SEARCHING FOR PHOTOMETRIC ANOMALIES OF THE LUNAR SURFACE WITH TELESCOPIC DATA.

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Introduction: We use telescopic images obtained with a 0.5 m aperture telescope equipped with a Canon 350D consumer camera to study photometric properties of the lunar surface. We map several phase ratios to access the steepness of phase function and find local anomalies of this function. These anomalies are discussed in terms of regolith maturity and geology.

Source telescopic data processing: The extensive photopolarimetric survey of the Moon was performed during the 2006 fall with the Kharkov 50-cm telescope at the Maidanak Observatory (Middle Asia) using a 6 Mpix Canon 350D camera [1]. Ability of color-imaging in raw format of the camera allows the observations in three wide spectral bands (λ_{eff}~0.48, 0.52, 0.63 μm). Small atmospheric turbulence at this place gives the angular resolution as low as ~0.7 arc sec. Two-months survey includes image data for a wide range of phase angles which allows a detailed study of lunar photometric function.

We used a phase-ratio method [2,3] for qualitative description of the photometric function. This method is used to study the steepness of phase curve and search for photometric anomalies. We performed several steps to construct phase ratios suitable for our analysis: (1) dark signal normalization using non-exposed part of CMOS matrix for every frame; (2) accounting for flat field with daytime sky observations; (3) calculation of the selenographic and photometric coordinates for each pixel in the frames; (4) transformation of the frames into a common orthographic projection. The atmospheric turbulence largely affects the images resulting in small-scale image distortions. These residual misregistrations were eliminated with a correlation procedure for subpixel transformation of images. The photometric function itself describes the dependence of lunar surface brightness on the photometric coordinates and can be factorized in two components. The first term is the phase function dependent solely on the phase angle α; the second one is the so-called disk function describing the orientation of the scattering surface to the Sun and observer for a given α [4]. We use the disk function proposed by Akimov [5], which was successfully applied to Clementine data [3,4]. After disk function normalization we produced brightness phase ratios $I(\alpha_1)/I(\alpha_2)$.

Mapping the phase ratios: We here present the phase ratio for a fragment of western part of the lunar nearside covering Mare Humorum, Mare Cognitum, and southern Procellarum. Figure 1a shows a brightness image of the area obtained in green filter (λ=0.52 μm) at α = 23°. The brightness ratio (23°/44°) is presented in Fig. 1b. The bright shades here correspond to higher values of the ratio, i.e. steeper phase function. We note that local surface tilts disturb the phase ratio; it looks like illuminated topography in Fig. 1b. Thus true variations of phase function can be detected for flat areas only (maria, crater floors, smooth plains etc).

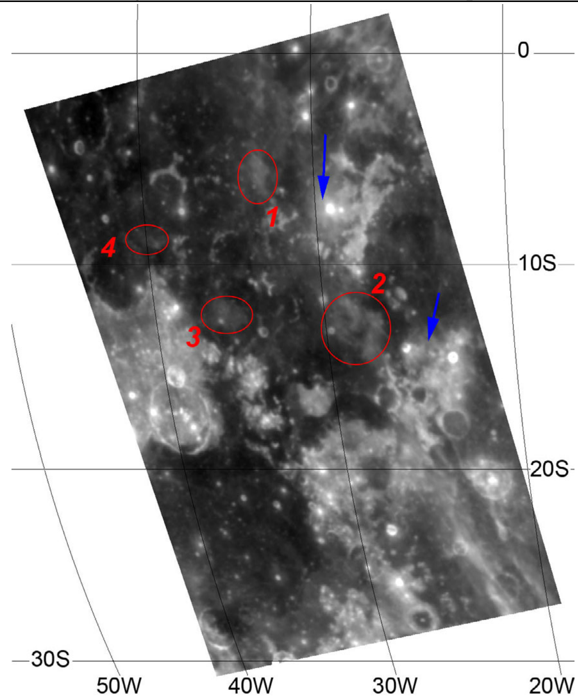

Fig. 1a. Telescopic image of the part of lunar nearside with selenographic reference. Numbered and outlined areas are discussed in text.

Mare / highland border is substantially suppressed in the phase ratio distribution, but the general anticorrelation “the lower the albedo, the steeper the phase function” still can be observed. Bright ejecta halos of mare craters appear as low phase ratio (i.e. less steep phase function) features. Figure 1b also reveals photometric details which do not obey this anticorrelation, we outline them with red ellipses in Fig. 1. These features have the same albedo as neighboring areas, but unusually high steepness of phase function. We refer to these areas as “positive” photometric anomalies. Area *1* in Fig. 1 is of similar albedo as crater Euclides ejecta (shown with upper blue arrow), but has the substantially high steepness. Area *2* is another example of the same albedo as adjacent area (lower blue arrow), but difference in phase ratio. There is no apparent topography associated with areas *1-4*. Area *2* is situated on the distal part of Tycho ejecta. We masked topography features which spoil the phase ratio and produced the correlation diagram "brightness – phase ratio" (drawn in grayscale in Fig. 2) using all the data presented in Fig.1 a,b. The same diagram for positive anomalies only is shown with red dots. A diffused anticorrelation trend is seen on the diagram whereas anomalies are out of the main cloud deviating to high phase ratios at moderate albedo.

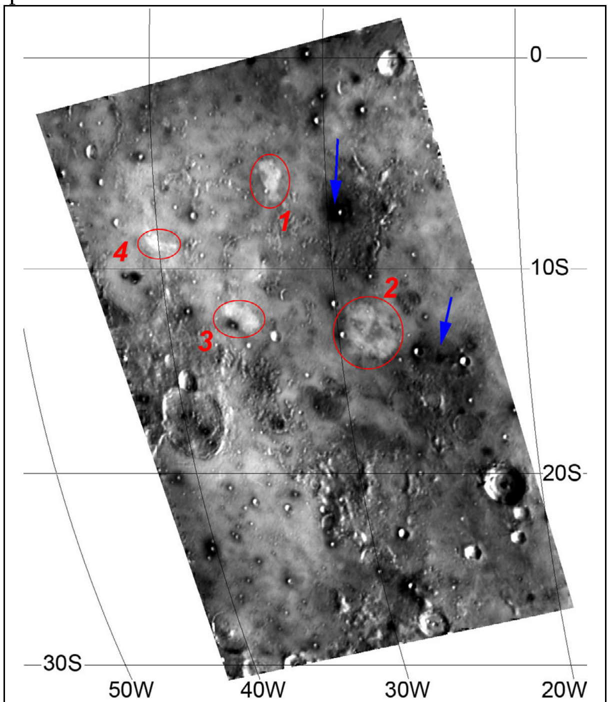

Fig. 1b. Phase ratio image for the area presented in Fig. 1a. Brighter tones correspond to higher phase ratio.

Discussion: The phase function steepness is controlled by the shadow-hiding effect and albedo. For bright surfaces the shadow hiding effect is suppressed due to multiple light scattering on the surface topography. As a result the steepness decreases. Thus one should expect a general anticorrelation of phase function steepness with albedo. The steepness also is sensitive to the surface structure at scales larger than the characteristic light diffusion length (~1 mm for the lunar regolith) [3]. The large scale variations of phase ratios were observed in [2] and thought to be related to variations of composition and age of the regions. Areas *1-3* reveal low values of color-index *C* (950/750 nm) from Clementine data (Fig. 1c). Site *4* does not show prominent color-index variations. The parameter *C* (950/750 nm) as an indicator of the 1 μm pyroxene band depth shows areas of immature regolith as those with low values of the color-index. Positive anomalies for proximal crater ejecta zones were interpreted as an increase of mesoscale roughness in the ejecta, making the phase function steeper [3,6]. This roughness can be due to the presence of an anomalously large number of boulders and blocks. Naturally this fresh topography should be associated with immature regolith as is observed (cf. Figs. 1b and 1c).

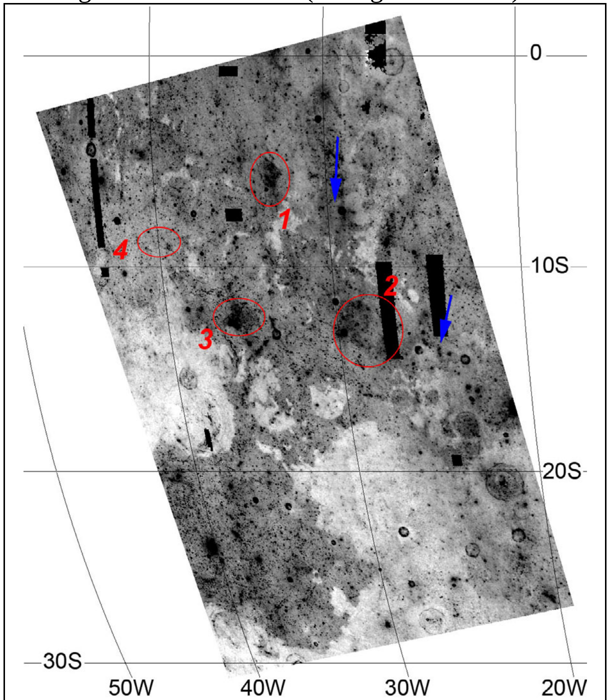

Fig. 1c. Image of color-index *C* (950/750 nm) from Clementine data for the area presented in Fig. 1a,b. Brighter tones correspond to higher values of color-index.

Conclusions: Our telescopic survey allows accessing the photometric properties of the lunar surface. Mapping the phase ratio (23°/44°) for the lunar nearside reveals local anomalies of the phase function. Positive photometric anomalies can be interpreted as increasing the surface roughness in presence of immature regolith affecting the steepness of phase function.

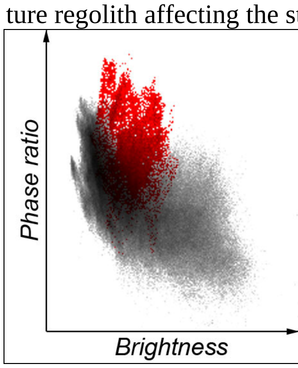

Fig. 2. Correlation diagram "brightness – phase ratio" for the studied region. Gray and red pixels correspond to all data and areas of positive photometric anomalies, respectively.

References: [1] Shkuratov Yu., et al. (2006), *Proc. Of 10th Int. Conf. on Light Scatt. by Non-spherical Particles*, Turkey, p. 205. [2] Shkuratov, Y., et al, (1994) *Icarus*, 109, 168–190. [3] Kreslavsky M.A., Shkuratov Y.G. (2003) *JGR 108*, 5015. [4] Kreslavsky M.A., et al. (2000) *JGR*, 105, 20281. [5] Akimov L.A. (1979) *Sov. Astron.*, 23, 231. [6] Kaydash V., et al. (2007) *LPSC XXXVIII*, Abstr. # 1535.