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Search for anomalies of surface roughness on Ceres using phase-ratio method

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Abstract

We investigate capabilities of the phase-ratio method and color-ratio imagery to distinguish between regolith microstructures and chemical composition of the Ceres surface. We have selected several regions of special interest (Ahuna Mons and craters Occator, Haulani and Datan) and built maps of phase- and color-ratios for these regions. We found the bright spots in Occator and Ahuna flanks differ in the phase function from their surroundings.

1. Introduction

Since 2015 the NASA Dawn spacecraft has been exploring geology of Ceres, the largest body in the Main asteroid belt [1]. The onboard Framing Camera was equipped with a clear filter and seven color filters in the wavelength range from 0.4 to 1.0 μm [2]. During the mission to Ceres a large volume of data at different illumination/observation geometries have been obtained with high spatial resolution. In total more than 100 000 images were obtained and about 50% of them were acquired on the High-Altitude Mapping Orbit (HAMO) and Low-Altitude Mapping Orbit (LAMO). The amount of obtained space data allows us to start a detailed investigation of the Ceres' regolith properties and to use methods that were successfully applied for the lunar surface.

2. Method

The slope of the phase function $f(\alpha)$ of a regolith-like surface strongly depends on its albedo and texture. The contribution of albedo variations over the surface can be significantly suppressed when the phase ratio $f(\alpha 1)/f(\alpha 2)$,i.e. the ratio of two images of the same region acquired at different phase angles is considered. The resulting phase-ratio image contains information mainly on the structural properties of the regolith. Reliability of this method has been proved by the detections of photometric anomalies related to changes in structure of lunar surface layer in the spacecraft landing sites [5].
Realization of the phase-ratio method requires exact knowledge of the illumination/observation conditions for each surface element. It means that the information about the surface topography should have the spatial resolution that is nearly the same as that of the images. Images of the same surface at two different phase angles should be geometrically aligned before the calculation of their ratio. It means that the pixels representing the same details on both images must overlap each other. The geometric sense of the alignment consists of selection of the reference points and further binding of the other points to them. For image corrections we used the global Ceres topographic model (DTM) which was constructed by a stereophotogrammetric method based on the global survey in HAMO orbit [3], therefore resolutions of the DTM and HAMO are the same and equal to 136.7 m per pixel, while the average error in the vertical direction reaches 10 m. In the case of LAMO, the influence of local slopes cannot be considered, because of the absence of the DTM for resolution same with LAMO.

3. Data selection and results

In order to obtain the distribution of the color- and phase-ratio images we used already calibrated, spatially combined, absolutized, photometrically normalized albedo images. Only after all this conversions it is possible to consider that the received images of color-ratio and steepness of the phase function distribution reflect real characteristics of the surface. For our purposes we used a set of calibrated Dawn FC2 images acquired during the HAMO and LAMO phases of the mission from the Planetary Data System (PDS) archive [3]. The main selection criteria of image pairs were the following: (1) difference between the phase angles should be more than 20 deg; (2) close values of the solar azimuth; (3) the same spatial resolution of the images.

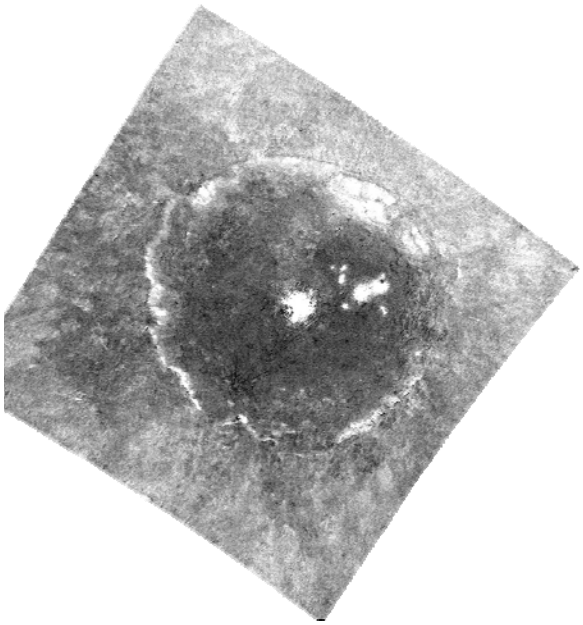

Figure 1: Color-ratio C(749/438 nm) distribution in region of the Occator crater.

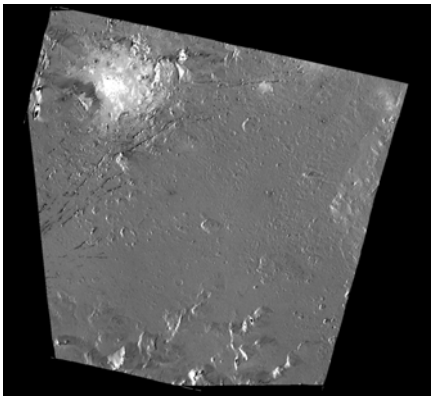

Figure 2: Map of the phase ratio f(50°)/(36°) in the central part of the Occator crater.

As an example, the first results for the Occator crater region are presented in Fig. 1 and 2. They revealed particular surface properties in the vicinity of the crater seen both in the color-ratio C(749/438 nm) distribution (Fig. 1) and in the phase-ratio f(50°)/f(36°) (Fig. 2). Analysis of phase-ratio distribution reveal lower values (i.e. steeper phase curve) for several small craters in the floor of Occator but higher values (more flat phase curve) for the Cerealia Facula in the center of Occator (Fig.2, Upper left). Following to studies of lunar regolith [4,5] we interpret features with steep phase curves as produced by material with microstructure of higher optical roughness. Vice versa flat phase curve correspond to smooth microstructure of upper regolith layer. We note bluish color (lower C(749/438 nm) values) for the small craters with steep phase curve and higher red slope for the Cerealia Facula of flat phase curve. We consider the regolith with higher optical roughness in the small crater of bluish color as less mature material which has been not subjected to space weathering.

4. Conclusions

The phase ratio method, which is well-known in studies of the lunar surface has been tested on the Dawn FC images of Ceres. Applying the phase-ratio method for two regions on Ceres (Ahuna Mons and Occator crater) we found out that bright spots in Occator and Ahuna flanks differ from their surroundings not only in spectra, but also in the steepness of the phase function.

References

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