COMMON EVOLUTION OF ADJACENT SUNSPOT GROUPS

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Abstract. The evolution of two adjacent bipolar sunspot groups is studied using Debrecen full-disc, white-light photoheliograms and Hz filtergrams as well as Meudon magnetograms. The proper motions of the principal preceding spots of both groups show quite similar patterns; the spots move along almost parallel tracks and change the direction of their motion on the same day at almost the same heliographic longitude. Also, three simultaneous emergences of magnetic flux were observed in both groups. These observations support the idea that these adjacent sunspot groups were magnetically linked below the photosphere. Matching the extrapolated magnetic field lines with the chromospheric fibril structure appears to be different in the two groups since they indicate quite different model solutions for each group, i.e., a near-potential magnetic field configuration in the older group (1) and a twisted force-free field configuration in the younger group (2). The latter configuration could be created by a considerable twist of the main bunch of flux tubes in Group 2, which is reflected in the relative sunspot motions. It is also showed how this twist contributed to the formation of a filament between the two groups.

1. Introduction

It is well known that the occurrence of flares is related to the presence of various special irregularities in the magnetic field configuration such as strong magnetic shear (Hagyard and Rabin, 1986), emerging flux (Priest, 1981), parasitic polarity, i.e., emerging flux in an opposite magnetic polarity environment (Martres and Soru-Escuat, 1977), δ-configurations (Zirin and Liggett, 1987), or the interaction of sunspot groups (Gaizauskas, 1990: Mandrini et al., 1991). Until now the relative importance of these conditions in the development of flares is not well known.

The conditions for the formation of filaments seem to be rather similar to the conditions for flare occurrence (Schmieder et al., 1991). Both flare and filament formation need a rearrangement of magnetic fields induced by photospheric activity, e.g., by sunspot proper motions. In the case of filament formation, converging motions accompanied by cancelling flux (Martin, Livi, and Wang, 1985; Malherbe and Priest, 1983; van Ballegooijen and Martens, 1989) seem to help the process.

In trying to provide answers to the open question of flare and filament formations, one way is to study the evolution of magnetic fields in high resolution magnetograms like those of Big Bear Observatory. But another way is to investigate white-light observations with good spatial and time resolution, like those of Debrecen Observatory. These full-disc photoheliograms allow the measurement and calculation of Carrington coordi-

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nates of pores and spots, and hence to follow their motions, which are continuously modifying the structure of magnetic fields. Frequently authors try to understand flare occurrences by studying daily magnetograms. This approach can only detect flares triggered by new emerging or cancelling flux and not flares due to fast sunspot motions.

Former studies (Martres, 1970; Sheeley, 1981) pointed out that adjacent regions can show signs of interaction in their proper motion and area development. It is also known that the chromospheric activity of different active regions can be related, which is shown by the appearance of sympathetic flares (Švestka, 1976, and references therein).

Two adjacent bipolar sunspot groups in Hale region 16898 (Mt. Wilson 21517 and 21526 or NOAA AR 2511 and 2512) were the sites of a great number of flares and of the formation of a filament (Schmieder et al., 1991; Falchi, Falciani, and Smaldone, 1992). In order to understand the physical process of such activity, we studied the long-time evolution of the region using Debrecen full-disc photoheliograms, Hα observations, and Meudon magnetograms.

These two sunspot groups appeared on the northern hemisphere of the Sun only 5 heliographic degrees apart. During a period of almost two weeks (June 9–20, 1980) we followed the emergence of new magnetic flux which occurred coincidentally in both sunspot groups in several waves. We found some spot proper motions characteristic of evolving bipolar regions and other (more unusual) proper motions related to the appearance of parasitic polarity spots in one of the active regions. We also measured the area of both groups and corrected it for foreshortening due to perspective effects. We investigated the possible interaction of the adjacent sunspot groups by searching for common features in the evolution of these sunspot groups, and we indeed found evidence in the proper motions of spots and in the simultaneous emergences of magnetic flux which suggest that the adjacent sunspot groups were linked under the photosphere.

We derived the magnetic field lines above the two groups during three days around their central meridian passage, extrapolating the longitudinal photospheric magnetic field component observed at Meudon, assuming a linear force-free field configuration with a parameter $x$. We chose $x$ by fitting the computed transverse magnetic field to the chromospheric fibril pattern. In Group 1, where the majority of flares occurred, the pattern could be well fitted with a potential configuration ($x = 0$), while in Group 2, where a large filament formed, we needed $x \approx -1.8 \times 10^{-2} \text{ Mm}^{-1}$.

Unlike the photospheric evolution, the chromospheric activity of the two groups was apparently not related. Flares were due instead to local processes, such as new emerging flux and fast spot motions. Twisting motions of flux tubes of spots led to magnetic shear which triggered the formation of a filament.

The observations and methods of data processing are described in Section 2. The evolution of the active regions and the proper motions of the spots are analysed in Section 3, and the relationship between the two active regions is studied in Section 4. The results of the extrapolation of magnetic field lines are described in Section 5, and we present our conclusions in Section 6.
2. Observations and Data Processing

One of the Solar Maximum Year's (SMY) numerous observing intervals was the period between 13 and 15 June, 1980. The chosen SMY target was one of the active regions (Mt. Wilson 21517 or AR 2151) which we analyse here. For the present study we used white-light photoheliograms and Hα observations obtained at Debrecen Observatory to investigate sunspot proper motions and area development as well as the chromospheric fibril patterns in the active regions, and magnetograms obtained at Meudon Observatory to study the evolution of the structure of the magnetic fields of the sunspot groups.

2.1. White-light and Hα Observations

Between 9 and 20 June, 1980, 387 white-light, full-disc photoheliograms were obtained with a 5" refractor at the Gyula Observing Station of the Heliophysical Observatory of the Hungarian Academy of Sciences in Debrecen. The intervals and number of daily observations are given in Table I. The diameter of the solar image at the secondary focus was 10.4 cm. For the orientation, two cross hairs are fixed at the principal focus of the heliograph (f ≈ 2 m) and their positions are permanently controlled. Photographs were taken on 14 × 14 cm Kodalith pan film through a yellow metal-interference filter. The positions of the sunspots were determined from the full-disc heliograms by means of an Ascocord coordinate measuring instrument, from which Carrington coordinates (heliographic longitudes (L) and latitudes (B)) were calculated, applying corrections for the differential refraction as well as for some instrumental effects, particularly the optical distortion of the enlarging system of the heliograph. The precision of the sunspot position measurements was better than ± 0.1 heliographic degree; the standard deviation of the velocity data given in present paper was equal to or smaller than ± 0.03 km s⁻¹.

<table>
<thead>
<tr>
<th>1980 June</th>
<th>Number of observations</th>
<th>Period of observation UT</th>
</tr>
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<tbody>
<tr>
<td>9</td>
<td>53</td>
<td>05:45–16:46</td>
</tr>
<tr>
<td>10</td>
<td>34</td>
<td>05:05–17:21</td>
</tr>
<tr>
<td>11</td>
<td>16</td>
<td>10:19–16:49</td>
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<tr>
<td>12</td>
<td>51</td>
<td>04:51–16:59</td>
</tr>
<tr>
<td>13</td>
<td>62</td>
<td>04:39–17:11</td>
</tr>
<tr>
<td>14</td>
<td>53</td>
<td>05:18–16:31</td>
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<tr>
<td>15</td>
<td>39</td>
<td>05:15–14:41</td>
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<tr>
<td>16</td>
<td>33</td>
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<td>17</td>
<td>18</td>
<td>05:41–16:38</td>
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<tr>
<td>18</td>
<td>12</td>
<td>05:01–11:36</td>
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<tr>
<td>19</td>
<td>4</td>
<td>14:41–15:24</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>05:15–17:20</td>
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</table>
We measured the areas of sunspot umbrae with a special instrument of Debrecen Observatory (DAREAL), which creates equidensity contours and defines the area inside the contour, using video equipment. All individual areas were then corrected for foreshortening (knowing the exact radius of the solar image and the actual distance of the spots from the centre of the solar disc). The method of observation, position measurements, and computation of heliographic coordinates and the method of area measurements are described in detail in the Introduction to the 'Debrecen Photoheliographic Results' by Dezső, Gerlei, and Kovács (1988).

For this study we also used a few Hα filtergrams obtained in Debrecen with a 53 cm Nikolsky-type coronograph, equipped with a 0.5 Å Halle filter. Part of the 12.5 cm diameter image at the Coudé focus was photographed on 35 mm Kodak Solar Patrol film in sequences of 5 frames (Hα ± 1 Å, Hα ± 0.5 Å, Hα).

2.2. Magnetograph Observations and Method of Extrapolation

The Meudon magnetograph measurements were made in the photospheric line of Fe I 6302 Å, obtaining simultaneous maps of the intensity, radial velocity, and longitudinal magnetic field \( B_l \); for a description of the data processing see Rayrole (1981). The spatial resolution is 1.2" × 2" and the size of the field of view is about 4' × 4'. Between 13 and 15 June, 8 magnetic maps were taken (see Schmieder et al., 1991). The magnetic field was extrapolated above the photosphere using a representation by a series of magnetic charges. A least-square fit to the observed longitudinal magnetic field was used to determine the intensity and the depth of the sources (see Mandrini et al., 1991, for further details). The transverse magnetic field was computed using a linear force-free field assumption (\( \alpha = 0 \) or \( \alpha \neq 0 \)) and its azimuth was compared with the chromospheric fibrils (see Section 5).

3. Development of the Active Regions

Hale region 16898 rotated onto the disc on 8 June, 1980 as a new active region, without being observed during the former solar rotation. It contained a bipolar sunspot group (Mt. Wilson 21517), hereafter referred to as Group 1 (Figure 1). On 11 June new flux emerged 5 heliographic degrees south of it, forming a smaller bipolar group by the next morning (Mt. Wilson 21526), hereafter named Group 2 (Figure 1). Between 11 and 18 June, 1980 we observed these two bipolar sunspot groups of different age (Group 1 was at least 4 days older than Group 2) developing very close to each other in the northern hemisphere of the Sun. Their longitudes were almost identical (\( L \approx 280^\circ \)) and their separation in latitude was only 5° (their mean positions were N 17.5° and N 12.5°, respectively).

3.1. Group 1

8–12 June, 1980

When the active region appeared at the east limb on 8 June 1980 Group 1 was a developed bipolar sunspot group formed by N1 and S11 as principal spots and a few
Fig. 1. The sunspot groups in Hale region 16898 between 10 and 18 June, 1980. The denotations of the umbrae indicate their magnetic polarity: N and S means north and south polarity, respectively.

scattered spots of S polarity (S12, S13) to the NW of S11 (Figure 1). This means that it was at least a one-day-old group. The following spot S11 was relatively big at the beginning, but it gradually diminished, and disappeared by 13 June, after which the principal following (S polarity) spots of the group appeared only at the former scattered spot area to the NW of S11. While S11 was shrinking the principal preceding spot N1 became bigger by new inclusion of flux through merging on 13 June with N12, which appeared on 9 June and approached N1 from the east (υ = 0.2 km s\(^{-1}\)); both spots moved rapidly southwestward along a parallel path, while several small, short-lived spots in the following part of the group were moving in the opposite (NE) direction (Figure 2(b)). This pattern of motions persisted until 15 June, when the continuously decelerating N1 stopped, turned back and started moving northeastward (Figure 2(a)).

In Group 1, new spots kept appearing for days (Figure 1). The start of the flux
Fig. 2a–d. Proper motions of umbras in Group 1 and in Group 2 (cf. Figure 1): (a) principal spots between 9 and 20 June, 1980; principal and other spots between (b) 10 and 12 June, (c) 13 and 15 June with an insert showing in more detail the motion of the parasitic polarity spots N20 and N21 as well as S1; the dashed lines point out particular spots; (d) between 16 and 18 June. (The preceding umbras are marked with the letter N and the following spots with the letter S, showing their magnetic polarity; note that in crowded parts of the groups the positions of certain spots have been indicated by a dashed line.)
Fig. 2c, d.
emergence coincides with the appearance of Group 2 on 11 June, producing spots of short lifetime (S 14–18, and N 11–14).

13 June, 1980

On 13 June we witnessed a more powerful emergence of flux in the centre of the group: new spots (S 1, 2, 4, and N 2–4), which could be followed for several days, grew quickly. The new \( p \) spots (N 2–4 and N 18) moved rapidly southwestward with velocities between 0.22 and 0.31 km s\(^{-1}\) (Figure 2(c)).

Beside these fast-moving new spots, parasitic polarity spots appeared among the following (S polarity) spots: N 20 and N 21 (Figure 1). Their appearance was apparently due to the presence of a weaker flux tube in the region, in which the field lines ran almost perpendicular to the field lines of the main flux tube forming the sunspot group (Figure 2(c)), and which intersected the main flux tube in the vicinity of the following part of the active region. Normally, an emerging flux tube produces opposite polarity spots with divergent motions, allowing the identification of the pairs of opposite polarity spots belonging to the same emerging flux tube. Spot S 3 (see Figure 1) is the only \( f \) spot moving southwestward, i.e., away from the nearby parasitic polarity spots (Figure 2(c)) on 13 June; it is therefore a likely candidate for magnetic connection to the \( p \)-polarity parasitic pores. The northeastward direction of the motion of N 20 and N 21 does not seem to support the idea of this magnetic connection, but the fact that these two spots were surrounded by northeastward moving following spots makes it possible that their motion was disturbed and that they were pushed towards the NE by spot S 1. The presence of the weaker flux tube across the main flux tube of Group 1 was also substantiated by the appearance of a number of other small spots (e.g., N 24, N 26, N 27, N 29, S 5) between 12 and 18 June (Figures 2(b–d)), whose proper motion differed from that of the main spots.

During the day, both parasitic polarity spots N 20 and N 21 as well as their probable opposite polarity companion, S 3, gradually diminished. The area of N 20 and N 21 (Table II) first showed a small increase with maxima at 06:55 and 08:44 UT, followed

<table>
<thead>
<tr>
<th>Time of observation UT</th>
<th>Area (10^{-6}) of the solar hemisphere</th>
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<tbody>
<tr>
<td></td>
<td>N20</td>
</tr>
<tr>
<td>05:15</td>
<td>3</td>
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<td>06:55</td>
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<tr>
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<td>5</td>
</tr>
<tr>
<td>09:20</td>
<td>4</td>
</tr>
<tr>
<td>11:00</td>
<td>2</td>
</tr>
<tr>
<td>15:50</td>
<td>0</td>
</tr>
<tr>
<td>17:11</td>
<td>0</td>
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</table>
by a decrease. By about 15:50 UT their area was smaller than $0.5 \times 10^{-6}$ of the solar hemisphere, and by 17:11 UT they died out; they are also invisible in the 20:33 UT MSFC magnetogram (Falchi, Falciani, and Smaldone, 1992). The intensive flare activity in this part of the sunspot group ended with the disappearance of the parasitic polarity (Schmieder et al., 1991). The area of S1, an important $f$ spot in the vicinity of the parasitic polarity spots, was relatively constant during the day (Table II).

14 June, 1980

On 14 June, as a result of the flux emergence of the day before, several young preceding spots (N2, N3, N4) were present in the centre of Group 1 (Figure 1), which were associated with the most intense non-thermal radio source ($\lambda = 6$ cm) in the whole region (Chiuderi-Drago, Alissandrakis, and Hagyard, 1987). The young spots moved in the direction of the main preceding spot (N1) with high velocity (0.17–0.38 km s$^{-1}$) which appears to be correlated with their distance from the centre of N1 (Figure 3). An extrapolation of the linear regression line fitted to the velocities of these spots gives the distance where the velocity of approach becomes zero: about 12,500 km from the centre of N1, i.e., roughly the sum of the radii of N1 and N2. In other words, the merging spots seemed to stop when reaching the edge of the old big umbra, which can be well expected. By the next day N2, N3, and N4 had overtaken the main preceding spot and moved into a common penumbra with it, and on 16 June they merged with the main spot, but not completely, as a light bridge always remained between them. New spots remaining distinct inside a big umbra is a relatively common feature of spots of secondary development merging with the principal spots. This may be a sign that their flux tubes remain distinct as well, down to a certain depth.

The young $p$ spots followed an almost identical narrow path while approaching N1 (Figure 2(c)). This kind of "channel of sunspot motions" has been observed before in different sunspot groups (see Vrabec, 1974, and further examples in Kovács, 1977; Kálman and Nagy, 1986; Gesztelyi, 1986). N18 appeared close to this channel, but it moved perpendicularly rather than parallel to it, and disappeared by the next day.

16–20 June, 1980

The next wave of flux emergence started on 16 June and developed over the next days (Figure 1). North of the central part of Group 1 several smaller spots (N23–N30) appeared which moved northeastward while in the following part of Group 2 small young spots moved in the opposite (SE) direction (Figure 2(d)). These small spots of Groups 1 and 2 could be produced by the emergence of flux belonging to the above-mentioned weaker bunch of flux tubes which produced the parasitic polarity spots on 13 June.

The new spots (belonging to the main as well as to the weak bunches of flux tubes) grew quickly, but the largest $p$ spot, N25, moved neither fast nor long enough to reach N1 (Figure 2(d)), diminishing relatively far behind it on 19 June. Afterwards we did not observe any further major flux emergence; the sunspot group started disintegrating and its area decreased. Before the sunspot group disappeared behind the west limb on
20 June it consisted only of N1 and a few tiny $f$ spots. The change of the total area of the sunspot group with time (Figure 4, upper curve) clearly shows the periods of new flux emergences as well as the period of disintegration of the group.

3.2. Group 2

This smaller group was born as (at least) two bipolar pairs of pores on 11 June. The following spots formed first, but they were unstable and disappeared by the next day. Close to their former place new $f$ spots (S1, S2) appeared on 12 June, which became stable spots. The $p$ spot N1 was the most powerful and fastest moving spot of the new group and it became its principal $p$ spot. N1 moved westward with a velocity of 0.9 km s$^{-1}$ during the first 3 hours after its appearance on 11 June but this velocity quickly decreased with time (Figure 2(a)).

On 12 June the following part of the group consisted of a smaller (S2) and a larger (S1) spot. At the beginning of the daily observations (at 04:51 UT) S1 was already a strong, relatively large spot, which started to move northeastward with a velocity of 0.15 km s$^{-1}$, which continuously decreased while it gradually approached the slowly-moving S2 (Figure 2(c)).

By 13 June the other $f$(S) polarity island was surrounded by N polarity magnetic fields. On this day, as in Group 1, new spots appeared in the middle part of Group 2 with fast divergent velocities ($v_{\text{div}} = 0.35$ km s$^{-1}$). At the beginning of the observations, we observed an area of mixed polarity fields in the middle of the group as a result of new flux emergence in the two-day-old magnetic configuration. Such a S–N–S–N configuration is not rare when a new flux emerges in a bipolar region (see Figure 3 in Schmieder et al., 1991); it is usually flare active and we indeed observed a subflare at 05:18 UT. In the magnetic maps (05:59–09:31 UT) we see a decrease of the strength of these mixed fields. By the next day (14 June) the magnetic configuration had simplified.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure3}
\caption{Velocities of young spots approaching the principal preceding spot N1 of Group 1 plotted against the distance of the spots to the centre of N1 on 14 June 1980. The radius of N1 is indicated with a thick bar.}
\end{figure}
A series of east–west elongated, positive-polarity areas ($B \sim 100$ G) appeared between the two groups, leading to the formation of an S-shaped magnetic neutral line along which a filament had formed by 14 June (the formation started already in the afternoon of 13 June, see Figure 3 in Schmieder et al., 1991).

The principal preceding spot of the sunspot group, N1, which was moving south-westward with continuously decreasing speed, stopped on 15 June and turned north-eastward (Figure 2(a)). On 16 June we observed a minor flux emergence in the central part of the group at the same time as the emergence of flux in Group 1. After that time the group gradually disintegrated (Figure 1), its area decreased (Figure 4) and eventually it disappeared by 19 June.

![Graph showing area development of the groups Group 1 and Group 2 between 9 and 20 June, 1980, in units of $10^{-6}$ times of the surface of the solar hemisphere.]

**Fig. 4.** Development of the global umbral area of Group 1 and Group 2 between 9 and 20 June, 1980, in units of $10^{-6}$ times of the surface of the solar hemisphere.

### 4. Does a Link Exist between These Two Active Regions?

This kind of question was first investigated by Martres (1970) who indeed found an effect on the growth and proper motion of the relative position of spots of adjacent groups. She pointed out that a group situated to the west of an older one evolves to a $\beta_f$ type (bipolar group with bigger $f$ than $p$ spots) and shows an eastward motion of the following spot greater than that of an isolated group. Symmetrically, the evolution to $\beta_p$ (bipolar group with bigger $p$ than $f$ spots) of a group situated to the east of the original formation is associated with a greater westward motion. In connection with the lifetime of active regions Sheeley (1981) stated that: “the lifetime of an individual bipolar magnetic region (BMR) is strongly affected by its surroundings. Thus, while a typical $10^{22}$ Mx BMR might last four solar rotations before its flux becomes undistinguishable from the background, two such BMRs might annihilate one another within a few weeks if they emerged with a suitable configuration. Indeed, the very largest BMRs often occur with complex spatial distributions that lead their premature decay.”
The adjacent sunspot groups in Hale region 16898 did not form the kind of configuration suitable for the type of interaction mentioned by Martres (1970) since their relative orientation was N–S and not E–W. However we still find certain similarities between the development of these two sunspot groups separated by only 5 heliographical degrees, which suggest that the sunspot groups were somehow related in the sub-photosphere.

The first similarity occurs in the proper motions of the two groups. At the beginning they showed the ordinary behaviour of young, developing bipolar active regions, i.e., in both groups the $p$ (N polarity) spots moved west/south-westward faster than the $f$ (S polarity) spots east/north–eastward (Figures 1 and 2), but then the principal $p$ umbrae of Groups 1 and 2 stopped on 15 June, changed direction (Figure 2) and moved towards the NE till the end of the observing period, 20 June (or in case of Group 2 until 18 June, when it was last seen, see Figure 1). Taking into account their different ages (Group 1 was at least 4 days older than Group 2), this parallel proper motion and the subsequent simultaneous change in the direction could be a sign of some kind of connection between the sunspot groups.

It might be that these sunspot groups are different branches of the same flux tube and that the common features of their proper motions reflect the behaviour of the common flux tube root. On the other hand, the simultaneous turn of the principal preceding spots could be an indication of the existence of large-scale flows in the vicinity of the close-by developing active regions, which influence the motion of these spots (see Marquette and Martin, 1988; Schrijver and Martin, 1990). But, finally, we cannot exclude the possibility that this simultaneous change in direction is merely pure chance.

Another similarity in the evolution of these adjacent sunspot groups lies in the history of flux emergence in the active region. During the fast development of the new Group 2 several new spots appeared in the older, larger Group 1 on 11 June and we observed simultaneous bursts of new activity in both groups on 13 and on 16 June. These coincidences also point towards a possible sub-surface connection of these two adjacent groups.

On the other hand the two groups did not seem to be interacting in the solar atmosphere, since there were no sympathetic flares observed in them.

5. Twisting Motions and Filament Formation in Group 2

5.1. Twist of Flux Tubes

Looking at the pattern of the chromospheric fibril structure in the active region, we find that the fibrils form an almost radial pattern around the principal $p$ spot of Group 1, while they show a spiral pattern around the main $p$ spot of Group 2 (see Figure 5). A considerable twist of the flux tube forming the main spot can result in such a spiral fibril pattern. We suppose that such a general twist of the main bunch of flux tubes should be reflected in the relative motion of the footpoints of the principal flux tube and of the flux tubes of secondary emergence(s) which are going to merge with the main tube (since
Fig. 5. Hα observations showing an arch-filament system in Group 1 (northern group) and the formation of a filament in Group 2 (southern group) on 13 June (a) and its extension between the 2 groups on 14 and 15 June, 1980 (b–e). Note the radial pattern around the leading spot in Group 1 and the spiral pattern in Group 2. On 16 June (f) the chromospheric fibril pattern indicated a connection between the preceding part of Group 1 and the following part of Group 2.
they are connected underneath the photosphere), so we expect to see a spiral pattern in the motion(s) of the satellite spots around the principal spot. In order to test whether the different chromospheric appearances of the sunspot groups are related to differences in the sunspot motions, we studied the relative motions of a few satellite spots with respect to the principal $p$ and $f$ spots of the groups (Figure 7). In Group 1 (Figure 7(a)) we found that between 13 and 17 June small young spots approaching N1 from the E–NE direction all moved in a direction corresponding to a minor clockwise twist. The twist seems to be most important between 14 and 15 June ($20^\circ$), and much smaller ($4$–$7^\circ$) before and after that time. In the following part of the group there is no real principal spot, and the magnetic field is much less concentrated than in the preceding part. The relative motions of the following spots with respect to S1 are contradictory, and we cannot trace a twist of the flux tube from them. In the following part of Group 2 (Figure 7(b)) we find a minor clockwise twist ($25^\circ$) between 12 and 13 June, while the preceding part of the region (Figure 7(c)) N2, which appeared on 12 June, approached N1 in a way which corresponds to an anticlockwise twist of $115^\circ$ between 12 and 15 June ($\approx 38^\circ$ day$^{-1}$). After 15 June the twist reversed and became a minor clockwise turn. The relative motions of sunspots suggest there was a considerable twist in the
preceding part of Group 2, where the chromospheric fibril structure indicated a sheared, spiral-like pattern, but no major twist in Group 1.

5.2. EXTRAPOLATION OF MAGNETIC FIELD LINES

A twist of the magnetic flux tubes in Group 2 and the lack of it in Group 1 is indicated by the computed extrapolation of magnetic field lines above the photosphere. Using photospheric magnetograms we extrapolated the magnetic field lines assuming a linear, force-free field configuration. We compared the result of our computations to the pattern of chromospheric fibril structure (Figure 5) in order to choose a realistic solution. The potential configuration ($\alpha = 0$) of magnetic fields gives a good fit to the chromospheric structure of Group 1 but not to the structure of Group 2 (Figure 6), where on 14 June we could only find an agreement between the chromospheric pattern and the direction of the transverse field in our model calculations using a force-free field approximation ($\alpha \approx -1.8 \times 10^{-2} \text{ Mm}^{-1}$). Increasing the value of $\alpha$, the models show an increasingly E–W oriented inversion line, till it resembled the observed S-shape (Figure 8). Introducing currents everywhere proportional to the strength of the magnetic fields, the orientation of the magnetic field lines became almost parallel to the inversion line only in the central part of the S-shaped line, where the formation of a filament was observed.
Fig. 8. Random distribution of magnetic field lines in a part of the Hale region 16898 located between the two groups (the footpoint density is proportional to the photospheric magnetic field strength and their height is limited to 10 Mm above the photosphere). Field lines are shown on 14 June with (a) a potential assumption ($\alpha = 0$ Mm$^{-1}$), and (b) a linear force-free field assumption ($\alpha = -1.8 \times 10^{-2}$ Mm$^{-1}$) as well as on 15 June for a linear force-free field configuration (c) with $\alpha = -1.2 \times 10^{-2}$ Mm$^{-1}$, and (d) with $\alpha = -1.8 \times 10^{-2}$ Mm$^{-1}$.

(see Schmieder et al. (1991), where the formation of the filament was explained by the presence of shearing motions created by fast-moving, opposite-polarity spots in the central part of Group 2. However, we would like to point out that both (moving) photospheric magnetic sources and the currents which produce a magnetic configuration are needed to create a suitable configuration for filament formation.)
On the next day, 15 June, a less twisted configuration with \( \alpha \approx -1.2 \times 10^{-2} \, \text{Mm}^{-1} \) gives a good fit to the observations, while the further decrease of the twist is indicated by the reversal of the twisting motion of the flux tube as derived from relative spot motions on 16 June. This continuously decreasing shear (implying decreasing currents as well) can explain the disappearance of the filament on 16 June.

6. Conclusions

We followed the evolution of two adjacent sunspot groups of different ages – one of which (Group 1) was at least 4 days older than the other (Group 2). The proper motions of their principal spots were almost parallel, and their preceding spots stopped simultaneously at almost the same heliographic latitude. New flux emerged 3 times simultaneously in the two groups. Their parallel proper motions and the recurrent simultaneous emergences of magnetic flux in the adjacent groups could support the idea that these sunspot groups were magnetically connected underneath the photosphere.

New emergences of flux in the central part of the active regions produced spots showing fast proper motions, up to 0.9 km s\(^{-1}\) in case of very young spots. From the trajectories of sunspot proper motions it appears that besides the principal bunch of flux tubes a weaker magnetic flux tube was present in Group 1, in which the field lines run almost perpendicular to those forming the main sunspot group. Emergence of flux in this weaker bunch of tubes caused the appearance of parasitic polarity spots in the following part of Group 1 on 13 June, triggering homologous flares until these spots disappeared. The chromospheric activity of the adjacent sunspot groups does not seem to be related; the majority of the flares observed occurred in Group 1, due to local processes: triggering by parasitic polarity or fast moving sunspots. In Group 2 the most important event was the formation of a filament on 13–14 June.

The magnetic field extrapolation gives a good fit to the chromospheric fibril structure, assuming a potential configuration in Group 1, and a linear force-free field configuration in Group 2. Between 12 and 15 June we observed an increasing twist of the flux tube in the preceding part of Group 2. The spiral fibril pattern around the leading spot as well as the filament corridor are well represented by a linear force-free field model with \( \alpha \approx -1.8 \times 10^{-2} \, \text{Mm}^{-1} \) on 14 June.

A nearly potential magnetic field configuration generally does not lead to strong flare activity. In fact, all flares observed in Group 1 (Schmieder et al., 1991) were relatively small flares (\( \leq \) importance 1).

It is clear that a large magnetic shear could in principle produce flares and filaments but it appears that for the occurrence of flares this is not a sufficient condition (see also Heyvaerts and Hagyard, 1991). However, a twist of the magnetic flux tube of sunspots seems to be suitable for the formation of filaments.

This study clearly needs to be extended through coordinated observations in white-light (to obtain proper motions of spots with good space and time resolution), in H\( \alpha \) and in photospheric lines leading to measurements of magnetic field vectors, Doppler-shifts, etc. The French–Italian vectorial magnetograph THEMIS will be very well suited for such studies.
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