MINERALOGICAL MAPPING OF ASTEROID RYUGU USING NIRS3 SPECTRA. D. Takir[1], L. Le Corre[2], J.P. Emery[3], C.A. Hibbitts[4], K. Kitazato[5], and the Hayabusa2 NIRS3 team, [1]Jacobs, NASA Johnson Space Center, Houston, Texas, USA (driss.takir@nasa.gov), [2]Planetary Science Institute, AZ USA, [3]Northern Arizona University, Flagstaff, Arizona, USA, [4]Applied Physics Laboratory, Laure, Maryland, USA, [5]University of Aizu, Aizu-Wakamatsu 965-8580, Fukushima, Japan.

Introduction: JAXA's Hayabusa2 mission completed a successful rendezvous with the near-Earth and Cb-type asteroid (162173) Ryugu in the summer of 2018 [1]. The mission revealed that Ryugu is a top-shaped and rubble-pile asteroid with a diameter of ~950 m and density of 1.19 g/cm^3 [1]. Near-infrared (NIR) reflectance observations of Ryugu were conducted by the Near-Infrared Spectrometer (NIRS3) onboard the Hayabusa2 spacecraft [2, 3]. NIRS3 is a point spectrometer that has a 0.1° field of view and takes continuous point-target spectra over the effective wavelength range from 1.8 to 3.2 µm [4]. On June 21st 2018, NIRS3 started measuring spectra of Ryugu that showed the presence of an ubiquitous weak and narrow absorption feature centered at 2.72 µm attributed to hydroxyl (OH)-bearing minerals [2]. The shape, intensity and center of the 3-µm band observed on Ryugu are consistent with thermally and/or shock-metamorphosed carbonaceous chondrites [2].

NIRS3 spectra extraction and calibration: NIRS3 observations were carried out in two modes [4]: the "home position" when the spacecraft stayed at 20 km from the surface of Ryugu for global mapping at 40 m resolution, and during spacecraft descent while studying the surface to an altitude of 1 km (up to a resolution of 2 m). We used the NIRS3 calibrated data provided by the Hayabusa2 team for preparing radiance files and their associated geometric backplanes needed to do the thermal and photometric modeling. The viewing geometry was computed based on latest version of the shape model of Ryugu using the middle of the exposure time for each footprint. Our custom IDL codes used to process the data include routines from the NAIF SPICE toolkit [5] and can extract parameters such as: phase angle, incidence angle, emission angle, center latitude and longitude coordinates, and the geographic coordinates of the footprint corners. The shape model was derived from the ONC images acquired during the entire proximity phase of the mission by stereo-photoclinometry[6]. We used the shape model with 786,432 facets with each facet being about 1 m.

Creation of maps of Ryugu: Having the center point information is sufficient for carrying out photometric modeling; however this is insufficient for mapping the data onto the asteroid shape model. Data reprocessing with our custom codes was required to retrieve the coordinates for the footprint corners and then map the spectra more accurately on the shape model. Ultimately, our goal is to create hyperspectral mosaics of Ryugu. The main phases of NIRS3 data acquisition for global mapping are called BOX A, BOX B and BOX C and consist in spectral observations at spatial resolution of ~20-40 m/pixel. To assess the spatial coverage from the available data, we created separate preliminary maps for each mode of observation (Figure 1 & 2) before applying any photometric correction. We plan to improve these maps by removing the infrared data that are ~0 visible as black footprints in the maps. Once we sort the data, define the photometric model and derive the thermal model, we will build the final maps used for interpretation of the mineralogy of Ryugu. Once we sort the data, define the photometric model and derive the thermal model, we will build the final maps used for understanding of the spatial variation in mineralogical composition of Ryugu surfaces. These mapping techniques and high-resolution mineralogical maps will provide geological context for the returned Ryugu samples.

Thermal modeling and excess removal: The NIRS3 spectra of Ryugu are dominated by reflected solar flux at the shorter wavelength end of the spectral scale ($\lesssim$ 2.4 µm), but contain a significant contribution from thermal emission at longer wavelengths. We remove this thermal component with techniques similar to those described in [7] and [2]. For each spectrum, we first isolate the thermal component by subtracting a model reflected component of the total flux. The model reflected component is the solar spectrum corrected for the heliocentric distance at the time of observation, multiplied by the average slope of Ryugu spectra (~0.04%; [9]), and scaled to the measured radiance at 2.1 µm. The remaining thermal radiance is fitted with a single-temperature blackbody by computing blackbody curves for every 1K from 250 to 400K, scaling to the measured thermal radiance, and minimizing the reduced χ^2. The best-fit blackbody temperature is taken to represent the temperature of the footprint and is subtracted from the total measured radiance spectrum. The resulting thermally-corrected spectra are divided by the solar flux spectrum to produce I/F reflectance spectra.

Photometric modeling and correction: The thermally-corrected NIRS3 spectra (in I/F units) are used to develop empirical photometric models (derived for each channel) for NIRS3. These models describe the scattering behavior of Ryugu as a function of viewing geometry and wavelength. Data are photometrically modeled and corrected using three empirical photometric functions: ROLO, Lommel-Seeliger, and Minnaert [9]. We are using the function that produces the best solution fit in order to normalize/correct spectra of NIRS3 to a common viewing geometry similar to the viewing geometry in the laboratory geometry (e.g., i = 30º, e = 0º, α = 30º).

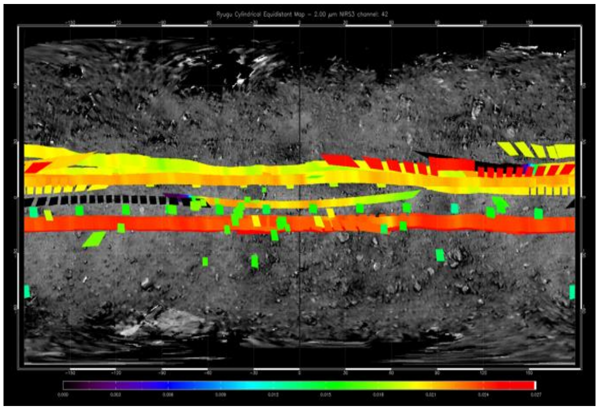

Figure 1. Preliminary cylindrical map of asteroid Ryugu showing the 2 microns data from NIRS3 obtained in the BOX A mode.

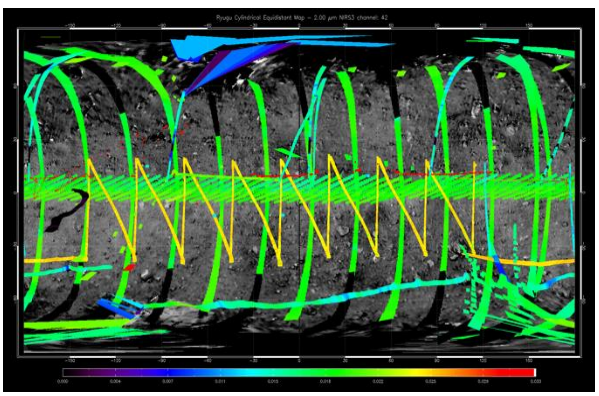

Figure 2. Preliminary cylindrical map of asteroid Ryugu showing the 2 microns data from NIRS3 obtained in the BOX C mode.

Spectral analysis: To quantify the relative mineralogical abundances on Ryugu, we calculate NIRS3 spectral parameters (e.g., band depth, center) using an IDL-based program, which will take the photometrically and thermally corrected NIRS3 spectra as an input. We will present our latest results on the mapping of spectral parameters related to mineralogical information and others linked to space weathering effects or photometric properties.

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