IMAGING NEGATIVE POLARIZATION PARAMETERS OF THE LUNAR SURFACE. A. Opanasenko, N. Opanasenko, Yu. Shkuratov, V. Kaydash, Yu. Velikodsky, V. Korokhin, Astronomical Institute of Kharkov Karazin National University, 35 Sumskaya Street, Kharkov, 61022 Ukraine opanasenko@astron.kharkov.ua

Introduction: To obtain the negative polarization parameters of the phase polarimetric curve of the lunar surface is important for studying the structure characteristics of the lunar regolith. Imaging negative polarization parameters of the lunar surface is the next step after discrete polarimetric observations of sites in studying of the structural characteristics of the lunar regolith. These parameters give information about the mechanisms of light scattering, the coherent and shadow-hiding effects, which are controlled by the structure of regolith and its particles. It should be noted that imaging of the negative polarization parameters of the lunar surface is a difficult task: one must attain the precision of polarization degree not low than 0.05%.

Images of the lunar nearside obtained by a telescope equipped with Canon-350 camera are used to study photopolarimetric properties of the lunar surface. We used polarimetric measurements at different phase angles for the determination of the following negative polarization parameters: the polarization minimum, $P_{\min}$, the inversion angle, α_{inv}, and the slope of polarimetric phase curve at the inversion angle, h.

Lunar photometric and polarimetric data: Photometric and polarimetric observations of the Moon were carried out from August 27 to October 17, 2006 using the Kharkov 50-cm reflector placed at the Maidanak observatory (Uzbekistan, Middle Asia) [1]. This observatory is characterized with very good astronomical conditions – low atmospheric turbulence and a large number of clear nights. All observations were carried out in 9-m Cassegrain focus. We used a Canon-350D camera with studied flat field, dark current, and non-linearity of the CMOS array photosensor. Three spectral bands were used (λ_{eff} = 0.48, 0.52, and 0.63 μm). The size of the photosensor is 3088 x 2056 pixels. This allows us to use a formal angle resolution of 0.17″ per pixel.

For image processing we used algorithms and codes allowing us to take into account dark current, non-linearity of the photosensor, its flat field, atmosphere distortion. After this reduction we calculated counts that are proportional to lunar brightness [1].

To obtain the albedo of lunar surface it is necessary to normalize the image on the photometrical function. The photometric function descrybes the dependence of lunar surface brightness on the photometric coordinates. We used the analytical expression of photometric function by Akimov [2]. This approximation allows the brightness normalization to the equigonal geometry (Fig. 1).

We use the direct orthographic projection for all photometric and polarimetric maps. For this the Clementine image mosaics are used as a basis.

For polarimetry we used a film polarizer whose rotation is governed with a computer. We used six orientations of the polarizer with step of 30°. The exposition time was of 0.3 – 0.8 s. The intervals between the expositions were of 1.7 – 2.5 s. The polarization degree was calculated by the well-known Fesenkov formula using brightness images obtaining for six orientations of the polarizer.

To calculate the parameters $P_{\min}$, α_{inv}, and h we apply a parabolic approximation of the measured polarimetric phase curves. For this purpose we use data obtained at six phase angles, 11°, 15°, 26°, 36°, and 43°.

The photometric and polarimetric observations in excellent photometric conditions of the Maidanak observatory enable us to carry out lunar observations at atmospheric distortions as low as 0.2″. Relative photometric errors were not more than 0.1-0.2 %. Polarization degree errors were as low as 0.02-0.05 %. The precision of our maps is confirmed by the data of discrete polarimetric and photometric telescopic observations [3,4].

Imaging the albedo and negative polarization parameters: Example of an albedo image is shown in Fig. 1 for an area comprising a southern portion of Procellarum Ocean and an eastern portion of Mare Humorum.

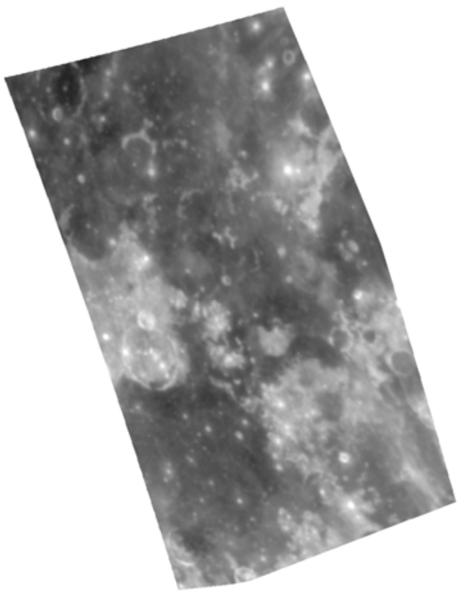

Fig. 1. Albedo image of Procellarum Ocean and Mare Humorum acquired with the Kharkov 50-cm telescope using CMOS array in green light at a phase angle of 11°.

An example of minimum polarization image $P_{\min}$ is shown in Fig. 2 for the same area. As can be seen two low $|P_{\min}|$ mare areas are revealed in the frame, near the upper edge and also a bit to right of and below the center. These areas are not peculiar in albedo. The border between highlands and maria is more or less seen in the $|P_{min}|$ image. Many young craters show up in the $|P_{min}|$ image. Typical values of $|P_{min}|$ are 0.5 – 0.9 %. We note that not all bright craters show up on the maps of P_{min}. A reason could be different amount of dust and coarse grains in deposited material. A high value of $|P_{min}|$ is also characteristic of the region to the left of the crater Euclides.

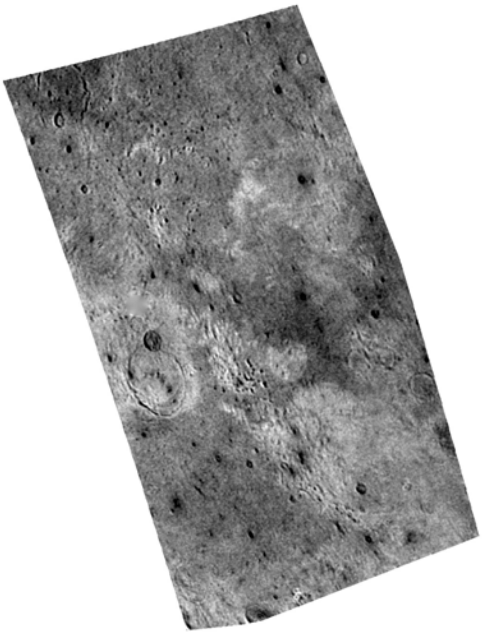

Fig. 2. An image of minimal polarization P_{min} for the region shown in Fig. 1.

Fig. 3. An image of the inversion angle α_{inv} for the region shown in Fig. 1.

An example of inversion angle image is shown in Fig. 3 for the same region. This image demonstrates different inversion angles for highlands and maria, respectively, 25-26° and 20-24°. Some highland and mare craters show 1-2° low α_{inv}, than highlands and mare neighboring regions.

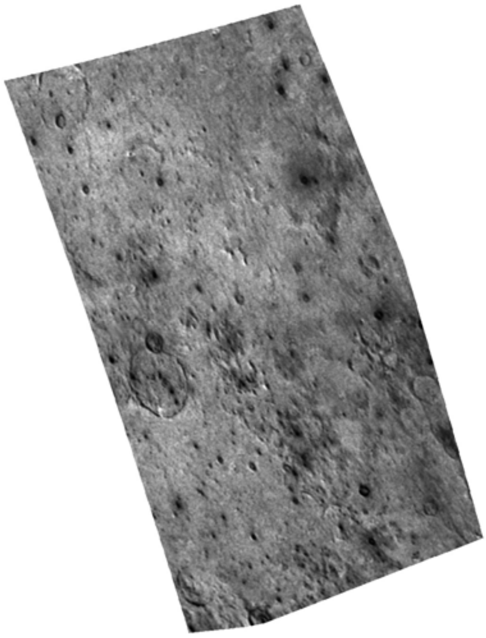

Fig. 4. An image of slope of polarization phase curve at the inversion angle *h* for the region shown in Fig. 1.

Finally, the distribution of polarimetric slope *h* is presented in Fig. 4. Typical values of this parameter are of 0.25-0.35 % per (°). There is no the border between mare and highlands on this image. Low values of *h* are mainly characteristic of halos around young mare craters. Bright highlands craters demonstrate the lowest values of *h*. The correlation between the parameter *h* and albedo is not so high, as can be anticipated.

Conclusions: Thus, we have mapped at first the three negative polarization parameters: P_{min}, α_{inv} and *h* for south-west portion of the lunar disk. All these parameters demonstrate complicated relation with albedo, which show that they potentially can be used for independent analysis of the lunar surface. Another regions of the lunar nearside will be studied soon.

Acknowledgments: This study was supported by CRDF grant UKP2-2897-KK-07.

References: [1] Shkuratov Yu., et al. (2007), *Proc. 10th Int. Conf. on Light Scatt. by Non-spherical Particles*, Bodrum, p. 205. [2] Akimov L. (1979) *Sov. Astron.*, 23, 231. [3] Shkuratov Yu., et al. (1994), Icarus 95, 283-299. [4] Opanasenko N., Shkuratov Yu. (1994), Solar System Res., 28, 233-254.