9.3 Imaging Polarimetry of the Solar Corona During the Total Solar Eclipse on 11 August 1999

The observation and investigation of the solar corona has a great popularity both in the scientific and amateur astronomy since the characteristics of the corona allows for conclusions regarding the solar activity, and thus the details of the predictions for sun models derived from different theoretical calculations and numerical simulations can be tested. The light of the corona is scattered sunlight: Thomson scattering takes place on free electrons surrounding the sun like a cloud. The corona visible in the neighbourhood of the sun from the Earth's surface during total eclipses, or through coronographs of high altitude astronomical observatories or satellites has been the subject of many investigations (e.g. Newall 1906; Sivaraman et al. 1984; Gabryl et al. 1998). The scattered corona light is highly polarized with E-vectors approximately perpendicular to the radii from the solar centre. The maximum degree of polarization p is about 40% at a distance of a quarter of the solar diameter from the edge of the sun (Können 1985). Farther away p gradually decreases. Taking the corona as a whole, the directions of polarization more or less neutralize each other with the result that the total radiance is very weakly polarized, if at all. On the basis of the polarization pattern of the solar corona the astronomers and solar physicists can calculate the electron density around the sun (e.g. Sivaraman et al. 1984), which is an important parameter in solar physics. The net p of the corona, if not zero, is also an important quantity characterizing the solar atmosphere. Since the polarization pattern of the solar corona changes from eclipse to eclipse, and may vary also during a given eclipse, it is always worth to measure these patterns and to compare them with each other. These patterns are an important part of the data basis related with the history of the sun.

Taking a pair of photographs of the solar corona through two linearly polarizing filters, the transmission axes of which were perpendicular to each other, Können (1985, p. 39, Plates 16 and 17) demonstrated that the solar corona is polarized. Other authors (e.g. Sivaraman et al. 1984; Gabryl et al. 1998; Horváth et al. 2001) have imaged the polarization pattern of the corona in form of high-resolution maps of the spatial distribution of the degree and angle of linear polarization of the corona light. Recently, Horváth et al. (2001) have studied the polarizational characteristics of the corona during the total eclipse on 11 August 1999 in Kecel (46°32'N, 19°16'E, Hungary). Using rotating-analyzer video and photo polarimetry, they measured the polarization pattern of the corona at 650, 550 and 450 nm. In this chapter some of their results are presented.

Figures 9.3.1A-C show the picture of the corona and the spatial distribution of p and α of corona light measured by rotating-analyzer photo polarimetry at 550 nm. The polarization patterns were quite similar at 650 and 450 nm (Fig. 9.3.1D). In the immediate vicinity of the sun the photoemulsion was overexposed, while at the periphery of the pictures the film was underexposed. In these over- or underexposed areas the evaluated p- and α-values are false. This is the reason for the random distribution of p and α at the periphery of the patterns. There is a relatively narrow annular zone around the solar disc where the radiance of the corona is neither too high nor too low. p and α of corona light can be evaluated only within this annular region, which could be made wider with the use of a grey filter, the rotation symmetric absorption of which decreases from the centre to the periphery in a similar way as the radiance of the corona decreases radially.

Figure 9.3.1D shows the radial change of p of corona light along a relative radius ρ directed at an angle $\beta = 185^{\circ}$ clockwise from the vertical measured at 650, 550 and 450 nm, where ρ is the quotient of the radius r measured from the solar centre and the radius r_{sun} of the solar disc. We can see that, depending slightly on the wavelength, the maximum of p is about 30-35% at a relative radial distance of about $\rho = 1.70\text{-}1.75$. Figure 9.3.1E represents the tangential change of α of the corona light along a circle shown in the inset measured at 650, 550 and 450 nm. Here we can see that α depends slightly on wavelength and the E-vectors of corona light are approximately perpendicular to the radial direction. The slight tangential change of α is due to the non-homogeneous structure of the corona.

Analysing qualitatively Fig. 9.3.1, we can establish the following: The light of the solar corona is partially polarized, and the polarization pattern of the corona possesses approximately a rotational symmetry. The polarizational characteristics of the corona are practically independent of the wavelength in the visible part of the spectrum. p first increases from zero with the radial distance from the solar disc, then reaches its maximum, and decreases gradually to zero. The E-vector alignment of corona light is approximately tangential with respect to the centre of the solar disc. In August 1999 the activity of the sun was high. Therefore the structure of the solar corona was relatively homogeneous and rotation symmetric, which is clearly seen in Figs. 9.3.1A-C.

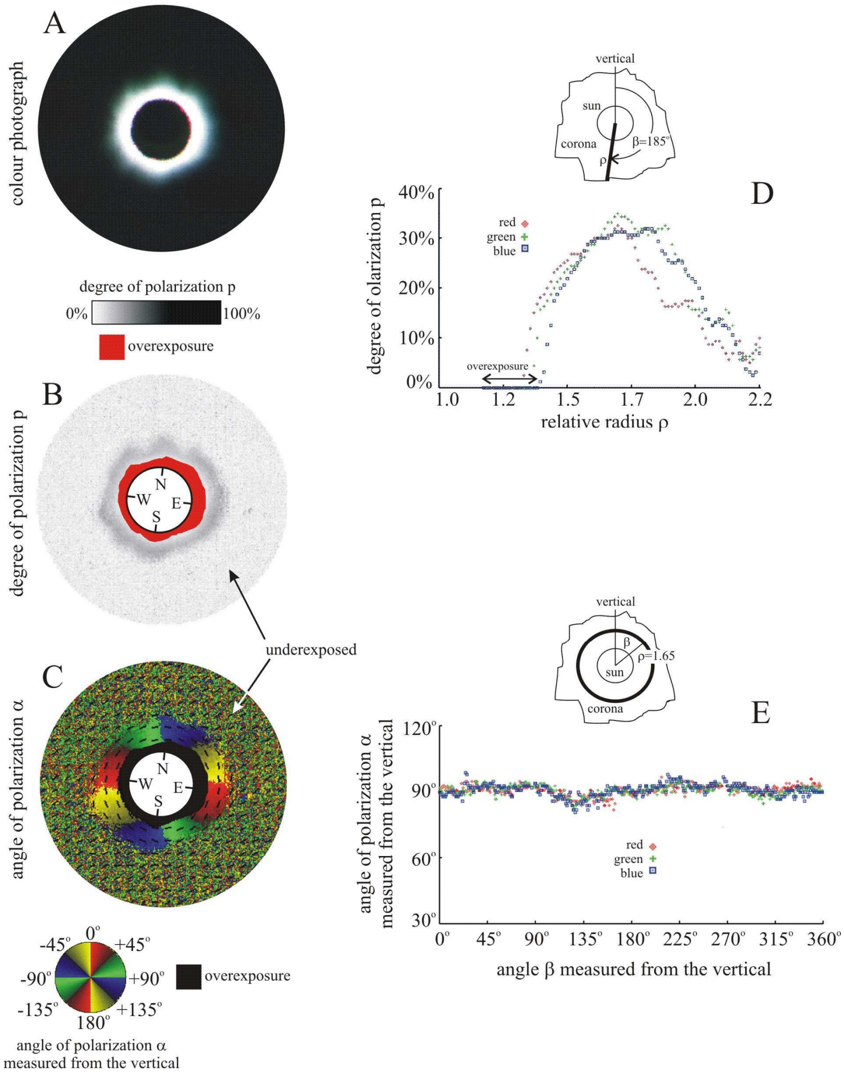

Fig. 9.3.1. A: Photograph of the solar corona taken during the total solar eclipse on 11 August 1999 in Kecel (46°32'N, 19°16'E, Hungary). B, C: Patterns of the degree of linear polarization p and the angle of polarization α measured at 550 nm with rotating-analyzer photopolarimetry. α is measured from the vertical. The black bars in the α–pattern show the local directions of the E-vectors. The obscured solar disc is replaced by a white disc, in which the North and South poles of the sun are marked. D: Radial change of p of the corona light along the radius (thick line) shown in the inset measured at 650, 550 and 450 nm. $\rho = r/r_{sun}$ is the relative radius, where r is the radius from the center of the sun and r_{sun} is the radius of the solar disc. E: Tangential change of α of the corona light along the circle shown in the inset (thick line) measured at 650, 550 and 450 nm. (After Fig. 5 of Horváth et al. 2001, p. 237).