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POLARIZATION OF WHITE-LIGHT SOLAR CORONA AND SKY POLARIZATION EFFECT DURING TOTAL SOLAR ECLIPSE ON MARCH 29, 2006

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SUMMARY: Ground-based total solar eclipse observations are still the key method for coronal investigations. The question about its white-light degree of polarization remains unanswered. There are hypotheses claiming that the degree of polarization in certain regions of the corona may be higher than the maximal theoretically predicted value determined by Thomson scattering.

We present polarization of the white-light solar corona observations obtained by three different teams during the March 29, 2006 solar total eclipse. We give an interpretation on how the polarization of the sky impacts brightness of the polarized solar corona, depending on the landscape during the totality. Moreover, it is shown that the singular polarization points of the corona are in linear dependence with the height of the Sun above the horizon.

Key words. Sun: corona – Polarization

1. INTRODUCTION

The investigation of polarized white-light total solar eclipse (TSE) observations offer a way to solve problems connected with the physics of the corona. Theoretical considerations require a knowledge of the polarization both as a function of the distance from the solar limb and as a function of the wavelength (Cohn 1938). Comparisons of results with distributions found by other authors allow estimation of the real accuracy of measurements of the white-light corona polarization, which is not worse than ±5% (Badalyan et al. 1997). The result is in accordance with previous reports (Petrov et al. 2010, Kokotanekova et al. 2007).

Polarization of coronal structures up to 6 solar radii can also be explored apart of TSEs. (Gulyaev et al. 2004). We can assume that scattered or reflected parasitic light is removed if such observations are taken at twilight.

Nowadays, there are hypotheses claiming that the degree of polarization in certain regions of the corona may be higher than the maximal, theoretically predicted, value for polarization by Thomson scattering (Molodensky 1973). This fact was first revealed by Nikolsky and Sazanov (1970) as a result of photometric measurements of the eclipse occurred on September 22, 1968, and supported by Koutchmy and Schatten (1971) and Sazanov (1973).

Molodensy and Starkova (1996) showed that two singular polarization points arise in the plane of the sky when the polarization of the auroral ring is taken into account. Using their analysis of the eclipse from March 29, 2006, Koutchmy et al. (2006) identified these points in the corona in the northeastern and southwestern directions.

As of the total solar eclipse in 1871 we know that the light from the solar corona is strongly polarized. Schuster (1879) suggests that the degree of polarization is due to the scattering matter in the solar corona. The question whether this matter originates from the Sun or it is a result of accretion remains open since Schwarzschild in 1905 claims that polarized light in the solar corona occurs from Thomson scattering by free electrons (Ney et al. 1961). This explanation for the coronal light polarization leads to the prediction that the direction of the E-vector in the electromagnetic wave should be tangential to the center of the solar disk or that the H-vector in the electromagnetic wave should be in the radial direction ("the radial polarization") (Ney et al. 1961). Investigation of the polarization in the coronal FeXIV 530.3 nm, shows that the plane of polarization (H-vector) significantly deviates from the radial direction (Badalyan et al. 2002).

Some anomalies in values of the degree and angle of polarization are the reason to continue looking for answers to the questions on physical mechanisms that define their nature. In this paper we present the position of singular polarization points in the solar corona as determined by three different observational teams situated on different locations. Our results on influence of the auroral ring on boundaries of the K and F components of the solar corona are shown.

2. OBSERVATIONS AND RESULTS

Since the K-corona emission is a result of scattering of photospheric photons on free electrons of the ionized coronal plasma, this emission is linearly polarized with the plane of polarization being tangential to the limb (Molodensky et al. 2009). Observations often show deviations or anomalies in estimated values. The method proposed by Molodensky et al. (2009) suggests the influence of the auroral ring as the main factor for detected anomalies. The technique consists of different overlapping images made with various positions of the polaroid. The singular polarization points show where the intensity of the K-corona equals the sky polarization emission. Their distance from the solar limb traces the effective boundary of the sky radiation influence. Within this limit we can receive reliable results on the influence of the sky radiation on the plane of the polarized corona. Outside the boundaries such corrections cannot be used due to the low signal/noise ratio. Similar experiments are held using data from TSE 1994, 1997, 2006 and 2008 and they show that Sun's altitude above the horizon during TSE is the key factor that effects the distance between the singular polarization points and the center of the solar disk.

To confirm previous conclusions, we show singular polarization points determination during the 2006 TSE obtained by three observational squads. Different teams from France, Bulgaria and Russia situated on different locations along the totality path participated in the experiment (Fig. 1). The latitude of the Sun during the totality for different locations is: 61°.6 (Egypt), 54°.1 (Turkey) and 41°.7 (Russia).

The Russian expedition organized by the Institute of Terrestrial Magnetism, the Ionosphere, and Radio Wave Propagation aimed to obtain polarization images of the white-light corona during the total solar eclipse on March 29, 2006. The imaging was carried out by a telescope with $D = 75$ mm, $F = 750$ mm, using a Moskva-5 camera with a 60×90 mm frame. The images were taken on the Kodak Professional Royal Supra 400 VC colour negative photographic film. The Bulgarian expedition was organized by the Institute of Astronomy and NAO, BAS. The observations were carried out by a telephoto lens 5.6/500, linear polarization filter and photographic camera Praktica with B/W negative film Ilford 50 ASA with a 24×36 mm frame. The French team used digital cameras. To analyze the polarization of the corona, it is sufficient to have a set of polarization isophotes for each polaroid position or to construct a map of the angle and degree of polarization at each point. On such a map that Koutchmy (Molodensky et al. 2009) found an area with zero polarization within the measurement errors. Fig. 2 shows the positions of the singular points in the corona from the 2006 TSE after processing.

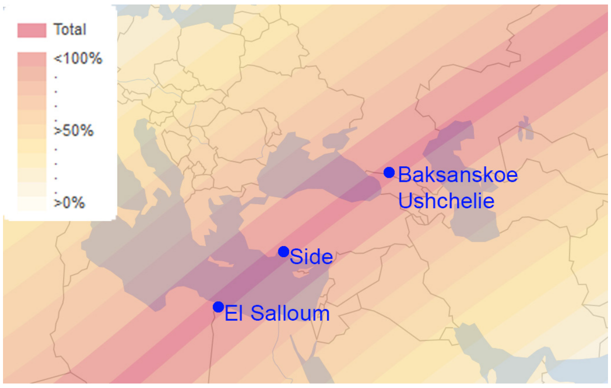

Fig. 1. *Map of totality during the TSE on March 29, 2006 (credit: timeanddate.com). Blue points are positions of the observers as follows: El Salloum, Egypt - French team; Side, Turkey - Bulgarian team; Baksanskoe Ushchelie, Russia - Russian team.*

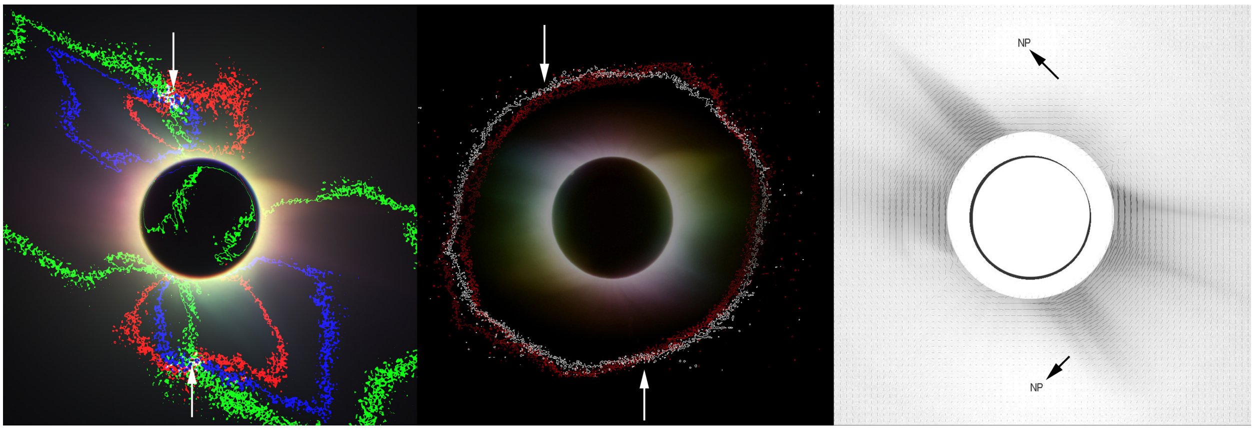

Fig. 2. *The arrows mark the positions of singular polarization points in the solar corona during the total solar eclipse on March 29, 2006. The images were obtained by research teams from Russia, Bulgaria and France (from left to right, respectively).*

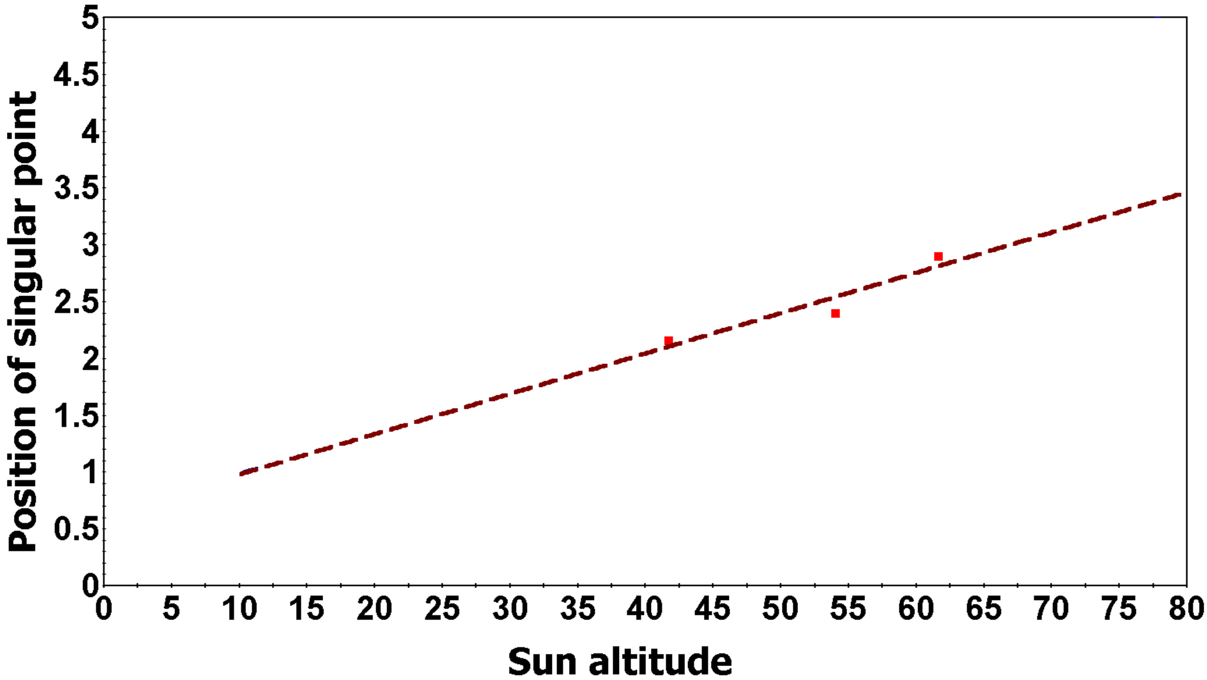

Fig. 3. *The dependence of the position of singular polarization points on altitude of the Sun during observations on the March 29, 2006 TSE from different locations.*

The distance from the center of the Sun of singular polarization points in the solar corona during the TSE on March 29, 2006 depends on the observational location. As the latitude of the Sun above the horizon rises, the singular polarization points move away from the Sun (Fig. 3). Our measurements from different locations show different values: Russia – $2.16R_\odot$, Turkey – $2.4R_\odot$, and Egypt – $2.9R_\odot$.

3. CONCLUSION

As the background signal from the sky during ground-based TSE observations always brings in an additional scattered light in measurements, we show that the auroral ring influences these values in observations of the eclipse on March 29, 2006. The residual scattered light in the Earth's atmosphere outside the Moon shadow is also polarized and it is superimposed on the light from the solar corona. Singular points occur in a two-dimensional plane depending on dominance of one of the components.

We determine the position of singular polarization points in the corona during TSE on March 29, 2006 using synchronous observations of 3 different teams located at 3 different places along the totality path. We find a linear dependence between the distance from the solar center of singular polarization points and Sun's altitude. The influence of the auroral ring on the position of the polarization points is still not sufficiently defined because of the statistically insignificant amount of data. Probably another factor that should be taken into account is the peculiarity of the landscape of the observational spot. We continue our joint efforts in looking for the answers of the open questions with the observations of the upcoming TSEs. Our research team for the July 2, 2019 TSE in Chile is already prepared to collect data for new scientific results on the current topic. Polarization observations of the TSE 2019 will give us a chance to explore the position of singular points in the corona when Sun's altitude above the horizon is less than 15 degrees. According to Shaw (1975), the polarization of the sky rapidly drops when the altitude of the Sun is below 20°. If the singular points are related to the polarization of the sky, we expect their distance from the solar centre to be $1.7R_{\odot}$. This value is expected if the observer is located nearby large areas of water (e.g. the ocean). If this expectations are not fulfilled and the linear dependence is confirmed, the singular points should be situated at $1.1R_{\odot}$ from the solar centre.

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ПОЛАРИЗАЦИЈА БЕЛЕ СВЕТЛОСТИ СУНЧЕВЕ КОРОНЕ И ЕФЕКАТ ПОЛАРИЗАЦИЈЕ НЕБА ТОКОМ ТОТАЛНОГ ПОМРАЧЕЊА СУНЦА 29. МАРТА 2006. ГОДИНЕ

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Стручни чланак

Посматрање тоталног помрачења Сунца са површине Земље остаје кључна метода у истраживању короне. И даље не знамо степен поларизације беле светлости короне. Постоје хипотезе да је степен поларизације у одређеним деловима короне виши него максимална теоријски предвиђена вредност одређена Томсоновим расејањем. Представљамо посматрања поларизације беле светлости короне обављена од стране три различита тима током тоталног помрачења Сунца 29. марта 2006. године. Дали смо могуће објашњење утицаја поларизације на сјај поларизоване короне Сунца у зависности од рељефа терена током помрачења. Показано је и да су појединачне тачке поларизације короне линеарно зависне од висине Сунца изнад хоризонта.