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Phase correction on Vesta: theoretical and empirical approach

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Abstract

We studied the effect of illumination conditions on the spectral properties of Vesta as observed by the VIR instrument onboard the Dawn spacecraft. In particular, we focused on the 1.9-µm pyroxene absorption band, which is affected by the phase angle (θ_p) especially when θ_p <30°. Typically photometric correction is applied in order to remove this dependence on incidence, emission and phase angles. Here we test two approaches; one theoretical, i.e. based on the Hapke model, and the other empirical, based on statistics on observed data.

1. Introduction

Since July 2011 Dawn's Visible and Infrared spectrometer (VIR) [1] has been acquiring hyperspectral images (0.25-5 µm) of Vesta. Prominent pyroxene absorption bands centered at 0.9 and 1.9µm dominate Vesta's spectrum, while thermal emission dominates beyond 3.5 µm [2]. Spectral band parameters of the two pyroxene absorptions, e.g. band depth, band center, band slope, band asymmetry, band minimum, derived from the VIR data [3] can be used to constrain surface properties such as mineral abundance, mineral chemistry and grain size. Due to multiple scattering, spectra are affected by illumination conditions [4,5,6] and hence an accurate photometric correction would be needed.
To accomplish this task we have developed an empirical algorithm as well as applied a Hapke model [6]. This offers two advantages: i) the variability of spectral parameters at different illumination conditions can be inferred; ii) an empirical procedure based only on statistical analysis of observed data may be extended to other planetary bodies (e.g. [7]).

2. VIR data

We used VIR observations during the Approach, Survey, High Altitude Mapping and Low Altitude Mapping (LAMO) orbits. The pixel resolution ranges from 1.3 km (Approach) to 0.07 km (LAMO).
We focused on the variability of spectral band parameters (especially Band II Depth) with phase angle on Vesta regions of limited extension, in order to avoid variations due to topography. Furthermore, the Vesta surface has been divided in 5°x5° areas, 60% of which have been observed by VIR two times at least, i.e. at two different illumination conditions. In particular, the equatorial regions have been observed at three to six different phase angles.

3. Behavior of spectral parameters

Band centers and band minima do not show dependence on illumination conditions [4]. However, spectral slopes became redder at increasing phase angle [5,8,9]. Band depths are also affected by phase angle, with an increase at increasing θ_p. The rate of change in band depth suggests a steeper increase for θ_p <30°, and a weaker trend above these value (Fig. 1a) [4].

4. Phase correction

For most of the 5°x5° regions considered, the observed Band II depth (BD_{obs}) behaves as shown in Fig. 1a. We are still developing a photometric correction based on the Hapke model [10] and are going to verify if it is sufficient to remove this behavior.

In addition, a clear correlation of BD_{obs} with emission angle θ_e has been observed (not shown here). For every area, the parameters of the relation:

$$BD_{obs} = BD_{ec} (\alpha_1 + \beta_1 \cos\theta_e) \quad (1)$$

have been calculated by means of a least squares technique and the value corrected for the emission angle (BD_{ec}) has been inferred.

After this correction, a dependence of BD_{ec} on the incidence angle θ_i (Fig. 1b) arose and has been corrected computing the parameters of the relation

$$BD_{ec} = BD_{iec} (\alpha_2 + \beta_2 \cos\theta_i), \quad (2)$$

where BD_{iec} is the band depth value corrected for both incidence and emission angle.

In more than 90% of cases, BD_{iec} is independent of the phase angle (Fig. 1c).

The obtained average values of the parameters of the Eqs. (1) and (2) are: α_1=0.98±0.01; β_1=0.02±0.01; α_2=0.97±0.01; β_2=0.03±0.01

5. Preliminary conclusions

The empirical analysis on the VIR spectra reveals that the dependence of the Band II depth on the phase angle can be corrected by working singularly on incidence and emission angles. The dependence on θ_i and θ_e is minimal (as inferred by the low β_1 and β_2 retrieved values) but can be responsible for the observed behaviour with θ_p. Comparison with photometric models can confirm this result.

We plan to apply both theoretical and empirical approaches for correcting other spectral band parameters.

Acknowledgements

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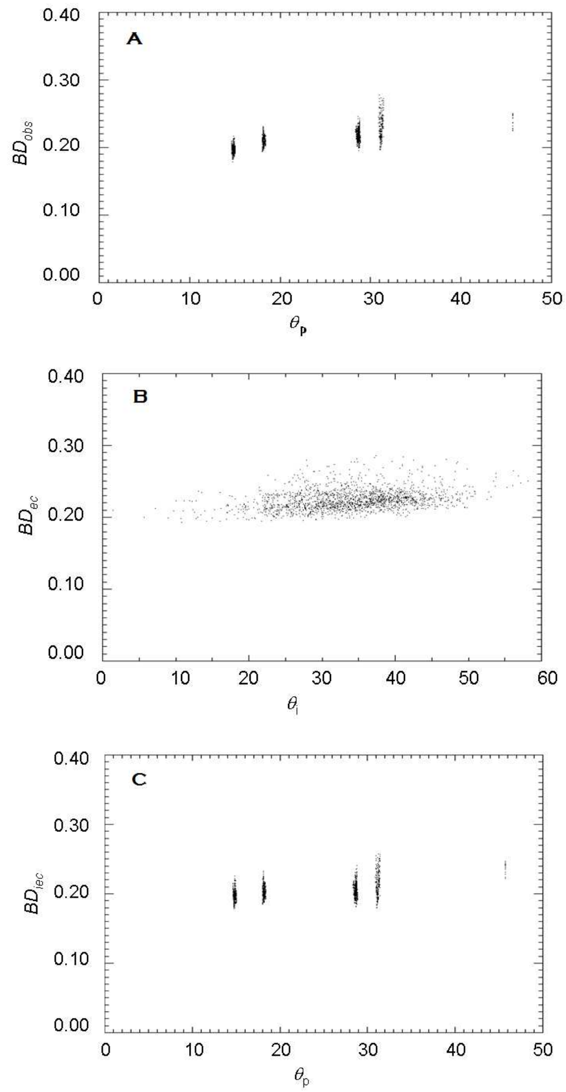

Figure 1. Band Depth II (relative to the region centered at latitude 2.5°S and longitude 292°E) as function of phase angle before (Fig. 1a) and after (Fig. 1c) the emission-incidence correction. In Fig. 1b the behavior of the emission-corrected band depth as function of the incidence angle is shown.

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