NIR HYPERSPECTRAL IMAGING OF HAYABUSA2 RETURNED SAMPLES BY THE MICROMEGA MICROSCOPE WITHIN THE ISAS CURATION FACILITY. C. Pilorget[1,2], J.-P. Bibring[1], T. Okada[3,5], R. Brunetto[1], T. Yada[3], D. Loizeau[1], L. Riu[1,4], T. Usui[3,5], K. Hatakeda[3,6], A. Nakato[3], K. Yogata[3], M. Abe[3,7], A. Aléon-Toppani[1], D. Baklouti[1], J. Carter[1], Y. Hitomi[3,6], K. Kumagai[3,6], Y. Langevin[1], C. Lantz[1], T. Le Pivert-Jolivet[1], A. Miyazaki[3], K. Nagashima[3], M. Nishimura[3], [1]Institut d'Astrophysique Spatiale, Université Paris-Saclay, CNRS, 91400 Orsay, France, [2]Institut Universitaire de France, [3]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara 252-5210, Japan, [4]ESAC, ESA, Madrid, Spain, [5]University of Tokyo, Bunkyo, Tokyo 113-0033, Japan, [6]Marine Works Japan, Ltd., Yokosuka 237-0063, Japan, [7]The Graduate University for Advanced Studies (SOKENDAI), Hayama 240-0193, Japan. (cedric.pilorget@ias.u-psud.fr)

Introduction: On December 6, 2020, the Hayabusa2 mission successfully returned to Earth ~ 5.4 g of samples collected at the surface of the C-type asteroid Ryugu [1,2]. Its surface was first sampled on February 22, 2019 ("bulk A"), then on July 11, 2019, close to a 15-meter large artificial crater, so as to possibly access sub-surface material ("bulk C") [3]. The collected samples are now kept at ISAS (Institute of Space and Astronautical Science) for a first round of preliminary analyses, with the objective of characterizing in a non-destructive manner both the bulk samples and a few hundreds of grains extracted from them [4]. In particular, the goal is 1) to support their further detailed characterization by the international Initial Analysis Teams, and 2) to build a catalogue of the grains, accessible to the international community through AO selection, starting mid-2022. Importantly, the analyzed samples have always been kept, since their collection, in a fully clean and controlled environment either under vacuum or ultra-clean GN2.

Methods: The preliminary characterization of these samples is being conducted with a visible microscope with six color filters [4], a FTIR spectrometer (1-4 µm) [4], and MicrOmega, a hyperspectral microscope [5], operating in the near-infrared range (0.99-3.65 µm) where diagnostic signatures of most candidate minerals and molecules of relevance (e.g. mafic minerals, altered phases, salts, ices, aliphatic/aromatic CH, NH-rich compounds) can be found. For each 22.5x22.5 μm^2 pixel of the 250x256 $pixels^2$ field of view, the reflectance spectrum is retrieved in up to 400 contiguous spectral channels. Both the negligible amount of illuminating power at less than 10^{-8} W/px and the lack of contact with the samples allow entirely non-destructive and non-invasive characterization. By the beginning of 2022, bulk samples from chamber A and chamber C of the Hayabusa2 returned capsule (each divided into 3 sub-bulks), as well as >200 individual grains and 14 “small-bulks” extracted from them have been analyzed with MicrOmega.

Results: When analyzed at the mm-scale by averaging thousands of pixels, the spectra of bulk A and bulk C exhibit a pattern similar to those acquired remotely down to the meter scale by the NIRS3 IR spectrometer on board Hayabusa2 [6]. The global reflectance is extremely low, 2-3 %, in agreement with the measurements of the ONCs and NIRS3 at Ryugu [7,8], and consistent with the taxonomic spectral classification of Ryugu as a C-type asteroid [1,2]. The main spectral feature is the diagnostic OH absorption centered at 2.715 +/- 0.005 µm, position compatible with that of NIRS3 spectra [8,9]. No significant differences can be observed between bulk A and bulk C for this specific feature. MicrOmega spectra also exhibit a broad feature in the 3.3-3.5 µm range, centered around 3.4 µm, present throughout the sub-bulk samples. This feature is considered indicative of the large-scale presence of a variety of CH-rich compounds and carbonates. A fainter ~3.1 µm broad feature, indicative of the presence of NH-bearing compounds is also detected, although with varying and much fainter intensities. Only at a sub-millimeter scale do heterogeneities clearly show up, either or both at grain level or as inclusions within grains. Detections include for example: 1) carbonates of various compositions, detected on a rather large number of occurrences with sizes ranging from a few tens to a few hundreds of micrometers [10] ; 2) spots enriched in organics, in particular through a 3.4 µm feature indicative of the presence of aliphatic compounds ; 3) spots enriched in a nitrogen-rich phase, through a ~3.1 µm feature sometimes coupled to additional spectral features. These detections, as well as others, will be presented and candidates will be discussed. Noticeably, no chondrules nor refractory inclusions have been identified yet.

Conclusion: The initial spectral characterization of the returned samples by MicrOmega currently points towards Ryugu containing a fascinating variety of grains, including OH-, CH- and NH- rich compounds spread at a global scale, and alteration products, among which highly diagnostic carbonates. The occurrence of volatile-rich species, likely originating from the outer solar system, would support Ryugu having preserved some of its building blocks, together with their partially altered phases. The Hayabusa2 returned samples, thus, appear among the most primordial material available in our laboratories.

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