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Eclipse Polarimetric Research of Prominences

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Abstract. A polarization analysis of E-limb prominences on November 3, 1994 is presented. Photometry and data reduction of 24 prominence pictures based on IDL software and Stokes-vector presentation and applied to H_α emission resulted in an accuracy of 1–1.5% in determination of the polarization degree and of 1.5–2.0° in the polarization direction. Distributions of polarization degree (polarization images) for prominences and the "white light" corona are presented. A polarization degree of 2–5% for prominences and 10–25% for the nearby white light corona are found. The polarization direction is found to be tangential to the solar limb. It is noted that eclipse observations can provide a powerful method for deriving the magnetic field at high altitudes in the coronal volume.

1. Introduction

Polarimetric research of prominences is very important for knowledge of the magnetic field structure which is the main parameter determining the prominence phenomenon. Until now prominence magnetic measurements based on the Zeeman and on the Hanle effects are very complicated even if a large coronagraph is used as the optics feed. Significant improvement of the signal-to-noise ratio is needed. Below, an attempt of polarimetric observations of prominences during totality of a solar eclipse is presented.

An eclipse color index polarization wave experiment carried out in Brazil (town of Criciuma) during the total solar eclipse of November 3, 1994 was aimed at polarization research within the innermost regions of the corona including prominences. Details of a portable coronagraph-polarimeter (D=55mm, 1:6) attached by a rotating polarizer placed in the plane of the Lyot stop have been given elsewhere (Kim et al. 1997). 1250 color negatives were obtained during the totality of 244 sec.

Below, the results of data reduction made by PDS through the color filter (λ_{max}=440nm, FWHM=20nm) of 24 frames exposed just after the second contact are presented. Photometry through the above–mentioned filter selects mainly densities caused by "red" emission. Digitizing was made with a pixel size corresponding to 6 × 6 arc sec on the film. The smoothing based on a moving-average method resulted in an angular resolution better than 18 arc sec for densities of 0.3 and more, and an accuracy of 1–2% for the polarization degree.

It is known that color eclipse pictures of the white light corona show prominences as red in slides or green in negatives. The color is caused by the prominence spectrum consisting of HI, HeI, HeII, etc. lines. As a rule the color of prominence images is mainly caused by dominant H_α emission. A detailed description of one of the eclipse color white light corona and prominence pictures was given by Leroy (1966). Employment of color film results in filtration due to the 3 layers sensitive to the blue, green and red emissions. Let S_λ be the spectral sensitivity of the "red" layer of the film used, $B_\odot$–the brightness of the Sun's center, B_{wc} –the brightness of the "white light" corona, $B_{H\alpha}$–prominences brightness in the H_α line. The spectral sensitivity S_λ of the "red" sensitive layer may be approximated by a Gaussian with a FWHM of 750Å. On average $B_{wc} \approx 10^{-6} B_\odot$ at distances R less than $1.2R_\odot$. The prominence brightness in the H_α line is $(10^{-2} - 10^{-1})$Å$\cdot B_\odot$. Then the contrast (C) of "prominence–to–corona" images recorded by the "red" sensitive layer may be described by the expression

$$C = \frac{B_{H\alpha}}{\int_{550nm}^{710nm} B_{wc}(\lambda) S_\lambda \, d\lambda} \approx 13 - 130.$$

The polarization degree of the white light corona does not exceed 25% at $R < 1.2R_\odot$ while the prominence brightness equals 13–130 of the corona one. That means that the input of the "white light" corona in polarization degree measurements at the location of prominence does not exceed 2–0.2%, respectively.

2. Data Reduction

Details of the photometry, data reduction and the algorithm of the statistical processing were presented recently (Kim et al. 1996, Belenko et al. 1997). Stokes–vector presentations and IDL software were used for the analysis. After coaligning the 24 frames, the averaged density image $\mathbf{D} \equiv$ D(i, j) is created, where i, j are integer rectangular coordinates of pixel images while the point of reference is at the center of the Sun. The distribution of densities in this frame is used as a noise level indicator in statistical procedures of the polarization map of the object under study. $\mathbf{S}_k$–intensity frames resulting from density images contain information about the distribution of polarization parameters, which could be extracted as a result of statistical processing.

24 equations for every (i, j) pixel can be written using the 24 consecutive frames

$$S_k \equiv S_k(i,j) = I + Q' \cos\frac{\pi k}{12} + U' \sin\frac{\pi k}{12}, k = 0, 1, \ldots, 23,$$

where vector (**Q',U'**) is related to (**Q,U**) by a $2\alpha_0$ rotation, where α_0 is the position of the plane of polarization in the first frame.

3. Results

Figure 1 shows a computer half–tone "polarization image" (distribution of polarization degree) of E–limb prominences imposed on the white light corona. It looks similar to a conventional coronal image revealing a high polarization of the white light corona and the regions of prominences near the Moon's limb, where the degree of polarization varies from 2 to 5% in the prominences. The polarization for the prominences is found to be tangential to the solar limb within the limits of errors.

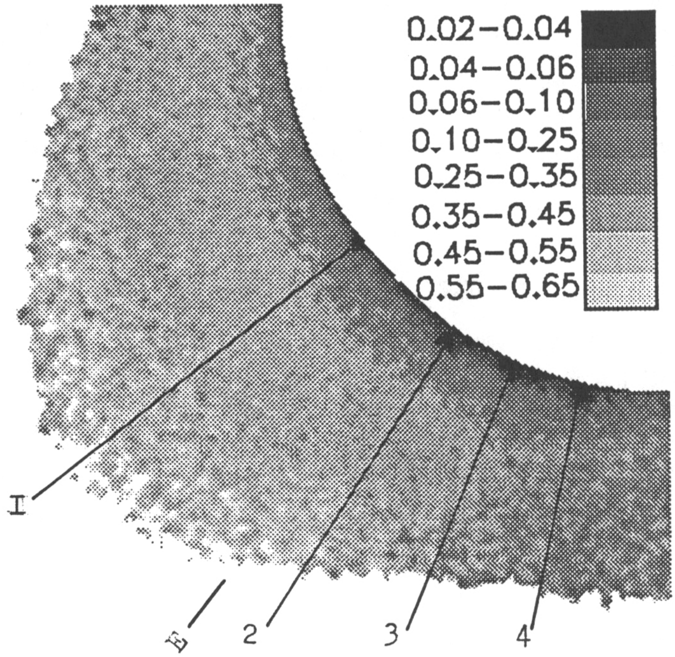

Figure 1. A computer half–tone "polarization image" (distribution of polarization degree) of E–limb prominences imposed on the white light corona.

The averaged value of the polarization degree and deviations within the prominences are presented in Table 1.

4. Conclusions

The polarization degree for the E–prominences of November 3, 1994 are found to be 2–5%. Within the limits of errors the polarization direction is tangen-

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Table 1.

N	Position Angle	Height	Polarization Degree
1	74.9^0	26″	$4 \pm 2\%$
2	93.5^0	34″	$3 \pm 2\%$
3	105.3^0	32″	$4 \pm 2\%$
4	116.8^0	52″	$5 \pm 3\%$

tial to the solar limb. It should be noted, that the above–mentioned analysis was applied to non–filtered, low–resolution, and small–scale prominence images. During totality of solar eclipses the sky brightness is reduced by 2–3 orders of magnitude, resulting in a significant improvement of the signal–to–noise ratio. A polarization analysis of filtered, high–resolution, and large–scale eclipse prominence images in the light of different lines (H_α, H_β, ... and D_3 or 10830Å) [Bommier et al. 1985, Leroy 1985, Landi Degl'Innocenti 1986] could provide reliable polarimetric data to deduce the magnetic fields at high altitudes in the coronal volume.

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