Contribution ID: **6** Type: **not specified**

Cluster multipole theory for anomalous Hall effect in antiferromagnets

Thursday, 22 June 2017 17:15 (15 minutes)

The modern formalism of the intrinsic anomalous Hall conductivity (AHC) provides profound insight into the AHE being closely related to the topology of one-electron energy bands [1,2]. Whereas the AHE is usually observed in ferromagnets and explained as an outcome of the macroscopic dipole magnetization, the AHE has been studied also for certain noncollinear AFM states by first-principles calculations [3,4]. Furthermore, a large AHC was recently discovered for the AFM states in Mn3Z (Z=Sn, Ge), whose magnetic geometry has no uniform magnetization [5-7].
We identified the antiferromagnetic (AFM) structures which induce the anomalous Hall effect (AHE) in spite of no net magnetization by introducing a novel concept, cluster multipole (CMP), to characterize macroscopic magnetization of antiferromagnets [8]. We applied the CMP theory to the noncollinear AFM states of Mn3Z (Z=Sn, Ge) and Mn3Ir and show that the AHE is associated with the cluster octupole moments which belong to the same symmetry as the magnetic dipole moments. We further compared the AHE in Mn3Z and bcc-Fe based on first-principles calculations and find out their similarity with respect to the CMP moments. The theory thus can also deal with the AHE in antiferromagnets on an equal footing with that of simple ferromagnets.

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