

## クレーター形状解析による小惑星リュウグウの過去の自転状態の推定

### Reconstruction of the past rotation state of asteroid (162173) Ryugu from a crater shape analysis

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#### Background

Proximity observations from the Hayabusa2 spacecraft reveal that Ryugu has a spinning-top shape [1] with 86 craters that have been reported on its surface [2]. The average surface tilt angle with respect to the net force of gravitational attraction and centrifugal force is nearly 35° when the rotation rate is 2.2 times the present value (period of 3.5 h), so that Ryugu's shape was formed by deformation induced by that high-speed rotation [1]. Owing to the YORP effect, the thermal torque changing the rotation state of small asteroids [3][4], Ryugu spun down from its past high-speed rotation state to its current low-speed (period of 7.63 h) on a timescale of about 10 million years. Therefore, craters on Ryugu must have been formed continuously under various rotation speeds. Laboratory experiments to investigate the shape of craters by varying the tilt angle and impact angle showed that the crater ellipse elongates in the tilt direction and the crater cavity moves downward when the tilt angle exceeds 20° at any impact angle [5]. In addition, the impact angle has little effect on the axial ratio of the ellipse [5]. Thus, we could constrain the change of rotation state of Ryugu by studying the shape of craters formed at various times in detail.

#### Method

We have measured the external shape of the craters in the existing list of craters on Ryugu [2]. We used the Small Body Mapping Tool (SBMT) to extract each crater profile from an 800,000-polygon shape model of Ryugu. Candidate points on the rim were extracted from the profiles of eight orientations through the crater center, and the crater outline that passed through them most consistently was determined and approximated by an outline ellipse. Craters with major to minor axis ratios ( $R$ ) greater than 1.1 were considered elliptical craters, and those with  $R < 1.1$  were considered circular craters. Craters with an angle of less than 45° between the meridian and the major axis of the ellipse were classified as north-south major axis craters, and those with an angle of more than 45° were classified as east-west major axis craters. The deepest point from the mean plane fitting through the rim was considered as the lowest point of the crater, and the deviation from the center of the ellipse was measured.

## Results and discussion

Of the 22 craters measured so far, 8 (36%) are circular, 6 (27%) are east-west major axis ones, and 8 (36%) are north-south major axis ones. Further, 3 of the east-west major axis craters had  $R > 1.2$ , and only 1 of the north-south major axis craters had  $R > 1.2$ . Two craters have the deepest points shifted in the high-latitude direction, i.e., downward of the present tilt, and one was shifted in the low-latitude direction, i.e., downward of the tilt during the past fast rotation. The rest have no significant shift of the deepest point in the latitudinal direction relative to the center of each ellipse.

As for the north-south major-axis craters, which account for about 30% of the total, the elliptical shape may have been caused by the surface tilt with respect to the direction of the net forces of gravitational attraction and centrifugal force. We will conduct detailed topographic analysis and compare the results with laboratory experiments. On the other hand, the formation of the east-west major-axis crater cannot be explained by the tilt angle, and the possible formation mechanisms are low-angle impacts, impacts to the equatorial ridge, and anisotropy of the subsurface structure of Ryugu. In the artificial cratering experiment using Small Carry-on Impactor (SCI), it is estimated that the bedrock in the southern part of the crater inhibited the growth of the crater, resulting in a semicircular shape [7]. The east-west major-axis craters may reflect the anisotropy of the subsurface structure of Ryugu, which inhibits crater growth in the north-south direction.

We will increase the number of craters measured, removing large boulders from the surface topography, which may cause errors in determining the crater shape, in order to obtain a more accurate understanding of the crater shape. Then, we will also discuss the formation scenario of the east-west major-axis craters and constrain the past rotation state of Ryugu from the crater shape analysis.

## References

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