# AN ATTEMPT TO ASSOCIATE OBSERVED PHOTOSPHERIC MOTIONS WITH THE MAGNETIC FIELD STRUCTURE AND FLARE OCCURRENCE IN AN ACTIVE REGION

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**Abstract.** We have tried to find empirical evidence for the role of photospheric motions in the building up of the flare productive magnetic patterns in Active Regions.

The bright Hα faculae are associated with $V_{\|}$ structures different from a classical Evershed flow and particularly 'anomalous' in the regions and periods of high flare occurrence. The flares observed occurred at 'crossings' of the lines $V_{\|}=0 (V\neq 0)$ and $H_{\|}=0$ and at places where $V_{\|}=0$ showed abrupt changes of direction. It is suggested that these anomalous $V_{\|}$ structures are evidence of vortex motions.

## 1. Introduction

The location and occurrence conditions of Hα flares in an eruptive Active Region (A.R.) have been roughly defined in relation with the magnetic field pattern:

– existence of an inversion line ($H_{\|}=0$) with strong gradient of $H_{\|}$ and often anomalous orientation to the meridian (Severny and Moreton, 1966; Martres *et al.*, 1966; Smith and Ramsey, 1967). The flares start on both sides of this line, whatever the position of the A.R. on the disk, implying that the inversion line of $H_{\|}$ nearly coincide with the line $H_V$ (for vertical) $=0$.

– the two 'evolving magnetic features' (E.M.F.) of opposite polarities separated by this inversion line evolve in opposite senses (Martres *et al.*, 1968; Ribes, 1969).

The equation for the field changes

$$\frac{\partial H}{\partial t} = \text{rot}\,(\mathbf{V} \times \mathbf{H}) + \eta\nabla^2\mathbf{H}$$

shows that the term rot $\mathbf{V} \times \mathbf{H}$ dominates the field variation (unless a fast dissipation of the field in unresolved fine structures occurs). Therefore the structure of the $\mathbf{V}$ field in relation to $\mathbf{H}$ should be essential for an understanding of the field changes associated with flares (see also the review by R. Michard in the same Proceedings).

We have tried to get some empirical evidence of these processes by a study of chromospheric structures, longitudinal magnetic fields, line of sight velocities patterns ($V_{\|}$) and flare localization in the A.R. No. 1512-16 (numeration according to *Cartes Synoptiques*) observed in Meudon from September 17th to 23rd, 1966 (60°E to 20°W). This A.R. at 20°N was then young and increasing in dimensions, of mild magnetic complexity (class Cp in Meudon classification) and produced about 50 little flares. $H_{\|}$ and $V_{\|}$ were observed in the line 6173 Fe I.

Line of sight velocities patterns are difficult to interpret in terms of actual motions. Short period changes (5 min oscillations for instance) are superimposed on more or

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less stationary and systematic motions: since the solar photosphere should remain spherical and conserve its matter, stationary $V_{\|}$ may result either from horizontal systematic motions, or from vertical motions involving an unresolved fine structure whose ascending and descending elements have different 'weights' in the resulting line profile. Of course intermediate or mixed cases are also possible!

## 2. Classification of Line of Sight Velocity Features in the A.R.

As a help to sort out different possible classes of $V_{\|}$ features, we look in Figures 1 and 2 at the $V_{\|}$ pattern in connection with the $H_{\|}$ pattern (Figure 1) and Hα structure (Figures 1 and 2).

It is possible to recognize the following classes of $V_{\|}$ features corresponding perhaps to different physical motions.

**1.** Around some of the sunspots, especially the extreme leading and following spots, we note the usual Evershed flow, which can be recognized from the orientation of the line $V_{\|}=0$ (normal to the direction of the center of the disk) and from the sign of velocities on both sides. At the poor resolution of our Hα pictures there are no particular relations between the regions of normal Evershed flow and Hα features.

**2.** Around the central spot, which is of following magnetic polarity but surrounded by 'parasitic' poles of leading polarity, we have (Figure 1) *an irregular* $V_{\|}$ pattern (different from the Evershed flow). In this same area we have very bright Hα features, better delineated at Hα $\pm 0.5$ Å (Figure 1). This is also the region where flares occurred on the 18th and following days. We suggest this 'irregular' pattern to be due to horizontal motions, similar to a strongly distorted Evershed flow.

**3.** There are islands of 'negative' $V_{\|}$ (away from the observer or downwards) overlying regions of Hα brightness above the average. At Hα $\pm 0.5$ Å (Figure 1) such an area is seen just above the following spot (left of the picture). On September 22, when the Active Region was relatively close to the center of the disk and flare activity had disappeared, these features represent a large part of the $V_{\|}$ pattern.

**4.** At the periphery of the A.R. we have $V_{\|}$ features of doubtful association with Hα features. We are looking at the transition between the A.R. and the surrounding photosphere and probably the complex superposition of supergranulation and oscillations dominates the $V$ field. In the 'quiet' photosphere the relations between motions and the Hα pattern are rather obscure as yet: In our observation of September 18 there is an indication of an association of $V_{\|}>0$ (upwards) velocities, with dark Hα features at $\pm 0.5$ Å bordering the magnetic poles east of the A.R.

## 3. Comparison of $H_{\|}$ and $V_{\|}$ Patterns in Relation to Flare Occurrence

In the following we shall concentrate on the comparison of the observed $H_{\|}$ and $V_{\|}$

patterns, which were observed simultaneously; 64 maps of these two quantities were available for the A.R. and period under consideration.

The relative dispositions of $H_{\parallel}$ features termed E.M.F. (for Evolving Magnetic Features) and $V_{\parallel}$ features are very diverse.

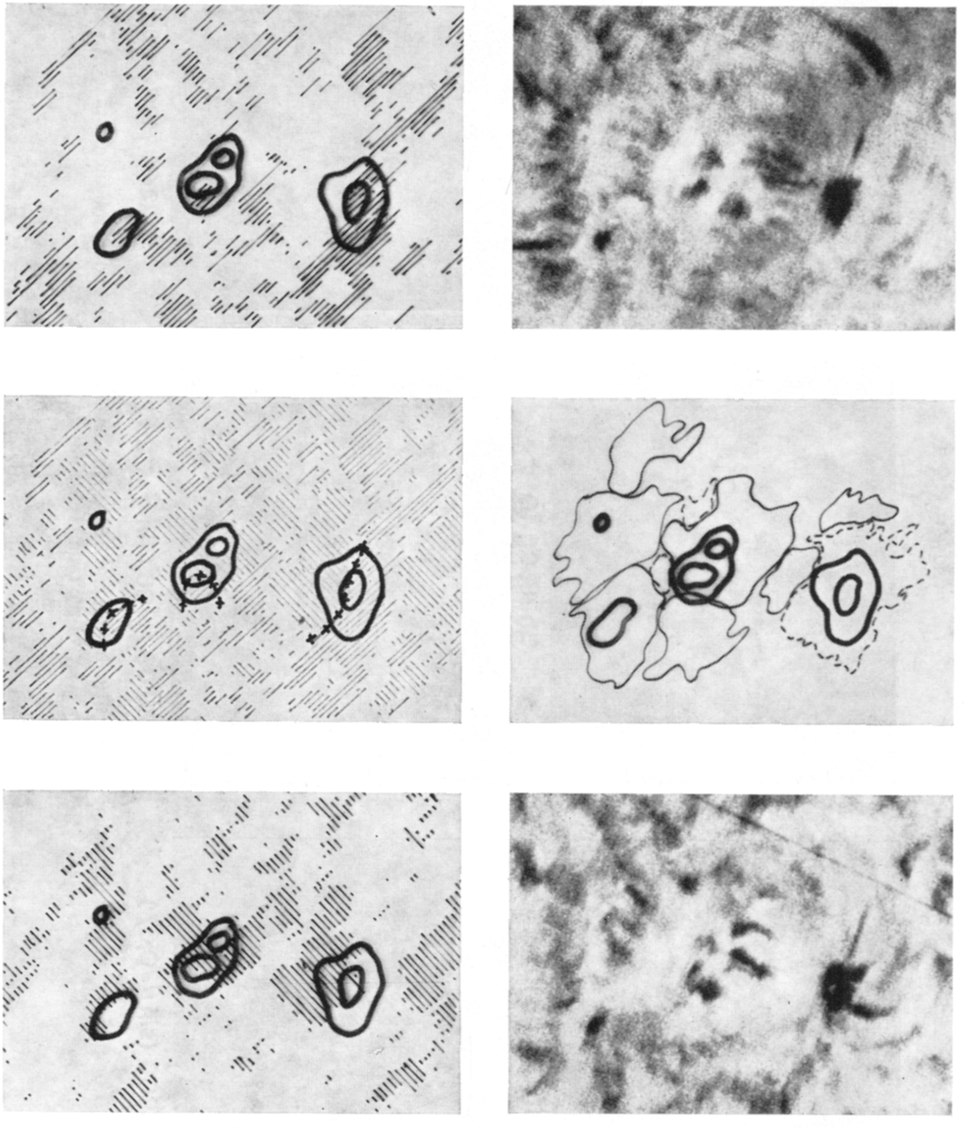

Fig. 1. 18–09–1966: Active Center at 42°E C.M. Left: radial velocity field 8h10 UT, from top to bottom: (1) component towards the observer (> 0); (2) the two components; (3) component away from the observer (< 0). Right: (1) spectroheliogram = Hα—0.5 Å, 9h07; (2) principal magnetic features of the active center according to the longitudinal magnetic map at 8h10; (3) spectroheliogram = Hα + 0.5 Å, 9h10.

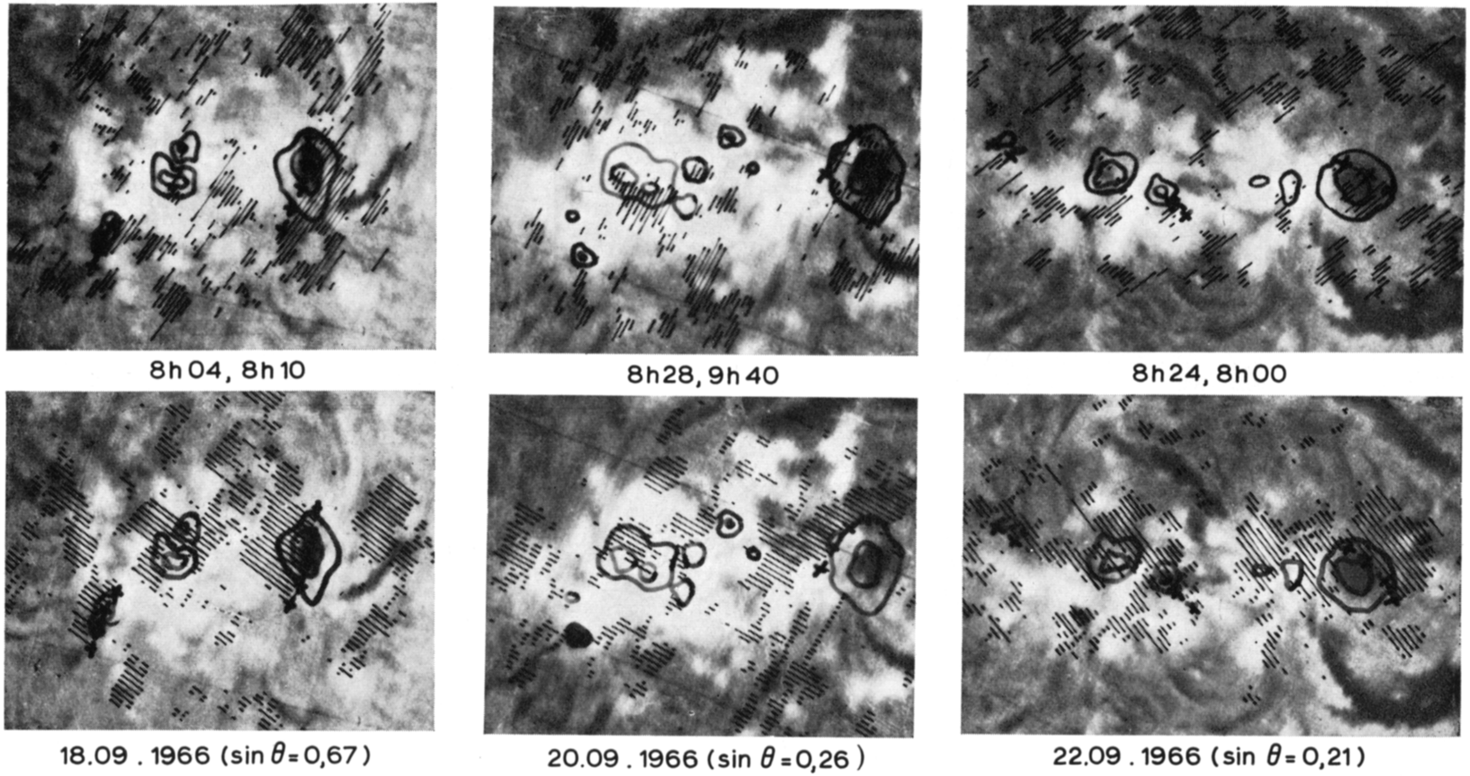


Fig. 2. Comparison between the radial velocity distribution and bright Hα faculae. The first hour indicated is that of the observation of the radial velocities.

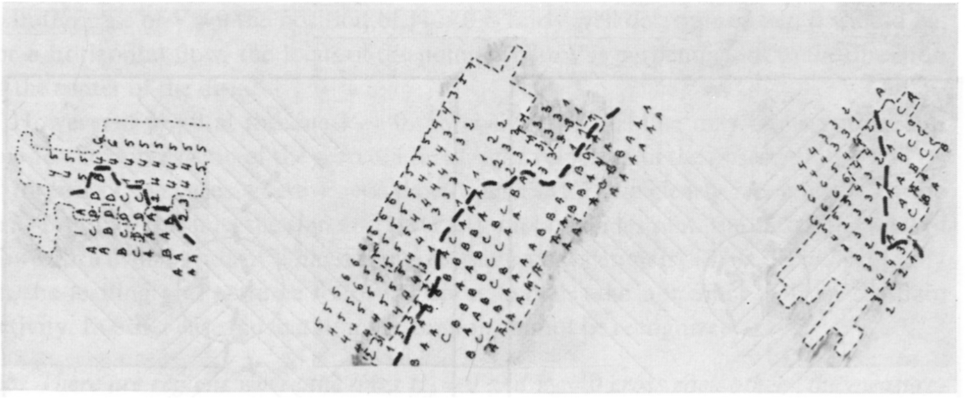

Fig. 3. Sample of islands of velocities crossed by $H_{\parallel}=0$ curve. 18 September 1966, 8h10; 19 September 1966, 7h50; 20 September 1966, 14h20. Numbers and letters correspond to $H_{\parallel}$ values in the magnetic map scale. The thick dashed line is the magnetic inversion line. The fine dashed line and the dotted line demark the regions where the velocity 'islands' are respectively positive and negative. The shadowed areas are regions without measurable velocities.

### 3.1. *There are inversion lines $H_{\parallel}=0$ (with opposite magnetic polarities on both sides) crossing area where $V_{\parallel}$ keeps the same sign (Figure 3)*

Such situations have been discussed already by Semel (1967) and Stepanov (1965), who proved that they cannot be due to errors in $V_{\parallel}$.

We have found that such E.M.F. pairs, having the same line of sight velocities, do not change much or evolve in the same sense. Although they may present large gradients of $H_{\parallel}$ at the inversion line, *they do not take much part in the flare activity.*

### 3.2. *There are lines with $V_{\parallel}=0$, with change of the sign of $V_{\parallel}$, crossing E.M.F. of strong $H_{\parallel}$ without magnetic inversion (Figure 4)*

Such situations were also pointed out by Semel (1967). They are fairly classical because they occur for instance in connection with the normal Evershed flow of an isolated sunspot.

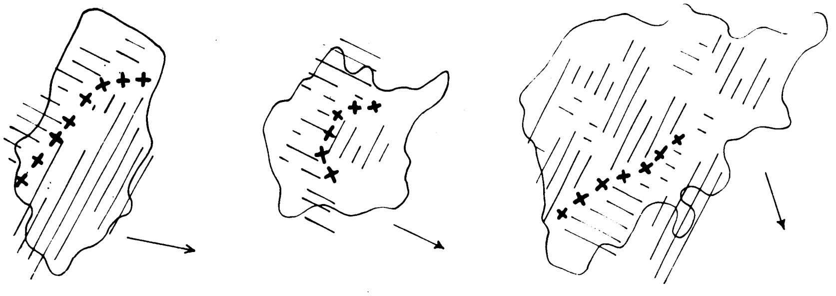

Fig. 4. Sample of magnetic structure with strong magnetic fields crossed by curves $V_{\parallel}=0$ which delimit islands of velocities of opposite sense. 17 September 1966; 20 September 1966; 21 September 1966. /// regions of positive velocities; \\\ regions of negative velocities. The crossed line is the $V_{\parallel}=0$ line. The arrows show the direction of the center of the solar disk. When these dispositions are observed, the regions are not flaring.

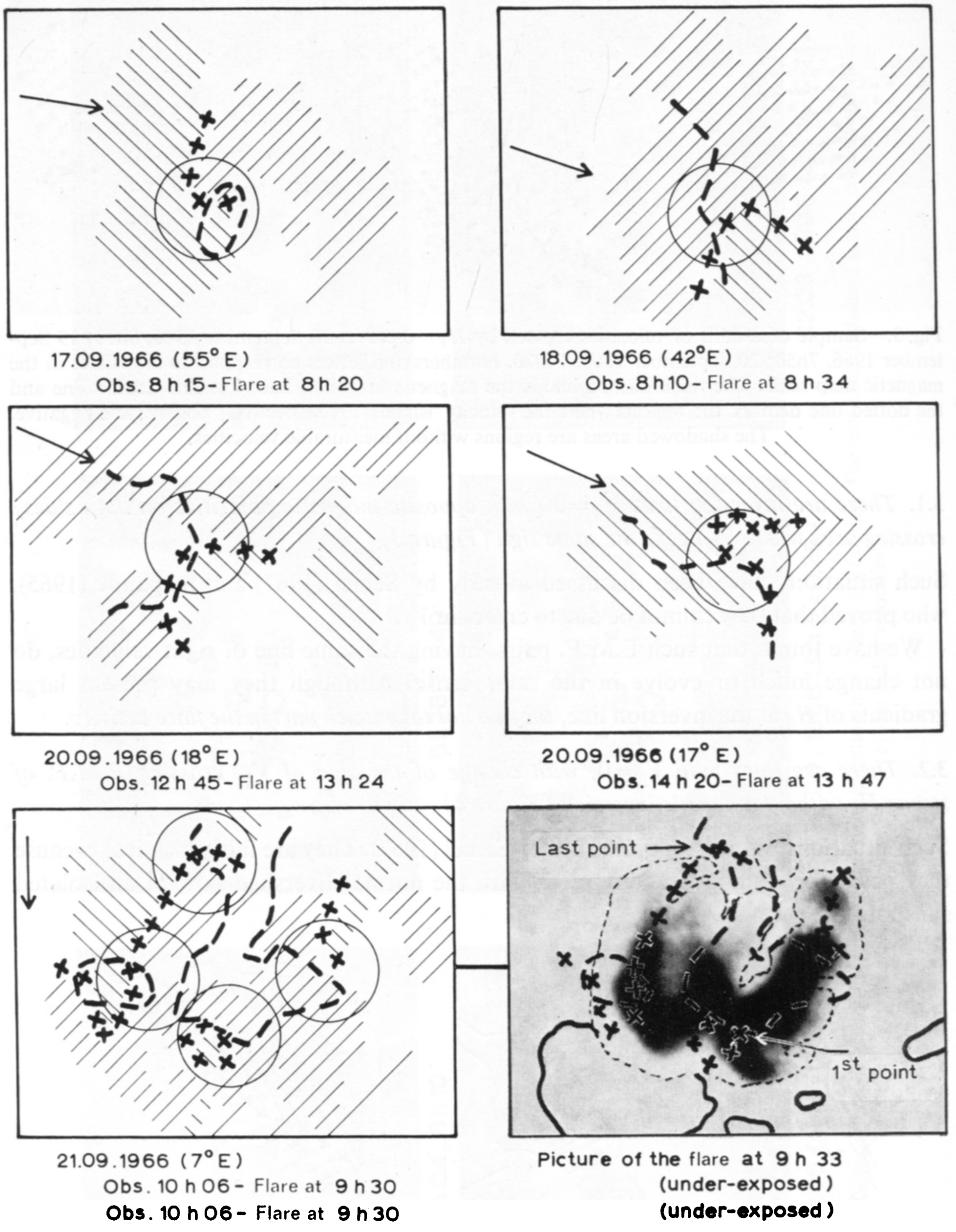


**Fig. 5. Sample of flare localization (the notation is the same as before). The circles indicate the region of flare occurrence where the lines $H_{\parallel} = 0$ and $V_{\parallel} = 0$ are crossing. At the bottom, on the right, Meudon photographic observation of the flare at 9h33 (low exposure).**

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In the case of $\mathbf{V} \neq 0$ the position of $V_{\|} = 0$ is fairly well determined and it should be, for a horizontal flow, the locus of the points where $\mathbf{V}$ is perpendicular to the direction of the center of the disk.

However if $\mathbf{V} = 0$ at the line $V_{\|} = 0$ the position of this line may be very uncertain due to the imprecision of the zero of line of sight velocities in the observations.

In part of the cases where $V_{\|} = 0$ crosses an E.M.F. we clearly recognize from the orientation of this line, the sign and size of $V_{\|}$ on both sides of it, the *classical Evershed flow* with a distribution of $\mathbf{V}$ having approximate axial symmetry. This occurs primarily on the leading and extreme following spots, which take not much part in the flare activity. In other cases such a simple situation cannot be recognized.

3.3. *There are regions where the lines $H_{\|} = 0$ and $V_{\|} = 0$ cross each other (the measurements of both quantities being significant).*

The E.M.F. involved in such configurations are bright in Hα and are generally the support of flare activity. The position of the line $V_{\|} = 0$ is not related to the contours of the E.M.F. The geometrical relations between the lines $V_{\|} = 0$ and $H_{\|} = 0$ in such regions do not form clear cut patterns.

Among the recorded flares we were able to examine the location of 15 events, occurring between the 17th and 22d of September at less than one hour of available $H_{\|}$ and $V_{\|}$ records.

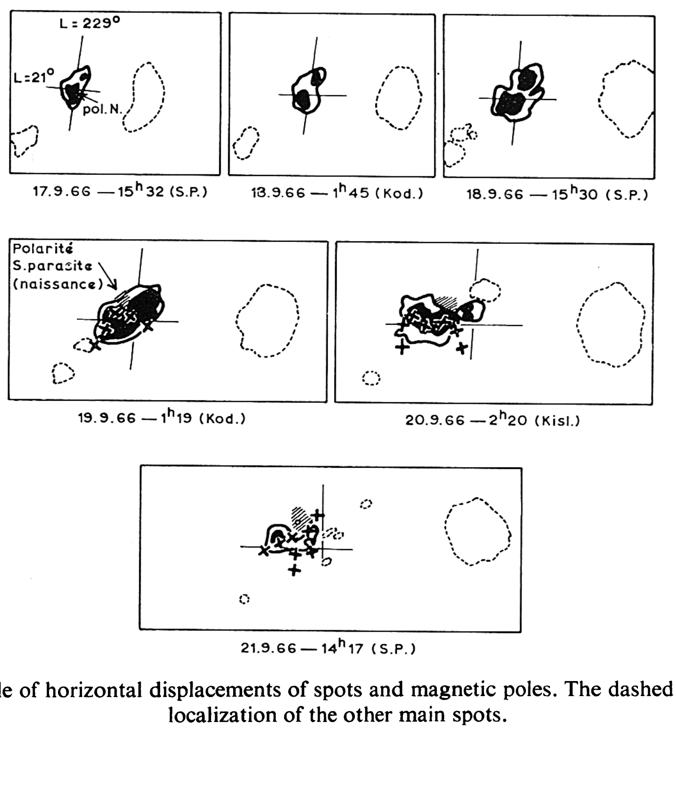


Fig. 6. Sample of horizontal displacements of spots and magnetic poles. The dashed line shows the localization of the other main spots.

12 of these started in regions of crossing of the lines $H_{\parallel}=0$ and $V_{\parallel}=0$ (examples in Figure 5) independently of the A.R. position on the disk.

Two started at places where the two lines were nearly crossing (less than 5″ distance).

One near a $V_{\parallel}=0$ line without an associated $H_{\parallel}=0$ line: however a parasitic magnetic polarity appeared a few hours after, leading to a situation similar to the above cases.

This result – the crossing of lines $H_{\parallel}=0$ and $V_{\parallel}=0$ in the flaring area – makes more precise Severny's result (Severny, 1960). Indeed he indicated that: "the neutral point is practically always found on the neutral lines of velocity maps", and he considered that the neutral point denotes the place of the most frequent appearance of solar flares.

In most cases we observe in the flare productive area an abrupt change of the direction of the line $V_{\parallel}=0$, one of its branches being perpendicular to the direction of the center of the disk, the other parallel. This suggests a kind of *vortex motion.*

Some support for this idea may be found in Figure 6 showing the evolution of the central most eruptive part of the A.R. where 43 minor flares where located. A vortex motion of the spot and of the parasitic polarity born in the night of September 18–19 is apparent.

## 4. Conclusion

These observations suggest that certain systems of photospheric motions may be the cause of the changes of surface magnetic fields, which influence the distribution of Hα structure, and eventually lead to the build up of flare productive situations.

Further observations may help to clarify the nature of the interactions between **V** and **H**; however the knowledge of only one component of these vectors (particularly in the case of **V**) will make the problem very difficult.

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