ASTRONOMY AND SPACE SCIENCE
eds. M.K. Tsvetkov, L.G. Filipov, M.S. Dimitrijević, L.Č. Popović,
Heron Press Ltd, Sofia 2007

Preliminary Results for Corona Polarization during Total Solar Eclipse on March 29, 2006, Observed in Side, Turkey

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Abstract. The preliminary results of the white-light polarization measurements performed during the March 29, 2006 total solar eclipse are presented. Three series of pictures by three different objectives with rotating linear or circular polarization optics, and two types of photographic cameras – analogous and digital – are taken. Distribution of the intensity of the polarized solar corona is obtained. The results for the degree of the corona polarization are comparable with the data for the solar cycle minimum. Short analysis of the images and discussion for the future processing and calculation are given.

1 Introduction

The investigation of the white-light corona polarization is one of the main tasks during the total solar eclipses. That is why the eclipse is the unique opportunity to measure the polarization of the corona larger than 1.3 solar radii ($R_\odot$) up to $5R_\odot$, *i.e.* in the middle and outer corona. When one uses different exposures it is possible to cover large scale of intensities from the most intensive inner corona (short exposure times) up to outer coronal layers where the intensity is rather faint and one has to use long exposure times.

A simple method of polarimetry is usually used to obtain information about different kind of physical characteristic of the corona.

First, this is the "separation" of the two components of the white-light corona: K- and F-corona. In the K-corona the white light radiation emerging from the solar disk is scattered by electrons in higher layers of solar atmosphere, while in the F-corona the photosphere light is scattered by dust particles. The effect of the radiation scattering by the free electrons is accompanied by polarization of the radiation. In the results the K-corona radiation is polarized versus the nonpolarized light of the F-corona.

This way the polarization measurements complement the photometric investigation of the coronal brightness at a number of points.

They are necessary for constructing any models of the corona. The basic results from polarization measurements are the degree of polarization and concentration of the matter because the level of scattering strongly depends on the electron density distribution.

Taking into account some vertically structured symmetric model of the electron density distribution one can compare the results of measuring the linear polarization, deduce, and specify its validity, especially as concerns its symmetry, dependence on height in the solar corona, inhomogenities, *etc.* [5]

Mainly, Van de Hulst 's integral equations and the model are used to characterize the electron density distribution problem.

Usually the distribution of coronal density can be derived by measuring the surface brightness of the K-corona versus the distance from the sun's centre.

The polarized brightness, pB, represents an independent source in determining the radial variations of coronal density. Structural features of the corona (helmet, streamers, coronal holes, *etc.*) are displayed in the qualitative representation of isolines of polarization (isoplets) almost as well as they are in the pictures of the corona taken through a neutral radial density filter.

In addition, the intensity of the radiation at a given point of the corona characterizes the total amount of coronal matter in a column along the line of sight, which is why one has to make certain assumptions about the dimension L of the structure along the line of sight in constructing a model. The degree of polarization p has proved to be sensitive to the extent of concentration of the coronal gas in the plane of the sky. In other words, the investigation of the quantities p together with B imposes particular limitation on the quantity L [1].

Thus, the investigation of the polarization can hopefully be informative in studying some structures in which the assumption of spherical symmetry can no longer be applied. Primarily this relates to the streamers in the middle and outer corona. The polarization data can also be useful for analyzing coronal holes and other large-scale coronal structures.

The polarization measurements during the different eclipses help us to follow the physical characteristics in the corona depending on solar cycle.

In the period of minimum solar activity the coronal plasma concentrates at equatorial latitudes, while in the period of the solar cycle maximum the density distribution more or less follows the spherically symmetric model of the corona with its typical circular isophotes.

The change of the shape of the isophotes itself represents a certain manifestation of the large-scale global structure of the coronal magnetic fields. A number of structures (helmet, streamers, coronal holes, *etc.*) are visible on pictures of the corona taken at different phases of the solar cycle. The picture manly shows the features located in the plane of the sky, and the fluctuations of brightness correspond to the variations of the plasma density close to that plane. Isophotes characterizing the solar corona in the period of the solar maximum reflect the above-mentioned features poorly because of their low contrast.

2 Observation

For observation of Total solar eclipse on March 29, 2006, the common expedition of Institute of Astronomy, Bulgarian Academy of Science (IA,BAN), and Sofia University (SU) chose town of Side, Republic of Turkey ($j = 36°47'00''.6N$, $l = 31°24'02''.6E$). The altitude above the see level was about 20 m. The total eclipse was observed from 10:55:00 UT to 10:58:45 UT. The duration of the totality was 3 min and 44 sec. The observations were performed under good weather conditions with some cirrus clouds.

Many experiments were carried out. One of them was polarization observation of the white-light corona. The aim of this task was the measurement and absolutely calibration of the polarization degree of the corona up to 5 solar radii and was performed in closed cooperation between the teems from Institute of Astronomy, BAN, and Astronomical observatory, Youth center – Haskovo, by leadership of Joanna Kokotanekova.

To receive images of the polarization solar corona were used three sets of instruments:

1. Telescope-refractor “Telementor” $63/840$, linear polarization filter and photographic camera Praktica with B/W negative film Ilford 50 ASA

The pictures with telescope $63/840$ were taken by J. Kokotanekova (IA, BAN) with exposure $1/125$, $1/60$, $1/30$, $1/15$ and 1 sec to cover the whole scale of the photographic density differences between the inner and outer corona.

2. Tele-objective $5.6/500$, linear polarization filter and photographic camera Praktica with B/W negative film Ilford 50 ASA.

These pictures were taken by G. Kokotanekov (Astronomical Observatory, Youth Center, Haskovo) with exposure $1/250$, $1/125$, $1/60$, $1/30$, $1/15$ and 1 sec.

3. Tele-objective $2.8/200$, circular polarization filter and digital camera Canon EOS 350D.

C. Paronova (Astronomical Observatory, Youth Center, Haskovo) took the pictures with exposure $1/500$, $1/125$, $1/60$, $1/15$, 1 sec and 100 ISO speed ratings.

In all three cases the polarization optic was placed in front of the lens and three position angles in distance of 60 degrees of it were fixed corresponding to every exposure times. In order images to be calibrated absolutely some minutes before and next the eclipse on the negatives were taken the Sun.

Later on one of the films was printed photographic calibration edge. That is possible because of using the same films from the same batch.

The two films were developed in National astronomical observatory – Rozhen (NAO-Rozhen), BAN by the same technique and method. The images were digitized with microdensitometer “Joyce-Loebl” in NAO-Rozhen with 50×50 mm square pixels and simple step of scanning 40 mm.

Besides, unpolarized pictures of the white-light corona were obtained with many long-focus cameras during the same expedition.

3 Results and Discussion

The white-light corona pictures for three positions of polarizing filter, taken with telescope-refractor $63/840$ and 1 sec exposure are shown in Figure 1.

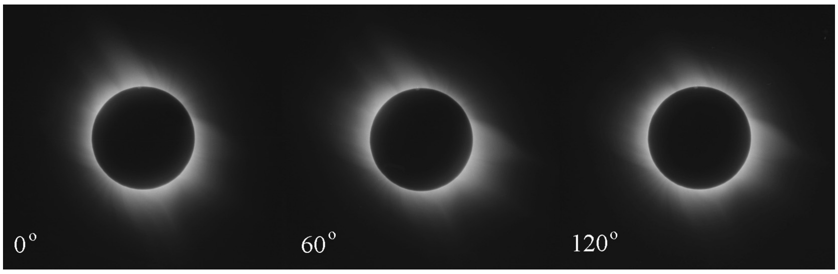


Figure 1. Pictures of 29.03.2006 white-light solar corona for three positions of polarizing filter, taken with telescope-refractor $63/840$ and 1 sec exposure.

Figure 2 is composite image of above pictures (every one of them in different color) and it demonstrates the differences between corona images for the three polarimeter positions.

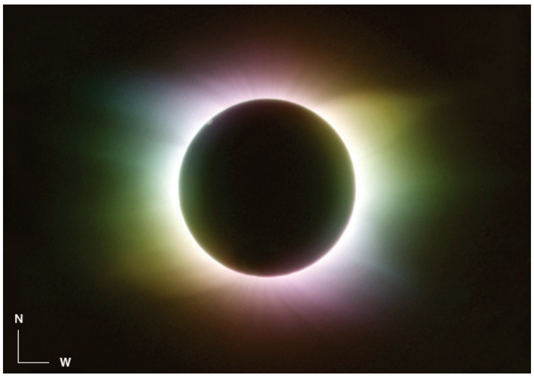


Figure 2. Composite image for three polarimeter positions with 1 sec exposure.

To determine of the polarization of the solar corona we use the well known method based on photographing of the solar corona by three positions (0°, 60° and 120°) of the linear polarization filter. If Θ is the angle of polarization of corona radiation and $I_0 = I_A$, $I_{60} = I_B$ and $I_{120} = I_C$ are the intensities of radiation corresponding to the three positions of the Polaroid ([3]), than:

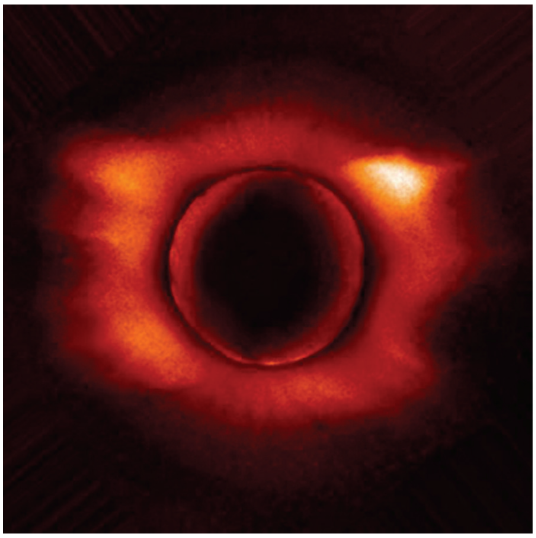
$$\Theta = \frac{1}{2} arccot \frac{2I_A - I_B - I_C}{\sqrt{3}(I_B - I_C)}$$

and

$$I_P = \frac{4}{3}[(I_A + I_B + I_C)^2 - 3(I_A I_B + I_A I_C + I_B I_C]^{\frac{1}{2}},$$

where I_P is the degree of polarization of the corona in that point.

After processing of the observing material from Figure 1 we deduced the next image (Figure 3) which demonstrates the distribution of the polarization light in the solar corona. The brighter areas in the corona correspond to the higher polarization.



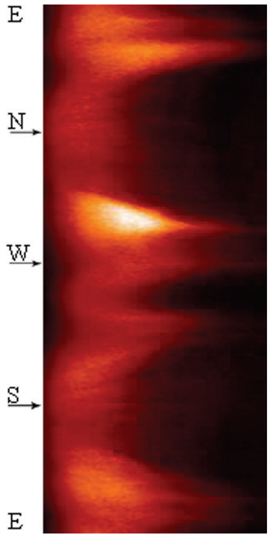


Figure 3. Images of polarized solar corona from 29. 03. 2006 in rectangular (a) and in polar coordinates (b)

Distribution of polarized brightness was obtained for the March 29, 2006 solar corona, too. Graphic image (isophote map) of the polarized corona of Figure 3 with the data for the degree of polarization respectively is presented in Figure 4.

The polarization reaches 40%. The value is comparable with the results for the solar cycle minimum from other authors [4]. Isophotes do not have circular shape, typical for the period of the solar cycle minimum. A variety of structural features are distinctly seen in the distribution of the polarization. Here the maximum of polarization is connected with the helmet streamers in NW direction.

This image also shows that the local maxima of the degree of polarization outline distinctly the region related to the coronal structures at heliocentric distances

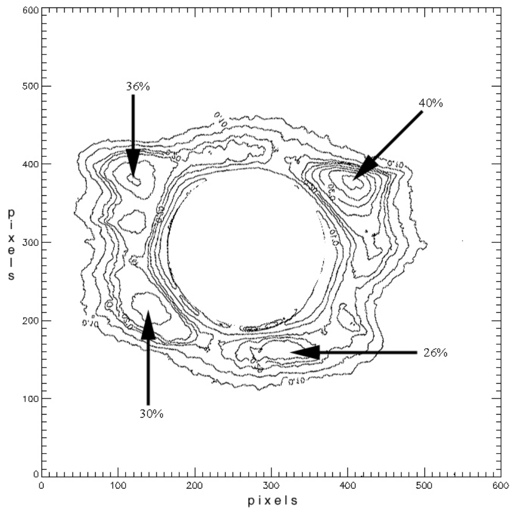


Figure 4. Isophote map of the polarized corona.

larger than $1.3R_{\odot}$. That also can be seen from Figure 5, which is the composite image from white-light corona (taken with $5.6/500$ tele-lens and 1sec exposure by G. Kokotanekov) and isophote map (Figue 4).

We have investigated the behavior of the polarization depending on heliocentric distance. The radial distribution of the degree of polarization in different directions and coronal structures is shown in Figure 6. In the results we can conclude that the polarization is different both as a degree and as a radial distribution. In the polar areas (1) the degree of the polarization reaches just about 20% on distance around 1.2–$1.4\ R_{\odot}$. In the equatorial plane (2) the maximum polarization

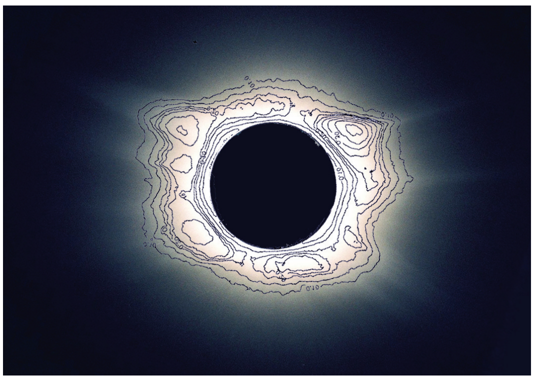


Figure 5. Composite image from white-light corona and isophote map.

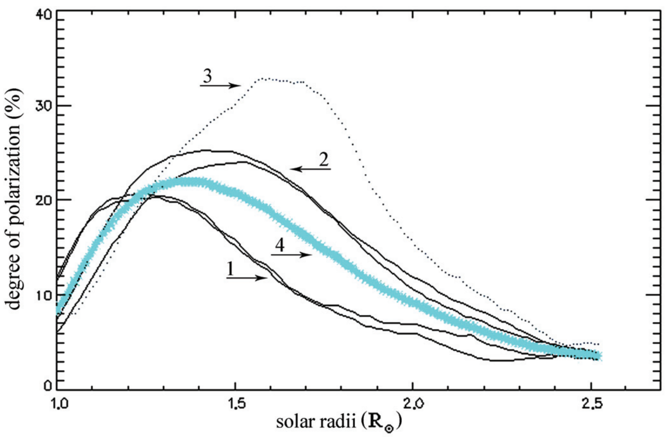


Figure 6. Radial distribution of the degree of polarization.

is 25% at $1.5\ R_\odot$. Maximal value the degree of polarization reaches in the coronal streamers (3) – mean 35% and in the same time the maximum is at distance about 1.6–1.7 $R_\odot$. The blue line (4) demonstrates the total distribution of the polarization, deduced from the image in polar coordinates (Figure 3b). These results are in good agreement with the date from other eclipses [1], [2].

4 Conclusions

Here we represented the results only from one series of pictures taken with equal exposure and three position of linear polarization filter by one instrument. The preliminary results are a good start for the future processing of all deduced pictures. Comparison of the data for all exposure (all distances in the corona respectively), instruments, and negative and digital pictures is coming. The electron density and its distribution in the corona will be obtained. The analysis of the data will show if the corona polarization during the March 29, 2006 eclipse is in good agreement with previous results and theoretical models.

Acknowledgments

The expedition of Institute of Astronomy, BAN, was financial supported by CNSys Computers & Networking, TeKo Telecommunication Company, Sofia, and particularly supported by National Scientific Foundation under Grants F1510/2005 and D0-406/2005.

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