PHOTOMETRIC PROPERTIES OF RYUGU'S SURFACE FROM BOTH THE HAYABUSA2 NIRS3 AND ONC-T INSTRUMENTS. D. Domingue[1], K. Kitazato[2], M. Matsuoka[3], E. Tatsumi[4,5,6], S. Sugita[6], Y. Yokota[3,7], R. Honda[7], T. Iwata[3], M. Abe,[3], M. Ohtake[3], F. Vilas[1], and the NIRS3 and ONC Instrument Development Teams. [1]Planetary Science Institute, AZ, USA, [2]Univ. of Aizu, Fukushima, Japan, [3]Inst. of Space and Astron. Sci., Japan Aerospace Exploration Agency, Kanagawa, Japan, [4]Instituto de Astrofisica de Canarias, Tenerife, Spain (etatsumi@iac.es), [5]Dept. of Astrophysics, Univ. of La Laguna, Tenerife, Spain, [6]Univ. of Tokyo, Tokyo, Japan, [7]Kochi Univ., Kochi, Japan.

Introduction: Photometric studies, as defined here, are the analysis of how the amount of reflected light changes with illumination and viewing geometries. The ability to describe how reflectance changes with incidence, emission, and phase angles provides a mechanism for standardizing observations to a common set of angles, in addition to setting constraints on the physical properties of the optically active portion of the regolith. Understanding and comparing the photometric properties as a function of wavelength (visible versus infrared, for example) also places constraints on the spatial scale of some of the physical properties. We present results, to date, for both the NIRS3 and ONC-T instruments.

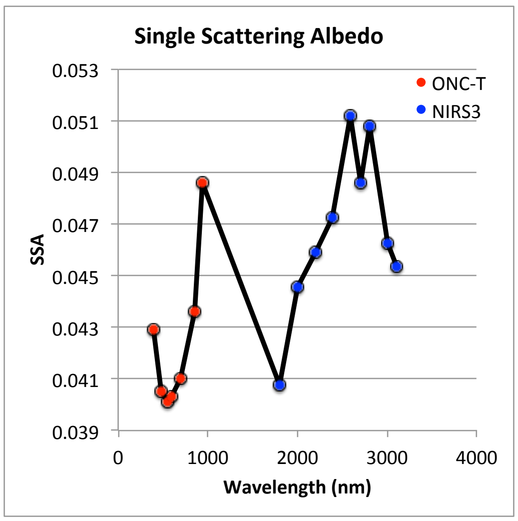

Figure 1. The variation in SSA as a function of wavelength. ONC-T values are in red, NIRS3 values are in blue.

Data Sets: The NIRS3 data used in this study were acquired between 30 June 2018 and 28 February 2019, and include observations acquired near opposition. The wavelength range covered in this study is from ~1850 nm to 3100 nm. The ONC-T data used in this study were acquired 3 July 2018 through 8 January 2019, and also include opposition measurements. Images from all seven filters (ranging from 400 nm to 950 nm) were used in the study. These datasets cover much wider ranges of phase angles than the initial reports for NIRS3 and ONC [1, 2]. The NIRS3 data are all disk-resolved while the ONC-T data are predominately disk-integrated observations.

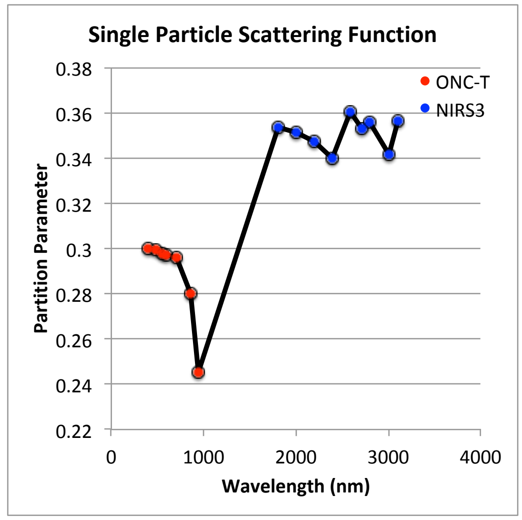

Figure 2. The variation in b *as a function of wavelength. ONC-T values are in red, NIRS3 values are in blue.*

Analysis: The data from both instruments were analyzed using Hapke's set of equations [3] and calibrations by [4] for NIRS3 and by [5] for ONC-T. The parameters used included the single scattering albedo (SSA or w), the opposition amplitude (B_0), the opposition width (h), the surface roughness (θ), and the single particle scattering function partition parameter (b). The single particle scattering function used was a single-term Henyey-Greenstein function.

Results: The Hapke model parameter values vary as a function of wavelength across both instruments. The graphs below show the single scattering albedo (Fig. 1) and the single particle scattering function partition parameter (Fig. 2) variations. The NIRS3 data is represented by 9 channels, to be comparable with the ONC-T in number of data points over wavelength span (and to show the 2700nm feature effects). The surface roughness value from the ONC-T data set was found to be 32° ± 5.63° across all visible wavelengths, while the surface roughness from the NIRS3 data set was found to be 29° ± 1.68°. These values overlap within the error-bars, however it should be noted that the ONC-T value is based on disk-integrated data, which maybe affected by the asteroid's shape [6].

Discussion: The incongruity in parameter values with wavelength between the visible ONC-T and infrared NIRS3 data are most likely due to the different types of data sets: one is disk-integrated and the other is disk-resolved. Surface roughness values are both high, and are similar within the uncertainties. Both instruments predict a backward scattering regolith, commensurate with the dark, opaque nature seen in the imaging data.

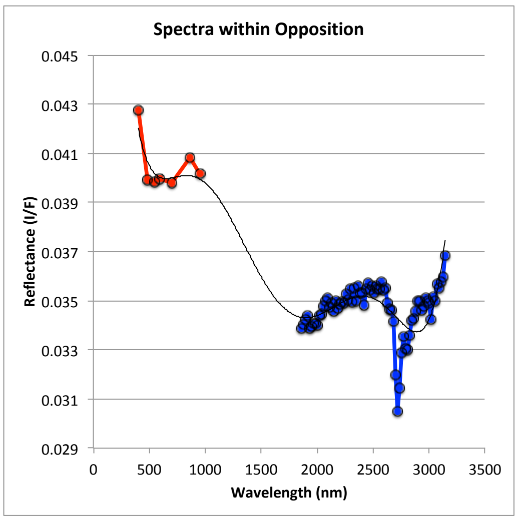

Figure 3. The ONC-T color spectrum (red) acquired at 0.14° phase is compared with the NIRS3 spectrum (blue) acquired at 0.15° phase. The ONC-T is a disk-integrated spectrum, the NIRS3 spectrum is the average of five disk-resolved spectra acquired across Ryugu's surface. A sixth-order polynomial is fit to the entire spectrum across both instruments.

Of interest is examining spectra from both instruments acquired at similar phase angles. The graphs below compare the disk-integrated reflectance from the ONC-T with the disk-resolved reflectance from the NIRS3. Within the opposition region (Fig. 3) the visible portion of the spectrum is brighter than the infrared portion of the spectrum. The opposite relation is seen at 18.5° phase (Fig. 4). Thus the opposition amplitude is larger in the visible compared to the infrared, yet note that the single scattering albedo (Fig. 1) shows smaller variation from visible to infrared than the reflectance values. The difference in particle scattering function suggests that Ryugu's surface is more strongly backward scattering in the infrared than the visible.

What does this imply for the physical properties of the optically active portion of the regolith? From these results we can conclude: 1) the regolith is highly absorbing across both wavelength regions, 2 0 the opposition amplitude differences imply the illumination of shadowed regions is greater at the 100 nm scale than the 1000 nm. The properties of the scattering centers are either more absorbing in the visible than the infrared, or more forward scattering in the visible than the infrared. The next iteration of this study will be to examine and compare disk-resolved reflectances from both instruments.

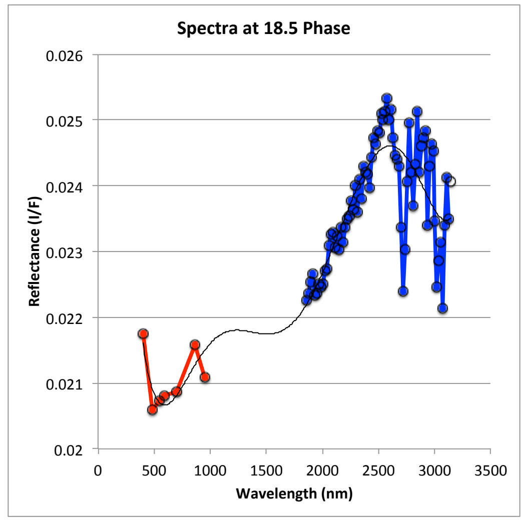

Figure 4. The ONC-T color spectrum (red) is compared with the NIRS3 spectrum (blue), both acquired at 18.5° phase. The ONC-T is a disk-integrated spectrum, the NIRS3 spectrum is the average of three disk-resolved spectra acquired across Ryugu's surface. . A sixth-order polynomial is fit to the entire spectrum across both instruments.

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