ΑΣΤΡΟΝΟΜΙΑ.--**Comparison of the Dimensions of the Flocculi at Periods of Maximum and Minimum Solar Activity,** *by H. C. Dara, C. J. Macris and Th. G. Zachariadis**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ι. Ξανθάκη.

A B S T R A C T

The flocculi dimensions are measured during the maxima and minima of solar activity and their relative frequency distributions are given. The results of the measurements show that there is a 7% increase in these dimensions from the minimum to the maximum of solar activity as well as that the large dimension flocculi are more numerous during maxima and those of small dimension during minima. The 7% increase has been tested statistically and found to be significant.

1. INTRODUCTION

The purpose of this paper is the study of a possible variation of the mean dimension of the K_3 chromospheric flocculi during the solar cycle and especially between periods of maximum and minimum solar activity.

By flocculi we mean the bright emission centers of the solar chromosphere, with dimensions of some seconds of arc, which are spread all over the solar disk, forming the chromospheric network.

The life time, the center to limb variation of the flocculi dimension, as well as their intensity relative to the chromospheric background have already been studied (Janssens 1970, Macris, 1962, 1968, 1974).

The dimension of the flocculi is one basic characteristic depending on many factors, especially on the resolution of the telescope and on the seeing conditions during observation. This paper refers to the measurement of the flocculi as they have been recorded by a spectroheliograph with a constant lens aperture and under satisfactory seeing conditions.

2. OBSERVATIONAL DATA AND MODE OF WORK

To determine the flocculi dimensions we have used an extensive

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series of spectroheliograms taken by the large spectroheliograph of Meudon Observatory (D' Azambuja, 1930) through the K_3 line of ionized calcium.

The mean diameter of the solar disk on the spectroheliograms is 86 mm which corresponds to 1920 seconds of arc, that is 1 mm on the spectroheliograms corresponds to 22,3 sec of arc.

To take the tracings of the spectroheliograms we used the Joyce - Loebl automatic microphotometer of the Research Center for Astronomy and Applied Mathematics of the Athens Academy. The tracings have been taken in quiet regions of the solar chromosphere, that is in regions without plages or other centers of activity, and at distance $\sin\vartheta = 0.82$ (55° heliographic latitude) from the equator, in the north and south polar regions and in the W - E direction. Each group contains six successive tracings which were taken by 200 μ displacement for each tracing. Since the dimensions of the second slit of the microphotometer were set at 200 × 200 μ, a zone of 1200 μ width was being scanned completety. The dimensions of the flocculi vary from 0,8 mm to 5,6 mm measured on the recording paper, that is from 160 to 1120 μ on the plates, since a five fold magnification of the image of the plate was made to facilitate the measurements and diminish their margin of error. Therefore all flocculi found in this zone, have been recorded in the tracings. Figure 1 shows one tracing.

On each tracing we draw the chromospheric background, which was defined as the curve which passes through the lower points of the tracings, which represent points with the lowest photometric density on the original negative spectroheliograms. In some tracings one can see points below the drawn background. They are due to small prominences projected on the solar disc or other irregularities of the photographic plates which diminish the density of the negative spectroheliogram. The backgrounds were drawn by the same person and with the same criterion, to include almost all the points of lowest density and form a smooth curve.

To measure the dimension of each flocculus on one of the six successive tracings, we chose the tracing on which the flocculus had its maximum deviation from the chromospheric background, that is its maximum intensity. The tracing was chosen by comparison of the six and study of the evolution of the same feature.

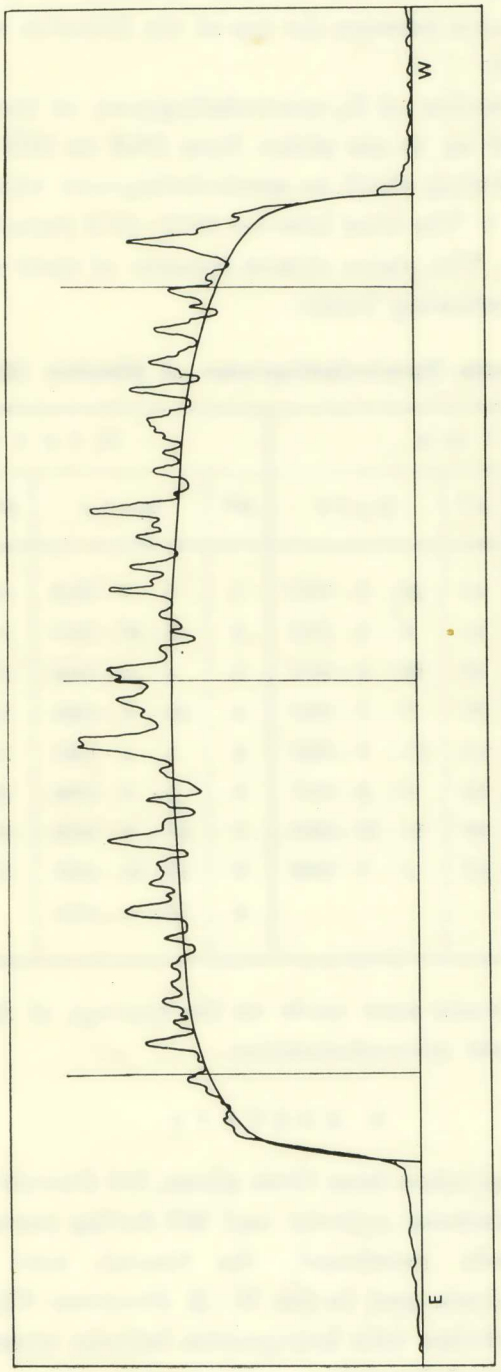

Fig. 1. Tracing taken in a polar region of the solar disk. Maximum deviations indicate the flocculi.

We define the mean size of each flocculus as the width at the middle of the distance between the top of the flocculus and the chromospheric background.

The rich collection of K_3 spectroheliograms of the Meudon observatory has allowed us to use plates from 1913 to 1973 except for the years 1915 - 1918, during which no spectroheliograms were taken because of the World War I. The time interval 1913 - 1973 includes five maxima and seven minima. The plates chosen because of their excelent quality are shown in the following Table:

Table of Chosen Spectroheliograms of Meudon Observatory.

Maxima				Minima			
Nº	Date	Nº	Date	Nº	Date	Nº	Date
1	4 - 3 - 1928	10	22 - 3 - 1957	1	8 - 7 - 1913	10	29 - 4 - 1944
2	12 - 3 - 1928	11	3 - 5 - 1957	2	12 - 10 - 1913	11	20 - 6 - 1944
3	19 - 4 - 1928	12	28 - 6 - 1957	3	4 - 6 - 1914	12	30 - 5 - 1954
4	5 - 6 - 1928	13	7 - 7 - 1957	4	30 - 3 - 1923	13	5 - 6 - 1954
5	25 - 6 - 1928	14	31 - 7 - 1957	5	7 - 4 - 1923	14	23 - 6 - 1954
6	23 - 5 - 1937	15	7 - 9 - 1957	6	5 - 6 - 1933	15	9 - 7 - 1954
7	25 - 5 - 1937	16	11 - 10 - 1957	7	28 - 9 - 1933	16	18 - 5 - 1964
8	1 - 6 - 1937	17	1 - 7 - 1968	8	10 - 10 - 1933	17	26 - 6 - 1973
9	10 - 6 - 1947			9	19 - 4 - 1934		

The measurements were made on the tracings of the plates taken with the Joyce - Loebl microphotometer.

3. RESULTS

On the tracings taken from these plates, 598 flocculi were measured during years of minimum activity and 589 during years of maximum activity. As already mentioned, the flocculi were measured at 55° heliographic latitude and in the W - E direction. Their size in this direction does not change with heliographic latitude when they are near the central meridian of the sun.

The calculations gave the following mean values of the flocculi size: 1) 2,67 mm $\pm$ 0,03 mm with standard deviation 0,80 for the minima of solar activity and 2) 2,86 mm $\pm$ 0,04 with standard deviation 0,88 for the maxima of solar activity. As already indicated 1 mm on the disk of the spectroheliogram corresponds to 22,3 sec. of arc. Taking into account the five fold magnification, 1 mm on the tracing should correspond to 4,47 sec. of arc. Therefore the mean size of the flocculi during minimum and maximum solar activity in seconds of arc is 11,9 and 12,8 respectively, and the difference between them is 0,9 sec. of arc. This difference has been statistically tested by Student's t-test ($t = 3,9$) and the probability that is due to chance was found to be very small ($p \ll 0,01$). Figure 2 gives the relative frequency distributions of the flocculi sizes during maximum and minimum solar activity.

4. DISCUSSION

The dimensions we found in this paper are not necessarily exactly the real flocculi diameters. This is so because firstly the maximum intensity (maximum deviation on the paper) is not necessarily found on its diameter, and secondly the flocculi mean dimensions depend on the resolution of the telescope and the seeing conditions which may not be perfect.

However the comparison between the two values found is possible, even though they are not the real diameters, because in all tracings we used the same system of measurement, the same criteria. Moreover the choise of the regions ($\pm 55°$) where the flocculi were measured excludes any possible measurement of plages and insures the same undisturbed chromospheric conditions during maximum and minimum solar activity.

The most important conclusion of this work derives from the relative frequency distribution of the flocculi sizes. In these distributions we see that for sizes of about 13,4 sec. of arc we have the same percentage of flocculi in both minima and maxima. For sizes larger than 13,4 sec. of arc we have a greater percentage in maxima than in minima, while for sizes smaller than 13,4 sec. of arc there are more flocculi during minima than during maxima.

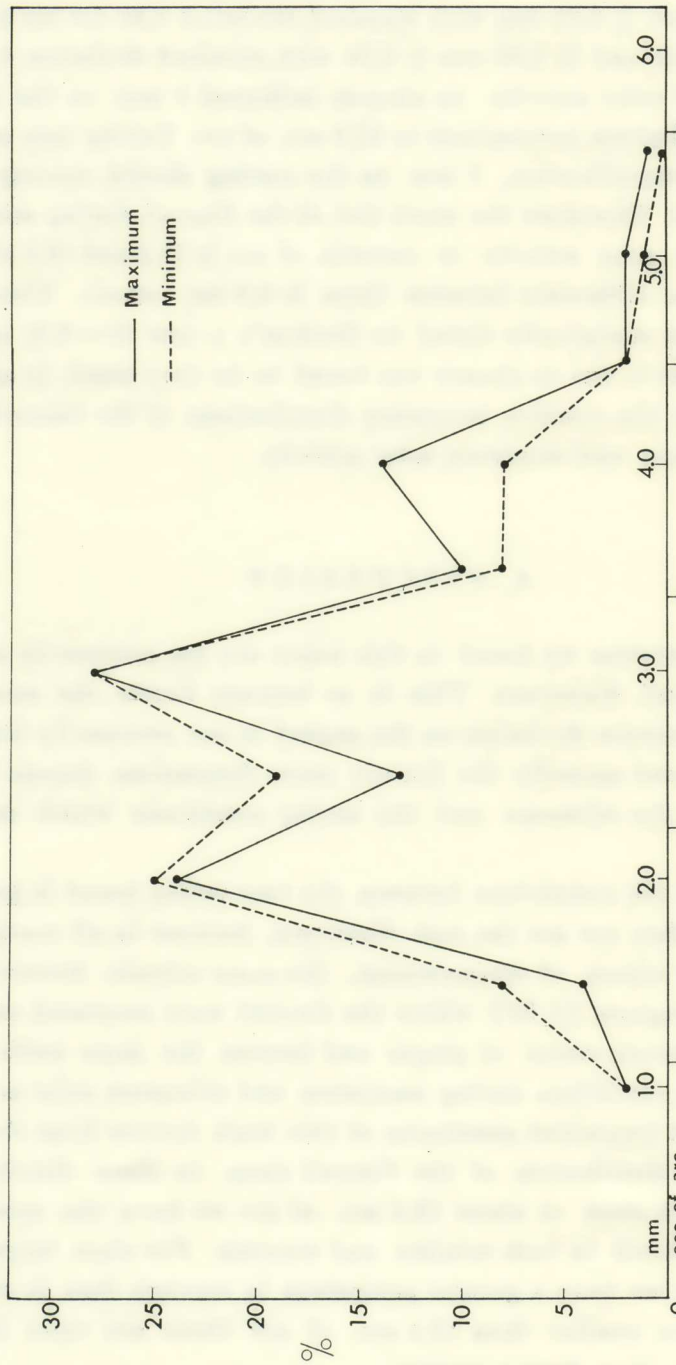

Fig. 2. Relative frequency distributions during periods of maximum and minimum solar activity.

Therefore we conclude that during the minima of solar activity the small size flocculi are more numerous, while in the maxima of solar activity the large size flocculi predominate.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the Director of Meudon Observatory for his kind permission to use the spectroheliograms, as well as to the Empirikion Foundation for its financial support which enabled the realization of this work.

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν ἐργασίαν προσδιορίζονται αἱ διαστάσεις τῶν νιφάδων τῆς χρωμοσφαίρας K_3, κατὰ περιόδους μεγίστης καὶ ἐλαχίστης ἡλιακῆς δραστηριότητος. Ἐκ τῶν ἀποτελεσμάτων τῶν μετρήσεων προκύπτει ὅτι αἱ μέσαι διαστάσεις κατὰ τὰ μέγιστα εἶναι 7 % μεγαλύτεραι ἐκείνων κατὰ τὰ ἐλάχιστα. Ἡ διαφορὰ αὕτη ἠλέγχθη διὰ τοῦ Student's t - test καὶ εὑρέθη στατιστικῶς σημαντική.

Ἐκ τῶν σχετικῶν κατανομῶν τῶν νιφάδων (Σχ. 2) κατὰ τὰ μέγιστα καὶ τὰ ἐλάχιστα συνάγεται ὅτι αἱ νιφάδες τῶν μεγάλων διαστάσεων εἶναι πολυπληθέστεραι κατὰ τὸ μέγιστον, ἐνῷ αἱ νιφάδες τῶν μικρῶν διαστάσεων εἶναι πολυπληθέστεραι κατὰ τὸ ἐλάχιστον τῆς ἡλιακῆς δραστηριότητος.

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Κατὰ τὴν ἀνακοίνωσιν τῆς ἐργασίας «Σύγκρισις τῶν διαστάσεων τῶν νιφάδων μεταξὺ μεγίστου καὶ ἐλαχίστου τῆς ἡλιακῆς δραστηριότητος» ὁ Ἀκαδημαϊκὸς κ. **Ἰωάννης Ξανθάκης** εἶπε τὰ ἀκόλουθα :

Ἡ παροῦσα ἐργασία ἀναφέρεται εἰς τὴν ἔρευναν τῶν διαστάσεων τῶν χρωμοσφαιρικῶν νιφάδων κατὰ τὸ μέγιστον καὶ τὸ ἐλάχιστον τῆς ἡλιακῆς δραστηριότητος.

Αἱ μετρήσεις, τὰς ὁποίας ἐξετέλεσαν οἱ ἐρευνηταὶ τοῦ Κέντρου Ἐρευνῶν Ἀστρονομίας καὶ Ἐφηρμοσμένων Μαθηματικῶν, ἀναφέρονται εἰς φασματοηλιογράμματα τοῦ Ἀστεροσκοπείου τῆς Meudon, τὰ ὁποῖα ἐλήφθησαν διὰ τοῦ μεγάλου φασματοηλιογράφου καὶ διὰ τῆς φασματικῆς γραμμῆς K_3 τοῦ ἰονισμένου ἀσβεστίου. Τὸ Ἀστεροσκοπεῖον τῆς Meudon διαθέτει πλουσίαν συλλογὴν πλακῶν ἀπὸ τοῦ 1910 μέχρι σήμερον, ἤτοι ὑλικὸν καλῦπτον ἓξ ἡλιακοὺς κύκλους. Μέρος τοῦ ὑλικοῦ τούτου ἐπέλεξεν ὁ κ. Μακρῆς, ὁλόκληρος δὲ ἡ ἐπεξεργασία αὐτοῦ ἐγένετο ἐν Ἀθήναις διὰ τῆς χρησιμοποιήσεως τοῦ αὐτογραφικοῦ μικροφωτομέτρου Joyce-Loebl τοῦ Κέντρου Ἀστρονομίας καὶ Ἐφηρμοσμένων Μαθηματικῶν.

Ἐπὶ τῶν ληφθέντων ἐγγραφημάτων τριάκοντα τεσσάρων φωτογραφικῶν πλακῶν, ἐκ τῶν ὁποίων δεκαεπτὰ ἐλήφθησαν κατὰ τὰ ἔτη μεγίστων καὶ δεκαεπτὰ κατὰ τὰ ἔτη ἐλαχίστων τῆς ἡλιακῆς δραστηριότητος, ἐξετελέσθησαν μετρήσεις ἐπὶ 1190 νιφάδων. Αἱ μετρήσεις τῶν μέσων διαστάσεων τῶν ἀνωτέρω χρωμοσφαιρικῶν σχηματισμῶν ἔδωσαν τὰ ἑξῆς ἀποτελέσματα. Κατὰ μὲν τὰ μέγιστα εὑρέθη ὅτι ἡ μέση τιμὴ τῶν διαστάσεων τῶν νιφάδων ἀνέρχεται εἰς $12{,}8 \pm 0{,}17$ δευτερόλεπτα τόξου, κατὰ δὲ τὰ ἐλάχιστα αὕτη ἀνέρχεται εἰς $11{,}9 \pm 0{,}13$ δευτερόλεπτα τόξου. Ἡ προκύπτουσα διαφορὰ μεταξὺ μεγίστου καὶ ἐλαχίστου ἀνέρχεται εἰς 0,9 δευτερόλεπτα τόξου. Τοῦτο σημαίνει ὅτι κατὰ τὰ μέγιστα τῆς ἡλιακῆς δραστηριότητος αἱ μέσαι διαστάσεις τῶν νιφάδων εἶναι κατὰ 7% περίπου μεγαλύτεραι τῶν μέσων διαστάσεων κατὰ τὰ ἐλάχιστα.

Τὸ σημαντικώτερον ὅμως πόρισμα τῆς ἐργασίας ταύτης προκύπτει ἐκ τῆς σχετικῆς κατανομῆς συχνότητος τῶν νιφάδων κατὰ μεγέθη. Εἰς τὰς κατανομὰς ταύτας παρατηρεῖται ὅτι διὰ μεγέθη 13,4 δευτερόλεπτα τόξου ἔχομεν τὸ αὐτὸ ποσὸν νιφάδων τόσον κατὰ τὸ μέγιστον, ὅσον καὶ κατὰ τὸ ἐλάχιστον τῆς ἡλιακῆς δραστηριότητος. Διὰ μεγέθη μικρότερα τῶν 13,4 δευτ. τόξου ἔχομεν μεγαλύτερον ποσοστὸν νιφάδων εἰς τὰ ἐλάχιστα ἀπ' ὅτι εἰς τὰ μέγιστα, ἐνῷ διὰ μεγέθη μεγαλύτερα ἔχομεν μεγαλύτερον ποσοστὸν νιφάδων εἰς τὰ μέγιστα ἀπ' ὅτι εἰς τὰ ἐλάχιστα. Ἐκ τούτου συμπεραίνομεν ὅτι κατὰ μὲν τὰ ἐλάχιστα πολυπληθέστεραι εἶναι αἱ νιφάδες μικρῶν διαστάσεων, ἐνῷ κατὰ τὰ μέγιστα πολυπληθέστεραι εἶναι αἱ νιφάδες μεγάλων διαστάσεων. Δηλαδὴ τὰ μεγέθη τῶν χρωμοσφαιρικῶν αὐτῶν σχηματισμῶν ἀκολουθοῦν ἔν τινι μέτρῳ τὸν κύκλον τῆς ἡλιακῆς δραστηριότητος.