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Comparison of the mean surface hydrogen content estimation of the asteroids (101955) Bennu and (162173) Ryugu and perspective for other asteroids.

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Two asteroid sample return missions studied, in-situ, two primitive asteroid targets to unravel their physical and chemical properties as well as obtain regolith samples for return to Earth. We describe remote observations from OSIRIS-REx and Hayabusa2 to determine the hydration content of these primitive asteroid surfaces and implications for their aqueous alteration histories.

The NASA mission—Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer—OSIRIS-REx [1] studied the asteroid (101955) Bennu for two and a half years starting on its arrival at the asteroid on December 2018. The sample collection of surface regolith occurred on October 20th 2020 followed by the spacecraft departure from the asteroid on May 10th 2021 to begin its return cruise to deliver the sample to Earth in September 2023.

The JAXA mission Hayabusa2 [2] studied the asteroid (162173) Ryugu for a year and a half (June 2018 to November 2019), and the twice-collected regolith samples with the re-entry capsule landed on Earth on December 5th 2020. These samples are currently being analyzed in Earth laboratories.

Both missions had a near-infrared spectrometer onboard, amongst other instruments, which are the OVIRS spectrometer (OSIRIS-REx Visible and InfraRed Spectrometer) [3] and the NIRS3 spectrometer (Near-Infrared Spectrometer) [4].

The analysis of the asteroid surface reflectance spectra revealed the presence of an absorption band associated with OH/H_2O centered near 2.74 microns [5] for asteroid Bennu and 2.72 microns for asteroid Ryugu [6]. This absorption band is caused by hydrated phyllosilicates across both asteroid surfaces. The absorption band, however, differs in center, shape and strength between the two asteroids with a weak and narrow band in the case of Ryugu and a wide asymmetric band for Bennu. This leads to the diagnoses of OH-bearing phyllosilicates on Ryugu [6] while H_2O- and OH-bearing phyllosilicates on Bennu [5].

A similar absorption band has been observed in laboratory spectra of carbonaceous chondrite meteorites [7, 8]. Separately, the meteorite H content for many of these meteorites was measured by Alexander et al. [9, 10]. Correlations between spectral parameters computed on the hydrated phyllosilicate absorption band of clay minerals and their laboratory-measured water content was found by Milliken et al. [11, 12, 13] and absolute water estimation of Mars regolith was performed by [14].

As described in Praet et al. [15, 16], the normalized optical path length (NOPL) and effective single-scattering albedo (ESPAT) spectral parameters have been applied to estimate the hydrated phyllosilicates water and hydroxyl group hydrogen content (hereafter H content) of each asteroid global average surface. The estimation of the global mean H content of Bennu is 0.71 ± 0.28 wt.% and $0.52\ _{-0.21}^{+0.16}$ wt.% for Ryugu.

In the case of Bennu, the H content surface distribution shows a correlation with the geomorphology with higher values in the high latitudes and lower values in the equatorial band (between –20° and 20° latitudes). Whereas no such correlation is evident in the case of Ryugu as the NOPL and ESPAT parameter computed across its surface do not display any correlation with its surface geomorphological structures. These estimates and spatial trends will be updated as new information is derived from the returned samples (e.g., with enhanced thermal tail removal).

The estimated global H content value for Bennu is consistent with the H content range of aqueously altered meteorites such as heated CMs and C2 Tagish Lake, which is in agreement with [5, 16, 18]. As for Ryugu, its global H content is most similar to more strongly heated CMs, which is coherent with the best meteorite analogs for Ryugu near-infrared spectra (thermally metamorphosed CIs and shocked CMs) [6].

Our estimates of phyllosilicate water and hydroxyl group hydrogen content on Bennu and Ryugu, if confirmed by laboratory analysis on both returned samples, will allow the application of the same method to other asteroids, observed from the ground, and from space-telescopes. For asteroids with spectra exhibiting hydrated phyllosilicate absorption bands, such as the ones collected by the AKARI spectral survey [19] for example, estimation of their global mean H content will be possible.

The study of water and hydroxyl abundance on primitive asteroids is important for understanding the origin of terrestrial water and to constrain dynamical models and evolutionary processes to better understand the origin and evolution of our Solar System.

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