熱赤外撮像でさぐるC型小惑星リュウグウの高空隙な表層
Thermal Infrared Imaging of C-type Asteroid 162173 Ryugu with Porous Surfaces

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Thermal images from global to close-up scales taken by the Thermal Infrared Imager TIR [1] on Hayabusa2 [2] have revealed thermophysical properties of the C-type Near-Earth Asteroid 162173 Ryugu. On 27 June 2018, Hayabusa2 arrived at Ryugu and started remote sensing to characterize the nature of the asteroid and find the proper landing sites. *In situ* surface experiments were conducted using the robotic landers Minerva-II and Mascot [3]. *In situ* radiometry was conducted by MARA on MASCOT during a day-night cycle to derive the thermal inertia of a single boulder [4]. Ground-based observations [5] have been informed that the averaged thermal inertia of the asteroid is from 150 to 300 [tiu = J m^{-2} $s^{-0.5}$ K^{-1}] [5,6], corresponding to the surface covered with cm-sized granules.

TIR is the same design as the LIR on Akatsuki Venus climate orbiter [6], with 8 to 12 μm wavelength range, 328 x 248 effective pixels, and the FOV and IFOV of 16.7° x 12.7° and 0.051° per pixel, respectively. The first image of Ryugu detected by TIR was a point source on 6 June 2018, as was previously predicted [7]. Disc-resolved thermal images of Ryugu was taken from the HP on 30 June. The surface temperature was measured at 300 to 370K at about 1AU from the Sun, and gradually decreased with the solar distance. Comparison of the results with modeling [8] shows that the surface of Ryugu is not like fine regolith nor base rocks. Most of large boulders on Ryugu show temperatures almost the same as the surrounding surfaces. Diurnal temperature profiles of Ryugu are rather flatter than expected for a smooth terrain. Apparent thermal inertia is ~300 tiu or larger, but probably lower than the value when the

surface roughness is considered. All these facts are consistent with a very rough and porous surface with low porosity (˜35 ±10 %) [9] and the surrounding surface is dominated by porous rocks larger than several centimeters. Macro porosity should be 30 to 50 % to account for the bulk density of Ryugu ˜1200 kg m^{-3}.

During the descent operations for the release of landers and the touchdowns for sample collection, TIR has taken close-up thermal images of the local sites, continually from the altitude of 500 m until the start of final descent at 10 or 20 m altitude. Close-up thermal images show the surface physical state and a variety of boulders. Most of the boulders in close-up images have temperatures similar to the surroundings but with more variety. A small number of boulders are remarkably colder than the surroundings, indicating dense rocks with lower porosity.

These facts indicate that Ryugu is probably a rubble pile of loosely-bound porous rocks, which might originate from the outer layer of parent body where compaction did not occur effectively, while the dense boulders might originate the compacted center region of parent body or from the different parent body. A different composition (e.g., organic rich materials) cannot be ruled out so far to account for such a low thermal inertia (and low density) of Ryugu.

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