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Photogrammetric co-registration and photometric analysis of HRSC Phobos images

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Abstract

HRSC images from Mars Express Phobos flybys are used to study the photometric character of the surface of the Martian satellite. This investigation involves measuring of surface reflectance and illumination angles for estimates of a phase curve, and fitting of theoretic photometric functions. As results we obtain information on multispectral and physical properties of the Phobos surface as well as photometrically corrected geomorphological and albedo maps [4].

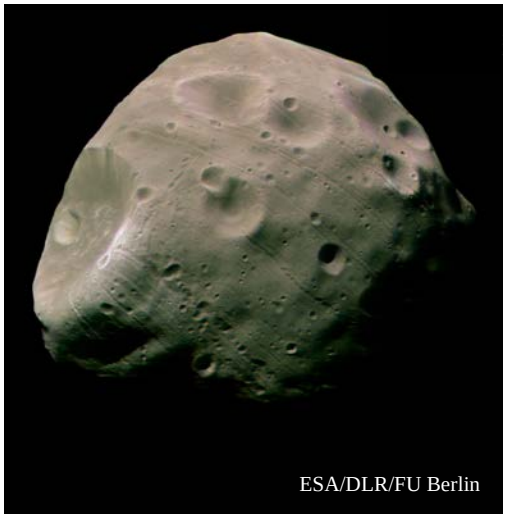

Figure 1: HRSC image of Phobos (Orbit 765)

1. Introduction

Phobos the larger among the two Martian satellites is revolving about the planet in a near-equatorial, near-circular (mean radius: 9,376 km) orbit. Phobos is tidally locked [6]. Its surface is characterized by a large number of impact craters in addition to several sets of parallel grooves. More recent works on the surface composition of Phobos distinguish a blue (leading side) and a red (trailing side) unit, the spectra of which are similar to those of low-albedo carbonaceous T-type and D-type asteroids, respectively. These findings are often related to theories about the origin and evolution of the Martian satellites: Are they captured asteroids or did they form in situ from a circum-Mars debris disk [3]?

The aim of this investigation is to put further constraints on the multispectral and physical properties of the surface of Phobos. From 2004 to 2011 the Mars Express spacecraft carried out over 175 Phobos flybys, during which a large number of HRSC images were acquired, relevant to this task. The HRSC images are unique as they cover several spectral bands at comparably high resolution. The HRSC images also cover parts of the Phobos far side, which has been difficult to access in previous spacecraft missions.

2. Methods

The HRSC camera is a pushbroom line scanner with five panchromatic and four color channels, each with different viewing geometry (Table 1).

Table 1: HRSC channels [2]

Channel	Bandcenter/-width	Viewing angle
S2	675 ± 90	+18.9°
NIR	970 ± 45	+15.9°
P2	675 ± 90	+12.9°
GREEN	530 ± 45	+3.3°
NADIR	675 ± 90	0°
BLUE	440 ± 45	-3.3°
P1	675 ± 90	-12.9°
RED	750 ± 20	-15.9°
S1	675 ± 90	-18.9°

2.1 Bundle block adjustment

For our photometric analysis, we aim at using a subset of images that cover a large part of Phobos' surface at high resolution and various phase angles. Therefore, images from different channels and orbits must be tied to a common reference frame. This is done by a photogrammetric bundle block adjustment that co-registers the images to the Phobos control network and the Phobos-fixed coordinate system [5].

2.2 Image pre-processing

Pixel values of blemish pixels were interpolated. Selected Level 2 red and infrared images that were found to suffer from noise were filtered with a Median filter. Further on, DN values were converted to surface reflectance by applying the reflectance scaling factor. Finally, images were rectified to the Phobos' latitude/longitude grid to warrant co-registered image pixels.

2.3 Measurement of illumination angles

The illumination angles are the incidence (angle between incident ray and surface normal), emittance (angle between emitted ray and surface normal) and phase angle (angle between incident and emitted ray). To determine those angles it is necessary to compute the surface normal based on a chosen reference body. Fortunately, for Phobos, an excellent shape model is available [6] which is being used in this study.

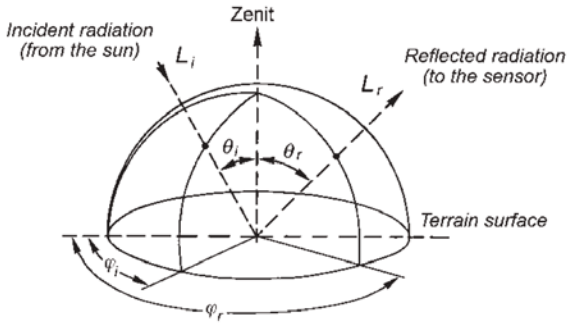

Figure 2: Illumination angles [1]

3. Results

We have carried out bundle block adjustments for 100 images obtained in 20 orbits. Co-registrations are available for large areas that cover approximately 60 % of Phobos' surface, including the Phobos far-side. Measurement and analysis results will be reported at the meeting.

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