実験報告書様式（一般利用課題・成果公開利用）

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Experimental Report	承認日 Date of Approval 2017/06/07 承認者 Approver Ryoichi Kajimoto 提出日 Date of Report 2017/06/07
課題番号 Project No. 2016B0116 実験課題名 Title of experiment Investigation of magnetic excitations in spin-web compound Cu_3TeO_6 実験責任者名 Name of principal investigator Yuan Li 所属 Affiliation School of Physics, Peking University	装置責任者 Name of Instrument scientist Kazuki Iida, Kazuya Kamazawa 装置名 Name of Instrument/（BL No.） 4SEASONS(BL01) 実施日 Date of Experiment 19 Feb 2017 to 28 Feb 2017

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

The sample is a copper tellurate, Cu_3TeO_6. It is an antiferromagnetic insulator with the transition temperature T_N at around 61K.

We have used about 16.9 grams coaligned Cu_3TeO_6 single crystal in the inelastic neutron scattering experiment.

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

We used the 4SEASONS neutron spectrometer based on the technique of time of flight (TOF).

The experiment basically consists of three parts. In the first part, we set the temperature at 4K to study spin dynamics in Cu_3TeO_6. For the second part, we raised the temperature to 73K to see its high temperature behavior. And finally, we went back to 4K for detailed study of the magnetic excitation. We have obtained the full spin wave spectrum in Cu_3TeO_6 from this experiment as the primary result.

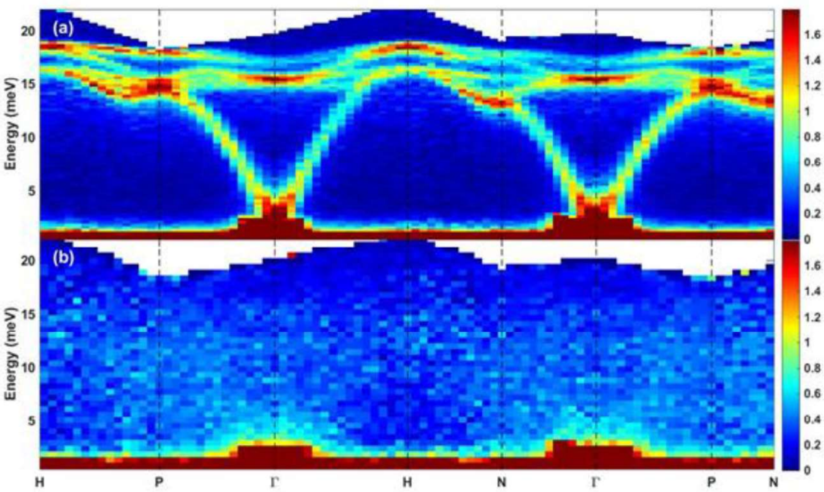
Most of our data analysis work and the results represented below are based on the Horace software package. We combined the data at symmetrically equivalent wave vectors in reciprocal space with the help of Horace. We carried out the experiment with the sample mounted in the [H H L] plane. During the experiment we rotated the sample every 0.5 degree and a total coverage of nearly 180 degrees was obtained. The incident energy we mainly used is 28.18meV. And thanks to the multiple-Ei method, additional data with several other incident energies such as 55.05 and 8.21meV are also available.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

We choose the high symmetry directions (H-P-Γ-H-N-Γ-P-N) in the reciprocal space to represent our data as shown in FIG 1.From the low temperature measurement (T=4K), we find that the magnetic excitation extends as high as 20meV and shows semiclassical spin wave spectrum features (FIG 1(a)). Six branches of spin waves are clearly discerned, each of which is two-fold degenerate due to symmetries in this magnetic system. The linear dispersion of the acoustic mode near Γ point is consistent with antiferromagnetic spin wave theory at zone center. If we scrutinize carefully in the data with Ei=8.21meV, we can find an energy gap at the Γ point (FIG 2), although it seems gapless from the full map. And the energy scan at the Γ point shows that the magnitude of the energy gap is around 2.5meV (FIG 2 inset). This gap is due to certain anisotropic effects in this material, most likely in the form of Dzyaloshinsky-Moriya interactions. The clear spin waves discussed above suggest that linear spin wave theory constitute an excellent description of the system. This is further confirmed in our measurement at 73K, which is higher than T_N. No spin wave is observed at this temperature (FIG 1(b)). But if we integrate the intensity over all reciprocal space and the energy range from 3meV to 22meV, we find the total spectrum weight is basically the same as in the low temperature case (not show). This result is consistent with the neutron scattering theory.

In order to study the optical branches in detail, we increased the frequency of the Fermi chopper from 250Hz to 500Hz, and measured the magnetic excitations at 4K with a higher energy resolution. We get an almost complete dispersion map with the help of Horace (FIG 3) despite of a smaller reciprocal space coverage.

The clear spin wave dispersion we got will be variable information for further study of the magnetism in this compound and set limitations for possible theoretical models.



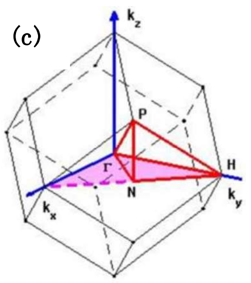


FIG 1: (a) A global spin wave dispersion along high symmetry lines in the first Brillouin zone at T=4K; (b) No clear feature shows at T=73K along the same trajectory. The intensity is in arbitrary unit. (c) Brillouin zone of the bcc lattice with the thick red lines indicating the high symmetry directions, along which the data are presented in (a) and (b).

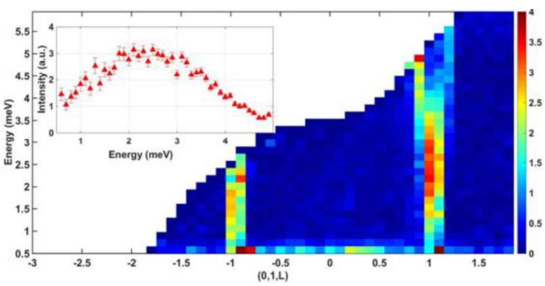


FIG 2: A colormap along (0,1L) direction from the data with the incident energy Ei=8.21meV. An energy can be seen in the Brillouin zone center (0,1,1). The inset shows the energy at this point.

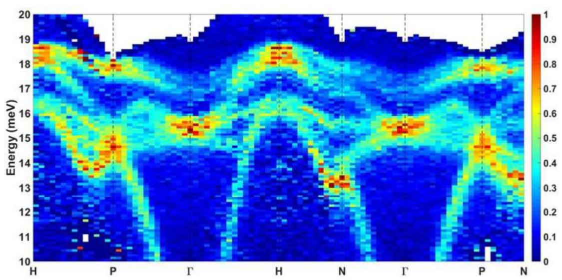


FIG 3: The spin wave dispersion measured with the increased Fermi chopper frequency. More details can be discerned comparing with FIG 1(a).