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Time-reversal symmetry breaking and spontaneous Hall effect without magnetic dipole order in $Pr_2Ir_2O_7$

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An electric current flowing through a conductor in a magnetic field produces a transverse voltage drop known as the Hall effect. In the absence of the field, this effect also appears in ferromagnets in a plane normal to its spontaneous magnetization vector owing to the spin-orbit coupling. Generally, it may also detect a nontrivial order parameter breaking the time-reversal symmetry on a macroscopic scale, for example, scalar spin chirality. In this talk, we present our recent results in the study of the frustrated magnetism and Hall transport of the metallic pyrochlore magnet $Pr_2Ir_2O_7$.[1,2] Strikingly, a spontaneous Hall effect is observed in the absence of both an external magnetic field and conventional magnetic long-range order.[3] This strongly suggests the existence of a chiral spin liquid, a spin-liquid phase breaking the time-reversal symmetry. Both our measurements indicate that spin-ice correlations in the liquid phase lead to a non-coplanar spin texture forming a uniform but hidden order parameter: the spin chirality. Interesting phenomena seen under high field will also be discussed. This is the work performed in collaboration with Y. Machida, Y. Ohta, T. Sakakibara, T. Tayama, Y. Uwatoko (ISSP, Univ. of Tokyo), S. Onoda (Riken, Tokyo), L. Balicas (NHMFL), D. E. MacLaughlin (UC, Riverside) and C. Broholm (JHU).

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