EPSC Abstracts
Vol. 13, EPSC-DPS2019-641-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Ryugu spectral surface regions via unsupervised machine learning classification of NIRS3 data.

E. Palomba (1,2) , M. D'Amore (3), A. Galiano (1), A. Zinzi (2), F. Dirri (1), A. Longobardo (1), K. Kitazato (4), T. Iwata (5), M. Matsuoka (5), T. Hiroi (6), D. Takir (7), T. Nakamura (8), M. Abe (5), M. Ohtake (5), S. Matsuura (9), S. Watanabe (10), M. Yoshikawa (5), T. Saiki (5), S. Tanaka (5), T. Okada (5), Y. Yamamoto (5), Y. Takei (5), K. Shirai (5), N. Hirata (11), N. Hirata (4), K. Matsumoto (12), Y. Tsuda (5)
(1) INAF-IAPS, Rome, Italy (anna.galiano@inaf.it), (2) SSDC-ASI, Rome, Italy, (3) German Aerospace Center, Institute of Planetary Research, Berlin, Germany, (4) University of Aizu, Aizu-Wakamatsu 965-8580, Fukushima, Japan, (5) Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency, Sagamihara, 252-5210, Japan, (6) Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA, (7) Jacobs/NASA Johnson Space Center, USA, (8) Tohoku University, Miyagi, Japan., (9) Kwansei Gakuin University, Hyogo, Japan, (10) Nagoya University, Nagoya 464-8601, (11) Kobe University, Kobe 657-8501, Japan, (12) National Astronomical Observatory of Japan, Mitaka 181-8588, Japan,

Abstract

The Japanese Hayabusa2 space mission approached the Near-Earth asteroid 162173 Ryugu in June 2018. Since then, it is taking data and mapping in detail the asteroid surface, finding a very dark and boulder rich asteroid with very homogenous spectral reflectance properties in the near IR. Statistical and machine learning tools are applied on NIRS 3 spectrometer data to explore them and search for structure embedded in the data and study their characteristics and correlation with geomorphological structures.

1. Introduction

The 27th of June 2018 the Japanese Haybusa2 spacecraft approached the C-type near earth asteroid 162173 Ryugu [1]. Haybusa2 is equipped with three remote sensing instruments such as the Thermal Infrared Imager TIR [2], the NIRS 3 spectrometer [3] and the Optical Navigation Camera-Telescopic (ONC-T) with a wideband and seven narrow band filters [4]. A Lidar instrument [5] allowed to reconstruct the shape model of the asteroid and to measure the altimetry, to perform a precise touchdown in sampling the asteroidal regolith. Additionally, by using the robotic landers Minerva-II and Mascot [6], Hayabusa 2 has been conducted in situ surface experiments. Ryugu is a top-shaped Cb type asteroid and is covered by a large number of boulders [7,8]. It is one of the darkest object in our Solar System with a quite homogenous composition, including OH-rich materials [7,9].

2. Method

We found that the NIRS3 data contains sensible variations, possibly linked to geomorphological structures, even though Ryugu surface varies only of few percent in reflectance. Out approach is to exploit the whole spectrometer data, to find to correlation that could be foreseen with traditional methods relying on fewer spectral points. Past experience on Mercury data shows that this is a sensible approach, in case of homogeneous featureless targets.

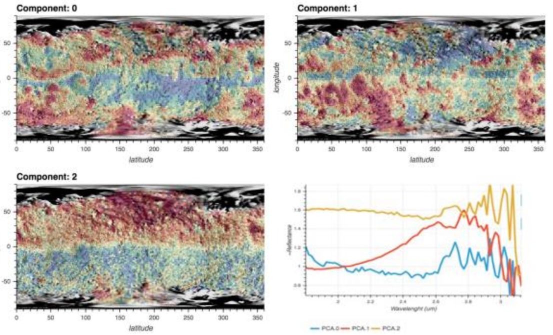

Fig 1: PCA coefficients distribution maps and eigenvectors (lower right).

We collect NIRS3 data from 20180711_l3a and 20180719_l3a counting around 20k useful spectra, covering almost the whole surface. The data were windowed between 1.8 and 3.1 um to avoid thermal residuals at higher wavelength, obtaining a data matrix of 20k row x 75 feature or bands. Then we apply a PCA transformation step to retain 10 component or 98% of the total variance, effectively compressing the data from 75 to 10 components. Even though the PCA components *per se* doesn't normally have a clear physical meaning, because they mix spectral feature in an unpredictable way, it is interesting to look at the results. The first PCA component has redder slope between 1.8 and 2.5 um, where the second has an inverted redder slope in the same range. The third is spectrally flatter, with an hint of absorption between 2.4 and 2.5 um. The concentration distribution of those three is also interesting: the PCA.0 is anti-correlated with the equatorial bulge and higher in craters, PCA.1 is also higher in crater but not visibly correlated with the equatorial bulge. PCA.3 is clearly showing a north-south asymmetry. The PCA component order indicate also the importance in explaining total data variance. After that, the apply T-distributed Stochastic Neighbour Embedding (t-SNE): this converts similarities between data to joint probabilities, minimize the divergence between the joint probabilities of the low-dimensional embedding and the high-dimensional data, typically 2 or 3 dimensions. Essentially, we can feed high dimensional data and get a lower dimension 2D map representation were closer point are also close in the original data space that is easy to visualize. On top of that we partitioned the data point using a Agglomerative Clustering algorithm: starting from all separated data point it clusters the closest together, where closeness is calculated with complete linkage, i.e. the maximum distances between all observations in each pair of classes. Hierarchical algorithm has the nice advantage to show which partition is more stable via a dendrogram plot. In our case, a 6 classes partition show as the most suitable one.

3. Results

The surface of Ryugu could be separated in 6 spectral classes, which have a similar spectral trend (Fig.2).

- Classes (0,1,5,3) have same trend, but different albedo (from lower to higher reflectance).
- Class 0 and 1 (C0/C1) are inter-craters terrains, the former mostly in the north, the latter in the south, with minor outcrops in the other hemisphere. C0 is up to -2% darker than Global Mean Reflectance (GMR) and C1 up to +4% brighter.
- Class 2 (C2) is the darkest class (-5% GMR), and it is found mostly in craters interiors.
- Class 3 (C3) is the brightest (+5% GMR) and it is found on the the equatorial bulge, but interrupted by Urashima, Momotaro, Kintaro and Kolobock craters.
- Class 4 and 5 (C4/C5) are two different trend of intermediate terrains. Those are the closest to GMR with a 2% variation around GMR. C4 is mostly found in the north, where C5 in the south, with substantial outcrops in the other hemisphere. The most interesting difference is that C5 follow the global trend of being slightly bluer than GMR between 1.9 um and 2.5 um, but C4 show an inverted trend, being redder then GMR.

In conclusion, we find an automated approach to extract spatially coherent region on Ryugu surface based only on spectral data using almost the whole NIRS3 spectral range. Those classes show a significant spatial correlation with geomorphological feature and different spectral trends.

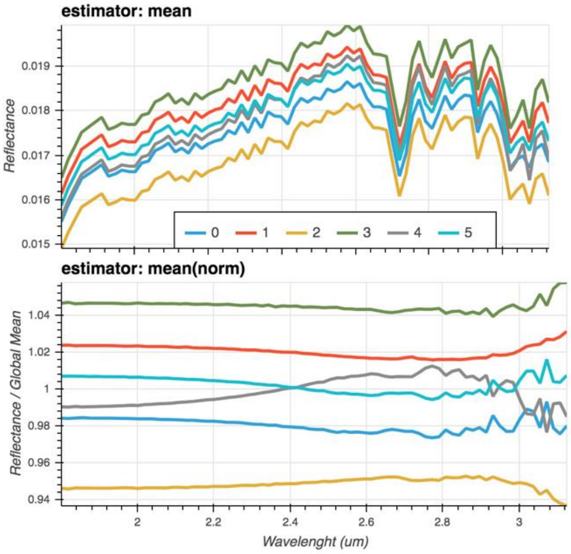

Fig 2: Classes average (top) and normalized to global mean.

References

[1] Watanabe S. et al. (2017) Space Sci. Rev. , 208, 3–16
[2] Okada T. et al. (2017) Space Sci. Rev., 208, 255-286
[3] Iwata T. et al. (2017) Space Sci. Rev., 208, 317–337 (2017)
[4] Kameda S. et al. (2016) Space Sci. Rev., 208, 17–31
[5] Mizuno T. et al. (2016) Space Sci. Rev., 208, 33–47
[6] Ho T.M. et al. (2017) Space Sci. Rev., 208, 255-286
[7] Sugita et al., (2019) Science, 364, eaaw0422
[8] Watanabe S. et al. (2019) Science, 364, 268-272
[9] Kitazato, K. et al., (2019) Science, 364, 272-275
[10] D'Amore, M. & al. (2013). Lunar Planet. Sci. 44. Abstract 1900.