STUDYING THE PHASE DEPENDENCE OF LUNAR SURFACE BRIGHTNESS USING DATA OF INTEGRAL OBSERVATIONS. V. V. Korokhin, and Yu. I. Velikodsky. Astronomical Institute of Kharkiv National University. Sumska ul., 35, Kharkiv, 61022, Ukraine. E-mail: dslpp@astron.kharkov.ua.

Introduction: Lane and Irvine carried out the integral photometrical observations of the Moon at Le Houga observatory (South France) in 1964-1965 [1]. These are the most full integral observations of the Moon: the Moon was observed over phase angles $6°\leq\alpha\leq120°$ in nine narrow bands (350-1000 nm) and in *UBV*. But their suitability for studying the phase dependence of brightness of lunar surface decreases through presence of systematical errors caused by influence of libration variations and changing of contribution of mares and highlands in integral brightness with phase changes. Therefore we have tried to correct Lane's and Irvine's data.

Initial data processing: First of all we transformed data from magnitudes to relative intensities. Unfortunately in [1] detailed information about photometrical bands is absent, so it is impossible to calculate spectral albedos of the lunar disk using Lane's and Irvine's data. Then we restored observations conditions for each date: selenographic longitude and latitude of observer (libration) (Obs_Long, Obs_Lat) and selenographic longitude and latitude of the Sun (Sun_Long, Sun_Lat).

Correction on libration variations: Correction coefficient for each Lane's and Irvine's observation was calculated, using a set of our digital maps of equigonal albedo [2, 3], as ratio:

$$k\_Libr(\alpha) = Int\_0/Int\_Libr, \qquad (1)$$

where Int_Libr - calculated integral relative intensity of the Moon on conditions that were during Lane's and Irvine's observation, Int_0 – analogous value, but on conditions: Sun_Long = α, Sun_Lat = Obs_Long = Obs_Lat = 0. We used Akimov-Velikodsky's empirical formula [2, 4] for calculation visible albedo from equigonal and made 3D transformation of images, using our "IRIS" software (http://www.cyteg.com) [5].

Our calculations demonstrated that taking into account libration effect decreases the regular errors of Lane's and Irvine's data by 2%.

Transformation the data to averaged relative equigonal albedo: It is suitable to study the phase dependence of brightness of lunar surface, using so-called equigonal albedo instead of visible one [2]. Equigonal albedo of surface area is albedo on "standard" conditions with mirror geometry, when incidence angle i is equal to reflectance angle ε and is equal to half of phase angle ($i=\varepsilon=\alpha/2$) (so, equigonal albedo is a function of phase angle). Therefore we have developed the procedure for transformation the Lane's and Irvine's data from relative intensities into averaged relative equigonal albedo. Required coefficient is calculated as:

$$k\_EA(\alpha) = EA/(VA \cdot LumPhase), \qquad (2)$$

where EA – averaged equigonal albedo, VA - averaged visible albedo, LumPhase – luminosity phase. EA and VA are calculated, using the technique similar to technique used for calculations of (1).

Taking into account changing of contribution of mares and highlands in integral brightness with phase changes: For full moon ratio of square of mares to full square of illuminated part of lunar disk is k_0 = 0.45. But the ratio changes with phase changing. For example, for $\alpha = 90°$ before full moon this ratio is k = 0.3 (fig.1, lower curve). This distorts phase dependence of equigonal albedo. Therefore we have calculated correction coefficients for reduction data to full moon ratio 0.45 (fig.1, upper curve) using our digital maps.

$$k\_Mr\_HL(\alpha) = (1 - kEA\cdot k_0)/(1 - kEA\cdot k), \qquad (3)$$

where $kEA = 1 - EA_{MR}/EA_{HL}$, EA_{MR} – mean equigonal albedo of mares, EA_{HL} – mean equigonal albedo of highlands.

Our calculations demonstrated that taking into account this effect for phase curve before full moon decreases the regular errors by 7%.

Studying the phase dependence of equigonal albedo: Akimov proposed for approximation of phase dependence of equigonal albedo an empirical formula [6]:

$$EA(\alpha) = m \cdot e^{-\mu\alpha}, \qquad (4)$$

where m – diffuse albedo, μ - effective roughness factor. Using observations of selected points on the Moon Akimov came to a conclusion, that this formula has a good agreement with observations over phase angles $20°\leq\alpha\leq80°$.

We used formula (4) for approximation of phase curves of EA, calculated on the base of Lane's and Irvine's observations. We worked with two diapasons of α: (1) 18°-43° and (2) 41°-120° before full moon (see Table). On fig.2 the example of approximation for λ = 457.3 nm is presented (blue curve - $18°<\alpha<43°$, red curve - $41°<\alpha<120°$). As shown from the table and plot, it is impossible to describe the phase dependence of equigonal albedo at phase angles 20°-120° using only one exponential function (4). At greater phase angles slope is smaller.

To study the influence of wavelength on phase dependence of brightness we have constructed diagram "Effective roughness factor μ – wavelength" (fig. 3). One can see on diagram, at small phase angles (18°-43°) decreasing the μ with wavelength growth is observed, and for 41°-120° μ is practically constant and is equal about 0.7. It means that at relatively small phase angles phase dependence is formed substantially by microrelief, and it is observed illumination of shadows due to increasing of regolith particles transparency with wavelength (illumination of shadows decreases value of μ). At great phase angles phase dependence is formed mainly by mesorelief (i.e. macrorelief within the limits of resolution).

Conclusions: (1) A procedure for correcting the data of integral photometry of the Moon of Lane and Irvine (1964-1965) has been developed. (2) On the basis of the corrected data, it is shown, that it is impossible to describe the phase dependence of equigonal albedo at phase angles 20°-120° using only one exponential function $EA(\alpha) = m \cdot e^{-\mu\alpha}$. (3) Also it is shown, that at small phase angles (18°-43°) decreasing the μ with wavelength growth is observed, and for 41°-120° μ is practically constant. (4) It means that at relatively small phase angles the phase dependence is formed substantially by microrelief and at great ones – by mesorelief.

References: [1] Lane A.P., and Irvine W.M. (1973) *Astron. J.*, 78, No 3. 267-277. [2] Akimov L. A. (1988) *Kinematika i fiz. nebesnykh tel*, 4, No 1, 3-10. [3] Korokhin V. V., and Akimov L. A. (1997) *Astron. Vestn.*, 31, No 2, 143-152. [4] L.A. Akimov, Yu.I. Velikodsky, and V.V. Korokhin (2000) *Kinematics and Physics of Celestial Bodies*, 16, No 2. 137-141. [5] Korokhin V. V. et al. (2000) *Kinematika i fiz. nebesnykh tel*, 16, No 1, 80-86. [6] Akimov L. A. (1988) *Kinematika i fiz. nebesnykh tel*, 4, No 2, 10-16.

Table. Parameters of function (4): m(1) and μ(1) – for 18°<α<43°, m(2) and μ(2) – for 41°<α<120°.

λ, nm	m(1)	μ(1)	m(2)	μ(2)
359.0	0.82370	1.20968	0.62900	0.73721
392.6	0.95038	1.07103	0.82624	0.78601
415.5	0.98402	1.15618	0.76660	0.74155
457.3	1.07243	1.05790	0.87639	0.72141
501.2	1.16091	1.03116	0.96982	0.72696
626.4	1.65850	0.85139	1.56377	0.76015
729.7	1.88245	0.84119	1.77833	0.73627
859.5	1.87514	0.76714	1.83687	0.72729
1063.5	2.08851	0.72329	2.11720	0.69126
U	0.41308	1.21424	0.30865	0.73998
B	0.57101	1.03895	0.49161	0.76831
V	1.23623	0.98468	1.03339	0.68022

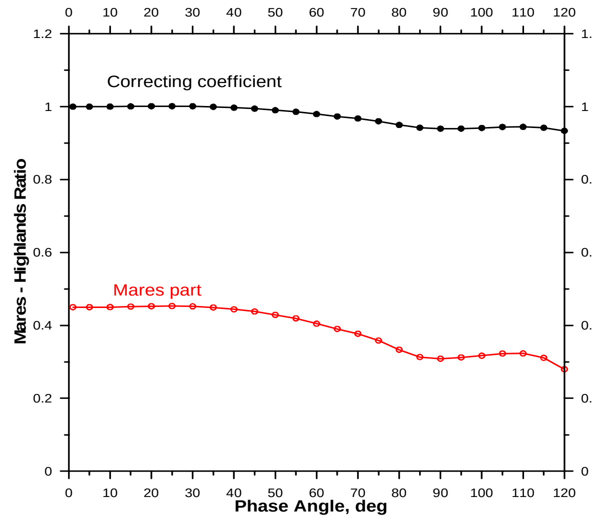

Fig. 1

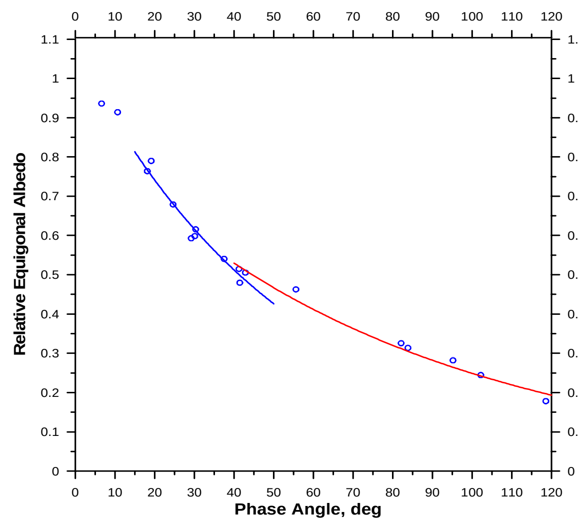

Fig. 2

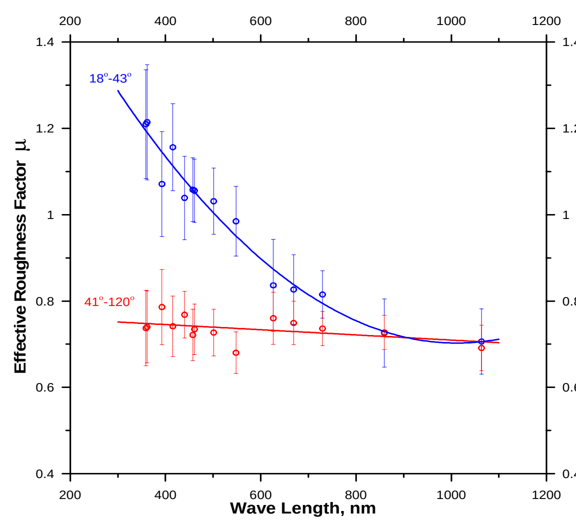

Fig. 3