（※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。）

# MLF Experimental Report	提出日 Date of Report 2017/02/07
課題番号 Project No. 2016A0306 実験課題名 Title of experiment Low energy spin wave excitations of the long periodic modulation in CaBaCo2Fe2O7 実験責任者名 Name of principal investigator Johannes Reim 所属 Affiliation IMRAM, Tohoku University, Sendai	装置責任者 Name of responsible person Kenji Nakajima 装置名 Name of Instrument/（BL No.） Amateras 実施日 Date of Experiment 2016/11/11 – 2016/11/15

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.

Cylindrical shaped single crystal of CaBaCo2Fe2O7

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.

The layered kagome system in the hexagonal Swedenborgite structure displays similarly to the Pyrochlores a highly frustrated network of tetrahedral coordinated magnetic ions. However, its broken inversion symmetry raises further the complexity of ordering due to non-vanishing Dzyaloshinski-Moriya interactions. Recently investigated compounds of this family show various signs for unusual geometric frustration and disordered ground states despite of the typically strong antiferromagnetic exchange.
Here, we studied the excitations of spin waves at low energies in single crystals of antiferromagnetic CaBaCo2Fe2O7. This system featuring layered kagome structure is prone to strong geometric frustration effects. The excitation spectrum of spin waves at high energies has been studied in experiments at time-of-flight spectrometer ARCS (SNS, Oak Ridge) and 4Seasons (J-Parc, Tokai) and modelled successfully using spin dynamics simulations based on a Heisenberg nearest neighbour model. Here the deviations to this model, the long periodic modulation observed in high resolution powder and single crystal neutron diffractometers and also the anisotropy gap visible at 4Seasons, will be investigated. The time-of-flight spectrometer Amateras was thought to provide sufficient resolution in Q and energy to resolve the excitations related to the different propagation vectors of the 3-q star at an high enough incident energy for the anisotropy gap.
In order to cover the low energy excitation in Q and energy, an angular segment of 60 degree was mapped in 0.5 degree steps using four incident energies at once for 8 minutes per step at 4K and a more focused 17degree angular region in 0.5 degree steps using three incident energies for 16 minutes at 0.3K. In the evaluation we intend to combine the Q,E-space measured by each

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

incident energy, as the lower incident energies provide high resolution at small transfer energies while the higher incident energies provide wide Q,E-space coverage (compare Fig. 1 and 2). This results in resolution adopted energy vs Q maps (shown in the proposal). Here, the measured sample was oriented in a way that the (hhl)-scattering plane corresponds with the instrumental horizontal scattering plane.
Due to some problem with the orange cryostat, initially planned to use in the experiment, a He3 cryostat was used. This is the first time this setup was used in user operation. While its use requires longer times for cooling and heating procedures, this also allowed us to measure at 0.3K effectively reducing the the scattering according to the Bose-Einstein statistics. However, installing the He3 cryostat currently restricts the angular range from around 280 to about 150 degree, due to the positioning of connectors and limit switches. Overall this was not a serious issue, however accidentally the magnetic peak (1/3 1/3 0) at low-Q could not be covered. The cryostat was working well at the intended temperature 4K, while we experienced slight stability issues at 0.3K. Nonetheless, we obtained complete datasets at 4K for Ei=15.2, 7.74, 4.68 and 3.13meV and at 0.3K for Ei=3.426, 2.420 and 1.799meV and an incomplete one at 0.3K for Ei= 15.2, 7.74, 4.68 and 3.13meV. Preliminary evaluation is shown in the following figures. However, further work is required to make best use out of the vast data sets.

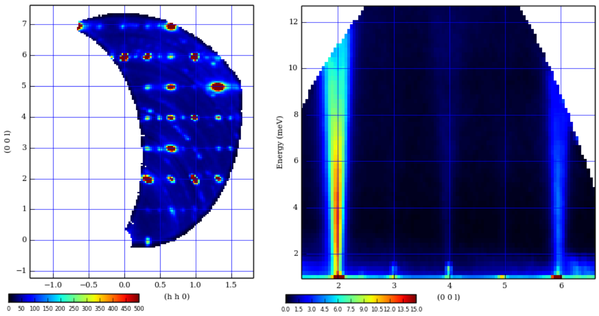

Figure 1: Intensity maps extracted from the data set obtained at 4K and Ei=15.2meV. (left) The elastic scattering in the (hhl)-scattering plane shows a wide coverage and numerous structural and magnetic peaks. (right) Inelastic scattering observed along [001] through the magnetic peak (1/3 1/3 2) where a steep and high intense spin wave excitation was observed.

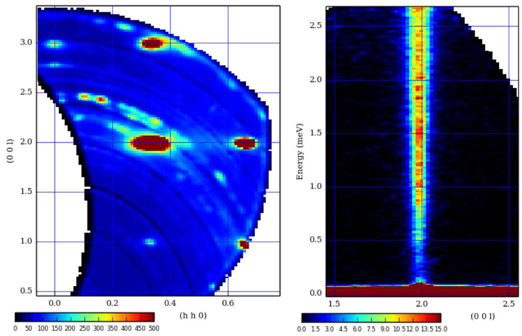

Figure 2: Intensity maps extracted from the data set obtained at 4K and Ei=3.13meV. (left) The elastic scattering in the (hhl)-scattering plane shows that the Q-space close to the magnetic peak (1/3 1/3 2) is covered. Furthermore, textured powder rings are visible stemming from background scattering and issues of sample quality. (right) In the inelastic scattering observed along [001] through the magnetic peak (1/3 1/3 2), an excitation gap of about 0.5meV is present between the high intense spin wave excitation and the elastic line.

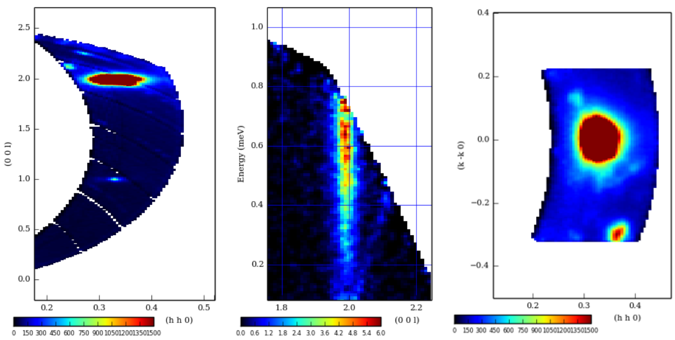

Figure 3: Intensity maps extracted from the data set obtained at 0.3K and Ei=1.799meV. (left) Only the Q-space close to the magnetic peak (1/3 1/3 2) was covered to increase counting time per step. (middle) Due to the lowered incident energy and temperature the excitation gap becomes better visible. (right) The (hk2) scattering plane reveals a triangular magnetic peak structure elongated along the magnetic BZ boundary, however, a peak splitting cannot be discerned.

In conclusion, we obtained very nice data sets to evaluate the low energy excitations. However, further evaluation is necessary to extract all the relevant information from the data sets. By this not only the spin excitation gap can be quantified more precisely, but also the existence or absence of other features can be evidenced. This is also necessary in order to determine, whether a magnetic peak splitting is present, which appears not to be the case in the preliminary evaluation.