THE SPECTROPHOTOMETRIC PROPERTIES OF RYUGU’S REGOLITH
AS SEEN AT OPPOSITION BY THE NIRS3 ONBOARD HAYABUSA2.

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I. Introduction. The Near-Infrared Spectrometer (NIRS3) onboard the Hayabusa2 spacecraft obtained infrared spectra of C-type asteroid 162173 Ryugu near opposition (phase angles below 1 deg) at various spatial scales over the near-equatorial, low latitude regions. We examine the wavelength dependence of the opposition region, photometric modeling of the opposition data sets, and comparisons with the opposition measurements acquired by the Optical Navigation Camera (ONC).

II. Data & Model. An example of the data set (Fig. 1) and the Hapke modeling [1] results (Fig. 2) show that the NIRS3 data set can be described by the Hapke set of equations (Fig. 3).

III. Spectral and Phase Slopes. Laboratory examinations of meteorite samples have attempted to correlate the spectral slope and spectral reddening characteristics with sample properties, such as granularity (rock vs powder) and grain size. We extrapolate these correlations to Ryugu’s regolith (Fig. 4).


Fig. 1 (left) NIRS3 opposition data at 2001.38 nm (diamonds) and 2701.81 nm (circles) within the various footprint resolutions.

Fig. 2 (left) Hapke model parameter values as a function of wavelength (right) As a test of the goodness of fit the ratio of the observed reflectance to the model predicted reflectance is plotted as a function of phase angle for the 2.0 μm data set over all the footprint resolution groups. These results are typical of those seen across all wavelengths.

Fig. 3. (top) Comparisons of NIRS3 spectra (solid lines) with model predicted spectra (dashed lines) for spectra acquired near opposition (top) and near 15 degrees phase (bottom)

Fig. 4 (top right) The spectral slope calculated from the ONC standardized mosaics (open diamonds) of Tatsumi et al. (2020) and the normal albedo mosaics (open circles) of Yokota et al. (2020) of the ONC-T equivalent reflectance to the NIRS3 opposition data in units of mm. The slopes were calculated using the b- and p-band reflectance values. The spectral slope calculated from NIRS3 opposition observations (center right) and the near 19 phase angle observations (bottom right). The slopes were calculated using based on the 1.5 μm and 2.5 μm reflectance values. The colors correspond to the footprint sizes (blue 4 – 6m, teal 6 – 8m, green 8 – 10m, and red 38 – 40m.

Fig. 5 Comparisons of spectral slope at (top left) opposition phase angles and (bottom left) near 19° phase as a function of near nadir (low incidence, black symbols) and grazing (high incidence, blue symbols). No distinctive trend with incidence angle implies the surface of Ryugu is granular.

Rock vs Powder: Powder is redder sloped than rock [2,3] and displays greater phase reddening than rock [3]. Powder’s spectral reddening is insensitive to incidence angle while rock is sensitive to incidence angle [3]. NIRS3 data show no correlation with incidence angle and spectral slope (Fig. 5) – argues for a granular component to Ryugu’s regolith.

Grain size: Coarse grains are spectrally blue, but a 5% or more fine-grained fraction changes slope from blue to red [4]. Increasing the average grain size produces darker, bluer spectra [2,4]. At phase angles commensurate with the laboratory work, Ryugu is red sloped in both visible (ONC-T) and near-IR (NIRS3), providing evidence for the inclusion of a fine-grained component to the regolith.