MICROMEGA HYPERSPECTRAL DATA ACQUISITION/PROCESSING METHODOLOGY AND CHARACTERIZATION OF RYUGU RETURNED SAMPLES IN JAXA CURATION.

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Introduction: The Hayabusa2 spacecraft successfully brought samples back to Earth in December 2020, collected at two different locations (TD1 and TD2, corresponding to Chambers A and C of the sample catcher, respectively) on the surface of the C-type asteroid Ryugu [1]. The returned samples have been transported to the Extra-terrestrial Samples Curation Center of JAXA and have been installed in the vacuum or pure nitrogen-purged chambers, to find the amount of approximately 5.4 g. As the initial description process of the returned samples, catalogue data acquisition and preliminary analyses for the aggregates and individual samples are ongoing prior to sample distributions, within the JAXA curation center in a non-destructive, non-contaminating and non-exposure manner [2]. In this process, basic properties regarding the appearance, weight and color of the samples are acquired and included in a database to be released in early 2022 for the announcement of opportunity (AO) [3]. One of the acquisition methods is near-infrared hyperspectral microscopic analyses with the MicrOmega, developed by IAS, which is the updated model of the on-board instrument of the Hayabusa2 small lander MASCOT developed by DLR and CNES [4]. Here we present the methodology for generating catalogue datasets for the AO and for characterizing samples using MicrOmega hyperspectral data.

Measurement system: MicrOmega is mounted on a temperature-conditioning copper plate inside a dedicated chamber, linked to the clean sample chamber through a sapphire window. The samples at the focal position in the clean sample chamber are illuminated through the sapphire window by a scanning monochromatic light source using an acousto-optic tunable filter (AOTF) from a 35° incident angle, and then the diffuse reflected light from the sample is captured through the sapphire window by the detector located directly above. Both the instrument chamber and the clean sample chamber are constantly purged with a pure nitrogen to prevent from atmospheric influence on the spectral profile and from atmospheric, particulate and human-derived organics contamination.

The instrument has a 5 x 5 mm Field of View (FOV) in 250 x 256 pixels to generate a hyperspectral image cube (x, y, λ) within the 0.99 to 3.65 µm wavelength range. This performance can mark the presence of absorption bands suggestive of hydrous minerals (e.g. 1.4, 1.9, and 2.7-3.0 µm), and of organics (e.g. 3.4 µm). Its FOV can cover full individual grains a few mm in size, and the image resolution allows to distinguish inclusions larger than few tens of microns typically. Radiometric calibration using Spectralon 99% and Infragold is performed at least once every few months [5].

Data acquisition and processing methodology: For the appropriate data acquisition and processing, it is important to take into account the photometric and geometrical effects depending on the sample shape and the incident light angle. The images usually show strong specular reflections and/or shadows at a certain angle depending on the sample position, and this can result in different apparent reflectance and spectral features for even the same sample (Fig. 1). Therefore, data acquisition is performed at each 90° angle and at different focal points. Furthermore, various measurement recipes are adapted according to the features of the sample, with different number of wavelength points, wavelength bands and integration times.

For the catalog data of individual grains, spectra in all the pixels on a grain are averaged to make an "averaged spectrum" for each measurement angle and focal position, then the averaged spectra acquired under different viewing geometries are compared to select the most representative one from a combination of features such as reflectance, depths of absorption, and signal-to-noise ratio (Fig. 1). If there are areas in the grains that show distinctive signatures different from most of the other part of the grain, specific regions of interest (ROIs) are also extracted. The database for the individual grains will contain monochromatic images, typical average spectra, ROIs' spectra, and comments on the inclusions and mineral species they may imply.

Results of characterization: 179 individual grains (Chamber A: 86 grains, C: 93 grains) and 21 aggregates have been measured by the end of 2021. ROIs consisting with a few pixels at minimum were extracted from 50 of those individual grains (A: 24, C: 26). Preliminary analyses show that within these 50 grains, 2 grains indicated relatively large carbonate inclusions (more

than a few hundred µm in diameter), and 18 grains potentially indicated small carbonate inclusions (~50-100 µm in diameter) [6]. Meanwhile, in the case of Ryugu aggregate samples, the former carbonates account for less than 1% and the latter for up to 5% of the total MicrOmega pixels [4]. Furthermore, so far, 17 grains were also identified with possible small spots of -CH enriched area (3.4 µm absorption), and 3 grains with those of -NH enriched area (3.1 µm absorption). These features will be listed in the curatorial database [3] ahead of the AO and would be clues to provide constraints on the formation and evolution processes of Ryugu.

Average spectra of 73 grains (A: 36, C: 37), already selected and validated as representative data, were analyzed using Principal Component Analysis (PCA) (Fig. 2). As a result, the influence of the variety of individual grains is more relevant than the difference between the samples in Chambers A and C. Relatively special particles were shown, for example, those with a metallic luster, a pronounced carbonate inclusion distributed over a range of more than 500 µm, and a shallow absorption at 2.7 µm. However, only a few grains (≤5%) have these distinctive features and most of the others show a similar pattern, regarding average reflectance around 3%, depth of 2.7 µm absorption, positive spectral slope at 1.0-2.6 µm, existence of organics absorption around 3.4 µm etc., regardless of Chambers A and C.

References: [1] Tachibana S. et al. *Submitted to Science.*, [2] Yada T. et al. (2021) *Nature Astron.*, doi: 10.1038/s41550-021-01550-6., [3] Nishimura M. et al. (2022) *this conference.*, [4] Pilorget C. et al. (2021) *Nature Astron.* doi: 10.1038/s41550-021-01549-z. [5] Riu L. et al. (2022) *Submitted to Review of Scientific Instruments.* [6] Loizeau D. et al. (2022) *this conference.*
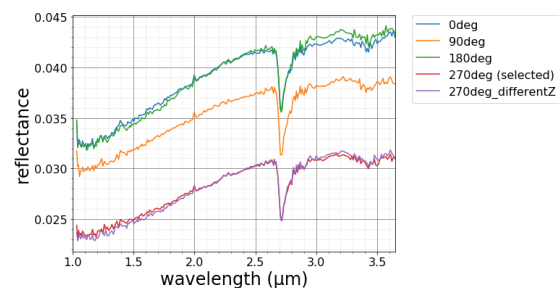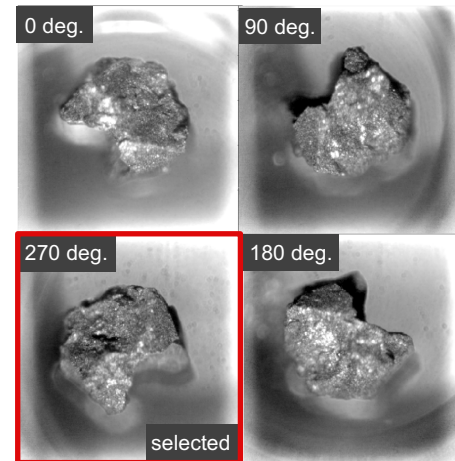
Fig. 1. Selection of representative spectrum by comparing the monochromatic images at 2.5 micron and averaged spectra obtained with various angles and focal positions.
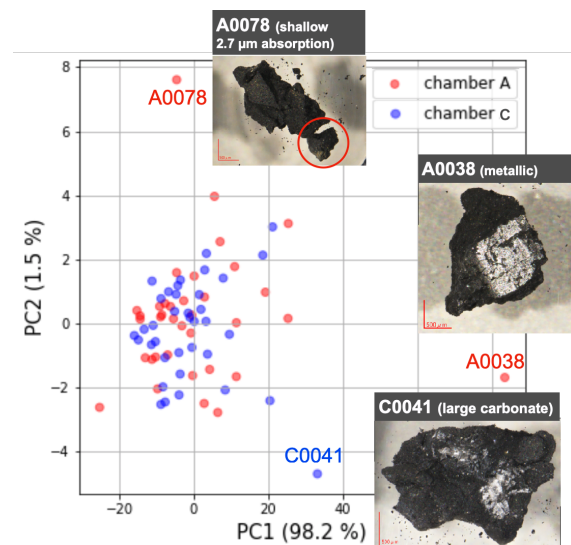
Fig. 2. PCA result of 73 single grains. The variety of the individual grains is more prominent than the differences between Chambers A and C.