RETRIEVAL OF DISK-RESOLVED PHASE FUNCTIONS OF VESTA AND COMPARISON WITH OTHER ASTEROIDS. A. Longobardo[1], F. Capaccioni[1], E. Palomba[1], M.C. De Sanctis[1], F.Tosi [1], S.E. Schroeder[2], J.-Y. Li[3], M.T. Capria[1], E. Ammannito[1], C.A. Raymond[4] and C.T. Russell[5]. [1]INAF-IAPS, via Fosso del Cavaliere 100, Rome, Italy (andrea.longobardo@iaps.inaf.it), [2]Deutsches Zentrum für Luft und Raumfahrt (DLR), Berlin, Germany, [3]Planetary Science Institute, Tucson, AZ, USA [4]California Institute Technology JPL, Pasadena, CA, USA, [5]UCLA, Los Angeles, CA, USA.

Introduction: The NASA-Dawn mission has observed for one year the Vesta surface, taking hyper-spectral data by means of the Visible and InfraRed (VIR) spectrometer [1].

The calibration of VIR data [2] allowed us to record the surface reflectance in both visible and infrared domains of the VIR instrument. The analysis revealed that Vesta has a large visual albedo (0.38 on average [3]) and shows the largest reflectance variations on its surface, with presence of high-albedo (bright) [4] and low-albedo (dark) units [5], which have been associated to uncontaminated HED (whose Vesta is believed to be the parent body) and presence of carbonaceous chondrites, respectively.

The measured reflectance strongly depends on the observation geometry, i.e. the solar incidence angle i, the emission angle e and the solar phase φ. The understanding of these behaviors is essential in the interpretation of data, because it allows: a) to apply a photometric correction to images/spectra, in order to rely on their comparison (meaningless in absence of this correction); b) to provide information on the physical and optical properties of the surface regolith, such as grain size, roughness, role of single and multiple scattering, and composition.

In this work we focus on the behavior of reflectance measured at two wavelengths (0.75 μm and 1.2 μm) as a function of phase angle. We studied the 20°-60° phase slope variations across the Vesta surface and compared the inferred values with those found in other asteroids of different spectral types (C, S, E), in order to find a "photometric equivalent" for the dark and bright endmembers. In this study, we considered the Lutetia asteroid, too, by analyzing the data provided by the VIRTIS (Visible InfraRed Thermal Imaging Spectrometer) instrument [6] onboard the Rosetta mission. This is an interesting case since the Lutetia spectral class is still debated (C, D, E or a combination of them [7]).

Vesta phase functions: [8] performed a photometric correction of VIR reflectance at 0.75 μm and 1.20 μm, by combining a disk function and phase function. The former removes the topography effects on the measured reflectance (primarily due to i and e variations), whereas the latter reproduces the brightness variations with phase.

The considered disk function is the parameter-less Akimov function [9], which is wavelength independent, while it depends only on the illumination and observation angles (i, e, φ). The calibrated radiance factor I/F has been then divided for the disk function in order to obtain the equigonal albedos at the considered wavelength.

The phase functions have been calculated over ten families of equigonal albedos. These have been empirically defined, by means of a statistical analysis on the whole VIR dataset (containing 20 million spectra) [8]. This analysis allowed to study the phase function variation across Vesta.

The reflectance decrease with phase has been found to be steeper in low-albedo regions and more moderate as reflectance increases (Figure 1). This has been ascribed primarily at the more important role in bright units of multiple scattering, which redistributes the incident radiation, causing a flattening of the phase curve.

To allow a comparison between phase functions of Vesta and other asteroids, these have been recalculated, considering the radiance factor instead of the equigonal albedo (Figure 1). These new phase functions are steeper than the previous ones, since the application of the disk function reduces the reflectance changes with phase.

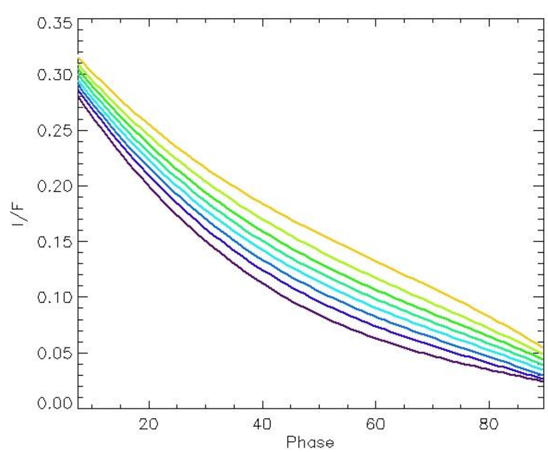

Figure 1: Radiance factor as function of phase angle for different Vesta reflectance families (reflectance increases from purple to yellow).

Lutetia phase function: The radiance factor behaviour with phase has been similarly studied on the dataset of VIRTIS observations of Lutetia, including about eighteen thousand spectra. The analysis has been performed at different infrared wavelengths, i.e. 1.00 μm, 1.28 μm, 1.56 μm, 1.85 μm and 2.13 μm [10].

The phase function has been found to be independent of wavelength (at least for $\varphi > 20°$). Since the reflectance variations across Lutetia are much lower than those observed on Vesta, we did not consider reflectance families, but the mean phase curve for each wavelength (producing specific disk-integrated phase functions).

Comparison with other asteroids: preliminary results. We define the phase slope as the reflectance decrease from 20° to 60°, relative to the reflectance at 20°. We calculated it on the phase functions averaged on Vesta bright regions, Vesta dark regions and the whole Vesta surface, as well as on the disk-integrated phase function of Lutetia. Finally, we considered phase slopes from phase functions obtained in literature of asteroids visited by spacecrafts, e.g. the S-type Gaspra, Ida, Eros and Annefrank, the C-type Mathilde and the E-type Steins.

These phase functions were obtained at different wavelengths of the visible and/or infrared domain. However, we can consider in a first approximation that phase functions do not present large spectral variations as long as they are calculated at wavelengths far from absorption bands. This assumption is justified by different photometry studies performed on Vesta (e.g. [8], [3]) and other asteroids (e.g. [10], [11]).

The phase slope comparison is shown in Table 1.

A preliminary analysis evidences that the Vesta average photometric properties are comparable with S-type asteroids, in agreement with [3].

The phase slope of the Vesta darker regions tends to values typical of the C-type asteroid Mathilde. This would be explained by the presence of charbonaceous chondrites in the Vesta dark units.

No equivalent asteroid spectral types are instead found for the Vesta bright regions, characterized by a lower phase slope. This may indicate that the multiple scattering has a more important role in the uncontaminated HED than in the chondrites, due to their larger albedo. However, it should be noted that Steins has a mean visible albedo similar to Vesta bright units [12], but a disk-integrated phase slope more similar to the Vesta average.

Finally, Lutetia shows a phase slope intermediate between the Vesta average and bright units, making it quite similar to the E-type Steins and much different from the C-type Mathilde. This would evidence that Lutetia could not be a C-type asteroid, as asserted by [16].

Asteroid	Type	λ(μm)	Phase slope	Ref
Mathilde	C	0.70	69%	[13]
Vesta dark units	V	0.75	68%	[8]
		1.20	67%	[8]
Eros	S	0.56	66%	[13]
		1.49	62%	[11]
Ida	S	0.56	62%	[11]
Annefrank	S	0.63	62%	[15]
Vesta average	V	0.75	56-60%	[8], [3]
		1.20	56%	[8]
Steins	E	0.63	57%	[12]
Lutetia	C, D or E	IR	50%	[10]
Vesta bright units	V	1.20	45%	[8]
		0.75	41%	[8]

Table 1: Phase slope of different asteroids (in decreasing phase slope order). The Lutetia phase slope is the same at all the five infrared wavelengths considered.

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