TOUCHDOWN-INDUCED DYNAMIC MOTION OF BOULDERS NEAR THE SAMPLING SITE ON RYUGU. S. Kameda[1], S. Kikuchi[2], T. Kouyama[3], S. Tachibana[4], S. Sugita[4], R. Honda[5], T. Morota[4], N. Sakatani[2], M. Yamada[6], E. Tatsumi[7], Y. Yokota[2], H. Suzuki[8], C. Honda[9], K. Ogawa[10], M. Hayakawa[2], K. Yoshioka[4], M. Matsuoka[2], Y. Cho[4], H. Sawada[2], [1]Rikkyo University, (3-34-1 Nishi-Ikebukuro, Tokyo, Japan, kameda@rikkyo.ac.jp). [2]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency. [3]National Institute of Advanced Industrial Science and Technology, Japan. [4]University of Tokyo, Japan. [5]Kochi University, Japan. [6]Chiba Institute of Technology, Japan. [7]Instituto de Astrofisica de Canarias, Tenerife, Spain. [8]Meiji University, Japan. [9]University of Aizu, Japan. [10]Kobe University, Japan.

Introduction: The Hayabusa2 spacecraft arrived at the target asteroid Ryugu in June 2018, and subsequent global observations revealed that the surface of Ryugu is globally covered by boulders [1] and its bulk density is 1.19 $\pm$ 0.02 g/cm^3, which indicates a high porosity [2]. The 1st touchdown operation for sampling was performed on February 21, 2019. In ascending phase of the spacecraft after the sampling, Optical Navigation Camera (ONC) images show many pebbles and boulders were moving around. It is clearly seen in ONC images that some boulders were moved by thruster jet from propulsion system of the spacecraft.

It is highly possible that the ~0.1-mm samples were captured, however, ~10-cm boulders were not captured because of small size of sampling system. In this study, we attempt to estimate the mass density of a boulder from its motion induced by touchdown to aim to know middle-scale structure of the surface material of Ryugu.

Observation: ONC-W1 is on the bottom panel of Hayabusa2 spacecraft as shown in Figure 1 [3]. ONC-W1 took images continuously before and after touchdown with an interval of 2 seconds. The pixel resolution is ~1.3 mm/pixel because the distance from the surface was ~1.1 m and angular resolution is 0.068 degree/pixel [4, 5].

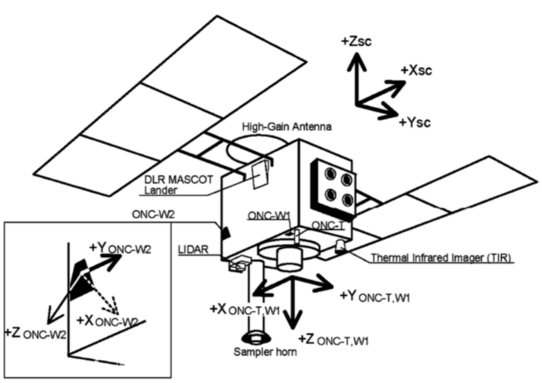

Figure 1. A schematic three-dimensional illustration of the Hayabusa2 spacecraft. ONC-W1 is located on the bottom panel. The ONC-W1 line of sight is in the -Z direction in the spacecraft coordinates (-Zsc) [3-5]

Motion of boulders: Comparing the two ONC images obtained just before and after the 1st touchdown, we found a boulder in the images could be a good target. Figure 2 shows the parts of the images obtained before and after touchdown. We measured size of the boulder as ~0.3 m using the image before touchdown (Fig. 2A). The area projected to the plane perpendicular to the line of sight with a distance of 1.12 m is ~0.011 m^2. In Fig. 2B, we can see several streaks on the surface of boulder caused by motion of bright spots during the exposure time (0.13 s). The average length of these streaks is 16 mm. Thus, the velocity of the boulder can be estimated as 124 mm/s. According to the start time of gas injection, acceleration is calculated as 0.11 m/s^2.

Thruster gas pressure at the position of the boulder and the cross-section to the gas injection are used to estimate the force on the boulder. Thus, the mass of boulder can be estimated, and the density is estimated as 1.26 $\pm$ 0.25 g/cm^3 from the estimated mass and volume.

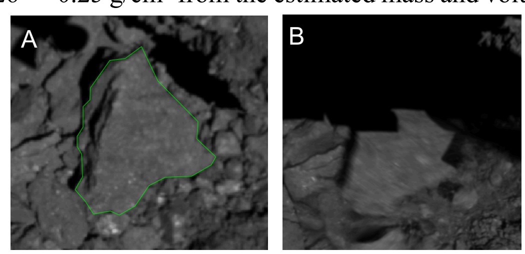

Figure 2. The image of the boulder obtained at 22:29:09UT before touchdown (A) and at 22:29:11UT after touchdown (B) on February 21, 2019.

Discussions: The estimated density of the boulder matches the bulk density estimated from global observation result within error. The surface of Ryugu shows a rubble-pile structure, and high porosity interior is indicated. However, if the average boulder density is so low as estimated in this study, the interior porosity might not be so low. Further careful error analysis is still to be done.

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