NEAR-INFRARED PHOTOMETRY OF ASTEROID 25143 ITOKAWA BY THE NIRS ONBOARD HAYABUSA.

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Introduction: We present the results of near-infrared photometry of asteroid 25143 Itokawa obtained by the near-infrared spectrometer (NIRS) [1] on board the Hayabusa spacecraft. Before the Hayabusa mission, Itokawa was classified as an S-type asteroid based on telescopic observations [2]. The main components detectable in near-infrared spectra of S-type asteroids are the minerals olivine and pyroxene, which exhibit absorption features in reflectance spectra centered near 1 and 2 μm. From previous work, it is known that S-type asteroid spectra exhibit variations in brightness and color due not only to compositional differences but also due to viewing geometry changes [3]. A photometric correction is needed for the purposes of comparing spectra obtained at highly variable viewing geometries.

Observations: During the rendezvous phase from September 12, 2005, until November 24, 2005, NIRS observations were conducted from the Home Position (HP) where the altitude of the spacecraft from the asteroid was about 7 km. NIRS obtained the disk-resolved spectra at phase angles ranging from 0.1 to 38.4 $^\circ$. Spectra were obtained with 64 channels covering the wavelength range 0.76 to 2.25 μm. The field-of-view of NIRS is 0.1 x 0.1 $^\circ$and typical spatial resolutions at HP are approximately 12 x 12 m.

Analysis: For this work, we used the photometric model for bidirectional reflectance as follows [4],[5],[6]:

$$r(i,e,\alpha) = \frac{w}{4}\frac{\mu_0}{\mu_0+\mu}\big([1+B(\alpha,h,B_0)]P(\alpha) + [H(\mu_0,w)H(\mu,w)-1]\big)S(i,e,\psi,\bar{\theta}) \quad (1)$$

where i, e, α and ψ denote the effective incidence, emission, phase and azimuth angles respectively. The single-particle scattering albedo w represents the total amount of light scattered from a particle with respect to the incident flux and depends on the optical constants of the particle, its size and so on.

The single-particle phase function, $P(\alpha)$, used in Eq. (1) is a single-term Henyey-Greenstein function of the form

$$P(\alpha,g) = \frac{1-g^2}{\left(1+2g\cos\alpha+g^2\right)^{3/2}}, \quad (2)$$

where g is the asymmetry factor [7]. The function H is the isotropic multiple-scattering function, and B is the opposition effect where B_0 describes the amplitude of the opposition surge and h the angular width of the opposition peak. In this analysis, the model assumes that the opposition effect is controlled entirely by shadow-hiding and does not include the coherent backscatter. The function S is the correction for surface roughness where $\bar{\theta}$ is the average slope over the resolution.

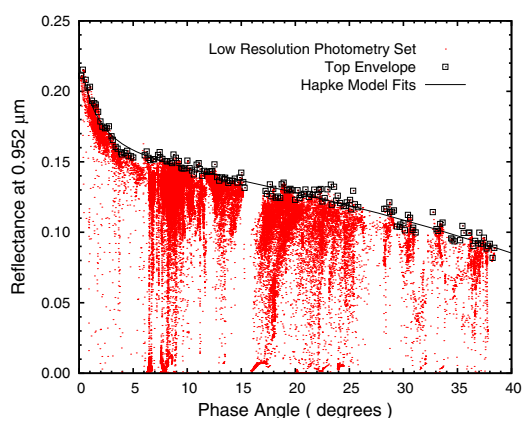

Figure 1: Brightness of Itokawa as a function of phase angle at wavelength 0.952 μm from NIRS observations. Solid line displays the fitted phase curve with Hapke's model.

Spectroscopic data used for this analysis has been reduced by subtracting the dark current and calibrating the values of detected flux from the asteroid surface using the correction factor obtained by laboratory examination before the launch.

Reflectance measured by NIRS was calculated by dividing the detected flux by the solar flux corrected

for the Sun-Itokawa distance at the time of observation. In addition, pointing geometry corresponding to each of NIRS observations was determined using the information of position and attitude of spacecraft and the shape model of Itokawa produced by Hayabusa AMICA imaging team [8].

For the photometric analysis of NIRS spectra, we binned the data with respect to phase angle and selected spectra with maximum reflectance within a 0.2 °phase angle bin. We fitted the theoretical model to the observed reflectance values for each wavelength using Nelder-Mead Simplex method to obtained the optimal solutions. We assumed a value of 28 degrees (from Eros [3]) for the macroscopic surface roughness parameter, for all wavelengths.

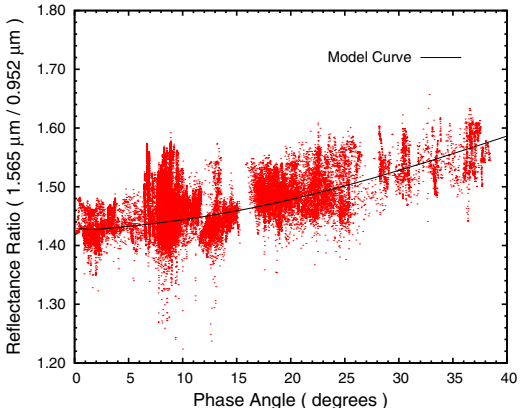

Figure 2: Ratio of the Reflectance at 1.565 μm to that at 0.952 μm plotted as a function of phase.

Results & Discussion: As a representative result, we show the reflectance of Itokawa at 0.952 μm as a function of phase angle in Figure 1. We found that each of the phase curves at different wavelengths show a strong opposition effect (a non-linear increase in brightness with decreasing phase angle near 0°). By estimating the Hapke parameter at each wavelength, this phenomena could be corrected with wavelength or albedo. According to theory, a strong wavelength dependence in opposition surge is consistent with coherent backscattering phenomena near opposition. This suggests that Itokawa's opposition effect may not be entirely due to shadow-hiding. During fitting, we found that the amplitude of the opposition surge did not exceed 1.0. Since Eros ' photometric behavior [3] could not be fit with values less than 1.0, this indicates that the surge is stronger at Eros than it is at Itokawa.

Relative to the reflectance behavior at a wavelength at the bottom of the 1-micron absorption band and that at a continuum point, the spectra of Itokawa's surface exhibit "phase reddening". Figure 2 shows the reflectance ratio at 1.565 μm and to that at 0.952 μm obtained by NIRS. The observed phase reddening (approximately 11% higher reflectance at longer wavelengths at 40 degrees phase angle than at 0 degrees phase angle) is consistent with that detected by NEAR at asteroid 433 Eros [3].

Conclusions: In conclusions, we derived the near-infrared photometric properties of asteroid Itokawa using Hapke's model, which can be used to remove spectral variations imposed on the NIRS spectra caused by viewing geometry. We find that Itokawa's surface shows strong phase reddening, similar to that observed at Eros.

References: [1] Abe M. et al. (2006) this volume. [2] Binzel, R.P. et al. (2001) Meteorit. Planet. Sci. 36, 1167-1172. [3] Clark, B.E. et al. (2002) Icarus, 155, 189-204. [4] Hapke, B.W. (1981) J. Geophys. Res., 86, 3039-3054. [5] Hapke, B.W. (1984) Icarus, 59, 41-59. [6] Hapke, B.W. (1986) Icarus, 67, 264-280. [7] Henyey, L.C., and J.L. Greenstein (1941) Astrophys. J., 93, 70-83. [8] Demura, H. et al. (2006) this volume.