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Photometric behaviour of Vesta spectral parameters

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Abstract

In this work, spectral parameters describing the composition and the physical properties of the Vesta's surface have been photometrically corrected by combining theoretical and empirical approaches. The obtained results evidence the different role of multiple scattering in Vesta dark and bright regions.

1. Introduction

The Vesta surface has been observed for one year by the NASA's Dawn spacecraft, which took color and hyperspectral images by means of the Framing Camera (FC) [1] and the Visual and InfraRed spectrometer (VIR) [2].
The surface reflectance recorded in images and spectra show a dependence on incidence i, emission e and phase φ. The understanding and the correction of this dependence is essential in interpretation of data, since: 1) it can provide information on the physical properties of the surface (such as reflectance, regolith grain size, composition, roughness); 2) the quantitative comparison between different images/spectra is meaningless if observations are not converted to the same illumination conditions.
The application of a suitable photometric model is the most used approach to correct the data. At present, Hapke, Minnaert and Akimov models have been successfully applied to the FC data (i.e. [3,4]).
Another approach based on statistics on observed data has proved to be very useful to understand the photometric behaviour of the parameters that describe the absorption bands [5] such as *band depth*, *band center* and *Band Area Ratio (BAR)* [6].
The absorption bands that dominate the Vesta spectra are the pyroxene Band I (centred at 0.9 μm) and Band II (centred at 1.9 μm). Their detailed analysis provides information on mineral abundance, topography and grain size.
This work is focused on the application of a photometric correction on VIR data, by combining reflectance correction as well as empirical correction of spectral parameters. We took into account the reflectance at two wavelengths, in the visible (0.75 μm) and infrared (1.2 μm) VIR domains respectively, and the spectral parameters Band I and Band II depth, Band I and Band II center, and BAR.

2. Reflectance at 0.75 and 1.2 μm

Reflectance is given by the product of two terms: the disk function $D(i,e,\varphi)$ and the phase function $F(\varphi)$, predicting the variation with local topography and with observation geometry, respectively.
[3-4] demonstrated that the Akimov disk function [7] best reproduces the FC data. Hence we used the parameter-less version of this function, depending only on the geometry. Any dependence on the wavelength is neglected and discussed a posteriori.
The Akimov-corrected reflectances do not depend on i and e, as expected. To derive the phase function we have performed a statistical analysis on the whole VIR dataset (containing 13 million spectra); we have further divided the data set into ten reflectance families, and applied a 3rd degree polynomial, whose coefficients depend on the reflectance (Fig. 1). Reflectance decreases with increasing phase angle, with this decrease being more steepened for dark regions than for bright ones. This occurs because multiple scattering is more efficient in brighter regions, and its effect is to scatter the radiation at all the phase angles, resulting in a relatively shallower phase slope. A mosaic of VIR photometrically corrected images is shown in Fig. 2.

3. Band depths

According to our assumption of a disk function depending only on the geometrical parameters, band depths should be independent of i and e. Otherwise, a residual effect of i on bright regions band depths and of e on dark regions band depths arises (see also [5]-

[8]). This again reflects the relative contribution of multiple and single scattering in bright and dark regions respectively [8]. However, the obtained phase function for band depths are able to remove any residual dependence on *i* and *e*.

Band depths linearly increase on phase up to $\varphi = 60°$, then remain constant. Also in this case the multiple scattering introduces a flattening of the phase curves relative to brighter regions.

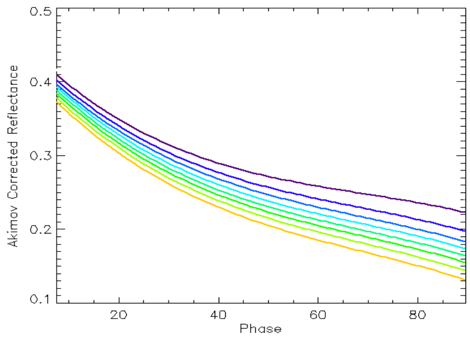

Figure 1. Phase functions of different reflectance families (reflectance increases from yellow to purple).

4. Band centers

The band center is defined as the band minimum location after continuum removal. Its exact location strongly depend on the mineralogical composition hence should not be affected by illumination conditions (e.g. [9,10]). On the other hand, the statistical analysis of VIR data shows a decrease in band center at increasing incidence angle.

We have to say that this decrease is very slight (less than the VIR IR spectral sampling for Δi=70°), and results presented so far are not affected by this small change, since they avoid to use extreme illumination conditions.

A possible explanation is that higher incidence angles generally correspond to cooler regions. Laboratory measurements on HED, i.e. Vesta analogues, reveal a band center displacement at decreasing temperature [9], similar to that observed in our data.

A more detailed investigation of this behavior is still ongoing.

5. Band Area Ratio

No dependence of BAR on illumination arises from the analysis of VIR data. This agrees with laboratory measurements on HED [10] and reflects the similar phase function found for Band I and Band II depth.

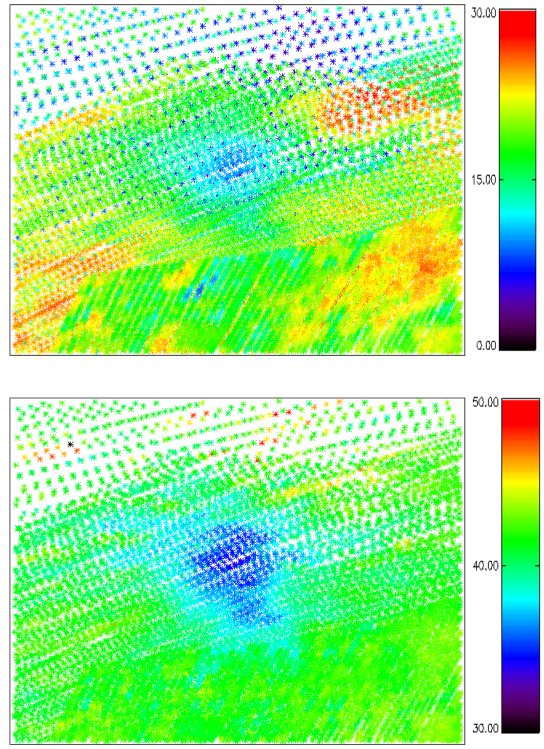

Figure 2. Mosaic of VIR IR images of the Aricia region (lat. 6°-16° and long. 156°-166°) before (above) and after (below) the photometric correction. The latter agrees with FC corrected map of Aricia [3].

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