RYUGU AND BENNU: MULTIVARIATE STATISTICAL ANALYSIS OF SPECTRAL DATA OBTAINED BY THE HAYABUSA2 AND OSIRIS-REx MISSIONS. M. A. Barucci[1], P. H. Hasselmann[1], M. Fulchignoni[1], A. Praet[1], J. D. P. Deshapriya[1], S. Fornasier[1], R. Honda[2], Y. Yokota[3,2], S. Sugita[4,5], K. Kitazato[6], M. Yoshikawa[3], A. A. Simon[7], V. E. Hamilton[8], B. E. Clark[9], J. P. Emery[10], D. C. Reuter[7], S. Watanabe[11,3], D. S. Lauretta[12], and Hayabusa2 & OSIRIS-REx Teams, [1]LESIA, Observatoire de Paris, PSL Research University, CNRS, Univ. Paris Diderot, Sorbonne Paris Cité, UPMC Univ. Paris 06, Sorbonne Universités, 92195 Meudon, France (antonella.barucci@obspm.fr), [2]Kochi University, Kochi 780-8520, Japan, [3]ISAS, JAXA, Sagamihara 252-5210, Japan, [4]The University of Tokyo, Tokyo 113-0033, Japan, [5]Chiba Institute of Technology, Narashino 275-0016, Japan, [6]The University of Aizu, Aizu-Wakamatsu 965-8580, Japan, [7]NASA Goddard Space Flight Center, Greenbelt, MD, USA, [8]Southwest Research Institute, Boulder, CO, [9]Department of Physics, Ithaca College, Ithaca, NY, USA, [10]Department of Astronomy and Planetary Science, Northern Arizona University, AZ, USA, [11]Nagoya University, Nagoya464-8601, Japan, [12]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA.

Introduction: We studied the visible and near-infrared spectral behaviour of the Ryugu and Bennu surfaces, as observed by the Hayabusa2 and OSIRIS-REx missions, using the G-mode multivariate statistical method, aiming to distinguish spectrally homogeneous groups. The objective of the statistical analysis is to identify any possible small surface compositional variation on both asteroids.

The two asteroids Ryugu and Bennu seem similar with very dark albedo (4.5% and 4.4% respectively) [1, 2], but with very different surface properties and spectral behaviour [3, 4]. The spectra of Bennu show negative, bluish slopes and large band depths at 2740 nm whereas the spectra of Ryugu show a red slope with a weak narrow absorption band at 2720 nm.

Method: The G-mode multivariate statistical analysis [5] has been widely used in the planetary field to classify asteroids [6, 7] and transneptunian objects [8, 9] in homogeneous compositional groups, and to search for compositional differences on the surface of the comet 67P/Churyumov-Gerasimenko [10]. The method allows the user to obtain an automatic statistical clustering of a sample containing *N* objects (in this work the pixels) described by *M* variables (the normalized reflectance of each filter for the camera data and of a selected set of wavelength channels for the spectral data) in terms of homogeneous groups without any *a priori* criteria and taking into account the instrumental errors in measuring each variable. The user selects the confidence level that corresponds to a given critical value q1: the larger the q1, the less detailed the classification. If the user wants to classify the whole sample with a 99. 7% probability of making the right decision in inserting a sample in a group, the critical value of q1 has to be 3.00, which is the value corresponding to the 3σ level of a standardized normal distribution (i.e. a probability of 0.3% of misclassifying an object). Allowing a lower confidence level increases the probability of making a wrong decision, but it is possible to have a more detailed grouping. The method gives metrics for the relative importance of the variables in separating the groups. For a detailed description of the method, we refer the reader to the aforementioned literature [6].

Data: For Ryugu, we used the ONC-T camera and NIRS3 spectral data obtained by Hayabusa2 in July 2018. For the camera the normalized reflectance measured in the seven band filters spanning from 400 to 950 nm with their errors have been used. The data have been co-registered and photometrically corrected as described by [1]. For the NIRS3 data, we used the spectra thermally and photometrically corrected as described by [3] selecting 24 variables among those most significant in the spectral range 1900 and 2900 nm.

For Bennu we used the spectral data from the OVIRS instrument [11, 4] onboard OSIRIS-REx. The data we used are thermally and photometrically corrected [4] and we selected 24 variables among those most significant in the spectral range 500 - 3400 nm avoiding wavelengths that could have residual instrument artefacts and imperfect thermal tail removal. For this preliminary analysis, we used data from the 12:30 pm Equatorial Station (acquired in May 2019), which are at similar spatial resolution as those of Ryugu (20 m/spectrum and a small phase angle (7.6°-9.5°).

Results: The analysis of both data for Ryugu and Bennu allows us to characterize spectral properties of the major morphological surface features. From the results of the multivariate statistical analysis on Ryugu and Bennu spectral (visible and near-infrared) data, we confirm small spectral variations characterized by the detection of different groups, increasing at the decrease of confidence levels.

The statistical analysis of the spectrophotometry by ONC-T and NIRS3 spectral data for Ryugu at 3σ confidence level clearly highlights a very homogeneous surface with slightly different small areas containing about 3% of the analyzed data. Decreasing the confidence level at 2σ, a few small groups are detected with different average spectral slopes. The different groups obtained from NIRS3 spectral data show also differences in the area of the 2720 nm band that could be attributed to different abundance of hydrated phyllosilicates, nevertheless particle size and porosity are also important parameters that could change not only the spectral slopes but also the band depth.

The small detected variations characteristic of the various groups obtained for Ryugu confirm it is a homogeneous object with possible i) slight differences in the abundance of hydrated phyllosilicates, ii) presence of fresh material, less altered by space weathering, and iii) different particle sizes. Some younger surfaces appeared around the equatorial ridge and on Otohime Saxum [1]. We suggest that the groups having redder spectral slopes are referring to surface zones with small particle size regolith. The obtained results show a clear spectral dichotomy both between the eastern and western hemispheres and between northern and southern hemispheres [12].

The preliminary statistical analysis of the OVIRS spectral data for Bennu shows also a general homogeneous surface with different small areas. Also for Bennu a very homogeneous surface is highlighted with slightly different small areas containing about 3% of the analyzed data at 3-2.5σ confident level. Decreasing the confidence level to 2.1σ, a few small groups are detected with different average spectral slopes, different depth of the absorption band at 2740 nm and different spectral behavior beyond 3000 nm. The depth of the band at 2740 nm is connected to the presence of phyllosilicates [10] and can be interpreted as different abundance of phyllosilicate and/or variation in particle size [13] whereas the variation of the spectra beyond 3000 nm is associated with different abundance of organic material. The groups having relatively redder spectra are concentrated at the big, dark boulder (24°, 28°) and near the equatorial ridge. Some of them are also located on more rough terrains. Decreasing the confidence level at 1.8σ, more small groups characterized by the presence of small specific variations are detected.

From the results obtained by the multivariate analysis on both asteroids, we confirm small spectral variations characterized by the detection of different groups. A spectral dichotomy has been detected both between eastern and western and northern and southern hemispheres on Ryugu. In this talk we will explore the range of spectral dichotomy that may also be present on Bennu in the region centered at latitude 0°. The detected spectral variations can give information on the formation phase of the two bodies.

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