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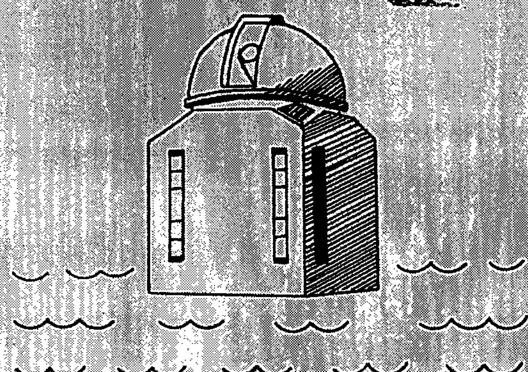
MORPHOLOGICAL RELATIONSHIPS IN THE CHROMOSPHERIC H-ALPHA FINE STRUCTURE.

By

Peter Foukal



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ABSTRACT

A continuous relationship is proposed between the basic elements of the dark fine structure of the quiet and active chromosphere. A progression from chromospheric bushes to fibrils, then to chromospheric threads and active region filaments, and finally to diffuse quiescent filaments, is described. It is shown that the horizontal component of the field on opposite sides of an active region quiescent filament can be in the same direction and closely parallel to the filament axis. Consequently, it is unnecessary to postulate twisted or otherwise complex field configurations to reconcile the support mechanism of filaments with the observed motion along their axis.

I. INTRODUCTION

It is agreed by many that the H-Alpha fine structure potentially provides the finest chromospheric vector magnetograph we are ever likely to have. At the same time, a detailed physical theory of the interaction of the absorbing and emitting features with the magnetic field is still rather far away. An attempt is made here to suggest some new relationships between the various elements of the fine structure and thus to make some progress toward at least a morphological, self consistent theory of the chromosphere.

The conclusions presented here are drawn from close examination of a number of recently obtained filtergrams and magnetograms of exceptional quality. Through good fortune, one large active region was followed from limb to limb with excellent seeing for the most part. This active region contained the full variety of representative fine structure, but was remarkably well ordered and easily analyzed for patterns in its H-Alpha appearance and in the accompanying magnetograms.

In this paper, four expressions will be used to describe the distinct types of absorbing features which are to be studied. Referring first to Figure 2 and then

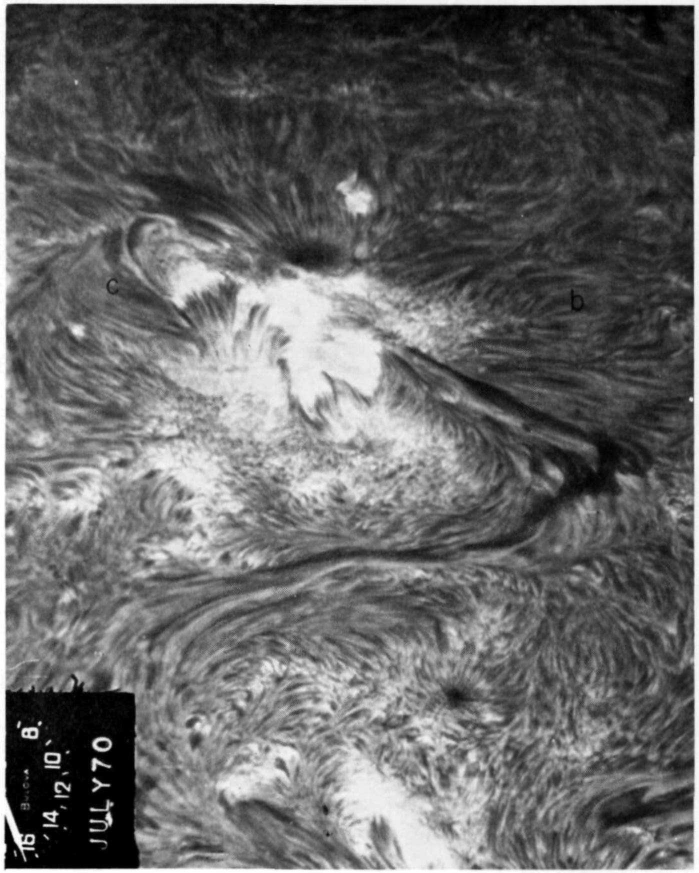


Figure 1 a

Active region of July 6th, 1970 showing fibrils (b) and chromospheric threads (c) (Halle 1/2 Å filter).

1 b

Active region of May 22, 1970, showing fibrils (b) and chromospheric threads (c). (Halle 1/2 Å).

to Figure 1 a, b these are: i) chromospheric "bushes," the characteristic absorption features of the quiet chromosphere (marked (a) on Figure 2);

ii) fibrils, the elongated dark dashes associated at one end with plage or plagettes and typical of the vicinity of all active regions (marked (b));

iii) chromospheric threads, similar to fibrils, but associated at both ends with plage or plagettes of opposite polarity, and generally somewhat longer and darker (marked (c));

iv) filaments - this is a category including all dark features larger than threads and includes several sub-groups to be discussed later.

Throughout the discussion, only dark, absorbing, features will be mentioned. This is not to imply that bright components of bushes, fibrils and threads do not exist. Such features certainly seem to be present, but in general they appear to behave similarly (morphologically) to the corresponding dark features, and a separate discussion is not included.

II. OBSERVATIONS

The filtergrams reproduced here were obtained during regular daily operation of the 25 cm photo-

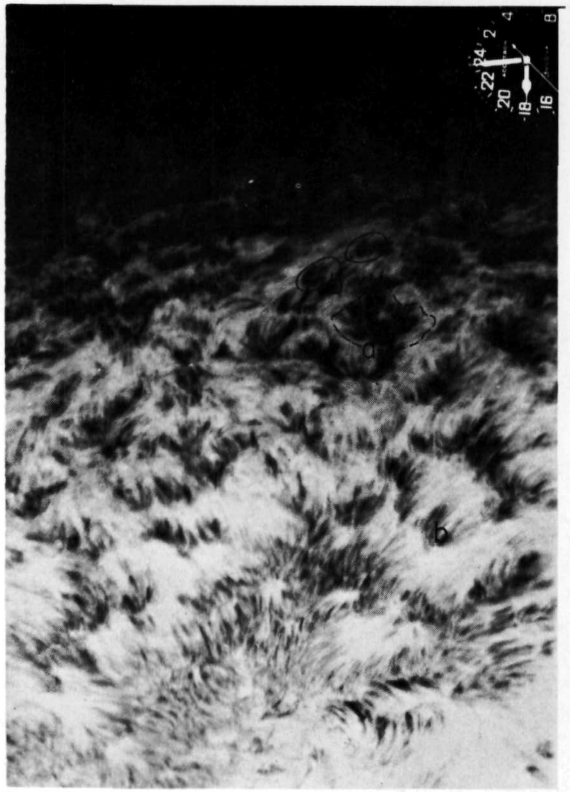


Figure 2

Boundary of active regions and quiet chromosphere, near limb, Oct. 23, 1969. Zeiss filter 1/4 Å, at H-Alpha +1/2 Å.

Typical clusters of quiet chromosphere "bushes" are marked (a), fibrils typical of stronger field regions are marked (b).

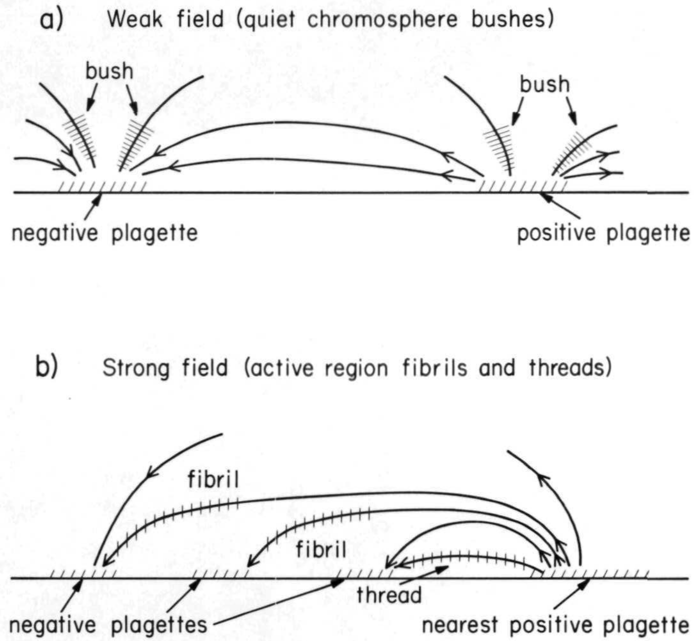


Figure 3

Schematic diagrams of a) the relation of a chromospheric bush to the local field and b) of fibrils and threads to the local field. Only the direction (not the intensity) of the field is given by the field line presentation in these diagrams.

heliograph at Big Bear Lake. The instrument has been described by Zirin (1970). Unless otherwise noted, the filtergrams were obtained with a Zeiss $\frac{1}{4}$ Å filter on SO 392 emulsion with exposures of about 1/25 second at a repetition rate of generally 10 seconds.

Of particular interest was a continuous sequence of films taken between October 20-31, 1969. This sequence gives the three dimensional appearance of a large active region at high resolution as it passes across the disc from limb to limb.

The photo-cancelled magnetograms at λ 6103 Å and the matching H-Alpha + 0.4 Å filtergram were obtained at the Aerospace Corporation Solar Observatory and were kindly supplied by Dale Vrabec. Mt. Wilson fine scan magnetograms of the region studied in October 1969 were kindly provided by Dr. A. Bhatnagar.

III. FIBRILS, CHROMOSPHERIC BUSHES AND SPICULES

Figure 2 shows the transition zone between an active region and the quiet chromosphere. This figure shows the gradual progression between the vertically oriented bushes of the quiet chromosphere such as at (a), and the horizontally deflected clusters of absorption features, typical of active regions, such as at (b).

Near b ~~(e)~~ ~~in particular~~, the deflection is uniformly in one direction and this is a common property of large fields of the so-called fibrils which always occur near active regions. The alignment is generally in the direction of a nearby region of opposite polarity of the longitudinal field component.

It is logical to conclude that the deflection of such bushes as at (b) is caused by the horizontal component of the magnetic field in regions where it is strong enough to influence the motions of the gas. This is illustrated in Figure 3. In the strong field case, the plasma is constrained to follow low-lying field lines to form horizontal structures (fibrils). Consequently, the quiet chromospheric bushes and the fibrils are probably similar to one another except for the strength of the local field.

The quiet chromosphere "bushes" have sometimes been referred to as the disc equivalent of spicules on the limb, but this correspondence has not yet been established beyond controversy. Since it is not the purpose of this paper to consider that question, I will conclude only that there is a continuous progression in the physical nature of the smallest component of the quiet and active chromosphere--that is, of the bushes and fibrils.

The lifetimes of fibrils and chromospheric bushes were compared by examining the change of features on the time lapse films. It was found that comparable features (individual fibrils and individual "spikes" of the bush) have similar lifetimes of several minutes.

The fibril changes visibly in these minutes but it oscillates about a "mean appearance" defined by a characteristic alignment, mean darkness and mean length which is preserved typically for several hours. This larger time scale is similar to that required for major rearrangements of the complete bushes in the quiet chromosphere. It is also comparable to the time scale of change in the larger absorbing structures to be discussed later--the chromospheric threads.

Actually, comparison of lifetimes of fibrils and bush structure is not a particularly useful way of studying their similarity because there is no reason to believe that the time scale of structures co-existing with such greatly different field strengths should be similar. However, a different conclusion may be drawn. It appears likely that the longer time scale of hours is indicative of the time scale of change of the magnetic field structure which constrains the appearance of the H-Alpha absorbing structures.

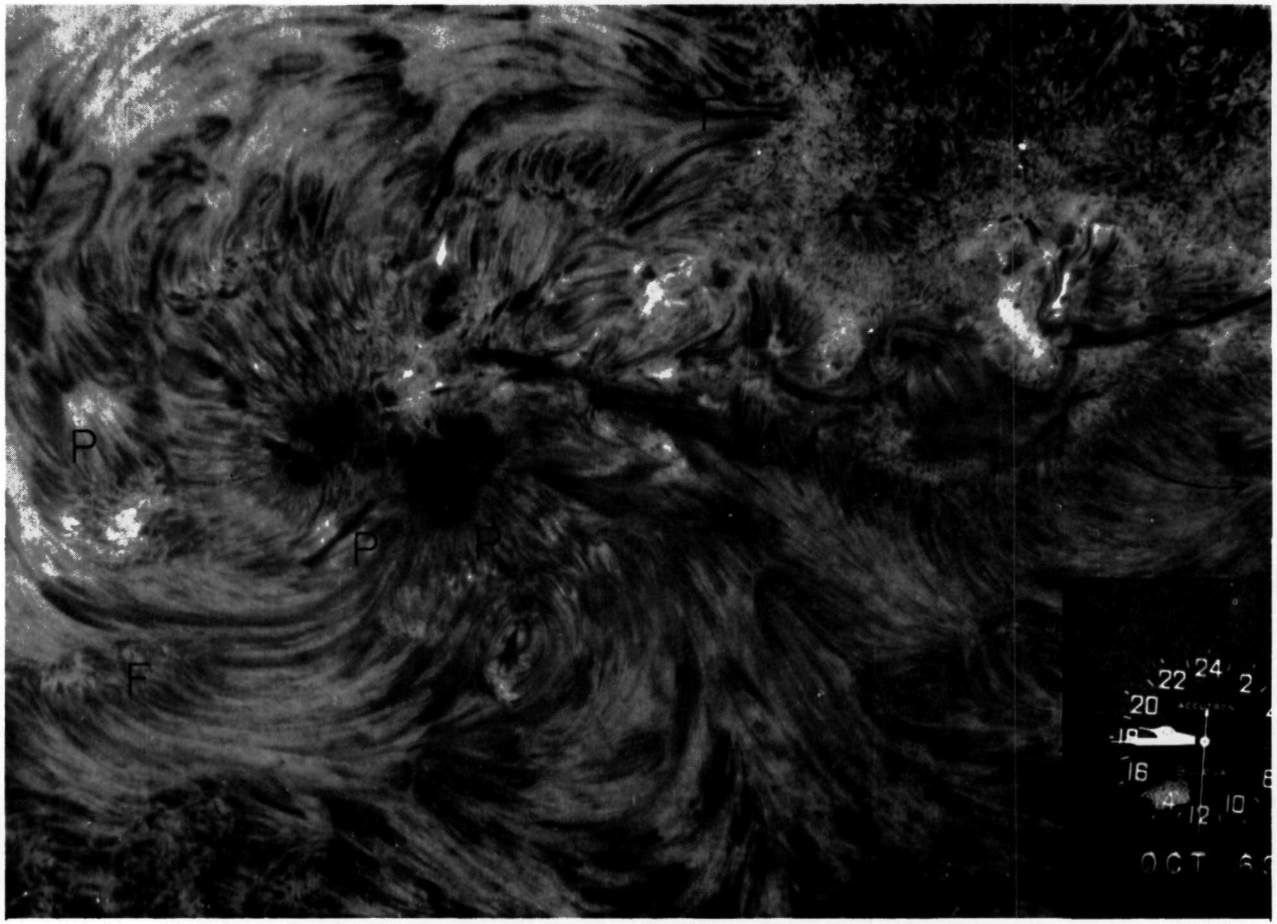


Figure 4 Active region of Oct. 26, 1969, H-Alpha +1/2 Å. Arrows denote characteristic lengths of fibrils and their behavior as field lines.

The shorter time scale of minutes is more likely to be indicative of changes in the plasma contained by the field lines which leads to the sporadic variation in the absorption produced by the contained material.

IV. FIBRILS

Figure 4 shows the structure of a field of fibrils near an active region. The fibrils are seen to be associated at one end (the darkest end) with the edges of a plage or smaller plagette, (Howard and Harvey, 1964) and the distance over which a given fibril can be identified is seen to be generally the distance between two such plagette areas. This is illustrated by the arrows in Figure 4. Also, a fibril, which seems to run along field lines, detours sideways, as would be expected, when it encounters plagettes of the same polarity as that in which it is "anchored." The fact that a given fibril generally can be followed for about the distance between two adjacent elements of plagette leads to the appearance that fibrils arch across supergranule cells. In Figure 5 (a,b) we see that this is not plausible. [The magnetogram, Figure 5 a, obtained at Aerospace Corporation, shows a different active region than pictured in the

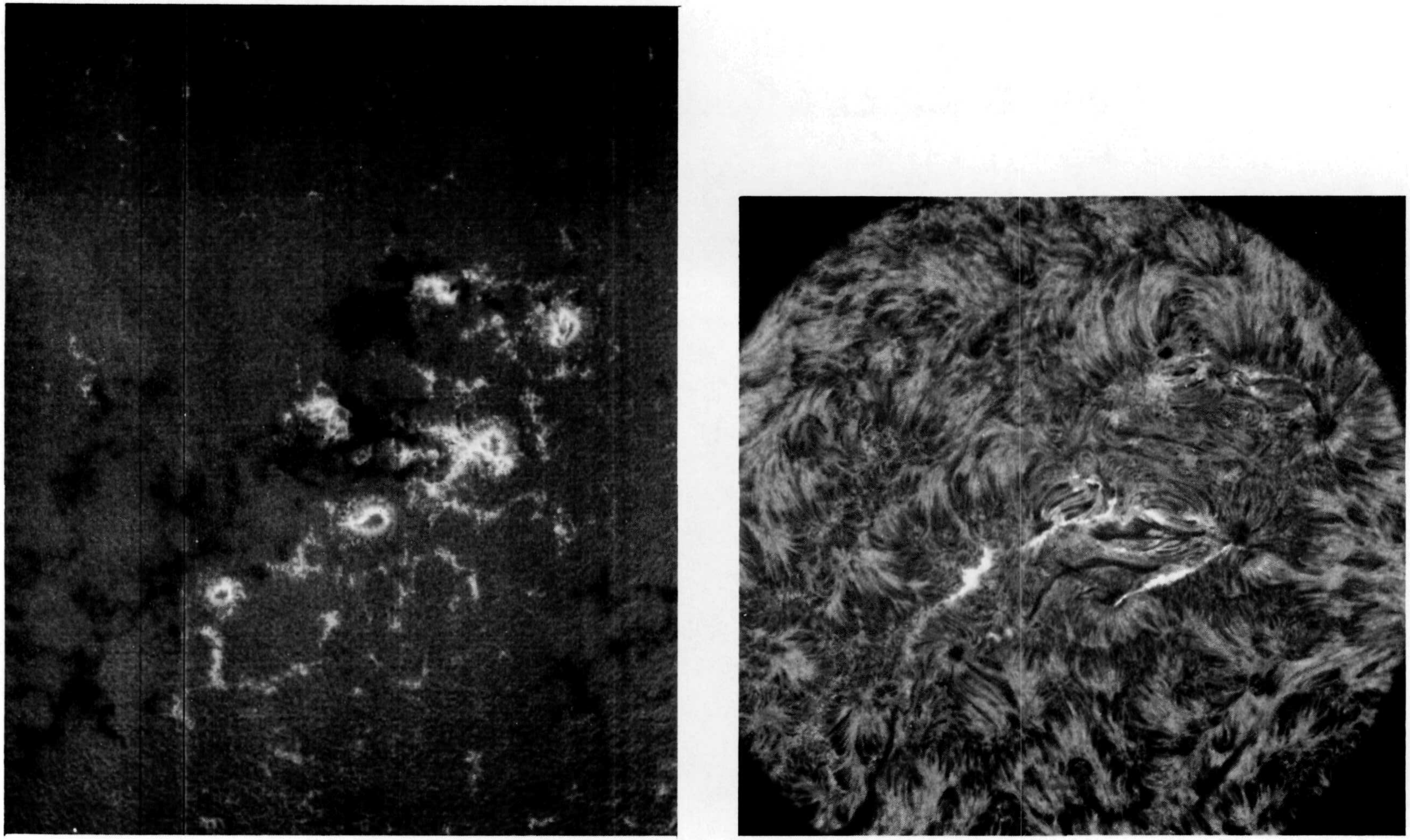


Figure 5

a) Magnetogram obtained by Leighton's method at Aerospace Corporation on Jan. 26, 1970, 1735 UT. The magnetogram is taken in the CaI line at 6103 Å.

b) Aerospace Corporation accompanying filtergram of same region at same scale, taken at H-Alpha +0.4 Å.

previous figures, and Figure 5 b gives the corresponding filtergram at H-Alpha + 0.4 Å.] From this figure we can see that the adjacent elements of plage, that is, in general the diametrically opposed points on a supergranule cell, are usually of the same polarity. In fact, large regions of several adjacent supergranule cells are usually of the same polarity. This leads to the conclusion that fibrils, which seem to follow field lines, cannot connect across supergranule cells and must be open ended absorbing features much as spicules and bushes seem to be. Unlike bushes, they follow field lines which run closely parallel to the surface. This is illustrated in Figure 3 b. Consequently, although the field lines which guide the dark fibril material connect back to the photosphere somewhere in an area of opposite longitudinal polarity, the fibril exists as a recognizable structure only for the distance across one supergranule. At the diametrically opposite boundary of the supergranule cell over which it leads, the fibril is rendered invisible by the darker roots of the fibrils anchored at that opposite boundary.

In general then, the structure recognized near active regions as a fibril is very similar to the dark bush characteristic of the quiet chromosphere. The difference is that the fibril is horizontally deflected

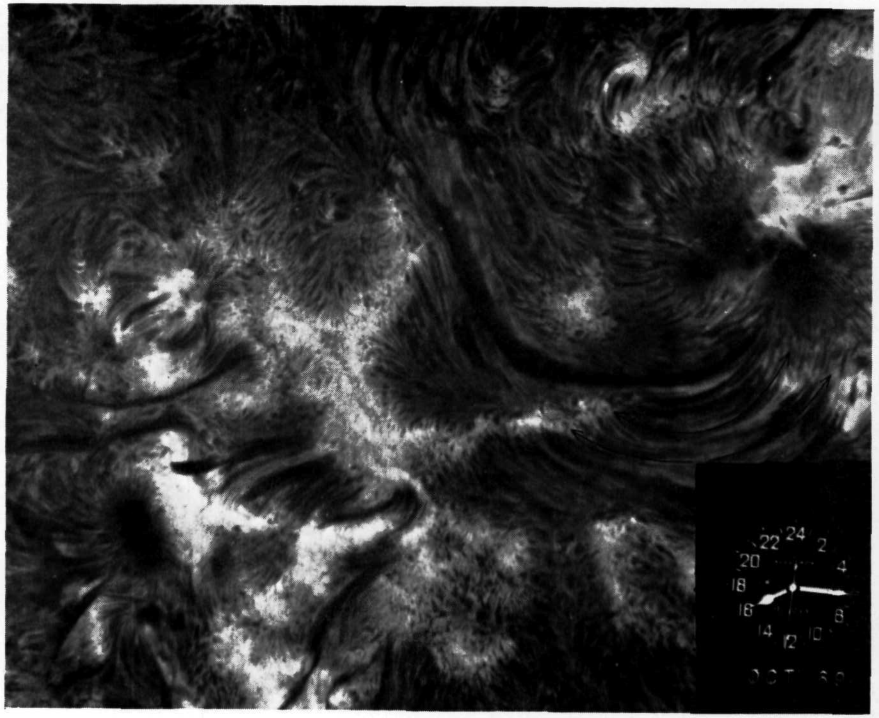


Figure 6

Active region of Oct. 26, 1969, including region slightly to west of that in Figures 2, 8, 9. Typical examples of chromospheric threads are marked by the arrows. The regions which the threads connect are of opposite polarity.

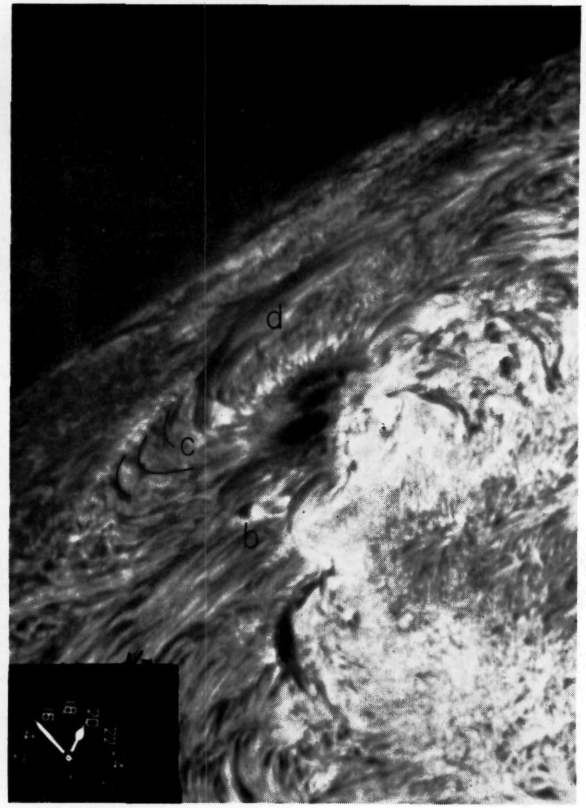


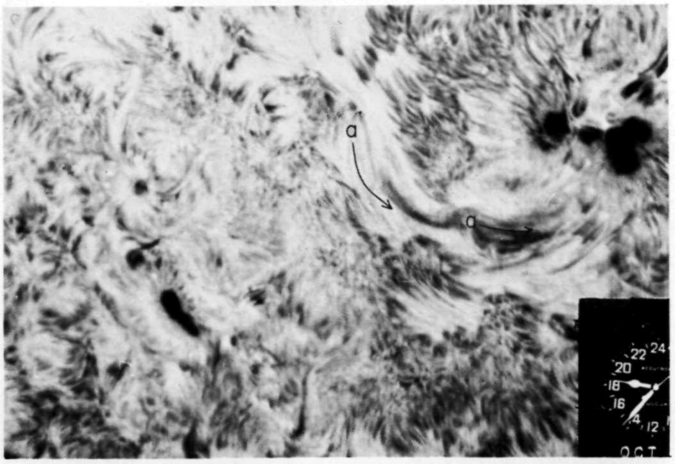
Figure 7

The active region on Oct. 30th, near the limb, showing height structure of the filament (d), fibrils (b) and threads (c).

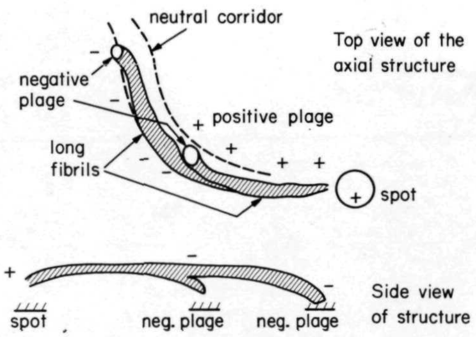
by the field to run closely parallel to the surface. Its characteristic length is determined by the distance over which it can follow a flux tube before encountering another plage (a source of fibrils itself) of the same polarity as that with which its own dark end is associated.

V. CHROMOSPHERIC THREADS

At times it happens that there is no like-polarity plage intervening in the path of a fibril and it will connect directly to opposite polarity plage. This is a common phenomenon illustrated well in Figure 6. Such structures I will call chromospheric threads. They are fibrils for which the full length of the flux tube in the chromosphere, as it leads from one polarity to another, can be followed as one absorbing structure. Consequently, both ends are well defined and opposite ends are associated with plage of different polarity. Generally, they can be traced for a larger distance than the fibrils. It seems reasonable to suppose that since these threads are associated with plage and flux tubes in much the same way as are the chromospheric bushes and fibrils, then the physical nature of these threads is also closely similar to that of the other



8c) The structure of an active region quiescent filament



8d) Active region quiescent well away from any spot
(top view of transverse structure)

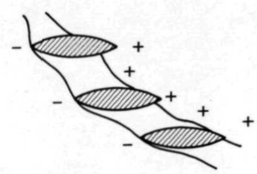


Figure 8 In (a) the region of the filament is shown off-band (H-Alpha + 1/2 Å) on Oct. 27. The plagettes which represent two points at which the filament is "anchored" are marked by a. In (b) the same region is shown (on the next day) in line center, correspondingly marked. (No good H-Alpha center frame was available on the 27th.)

two categories mentioned. A glance at the Figures 1 b and Figure 7 where such threads appear near the limb, confirms that their height in the atmosphere is roughly similar to that of fibrils, and that both lie somewhat above the surface of the plage as seen in H-Alpha.

IV. FILAMENTS

A morphological explanation of the different appearance and characteristics of the class of large objects known as filaments can be constructed from what has been said above about the fibrils and chromospheric threads.

The on-band filtergram Figure la shows the typical multi-thread structure of a large active region filament. In Figure 7, we see another such filament near the limb where the vertical cross section of its fine structure can be recognized. When seen off-band, near the center of the disc, (Figures 8, 9) the same filament as seen in Figure 7 is seen to run in the characteristic corridor relatively free of short fibrils. As is well known, this corridor marks a locus of zero longitudinal field component.

In Figure 9 (note arrows) we remark an im-

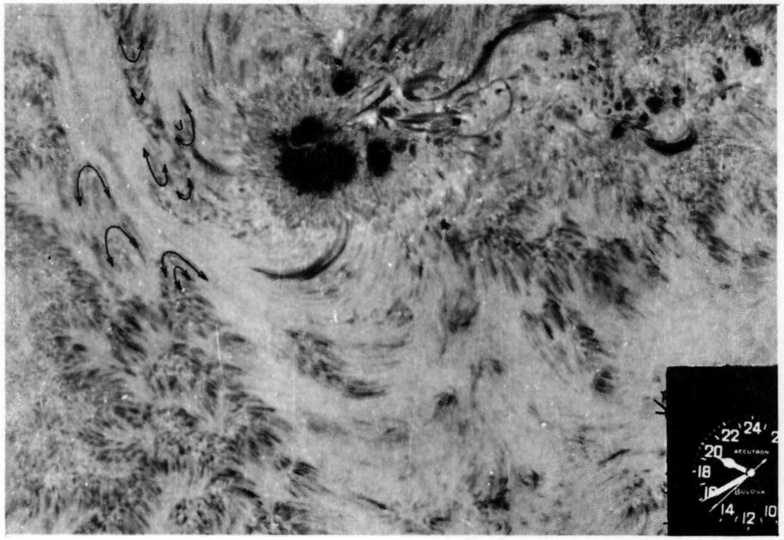


Figure 9

Filament neighborhood showing direction of streaming of fibrils from plage on either side. The arrows show that the fibrils run in antiparallel directions on opposite sides of the neutral line.

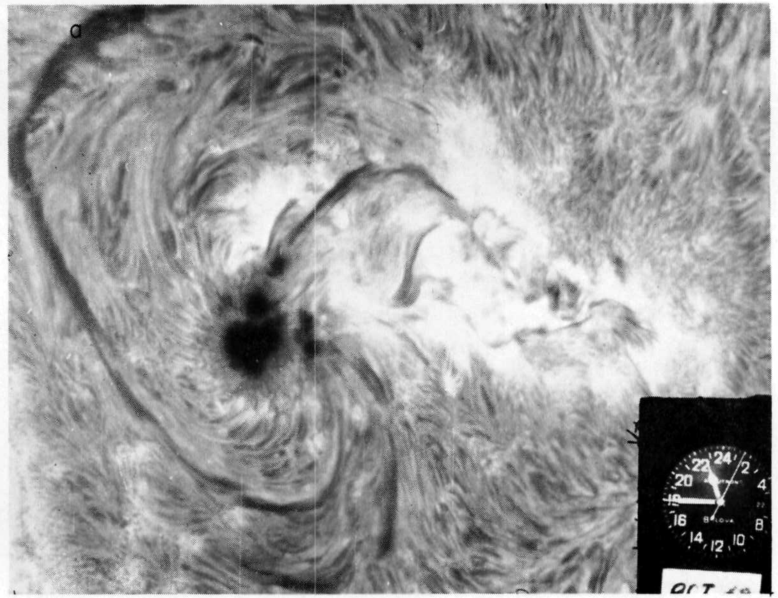


Figure 10

The full extent of the filament as seen on Oct. 22, 1969, showing the whole active region.

portant characteristic of the fibrils near this corridor. The fibrils are bent (as they "issue" from their plagettes) in opposite (antiparallel) directions on opposite sides of the filament line. This observation has been confirmed in the case of a few other similar filaments. Since the plagettes on opposite sides of the filament have opposite longitudinal polarity, the antiparallel streaming of the fibrils implies that the horizontal component of the field on opposite sides of the filament is parallel and in the same direction. It seems then that the interpretation of a lack of observable longitudinal field along such a filament as a neutral line in the sense of horizontal field connecting across the filament axis is in general incorrect. It seems more likely that the field on each side and within such a long narrow active region quiescent filament runs at a very small angle or parallel to the filament axis, rather than across it. In this case, the corridor followed by the filament would be more aptly described as a line of shear in the field than as a neutral line.

The detailed structure of this field and the constitution of the filament itself can be deduced from an off-band filtergram such as Figure 8. Figure 8 a shows that long fibrils (shown by arrows) stream from plagettes (a) along one side of the shear line and continue toward the sunspot. We have seen previously, (in Figure 7 b, near the limb), that the filament shows evidence of being composed of several arches, connecting as "feet" to the surface at numerous points. Unfortunately, no filament is quiescent enough to be able to confidently observe the exact same features in its fine structure as it moves from disc center to limb. But we may probably say that the feet are the points at which the filamentary threads connect to the plagettes (Figure 8 c and 8 d).

What has been said so far pertains to filaments of the active region variety. These quiescent objects are generally very dark, narrow and are only marginally detectable at the limb above the level of the fibrils and chromospheric threads. Rust (1967) mentions that from the few direct measurements of the field in such filaments, there is evidence that a considerable axial component is present. This distinguishes them in his study from the amorphous filaments which appear on the limb as high prominences and contain a field predominantly transverse to the axis of the filament. These have H-Alpha fine structure (transverse to the axis) clearly reaching to considerable altitude when the object is seen near the limb.

Further, the primarily axial field deduced above for such filaments is in agreement with the observations of pronounced motion of ionized material along the axis of such filaments.

This description indicates that such objects consist of a number of long fibrils and chromospheric threads lying rather lower in the chromosphere than the more amorphous filaments. Such an object would then be supported by a combination of gas pressure and magnetic field and could be constrained to a narrow shape by the highly sheared field along its axis.

The geometry of the field in the vicinity of a filament of this type is determined by the proximity of a very strong magnetic pole--i.e. a sunspot. The vector field leads from the plage at one side of the shear line along the shear line to the very strong pole of the sunspot. The connection directly across the neutral line to plage of opposite polarity can be relatively weak because the spot, although further away, is a much more intense pole than the nearby plage.

Examining Figure 10 we see that this thinking can probably be consistently generalized to the case of the large diffuse quiescent filaments which occur father away from centers of strong magnetic attraction. That figure shows the same filament as Figures 8, 9 etc., but as seen on October 22nd. We notice that at the end (a) of the filament farthest from the spot, a pronounced structure transverse to the filament axis becomes evident. This is consistent with the fact that at points along the filament far from the spot, the field from the plage connects more between the plage of opposite polarity transversely across the filament and connects progressively less along the neutral line to the spot.

That is, the threads which make up such a filament run progressively more transverse to the filament axis and the characteristic pattern of H-Alpha and field structure transverse to an amorphous quiescent filament emerges (the herring bone structure). At the same time this end of the filament (see Figure 10) becomes more diffuse and probably attains greater altitude than the end nearer the sunspot.

In this way, a connection can be established between the classical diffuse, high quiescents located along neutral lines well away from sunspots and containing structure transverse to the axis, and the narrow, low, axially structured, active region quiescents.

This description of a morphological theory of the chromospheric fine structure omits the class of filaments known as AFS (Weart, Ap.J. in press) which are now being studied as very interesting indicators of emerging field. The nature of the material motions in such filaments suggest that they are of a quite different nature.

Of course, the various perturbations of quiescent filament structure associated with violent surge action (sometimes also seen at the limb as mass motion, but not necessarily along an active region filament) are not inconsistent with the description given above of quiescent structures. Clearly, these last structures are transient and do not belong in the morphology of features which appear to be in rather impressive static or dynamic equilibrium.

A significant feature of the chromospheric fine-structure is the clear appearance of large fields of features whose difference in altitude is small compared with their large horizontal extent. This suggests that in the vicinity of active regions, if the H-Alpha features are significantly supported by the magnetic field, such a field must also exist mainly in a uniform low-lying sheet.

ACKNOWLEDGEMENTS

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