RECALIBRATING INTEGRAL PHOTOMETRY OF THE MOON USING TELESCOPIC AND CLEMENTINE OBSERVATIONS. V.V. Korokhin, Yu.I. Velikodsky, V.G. Kaydash, and Yu.G. Shkuratov. Astronomical Institute of Kharkov National University. Sumskaya St., 35, Kharkov, 61022, Ukraine. E-mail: dslpp@astron.kharkov.ua.

Introduction: Attempts to use the Moon as a photometric standard for calibration of spectral observations of planets and the Earth's surface from the space were done many times. In particular integral observations of the Moon were used for this aim. We suggest here a recalibration of previous integral data including telescope and Clementine measurements.

Telescopic integral observations of the Moon and their correction: The integral photometrical observations carried out by Lane and Irvine [1] (a range of phase angles α is 6° - 120°) and Rougier [2] (2°≤α≤152°) can be used for the calibration purposes. The data [1] were obtained in the 9 narrow spectral bands from the range 350-1000 nm and in *UBV* wide bands. Rougier's data were acquired in *B*-filter. Unfortunately applicability of these data for calibration purposes is limited because of systematical errors caused by the influence of libration variations (up to 2% errors). The data can be also used to study lunar surface properties. However changing the contribution of maria and highlands to integral brightness with phase angle variations is high and this gives up to 10% of errors. We have developed a procedure to compensate these effects, see also [3].

Describing phase angle dependence of lunar reflectance: To study the phase dependence of brightness of lunar surface, it is convenient to use so-called equigonal albedo (EA) instead of visible albedo [4]. The equigonal albedo of a surface area is reflectance measured at a fixed illumination and observation geometry, when the incidence angle *i* is equal to the reflectance angle *ε* and is equal to half of the phase angle α (*i*=*ε*=α/2). Bringing all lunar sites to similar photometrical condition allows us to avoid 3D image transformations, if one takes into account lunar libration variations. We have developed the procedure for the transformation of the integral data from relative intensities into averaged relative equigonal albedo and back [3].

For approximation of the experimental data obtained for all filters we used the following empirical formula:

$$EA(\alpha) = m_1 e^{-\mu\alpha} + m_2 e^{-0.7\alpha}, \qquad (1)$$

where m_1 and m_2 are empirical constants, μ characterizes the slope of phase curves (an effective roughness factor). This formula gives good agreement with observations over phase angles 6° ≤ α ≤ 120°.

Spectral effect: To study the influence of wavelength on phase dependence of brightness we have constructed a diagram "μ – wavelength" (Fig. 1). One can see, that at relatively small phase angles (16°-43°) decrease of μ with wavelength is observed, and for 41°-120° μ is practically constant being approximately 0.7. It means that at relatively small phase angles the phase dependence is formed substantially by micro-topography, and it is observed suppressing the shadow-hiding effect due to increase of transparency of regolith particles with wavelength increasing (illumination of shadows decreases value of μ). At large phase angles the phase dependence is mainly formed by meso-topography and almost does not depend on wavelength.

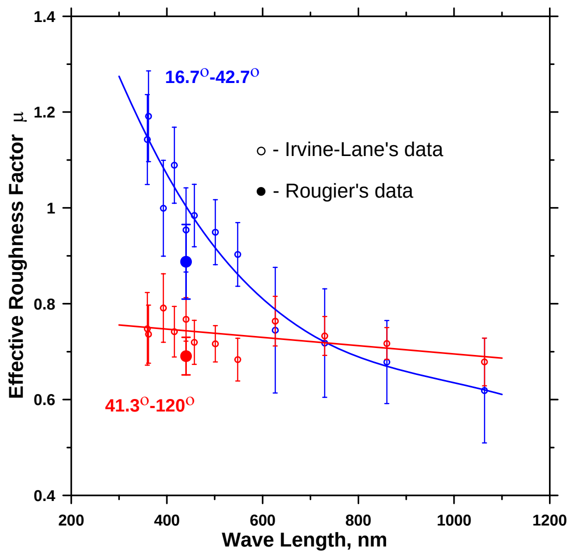

Fig. 1. The parameter μ (slope of phase angle curve) as a function of wavelength for the two sub-ranges of phase angles.

Variations of integral lunar spectra with phase angle: Unfortunately because of internal calibration problems the Lane-Irvine multispectral observations do not allow one to study directly the real spectrum of the Moon. However we have studied the behavior of a relative slope of the lunar spectrum with phase angle. For each filter a fit of phase curve to experimental data with formula (2) was done. Using obtained fitting parameters, model curves for 6° ≤ α ≤ 120° with a step Δα = 1° were calculated. This allows us also to obtain spectral curves for each phase angle. Each of these curves was normalized on the spectrum at 6°. For all relative spectra a linear regression was found. The slope of the relative spectrum is equal to slope coefficient of the regression line. Blue curve in Fig. 2 has been constructed using this procedure. One can see that there are the minimum near α = 10° and the maximum near α = 50°. That confirms early uncertain conclusions of some authors on phase dependence of the lunar color-index and coincides very well with the result of model calculations [5]. For comparison we show also observation data (red plot in Fig. 2). The behavior of both of curves is generally similar (note that the blue curve is not a RMS approximation of red points).

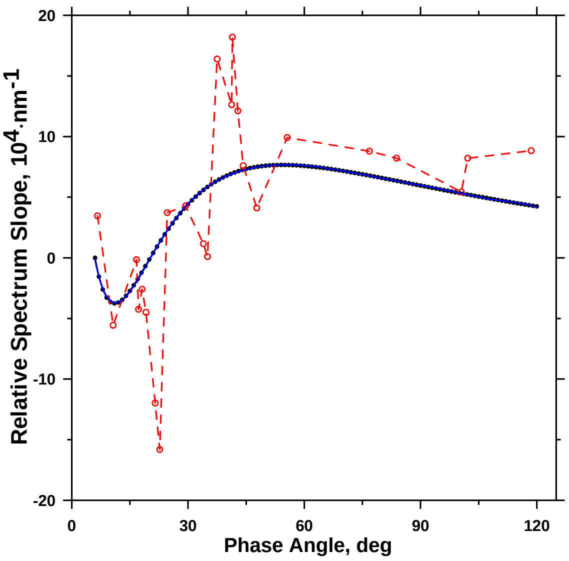

Fig. 2. The dependence of relative slope of the lunar spectra on phase angle.

Integral brightness variations from Clementine data: Clementine UVVIS data are unique whole-Moon survey characterized by 100m/pix spatial resolution in several spectral ranges from near-UV to near-IR [6]. The Clementine data are available in form of digital photometric mosaics. To characterize the lunar integral brightness with these data, we averaged all pixels over the whole lunar disk with the center at the zero latitude, varying the longitude (changing with 10° step). In other words we calculated the dependence of the integral brightness on the lunar disk rotation. In Fig. 3 we present five such curves for wavelengths from 0.42 to 1.00 microns. The symmetry center (and minimum) for all curves is shifted to -10º (west longitude) value. To make a comparison we normalize each curve at its minimum. The changes of brightness by factor of 1.30 - 1.35 with rotation phase reveal the mare-highland dichotomy of the lunar nearside and farside. When the central longitude is gradually approach to the farside, all the curves clearly show increasing the color-index (IR / UV) of the lunar disk. We note the importance of these estimates for integral disk photometry (especially for the farside) performed onboard of lunar space missions.

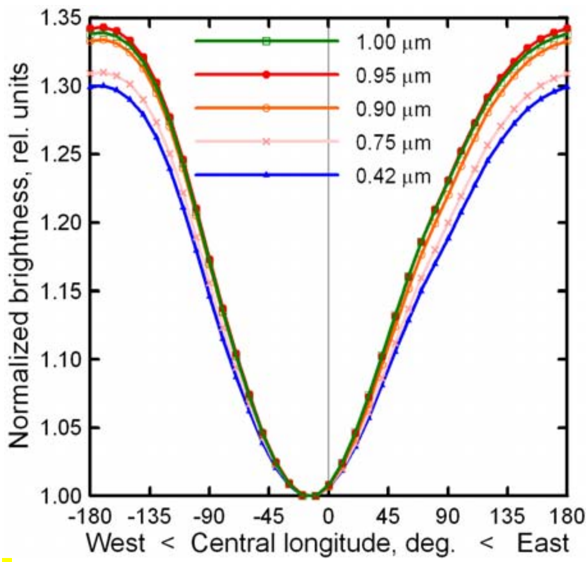

Fig. 3. Dependence of integral brightness of the Moon on its rotation phase from Clementine observations.

Conclusions: Our posteriori processing of integral observations of the Moon [1, 2] provides more reliable phase curves of lunar brightness. Using these data together with the Clementine integral brightness curves enables using the Moon as a photometrical standard for photometry from spacecrafts.

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References: [1] Lane A.P., and Irvine W.M. (1973) *Astron. J.,* 78, No 3, 267-277. [2] Rougier G. (1933) *Ann. Obs. Strasburg.* 2, 1-339 [3] Korokhin V.V., Velikodsky Yu. I. (2005) *LPSC* 36, Abstract #1437 [4] Akimov L. A. (1988) *Kinematika i fizika. nebesnykh tel*, 4, No 2, 10-16. [5] Shkuratov Yu.G. et al. (1996) *Solar System Research,* 30, 82-91. [6] Eliason, E. M., et al. (1999). USGS, Flagstaff, Ariz.