Spectral heterogeneities at the surface of Ryugu as seen by the NIRS3 spectrometer

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Asteroid Ryugu has been the prime target of the Hayabusa2 spacecraft which performed orbital characterization of the asteroid for a 1.5 yr with on his board the near-infrared spectrometer NIRS3. NIRS3 acquired data throughout the overall proximity phase resulting into a complete dataset of 101 spectral observations of Ryugu. Each observation was performed at various time, spacecraft altitude, observational conditions (incidence/emergence angles), surface temperature, resulting into a very rich dataset for mineralogical characterization. Based on the global mapping observations, that provides a resolution of 20m/px, Ryugu has been identified as a very dark asteroid (average albedo ~1.9%) with very homogeneous surface properties: a slight red slope and a sharp 2.72 um absorption feature attributed to the presence of OH [1]. Morphological and spectral heterogeneities have been highlighted at higher spatial resolution with the ONC camera and the TIR thermal infrared spectro-imager suggesting irregularities at finer scale: bright boulders of possible exogenous origin [2], hot spots inside craters [3], slope difference inside craters [4]. Based on the last two findings, we decided to perform a survey of the 86 craters that were identified at the surface of Ryugu [5] using the global NIRS3 dataset. The methodology applied aimed at evaluating the spectral properties (*e.g.,*spectral slope, absorption features, albedo) inside each crater and compared them to its vicinity. To smooth out potential calibration artifacts or biases based on photometry or thermal corrections, we used all NIRS3 observations to perform this analysis. For each crater, we look for all NIRS3 observations that falls inside the crater with a spot size smaller or equal to the crater. We also extract the spectra of the vicinity of the crater for the same day of NIRS3 observation to perform spectral comparison. For the majority of craters, several NIRS3 spectra are available, the results are thus combined. As an example, we display in Figure 1 the analysis of crater #ID69 [5] that corresponds to a hot spot as detected by TIR [3], that was analyzed based on the high-resolution observation of NIRS3 on October 31st 2018.

We observe that the spectral properties inside and outside the crater are very similar (ratio close to 1 and very flat, Fig.1c). However, the ratio display an increase in the band depth showing that the absorption feature attributed to the presence of hydrated minerals is larger in the crater. For the majority of craters, we observe that the 2.72 um band depth is larger inside compared to the surroundings, but changes in the slope and albedo are often observed. Several possibilities can explain this observation such an increase in the hydration degree, a change in surface properties (grain size for example), fresher material that was less altered by space weathering. The followings steps will be to cluster all craters based on their spectral similarities, morphologies and surface types to outline a story for Ryugu's surface formation and evolution and decipher between the different scenario that account for such differences.

Figure 1- (a) Map of the crater based on [5], the blue squares corresponds to the NIRS3 spectra inside the crater, the orange squares corresponds to the spectra outside. (b) Inside spectra (grey = individual, red = average) and outside spectra (black = average), corresponding respectively to the spectra extracted from locations in blue and orange on (a). The vertical blue line corresponds to the position of the 2.72um band. (c) Ratio of the average spectra inside the crater divided by the average spectra outside the crater.

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