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Phase Reddening and Bolometric Bond Albedo Variations in Global Photometry of (101955) Bennu with OVIRS

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Abstract

We study the photometric behavior of Bennu using the OSIRIS-REx OVIRS observations. We report the modeling results and show evidence of phase reddening. We also present our bolometric Bond albedo map and discuss the variations we see across the surface of Bennu. Finally, we provide a comparison with other asteroids and comets.

1. Introduction

NASA's OSIRIS-REx asteroid sample return mission is surveying the B-type near-Earth asteroid (101955) Bennu to understand its physical, mineralogical, and chemical properties. The spacecraft arrived at the asteroid on 3 December 2018 and will return to Earth with a surface sample on 24 September 2023 [1]. The OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS) is a point spectrometer covering the spectral range of 0.4 to 4.3 microns. Its primary purpose is to map the surface composition of Bennu [2]. It will help guide the selection of the sample site, provide global context for the sample and high-spatial-resolution spectra that can be related to spatially unresolved terrestrial observations of asteroids.

2. Photometric modeling

We perform a global average photometric analysis of Bennu over the wavelengths ranging from 0.4 to 3.5 microns. The results we present are from the Preliminary Survey mission phase and the Detailed Survey phase. From 2 December 2018, OVIRS has obtained more than 155,000 spectra. We have tested and applied filtering factors—including spatial resolution and distribution, observation quality, range of geometry angles, and spectrum quality—to select the spots for fitting the photometric models. To perform the best modeling, we tested different binning and smoothing strategies. Then we compared the results of various empirical models: Lommel-Seeliger, Minnaert, McEwen, and two forms of the Akimov model. We also derived the global photometric properties of Bennu in terms of Hapke's photometric model [6]. The wavelength dependence of the photometric properties is analyzed through the independent fitting result. We will compare these preliminary photometric modeling results with those for other asteroids [7, 8] and comets.

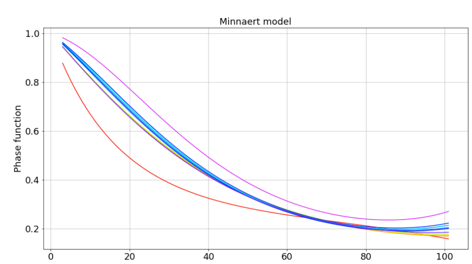

Figure 1. Comparison of Minnaert model phase functions of 11 OVIRS channels (rainbow-colored: red to purple, short wavelength to long wavelength).

3. Phase reddening

We analyzed the phase function of each model (Figure 1). Phase slope (Figure 2) is shallower at the long end of wavelength, indicative of phase reddening. The results show phase reddening up to 2.7 μm, and no reddening after that. We considered the partial illumination and used a linear-magnitude phase function to model this value; the result is slightly smaller than for typical comets and dark asteroids, which have slopes of 0.04 mag/deg [8,9].

Previously published results [11] have shown Bennu's phase reddening from multicolor images, consistent with our result. Phase reddening could be evidence for multiple scattering, roughness, or the characteristics of single-particle scattering [12].

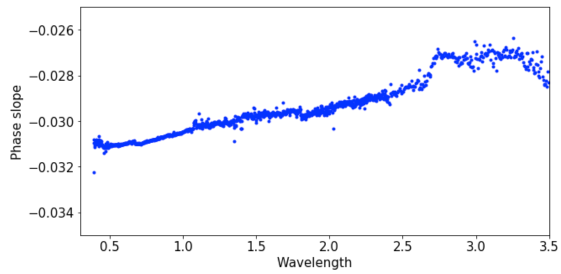

Figure 2. The phase slope (magnitude/degree). Phase slope is shallower at the long end of wavelength, indicating phase reddening.

4. Global albedo

Bolometric Bond albedo is the quantity required for Yarkovsky and thermal inertia measurements by the OSIRIS-REx mission. It is the average of the spherical Bond albedo weighted by spectral irradiance of the Sun, $J_s(\lambda)$. This integrates spherical albedo over all wavelengths, λ . By studying the global bolometric Bond albedo, we infer the thermal distribution, which affects dehydration, thermal fatigue, and how the regolith is processed.

5. Summary

Our analysis shows phase reddening up to 2.7 μm, and no reddening after that. The slope of Bennu's phase function is smaller to typical comets and dark asteroids. Our map of bolometric Bond albedo shows excellent correlation with features across the surface of Bennu. The Detailed Survey is ongoing at the time of writing and will yield more data with better phase coverage and quality. The detailed photometric results, analysis, and comparisons to other asteroids and comets will be presented.

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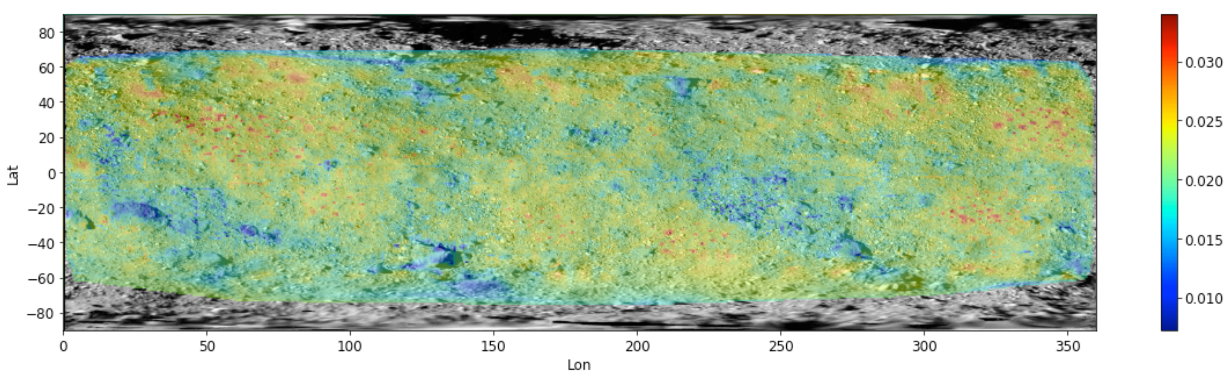

Figure 3 Bolometric Bond albedo.