Magnetic structure analysis for $CoTa_3S_6$ by polarized neutron scattering

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In ferromagnets, electric current generally induces transverse Hall voltage in proportion to magnetization (anomalous Hall effect), and it is frequently used for electrical readout of the up and down spin states. While these properties are usually not expected in antiferromagnets, recent theoretical studies predicted that non-coplanar antiferromagnetic order with finite scalar spin chirality (i.e. solid angle spanned by neighboring spins) can often induce large spontaneous Hall effect even without net magnetization or external magnetic field[1]. This phenomenon, i.e. spontaneous topological Hall effect, can potentially be used for the efficient electrical readout of the antiferromagnetic states, but its experimental verification has long been elusive due to the lack of appropriate materials hosting such exotic magnetism.

In this study, we focused on a triangular lattice antiferromagnet $CoTa_3S_6$, which has been reported to host unconventionally large spontaneous Hall effect despite their vanishingly small magnetization [2,3]. To identify their detailed magnetic structure, we have performed the polarized neutron scattering experiments at 5G PONTA beamline in JRR-3. In the present setup, the neutron spin direction is aligned along the [001] direction. Figure 1 indicates the polarized neutron scattering profile for the (1/2, 1/, 1/2, 0) magnetic reflection, where the spin flip (SF) and non-spin-flip (NSF) scattering mainly reflects the in-plane and out-of-plane spin components. Here, both SF and NSF scattering intensities are clearly observed, which indicates the appearance of non-coplanar spin texture in this compound. By further performing the detailed representation analysis, we concluded that this compound hosts the all-in-all-out type non-coplanar antiferromagnetic order. Our finding suggests that the reported giant spontaneous Hall effect can be well explained in terms of topological Hall effect, which originates from the fictitious magnetic field associated with scalar spin chirality in non-coplanar antiferromagnetic orders.

The present results indicate that the scalar spin chirality mechanism can offer a promising route to realize giant spontaneous Hall response even in compensated antiferromagnets, and highlight intercalated van der Waals magnets as an unique quasi-two-dimensional material platform to enable various nontrivial manner of electrical reading and possible writing of non-coplanar antiferromagnetic domains.

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[3] P. Park *et al.*, npj Quantum Materials **7**, 42 (2022).

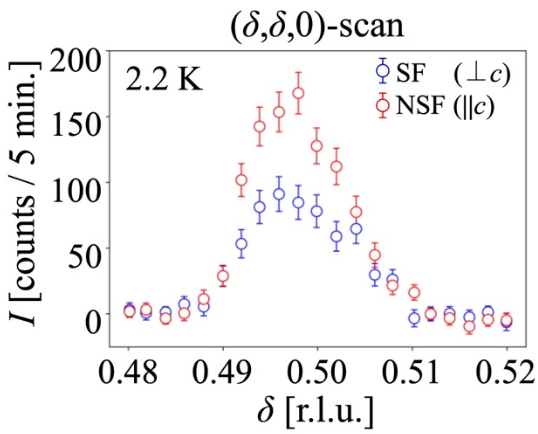

Fig. 1. The polarized neutron scattering profiles for the $(\delta, \delta, 0)$ line scans measured at 2.2 K near zero field. Intensities measured at 50 K in the paramagnetic phase are subtracted as background. Spin-flip (SF) and non-spin-flip (NSF) scattering represent the in-plane ($\perp c$) and out-of-plane ($|| c$) component of the modulated spin component, respectively.