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Abstract

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EXPERIMENTAL DETECTION OF THE ELLIPTICITY OF THE POLARIZATION OF SCATTERED LIGHT

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1. The degree of ellipticity of the polarization of scattered light, so far as we know, has until now been investigated neither theoretically nor experimentally. At the same time, measurements of this quantity make it possible to increase the amount of information about the properties of the scattering medium; moreover, allowance for the degree of ellipticity is necessary in problems involving multiple scattering of light. The aim of the present work was to obtain preliminary information on the degree of ellipticity of light scattered by the near-ground layers of the Earth' s atmosphere, and on the character of its dependence on the scattering angle.

2. The polarimeter was a theodolite, in the focal plane of whose objective a circular diaphragm with an angular diameter of 6° was placed. Behind the diaphragm there were arranged in succession two rotating frames with a quarter-wave plate (angle of rotation relative to the vertical ψ) and a Wollaston prism, separating the beams by 6° (angle of rotation relative to the vertical χ). In front of the eyepiece, which gave an image of the diaphragm, there was a polaroid (angle of rotation relative to the vertical η) and a broadband SZ S-16 light filter 5 mm thick.

The angles η at which equality of the brightnesses of the two photometric fields situated in the field of view was attained were determined directly for prescribed values of ψ and χ: η_+ for $\psi = +45°$, $\chi = 0°$; η_- for $\psi = -45°$, $\chi = 0°$.

The degree of ellipticity q of the light entering the instrument was found by means of the relation, following from the theory of the instrument' s operation,

$$q = \frac{1}{2}(\cos 2\eta_+ - \cos 2\eta_-). \quad (1)$$

By choosing other values of ψ and χ, it was possible to determine the degree of polarization of the light p and the angle of inclination of the plane of preferential polarization ψ_0 relative to the vertical.

Fig. 1

Figure 1: Fig. 1

3. The measurements were made on moonless nights in the second half of September 1957 in the foothills of the Northern Caucasus. In a rather narrow valley of a stream bordered by hills there was a searchlight (reflector diameter 150 cm, power 11.5 kW), which produced a horizontal light beam directed along the valley. From the outside the searchlight was covered by an opaque mask with a circular aperture 40 cm in diameter, exposing the upper right part of the mirror. At a distance of 1 m from the searchlight there was a polaroid 40 cm in diameter, set into a screen made of black material. Farther on, at a distance of 8 m along the beam, there was a second screen of black material, 5×5 m in size, with an aperture of the same diameter and serving as a diaphragm that rather sharply limited the cross-section of the light beam. At a distance of 12 m from the screen and 2 m from the light beam there was the polarimeter; the beam was viewed at an angle close to the horizon, against the background of hills whose brightness was negligibly small. During the measurements the weather was predominantly damp and overcast, with high atmospheric transparency and, at times, weak radiation fogs at night.

Owing to the relative purity of the air, the scattered light proved to be rather weak, and visual measurements required a long time (obtaining one curve of the dependence of q on the scattering angle θ took ···

about 4 hours) and were not highly accurate (the error in measuring q was ± 0.03).

4. From theoretical considerations it follows ([1]) that if the incident beam is linearly polarized in a plane making an angle ξ with the plane of scattering, then the ellipticity of the polarization of the scattered light will be observed only as a result of scattering by aerosol and will be maximal at $\xi = \pm 45^\circ$; moreover, the relation $q_{\xi=+45^\circ} = -q_{\xi=-45^\circ}$ must hold.

Fig. 1. a–18-19 IX; b–19-20 IX; v–23-24 IX; g–25-26 IX; d–27-28 IX (without fog), $p_\perp = 0.75$, $\psi_{0\perp} = -23^\circ$; e–29-30 IX, $p_\perp = 0.68$, $\psi_{0\perp} = -15^\circ$; zh–30 IX–1 X, $p_\perp = 0.72$, $\psi_{0\perp} = -8^\circ$; z–1-2 X, $p_\perp = 0.76$, $\psi_{0\perp} = -14^\circ$.

Figure 1 collects the measured dependences $q(\theta)$ for $\xi = +45^\circ$ for all cases in which there was no sharply expressed haze. Despite the noticeable scatter of the curves, evidently caused by differences in atmospheric conditions, it is seen that: a) the degree of ellipticity has a distinct dependence on θ, roughly corresponding to $\sim \cos 3\theta$; b) at the extrema $q \simeq 0.1$, i.e., it is by no means small.

Figure 2 shows the dependences $q(\theta)$ for two cases with more or less heavy fog. The region of the rainbow ($\theta = 130$–140°) is clearly expressed, in which $q \simeq 0.5$, as is the change of sign of q in the region $\theta \simeq 40$–90°. The region of the rainbow

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

is sometimes distinguished even in the absence of a clearly expressed haze (see Fig. 1), which indicates the presence in the atmosphere of a coarse-droplet aerosol fraction.

Figure 3 shows the dependences $q(\theta)$ obtained during one night at $\xi = +45^\circ$ and $\xi = -45^\circ$. Some deviation from mirror symmetry is evidently due to changes in atmospheric conditions during the night.

Measurements of the degree of polarization p at $\theta = 90^\circ$ showed that, except for the case of strong haze, when $p = 0.44$, the value of p varied within the limits 0.68–0.76, while the plane of polarization was inclined relative to the vertical by an angle from 8 to 27° counterclockwise.

Fig. 2. a–27-28 IX, strong haze with a rainbow, $p_\perp = 0.44$, $\psi_{0\perp} = -21^\circ$; b–28-29 IX, slight haze, turning into rain, $p_\perp = 0.73$, $\psi_{0\perp} = -27^\circ$

5. The fact of detecting ellipticity of the polarization of scattered light does not represent anything unexpected from the theoretical point of view ([1]). However, establishing the circumstance that q is sufficiently large, clarifying the conditions necessary for measuring q, and finding the character of the dependence $q(\theta)$ are essential from the point of view of further studies in the field of light scattering, especially by colloids and aerosols. In particular, the possibility of obtaining information pertaining separately to the non-Rayleigh component of scattered light is very important, since for the Rayleigh component $q = 0$. It must be assumed that study of the angular and spectral dependence of q will make it possible substantially to expand the amount of information about the scattering medium and will help substantially to advance the development of experimental methods for solving the inverse problem of scattering theory, i.e., optical methods for determining the structure and properties of the scattering medium.

Fig. 3. Night of 1-2 X. a–$\xi = +45^\circ$, b–$\xi = -45^\circ$, $p_\perp = 0.76$, $\psi_{0\perp} = -14^\circ$

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CITED LITERATURE

1. G. V. Rozenberg, *Uspekhi fizicheskikh nauk*, **56**, no. 1, 77 (1955).

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