（ ※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。 ）

CROSS TOKAI **Experimental Report** J-PARC	承認日 Date of Approval 2014/7/24 承認者 Approver Ryoichi Kajimoto 提出日 Date of Report 2014/7/18
課題番号 Project No. 2013A0141 実験課題名 Title of experiment Identifying orbital excitations in a spinel vanadate 実験責任者名 Name of principal investigator Sagayama Hajime 所属 Affiliation The University of Tokyo (currently KEK)	装置責任者 Name of Instrument scientist Ryouchi Kajimoto 装置名 Name of Instrument/(BL No.) 4SEASONS (BL1) 実施日 Date of Experiment 5 月 4 日 11:00am – 5 月 8 日 9:00am

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.

2 pieces of MnV_2O_4 single crystals grown by using the floating zone technique. Dimension of one peace sample is 5×5×5 mm^3.

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.

MnV_2O_4 is a Mott insulator with V^{3+} ions at octahedral B sites. Since the nearly t_{2g} level of each V^{3+} ion is occupied by two electrons, V^{3+} ions have spin and orbital degrees of freedom. Mn^{2+} ions with the high-spin $3d^5$ configuration are inactive with respect to the orbital degree of freedom. As the material is cooled down from the cubic paramagnetic phase, collinear ferrimagnetic order take place at T_N = 60K. As the temperature further decreases below T_{OO} = 48K, it undergoes a transition ascribed to orbital order. The spin moments are canted below T_{OO}, which confirms relatively strong coupling between spin and orbital sections. Due to the orbital ordering, lattice system changes from cubic to tetragonal (c<a) at T_{OO}. To explore elementary excitation of the orbital degree of freedom through the spin sector in this material, we performed inelastic neutron scattering experiment below T_{OO}.

In the previous experiment performed in November 2012, we have observed magnetic excitations at 10K. Dispersive magnetic excitations are clearly found below 10meV. From our classical spin-wave-model calculation, we succeeded in assigning them as Mn-spin-rotation mode. On the other hand, magnetic

excitations above 10meV are indistinct. The excitation above 10meV might be mainly contributed by the Vanadium spin, resulting large anisotropy of dispersion curves. In a magnetic multi-domain state, magnetic scattering signals complicatedly overlap. Therefore, we could not identify the dispersion relations above 10meV.

Single domain state can be realized by applying magnetic fields along the (001) direction because the c-axis of tetragonal is magnetic-easy axis below T_{OO}. So, in this study, we performed an inelastic neutron scattering experiment under magnetic fields applied with paired permanent magnets. Two single crystals of sample and the magnets were cooled down to 10K by using a closed-cycle-He4-gas refrigerator. Frequency of the Fermi chopper was set to 300 Hz. Sample was rotated from phi = 0 to 120 degree, where phi is a rotation axis vertical to the horizontal plane. The [100] and the [010] direction were parallel to the horizontal plane. We conformed single-domain state by measuring TOF peak profiles of (4 0 0) Bragg reflection.

Figure 1 shows the representative experimental result showing magnetic scattering intensities along (100) direction observed at 10K. Unfortunately, scattering intensities above 10 meV are not enough to identify the dispersion relations. The excitations above 10meV might be mainly contributed by the Vanadium spin, which is one Bohr magneton at the largest. Sample volume was not enough to detect such small signal, because gap of the permanent magnets limited the sample length.

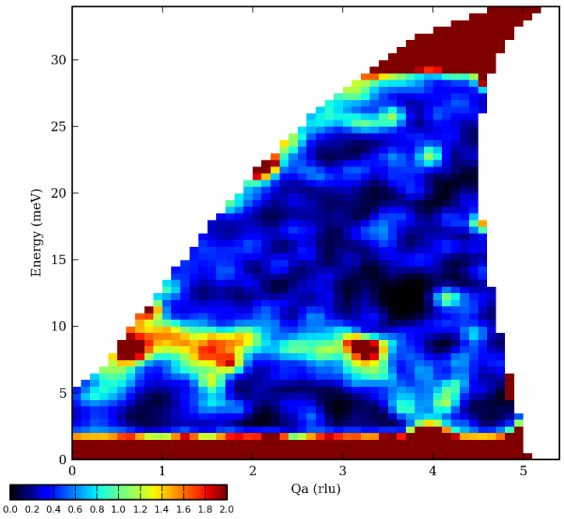

Fig.. 1 Counter plot along the (100) direction observed at 10K.