（ ※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 2014/8/8 承認者 Approver Ryoichi Kajimoto 提出日 Date of Report 2014/8/7
課題番号 Project No. 2014A0074 実験課題名 Title of experiment: “Study of the high-temperature magnetic excitations in the parent compound of high-T_c cuprates La_2CuO_4” 実験責任者名 Name of principal investigator: Masato Matsuura 所属 Affiliation: CROSS, Tokai	装置責任者 Name of responsible person: Ryoichi Kajimoto 装置名 Name of Instrument/（BL No.）: BL01 実施日 Date of Experiment: 2014/5/14-19

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.
Single crystals of La_2CuO_4 (a total mass of 33g)

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 high-T_c superconductivity in cuprates appears when holes or electrons are doped into CuO_2 planes. Recently, similar magnetic excitations have been observed in high-Tc cuprates by inelastic hourglass dispersion consists of upward and downward branches separated at the waist of the hourglass.[1),2)] Two characteristic parameters determining the shape of the low-energy part of the hourglass dispersion exhibit scaling behavior with respect to T_c: the incommensurability δ, and the “waist” energy of the hourglass, E_{cross}. However, the relation between the pairing interaction and hourglass dispersion is still under debate because the origin of the two types of branches is not fully understood.

In order to elucidate the origin of the hourglass dispersions, we have performed INS experiment on the underdoped $La_{2-x}Sr_xCuO_4$ (LSCO) with x=0.075 at 4SEASONS in 2012B with special attention to thermal change at high-temperatures. Above the pseudogap temperature (T^*~350 K), we have clarified that the hourglass-like dispersion at 5 K changes into chimney-like excitations at 400 K, which is similar to what observed in the itinerant antiferromagnets Cr and V_2O_3. However, it is not clear if the thermal change in magnetic spectra across T^* for x=0.075 is related to a change in Fermi surface or thermal damping due to high temperature. In order to resolve this issue, we have performed INS experiment at the same high temperatures 400 K on the parent Mott-insulator La_2CuO_4, which is insulator at high temperatures. INS experiments were carried out by using the Fermi chopper spectrometer ”4 SEASONS” installed at BL01 of Materials and Life Science

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

Experimental Facility in the J-PARC. The beam power of J-PARC accelerator was ~300 kW at the experiment. By using multi-incident energies (E_i) technique, we could obtain several data sets with different E_i; 404 meV, 94 meV, 41 meV, and 23 meV, simultaneously. The frequency of the Fermi chopper was set to 250 Hz. The data was collected at 6K and 400 K. In this report, we label the momentum transfer (Q_x, Q_y, Q_z) in the pseudo-tetragonal notation with a=3.783 Å.

Figure 1 shows constant-energy slices of data obtained at T=6K. At low energy, E=25meV, we confirmed spin wave signal at (1/2, 1/2). As energy increases, the magnetic excitation disperses outwards from the magnetic zone center. At E=150 and 250 meV, the scattering pattern forms ring around antiferromagnetic zone center (1/2, 1/2). The radius of the ring increases, which is expected from spin-wave. The observed magnetic excitations are well-described with a spin wave model for two dimensional Heisenberg Hamiltonian with the nearest neighbor exchange interaction J of 137+-5 meV, which is consistent with the previous report of J=136 meV[3].

As temperature increases up to T=400 K, which is higher temperature than the Neel temperature (~325 K), we observed clear spin wave signal with slight soft dispersion compared to that at 6 K. The contrasting thermal variation of high temperature (>400K) magnetic excitations between the underdoped LSCO (x=0.075) and LCO indicate that small (7.5%) carrier doping does affect magnetic excitation drastically. On the other hand, upward branch observed in the underdoped LSCO (x=0.075) below pseudogap temperature T* is similar to the spin wave dispersion in La_2CuO_4. This similarity suggests that localized spin nature is recovered below T*. We are preparing a draft including the results of LCO and LSCO (x=0.075), which will be submitted in near future.

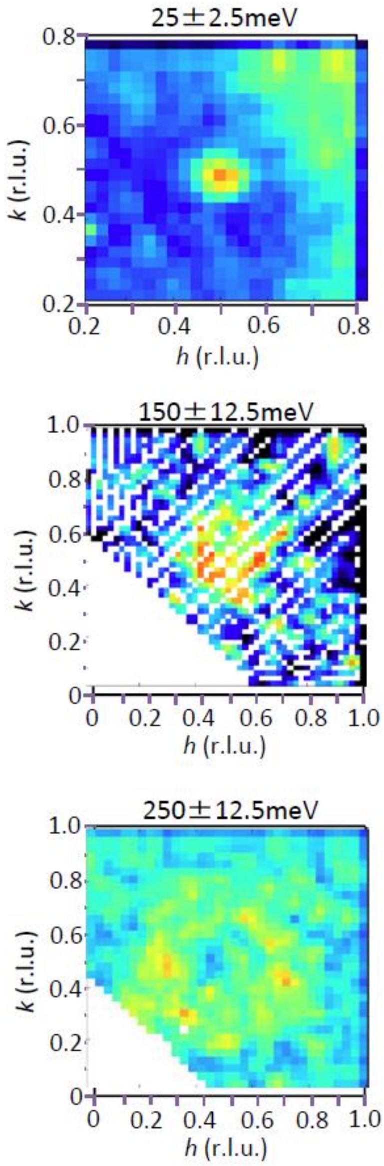

Fig.1 Constant-energy slices of data obtained at T=6K.

[1] J. M. Tranquada et al., Nature 429 (2004) 6991.
[2] S. M. Hayden et al., Nature 429 (2004) 6991.
[3] S. M. Hayden et al., Phys. Rev. Lett. 67 (1991) 3622.