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# Spectrometric characteristics of the surface of Phobos from data obtained by HRSC on Mars Express

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## Abstract

We investigate the spectral reflectance of the surface of Phobos using remote sensing data obtained by the HRSC on the European Mars Express mission. Color ratios reveal that the Phobos surface is heterogeneous, in agreement with previous studies based on Phobos-2 and Mars Reconnaissance Orbiter data.

## 1. The object of study

Phobos, a small satellite of Mars, has an irregular shape, represented by an ellipsoid whose dimensions are 13.3 x 11.1 x 9.3 km [1]. The satellite is locked in its orbit, with its major axis directed to Mars. Phobos has an almost circular orbit close to the equatorial plane of Mars with a radius of 9515 km [2]. The analysis of Phobos' surface material can provide information about the early formation of the Martian satellites and the Solar system.

## 2. Available data and survey geometry

To study the spectral characteristics of Phobos' surface we used 4 spectral bands (IR, Red, Green and Blue) from image data obtained by the HRSC (High Resolution Stereo Camera) on Mars Express [3]. The HRSC data has more spectral bands than previous color imagers and images have wider coverage (including parts of the Phobos far side) than previous data sets.

Table 1: Characteristics of spectral channels

| Channel | The angle of deviation,° | Spectral range, nm |
|---|---|---|
| IR | +15.9 | 970±45 |
| GREEN | +3.3 | 530±45 |
| ND | 0 | 675±90 |
| BLUE | -3.3 | 440±45 |
| RED | -15.9 | 750±20 |

## 3. Geometric transformation

The software ISIS (Integrated Software for Imagers and Spectrometers) was used for the geometric projection of images of Phobos in the object-fixed cartographic coordinate system [4], taking into account orbit and attitude of the spacecraft, the Phobos shape and its orientation. For accurate co-registration of projected images "pixel by pixel" a method, implemented in the Scanex Image Processor software was applied [5]

## 4. Photometric corrections HRSC data

Photometric processing was carried out according to Hapke formula:

$$\frac{I}{F} = \frac{\omega}{4} \times \frac{\mu 0}{\mu 0 + \mu} \times \{[1 + B(\propto, h, B0)] \times P(\propto) + [H(\mu 0) \times H(\mu) - 1]\} \times S(\propto, \theta) \quad (1)$$

where I is the scattered radiance in a given direction; F is the solar irradiance; μo, μ are the cosines of incidence (μo) and emission (μ) angles; α is the phase angle; ω is the single scattering albedo, B(α, h, B0) is the opposition effect function; B0, h are Hapke opposition surge components; P(α) is the phase function; H(μ) is the multiple scattering function, S(α, θ) is the function for macroscopic roughness; θ is the Hapke macroscopic roughness component. Hapke parameter values were adopted from [6].

## 5. Spectral processing HRSC data

On the basis of accurate co-registered images, spectral indices - color ratio were calculated; in particular, the *"Index"* value was computed*:*

$$Index = \frac{V}{NIR} \quad (2)$$

Where $V = \frac{G+B}{2}$ is the spectral brightness in the visible range (obtained by adding green and blue channels, divided by 2), and NIR is the spectral brightness in the near-infrared channel.

This formula allowed us to compare the results of the Mars Express spacecraft survey with those obtained in the Phobos-2 Soviet mission [7].

## 6. Summary and Conclusions

Data analysis reveals anomalous values of the color ratio near the terminator, as well as in the areas of inaccurate matching of the spectral channel images. These anomalies are easily identified on the images, and excluded from the analysis.

Repeatability of spectral indices were estimated from comparing areas in different images, obtained in different resolutions and under different imaging geometries. Reproduction was found to be excellent on almost all index images.

Index images confirm that the Phobos regolith is spectrally heterogeneous. The color ratio of V/NIR ranges from 0.70 to 1.60.

The spectral heterogeneity of Phobos' surface is probably the result of space weathering processes that affect the material composition of the regolith.

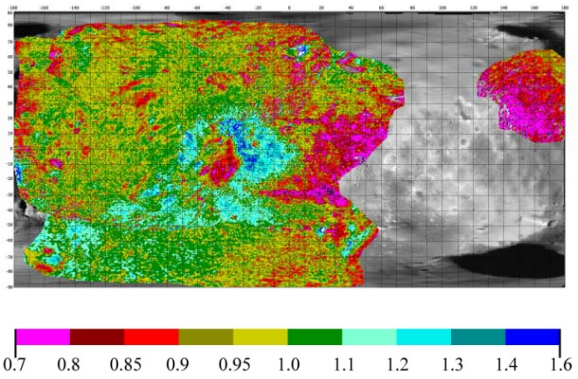


Figure 1: Mosaic images of the index V/NIR, combined with the map of Phobos


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