THE PARAMETERS INVOLVED IN HAPKE'S MODEL FOR ESTIMATION OF THE COMPOSITION OF THE EJECTA LUNAR TERRAINS. S.G. Pugacheva, V.V. Shevchenko. Sternberg State Astronomical Institute, Moscow University, 13 Universitetsky pr., 119992 Moscow, Russia, pugach@sai.msu.ru.

Introduction. In the previous papers we were estimated the surface roughness of the ejecta lunar terrains by means comparison of the local phase function and the average integrated lunar indicatrix. The difference between the modeled and observed phase functions was obtained for surface having various degree of the surface roughness. We were investigated the surface of the lunar landing sites. The great difference between the modeled and observed phase functions demonstrates for phase angle in range about 18^o and corresponds a high degree of the surface roughness [1]. The value of this difference of intensities was used as a photometric parameter of the surface roughness ΔI. In this article we compared the values photometric parameter of the roughness ΔI with the parameters the Hapke's model.

The Hapke's theoretical model of the lunar surface reflection. The Hapke's formula is well known model for the estimation of the surface roughness [4, 5, 6]. The model allows to define of the physical and chemical characteristics of the lunar surface by means phase function. This model is the only existing one, which accurately represents the reflection properties of the Moon. The photometric function by Hapke of the bidirectional reflectance (R) may be written in the general form:

$$R=\{w\mu_o/[4\pi(\mu_o+\mu)]\}\{[1+B(g)]P(g)+$$
$$+H(\mu_o)H(\mu)-1\}S(\theta),$$

where μ_o, μ are cosines of incidence (μ_o) and emergence (μ) angles, g is the phase angle, i, e are angles of incidence and emergence, w is the single scattering albedo, B(g) is the opposition effect function, P(g) is the phase function, $H(\mu)$ is the multiple scattering function, $S(\theta)$ is the function for macroscopic roughness.

The function B(g) describes the brightness of a surface near zero phase angle. The parameters of the function B (g) describe the backscatter due to blocking and shadowing within the soil.

$$B(g) = B_o/[1+(1/h)\tan(g/2)].$$

The parameter h characterizes compaction of the regolith and size of the particle. The parameter B_o defines amplitude of the opposition effect.

The function P(g) includes two parameters b and c, which determines the phase function form and the nature of scattering (c<0.5 corresponds to forward scattering and c>0.5 to backward scattering).

$$P(g)=(1-c)[(1-b^2)/(1+2b\cos(g)+b^2)^{3/2}]+$$
$$+c[(1-b^2)/(1-2b\cos(g)+b^2)^{3/2}],$$

where g is the phase angle, b and c are the parameters with the material properties of the lunar regolith.

The function of the isotropic multiple scattering H(x) includes angles incidence and emergence and the single scattering albedo w.

$$H(x) \cong (1+2x)/[1+2x(1-w)^{1/2}],$$

where x is either μ_o or μ.

The equation $S(\theta)$ allows to calculate the effects of macroscopic roughness on light scattered by a surface having an arbitrary diffuse-reflectance function [3, 6]. The parameter θ is a mean topographic slope angle of the surface. The effects of macroscopic roughness will modify the reflectance. The geometry of the reflectance is shown in figure 1. The signal r(i,e,g) is interpreted as if it came from a smooth, horizontal area, the bidirectional reflectance from sloping area is $r(i_e,e_e,g)$. The expressions for r(i,e,g), $r(i_e,e_e,g)$ and $S(\theta)$ will make the following equation true:

$$R(i,e,g,)=r(i_e,e_e,g)S(\theta).$$

The mean slope angle θ equal $A=1/(\pi\tan^2\theta)$ and $B=1/(\pi\tan^2\theta)$, where A and B are empirical coefficients of the equation described by a Gaussian [6].

The Hapke's theoretical integral phase function involves six parameters: w, B_o, h, θ, and two parameters to describe P(g). For a low-albedo lunar surface parameter Bo = 1. The parameters have been used in a number of analyses to describe the integral scattering properties of lunar objects.

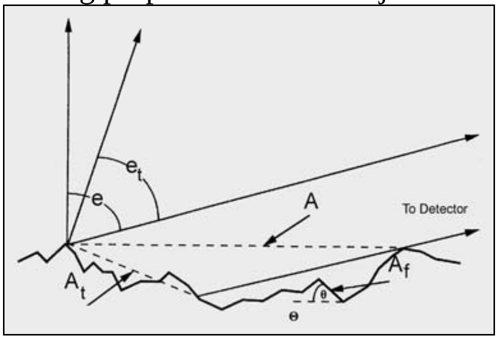

Figure 1. The parameter θ is the mean slope angle, which indicates the rough-surface bidirectional reflectance. (From Hapke, 1993 [6])

The bi-directional reflectance of the lunar scatters of landing sites. We used the Monte Carlo method for calculation of the model parameters of the Hapke's function. The algorithm of the calculation is minimizing the difference between measured and modeled reflectance spectra. The parameter θ was calculation from the empirical expression [6]. The Saari and Shorthill catalogue were used as observed phase functions [2]. The separate points represent of number of landing sites (Surveyor I, III, V, VI, VII, Apollo 11 and 12, Lunokhod 1 and 2). Each group can be corresponded to the ejecta with individual character of the surface distribution of KREEP materials. Figure 2 represents the diagram of relationship between the photometric roughness parameter (ΔI) and parameters of the Hapke (w, h, b, c, θ) in different lunar landing sites. The reflectance of real, high- and low-albedo surfaces contains a similarly shaped crater. The changes of brightness of the surface are altered by increasing values roughness and albedo. The physical albedo and integral phase function of the Moon may be corrected for effects of macroscopic roughness.

Conclusions. The present work allows study optical characteristics of surface and to determinate grain sizes and material composition of the ejecta of the lunar terrains. The texture roughness in the submillimetric and centimetric range is the most representative than a high macroscopic roughness with large slopes at the hundred meter scale. According to these results, there may be a possibility to describe the real case of natural regolithic surface, and to investigate specific anomalous of the local KREEP assimilation.

References. [1] Pugacheva S.G. and Shevchenko V.V., (2003). LPS XXXIV, Abstract # 1112. [2] Shorthill R.W. et al., (1969). Photometric Properties of Selected Lunar Features. NASA CR-1429. [3] Chevrel S.D. et al., (2002). Astronom. Vestnik, 36, No. 6, 495-503. [4] Hapke B., (1981). J. Geophys. Res. 86 (B4), 3039-3054. [5] Hapke B., (1986). Icarus 67, 264-280. [6] Hapke B., (1993). Cambridge Univ. Press, New York.

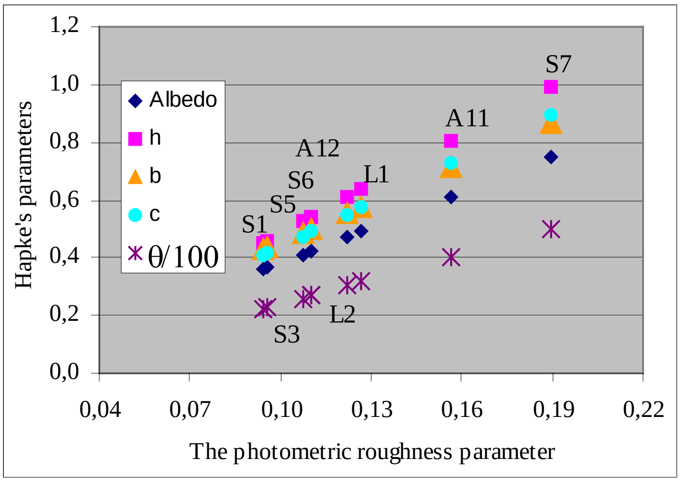

Figure 2. Hapke's parameters plotted against the photometric roughness parameter (ΔI).