ULTRAVIOLET PHOTOMETRY OF THE MOON WITH THE CELESCOPE EXPERIMENT ON THE OAO-2

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ABSTRACT

Thirteen television frames of the Moon taken in the wavelength regions of 1350-2150 Å by filter U_3 and 1050-2150 Å by filter U_4 of the Smithsonian Astrophysical Observatory's Celescope experiment are discussed. The data include phase angles from -81° to -26°. The brightness dependence on phase angle differs slightly from that of visual observations. The brightness dependence on selenographical longitude is compared with the theoretical photometric function derived by Hapke.

I. INTRODUCTION

Many people have studied the photometric properties of the Moon in the infrared, visual, and near-ultraviolet ranges at wavelengths longer than 1900 Å. In the summer of 1969, we lowered this range to 1050 Å with the data gathered by a television photometer whose field of view was divided in half by broadband filters. The effective wavelengths are 1600 Å for filter U_3 and 1500 Å for U_4. Figure 1 gives the transmission for each filter.

Figure 2 shows two representative television pictures of the Moon. Thirteen such pictures were used in this study; eight were taken with the U_4 filter, and five with the U_3. The Moon's phase angle ranged from -81° to -26°, permitting us to examine the Moon's phase law as well as its normal reflectivity. We were unable to obtain smaller phase angles because of spacecraft constraints.

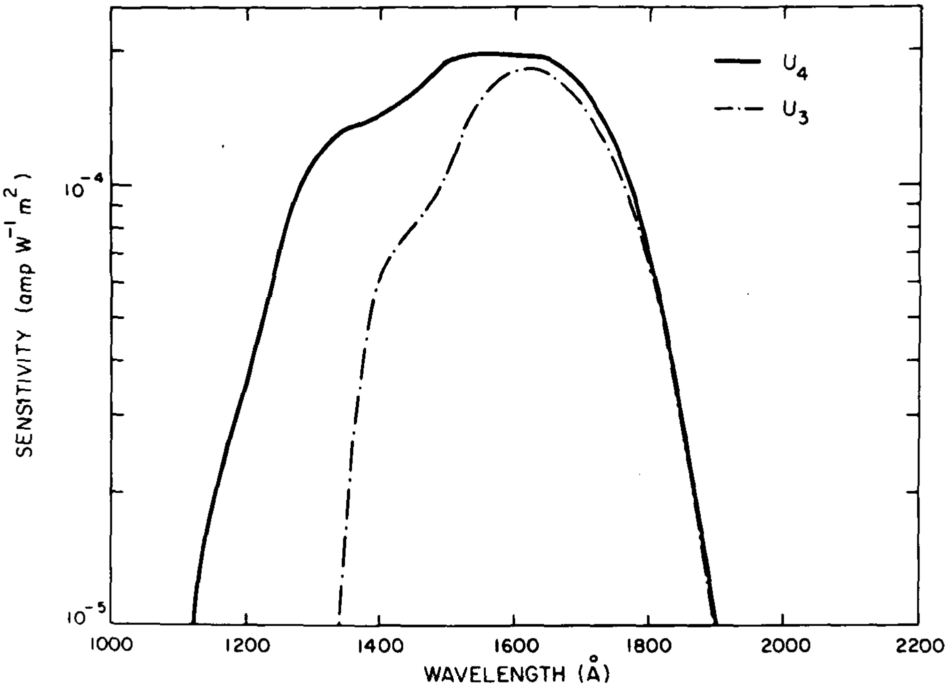


Figure 1.—Transmission of Celescope filters.

II. THE MOON'S PHASE LAW

The phase law of the Moon at intermediate phase angles is

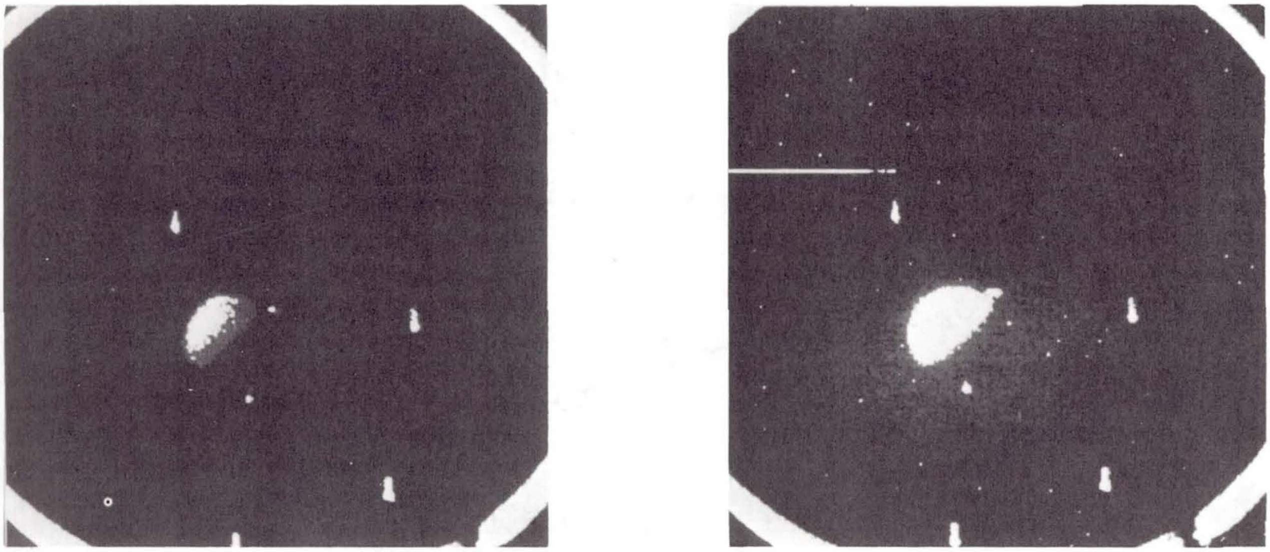
$$I_0 = I(\theta) - \beta\theta \tag{1}$$

where $I(\theta)$ is the intensity of the Moon measured at phase angle θ, and β is the phase coefficient. At small phase angles, this relationship does not hold; however, our observations were at phase angles large enough to lie wholly in this linear region. We determined with a least-squares fit that the best coefficient is $\beta = 0.04$ mag/deg. This value is 0.012 mag/deg larger than the phase coefficient in the visual range.

Figure 3 shows our values of β plotted with those from the visual range (Gehrels et al. 1964). They appear to fall on a straight line over the entire range.

III. THE NORMAL REFLECTIVITY OF THE MOON

The normal reflectivity of the Moon is given by



Orroral 2851
16:37 UT 23 June 69

MOON

R.A. $12^h\ 28^m\ 01^s$
DEC. $-4^o\ 40'\ 08''$

5 sec. exp.
Camera 4

Madagascar 2853
19:44 UT 23 June 69

MOON

R.A. $12^h\ 33^m\ 25^s$
DEC. $-5^o\ 58'\ 07''$

15 sec. exp.
Camera 4

Figure 2.—Celescope pictures of the ultraviolet Moon.

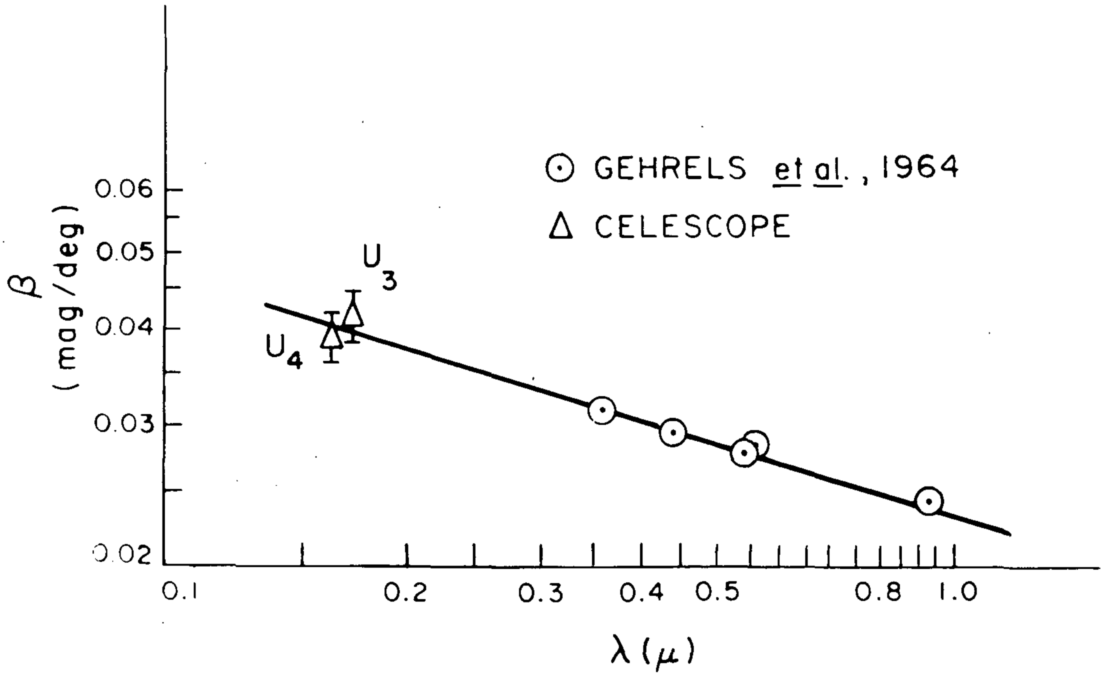


Figure 3.—Moon's phase coefficient vs. wavelength.

$$\frac{I_{\leftmoon}}{I_{\odot}}\left(\frac{a}{r}\right)^{2} \tag{2}$$

where $I_{\leftmoon}$ is the intensity of the Moon at zero phase, $I_{\odot}$ is the intensity of the Sun that would be measured by Celescope, a is the semidiameter of the Moon, and r is the Moon-Sun distance. We use the phase coefficient derived in equation (1) to extrapolate to the brightness of the Moon at zero phase. Obtaining the solar intensity needed in these calculations presents problems. There is some question as to what the Sun's intensity is at Celescope wavelengths. The values published earlier by NRL (Widing et al. 1970) are higher than those of Parkinson and Reeves (1969) by a factor of 3 at 1600 Å and of 2 at 1800 Å. However, a calibration problem caused a zero-point error in the NRL data; its discovery makes the discrepancy even larger, for the corrected NRL intensities are 40% higher than the published values at these wavelengths (Widing 1970). Figure 4 shows the normal reflectivities from earlier studies at short wavelengths and the Celescope reflectivities derived from two different intensity measurements. The one marked NRL uses the revised NRL solar intensities for

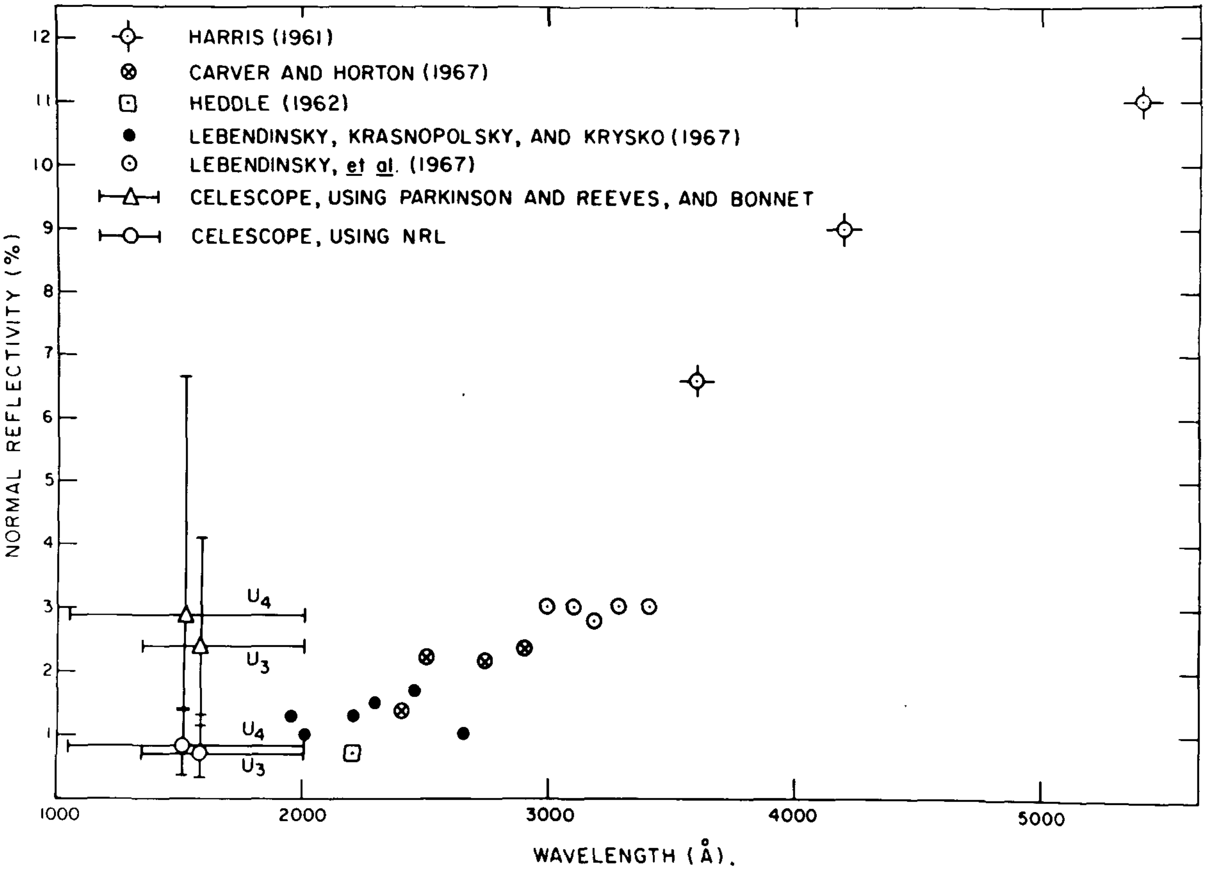


Figure 4.—Normal reflectivity of the Moon.

λ ≥ 1400 Å, the OSO-IV intensities for λ < 1400 Å (Parkinson 1970), and the intensity of Lyman alpha from Hinteregger (1965). The one marked Parkinson and Reeves-Bonnet uses the Parkinson and Reeves data for 1400-1850 Å and the findings of Bonnet at 1900 Å (Parkinson 1970), the OSO-IV intensities for λ < 1400 Å (Parkinson 1970), and the intensity of the Lyman alpha line from Hinteregger (1965). The reflectivity from these measurements depends not only on the absolute value of the solar flux but also on the absolute value of the Celescope data. Our instrument is calibrated for point sources, not area sources. We have indicated the worst-case effects of the error on the reflectivity. If the Parkinson and Reeves values are correct, the Moon's reflectivity is leveling off or increasing in the 1000-2000 Å range covered by the Celescope filters even if the minimum reflectivity values allowed are used.

IV. THE ULTRAVIOLET PHOTOMETRIC FUNCTION

Bruce Hapke (1963,1966) devised a model for the Moon's photometric function, $\phi(\lambda,\alpha)$, defined as

$$\phi(\lambda,\alpha) = \frac{B(\lambda,\delta,\alpha)}{B(\lambda,\delta,0°)} , \qquad (3)$$

where $B(\lambda,\delta,\alpha)$ is the brightness of a unit region of the Moon at longitude λ, latitude δ, and phase angle α — that is, the change of brightness with the selenographic longitude and phase angle. Figures 5 and 6 show Celescope data points plotted along with a Hapke curve. For these points, ϕ has been computed from the formula

$$\phi(\lambda,\alpha) = \frac{\zeta(\alpha)\ B(\lambda,\delta,\alpha)}{\zeta(0°)\ B(62°,0°,\alpha)} , \qquad (4)$$

where $\zeta(\alpha) = \phi(\lambda,\alpha)$ as defined by the Hapke theory, and $\zeta(\alpha)/\zeta(0°)$ serves as a normalizing factor to fit the Celescope points to the Hapke curve. The photometric function from the ultraviolet data at -25° shown in Figure 6 is very similar to that of Herriman et al. (1963); they derived theirs from the

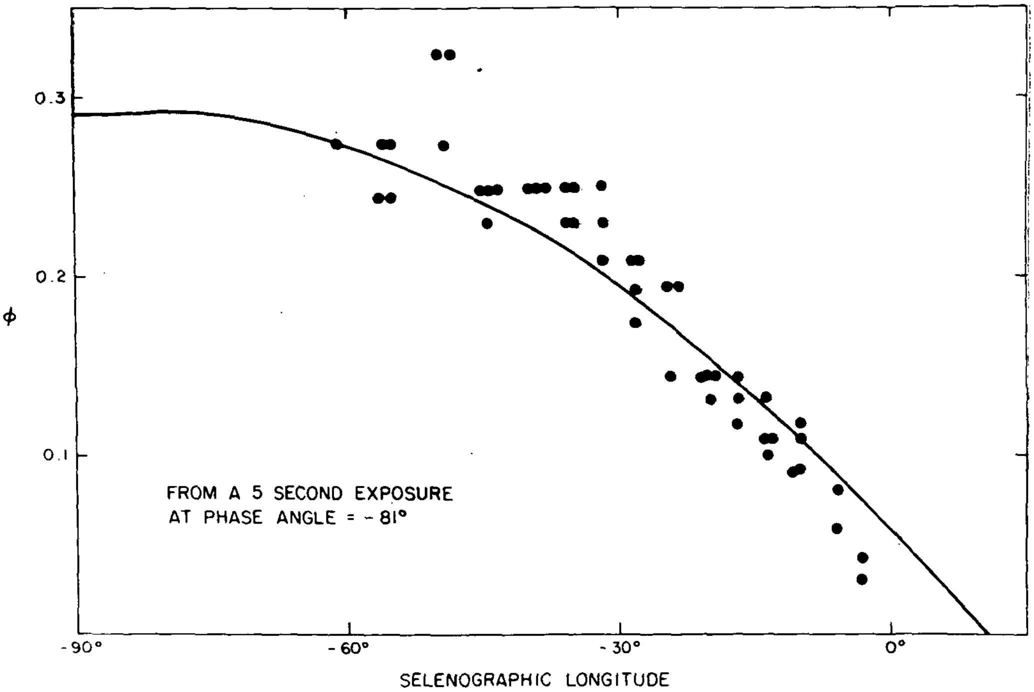


Figure 5.—Celescope data (points) vs. theoretical Hapke function.

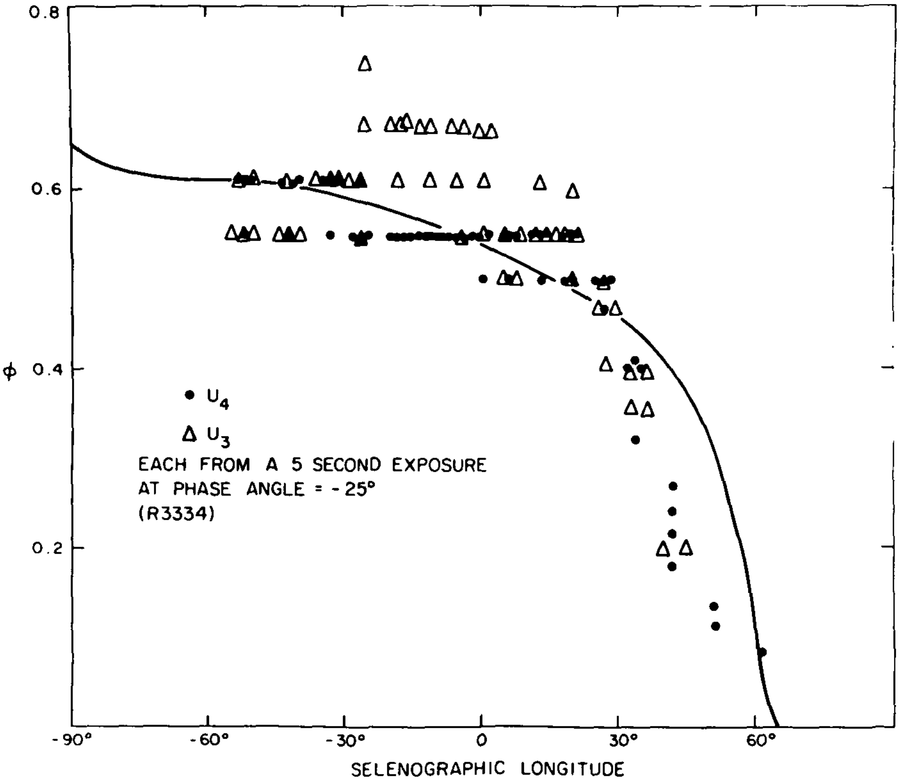


Figure 6.—Celescope data (points) vs. theoretical Hapke function.

data of Fedoretz (1952) as reported by Hapke (1966); theirs is reproduced here in Figure 7. Our ultraviolet measurements also fall under the curve in the 30-60° region.

We conclude that the phase coefficient β is larger in the ultraviolet than in the visual, that the normal reflectivity is leveling off or perhaps increasing, and that the Hapke photometric functions predict our results as well as they do the visual results.

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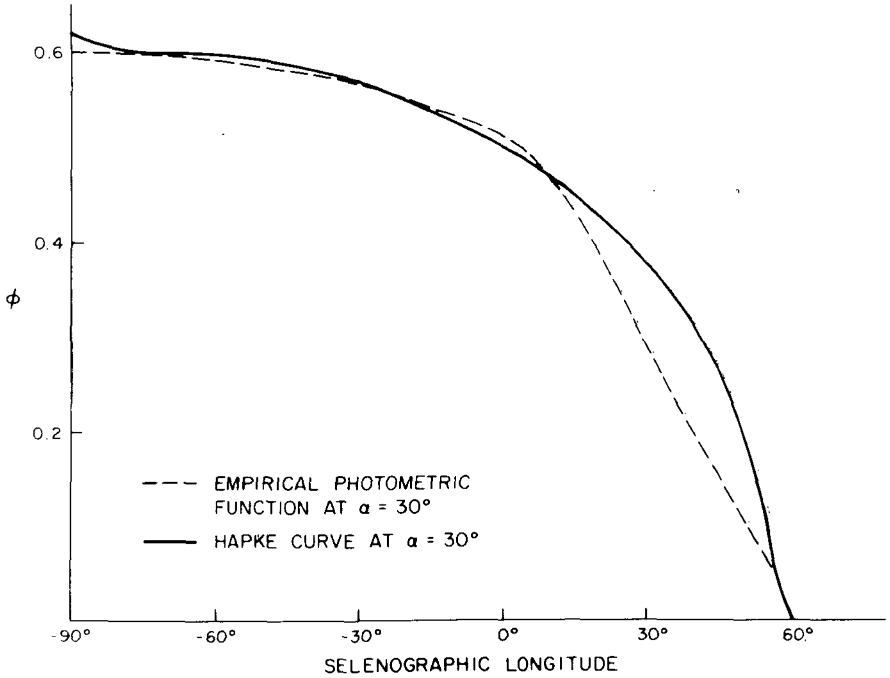

Figure 7.—A comparison of the visual Moon with the Hapke photometric function.

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