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ΑΝΑΚΟΙΝΩΣΕΙΣ ΜΗ ΜΕΛΩΝ

ΑΣΤΡΟΝΟΜΙΑ.— **On the relationships between bright mottles and spicules of the solar chromosphere,** *by C. E. Alissandrakis and C. J. Macris* (*) (**). Ἀνεκοινώθη ὑπὸ τοῦ κ. Ἰω. Ξανθάκη.

Abstract.

Isophotometry of Hα photographs of the solar limb reveals that in most cases bright mottles appear at spicule roots. Discussion and comparison with related limb and disk observations follows.

1. Introduction.

The dark and bright mottles are the main constituents of the quiet Solar Chromosphere observed in projection on the disk. On the other hand spike-like structures, the spicules, project above the low chromosphere at the limb. Several papers concerning the problem of the chromospheric structure have appeared recently (Bray 1968, 1969, Loughhead 1969, Pikel'ner 1969, Macris and Alissandrakis 1970, Banos and Macris 1970, Nikolsky 1970, Alissandrakis and Macris 1971). For works earlier than 1968 the reader should refer to the review paper by Beckers (1968) and the literature cited therein. Most studies are in the Hα line.

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* Κ. Ε. ΑΛΥΣΣΑΝΔΡΑΚΗ - Κ. Ι. ΜΑΚΡΗ, Ἐπὶ τῶν σχέσεων μεταξὺ τῶν λαμπρῶν ψηφίδων καὶ τῶν πιδάκων τῆς ἡλιακῆς χρωμοσφαίρας.

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In this paper we discuss the problem of the relationships between bright mottles and spicules. The problem is not new and is closely related to the problem of spicule appearance on the disk. The following possibilities have been suggested as answers to the question of the identification of spicules with disk structures :

1. The spicules appear in absorption, that is as dark mottles on the disk. This was originally suggested by Macris (1956, 1957) and supported by most authors (De Jager 1957, Kiepenheuer 1957, 1960, Bruzek 1959, Beckers 1964, Bray 1969, Loughhead 1969). There is indeed a strong similarity in the properties of dark mottles and spicules (shape, dimensions, spatial orientation, numbers, lifetimes). Moreover the dark mottles are better visible at the wings of Hα; this indicates that their motion is vertical with a velocity of 20 - 40 km/sec., like the motion of spicules. Also both spicules and dark mottles are structures of the upper chromosphere, while the bright mottles appear at lower heights (Beckers 1968, Bray 1969).

2. The spicules appear as bright mottles on the disk. This has been suggested by Bhavilai (1965). Using a 13 cm refractor and a narrow band Hα filter, Bhavilai observed that the bright mottles extend beyond the limb as spicules. In what concerns the dark mottles he found «gaps» in the chromosphere when he traced them outwards. He interpreted his observations by assuming that the bright mottles are the spicules and that the dark mottles are separate features occuring near the bright ones. No other observer has either confirmed or contradicted Bhavilai's limb observations.

3. The spicules are either dark or bright on the disk, depending on their position on the disk, the position in the Hα (line center or wings), the part of the spicule that is observed and their evolution. This has been suggested by Beckers (1968) in an attempt to present a unified theory of the chromospheric structures. Beckers presented a theoretical model according to which the upper part of a spicule (height $>$ 6.000 km at the center of the Hα and near the center of the disk) should appear dark, while the lower part should appear bright. Avery and House (1969) came to the same conclusions, but for the Ca II K line. An immediate implication of the model is that the root of a spicule should be bright. In what concerns the direct observational evidence about Becker's model

there is one confirmating and one contradicting view. Bray (1969) expressed the opinion that although bright mottles occur in close juxtaposition to dark mottles they cannot be identified with a single structure; in photographs near the limb he did not find any welldefind pairs of bright and dark mottles forming a continuous structure. On the other hand Banos and Macris (1970) were able to identify numerous pairs in their photographs. They concluded that bright and dark mottles are indeed part of the same structure; the upper part of the structure extends above the chromosphere and appears as a spicule when the structure crosses the limb.

The question of the appearance of spicule on the disk has not been given a definite and satisfactory answer yet. The main difficulty is that the size of the structures involved is near the resolution limit of the solar telescopes, making the observations, especially the spectroscopic ones very difficult.

2. Limb isophotes.

High resolution limb observations are important for the study of the problem of the identification of spicules with disk structures. One may expect to see the structures actually crossing the limb and deduce their vertical structure. The only observation of this kind are those of Bhavilai (1965) described in section 1.

Our own limb observations were carried out in 1968 with the 40 cm refractor of the National Observatory of Athens and a Halle Hα filter (0,5 Å passband). The enlarging system used produced a 155 mm diameter solar image, a part of which was photographed on Kodak [SO]-375 film. Careful examination of our best photographs confirms Bhavilai's observation that the bright mottles extend beyond the limb as spicules. However we were unable to find any «gaps» in the chromosphere as described by Bhavilai. No «gaps» appear either in the photographs of the lower chromoshere of Loughhead (1969). These «gaps» if they were indeed the dark mottles, should be as numerous as the bright mottles.

The photographs of the limb are very difficult to reproduce on paper prints due to the great intensity difference between the spicules and the lower chromosphere. A precise idea about a photograph can be obtained by constructing isophotes. For this purpose we used a Joyce-

Loebl Isodensitracer and scanned several regions of the limb in our best photographs. Three of these regions appear in figures 1, 2 and 3.

The only other limb isophotes the authors are aware of are those of Dunn (1960), who had used a wide band Hα filter (2,5 Å) and was interested mainly in spicules. Therefore in his photographs the lower chromosphere was too overexposed to show any structure, as becomes evident from his isophotes. On the contrary our photographs had been properly exposed to reveal details in the low chromosphere, as well as spicules.

The well known inner limb is visible in our photographs, in addition to the outer chromospheric limb. The inner limb, most probably, is not a real solar phenomenon, but arises from unwanted photospheric light through the sidebands of the filter (White and Simon, 1968) The bright mottles are visible at the center of Hα up to the chromospheric limb. On the other at the wings the dark mottles are clearly visible up to the inner limb; beyond the inner limb only spicules occur at Hα $\pm$ 0.75 Å.

We restricted our studies in the region above the inner limb and at the line center. By properly adjusting the density difference between successive isophotes, we managed to reproduce the individual bright mottles and spicules in isophotal maps. It is difficult to assign an intensity level to each isophote line, because of the corrections that are needed in order to account for the instrumental profile and because the areas close to the chromospheric limb do not lie within the linear part of the characteristic curve of the film. We have only labeted with the letter B the regions that are brighter than their surroundings, the darker regions with the letter D and spicules with the letter S. The inner and outer limbs are at positions 1 and 2 respectively, where the density gradient is great, that is where the isophotes are closer to each other.

Spicules are distinguishable down to a distance of approximately 4″ of arc above the inner limb. In offband observations, where the chromosphere is optically thin one can see the spicules down to the inner limb; these are usually interpreted as projected foreground spicules. In figure 1 three spicules appear. Under two of them distinct bright mottles occur. It is interesting to remark that the spicule isophotes follow the shape of the mottle isophotes, indicating that they are part of a unique structure. Spicules and their associated bright mottles have

also the same inclination. No bright mottle appears under the third spicule at left.

Figure 2 shows two more associated pairs of bright mottles and spicules. Here the bright mottles are quite prominent and appear as roundish structures embeded in darker material. In figure 2 there is a bright mottle (at the left) that it is not associated to any spicule.

A very prominent spicule appears in figure 3. If one follows it inwards he finds a brighter than average area at its root. The same is true also for the spicule at the extreme right of the map, but it is not evident is the case of the spicule at left.

3. Discussion.

Our limb observations that were presented above indicate that the bright mottles (or at least most of them) have spike like extentions that

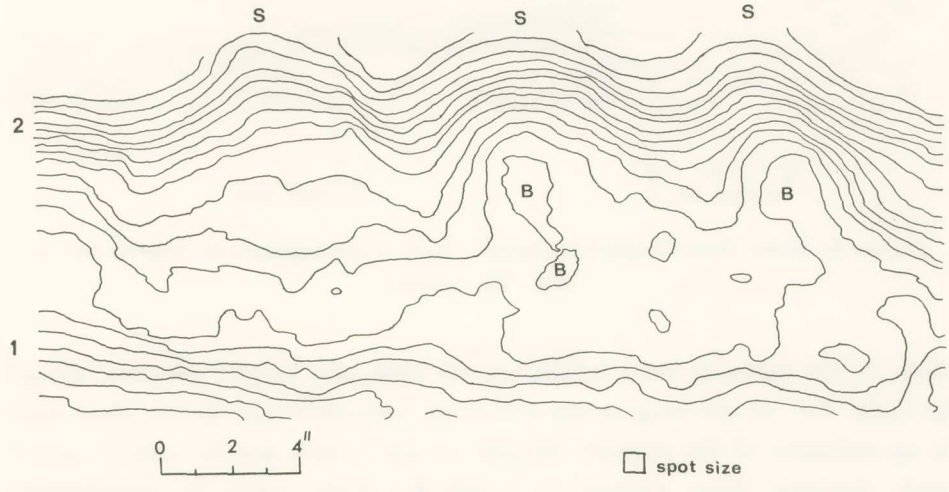

Figure 1. Solar limb isophotes plotted from a photograph at the Hα center on September 12, 1968. B denotes features brighter than their surroundings, D features darker than their surroundings and S spicules. 1 and 2 designate the approximate position of the inner and outer limb respectively.

appear as spicules at the limb. Spicules and bright mottles have lifetimes of about 6.5 min (Lippincott 1957, Alissandrakis - Macris 1971) and about 11 min (Bray 1969, Macris - Alissandrakis 1970) respectively; thus one would expect that the bright mottle is not accompanied by the spi-

cule during all its lifetime. The spicule is probably a post maximum phase of the bright mottle so that it decays after the disappearence of the mottle. We can thus explain the existance of individual bright mottles and spicules.

Our observations are consistent with Bhavilai's (1965); however they do not necessarily imply that the spicules should be bright on the

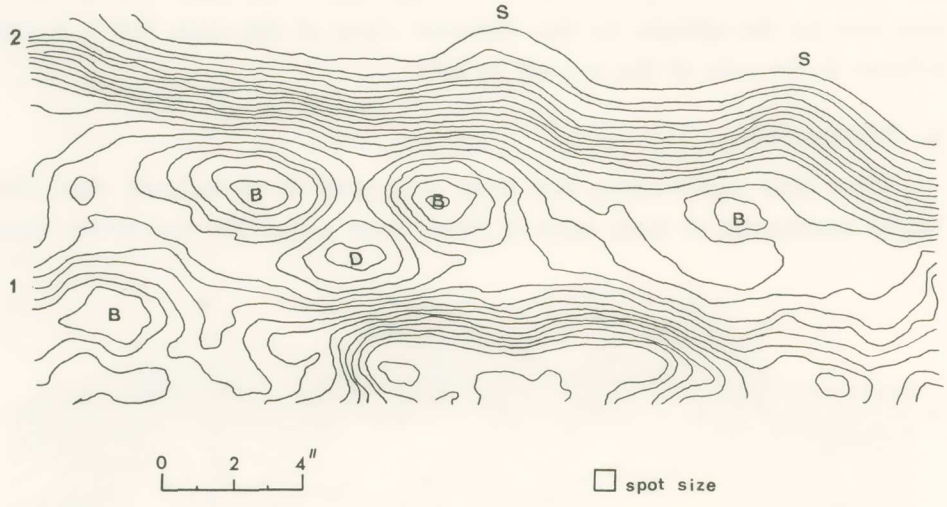

Figure 2. Solar limb isophotes plotted from a photograph on September 12, 1968, Hα center.

disk. If the spicules were bright on the disk, the bright mottles should be about 10″ of arc long is the direction perpendicular to the limb (this is an estimate of the overall height of the bright mottle - spicule structure, derived from figures 1, 2 and 3). This value is considerably greater than that estimated by Bray (1969) of 2″ - 3″ of arc, for bright mottles very close to the limb. Therefore the spicules cannot be bright on the disk.

If our observations are compared with those of Banos and Macris (1970) on the disk, the conclusion is that the spicules are identical to the dark mottles and that the dark and bright mottles compose a single structure which has a bright root and a dark top. The top of the struc-

ture is in the upper chromosphere and appears as a spicule at the limb. Thus the model of Beckers is correct, at least qualitatively.

The conclusions reached above contradict Bray (1969). If Bray is correct our limb observations cannot be explained. Certainly the investi-

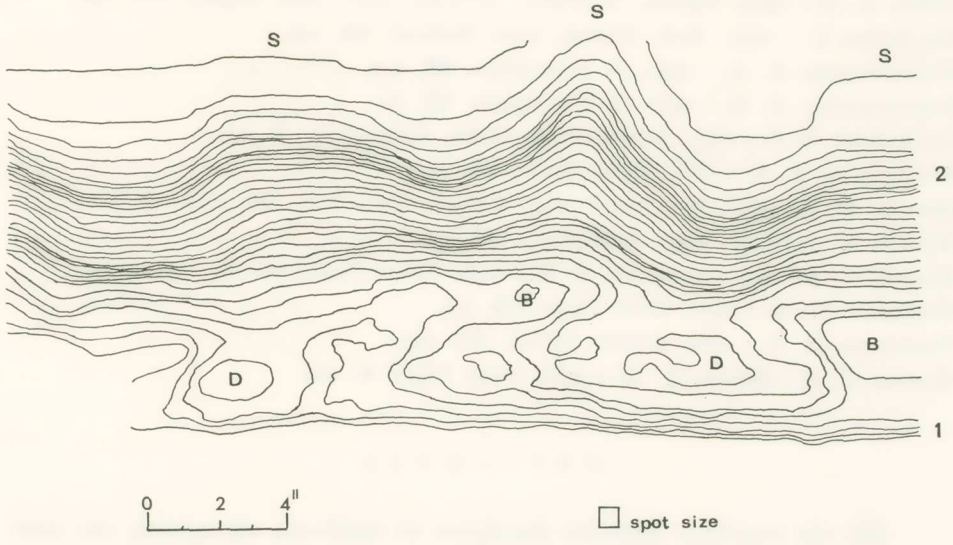

Figure 3. Solar limb isophotes plotted from a photograph on August 27, 1968, Hα center.

gation on whether bright and dark mottles are parts of the same structure or not is still at its beginning.

Aknowledgements

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Π Ε Ρ Ι Λ Η Ψ Ι Σ

Εἰς τὴν παροῦσαν ἐργασίαν ἐξετάζεται τὸ πρόβλημα τῆς σχέσεως τῶν πιδάκων τῆς ἡλιακῆς χρωμοσφαίρας καὶ τῶν λαμπρῶν ψηφίδων, βάσει παρατηρήσεων ἐπὶ τοῦ ἡλιακοῦ χείλους εἰς τὴν γραμμὴν Ηα. Τὸ πρόβλημα τοῦτο συνδέεται στενῶς πρὸς τὸ πρόβλημα τῆς ἐμφανίσεως τῶν πιδάκων ἐν προβολῇ ἐπὶ τοῦ ἡλιακοῦ δίσκου. Διὰ τὸ τελευταῖον ἔχουν προταθῆ αἱ ἑξῆς λύσεις :

1. Οἱ πίδακες ἐμφανίζονται ὡς σκοτειναὶ ψηφῖδες (Macris 1956, 1957 καὶ ἄλλοι).

2. Οἱ πίδακες ἐμφανίζονται ὡς λαμπραὶ ψηφῖδες (Bhavilai 1965).

3. Οἱ πίδακες δύνανται νὰ εἶναι εἴτε λαμπροὶ εἴτε σκοτεινοί, ἐξαρτᾶται δὲ τοῦτο ἀπὸ τὴν περιοχὴν τῆς γραμμῆς Ηα, εἰς τὴν ὁποίαν ἐκτελεῖται ἡ παρατήρησις, ἀπὸ τὸ τμῆμα τοῦ πίδακος, τὸ ὁποῖον παρατηρεῖται, καὶ ἀπὸ τὴν φάσιν τῆς ἐξελίξεως τοῦ πίδακος (Beckers 1968).

Αἱ παρατηρήσεις εἰς τὸ χεῖλος ἐπιτρέπουν ἄμεσον ἐξέτασιν τῆς σχέσεως τῶν πιδάκων μὲ τὰς λαμπρὰς ψηφῖδας τῆς κατωτέρας χρωμοσφαίρας. Πρὸς καλυτέραν μελέτην τοῦ θέματος ἐλήφθησαν ἰσόφωτοι περιοχῶν τοῦ χείλους διὰ τοῦ ἰσοφωτομέτρου Joyce - Loebl, εὐγενῶς παραχωρηθέντος ὑπὸ τοῦ Διευθυντοῦ τοῦ Ἐργαστηρίου ἀντοχῆς ὑλικῶν τοῦ Ε. Μ. Πολυτεχνείου καθηγητοῦ κ. Π. Θεοχάρη. Αἱ ἰσόφωτοι παρουσιάζονται εἰς τὰς εἰκόνας 1, 2 καὶ 3. Οἱ λαμπροὶ σχη-

ματισμοὶ σημειοῦνται διὰ τοῦ γράμματος Β, οἱ σκοτεινοὶ διὰ τοῦ D καὶ οἱ πίδακες διὰ τοῦ S. Εἰς πλείστας τῶν περιπτώσεων οἱ λαμπροὶ σχηματισμοὶ εὑρίσκονται ὑποκάτω τῶν πιδάκων. Τοῦτο εἶναι ἐμφανὲς καὶ εἰς τὰ ἀρνητικὰ τῶν φωτογραφιῶν.

Ἐν συνδυασμῷ πρὸς τὰς παρατηρήσεις τῶν Banos καὶ Macris (1970) ἐπὶ τοῦ δίσκου, συμπεραίνεται ὅτι ἡ ὑπόδειξις τοῦ Beckers (1968) εἶναι ὀρθή. Ἤτοι μία λαμπρὰ καὶ μία σκοτεινὴ ψηφὶς ἀποτελοῦν ἑνιαῖον σύστημα λαμπρὸν εἰς τὴν βάσιν του καὶ σκοτεινὸν εἰς τὴν κορυφήν του, ὅταν παρατηρῆται ἐπὶ τοῦ δίσκου. Τὸ ἄνω μέρος τοῦ σχηματισμοῦ ἐμφανίζεται ὡς πῖδαξ, ὅταν ὁ σχηματισμὸς διασχίζῃ τὸ χεῖλος.

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Κατὰ τὴν ἀνακοίνωσιν τῆς ἐργασίας τῶν κ. κ. Κ. Ἀλυσσανδράκη καὶ Κ. Μακρῆ, «Ἐπὶ τῶν σχέσεων μεταξὺ λαμπρῶν ψηφίδων καὶ πιδάκων τῆς ἡλιακῆς χρωμοσφαίρας», ὁ Ἀκαδημαϊκὸς κ. **Ἰω. Ξανθάκης** εἶπε τὰ ἀκόλουθα :

Εἰς τὴν ἐργασίαν ταύτην ἐξετάζεται τὸ πρόβλημα τῆς σχέσεως τῶν πιδάκων τῆς ἡλιακῆς χρωμοσφαίρας καὶ τῶν λαμπρῶν ψηφίδων. Αἱ παρατηρήσεις ἐξετελέσθησαν ἐπὶ τοῦ ἡλιακοῦ χείλους διὰ τῆς χρησιμοποιήσεως πολωτικοῦ μονοχρωματικοῦ ἠθμοῦ Lyot εἰς τὴν γραμμὴν Ηα τοῦ Ὑδρογόνου. Ἐχρησιμοποιήθη δὲ τὸ τηλεσκόπιον Δωρίδου μὲ ἀντικειμενικὸν φακὸν 40 ἑκ. τοῦ Ἐθνικοῦ Ἀστεροσκοπείου Ἀθηνῶν. Τὸ πρόβλημα τοῦτο συνδέεται στενῶς πρὸς τὸ πρόβλημα τῆς ἐμφανίσεως τῶν πιδάκων ἐν προβολῇ ἐπὶ τοῦ ἡλιακοῦ δίσκου, τὸ ὁποῖον παλαιότερον εἶχεν ἀπασχολήσει τὸν κ. Μακρῆν.

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