ON THE OPTICAL POLARIZATION OF THE WHITE-LIGHT CORONAL STRUCTURES

B. P. FILIPPOV¹, M. M. MOLODENSKY¹ and S. KOUTCHMY²

¹ Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation
Russian Academy of Sciences, 142092 Troitsk, Moscow Region, Russia

² Institut d’ Astrophysique de Paris, CNRS, 98 bis Bd Arago
F-75014, Paris, France

Abstract. A special experiment was designed to measure the orientation of the polarization plane in the solar corona during the total eclipse of July 11, 1991. Rotating polaroids with the axes directed at +45° and at −45° of the radial direction in all directions were used. The polarization plane was found to be tangential to the solar limb everywhere with an accuracy within 1°, in agreement with the Thomson scattering theory.

Key words: Sun – Solar Corona

Koutchmy (1972) put into practice for the first time the new method of polarization measurements in which two circular rotating sector analyzers were used to increase the accuracy of polarization analysis. Molodensky (1973) proposed to modify the method of Koutchmy by rearranging the polaroid axes symmetrically by the angle $\varphi$ to the sector central radii; the intensity difference in each point of two images of the corona would then be equal to zero in the case of absence of deviations from tangential directions ($\alpha = 0$); in the other cases ($\alpha \neq 0$):

$$\delta I = I_\varphi - I_{-\varphi} = 2I_p\alpha \sin 2\varphi,$$

(1)

where $I_p$ is the intensity of polarized light. This difference has maximum at $\varphi = 45^\circ$, the angle corresponding to the best arranged polaroids. Taking into account the finiteness of $\beta$, the sector angle of analyzer, the eq. (1) in the case of $\varphi = 45^\circ$ should be replaced by (Molodensky, 1973)

$$\delta I = 2I_p\alpha \frac{\sin \beta}{\beta}.$$

(2)

As $\delta I$ is proportional to the deviation angle $\alpha$ it is enough to use the photographic subtraction of two images. The inequality of intensities immediately gives us the evidence of a deviation of the polarization plane from the tangential direction. Keeping in mind that the regions differing in intensity by 1\% can be quite easily distinguished.


© The Astronomical Institute, Slovak Academy of Sciences • Provided by the NASA Astrophysics Data System
and taking a polarization degree of $P = 50\%$ we obtain from eq. (2) $\alpha \approx 0.25 \div 0.5$, which is the typical sensitivity we reached using this method. A setup based on this method was made to observe the eclipse of July 11, 1991. The telescope had a 15-cm

![Image](image_url)

**Figure 1.** The solar corona of July 11, 1991. Pair of pictures with polarization axis oriented at $+45^\circ$ and $-45^\circ$ of the radial direction and obtained with an exposure time of 45 seconds.

lens with a focal length 225 cm and it was put on an equatorial mount. An opaque disk in which narrow sector had been cut and covered with a polaroid film was placed in front of the plate. The aperture of the disk did not have the form of a sector but of a figure that compensated for the decrease of the coronal brightness from the limb, so it played the role of a radial filter.
The observations were made in La Paz, Baja California Sur, Mexico. One pair of the pictures of the corona is shown in Fig. 1. The spatial resolution on the negative is about 10″. The difference between the pictures $\varphi = +45^\circ$ and $\varphi = -45^\circ$, obtained by photographic subtraction, is shown in Fig. 2a. In Fig. 2b the result of subtracting of the negative and of the positive of the same picture is also shown. On both figures, some traces of the coronal image can be recognized. This is due to (i) errors in the photographic subtraction, because of not very precise fulfillment of the condition $\gamma = 1$ on duplicates, (ii) the use of the nonlinear part of the emulsion characteristics (inevitable in spite of the use of the radial filter), (iii) difficulties in the accurate
Figure 3. Photometric curves. (1) difference of the negative and the positive of the fan of polaroid films, (2) variations of optical densities when the polarization plane is turned at ±2°, (3, 4) photometric cross-sections of Figs. 2a and 2b, respectively.

superposition of the contratypes, (iv) small differences in position of polaroid axis of rotation relative to the center of the solar disk for the pictures \( \varphi = +45^\circ \) and \( \varphi = -45^\circ \).

To calibrate the results the images of a source of light with a known polarization were made. A fan of polaroid film strips was placed in front of an opal glass which diffused the light of a point source. The strips were snipped off from a film along the transmission axis and by angle 2°, 4° and 10° to it. With the help of an additional objective, the image of the fan was projected on the focal plane of the setup. Then, the same procedure of photographic subtraction was used (see the results in Fig. 2).

Fig. 3 shows the results of photometry of the photographic differences. Curve 1 corresponds to the subtraction of the negative and the positive of the same picture of the fan and it defines the “noise level”. Curve 2 demonstrates the change of optical density when the polarization plane is turned by ±2°. Curves 3 and 4 show the photometric cross-section of Figs. 2a and 2b correspondingly along the lines being shown there. The comparison of these curves shows that in the corona of July 11, 1991 there were no deviations of the polarization plane from the tangential direction by more than 1°.

References

Koutchmy, S.: 1972, These d’Etat, Paris University, C.N.R.S. 407179