Jan Bouška

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Enlargement of the Earth's Shadow During the Lunar Eclipses of September 16, 1978 and of March 13, 1979

J. BOUŠKA

Department of Astronomy and Astrophysics, Faculty of Mathematics and Physics, Charles University, Prague*)

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From the timing of crater entrances into the umbra and from their exits from the shadow, the enlargement of the Earth's shadow during the total lunar eclipse of September 16, 1978 and during the partial lunar eclipse of March 13, 1979 was determined. This enlargement of the umbra was found to be 1/57 during the former and 1/36 during the latter eclipse.

По моментам вступления кратеров в земную тень и выхода из нее, отмеченных во время лунных затмений 16-го сентября 1978 г. и 13-го марта 1979г., было найдено увеличение тени 1/57 и 1/36.

Z pozorovaných časů vstupů kráterů do stínu a výstupů z něho bylo určeno zvětšení stínu při úplném zatmění Měsíce 16. září 1978 a při částečném zatmění 13. března 1979. Při prvním zatmění bylo zjištěno zvětšení stínu 1/57, při druhém 1/36.

1. Introduction

Lunar eclipses were systematically observed in Czechoslovakia starting from the year 1943 with a view to analyse the variations of the enlargement of the Earth's shadow. Up to the year 1975 altogether 19 lunar eclipses were observed and the mean value of the enlargement of the umbra 2.20 per cent was obtained by the author.

The values of the enlargement of the umbra were computed from the timings of craters entrances into the shadow and from their exits from the umbra using the Kozik's [1] method. The Sun's and Moon's equatorial coordinates and parallaxes, the Sun's selenographic longitudes and latitudes, the position angles of the Moon's axis and the differences between Ephemeris Time and Universal Time (ΔT) were

*) 150 00 Praha 5, Švédská 8, Czechoslovakia

taken from the American Ephemeris and Nautical Almanac. The rectangular coordinates of the observed lunar formations published in catalogues by Bouška, Hřebík and Švestka [2], by Bouška and Vanýsek [3] and by Kozik [4] were used for the computation. In some cases the rectangular selenographic coordinates of the observed lunar craters were computed from their selenographic longitudes and latitudes.

2. Total Lunar Eclipse of September 16, 1978

This eclipse was observed by 20 observers on 7 Czechoslovak observatories and stations under very good weather conditions. Altogether 285 times of crater entrances into the umbra and of their exits from the shadow were used for the computation. The difference $\Delta T = +49.0^s$ was accepted.

The mean value of the radius of the western part of the umbra, computed from 187 crater entrances observed by 17 observers, expressed in units of the Earth's equatorial radius in the distance of the Moon ($\Delta = 1/\sin \pi_\mathfrak{C} = 57.65$) is

$$r_0 = 0.7485 \pm 0.0019 .$$

The crater entrances were observed between the position angles $-8.7° < \psi < +28.1°$, mean value of ψ is $+13.6°$.

The mean value of the radius of the eastern part of the umbra, computed from 98 exits of lunar formations from the shadow observed by 15 observers is

$$r_0 = 0.7475 \pm 0.0015 .$$

The crater exits were observed between the position angles $+24.2° < \psi < +62.6°$, mean value of ψ is $+46.4°$.

The theoretical radius of the umbra in the Moon's distance Δ computed from the oblateness of the Earth, from the Sun's and Moon's parallaxes and from the declination of the Sun is

$$r_c = 0.7359 - 0.0034 \sin^2 \psi .$$

The enlargement E of the Earth's shadow is defined by the equation

$$E = \frac{r_0 - r_c}{r_0}$$

The mean value of the enlargement of the western part of the umbra is

$$E_W = 1.71 \text{ per cent}$$

and the mean value of the enlargement of the eastern part of the shadow is

$$E_E = 1.79 \text{ per cent} .$$

The mean value of the enlargement of the Earth's shadow computed from all the 285 observed contacts is

$$E = 1.74 \text{ per cent} .$$

Blasberg [5] collected timings of 68 crater exits of 10 lunar formations observed by 12 observers during the eclipse of September 16, 1978. The enlargement of the eastern part of the umbra computed from these contacts by the author is $E_E = 1.75$ per cent. During this eclipse from timings of 59 lunar formations Ashbrook [6] obtained $E = 1.79$ per cent. Both these values are in a agreement with the enlargement of the Earth's shadow found by the author.

3. Partial Lunar Eclipse of March 13, 1979

This lunar eclipse was observed by 9 observers on 2 observatories in Czechoslovakia and on one station (Munich) in Germany [7]. The observation conditions were not too favourable, especially during the second half of the phenomenon. The observation of crater exits was interrupted (or impossible) by clouds. The Earth's shadow was considerably bright, during this eclipse the brightness of the eclipsed Moon was $L = 3$ in the well-known five-step Danjon's scale.

Altogether 137 contacts of the lunar formations with the shadow were used for the computation, the difference $\Delta T = +49.85^s$ was accepted. The radius of the shadow computed from 121 crater entrances ($+44.7° < \psi < -89.6°$, mean value $\psi = +71.9°$) and from 16 exits ($+10.3° < \psi < -58.2°$, mean value $\psi = -31.6°$) is

$$r_0 = 0.7253 \pm 0.0017$$

for mean position angle $\psi = +67.2°$.

The theoretical radius of the Earth's shadow in the distance $\Delta = 62.95$ is

$$r_c = 0.7081 - 0.0034 \sin^2 \psi .$$

From all the 137 observed contacts of the lunar formations with the umbra, the mean value of the enlargement of the Earth's shadow was found to be

$$E = 2.78 \text{ per cent} .$$

4. Discussion of Results

The values of the enlargement of the umbra found during the eclipses of September 16, 1978 and March 13, 1979 show no expressive assymetry between the western and eastern part of the Earth's shadow, which was found by the author during some past lunar eclipses.

The enlargement of the umbra during the eclipse of September 16, 1978 was smaller than its mean value. The following values of the enlargement of the umbra found during the lunar eclipses observed during the years 1972–1978 were collected in [6]:

1972 January 30	$E = 1.68\%$
1975 May 24–25	1.70
1975 November 18–19	1.91
1977 April 3–4	1.76
1978 March 24	1.86 .

The enlargement of the Earth's shadow is caused principally by the absorption in the thick Earth's atmospheric layer (up to heights ~130 km), in which the dust of meteoritic and volcanic origin is present. The observation of the lunar eclipse of September 16, 1978, and also the observations of the eclipses between the years 1972–1978 show that that absorption coefficient of the Earth's thick dust layer was in the past years somewhat smaller than usually.

On the contrary, the enlargement of the umbra found during the eclipse of March 13, 1979 was considerably higher than its mean value. During the period 1943–1975 only during the total eclipse of December 8, 1946 the same value of the enlargement of the shadow ($E = 2.8$ per cent) was found by the author [8], higher enlargement ($E = 3.7$ per cent) was obtained only during the total eclipse of October 6/7, 1949 [9].

The mean value of the enlargement of the umbra computed from the lunar eclipses observed between the years 1975–1978 is $E = 1.79$ per cent and the enlargement of the shadow was nearly constant during this period (Fig. 1). The increase of the enlargement between September 1978 and March 1979 is remarkable. It may

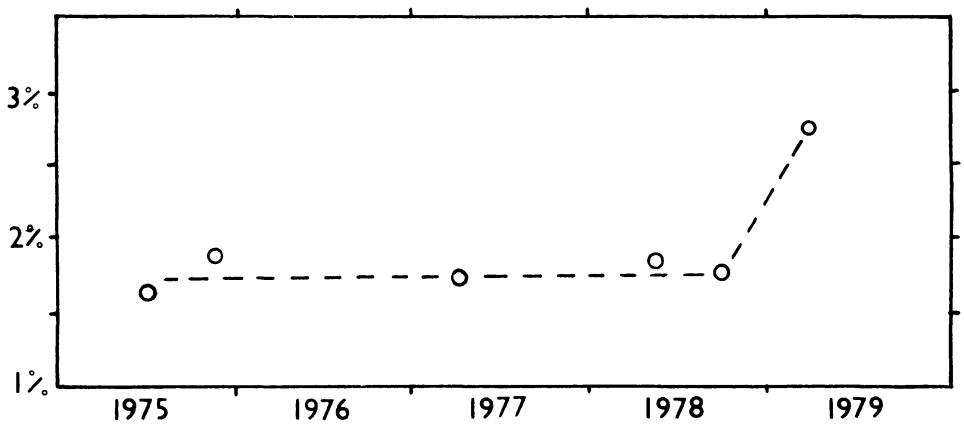

Fig. 1. Enlargement of the Earth's shadow during the lunar eclipses observed between the years 1975–1979.

be explained by the increase of the absorption coefficient of the Earth's thick dust layer, which was probably polluted between August 1978 – February 1979 by substantial amount of dust particles more probably of volcanic than of meteoric origin.

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