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ΠΡΟΕΔΡΙΑ ΙΩΑΝΝΟΥ ΤΟΥΜΠΑ

ΑΣΤΡΟΝΟΜΙΑ.— **Asymmetries of the green and red line intensities of the solar corona,**
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ABSTRACT

The analysis of the daily measurements of the coronal green and red line intensities observed at the Pic-du-Midi Observatory during the period 1944-1974 has revealed some characteristic asymmetric variations in the intensity of these lines. The main feature obtained in the period 1949-1971 is a north-south asymmetry of these lines while a south-north one is obvious within 1972-74. On the other hand a significant E-W asymmetry has been confirmed in the whole period 1944-1974.

The combination of N-S and S-N asymmetry with a E-W one makes the NE solar quarter to appear as the most active of all in the 22-year cycle 1949-1971 while in the periods 1944-1948 and 1972-1974 the SE quater is the most active.

1. INTRODUCTION

The coronal intensity of solar activity is a numerical expression of the total radiation energy of the coronal emission lines which are caused from highly ionized atoms. The most important of these lines are in the visible wavelenghts, the green (Fe XIV, λ5303 Å) and the red (Fe X, λ6374 Å) lines. Ob-

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servations of these radiation lines have been collected by a Lyot-type coronograph and spectrograph in Pic-du-Midi Observatory as well as in other Observatories. Many authors have studied the characteristics of these radiation lines (Trellis, 1960; Rusin, 1980; Leroy, 1974; Pathak, 1972; Waldmeier, 1971 e.t.c.).

The distribution of the green line intensity in a yearly basis has been studied by Xanthakis et al (1981) for the time period 1965-1972. They have given an analytical relation between the green line intensity and other solar phenomena as the area indices of solar activity, the number of proton events and the intensity of solar magnetic field. The influence of coronal holes in the annual distribution of the green line intensity has been also studied by Xanthakis et al (1990) recently.

A North-South asymmetry for the distribution of the green line intensity has been found by different authors (Pathak, 1972; Rusin 1980). A time variable disymmetry of the green line intensity between east and west solar limbs for the time period 1947-1954 has been found by Trellis (1960). Tritakis et al (1988) studied the yearly distribution of the green line intensity observed at the Pic-du-Midi observatory for the period 1944-1974 and reported a longitudinal E-W asymmetry, that persists along all data records.

In the present work we have studied yearly and monthly distributions of the emitted green line intensity from the four solar quarters, so that preferential suractive areas of the solar corona to be found.

2. SELECTION OF DATA

In order to study possible enhancements of the emitted radiation lines in the four solar quarters, daily measurements of the absolute intensity of the coronal emission lines at 5303 Å and 6374 Å, taken from the Pic-du-Midi observatory by a classic Lyot-type coronograph for the period 1944-1974 have been used.

These measurements have been obtained for all heliocentric sectors around the solar limb with a resolution of 5° and a distance of about 40″ until 22″ from the Sun's edge. Our data are obtained in a polar coordinate system defined by the central meridian passage. The unit of the measured intensity of this line is 10^{-6} times the intensity at a width 1 Å wavelength of the continuous photospheric spectrum.

From the daily measurements of these data set we have computed yearly and monthly mean values of the green and red line intensities, in each heliocentric sector and in each north-south, east-west solar hemispheres as well as in the four quarters of the solar disk.

3. YEARLY DISTRIBUTION OF THE ASYMMETRY COEFFICIENT

a) N-S asymmetry

As it is known the asymmetry coefficient of the intensity between the i and j solar limb is defined by the relation

$$A = \frac{I_i - I_j}{I_i + I_j}$$

The yearly distribution of the green line intensity asymmetry coefficients of the NE-SE, NW-SW solar quarters and N-S solar hemispheres are appeared in Fig. 1. The coefficient

$$B = \frac{\Sigma H_N - \Sigma H_S}{\Sigma H_N + \Sigma H_S}$$

where ΣH_N, ΣH_S are the annual sums of the maximum values of the sunspot magnetic field intensity observed in every hemisphere for each group of sunspots during each passage of this group over the visible solar hemisphere is also given in the same Figure (1a). These data have been obtained by the Mount Wilson Observatory.

We can report a close correlation between the N-S asymmetry coefficient and the B coefficient. The correlation coefficients between the total green line intensity I_{tot}, the green line intensity in the north corona I_N, the green line intensity in the south corona I_S and the corresponding maximum values of the magnetic field have been computed by Tritakis et al (1988) and have been found equal to,

$$(I_{tot}, H_{tot}) = 0.88$$
$$(I_N, \Sigma H_N) = 0.86$$
$$(I_S, \Sigma H_S) = 0.78$$
$$(\Delta I_{N,S}, \Sigma \Delta H_{N,S}) = 0.80$$

These results show a possible correlation between the solar magnetic fields and the green line intensity for the time period 1948-1958. From the Figure 1 it

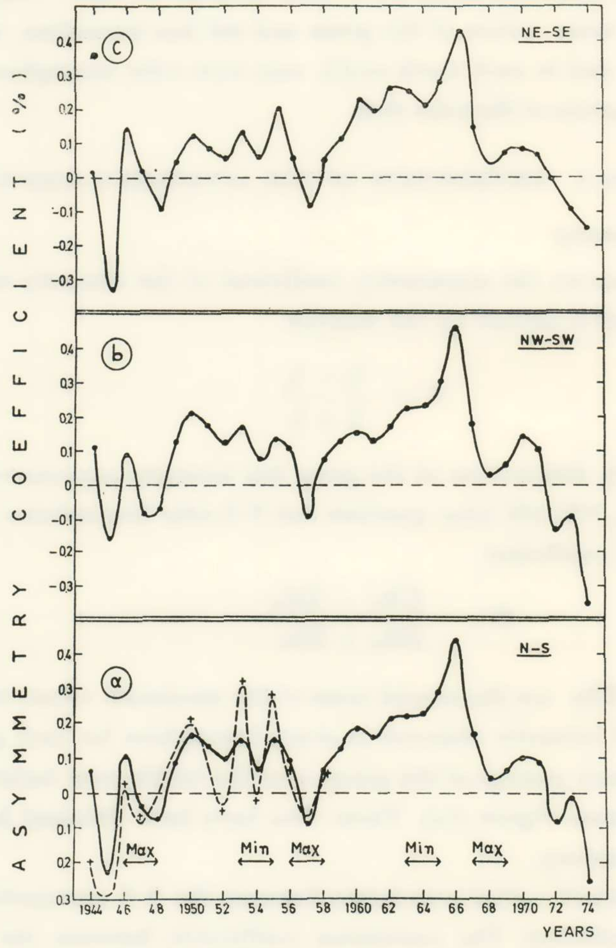

Fig. 1. Variations of the north-south, northeast-southeast and northwest-southwest asymmetry coefficient in the time period 1944-1974. The dotted line in the lower panel represents the variation of the asymmetry coefficient of the maximum values of the sunspot magnetic field intensity observed for each group of sunspots during each passage at it over the visible solar hemisphere.

is obvious that the N-S asymmetry is homogenously distributed in the direction of the solar equator. It means that there is a maximum of N-S, NE-SE and NW-SW asymmetries about the year 1966. It is consistent to the fact that the north hemisphere appears more active for the time period 1948-1971 and that the N-S asymmetry around the maxima of the solar cycles 18,19 turns to be negative, while in the maximum of the cycle 20 it is positive. The above mentioned consideration represents the effect of the 22-year variation in the epochs of the green line intensity maxima.

As we can see from the Figure 1 the N-S asymmetry turns to S—N asymmetry in the periods 1944—1948 and 1972—1974, which they do not belong to the 22—year solar cycle 1949—1971 where the north hemisphere is more active than the south. The area of sunspots and the number of major flares seems to have a similar behaviour.(Shea et al, 1990).

b) E-W asymmetry

For the time period 1945—1971, we give also the yearly variation of the W-E, NW-NE, SW-SE asymmetry coefficient of the green line intensity (fig. 2). We can remark that the descending branch of the SW-SE asymmetry coefficient after the year 1971 reveals that the N-S asymmetry inversion to S-N starts in the SE solar quarter. Moreover the NW-NE asymmetry appears to be higher than the SW-SE one. This implies the fact that the NE solar quarter is more active than the SE for the time period 1944—1971. The above result is in good agreement with the conclusion obtained from the study of the monthly distribution of the green line intensity (section 5).

In the Fig. 3 we give also the variation of the NW-SE and the NE-SW asymmetry, namely the asymmetries among the four solar quarters crosswise. The high negative values of the NW-SE after 1971 argue for the predominance of the SE solar quarter and in contribution to the N-S to the S-N asymmetry inversion. On the other hand from this figure it is obvious that the NE-SW asymmetry is positive within the most of the period 1944—1974 that is, the NE solar quarter predominates on the SW one.

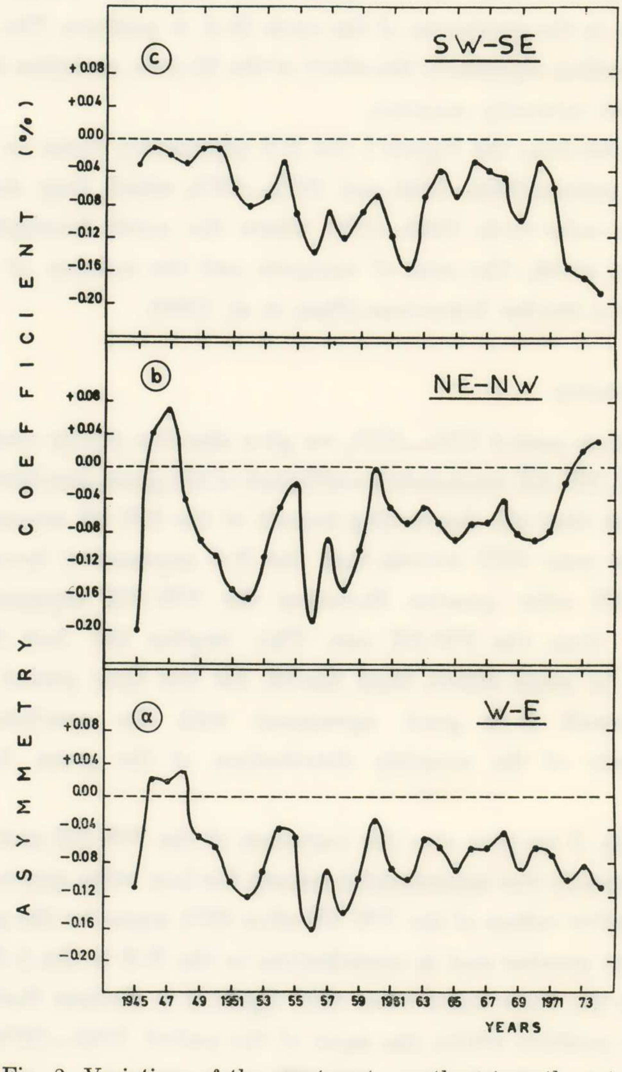

Fig. 2. Variations of the west-east, northwest-north east and south west-south east asymmetry coefficient in the time period 1944-1974

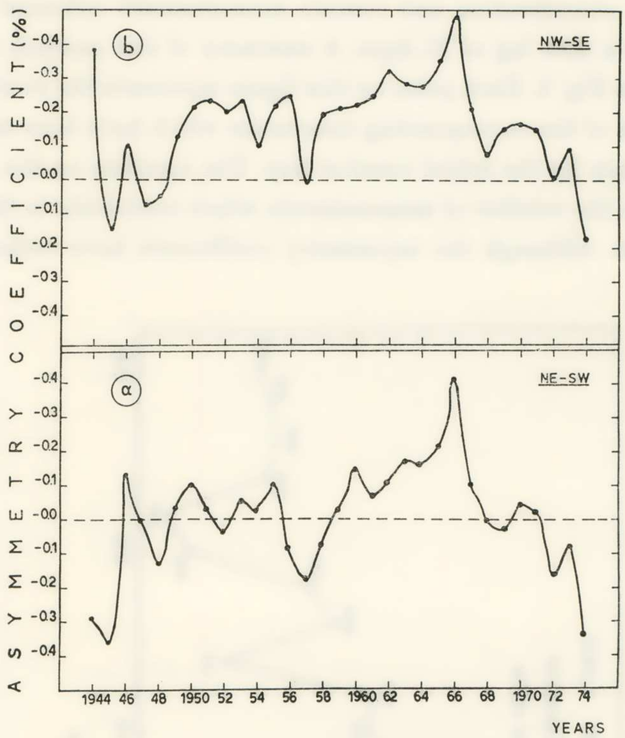

Fig. 3. Variations of the northwest-southeast and northeast-southwest asymmetry coefficient in the time period 1944-1974.

4. E-W ASYMMETRY OF THE GREEN AND THE RED LINE INTENSITIES NEAR THE SOLAR EQUATOR

The asymmetry coefficients between the east and the west limbs of the green and the red line intensities at the region of the solar equator have been computed also from the daily measurements. For this computation we have taken data that have been obtained within a narrow zone 5° wide on both sides of the solar equator. The differential rotation of solar corona near the equator is estimated to be about 25. 28 days. So data obtained within the above mentioned equatorial zone every 25 days or one solar rotation corresponds approximately to the same areas of the solar corona. We have separated our data in twenty five time series which start the first twenty five days of the period under consideration and contain measurements collected on the solar equator with a time lag of 25 days. A summary of this analysis for the green line is given in Fig. 4. Each point on this figure represents the average asymmetry coefficient of the corresponding time-series which have been marked on the horizontial axis by the initial rotation day. The numbers on the points of this figure refer to the number of measurements which contribute to the calculation of each point. Although the asymmetry coefficients have rather low values

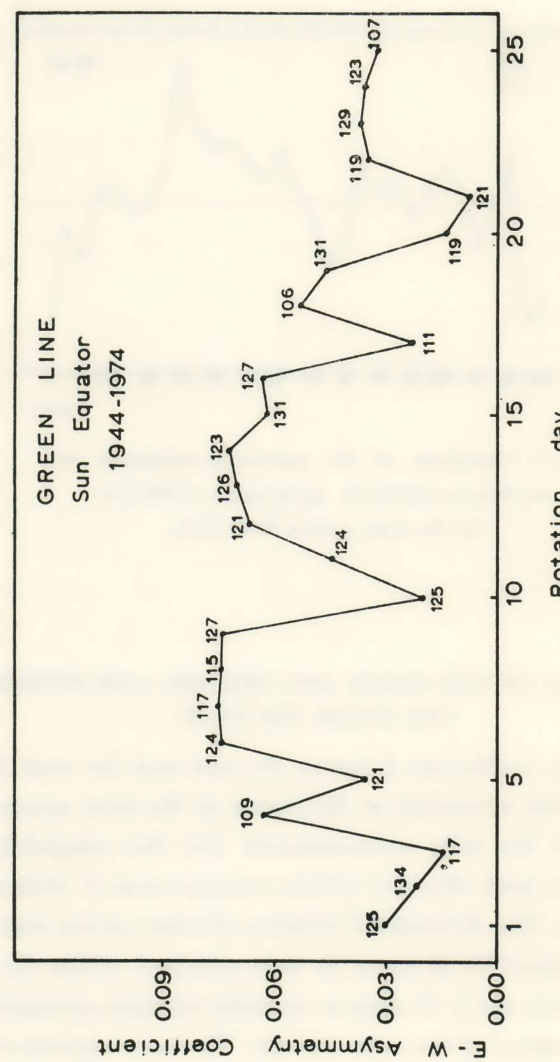

Fig. 4. Variation of the mean asymmetry coefficient of the green line intensity of twenty five time series they start the first twenty-five days of our data period and contain measurements collected every 25 days.

they are all positive. This fact supports the existence of an E-W asymmetry.

Figures 5 and 6 presents an additional summary of our analysis for the

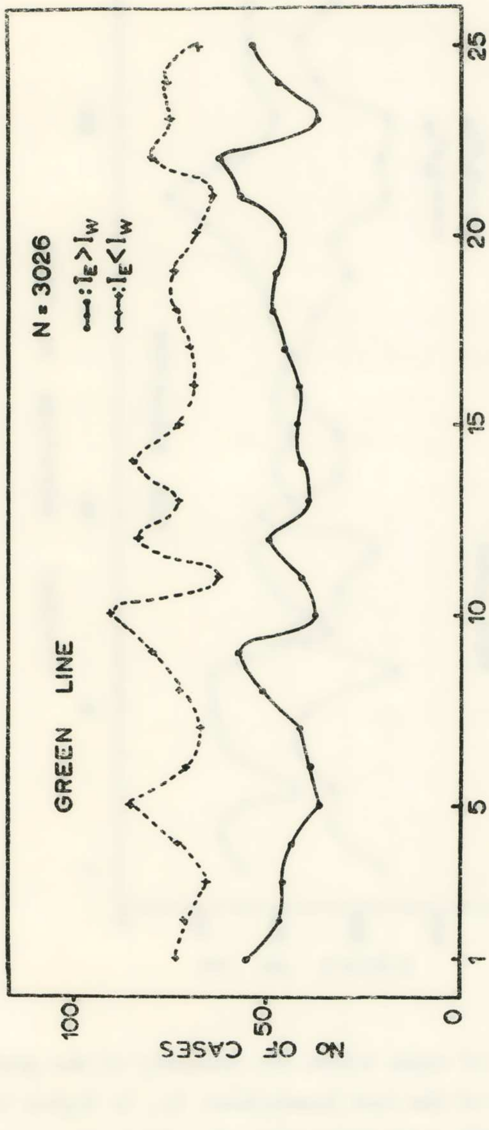

Fig. 5. Number of cases where $I_E > I_W$ or $I_W < I_E$ for the green line intensity in twentyfive time series which contain asymmetry coefficients which have been calculated every twenty-five days.

data of both green and red line intensities, respectively. The horizontal axis of these figures represents the first 25 days of our data which are also the initial days of the time series we have considered. On the other hand vertical axis

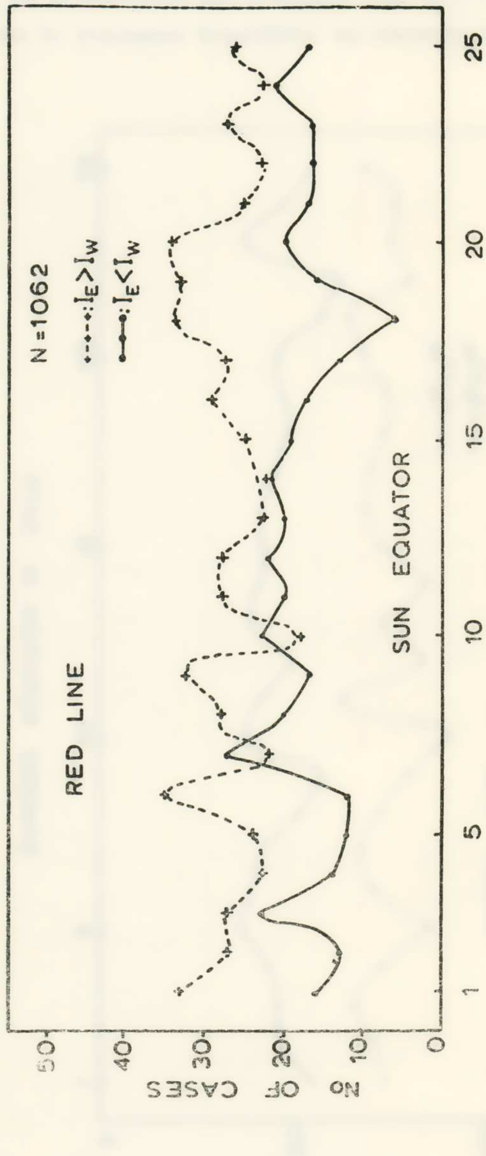

Fig. 6. Figure similar to the figure 5 refering to the red line intensities.

represents the number of cases where the intensity of the green or red line intensities respectively of the east hemisphere, I_E, is higher or lower of the corresponding one's of the west hemisphere I_W. From these two last figures it is clear that in all twenty five time series of the green line data and the additional twenty five of the red line data the case $I_E > I_W$ predominates systematically of the opposite case $I_E < I_W$.

In Figure 5 where the green line data are presented the case $I_E > I_W$ is valid in all the days of the synodic rotation. In addition, in the Figure 6 where the red line data are depicted, the case $I_E < I_W$ is valid except in two cases where the opposite case occurs and 3 or 4 more cases where $I_E \approx I_W$. It is possible that the limited sample of the red line data which is the one third of that for the green line data introduces the above mentioned uncertainties.

5. MONTHLY DISTRIBUTION OF THE GREEN LINE INTENSITY IN THE FOUR SOLAR QUARTERS

Monthly values of the green line intensity for each of the four quarters of the solar corona for the period 1959-1973 have been computed. Diagrams of these values for the NE (1), SE (2), NW (3) and SW (4) quarters are given in Fig. 7. From this figure we can note an excessive activity in the NE quarter for the period 1965-1971 while after 1971 the SE quarter of the solar corona is the most active one. We note that there is a similarity between the descendant branch of the solar cycle 19 (1959-1964) and the ascendant branch of the cycle 20 (1965-1970). The maximum of the NE intensities is appeared in the year 1960 for the descending part of the cycle 19 and in the year 1966 for the ascendant part of the cycle 20. These maxima correspond to the maximum activity of the solar cycle 19 and to the maximum of the solar cycle 20 respectively.

White and Trotter (1977) have also observed an excess of sunspot areas in the northern hemisphere of the sun with a clear dominance between the years 1958 and 1971. Swinson et al (1986) indicate also that the northern hemisphere of the Sun has more Ha solar flares than the southern hemisphere. The same authors note that much more «major flares and type II radio bursts» have been observed during the year 1960 than the other years of solar cycle 19. Leftus et al (1980) and Rusin (1980) have also observed a N-S asymmetry in the green line intensity in Lomnicky Stit data.

All the above considerations are in agreement with the theoretical interpretation of the green line intensity attribution given by Xanthakis et al (1981) where the green line intensity is related to the number of proton events and the area index of solar activity (function of the sunspot area).

The green line intensity inversion which appears in the NE and SE

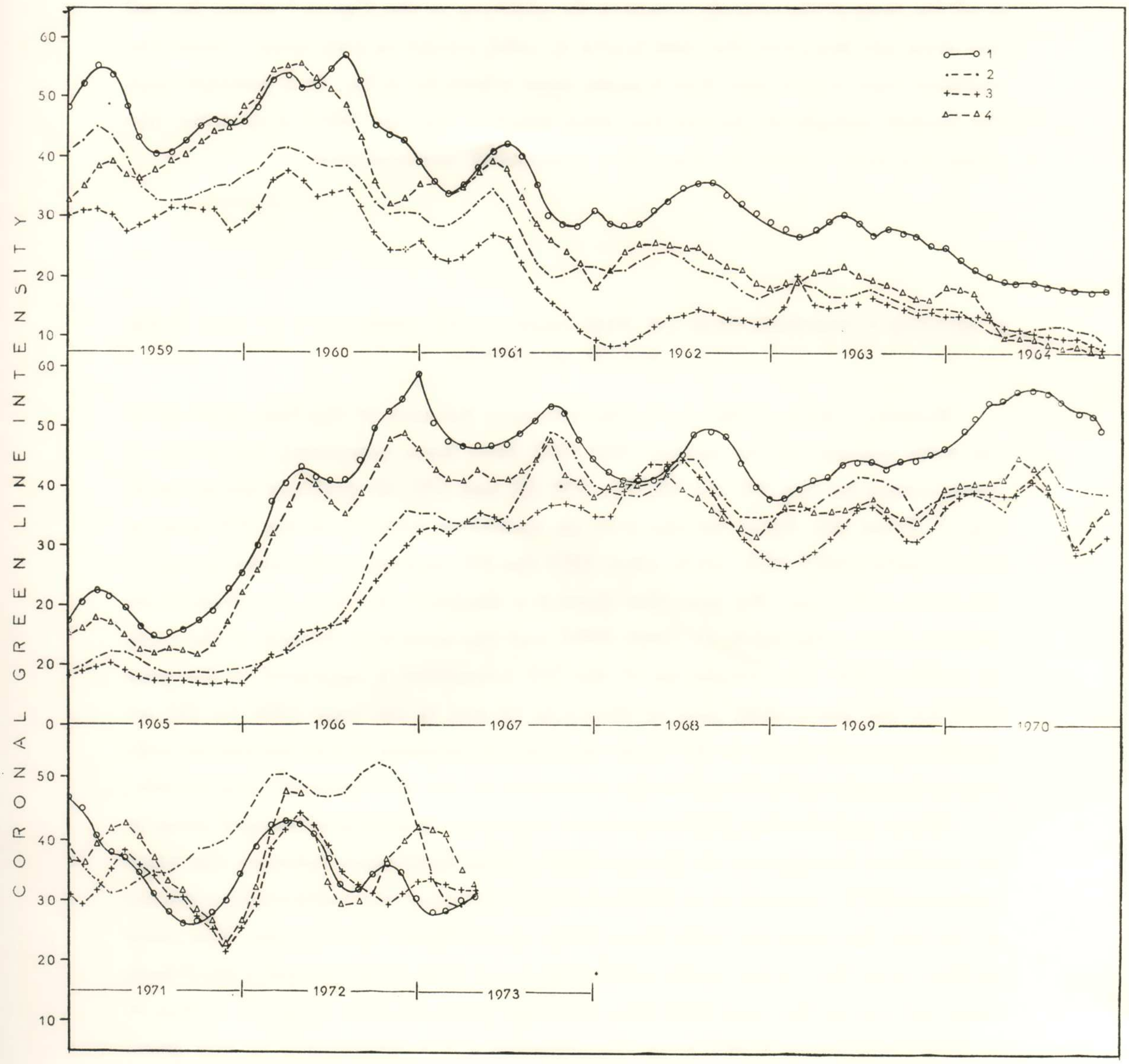

Fig. 7. Monthly values of the green line intensity for the span 1959-1973 for the four quarters of the solar corona. NE(1), SE(2), NW(3), SW(4).

curves during the year 1971, as it is shown in Fig. 1, could be interpretated by the effect of the sunspot magnetic field to the green line intensity that ought to be taken into account in the estimation of this intensity (Xanthakis et al, 1981).

It is well known that the solar magnetic field changes polarity around the year 1971 (Wilcox et al, 1972). This years corresponds also to the secondary maximum of the green line intensity (Xanthakis et al, 1981).

In summary, we can say that there are several temporal or observational reasons which could introduce the above mentioned E-W asymmetry in the green line intensity of the solar corona as well as in the red one. The predomination of this effect on the green line in relation to the red one as well as systematic seasonal variations which have been already detected in this asymmetry has almost convinced us that this E-W asymmetry is a real phenomenon.

CONCLUSIONS

From the above mentioned arguments we have concluded that there is a non—homogenous emission of the green and red line intensities measured at the Pic-du- Midi Observatory. These asymmetries are persistent in all the time period which have been analysed in this work (1944-1974) that is, the solar cycles No 18, 19 and 20.

The analysis of the monthly values of these intensities during the 19th and 20th solar cycles has shown that the NE quarter of the solar corona appears more active than the other ones with an inversion at the year 1971.

It is known that N-S and E-W asymmetries appear in other solar phenomena as the number of flares, the number of sunspots e.t.c. (Shea et al, 1990). The existence of such asymmetries in the coronal green line define this line as an integrated index of the solar activity which can express all the photospheric and coronal phenomena of the sun and could be useful in the study of special areas of the solar corona on the NE region. This region has a suractivity for all the 22-year cycle 1949-1971. This suractivity seems to depend on the orientation of the total solar magnetic field.

A detailed analysis of the Pic-du-Midi coronal data which will appear very soon will probably reveal the reasons of the appeared asymmetries on these coronal lines.

Aknowledgements: Thanks are due to Mrs. P. Tatsi for her important technical help.

Ἀσυμμετρία τῆς ἔντασης τῆς πράσινης καὶ τῆς ἐρυθρᾶς φασματικῆς γραμμῆς τοῦ ἡλιακοῦ στέμματος

Στὴν ἐργασία αὐτὴ μελετήθηκαν οἱ ἡμερήσιες παρατηρήσεις τῆς πράσινης καὶ τῆς ἐρυθρᾶς γραμμῆς τοῦ στέμματος ποὺ ἔγιναν ἀπὸ τὸ Γαλλικὸ Ἀστεροσκοπεῖο Pic-du-Midi κατὰ τὴν περίοδο 1944-1974.

Ἡ μελέτη αὐτὴ ἀπεκάλυψε σημαντικὲς ἀσυμμετρίες μεταξὺ τῶν ἐντάσεων τῶν παραπάνω γραμμῶν ποὺ ἔχουν ληφθεῖ σὲ διάφορα ἡμισφαίρια καὶ τεταρτημόρια τοῦ ἡλιακοῦ δίσκου. Τὸ κύριο χαρακτηριστικὸν τῶν ἀσυμμετριῶν αὐτῶν εἶναι ὅτι τὸ ἀνατολικὸ ἡμισφαίριο τοῦ ἡλιακοῦ δίσκου παρουσιάζει αὐξημένη ἔνταση ἐκπομπῆς στὶς παραπάνω στεμματικὲς γραμμὲς ἔναντι τοῦ Δυτικοῦ ἡμισφαιρίου καθ' ὅλο τὸ χρονικὸ διάστημα 1944-1974.

Ἐπιπλέον, κατὰ τὴν διάρκεια τοῦ 22-ετοῦς ἡλιακοῦ κύκλου 1949-1971 τὸ Βόρειο ἡλιακὸ ἡμισφαίριο παρουσιάζει αὐξημένη ἔνταση ἐκπομπῆς στὶς παραπάνω γραμμὲς ἐνῶ κατὰ τὸ διάστημα 1972-74 τὸ Νότιο ἡμισφαίριο ὑπερέχει τοῦ Βορείου.

Ὁ συνδυασμὸς τῆς μόνιμης ἀσυμμετρίας μεταξὺ τοῦ Ἀνατολικοῦ καὶ τοῦ Δυτικοῦ ἡμισφαιρίου καθὼς καὶ τοῦ Βορείου-Νοτίου τελικὰ ἀποδεικνύει ὅτι τὸ Βορειοανατολικὸ τεταρτημόριο τοῦ ἡλιακοῦ δίσκου εἶναι τὸ δραστηριότερο γιὰ τὸ διάστημα 1949-1971 ἐνῶ γιὰ τὰ ἔτη 1972-74 ὡς δραστηριότερο παρουσιάζεται τὸ Νοτιοανατολικὸ τεταρτημόριο.

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