PHOTOMETRY OF THE LUNAR SURFACE DURING LUNAR ECLIPSES

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Abstract. The photometric observations of the lunar surface during lunar eclipses were carried out on four nights between 1972 to 1978, using the 91 cm reflector of the Dodaira Station of the Tokyo Astronomical Observatory. The photometry was performed in B-, V-, and R-colours, and arranged in accordance with the angular distance from the centre of the Earth's shadow. The results do not show any large systematic differences between the four nights, showing no support for Danjon's proposition.

1. Introduction

The Danjon (1920a)'s proposition, according to which the Moon's brightness during total lunar eclipses changes synchronously with the cycle of the solar activity describing the saw-tooth curve, has been repeatedly confirmed so far (Danjon, 1920b; De Vaucouleurs, 1944a, b; Bell and Wolbach, 1965). But in all these re-examinations, the adopted brightness scale is always the same one as that which Danjon (1920a) proposed: namely, the brightness degrees from $L = 0$ to 4 depend only on the impressions of the observers with naked eye. Therefore, the doubt remains as to whether Danjon's proposition is still valid when we adopt the modern method of photoelectric photometry for the evaluation of the Moon's brightness.

For the purpose of examining this problem, the author tried to make the photoelectric photometry of the Moon's surface on the occasions of the total lunar eclipses since 1972, using the 91 cm reflector of the Dodaira Station of the Tokyo Astronomical Observatory, and succeeded in observing the four lunar eclipses shown in the Table I.

2. Observations

The apparatus for the present observations has been the same as the one which has been used for the ordinary Moon's photometry and polarimetry by the author, a short description of which has already been published (Sekiguchi, 1972) – except for the following point. In the present observations, the diameter of the diaphragm was changed to 2.35 mm, which corresponds to about 54 km at the Moon's distance, with due regard to the faintness of the lunar brightness during eclipses.

As in the author's usual photometry, the photometric standards are the stars in the Arizona–Tonantzintla Catalogue (Iriarte *et al.*, 1965); and most of them have a visual magnitude of about 4 or 5. Observations were made in V-, B- and R-colours. The corrections due to the background brightness of the sky have not been applied to the observed

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Table I
Times of maximum obscuration

(a)	1972	Jan.	30	10h	53.4 m	(U.T.)
(b)	1974	Nov.	29	15	13.3	
(c)	1978	Mar.	24	16	22.4	
(d)	1978	Sept.	16	19	4.2	

observed results, because in almost all cases the Moon's sufrace is much brighter than the sky background except for the B-colour. This point will be discussed further at a later date.

The observations were carried out for the four eclipses tabulated in Table I. The observation (a) was on the Moon-rise eclipse and that of (d) was the Moon-set eclipse. On the nights of (a) and (b), the Moon was frequently covered by clouds, but the transparency of the sky was fine. On the nights of (c) and (d), the sky was completely clear. The eclipse of (c) has the time of maximum obscuration near midnight in Japan, and the observation was carried out completely.

The measurements were performed exclusively on the central part of the mare regions during the eclipses, owing to the ease of guidance. In eclipse (a), the observations were made for many mare regions; namely, on Mare Imbrium, Lacus Somniorum, Mare Serenitatis, Mare Tranquillitatis, Mare Crisium and Oceanus Procellarum. But by the experience of these observations, the number of the observed regions were reduce in seccessive observations. In eclipse (b), Mare Imbrium, Mare Serenitatis and Mare Nubium were observed. In eclipse (c), Mare Imbrium and Mare Serenitatis were observed. Finally in eclipse (d), Mare Serenitatis alone was observed. For the sake of comparisons, the region near the Aristarchus was observed in (b) before the beginning of the penumbra eclipse, and in the same way the regions Plato and Proclus were observed in (c).

In (a), the observations were carried out only on V- and B-colours, and the R-colour observation was not included.

The present observations were able to record the polarization degrees. But in the lunar eclipses, the polarizations were very weak, and we cannot discuss it with sufficient reliability. Therefore, in the present study, the results of the polarimetry were ruled out of the discussion.

3. Observational Results

The observed brightness were all reduced to the magnitude per square second of arc and arranged in accordance to the angular distance from the centre of the Earth's shadow expressed in minutes of arc. The results are shown in Figures 1, 2 and 3 for the V-, B- and R-colours, respectively; and the colour indices B–V and V–R are shown in Figures 4 and 5, respectively. In each diagram, the radii of umbra and penumbra are shown on respective nights.

The results of observation before the beginning of the penumbral eclipse are, for the

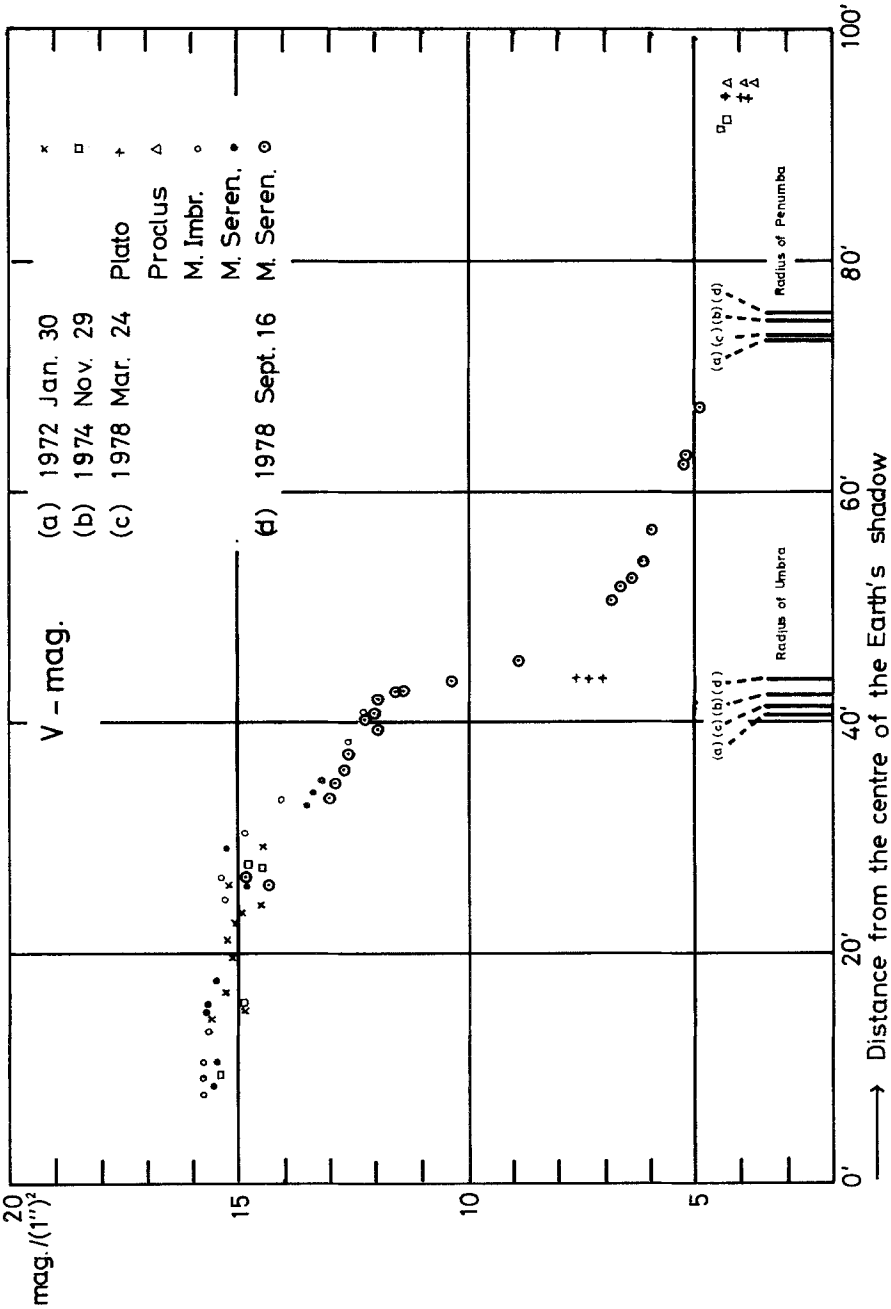

Fig. 1. Brightness in V-magnitude.

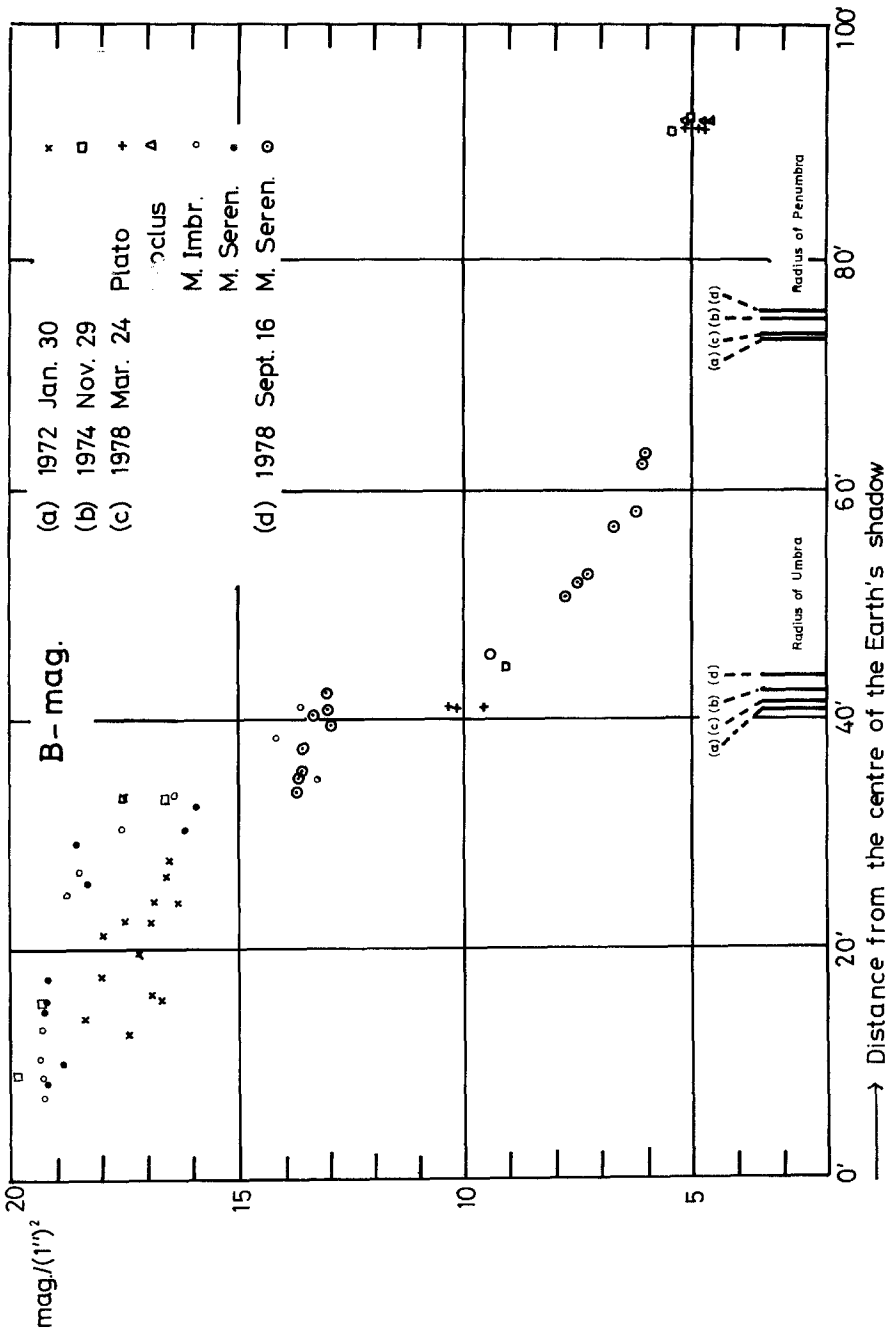

Fig. 2. Brightness in B-magnitude.

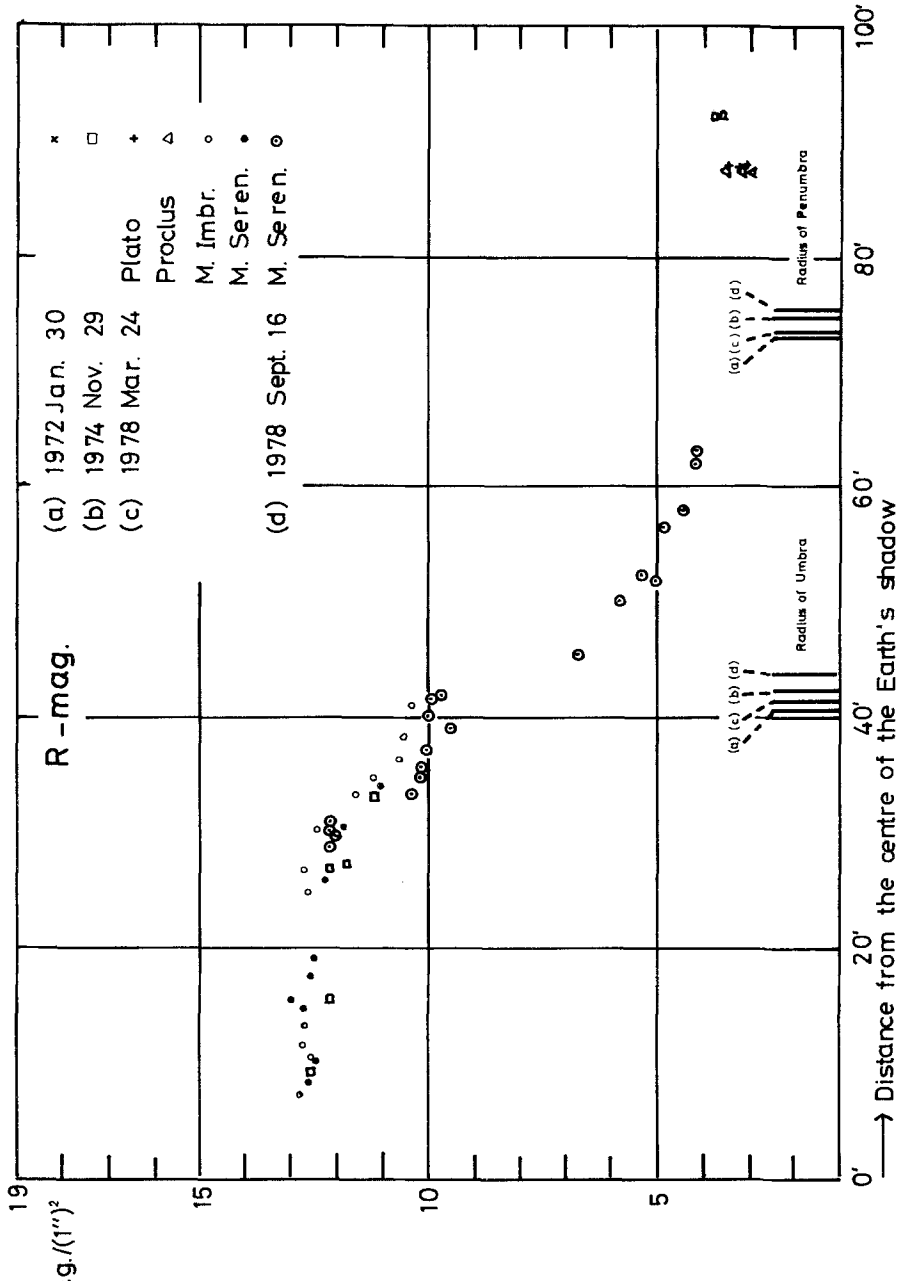

Fig. 3. Brightness in R-magnitude.

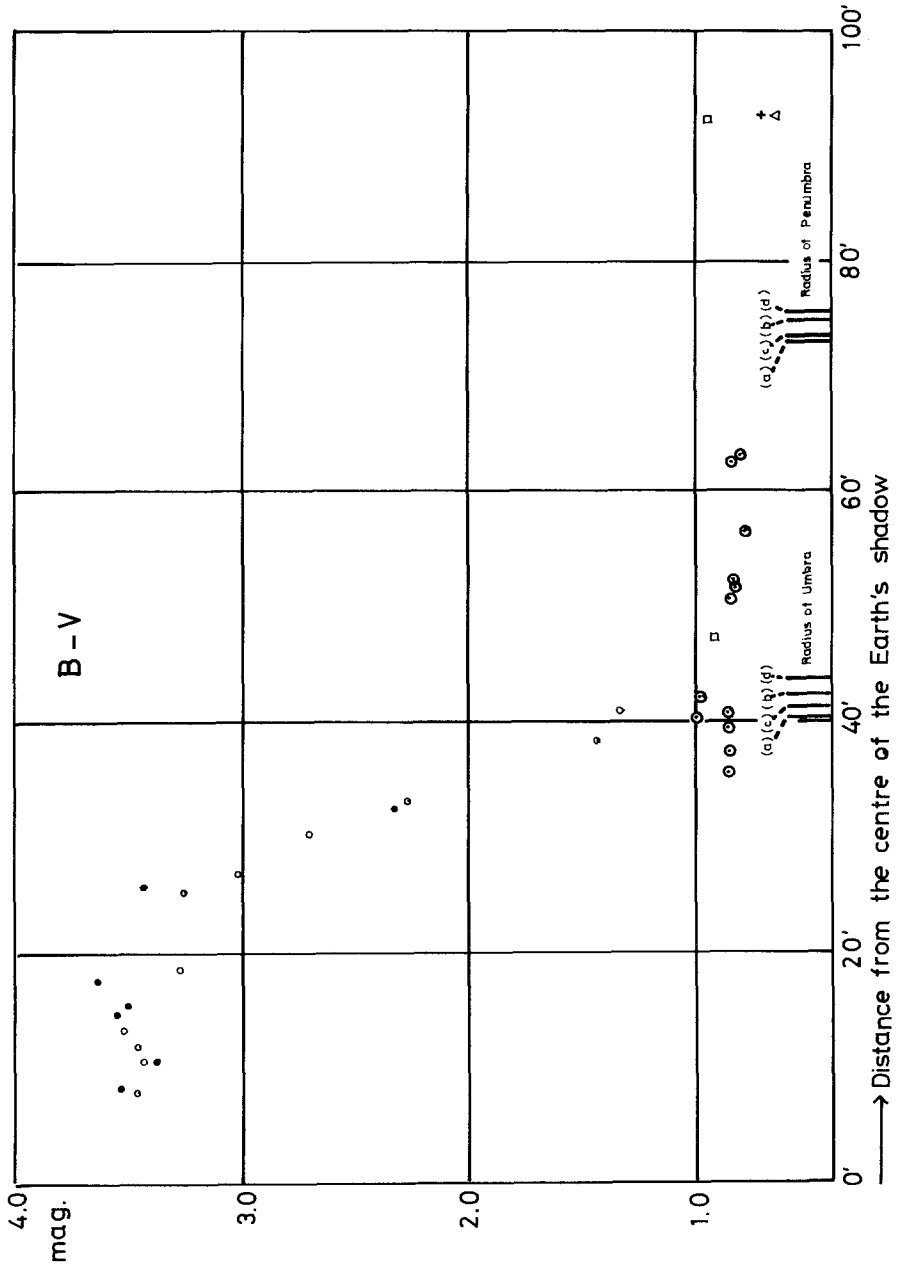

Fig. 4. Colour in B–V.

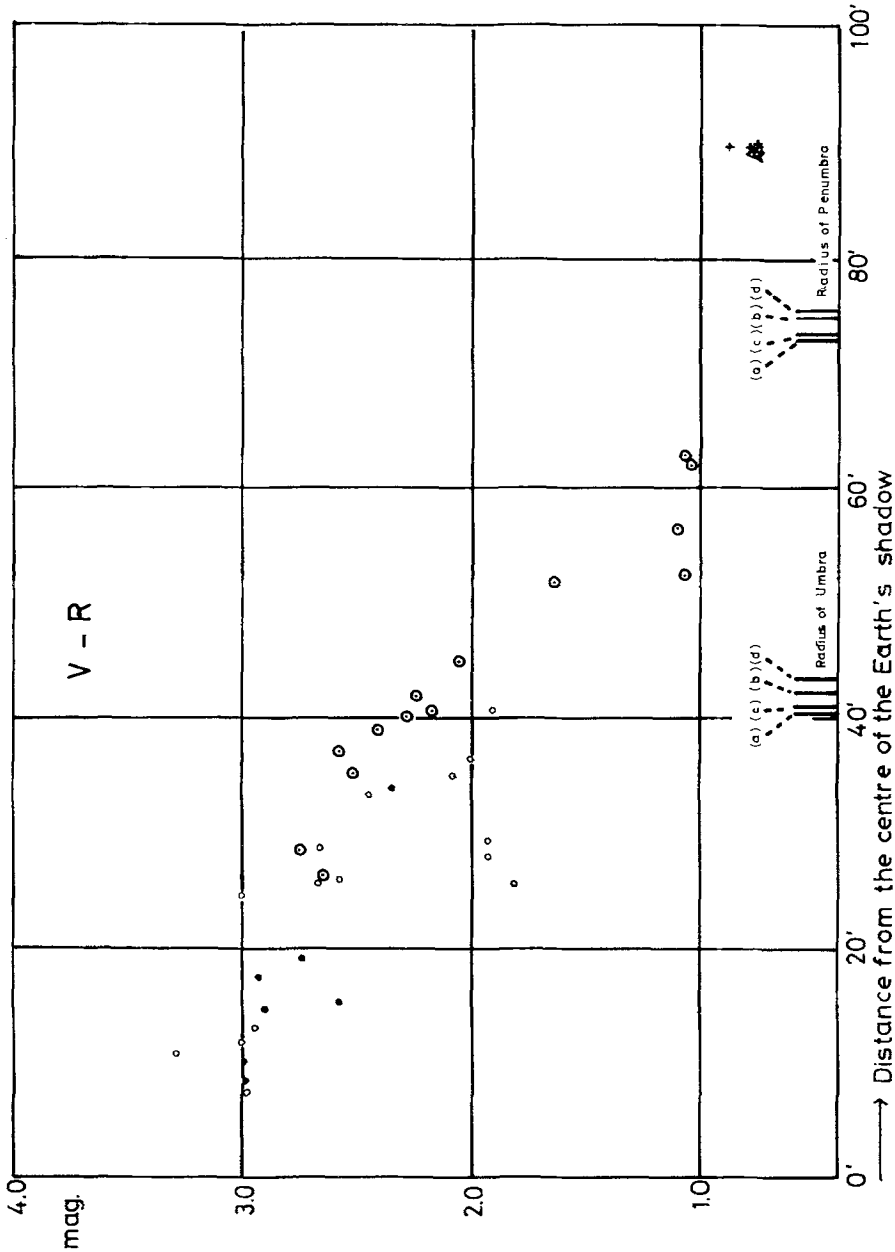

Fig. 5. Colour in V–R.

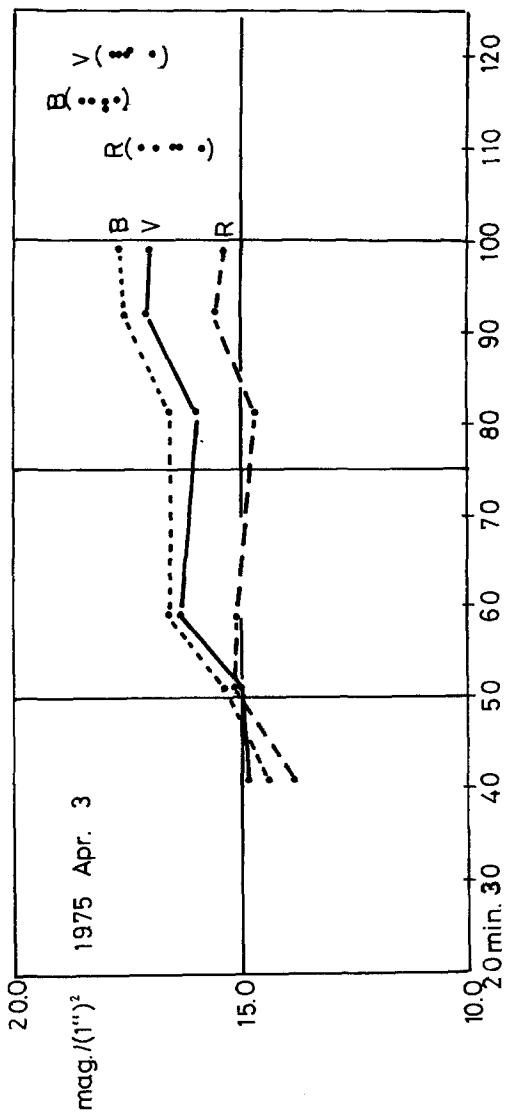

Fig. 6. Background intensity of the sky.

sake of comaprisons, shown in the right hand-side of these figures. These observations were made on both mare and highland ground, and the dispersions between these points are mainly due to the brightness differences between the observed points.

The dispersions of the observational results about the penumbra and umbra may be partly caused by the difference of the radii of the umbra and penumbra between respective eclipses; and partly for the following reasons.

As mentioned above, the background intensities of the sky were not corrected in the present observations. These intensities may be caused mainly by the reflection of the city light on tenuous haze, and are variable from time to time according to the variation of the sky transparency. Figure 6 shows an example of the measurement of the sky intensity of the Dodaira Station on a clear night. In this case, the Moon's age was about 21 days and the observed direction was near zenith. The observed intensities were arranged according to the interval until the time of the sunrise in minutes. The points on the right-hand side of Figure 6 are the results of measurements taken long before sunrise, which show the variability of the transparency of the sky during this night. Although the example of the measurement is only one and is not the observation on the eclipse night, we can fairly safely conclude the following.

In R-colour measurements, the sky background may be almost negligible. In V-colour, a considerable part of the intensity in the total lunar eclipse may be due to the sky background. In B-colour, the observed intensity of the total lunar eclipse may be largely due to the sky background. The large dispersion in B-colour during the total lunar eclipse may be due to the variability of the sky background intensity.

4. Discussion

These results do not show any systematic difference during the period from 1972 to 1978, giving no support to Danjon's proposition. Especially in the R-colour (effective wavelength is about 0.72 μ), where the effect of the sky background may be slight, we cannot perceive any remarkable changes during these four examples, while the naked-eye observers often noticed the changes mainly in red colour.

Danjon's proposition is the statistical result of the aggregate of very many historical observations. In the present study, the number of the examples is very small. Therefore, it is desirable to accumulate results of similar observation of the future lunar eclipses.

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