

Ryugu Coordinate System Description

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The spin parameters of Ryugu are determined simultaneously with the global shape of the asteroid by Stereo Photoclinometry (SPC) (Gaskell et al., 2008) (Table 1). Detailed descriptions of this effort will be reported in a separate manuscript (Hirata et al., in prep). Their initial values were published in Watanabe et al., 2019, then updated through further analysis with new images available after that. The final parameters have been determined on Mar. 23, 2020 (v20200323), with all images obtained during the proximity observation phase. The observations that provide the strongest constraints on the spin parameters are the Box-C and the mid-altitude observations (see Supplementary Material for Watanabe et al., 2019) from the altitude of 5-7 km, which were carried out multiple times during the asteroid proximity phase (Jun. 2018-Nov. 2019) of Hayabusa2 mission. The spatial resolutions of ONC-T (IFOV 0.1074 mrad, Suzuki et al., 2018) images obtained in these observations range 0.5-0.7 m/pixel. Accuracies of the determination of the spin parameters are estimated from these spatial resolutions, the asteroid size, and the span of observations; 0.03 deg for the pole direction and 10^{-4} deg/day for the rotational rate.

The Ryugu-fixed frame in the International Celestial Reference Frame (ICRF; Archinal et al., 2018) is modeled with $\{\alpha, \delta, W_0 + \Omega\Delta t\}$, where α represents the spin pole right ascension, δ represents the spin pole declination, W_0 represents the prime meridian angle, Ω represents the rotation rate, and Δt represents the time elapsed since J2000 = JD 2451545.0, i.e., 2000 January 1 12 hours TDB. The Ryugu coordinate system is anchored to a ~50 m boulder named Catafo Saxum near the equator. Catafo has a small but remarkable mound at its center, which was originally defined as the prime meridian marker by the Hayabusa2 project at July 1, 2018 00:00:00 (TDB) in the initial global observations from the altitude of 20 km (Jul. 2018) (Fig. 1A). The Hayabusa2 project later found that the primal meridian is not exactly on the mound of Catafo Saxum in better resolution images (Fig. 1B), but decided to keep the original definition to ensure consistency. The global context of the prime meridian is shown in Fig. 2.

The SPICE planetary constant kernel (PCK) for Ryugu is produced with those values. Although the accuracies of the spin parameters are estimated as the above discussion, the values in PCK store more digits than them (see Table 1). They are direct outputs of determination of the spin parameters by SPC. By using these long digits, it is secured consistency on the location of the prime meridian $W (= W_0 + \Omega\Delta t)$, integrated from J2000 to the epoch of observation (2018-2019).

Table 2 also summarizes the equivalent spherical body radius, **R**, the average equatorial radius of the oblate spheroidal shape, **A**, and the polar radius **B**, reported in Watanabe et al. (2019) and estimated in the final version of SPC product.

Table 1. Ryugu coordinate systems.

	(α, δ) [deg]	W_0 [deg]	P [hour]	Ω [deg/day]
Watanabe+2019	(96.40, -66.40) ± 0.03	-	7.63262 ± 0.00002	-
SPC v20200323	(96.43, -66.39) ± 0.03	-	7.6326247 ± 0.0000007	1131.9828 ± 0.0001
PCK ryugu_v10.tpc	(96.43112, -66.38741)	274.16225	-	1131.98280286

Table 2. Ryugu radii.

	R [km]	A [km]	B [km]
Watanabe+2019	0.448 ± 0.002	0.502 ± 0.002	0.438 ± 0.002
SPC / PCK ryugu_v10.tpc	0.449	0.502	0.438

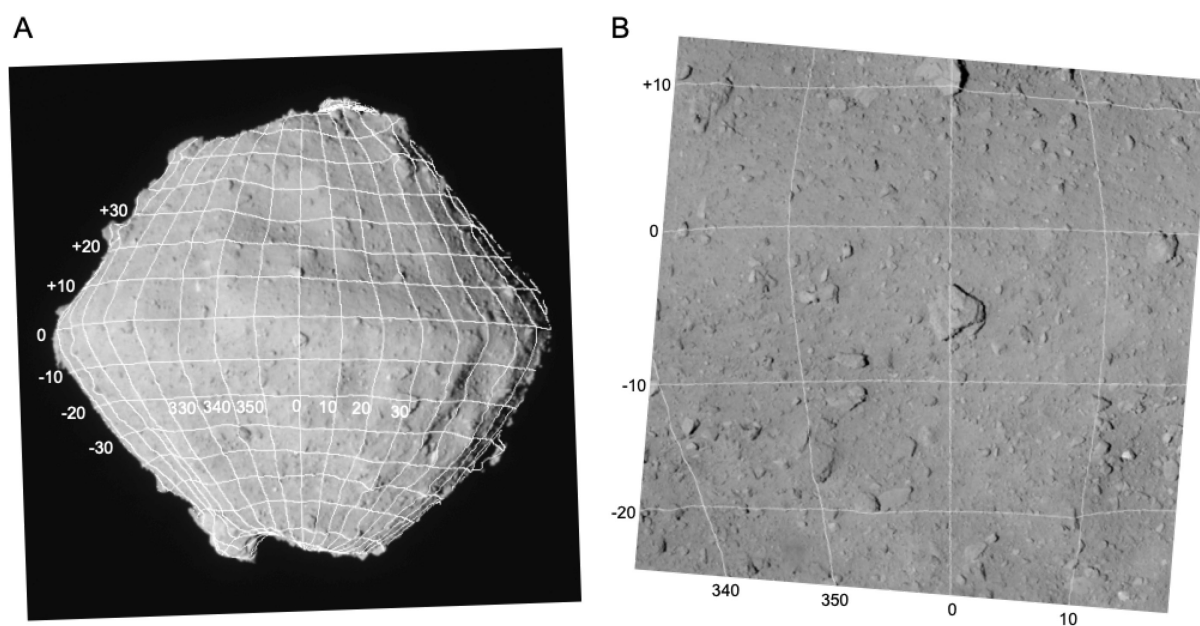


Fig. 1. The location of prime meridian and Catafo Saxum defining the prime meridian of Ryugu. A) global image hyb2_onc_20180703_123814_tuf acquired by ONC-T at the altitude ~ 19 km, B) close-up image hyb2_onc_20181003_235509_tvf acquired by ONC-T at the altitude ~ 2.7 km. North (the positive pole) is up. White thin lines indicate planetocentric longitude and latitude, and label texts are in degrees.

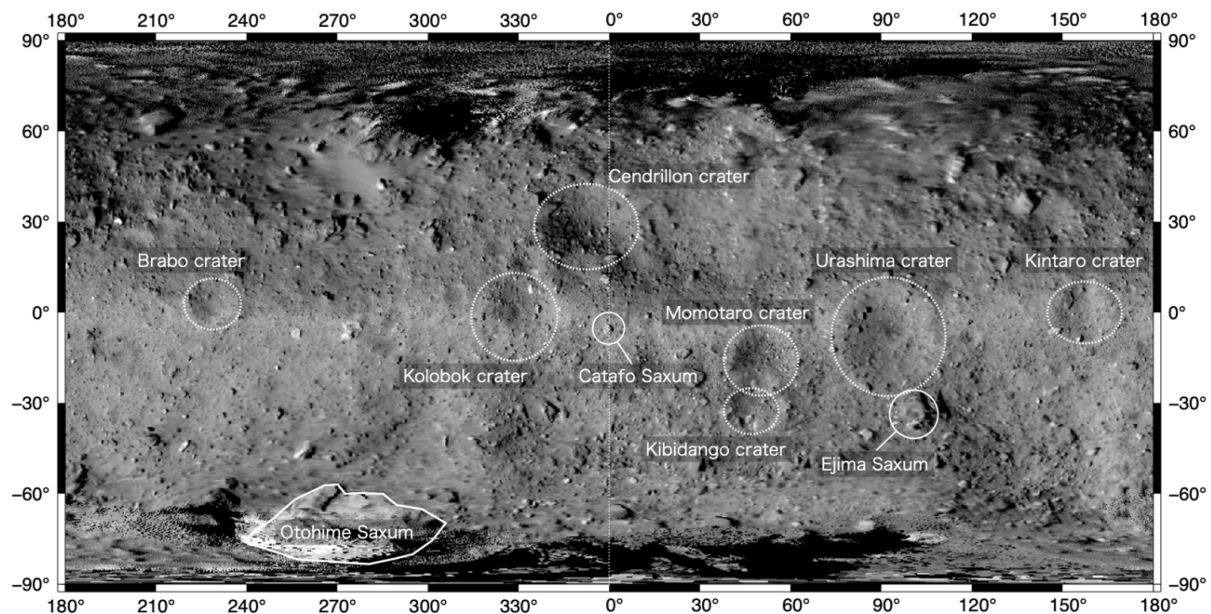


Fig. 2. Global map of Ryugu centered at the prime meridian. Names of craters and saxa including Catafo Saxum approved by IAU are also indicated. Fig. 1A of Sugita et al. (2019) is used as the basemap (available at https://darts.isas.jaxa.jp/pub/hayabusa2/paper/Sugita_2019/).

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