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Topography of large craters and equatorial bulge of 162173 Ryugu

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Abstract

Hayabusa2 Laser Altimeter (LIDAR) conducted two-dimensional scanning observation of the equatorial band of asteroid, 162173 Ryugu on Oct. 30, 2018 to obtain detailed topography data. The observation range covers three circular depressions which are recognized as large craters, and notable equatorial bulge. Topography of these three craters indicates crater formation in porous medium, an influence of spin on ejecta distribution, and north-south asymmetry of equatorial bulge.

1. Introduction

High-velocity impact and ejection of surface materials are important processes. An efficiency of disruption and surface alteration of C-type rubble pile asteroids are of particular significance in the view of transportation of water and organic materials to the early Earth, Mars, and icy satellites. 25143 Itokawa is the first rubble pile body ever identified via remote sensing and returned samples of Hayabusa mission [1]. 253 Mathilde and 21 Lutetia are C-type asteroids visited by NEAR [2] and Rosetta [3]. Craters on these asteroids, however, are widely different, and impact processes occurring on the C-type rubble pile bodies has not been understood well yet. The target of Hayabusa2, 162173 Ryugu, is a rubble pile asteroid of C-type [4] possessing a key to link variable cratering records on Itokawa, Mathilde, Lutetia, and Bennu which was recently visited by OSIRIS-REx spacecraft.

Ryugu is the second asteroid whose topography is measured accurately by laser altimeter (LIDAR) [5] after 433 Eros [6]. Compared with photoclinometry and stereogrammetry, LIDAR observation is straightforward and less constrained by solar lightning conditions and photometric properties of surface.

On Oct. 30, 2018, Hayabus2 conducted Box-C science observation operation inn which the altitude of the spacecraft was maintained between 5 and 6 km above the surface of Ryugu, and the attitude changed back and forth so that LIDAR footprints moved north to south and vise versa. Then we have obtained topography data in the equatorial band from 40ºS to 20ºN except for the longitudinal range between 117ºE to 169ºE.

2. Crater Topography

In LIDAR topography data, 3 circular depressions are found near the equatorial bulge [4, 7]. All of these circular depressions are identified as craters and have been given names approved by IAU, namely Urashi-ma, Kolobok, and Brabo craters. From repeated observations from 20-km altitude before Oct. 30, consistent and precise cross sections of the craters have been derived.

Depth-to-diameter ratios (d/D) of Urashima, Kolobok, and Brabo craters are 0.2, 0.14, and 0.155, respectively, and are consistent with previous in situ observations of asteroid topography [3, 8, 9, 10], while there seems marked difference from craters on Itokawa [11] and Bennu. Both Itokawa and Bennu are comparable in size and surface gravity to Ryugu, and these 3 asteroids are regarded as rubble pile bodies. On the contrary, the d/D of Itokawa craters, 0.08 ± 0.03 [11], is significantly shallower than that of Ryugu and other asteroids. The d/D of Bennu is apparently shallower, too. In addition, craters on Ryugu have topographically distinctive raised rim while those on Itokawa do not [11].

The low d/D of Itokawa is regarded as a result of either an influence of curvature of small body, a lack of raised rim, or fine grains infilling the craters [11], but has been unsolved. On the other hand, craters of Mathilde have characteristics much alike to those on Ryugu; the d/D ranging from 0.12 to 0.25, prominent raised rim, and a lack of ejecta blanket. While Mathilde is 50 times larger than Ryugu, the bulk density of Mathilde is only 1.34 ± 0.2 g cm 3 [2]. Such low density is likely suggesting that Mathilde is as porous as 50 % [2].

The shapes of the three craters are neither bowl-shaped like 951 Gaspra and Eros [9, 12, 13] nor flat like Itokawa [11]. It is notable that slopes of inner wall of Ryugu craters are linear rather than paraboloi-dal, and that Kolobok and Brabo craters are flat-bottome. We reconstruct three-dimensinal topography model of Urashima crater which is derived from LIDAR topography data taken on Oct. 30, 2018. Such conical shape is in an agreement with impact cratering experiments into porous targets [14], while the d/D of Ryugu crates is lower than experimental results which is between 0.2 and 0.5 [15]. It is interesting that slopes of the 3 craters are almost identical. Such nearly identical conical shape indicates that either the crater shape is well relaxed, or in the contrary, is holding initial shape.

3. Asymmetry in East-West Profile

A close examination of crater topography reveals interesting characteristics of Ryugu craters. Width of rim is wider on eastern wall than western wall. The cause of this east-west asymmetry is difficult to explain, and we consider three hypotheses. First, oblique impact from west could produce wider and thicker rim by either enhanced compaction or thicker ejecta deposits on eastern side. Because TIR observation does not show any variation of thermal properties of crater walls from surrounding area, compaction is unlikely. This hypothesis requires angular momentum of projectiles aligned with rotation axis of Ryugu.

Second, similar asymmetry is found for Stickney crater on Phobos. Thomas [16] proposes that Coriolis force acting on low velocity ejecta leads ejecta to accumulate on east side of Stickney crater. Apparent similarity of morphology of Ryugu craters and Stickney crater on Phobos indicates that spin og small body and consequent Coriolis force are important to explain E-W asymmetry.

Third, dusts could accumulate on western inner walls. When levitating dusts fall to the surface at the dusk, it is possible that dusts would be flown by solar wind and accumulate more on western side than eastern side. If this is the case, any difference of eastern and western sides in TIR observation is expected. To date, observation data are insufficient to prove or disprove this hypothesis [17].

4. Equatorial bulge

Using the LIDAR data taken on Oct. 30, 2018, we have reconstructed topography of equatorial bulge. South to north cross sections of the bulge do not reveal distinction of slope of the bulge from surrounding area. Instead we have identified north-south asymmetry of roughness. In general, southern slope of the bulge is rougher than the northern slope, yet the cause of different roughness has not been elucidated

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