Magnon spin-momentum locking in kagome antiferromagnets

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A topological insulator is an insulator that has conducting edge states. The bulk material is insulating due to the energy gap induced by the spin-orbit interactions that act on up-spin and down-spin bands, whereas edge states are conducting since they are formed across the energy gap. At the topological edge state, electron spin depends on its momentum, which is called spin-momentum locking. Recently, its magnetic analogue, magnon spin-momentum locking has proposed theoretically [1,2]. The key is the presence of magnetic sublattices, which yield the pseudospin degree of freedom. DM interactions induce an energy gap between the pseudospin-up and pseudospin-down bands, together with the magnon edge states formed across the energy gap. Identifying the magnon spin-momentum locking would give a hint to understand the topology of the magnon bands.

Potassium jarosite ($KFe_3(SO_4)_2(OH)_6$ [3]) is one of the candidate compounds to observe the spin-momentum locking due to the 120 degrees magnetic structure below $T_N = 65$ K. In this study, we tried to detect the small energy gap formed between hybridized magnon bands through single crystalline inelastic neutron scattering experiments by using a general-purpose triple axis spectrometer GPTAS. Totally 49 mg of two single crystalline samples were coaligned with setting the *HK*0 plane as a horizontal scattering plane. The energy of outgoing neutrons from the sample was fixed to 14.7 meV using pyrolytic graphite (PG) 002 reflections. A PG filter was installed in the upstream of analyzer to remove higher harmonic neutrons. The analyzer was set in the focusing condition by using 3 blades out of the 9 blades. The sample was cooled down to 2.7 K using the closed cycle GM refrigerator.

The constant Q scans between Γ and M points are shown in Fig. 1(a,b). Three magnon branches induced from the three magnetic sublattices were identified. The formation of the energy gap should be reflected in the intensities of the two magnon branches with a large and small dispersion around the 1.15, -0.15 0 position (see Fig. 1(a)). However, the wavevector variation of the scans looks very continuous and the energy gap was detected.

On the other hand, we find that the energy gap could be formed between the two magnon branches existing at 7 meV around the Γ point. This is suggested by the contrasting intensities at the 100 and 110 positions. While the almost dispersionless magnon branch was clearly detected around 100, it was not observed in the equivalent constant Q scans around 110. On the other hand, the other magnon branch was identified much clearer around 110, not 100. Based on the spin-wave calculations using the exchange parameters estimated in the previous study [4], this behavior should indicate a pinch-point like singularity at the Γ point. We expect that this singularity reflects nontrivial topology of magnon bands. Indeed, a theoretical proposal suggests the relevance between the singularity and finite Berry curvatures around the singular point induced by DM interactions in a forced-ferromagnetic state in kagome antiferromagnets [5]. Further detailed analyses are necessary to confirm if the similar mechanisms can be applied to the 120 degrees structure.

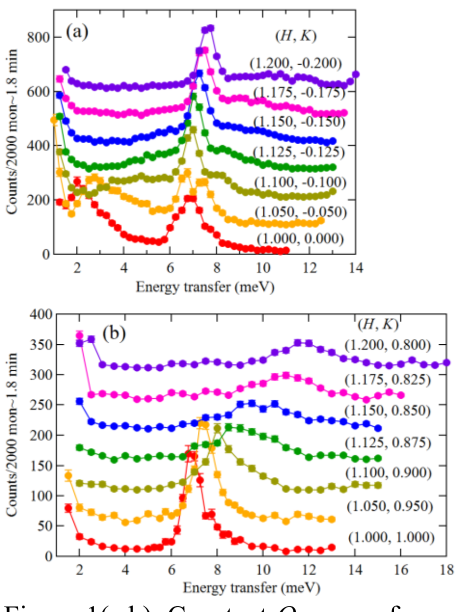

Figure 1(a,b). Constant Q scans of measured at 2.7 K. Some scans are shifted for clarity.

[1] N. Okuma, Phys. Rev. Lett., **119**, 107205 (2017). [2] M. Kawano, Commun. Phys. **2**, 27 (2019). [3] D. Grohol *et al.*, Nat. Mater. **4**, 323 (2005). [4] K. Matan *et al.*, Phys. Rev. Lett., **96**, 247201 (2006). [5] H. Yan et al., arXiv:2304.02203v2 (2023).