THE SURFACE ROUGHNESS OF 162173 RYUGU BASED ON THE TOPOGRAPHY FROM HAYABUSA2 LASER ALTIMETER (LIDAR). Y. Masuda[1], S. Abe[1], N. Namiki[2], K. Matsumoto[2], H. Noda[2], H. Senshu[3], F. Terui[4], T. Mizuno[4], [1]Nihon University, 7-24-1 Narashinodai, Funabashi, Chiba 274-8510, Japan (shinsuke.avell@gmail.com), [2]National Astronomical Observatory of Japan, [3]Planetary Exploration Research Center, Chiba Institute of Technology, [4]Institut of Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA/ISAS).

Introduction: The Japanese asteroid explorer Hayabusa2 spacecraft explored the near-Earth asteroid (162173) Ryugu between June 2018 and November 2019. During this period, the laser altimeter (LIght Detection And Ranging, LIDAR) onboard Hayabusa2 collected over 7 million measurements of the spacecraft range to the asteroid surface [8,10]. The surface roughness and global surface roughness maps for Ryugu were carried out using the LIDAR topography data. The surface roughness which is defined as RMS deviation over different horizontal scales enables to give a new insight into an origin and geologic processes of a small body. The surface roughness is also related to the self-affine nature of planetary surfaces through a value called the Hurst exponent, H (0<H<1), which is described by a power-low index of RMS deviation and baseline, if the surface has self-affine behavior. The surface roughness of (25143) Itokawa [1,2,5,6] and (433) Eros [4] showed different Hurst exponent values which might reflect the variation of interior structures of both bodies, on the other hand, the surface roughness correlated well with the geologic features such as boulders [4,5].

In this study, we investigated the correlations between the surface roughness and the geological features on Ryugu compared with those on Itokawa and Eros. Comparing Hurst exponent of Ryugu with other bodies, the surface evolution of rubble-pile small bodies will be discussed.

Data Selection: In calculation of surface roughness along LIDAR tracks, it is desirable to be as straight as possible for best results in estimating the distance between LIDAR points. We thus used the previous methods as reference [3-5] and filtered LIDAR tracks to cut them at points for abrupt changes in direction of LIDAR track latitude.

Calculation Method: Surface roughness is defined as root-mean-square (RMS) deviations (the change in detrended height for a given baseline) or heights (the change in detrended height about the mean height of the profile over all points) [7]. We chose RMS deviations as our measurements of surface roughness to compare with the previous studies [3-5].

We started by using individual 'cut' LIDAR tracks and then calculated the geopotential elevation based on the 'cut' track using the method described in [2]. We finally calculated the change of detrended elevation Δh for a specified baseline distance (the distance, as simple Euclidian distance between LIDAR points along the straight-line obtained by fitting the x, y, and z points as straight-line function of time [6]). In the range of baseline L, it is recommended that maximum baseline should be less than one-tenth of the track length used to generate the deviogram (log-log plots of RMS deviations versus baseline, [7]). In addition, to generate the global surface roughness map requires sufficient number of valid Δh for each plate on the shape-model. That is why the baseline range is restricted from 8m to 60m. Minimum baseline, 8m, is determined from the majority of LIDAR points. Finally, after calculating Δh over all baselines for all points on all tracks, we generated global surface roughness map by using a shape-model (re-sampled down to 6,000 plates so that we had sufficient Δh for each plate) of Ryugu.

Results: Figure 1 shows a deviogram of Ryugu. Deviograms provide a quantitative way to compare the surfaces of different bodies to one another [2-7]. The deviogram of Ryugu appears to have shallower slopes over all baselines than Eros and Moon. On the other hand, comparing the deviogram with Itokawa, it looks like a straight line that increases with increasing baseline.

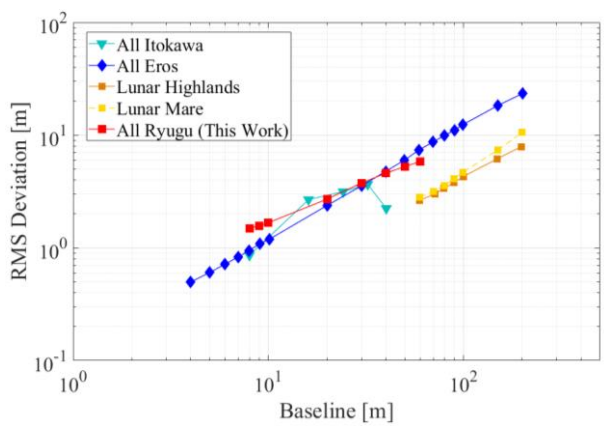

Figure 1. Deviograms of Ryugu and previous works over-plotted [2,4,5] (extract data from the previous plots by using WebPlotDigitizer [11]

Figure 2 shows maps of the surface roughness for Ryugu at the baseline of 20m projected onto the shape-model. Gray plates represent regions where there were insufficient data to calculate RMS deviation for that plate.

Discussion: The Hurst exponent of Ryugu is 0.69 (L=8~60m). The deviograms of Eros and Moon showed self-affine (straight-line in the deviogram) nature [4], and have a similar Hurst exponent (0.97, L=4~200m) compared to Mercury [3]. On the other hand, the Hurst exponent of Itokawa is 0.51 (L=8~32m) [5]. According to [4,5], Higher Hurst exponent (~1) might be indicative of the surfaces dominated by impact cratering. Several craters on Ryugu have topographically distinctive raised rims while those on Itokawa do not. In addition to this, unlike Eros (which is believed to be a Fractured Monolith), Ryugu is thought to have a rubble-pile structure [9]. Therefore, due to lack of the ability to support large-scale topography, it is assumed that the Hurst exponent of Ryugu is higher than Itokawa but lower than Eros, Moon and Mercury. It is indicated that the Hurst exponent of Ryugu showed well-correlation to the surface topography which is dominated by impact cratering [3-5].

In figure 2, the highest roughness values are found at the rim of craters near the equatorial region and large boulders such as Ejima Saxum. Relationships between individual boulders and the surface roughness of longer baselines are not clear while boulders are associated with the overall higher surface roughness near the poles. Further investigations of surface roughness and boulder distribution on Ryugu will provide more information on the geological history. The surface roughness change by a collision will be examined by using the SCI (Small Carry-on Impactor) event.

References: [1] Abe S. et al. (2006) Science, 312, 1344-1347. [2] Barnouin-Jha O. S. et al. (2008) Icarus,198,108-124. [3] Susorney H. C. M. (2017) J.Geophys.Res.,122, 1372-1390. [4] Susorney H. C. M. (2018) Icarus, 314, 299-310. [5] Susorney H. C. M. et al. (2019) Icarus, 325, 141-152. [6] Susorney H. C. M. et al. (2019) LPSC XXXIX, Abstract #2083 [7] Shepard M.K. et al. (2001) J. Geophys. Res., 106, 32777-32796. [8] Matsumoto K. et al. (2020) Icarus,338,113574. [9] Watanabe S. et al. (2019) Science,364,268-272. [10] Matsumoto K. et al. (2020) LPSC-51th.,this-meeting, [11] https://automeris.io/WebPlotDigitizer/

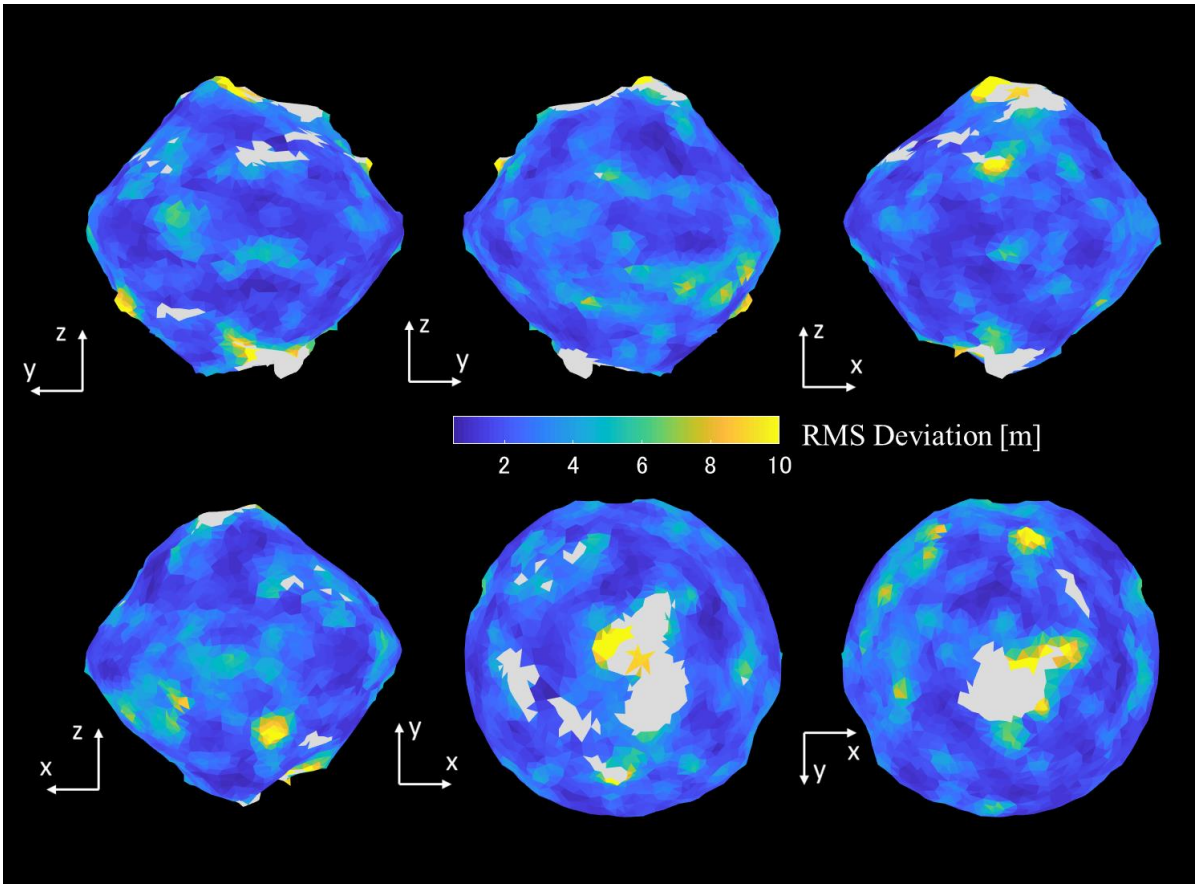

Figure 2. The global surface roughness map of Ryugu for a baseline of 20m.