Constraining Mineralogical Composition of Asteroid Ryugu with Ground-Based Observations

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In preparation for the arrival of the Japanese Space Agency's (JAXA) Hayabusa2 sample return mission to near-Earth asteroid (NEA) (162173) Ryugu, we took the opportunity to characterize the target with a ground-based telescope. We observed Ryugu using the SpeX instrument in Prism mode on NASA Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii, on July, 12 2016 when the asteroid was 18.87 visual magnitude, at a phase angle of 13.3°. The NIR spectra were used to constrain Ryugu's surface composition, determine meteorite analogs and study spectral affinity to other asteroids. We also modeled its photometric properties using archival data. Using the Lommel-Seeliger model we computed the predicted flux for Ryugu at a wide range of viewing geometries as well as albedo quantities such as geometric albedo, phase integral, and spherical Bond albedo. Our computed albedo quantities are consistent with results from Ishiguro et al. (2014). In previous work, Ryugu's visible spectrum revealed that it can be classified as a C-type object. In addition, not all previous ground-based observations of Ryugu detected the 0.7 μm absorption feature due to the presence of phyllosilicates. Our spectrum of Ryugu has a broad absorption band at 1 μm, a slope change at 1.6 μm, and a second broad absorption band near 2.2 μm, but no well-defined absorption features over the 0.8-2.5 μm range. The two broad absorption features, if confirmed, are consistent with CO and CV chondrites. We computed the Reflectance Factor (REFF) of Ryugu at 550 nm, which is consistent with the reflectance measured for the CM and CI carbonaceous chondrite groups. Samples of CO and CV chondrites are usually brighter and less red sloped than Ryugu. It is interesting to note that recent work suggested space weathering could darken and redden the spectra of carbonaceous chondrites. Our spectrum of Ryugu is different from previously published spectra showing a more neutral spectral slope, however, this is not the only object with this kind of spectral shape. The shape matches very well those of NEA (85275) 1994 LY and Mars-crossing asteroid (316720) 1998 BE7, suggesting that their surface regolith have similar composition. With a semi-major axis of ~ 1.9 AU, and NEA 1994 LY may come from the inner part of the main asteroid belt. Asteroid 1998 BE7, with a semi-major axis of ~ 3 AU, probably formed far in the outer part of the main belt. The differences observed between the spectra of these asteroids could be explained by differences in composition, grain size, space weathering, and phase angle. We also compared the spectrum of Ryugu with that of main belt asteroid (302) Clarissa, the largest asteroid in the Clarissa asteroid family, suggested as a possible source of Ryugu by Campins et al. (2013). We found that the spectrum of Clarissa shows significant differences with our NIR spectrum of Ryugu. Our analysis shows Ryugu's spectrum best matches two CM2 carbonaceous chondrites, Mighei and ALH83100. Previous work suggested CM and CI carbonaceous chondrites are the most consistent with Ryugu's spectra. We expect the surface regolith of Ryugu to be altered by a range of factors including temperature, contamination by exogenic material, and space weathering, posing challenges to link spacecraft and ground-based data, and sample site selection.

References

[1] Campins et al. (2013), The Astronomical Journal, 146:26. [2] Ishiguro et al. (2014), The Astrophysical Journal, 792, 74.