THERMOPHYSICAL PROPERTY OF THE ARTIFICIAL IMPACT CRATER ON ASTEROID RYUGU.

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Introduction: The Hayabusa2 spacecraft has completed the rendezvous phase around Cb-type asteroid Ryugu in 2019. Ryugu has numerous craters [1], and physical property of these floors is considered to represent that of the sub-surface materials. From thermal infrared imaging by TIR, global temperature distribution of Ryugu is consistent with the thermal calculation with thermal inertia of 300±100 J m^{-2} K^{-1} $s^{-0.5}$ [2], and thermal inertia of the crater floor is roughly comparable with the global average [3]. A couple of the small craters show anomalously low thermal inertia about 50 J m^{-2} K^{-1} $s^{-0.5}$, which might be contributed from the thermal insulating nature of the fine-grained and unconsolidated materials [4]. However, it is unknown how relaxation process of the crater relates to the thermophysical property and physical condition of the surface materials.

On April 2019, Hayabusa2 have carried out artificial impact (Small Carry-on Impactor or SCI) experiment [5]. In this experiment, an explosively formed projectile made of copper of the mass of 2 kg was fired with the velocity of 2 km/s from a SCI unit separated from Hayabusa2 down to the surface of Ryugu [6]. As a result of the successful operation, an artificial crater (SCI crater) with diameter larger than 10 m was created on the asteroid. In this study, we investigated thermal property of the SCI crater as the freshest crater on Ryugu.

Observation data: After the SCI impact, Hayabusa2 spacecraft carried out three-times descending operations, from its nominal position at about 20 km from Ryugu. First is the SCI crater search operation (CRA2) at April 24-25, 2019. The spacecraft hovered at the altitude about 1.7 km from the surface, and took the several images by varying its attitude. In this operation, the SCI crater was found by TIR and optical camera (ONC-T).

The second operation observing the SCI crater by TIR with high resolution was PPTD-TM1A operation at May 29-30, which was with the aim of release a target marker for the next touch-down and sampling. During the ascent phase of the spacecraft, TIR acquired an image of the SCI crater with higher resolution (~40 pixels corresponding to the crater diameter) than images in CRA2 operation.

The final change was PPTD-TM1B operation at June 12-13. This operation aimed to confirm the safety of the spacecraft on touch-down candidate regions. Similar to the PPTD-TM1A operation, the SCI thermal images were acquired during the ascending phase. The SCI crater was resolved with 70 pixels across its diameter.

All of these images showed higher temperature in the SCI crater than surroundings by ~10 K, especially on the western side of the crater. This high temperature would indicate low thermal inertia materials in the crater, or the high solar incident angle on the crater inner wall would make the temperature higher.

Data analysis: Since the number of images and observation duration were limited for each operation, we could not examine diurnal temperature profile of the crater. In order to estimate the thermal inertia of the SCI crater from single thermal image, we conducted surface temperature simulation using a local digital elevation model (DEM) around the SCI crater. The local DEM was generated from the ONC-T high resolution images acquired during PPTD-TM1A and PPTD-TM1B operations. Typical facet size of the local DEM we used in the calculation is about 15 cm, comparable with the pixel resolution of TIR image taken in the PPTD-TM1B operation. With varying thermal inertia, the simulated images were produced, and thermal inertia was estimated by comparison with the simulation results and observed temperature images.

Preliminary results: The highest resolution image in PPTD-TM1B was used for the analysis. Surprisingly, the simulated temperature distribution inside the SCI crater agrees well with the observed image. In this preliminary analysis, we expect that the thermal inertia in the SCI crater is uniformly about 300 J m^{-2} K^{-1} $s^{-0.5}$, consistent with large boulders (Iijima boulder and Okamoto boulder) in the crater, surrounding materials, and the global average. Therefore, the chief determinant of the high temperature in the SCI crater would not be the change of the thermal inertia. It seems to be contributed from the higher solar incident angle, which makes the solar flux larger than the surroundings by a few tens %. The location of the SCI crater is about 301°E of longitude and 8°N of latitude, and the subsolar longitude and latitude at the PPTD-TM1B operation were 314°E and 7.9°N, respectively, so that the western side of the crater inside has higher temperature.

The inside of the SCI crater seems to contain finer grains than the surroundings [5]. Therefore, we considers that some size-sorting effects occurred on Ryugu's surface, where large boulders and pebbles are laid on the fine grains layer. Diurnal thermal skin depth of Ryugu is a few centimeter, assuming the thermal inertia of 300 J m^{-2} K^{-1} $s^{-0.5}$. Thermal conductivity and thermal inertia of regolith bed, whose grain size is smaller than this thermal skin depth, should be lower than that of the individual grains due to thermal contact resistance between grains [7]. Less change in thermal inertia of the SCI crater compared with the surroundings or top-surface large boulders indicates that the typical grain size of the subsurface layer (meter-scale in depth) is larger than a few centimeters. Furthermore, since the centimeter-sized grains have thermal property consistent with the larger boulders and the small grains are considered to be crushed from the large boulders, the thermophysical property of the boulders is expected to be homogeneous in centimeter-scale or larger.

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