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Surface composition of (4) Vesta by modelling light scattering

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Abstract

We have obtained the particle size distribution of Vesta's surface regolith by modelling its absolute reflectance spectrum and photometric and polarimetric phase functions using a simulation framework that is based on the first principles in light scattering. Our model successfully explains the observed opposition effect and negative linear polarization, and produces a good match between the observed and modelled absolute reflectance spectra.

1. Introduction

Understanding light scattering on planetary surfaces is an open problem. Spectroscopic, photometric, and polarimetric features depend strongly on a number of surface properties that can also be affected by space weathering. The surface composition of asteroids has been studied in numerous laboratory experiments and by using empirical models, such as the Hapke model [1], but never before using numerical simulations based on first-principles in light scattering.

We have recently developed a new simulation framework to model the spectroscopy, photometry, and polarimetry of planetary surfaces. This approach is used to study the asteroid (4) Vesta. We combine approximate multiple scattering codes SIRIS[2,3,4,5] and radiative transfer with coherent backscattering (RT-CB)[6], and an exact multiple scattering code that utilizes the electric current volume integral equation method (JVIE) [7] to account for both the wavelength-scale particles and particles that are larger than the wavelength.

2. Measurements and observations

We utilized the University of Helsinki UV-vis-NIR integrating-sphere spectrometer [8] to measure the reflectance spectrum of howardite powder using a wavelength range of 0.25 to 3.2 μm with 5-nm resolution. The particle sizes of the howardite powder ranged from 50 to 100 μm.

The polarimetric data was obtained from [9] and the photometric data from [10]. We used the reflectance spectra of Vesta observed by Reddy 2011 [11]. The data set contains Vesta's normalized reflectance spectra observed at a 17.4-degree phase angle during different rotational phases. We selected 12 of the normalized (see Fig. 1) spectra that were not affected by Vesta's albedo spot.

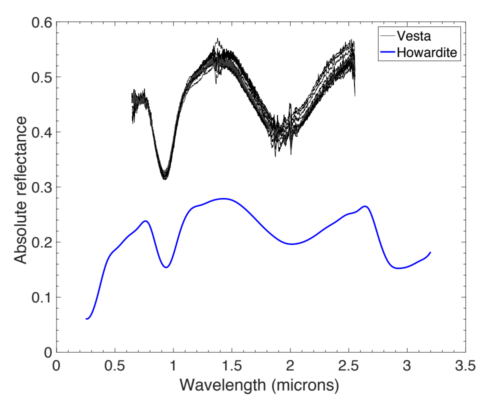

Figure 1: The observed reflectance spectra of Vesta and the measured howardite spectrum.

3. Modelling

First, the complex refractive indices of howardite powder were derived by using SIRIS at the wavelength range of 0.4 to 2.5 μm. The derived values were then further utilized in SIRIS to compute scattering properties for Gaussian-random-sphere particles with sizes ranging from 10 to 200 μm and averaged over a power-law distribution.

Second, we used JVIE to compute the scattering properties of volume-elements containing Voronoi-shaped particles to account for the particles that are smaller than the wavelength.

Finally, we utilized the computed large-particle and small-particle populatios in RT-CB to obtain the photometric and polarimetric (see Fig. 2) phase functions and the absolute reflectance spectrum of Vesta.

4. Summary

By accounting for both the wavelength-scale particles and particles that are larger than the wavelength, we have modelled the spectroscopy, photometry, and polarimetry of asteroid (4) Vesta and obtained the particle size distribution of its surface regolith. Our approach can be further used to model other planetary surfaces.

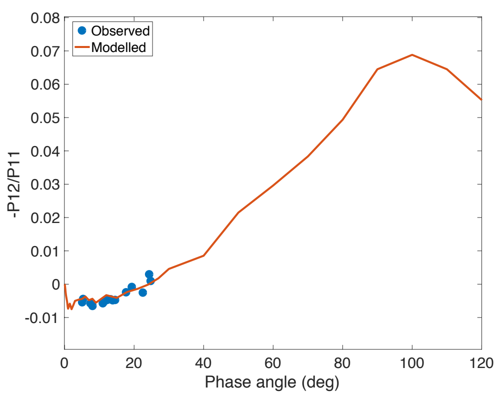

Figure 2: The degree of linear polarization for Vesta at 0.45 μm.

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