Visible spectra of small bright spots on asteroid 162173 Ryugu

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The Optical Navigation Camera (ONC) onboard the Hayabusa2 spacecraft has obversed asteroid 162173 Ryugu at various scales and found that Ryugu has a uniform spectrum in km-scale and that boulders exhibit a range of albedo (0.89 –1.3 times of the surface average) and spectra [1]. Higher resolution images taken during descent operations revealed the presence of bright spots, which are typically much brighter than the brightest large boulders. Brightness variation may reflect differences in composition, thermal alteration, or space weathering maturity. Such materials would follow spectral trends seen on other materials on Ryugu. In fact, brightest boulders are the end-members in reflectance/slope statistics and Principal Component Analysis (PCA) of boulders on Ryugu. If bright spots are fragments of the parent body at the origin of Ryugu, they may correspond to the fresher components of the boulder population constituting Ryugu, contributing to the spectral variety observed on the asteroid. In contrast, it is also possible that Ryugu contains materials of exogenous origin. In that case, the spectra of bright spots should not follow the spectral trends observed for other materials on Ryugu and should rather be consistent with the spectra of asteroids found in the inner main belt. In either case, bright spots will help us place important constraints on to the formation and evolution of Ryugu.

In this study, we analyzed the brightest spots whose reflectance is ≧ 1.7 times the reflectance global average. The dimensions of these sports are very small: ≦ 3 m. The spectra of these brightest spots were extracted from I/F images taken at altitudes of Hayabusa2 between 100 and 500 m (i.e., low-altitude descent observations) and 3 –4 km (hovering operation after MASCOT deployment) and were compared with meteorite spectra. As for low altitude images, we conducted a photometric correction because the rotation of Ryugu results in a several degrees phase angle gap between different filters. The spectra of meteorites include 250 carbonaceous chondrite spectra and 106 ordinary chondrite spectra from RELAB of Brown University and they are linearly interpolated to match the bands of ONC-T [2]. We searched for meteorite spectrum that gives minimum residual sum of squares (RSS) of spectra among the 356 samples.

Analysis results indicate that 5 out of 10 bright spots have spectra consistent with carbonaceous chondrites (CC), such as CM2 and CV3, and that the other half are consistent with ordinary chondrite (OC) such as LL6. Some of CC-like bright spot spectra are very similar to that of type3 (bright and molted) boulders found in [1], which was one of the end-members in reflectance/slope statistics and PCA of boulders. This suggests that these bright spots can be new members of this boulder group.

Because Ryugu most likely comes from the inner main bet, OC-like bright spots are consistent with exogenous origin. Preliminary results indicate that two types of spectra are present. One has a spectral peak at v-band (centered at 0.55 micron) and the other has a peak at w-band (0.86 micron). If this spectral variation is large enough to require the delivery of meteoritic materials from asteroids, it would reflect the variety in composition among many projectiles that collided with Ryugu after its formation. In contrast, if the shift in spectral peak is consistent with spectral modification mechanisms within a large OC-like projectile, such as thermal metamorphism, these bright spots could be remnants of one projectile only. In either case, however, because the average impact velocity in the main belt is very high ~5km/s [3], the fact that we may observe remnants of projectiles impacting at such speeds on the surface of Ryugu has strong implications in our understanding of the impact process and in our interpretation of the compositional heterogeneity of small bodies and meteorites.

[1] Sugita, S. et al., (2019) submitted to *Science*
[2] Tatsumi et al., (2019) *Icarus*
[3] Bottke et al., (1994) *Icarus*

