Polarized neutron scattering study of a field-induced magnetic phase in a van der Waals antiferromagnet

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Van der Waals intercalated antiferromagnets provide a promising platform for realizing large electromagnetic responses originating from nontrivial magnetic structures. The target compound consists of triangular magnetic Co-ion layers intercalated between conducting TaS_2 layers and exhibits four distinct magnetic phases as functions of temperature and magnetic field. A large anomalous Hall effect appears in both the zero-field ground state (phase I) and the field-induced phase II, despite their small net magnetization [1]. Previous zero-field polarized neutron scattering measurements established that phase I has a noncoplanar antiferromagnetic structure characterized by the propagation vector $\boldsymbol{q}$ = (1/2, 0, 0). In this study, to investigate the magnetic structure of phase II, in which the anomalous Hall effect remains large, we performed polarized neutron scattering measurements under a magnetic field applied along the *c* axis.

A single crystal was mounted with the (H, K, 0) plane as the horizontal scattering plane and the *c* axis parallel to the applied magnetic field. P_{zz} polarization analysis was performed using Heusler monochromator and analyzer crystals. In this geometry, the non-spin-flip (NSF) channel probes the magnetic component along the *c* axis, whereas the spin-flip (SF) channel probes the in-plane component perpendicular to the scattering vector. The main measurements were performed at 3 K and 5 T, corresponding to phase II. Complementary unpolarized neutron scattering measurements were also conducted as functions of temperature and magnetic field to follow the evolution of the magnetic reflections across the phase boundaries.

In phase II, magnetic reflections were observed at (3/2, 0, 0) and (1/2, 1/2, 0), demonstrating that the field-induced phase retains the propagation vector $\boldsymbol{q}$ = (1/2, 0, 0). The (3/2, 0, 0) reflection was observed predominantly in the NSF channel, indicating a substantial magnetic component along the *c* axis. In contrast, the (1/2, 1/2, 0) reflection exhibited clear signals in both the NSF and SF channels, indicating the presence of both *c*-axis and in-plane components. The (1/2, 0, 0) signal appeared weaker than in phase I, with no appreciable SF contribution. The unpolarized measurements further revealed systematic changes in the magnetic reflection intensities across the field-induced magnetic transitions.

Comparison with the previous zero-field results indicates that phases I and II share the same magnetic propagation vector and contain both out-of-plane and in-plane magnetic components but differ in the relative intensities of the magnetic reflections. In particular, the weaker (1/2, 0, 0) intensity in phase II suggests a field-induced rearrangement of the spin structure rather than a simple uniform canting of the zero-field spin configuration. The present measurements thus provide important constraints on the microscopic magnetic structure of phase II and form a basis for clarifying the relationship between the field-induced antiferromagnetic order and the large anomalous Hall effect.

[1] H. Takagi *et al*., *Nat. Phys.* **19**, 961 (2023).

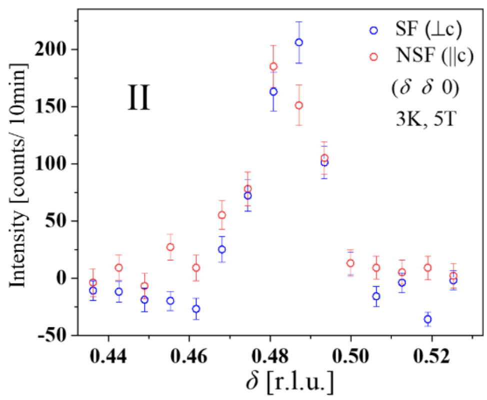

Fig. 1. P_{zz} polarized neutron scattering profiles measured along (δ, δ, 0) in phase II.