ABSOLUTE CALIBRATION OF LUNAR SPECTROPHOTOMETRY DATA. L. A. Akimov, and Yu. I. Velikodsky. Astronomical Institute of Kharkov National University. Sumskaya ul., 35, Kharkov, 61022, Ukraine. E-mail: velikodsky@astron.kharkov.ua.

Introduction: A problem of absolute calibration of lunar albedo is very important and actual. Accurate knowledge of albedos of lunar areas (as well as its photometric functions) lets use them as photometric standard for observations of planets and the Earth's surface. Moreover, albedo is an important photometric parameter, which may be used for studying of physical properties of lunar regolith.

Absolute measurements of the Moon is a difficult task because magnitudes of possible photometric standards (the Sun or stars) greatly differ from the lunar one. Using the Sun is more preferable, because the Sun is a light source for the Moon and such a measurement is direct. But in this case there is a problem of non-simultaneous observation of the Moon and the Sun. In all cases, there is a problem of taking into account possible changing of atmosphere transparence during observation. As a result of presence of these difficulties an accuracy of existing measurements is not enough.

We suppose that most precise absolute calibration has been obtained by Akimov [1] in red light (λ=660 nm). His albedo is based on Sytinskaya-Sharonov's absolute system obtained with visual photometry. Phase dependence at large phase angles is based on Sytinskaya-Sharonov's [2] and Peacock's [3] data. And phase dependence near opposition is based on Wildey-Pohn's data [4]. Moreover, Akimov experimentally studied the law of brightness distribution over lunar disk [5] that let him correctly calculate the albedo.

Akimov's photometric system has a good agreement with Saary-Shorthill's system [6] within accuracy about 10% [7]. So, 10% is the accuracy of existing data. But it is desirable to improve accuracy of absolute data to use them as photometric standard.

At the same time Clementine spacecraft lunar data have been calibrated using laboratory measurements of lunar samples and their albedo is 2.5 times greater than Akimov's one [8]. Therefore it is necessary to provide new independent observations to check different absolute photometric systems.

Observational data: In 1986 we have performed a series of photometric observations of the Moon and the Sun during 4 days and 3 nights in 3 narrow spectral bands (440, 550, 660 nm). Phase angle was changed in interval 0.8-25° (observations includes near-eclipse phase). Observations have been performed at 70-cm reflector in Grakovo station of Kharkov observatory (near Kharkov, Ukraine) with photoelectric photometer. 75 lunar areas (from catalogue [1]) were measured with 50-cm objective diaphragm and center of the Sun was measured with 16-cm diaphragm. Full luminous intensity of the Sun was calculated with taking into account of darkening to the solar limb at corresponded wavelength.

Data processing: Using observations of solar center we have studied changes of atmosphere transparence during observation and have calculated "exoatmospheric" brightness of all lunar areas and solar center. Then absolute visible albedo A has been calculated with formula:

$$A = \frac{B_{LA}}{B_{SC}} \cdot \frac{R_{S-L}^2}{R_S^2 k_\lambda K},$$

where B_{LA} – brightness of lunar area, B_{SC} – brightness of solar center, $R_{S\text{-}L}$ – Sun-Moon distance, R_S – radius of the Sun, k_λ - coefficient that takes into account darkening to solar limb, K – "instrumental" coefficient that contains diaphragm squares ratio and input resistances ratio. K is equal to 470016, and k_λ is equal to 0.747 (for 440 nm), 0.803 (550 nm), and 0.825 (660 nm).

For calculating of precise phase angles and others photometric conditions with taking into account location of area on the Moon and location of observer on the Earth we have used formulas of coordinate transformation [9].

Equigonal albedo obtaining: We obtain from observation a *visible albedo* and can not calculate *normal albedo* (also named simply *albedo*) because photometric function of the Moon is not studied with enough precision. In [5,10] it was shown that photometric function can be separated up on two parts:

$$A_v = \rho(\alpha)\Psi(\alpha, i, \varepsilon), \quad (1)$$

where A_v – visible albedo, $\rho(\alpha)$ – *equigonal albedo* (albedo on "standard" conditions with mirror geometry, when incidence angle i is equal to emergence angle ε and is equal to half of phase angle α ($i=\varepsilon=\alpha/2$) [10]), $\Psi(\alpha,i,\varepsilon)$ – disk brightness distribution function for fixed phase angle. For small phase angles ($\alpha<25°$) function Ψ is known precisely enough [5,11,12]. So, we can calculate equigonal albedo ρ by (1) and study phase dependence $\rho(\alpha)$. The normal albedo can be obtained as $A=\rho(0)$.

Phase dependence: For approximation of phase dependence of equigonal albedo we used semi-empirical formula of Akimov [10,13]:

$$\rho(\alpha) = g \cdot e^{-\gamma\alpha} + m \cdot e^{-0.7\alpha}, \quad (2)$$

where g and γ – parameters of opposition peak, and the term with coefficient m describes phase dependence on large phase angles (we used average value of exponent coefficient 0.7 [10,13]). Obviously, albedo A=g+m.

Preliminary results: Now we have results for one lunar area (crater Le Monnier), which has the most number of measurements. Obtained equigonal albedo (in red band) at α~25° (the night with best atmospheric stability) is exactly equal to old Akimov's equigonal albedo [1] of Le Monnier 0.049 with standard deviation 3% (fig.1). For smaller phase angles observed albedo is slightly greater than old one, and near opposition (α=1-2°) albedo is greater by 15% (old normal albedo is 0.099, new – 0.115).

So, our new independent observations, as a preliminary, confirm Akimov's absolute photometric system at least for α>15°. Equigonal albedo for smaller phase angles (and, as result, normal albedo) is greater than Akimov's ones up to 15%. The last fact may be connected with the circumstance that Sytinskaya and Sharonov did not obtain phase dependence for small phase angles, and Akimov used data of Wildey and Pohn [4] for this phase interval.

Also we compared albedos of Le Monnier at 3 wavelengths with spectrum of lunar mares built by V.Kaydash on the base of C.Pieters catalogue. Our data repeat spectral slope of this spectrum with deviations about 4%.

We plan to obtain absolute albedo for all 75 lunar areas and to study phase dependence at small phase angles more detailed.

Also we plan to process data of our new absolute observations of 2005 year at large phase angles.

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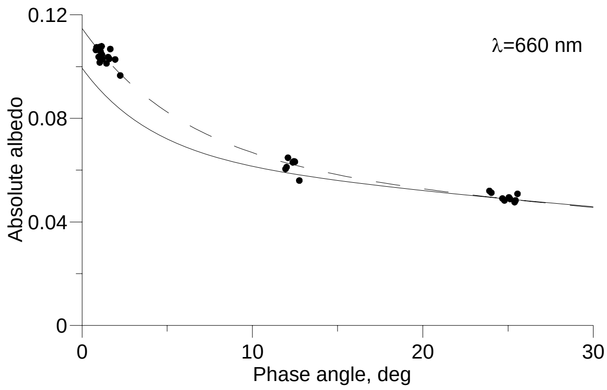

Fig.1. Phase dependence of equigonal albedo of Le Monnier: points – observations, solid line – old Akimov's absolute data [1], dotted line – new approximation with (2).