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Preliminary report

INTEGRAL POLARIZATION OF THE CORONA DURING 1973, 1980 AND 1983 ECLIPSES

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SUMMARY: From observations of the three total solar eclipses, we calculated the global linear polarization of the solar coronae in order to find out a possible connection between changes of this quantity and solar activity variations measured by some parameters characterizing the solar activity cycle.

Calculations were based on photographic observations made during the total eclipses in 1973 and 1980 (Kenya) and in 1983 (Indonesia) by three Belgian expeditions. The instrument was an one – meter focal length refractor equiped with a polaroid filter oriented in three directions 60° apart.

The parameters characterizing the integral polarization of the corona, degree of polarization and and the position angle of the electric vector, were summarized over the circular rings of the coronae between 1 and 2.2 solar radii. Different values of the integral polarization were obtained for the three eclipses studied. In 1980, when the Sun was very close to its maximum of activity, the amount of the integral polarization was considerably less then for the two other eclipses, which occured near the minimum phase of the solar cycle. The origin of such differences could be probably explained by corresponding changes in the electron densities and the geometry of the corona.

1. INTRODUCTION

The variation of the general shape of the solar corona with the solar activity cycle is a well known phenomenon (Allen, 1947 and Van de Hulst, 1950). More recent works (Dzubenko, 1984; Koutchmy and Nitschelm, 1984; Loucif and Koutchmy, 1989) confirmed that the flattening of the corona as well as electron dencity and integral brightness, are correlated with the phase of the solar cycle.

The global linear polarization parameters, on the other hand, might depend on the geometry and physical state of the corona and indirectly on the *solar activity cycle.* But, coronal polarization was measured point by point and integral or global polarization, which is normaly observed in the case of star, was not known for the Sun. Having in mind the importance of global polarization effect we proposed a simple method of calculation of integral polarization parameters of the Sun.

The purpose of this paper is primarily to calculate and then to examine the behavior of this global quantity, which was not calculated till now, namely, the integral polarization of the corona in white light. There were reasonable reasons – owing to very simple geometrical considerations – that the two parameters characterizing the phenomenon (degree and position angle of polarization) will show dependence on the solar cycle, in the case of three total solar eclipses observed by Belgian Royal Observatory expeditions.

We hereafter have used eclipse observations performed by three Belgian expeditions in Kenya 1973 and 1980 and in Indonesia 1983.

2. THE OBSERVATIONS

During the totality of the three eclipses the photographic images of the coronae were taken on a Kodak PLUS-X *emulsion, using a reflex camera* mounted at the focus of an 1–meter focal length and 7 centimeter aperture refractor. The analyzer was a polaroid filter placed a little in front of the focus, and oriented in three directions 60° apart (0°, 60° and 120°). Different exposure times were used in order to allow the best possible choice depending on the studied region of the corona.

The initial purpose of the observations was in fact *the study of the* local polarization in the K – corona in order to derive new models of the electronic density. However, this material can evidently be used to compute a more global quantity like the integral coronal polarization.

The observations of 1980 were reduced using a Joyce and Loebl analogic scanning isodensitograph (Clette et al, 1985). The isodensitograms were then digitized allowing the calculation by cubic spline interpolation of densities at the nodes of a radial network (72 directions with a maximum of 23 points). For the eclipses of 1973 and 1983, we used the Elmer Person isodensitometer of the Observatoire de Nice, obtaining so a much better spatial resolution (a rectangular network of 360 x 240 pixels), and also a better dynamics.

The densities were then converted into intensities using the calibration curve of the film established for our specific conditions. However, for the case in which we are interested here, no absolute calibration is necessary, so that only relative intensities were computed. The intensities and polarization parameters for each point of the network were calculated (Fessenkov, 1935, Arsenijević, 1969).

3. THE INTEGRAL POLARIZATION

Under the term integral polarization one can understand the sum (average) of the polarization parameters within the series of circular rings concentric with the solar disc.

Before computing the integral polarization, it was necessary to re- center the three networks of intensities corresponding to the three analyzer orientations with respect to each other, because of a possible shift of the data, either during the observational procedure or during the reductions. For 1980, this was done using details of the coronal structure and the knowledge of the relative motion of the centers of the Sun and of the Moon. For the two other eclipses, because of the absence of immediate visualization, the "re-centering" was obtained through cross-correlation method suggested by Clette (1989).

The integral polarization was then computed in two steps:

a) For each network of the sets of observations, the intensities inside the rings of different external radii, from 1.5 to 2.2 solar radii, with the inner one being always 1.2 solar radius, were summarized.

b) The calculation of the percentage of polarization and of the position angle θ, using the classical Fessenkov formulae (Fessenkov, 1935):

$$p = \frac{2\sqrt{I_1^2 + I_2^2 + I_3^2 - I_1 I_2 - I_2 I_3 - I_1 I_3}}{I_1 + I_2 + I_3},$$

$$\tan 2\theta = \frac{\sqrt{3}(I_2 - I_3)}{2I_1 - I_2 - I_3}. \qquad (1)$$

4. RESULTS

Table I shows, for the case of the total eclipse of 1983, the calculated integral degree of polarization of the rings *with different outer radii.* The *inner* radius for all rings are the same, 1.2 $R_\odot$. We notice a slow decrease of the degree of polarization with larger outher radius. This result is worth farther investigation in a more detail paper.

In Table II the values of the integral polarization of the parts of corona between 1.2 and 2.2 $R_\odot$ for the three eclipses are presented. Together with this data some other data are sumarized: the *phase of the eclipses in the solar cycle,* the daily sunspot number (Zurich, Brussels), the flattening index ε of the corona (taken from our data), defined as: $\varepsilon = R_{eq}/R_{pol} - 1$, where R_{eq} and R_{pol} are equatorial and polar radius.

Table I

$R_{outher}(R_\odot)$	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2
P (%)	17.2	16.9	16.5	16.2	16.0	15.8	15.7	15.6

Table II

Eclipse	Phase	Wolf number	Flattening index	Degree of polarization	Position angle of polarization
Jun 30, 1973	-0.40	33	0.176	22%	21°
Feb 16, 1980	-0.97	163	0.080	3%	not significant
Jun 11, 1983	-0.40	73	0.180	16%	1°

5. DISCUSSION AND CONCLUSIONS

The degrees of the integral polarization presented in Table II are much higher for two eclipses of 1973 and 1983, which both occured in the decreasing phase of the cycle near minimum, than for the eclipse of 1980, near maximum of solar activity. It is interesting to note that for exactly the same phase, the flattening indexes of the corona show the same behaviour. Moreover, as consequences of the high level of integral polarization, the position angle of polarization is well defined in both cases (estimated error: 3°). Contrariwise, for the eclipse of 1980, this angle is found to be erratic and hence with low significance.

As expected, the geometry of the corona seems to play a fundamental role in the quantity of global polarization percent. Indeed, two combined effects (having in fact the same origin) increase the level of the degree of polarization during solar activity decreasing:

a) the flattening of the corona has a consequence that the western and eastern part of the corona are more important in the summation than the polar. The resulting electric vector is more or less perpendicular to the solar equator;

b) the local polarization being actually lower in the polar direction enhances this effect.

A peculiarity of the 1973 corona is, besides its high level of integral polarization, the direction of polarization that makes an angle of 20° with the polar direction. At first glance, an immediate explanation appears to be that the solar equator is far to be, for this eclipse, the "mean" – equatorial plane of the solar corona. This point needs however a more detailed investigation.

It is also important to note for all three eclipses: the lower the sunspot Wolf number is, the higher residual polarization is.

It is however premature to conclude which one of the parameters indicated in Table II should be the best indicator of coronal activity, because we do not have at our disposal a significant statistical sample. More investigations are needed. That is the reason why the observational program will be continued with the new and old eclipses observations. The observational data of the total solar eclipse in Mexico two years ago and possible past polarization observations should be worked on.

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ИНТЕГРАЛНА ПОЛАРИЗАЦИЈА СУНЧЕВЕ КОРОНЕ ЗА ВРЕМЕ ПОТПУНИХ ПОМРАЧЕЊА 1973, 1980. И 1983. ГОДИНЕ

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Претходно саопштење

На основу посматрања три потпуна помрачења Сунца, у раду је рачуната нова величина – интегрална линеарна поларизација сунчеве короне, са намером да се нађе веза између промена ове величине и варијација у сунчевој активности, одређених на основу других параметара који карактеришу циклус сунчеве активности.

Рачун је базиран на фотографским посматрањима короне током потпуних сунчевих помрачења 1973. и 1980. (Кенија) и 1983. године (Индонезија), која су извршиле три белгијске експедиције. Инструмент је био рефрактор жижне даљиине од 1м, опремљен поларизационим филтером, са три могуће оријентације.

Параметри који карактеришу интегралну поларизацију короне (степен поларизације и правац електричног вектора), рачунати су у концентричним прстеновима, на растојањима од 1 до 2.2 сунчева полупречника. За помрачење из 1980. године, када је Сунце било близу максимума активности, добијена вредност интегралне поларизације је значајно мања него за друга два помрачења, када је Сунце било близу минимума активности. Порекло ових разлика се вероватно може објаснити променама електронске густине и геометрије короне.