Clustering analysis of Ryugu spectral data obtained by NIRS3 infrared spectrometer onboard Hayabusa2 spacecraft

*Moe Matsuoka[1], Hikaru Iwamori[2], Deborah Lolin Domingue[3], Tomohiro Usui[1], Kohei Kitazato[4], Takahiro Iwata[1]

1. ISAS/JAXA, 2. Earthquake Research Institute, the University of Tokyo, 3. Planetary Science Institute, 4. University of Aizu

The Near-infrared Spectrometer (NIRS3) onboard the Hayabusa2 spacecraft obtained near-infrared (NIR) reflectance spectra of C-type asteroid 162173 Ryugu at an altitude of ~20 km from July 10-12 2018 with a spatial resolution of ~40 m (Box-A). The NIRS3 data, ranging from 1.8–3.2 μm with a spectral sampling resolution of 18 nm [1], show a 2.72-μm OH stretching absorption and a low reflectance which are globally homogeneous and similar to moderately-heated or shocked carbonaceous chondrite spectra [2, 3].

This study performs cluster analysis of Ryugu's NIR spectral data using a new statistical method [4] based on combinations of k-means cluster analysis (KCA), principal component analysis (PCA), and independent component analysis (ICA) for the seven channels ranging from 1.8 to 3.0 μm with ~200 nm interval and one channel at 2.72 μm of NIRS3 Box-A data. We performed three-step cluster analysis: (1) standardization and whitening of the original data using PCA, (2) dimension reduction of the data by selecting principal components (PCs) with significant eigenvalues and the corresponding scores of the individual data, and (3) performing KCA (and ICA) [4]. Whitening is essential to extract the independent features hidden in the data, which is not possible only by standardization.

The preliminary result of KCA and PCA using photometric-corrected Box-A global data obtained on July 11th 2018 shows that the data variation can be characterized with three significant PCs. We performed KCA using the values of these three PCs as the whitened and dimension-reduced data. To find the optimal number of clusters (k), k was varied from five to eight. The case with k = 6 (Fig.1) best captures the spectral properties. Regional heterogeneity is observed, even in the northern equatorial region which displays homogeneous morphologies in the Optical Navigation Camera Telescope (ONC-T) images [3].

All the clusters have a common OH-absorption at 2.72 μm with similar depths, yet they have differences in albedo and slope. The brightest average spectra are distributed around the equatorial ridge and in the Southern hemisphere around 150 to 300 degrees in longitude. The reddest spectra are located in the Southern region around 90 to 150 degrees in longitude. Interestingly, the spectra of the pole regions are grouped into the same clusters as those distributed in other areas. In addition to global thermal alteration, more plausible causes producing this NIR feature differences possibly reflecting variations in; (a) carbon content, (b) opaque material abundance, (c) grain size and porosity, and (d) space weathering maturation across the surface of Ryugu. A previous clustering study [5] suggest that NIR clusters indicate hydrous mineral contents variation. Our study further proposes a possible grain size and porosity variation to explain the spectral reddening.
In this study we found that the clustering results indicate NIR spectra would have a heterogeneity depending on location. For further study, we will perform KCA, PCA, and ICA analyses using photometric-corrected NIR data of lower altitude observations.

Figure 1. A NIRS3 spectral cluster map using data obtained on July 11th 2018 at ~20 km altitude. The six

clusters are separately distributed possibly reflecting the geomorphology and/or surface mineralogical/physical properties.

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