Magnetic-ion resolved origins of magnetoelectric responses in chiral antiferromagnets $RFe_3(BO_3)_4$

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While there were extensive studies on the linear magnetoelectric (ME) effect, the cross-correlated phenomena between electricity and magnetism in solids remained mostly unexplored. Recent discoveries of the spin-induced ferroelectricity in frustrated magnets and the strong ME correlation in noncentrosymmetric magnets have stimulated the revived interest on the ME phenomena [1].

Rare earth iron borates $RFe_3(BO_3)_4$, whose structures possess a noncentrosymmetric space group ($R32$ or $P3_121$), have recently been discovered to show multiferroicity or magnetic-field induced electric polarization ($P$) [2]. While their magnetic and ME properties were extensively investigated, the origin of the $P$, or specifically the relationship between the electricity and the respective magnetism of iron ions (Fe) and rare-earth ions ($R$), remains elusive.

We measured the $P$ under a magnetic field and observed the linear ME effect and/or the spontaneous $P$ which are ascribed to spins of Fe and/or magnetic moments of $R$. We constructed a model for the spin-induced $P$ at the Fe/$R$ sites, with which we could reproduce the observed behavior of the magnetic field dependence of $P$. Thus, we could extract the respective contributions to $P$ from Fe and $R$ magnetic ions.
