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Abstract

Full Text

ASTRONOMY

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ON THE POLARIZATION OF THE LIGHT OF THE TWILIGHT SKY AT THE ZENITH

(Presented by Academician V. G. Fesenkov, 17. IX. 1956)

In September-October 1955, at the Mountain Observatory of the Astrophysical Institute of the Academy of Sciences of the Kazakh SSR ($\varphi = 43^\circ.2' N$, $\lambda = 76^\circ 56' E$, $h = 1450$ m above sea level), together with V. I. Moroz, we carried out determinations of the intensity and degree of polarization of the light of the twilight sky. The observations were made with a photoelectric photometer designed by V. I. Moroz, using an FEU-19 photomultiplier as the radiation receiver (Fabry scheme). The degree of polarization was determined with a polyvinyl polaroid by the method of three positions proposed by V. G. Fesenkov ([1]). Observations were made in four spectral regions, isolated by filters with effective wavelengths of 470, 520, 570, and 600 mµ.

Fig. 1. Mean values of the degree of polarization at the zenith as a function of the Sun' s depression, according to observations on October 24 and 25, 1955. (Dashed line—the theoretical curve)

In Fig. 1, as an example, mean values are presented for the degree of polarization at the zenith as a function of the Sun' s depression $g_\odot$ ($g_\odot = Z_\odot - 90^\circ$, where $Z_\odot$ is the zenith distance of the Sun), obtained from morning observations on October 24 and 25, 1955. The observed values of the degree of polarization at the zenith, for all wavelengths and at all solar depressions, are noticeably smaller than the theoretical values of the polarization of light of first-order scattering, calculated for a Rayleigh atmosphere with allowance for the anisotropy of the molecules. (In Fig. 1 the upper curve represents the theoretical polarization for a depolarization factor equal to 0.04.) As is seen from the graph in Fig. 1, the variation of the degree of polarization is not the same for different wavelengths. For blue rays (λ470 mµ), the curve has a horizontal region of approximately

Fig. 2

Figure 2: Fig. 2

constant polarization corresponding to the interval of solar depressions from 8° to 11.5°, which agrees well with observations by other authors (2,3). This horizontal section becomes smaller in the green rays (λ520 mμ) and disappears in the red (λ600 mμ). The curve corresponding to the red part of the spectrum is characterized by a rather smooth decrease.

Particularly noteworthy is the fact that, for solar depressions from 5° to 9°, the degree of polarization increases with wavelength, whereas for solar depressions greater than 9° the opposite picture is observed. For depressions from 10° to 14°, the polarization in the blue rays noticeably exceeds the polarization in the red.

The observational method used made it possible to estimate the angle φ, formed by the plane of polarization and the plane of the vertical ···

of the Sun, which was carried out with an accuracy of 2—3°. The accuracy of the measurements also depended on the care with which the instrument was aimed at the solar vertical, which was done with an accuracy of 1—2° according to a previously calculated ephemeris.

The observations carried out show that during twilight, in blue and green rays, the plane of polarization at the zenith retains its direction up to a depression of the Sun of 14—15°. At greater depressions of the Sun the plane begins to rotate in one direction.

Fig. 2. Dependence of the angle φ on the depression of the Sun according to observations of 25 X 1955.

No sharp irregular oscillations of the direction of the plane of polarization of such a magnitude as were obtained by G. V. Rozenberg from observations in 1940 carried out near Moscow (4) were found by us. From the graphs presented for the dependence of the angle φ on the depression of the Sun it is evident that the values of the angle φ remain fairly constant during the greater part of twilight. Individual deviations of the order of 2—3° (or a maximum of 5°, which is sometimes encountered) may be caused by observational errors and cannot be assigned real significance. However, during deep twilight, beginning at 14—15°, and sometimes earlier, a systematic rotation of the plane of polarization occurs. In this case the degree of polarization is about 10%. The beginning of the change in the direction of the plane of polarization does not occur simultaneously in all rays. As is seen from Fig. 2, on 25 X 1955 in red rays the angle φ remained constant within 1—2° up to a depression of the Sun of 12.5°. After this the angle increased systematically. In green and blue rays no such sharp change was observed. This difference in the position of the plane of polarization for light of different wavelengths is apparently connected with the difference in the course

Fig. 3

Figure 3: Fig. 3

of the change in the degree of polarization for rays of different wavelengths.

Fig. 3. Dependence of the ratio I_{470}/I_{600} on the depression of the Sun according to observations of 24 X 1955.

A comparison of the course of the intensity of twilight light at the zenith in different rays shows that the distribution of energy in the spectrum of twilight light changes rather rapidly. As is seen from Fig. 3, the ratio of the intensities I_{470}/I_{600} with the depression of the Sun at first increases, reaches a maximum at a solar depression of 9 or 10°, and then rapidly falls. In this case values are reached that are smaller than those at the beginning of twilight. (The same picture occurs for the ratio I_{470}/I_{520}, although the maximum is less pronounced.)

A similar course for the ratio I_{379}/I_{527} was obtained by T. G. Megrelishvili (^{5}) from observations in 1942–1946 carried out on Mount Kanobili (Abastumani Observatory). Thus, as the Sun descends, the light of the twilight sky at the zenith becomes bluer up to $g_{\odot} \sim 10°$, after which reddening begins; moreover, at deep depressions of the Sun the twilight light is redder than at the beginning of twilight.

As is seen from a comparison of the course of change of the ratio I_{470}/I_{600} with the course of change of the degree of polarization p in different rays, in the region of increase

I_{470}/I_{600} (small depressions) $p > p_{\text{blue}}$, while in the region where I_{470}/I_{600} decreases (large depressions) $p_{\text{red}} > p_{\text{blue}}$. This fact directly indicates that in the upper layers of the atmosphere there is a relative increase in the fraction of unpolarized (or very weakly polarized) red radiation. On this basis one may conclude that above 100 km the dependence of scattering on wavelength is not determined by Rayleigh' s law. Since the red part of the spectrum is considerably enhanced (with a simultaneous decrease in the degree of polarization of this radiation), it may be assumed that, with increasing height, beginning at an altitude of about 100 km, particles appear in the atmosphere that scatter neutrally or even according to a law $\sim \lambda^{+1}$. The latter law is valid for particles for which the quantity $\alpha = 2\pi\rho/\lambda$ (ρ is the particle radius) is of the order of 10 [6], i.e. $\rho \sim 10^{-4}$ cm. F. Link [7] obtained the same value for dust particles in the upper atmosphere.

Table 1

Correlation coefficients for different depressions of the Sun

λ_{eff}, mμ, in determining polarization	λ_{eff}, mμ, in determining transparency	2°	4°	6°	8°	9°	10°	12°
470	445	–	+0.63	+0.87	+0.41	+0.73	+0.81	+0.79
520 or 570	546	+0.61	+0.80	+0.58	+0.41	+0.76	+0.96	+0.57

Table 2

	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°
Morning	0.76	0.73	0.69	0.61	0.54	0.53	0.53	0.53	0.51	0.43	0.34
Evening	0.72	0.72	0.64	0.58	0.55	0.49	0.50	0.48	0.46	0.38	0.28

The conclusion that particles of meteoric dust are present at great heights agrees with the results of observations by other authors. In particular, Hoffmeister [8] considers that meteoric dust is present in the atmosphere at an altitude of 90–180 km.

The depolarization of the light of the daytime sky is fairly well explained by the optical anisotropy of air molecules and by the influence of scattering of higher orders [9]. However, aerosols present in the atmosphere may also exert a depolarizing effect. In this connection, a comparison was made between the degree of polarization of the twilight sky in the zenith and the transparency coefficient. The transparency coefficient was determined by N. I. Ovchinnikova from daytime observations before noon for morning twilight and after noon for evening twilight. Observations were carried out in three spectral regions with effective wavelengths of 445, 546, and 636 mμ.

For different depressions of the Sun, the correlation was determined between the degree of polarization in rays of 470 and 520 or 570 mμ, on the one hand, and the atmospheric transparency coefficient respectively in rays of 445 and 546 mμ, on the other. The values of the correlation coefficient, obtained from 7 or 8 days, with transparency coefficients (from 0.547 to 0.805 for blue rays and from 0.748 to 0.887 for green rays), are given in Table 1.

As is seen from Table 1, a reliable positive correlation is obtained at depressions of 9–10°. At other depressions the correlation is poorer. The result obtained shows that turbidity of the atmosphere reduces the polarization of the light of the twilight sky.

A comparison of the morning and evening values of the polarization of the light of the twilight sky shows that the degree of polarization is, as a rule, higher in the morning,

than in the evening. Table 2 gives the mean values of the degree of polarization in the blue rays, separately for the morning and evening observations, for various depressions of the Sun.

This difference between the morning and evening values of the degree of polarization may be due to the fact that at the Mountain Astrophysical Observatory the transparency of the atmosphere is usually noticeably higher in the morning than in the evening.

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Note: Figure translations are in progress. See original paper for figures.