Interplay between magnons and Weyl fermions in a magnetic Weyl semimetal

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1. Introduction

Topological Weyl semimetals, a new quantum state of matter, have attracted huge interests, owing to their exotic physics and great application potentials. Very recently, it has been reported that $Sr_{1-y}Mn_{1-z}Sb_2$ is a rare example of a magnetic Weyl semimetal, where itinerant Weyl fermions and magnons coexist. Compared to other materials, the entanglement between these quasiparticles are expected to be stronger, due to the weaker spin-orbit coupling. Here, we propose to explore the interplay between the Weyl fermions and the magnons.

2. Experiment

For this experiment (2018A0018), we prepared the 3.2 g single crystals which have been already co-aligned with [100] and [001] directions in the horizontal plane. Firstly, we mapped out the magnetic excitations to explore the interplay between Weyl fermions and magnons in $Sr_{1-y}Mn_{1-z}Sb_2$ at the low temperature (6 K). At the beginning, [001] direction is along the beam, and then scattering data were collected by rotating the sample about the [010] axis from 0 to 60 degrees with 0.33 degrees per step. Each step cost 15 minutes, and we attained the whole magnetic excitation spectrum at 6 K. Through the excitation spectrum, the gap (at about 5 meV) can be clearly seen. Secondly, due to the weak layer coupling, the spectrum covers enough area without rotating the samples. Therefore, twenty temperatures (6, 20, 39, 58, 78, 98, 118, 139, 159, 169, 179, 189, 200, 210, 220, 241, 260, 269, 281, 295 and 306 K) were selected to describe the picture in detail. We spent two hours for each temperatures achieving the temperature dependence of magnetic Bragg peak. Some errors happened to the hot stickers, so we just collect data near the T_N (304K). Furthermore, we are going to perform a new experiment for high temperature data. Last but not the least, we collected data of vanadium standard sample with the same measurement conditions. To sum up, 4SEASONS with fine resolution makes this experiment clearly and effectively.

3. Results

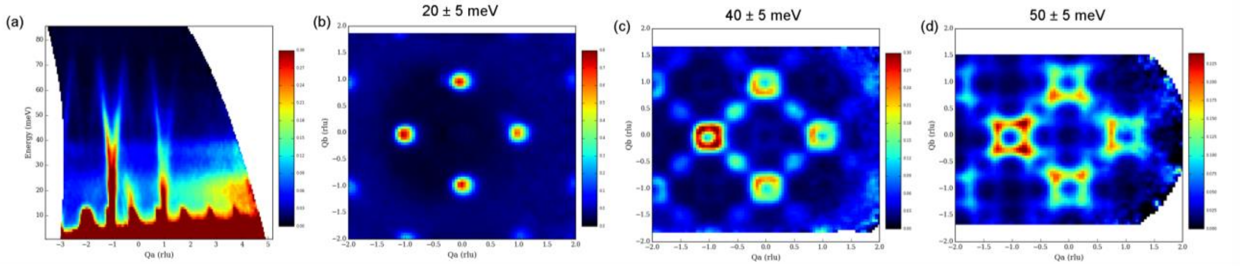

Fig. 1. Magnetic excitations using E_i = 100 meV at 6 K. (a) Dispersion along [*H*00] direction with wave vector L integrated over [-11.55 to 37.8] rlu. (b), (c) and (d) Constant-energy contour at (*H, K,* 0) plane. The integrated energy range is 20±5 meV, 40±5 meV and 50±5 meV, respectively. Another wave vector *L* in (0, 0, *L*) is integrated over range [-10, 10] rlu.

The excitations at 6 K are shown in Fig. 1. The dispersion along the [*H*00] direction is shown in Fig.

1(a). Moreover, fig.1(b), (c) and (d) display that the excitations are originated from the positions of magnetic Bragg peak which are indexed by (±1, 0, 0) and (0, ±1, 0), indicating the spin excitation behavior. According to this result, it ought to be the normal spin-wave excitation. In other words, the interplay between the itinerant Weyl fermions and magnons cannot be clearly observed. Actually, there are still some anomalies here. Focus on the point (0, 0 ,0), it seems that the acoustic branch may cross at about 40 meV, where neither the spectrum nor the constant-energy contour is very clear. Also, the low energy background of the spectrum is not clean, where some signals still can be observed. We are going to do the simulation to check whether it is influenced by the itinerant part or not.

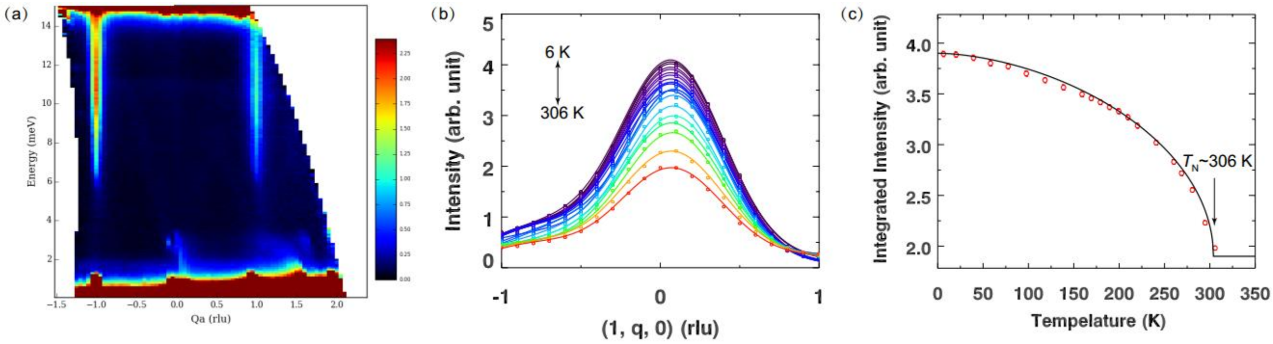

Fig. 2. (a) Dispersion at 6 K along [H00] direction with wave vector L integrated over [-5.7 to 16.8] rlu. (b) Elastic peaks at different temperatures. Circles with error bars are original data gotten from 4SEASONS, while lines are fitted with Gaussian functions. (c) Integrated intensities as a function of temperature. Solid line is a guide line. T_N=304 K is the Neel temperature.

Luckily, Fig. 2(a) demonstrates a very clear gap when we selected the proper E_i (18 meV). Moreover, for characterize the magnetic transition in detail, we selected twenty temperatures from 6 K to 306 K. Due to the weak layer coupling, the spectrum covers enough area without rotating the samples. The results are shown in Fig. 2(b). There still exists peak centered at (1, 0, 0) position, although the temperature is around the Neel temperature. The integrated intensities of those peaks can be seen as an order parameter of the magnetic transition in Fig. 2(c). Also we lack in data of high temperature. Furthermore, we need to collect data between 300 K and 500 K.

4. Conclusion

4SEASONS with its large momentum-energy coverage and fine resolution makes this experiment (2018A0018) effectively and clearly. We hope to map the magnetic excitation spectrum to observe the interplay between the itinerant Weyl fermions and magnons. However, it seems to be the spin-wave excitation, and we will do the simulation to check whether it is influenced by the itinerant part or not. In addition, further neutron scattering measurements at higher temperature are needed to characterize the magnetic transition in $Sr_{1-y}Mn_{1-z}Sb_2$.