TEMPERATURE DISTRIBUTIONS AND THERMAL PROPERTIES OF BOULDERS ON C-TYPE ASTEROID 162173 RYUGU OBSERVED IN LOW ALTITUDE OPERATION OF THE ASTEROID EXPLORER HAYABUSA2

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The asteroid explorer Hayabusa2 [1] has the Thermal Infrared Imager (TIR) [2,3] which obtained the digital thermal images to indicate the thermal radiation from C-type asteroid 162173 Ryugu. In this study, to obtain thermal properties of boulders, we analyzed TIR images taken below the altitude of 500 m and investigated temperature variations of boulders taken with more than 100 pixels and their physical state in the specific regions.
We used TIR images taken during the release paths for the MINERVA rover (MNRV) on 21st September 2018, and the MASCOT lander (MSCT), on 3rd October 2018 1st touchdown (TD1-L08E1) on 21st February 2019, and the touchdown rehearsals (TD1-R1A) on 15th October 2018.
Total numbers of detected boulders were 355 (MNRV), 312 (MSCT), 368 (TD1-L08E1), and 311 (TD1-R1A). Also, the detection errors were obtained as ±5.2 % (MNRV), ±5.5 % (MSCT), ±5.1 % (TD1-L08E1), and ±5.6 % (TD1-R1A) by Wald inequality [4]. In terms of the maximum temperature distribution, the values of full width at half maximum (FWHM) of MNRV, MSCT, TD1-L08E1, and TD1-R1A were 11.0±0.49 (K), 13.6±0.68 (K), 13.4±0.44 (K), and 11.5±0.84 (K), respectively. From the FWHM values, the boulders of MSCT and TD1-L08E1 showed wider varieties of thermal inertias than those of MNRV and TD1-R1A. It is considered that the temperatures were different due to the variation in the geometric shape of the boulder surface and the difference in the structure inside the boulders.
Furthermore, the calculated size-frequency distributions (SFD) divided by measured altitudes were in the range of -4.38 to -0.36 and these values were consistent with those investigated by Michikami T *et al.*, (2019) [6]. Moreover, we calculated thermal inertias using the average values of maximum temperatures. As a result of calculation, the range of thermal inertias [7] was calculated as low as 198.5 to 299.1 [J m^{-2} s $^{-0.5}$ K^{-1} (hereafter, tiu)] with the one-dimensional heat diffusion equation [8]. Our results are consistent with that of the global average estimated as 225 ±45 tiu by Shimaki *et al.* (2020) [9] and are higher than that of a high-temperature boulder assembly (HS1) as 73 ±25 tiu reported by Sakatani *et al.,* (2021) [10]. As the porous and fluffy material has low thermal inertia, the boulders were considered to be porous compared with typical carbonaceous chondrite meteorites.
In summary, the total numbers of detected boulders were 355 (MNRV), 312 (MSCT), 368 (TD1-L08E1), and 311 (TD1-R1A), and the reason why temperature distributions were diverse is that the temperatures of boulders were different due to the variation in the geometric shape of the boulder surface and the difference in the structure inside the boulders. Moreover, the values of slopes of SFD and thermal inertias suggested the existence of boulders formed when Ryugu's parent body was destroyed, boulders covered with regolith layers, and porous and fluffy boulders. Moreover, we will report and discuss the details of the case of DO-S01: Decent operation for S01.
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References: [1] Watanabe S. *et al.*, Science **364**, 268-272 (2019), [2] Okada, T. *et al.*, Space Sci. Rev., **208** , 255-286 (2017), [3] Okada, T. *et al.*, Nature **579**, 518-522 (2020), [4] Kurihara, S., Introduction to statistics: from testing to multivariate analysis and experimental design, Ohmsha Ltd., pp.336 (2011), [5] Walsh *et al.*, Nature **454**, 188-191 (2008), [6] Michikami, T *et al.*, Icarus **331**, 179-191(2019), [7] Okada, T. *et al*, 13th Space Science Symposium, ISAS/JAXA, P2-117 (2013), [8] Takita, J. *et al.*, Space Sci Rev, **208**, 287-315 (2017), [9] Shimaki Y. *et al.*, Icarus **348**, 113835 (2020). [10] Sakatani N. *et al.*, Nature Astronomy, **vol5** 766-774 (2021).

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