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Global and Regional Thermophysical Model of asteroid 162173 Ryugu by the Observation of Thermal Infrared imager TIR

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Abstract

Thermophysical Model (TPM) of the asteroid Ryugu has been revised since the start of remote-sensing observations of the asteroid Ryugu. Main instrument to determine its TPM is Thermal Infrared Imager (TIR) on board the HAYABUSA-2. So far, we found that the thermal inertia(TI) of the global scale with 5-20m resolution is widely uniform but strongly affected by surface roughness. We estimated an average TI of 200-400 ($J/m^2K^2s^{0.5}$) based on thermal imaging data taken every 6 degrees of rotational angles. On the other hand, we succeeded in obtaining close up imaging below 100m to 8.5m altitude, which shows regional thermal images up to 1cm resolution. We found various temperature distribution of boulders with having TI of 100 to 1000 ($J/m^2K^2s^{0.5}$) inferred by maximum temperature measurement. At the hovering phase at 8.5m height before final descent of touch down operation, some area in the field of view was shaded instantaneously by solar array paddles (SAP). From these images, we found TI of the almost area consistent with global values, however, we detected unexpectedly large temperature drop right after the shading, which indicates that the surface is covered by very thin layer of very low TI less than 50 ($J/m^2K^2s^{0.5}$). TIR observations are expected to demonstrate horizontally and vertically various and complicated TPM structure.

1. Introduction

Thermophysical model is crucial to understand asteroids, design of near surface operations of spacecrafts (e.g.[1]). Thermal Infrared Imager TIR [2] is one of the remote sensing instruments onboard the Japanese asteroid explorer Hayabusa2 [3] to investigate thermo-physical properties of the surface of asteroid 162173 Ryugu. This camera is based on the uncooled micro-bolometer array of 328 x 248 effective pixels, with the FOV of 16° x 12°, and with a band pass filter of 8 to 12 μm. Since approaching to Ryugu at the distance of 2500km, TIR has started science observations. In this paper, we summarizes updated TPM by the global mapping observation in comparison with regional TPM based on close-up images obtained by some descent operations including the first touch down operation performed in Feb. 2019.

1.1 Global thermophysical model by dirunal temperature change

Global thermophysical model is deduced by the Home Position (HP) observations at 20km and mid-altitude observations at 5km because whole body of the asteroid can be taken within the field of view. In these observations, thermal images of sunlit hemisphere during one rotation period (7.6 hours) with every 6 degrees were taken. By the analysis of diurnal temperature change, we estimated TI of 200 to 400 ($J/m^2K^2s^{0.5}$) [4] . It should be noted that diurnal temperature profile is strongly affected surface roughness [5], then the data analysis is still ongoing to evaluate solar phase angle dependency using different insolation and observation angles.

1.2 Regional variations of thermal model by close up observations

During the descent operations for the release of landers and the touchdowns for sample collection, close-up thermal images of the local sites have been taken by TIR. As of now, we have taken more than several hundred images below 100m altitude (about 8.9cm/pix). The surface of Ryugu is nominally widely covered by several tens centimeters to meter sized boulders[6], then thermal behavior of each boulder and crater can be well characterized by these images. Since these close-up images were taken by nearly subsolar condition, temperatures of the boulders should be maximum in response to the low thermal inertia. Detailed analysis is ongoing, but most of the boulders and craters have equivalent TI of the global averaged value. However, we could find 20-30K lower temperature boulders which indicate TI of twice or three times higher than the global average TI [7]. On the other hand, bottom part of some craters showed higher temperatures whose TI is as low as 100 ($J/m^2K^2s^{0.5}$). Detailed analysis using close-up images is ongoing, and there exist many interesting regional TPM structures surface on Ryugu.

1.3 Thermal response by instantaneous shading by Solar Array Paddles(SAP)

At the first touch down operation on Feb. 21, the space craft hovered at the altitude of 8.5m before final descent operation for about four minutes. During this phase, TIR successfully took the closest images every 32sec., at the same time, some part of the field of view was shaded by solar array paddles(SAP). We could estimate TI of the touch down area by tracing temperature change as a function of duration of shading. We found large temperature drop as soon be covered by SAP, and rather gentle temperature change after. This rapid temperature decrease showed very low TI lower than 50($J/m^2K^2s^{0.5}$), which implies that the upper most surface was covered by fluffy dust material. We observed flinging up dust like material by the RCS jettison at ascent operation after touchdown, we speculate this dusty material widely covers the surface of Ryugu,.

2. Summary

We report our updated results of thermophysical Model (TPM) of C-type primitive asteroid 162173 Ryugu. Global TPM is widely uniform, however, regional TPM shows wide variety of thermal structure. We should notice that not only the horizontal variation of the TPM, but vertical (depth) structure should be taken account in order to understand the real TPM of the asteroid. Since mineralogical variation is globally homogeneous[8], thermophysical structure seems to be unexpectedly various and sundry.

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