$. Another sector is the 5*d* conduction electrons for which we found a Fermi node state with a quadratic band touching was found at the Fermi energy [3]. Thus, this compound can be viewed as a hybrid of quantum spin ice and Luttinger semimetal state [3,4]. We will discuss our recent updates of our study on the chiral spin liquid state in the bulk and the high-temperature spontaneous Hall effect in the thin film form of $Pr_2Ir_2O_7$ [5]

Second part will discuss our recent work on the antiferromagnets Mn_3Sn [6] and Mn_3Ge [7]. These antiferromagnets have a non-collinear chiral spin order known as an inverse triangular spin structure [6,7]. We recently discovered that they exhibit a large anomalous Hall effect at room temperature. Moreover, the sign of the large AHE can be softly flipped by the rotation of magnetic field, indicating that the direction of a fictitious field equivalent to a few 100 T is tunable by a small external magnetic field less than 0.1 T and thus the AHE could be useful for applications [6,7,8]. We will discuss that the magnetic Weyl metal states are the origin for such a large anomalous Hall effect observed in the antiferromagnets that possess almost no magnetization [6,7,8].

This is based on the collaboration with Takeshi Kondo, Shik Shin, Michi-To Suzuki, Takashi Koretsune, Ryotaro Arita, Yoshichika Otani and Mikk Lippmaa.

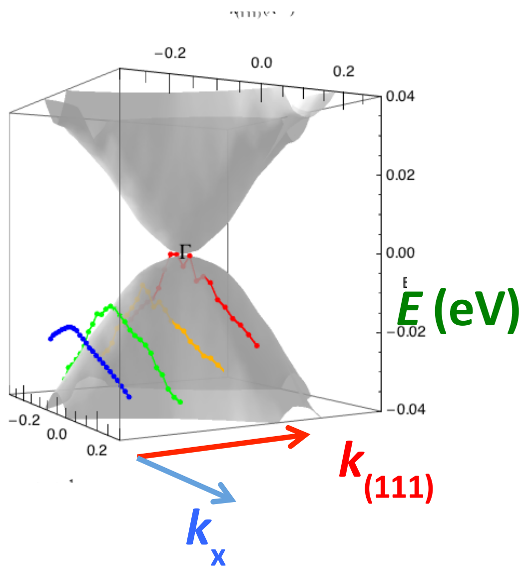

Figure 1. Quadratic Fermi Node in $Pr_2Ir_2O_7$

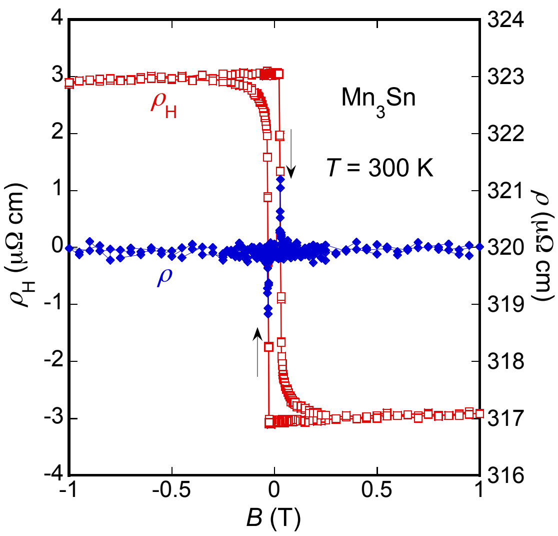

Figure 2. Hall resistivity and magnetoresistivity in Mn_3Sn

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