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ISOPHOTS OF ZODIACAL LIGHT

AND ITS TERRESTRIAL COMPONENT

by

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## SUMMARY

The effect of the Moon on the brightness distribution of
zodiacal light cones was revealed on the basis of an analysis
of zodiacal light isophots obtained under various latitudes,
and it was concluded that the zodiacal light contains a terres-
trial component due to dust concentrated either in the form of
a ring at a certain distance from the Earth, or in the vicinity
of the libration points of the Earth-Moon system, or in the
vicinity of the lunar orbit.

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In their observation of zodiacal light, the majority of
the authors have been investigating brightnesses and polarization
only at points located along the ecliptic. Almost all theories
on dust matter distribution in the zodiacal cloud are based on
this material. However, it is obvious that such an unwarranted
limitation, which ignores the possibility of other observations,
cannot reliably answer the main question concerning the location
of the matter causing zodiacal light. On the other hand, it is
clear that analysis of the integral pattern of zodiacal light
isophots could yield a more extensive material for developing
the theory on dust matter distribution in the interplanetary
space. As was shown by V.G. Fesenkov [1] and then by N.B. Divari
[2] the position of the brightness maximum of zodiacal light is
directly connected with the role of the near-terrestrial dust
matter in the formation of zodiacal light. However, to date, the
nature of brightness distribution in zodiacal light cones had not
yet been accurately determined. In some works, for instance in
[3,4], it is tacitly assumed that the zodiacal light is symmetri-
cal to the ecliptic and isophots are produced, identical for the
northern as well as southern ecliptic hemispheres. On the other
hand, according to available results of observations, the distri-
bution of brightness of zodiacal light is not identical in the
northern and southern hemispheres. A difference in the nature

of northern and southern zodiacal light isophots is evident
from the observations of V.G. Fesenkov [5] who has detected
the effect of isophot expansion at the northern horizon.
Asymmetry of zodiacal light isophots was clearly manifest
in the observations by Elvey and Roach [6], Huruhata [7],
Behr and Siedentopf [8] and others. A recent comparison of
zodiacal light brightness and polarization near the ecliptic
poles [9,10] shows that the brightness of zodiacal light at the
South pole is in excess as compared to that at the North Pole. A
correct accounting of the tropospheric effect is of major im-
portance for determing the real extraatmospheric brightness
of zodiacal light. For instance, Regener [11] succeeded in
selecting artificially the parameters for the atmospheric dust
layer so as to eliminate the irregularities in the observed
distribution of zodiacal light iosophots. The position of the
axis of zodiacal light has a direct bearing on the problem of
zodiacal light isophot distribution. This problem was investi-
gated in detail in [12,13].

To analyze the brightness distribution in zodiacal light
cones we used the photoelectric observations carried out in
1955-1958 and described in [14-17]. Observations were then
studied for each individual night. The extraatmospheric zodia-
cal light brightnesses $J$ were obtained by means of the reduction
of observed brightnesses $\overline{J}_{app}$ at the expense of atmospheric glow
$A(z)$, of direct light of all the stars $\sigma$, of tropospheric side-
real light diffusion G.R., the tropospheric scattering of zodia-
cal light B, as well as of twilight-sky glow S, according to
formula

$$J = [J_{app} \quad A(z) \quad \sigma p^{sec\,z}$$
$$- B \quad G.R. \quad S]p^{-sec\,z}$$

Corrections for tropospheric scattering were calculated by
the method described in [18] i.e. by way of integration over
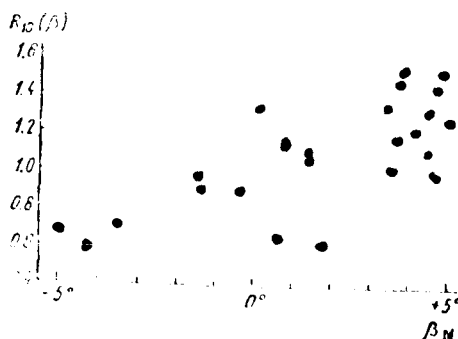the entire visible part of the celestial sphere. The brightness
used for the analysis are the extra-
atmospheric brightness of zodiacal
light cones without continuous night
sky background. In other words, these
are brightness excesses in zodiacal
light cones relative to the continuous
background far off the cones. To cha-
racterize the asymmetry of zodiacal
light isophots, we adopted the ratio
$R = R(\beta, \lambda_\theta - \lambda)$ of the zodiacal light
brightness at a point to the north of
the ecliptic with the coordinates
$(\beta, \lambda_\theta - \lambda)$, to the brightness at the
point $(-\beta, \lambda_\theta - \lambda)$, to the south of the
ecliptic. The values of this ratio

$R_{10}(\beta)$

Fig.1. Values of ratio
$(R_{10} = I(\beta = 10°)/I(\beta = -10°)$ as a function of
Moon's lunar ecliptical
latitude $\beta$

measured in the $45° \leqslant \lambda_\theta - \lambda \leqslant 65°$ range, are compiled in table I for β = 5, 10, 15 and 20°. As may be seen from the Table I these ratios vary considerably from one night to another, i.e. the isophot asymmetry relative to the ecliptic is strongly noticeable. Taking into account the results obtained in [12],

| Year | Date | $\beta = 5°$ | $\beta = 10°$ | $\beta = 15°$ | $\beta = 20°$ | Year | Date | $\beta = 5°$ | $\beta = 10°$ | $\beta = 15°$ | $\beta = 20°$ |
|------|------|------|------|------|------|------|------|------|------|------|------|
| 1955 | 22.9 | 0.88 | 0.90 | 1.09 | 1.64 |      | 31.10 | 0.77 | 0.57 | 0.36 | 0.26 |
|      | 23.9 | 0.90 | 0.90 | 0.95 | 1.11 |      | 1.11 | 0.86 | 0.70 | 0.59 | 0.59 |
|      | 24.9 | 0.72 | 0.65 | 0.64 | 0.68 | 1957 | 24.10 | 1.17 | 1.33 | 1.12 | 1.19 |
|      | 25.9 | 0.72 | 0.62 | 0.58 | 0.69 |      | 25.10 | 1.08 | 1.10 | 1.13 | 1.19 |
|      | 27.9 | 1.06 | 1.02 | 1.07 | 1.33 |      | 2.11 | 1.32 | 1.44 | 1.51 | 1.54 |
|      | 14.10 | 0.77 | 0.68 | 0.53 | 0.41 |      | 3.11 | 1.01 | 1.21 | 1.37 | 1.63 |
| 1956 | 8.3 | 1.21 | 1.53 | 2.49 | — |      | 4.11 | 1.19 | 1.35 | 1.51 | 1.48 |
|      | 9.3 | 1.08 | 1.11 | 1.15 | 1.17 |      | 21.11 | 1.12 | 1.15 | 1.17 | 1.11 |
|      | 10.3 | 1.27 | 1.53 | 1.66 | 2.32 |      | 22.11 | 1.06 | 1.07 | 1.12 | 1.15 |
|      | 14.3 | 1.12 | 1.18 | 1.03 | 0.84 | 1958 | 12.10 | 0.93 | 0.96 | 0.93 | 0.98 |
|      | 13.10 | 0.92 | 1.00 | 1.12 | 1.14 |      | 16.10 | 1.38 | 1.47 | 1.30 | 1.17 |
|      | 14.10 | 1.25 | 1.27 | 1.21 | 1.24 |      | 17.10 | 1.25 | 1.31 | 1.24 | 1.13 |

## TABLE I

Values of $R = R(\beta, \lambda_\theta - \lambda)$ averaged for the 45° $|\lambda_\theta - \lambda| < 65°$ differential longitude range.

we have compared the ratios R with the ecliptical latitude of the Moon. The dependence between R and the Moon's latitude $\beta_M$ for β = 10° is shown in Fig. I. The correlation factors $k_\beta$ for various values of β were found to be as follows: $k_5 = 0,70$, $k_{10} = 0,74$, $k_{15} = 0,70$ and $k_{20} = 0,64$. No dependence was detected between the ratios $R(\beta, \lambda_0 - \lambda)$ and the inclination of the ecliptic to the horizon, although, according to Weinberg [19] a connection between the zodiacal light brightness and the inclination of the ecliptic does exist.

Besides the ratios $R(\beta, \lambda_\theta - \lambda)$, ratios $R_1 = R_1(\beta - \beta_m, \lambda_\theta - \lambda)$, have also been analyzed. The latter were obtained in the following manner. The latitude $\beta_m$ of the point of brightness maximum was found on the graph of the dependence of zodiacal light brightness on the ecliptical latitude β for the given cross-section $\lambda_\theta - \lambda = \text{const}$ After that the brightness values for this cross-section were taken down from this graph for the values of $\beta - \beta_m$, equal to ±5, ±10, ±15 and ±20. The quantity $R_1(\beta - \beta_m, \lambda_\theta - \lambda)$, equal to the brightness ratio at two points located at equal distances to the North and to the South of the maximum and characterizes the cross-section symmetry relative to the line of brightness maximum. In this it differs from the quantity $R(\beta, \lambda_\theta - \lambda)$, which characterizes symmetry relative to the ecliptic. Fig.2 shows the values of $R_1(\beta - \beta_m, \lambda_\theta - \lambda)$ for $\beta - \beta_m = 10°$ averaged for the differential longitudes

in the $45° \leqslant (\lambda_0 - \lambda) \leqslant 65°$. interval. As may be seen in the Fig. the quantity $R_1$ ($\beta - \beta_m$, $\lambda_0 - \lambda$) does not depend on the Moon's latitude and is close to the unity. (the correlation factor is 0.48). Hence follows, that the effect of the Moon is manifest in that the zodiacal light cones are so displaced that their symmetry relative to the axis of zodiacal light is not disrupted in the vicinity of the maximum. In other words, a displacement takes place of the brightness line maximum. The connection between the position of the axis of the zodiacal light and the latitude of the Moon was investigated in detail in [12] where it is shown that the basic plane relative to which dust particles of a zodiacal cloud are oriented is the ecliptic plane. The Moon exerts upon its position merely a disturbing effect. Hence it follows, that the lunar component of the zodiacal light cannot be predominant.
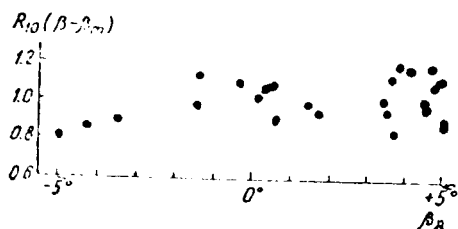
$R_{10}(\beta-\lambda_m)$



Fig.2. Values of the ratio $R_1(10°) = I(\beta-\beta_m = 10°)/I(\beta-\beta_m = -10°)$ as a function of Moon's latitude $\beta_M$.

Inasmuch as the near-terrestrial component can be made apparent owing to the parallactic displacement of the zodiacal light during its observation at different geographical latitudes, we have compared the observations carried out in the region of Alma-Ata ($\phi = 43°$ N) with those made in Egypt ($\phi = 24°$ N).

Examination of extraatmospheric brightness of the zodiacal light obtained in 1955-1958 shows that it is not constant but subject to annual variations. Fig.3 shows the course of extraatmospheric brightness variation of the morning zodiacal light averaged with respect to the region of $-20° \leqslant \beta \leqslant +20°$, $40° \leqslant \lambda_0 - \lambda \leqslant 65°$. As may be seen in the figure, the zodiacal light brightness was apparently minimum in the period of solar activity maximum (1956-1957) and began to increase with the decrease of the latter. This result is in agreement with the data obtained by Well [20] and Asaad [21] on the basis of a more extensive material. In this connection, when comparing the brightnesses of zodiacal light all the brithnesses were reduced to one epoch by means of multiplying them by the respective coefficients determined by way of brightness comparison at different epochs. Thus, with the reduction to a single epoch, the brightnesses of each night varied by an equal number of times, while the relative brightness distribution remained unchanged. The isophots obtained in Egypt on the basis of morning observations on September 24 and November 3, 4 and 22, 1957 for an average inclination of the ecliptic plane to the horizon equal to 88° and mean ecliptical latitude of the Moon $\beta_M = +2°.2$ were adopted as standard isophots. After their reduction to the epoch of observations, the brightnesses corresponding to the 1957 standard isophots were subtracted from the brightnesses of each

night of observations. The obtained differences Δ were plotted
on the graph for each $\lambda_\theta$ -λ = const. cross-section. Fig.4 shows
three curves Δ = Δ(β) conveying and idea on the nature of vari-
ations in differences Δ as a function of β. The majority of the
curves had a clearly expressed maximum whose ecliptical latitudes
are shown in Fig.5. Only two curves, for October 16 and 17, 1958
are devoid of a maximum and are characterized by a minimum in the
vicinity of the ecliptic (see Fig.4). Taking into account that
the mean latitude of the Moon for the epoch of standard isophots
is +2°2, the dependence is considered between the position of
the curve's maxima and the differences between latitude of the
Moon $\beta_M$ at the time of observation and the mean latitude of the
Moon in the epoch corresponding to the standard isophots, namely
Δβ = $\beta_M$ -2°2, This dependence is shown in Fig.5 and the corre-
lation coefficient corresponding to it is k = 0.76.



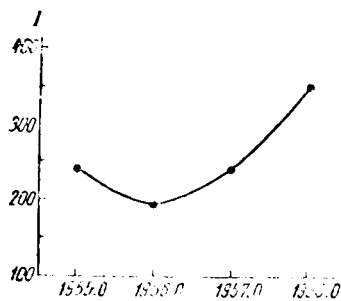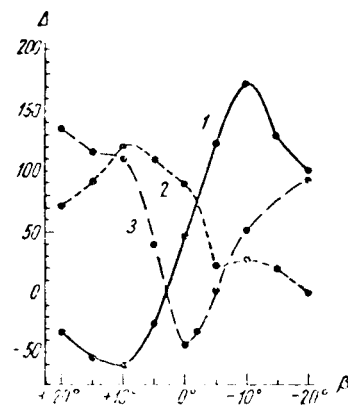Fig.3                     Fig.4

Fig.3.    Yearly variations in the morning zodiacal light
          brightness.

Fig.4.    Examples of three curves Δ = Δ(β) representing
          the difference Δ between the observed extraat-
          mospheric brightnesses and the brightnesses of
          standard zodiacal light as a function of the
          ecliptical latitude β:
          1.   November 31, 1956 $\lambda_\theta$ -λ = 50°;
          2.   March 10, 1958 $\lambda_\theta$ -λ = 45°;
          3.   October 17, 1958 $\lambda_\theta$ -λ = 50°.

Therefore comparison of zodiacal light isophots with the
standard ones, obtained for an ecliptic plane inclination to the
horizon close to 90°, has shown that the distribution of bright-
ness in the zodiacal light cones is highly variable. However,

no stable parallax was detected. According to the observations
in Alma-Ata and Egypt, the displacement of the maximum of bright-
ness differences is connected with the latitude of the Moon.
This may be understood if one considers that a certain part of
zodiacal light matter is located in the vicinity of the Earth
where the influence of the Moon on the spatial distribution is
possible. However, this matter cannot be located in the immediate
vicinity of the Earth because no effects of twilight nature were
detected in zodiacal light, i.e. there is no dependence of zodiacal
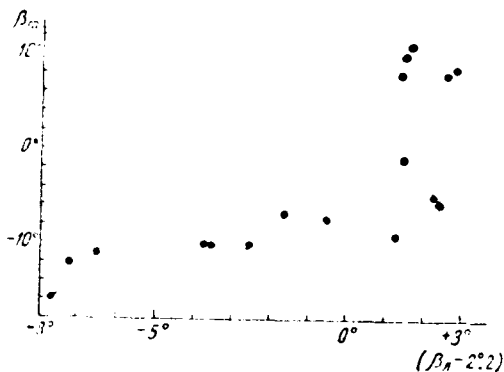light brightness on the azimuth or the solar depression. Analysis
of the obtained differences Δ shows
that neither their value nor the
position of the maximum correlate
with the azimuth of solar depression.
Moreover, as already mentioned, at
solar depressions of at least less
than 20°, was not detected in the
observed brightnesses [22]. If the
zodiacal light were entirely due to
a geocentric cloud immediately ad-
jacent to the upper layers of the
Earth's atmosphere, the twilight
effect would have been detected in

Fig.5. Dependence between the zodiacal light phenomenon, i.e.
the ecliptical latitude $\beta_m$ the brightness of the zodiacal light
of the brightnesses diffe- would have depended on Sun's immer-
rence Δ maximum and the sion and azimuth. Since such is not
difference $\Delta\beta_1 = \beta_1 - 2°2$. the case, it follows that the dust
matter, located in the vicinity of
the Earth and contributing to the zodiacal light, cannot be an
extension of the dust layer responsible for twilight phenomena
and located at altitudes of the order of hundreds of km above
the Earth's surface. On the basis of the foregoing, it can be
concluded that the matter responsible for the lunar variations
of zodiacal light is either located in the form of a ring at a
certain distance from the Earth, or constitutes a cluster at the
libration points of the Earth-Moon system, or is located on the
lunar orbit.

The results presented in this work require confirmation
before they can be considered absolutely reliable. However, in
our opinion, reliable data on isophots of the zodiacal light
cones and their variations should be obtained for the development
of any theory on the zodiacal light. At the same time one should
also take into account the very important and interesting phen -
menon of the false zodiacal light sometimes observable simulta-
neously with the basic zodiacal light cone on the opposite side
of the sky. The fact that the false zodiacal light is not always
visible and that it can be quite bright as it happened on Octo-
ber 25, 1946 [23] may play a major role in the selection of a
model for the distribution of the dust concentration responsible
for the phenomenon of zodiacal light.

* * * THE END * * *

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