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Novel transport phenomena in noncollinear antiferromagnets

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Despite the significant academic interest in them and their richness in nature, antiferromagnets have always been overshadowed by ferromagnets in real-life applications based on magnetism or spintronics. This is primarily due to the fact that antiferromagnet order parameters, in contrast to the ferromagnetic magnetization, are only weakly coupled to magnetic fields, and are hence difficult, in conventional view, to be manipulated. In this talk I will discuss a number of recent theoretical and experimental developments that counter this conventional wisdom, in a class of antiferromagnets that have stable noncollinear magnetic orders. As an introduction I will talk about the discovery of the anomalous Hall effect (AHE) in noncollinear antiferromagnets. Then I will explain a theory for the recent experimental discovery of time-reversal-symmetry-breaking counterparts of the conventional SHE and ISHE in the noncollinear antiferromagnet Mn_3Sn, which we name as the magnetic spin Hall effect (MSHE) and the magnetic inverse spin Hall effect (MISHE), respectively. Finally I will discuss the concept of spin density polarization, and how to use it to describe the spin-Hall effect in a magnetic insulator as a bulk effect, without using the spin current language.