Cluster multipole theory for anomalous Hall effect in antiferromagnets

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The anomalous Hall effect (AHE) occurs in solids with broken time-reversal symmetry. In early studies, the AHE was considered to arise in ferromagnets and scale with the magnetization of the system. On the other hand, it has been revealed in this decade that the AHE does not necessarily scale with the magnetization and it can arise even in antiferromagnets. Indeed, for some systems with non-coplanar spin configurations, the AHE occurs since the electrons feel a fictitious magnetic field characterized by the scalar spin chirality [1].

Recently, the AHE in systems with coplanar spin configurations has attracted much interest [2,3,4,5]. In particular, the AHE in Mn_3Sn [6] and Mn_3Ge [7,8] is of great interest, in that the anomalous Hall conductivity is comparable to that of ferromagnetic metals, although neither the magnetization nor scalar spin chirality is finite. While the relation between the AHE and the topological properties of the electronic structure has been extensively studied [9], it is not fully understood whether there is a macroscopic quantity characterizing the AHE in coplanar antiferromagnets.

In this talk, we introduce a new order parameter, which we call cluster multipole (CMP) moment, and show that CMP quantifies the AHE in antiferromagnets with general spin configurations. In particular, we demonstrate that the antiferromagnetic states in Mn_3Sn and Mn_3Ge are characterized by a cluster octupole moment, and the AHE in those antiferromagnets and that in elemental Fe can be discussed in the same scheme [10].

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