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Complexity of the Doppler motion field of an active region

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Abstract. We have investigated numerous sets of photoelectric measurements of the line-of-sight velocity and magnetic field components in active region NOAA 7757 (July 1994) and its wide surroundings. The observations, made during 8 days with electronically enhanced sensitivity of velocity measurements, show the complexity of motions in and around the spot group.

The NOAA 7757 Doppler motion field represents a specific disturbance of the semiregular motion patterns of the quiet photosphere. Close to the solar disk center, there exists a striking difference in the concentration and organization of the line-of-sight motion components away from (red-shifted) and toward (blue-shifted) the observer in and outside the active region. In contradiction to the quiet photosphere, in the area occupied by the region's magnetic field body, the red-shifted Doppler velocity components are strongly concentrated and organized into a few cellular-like structures, while the blue-shifted motion components are considerably diluted, mostly surrounding this area. Moreover, this difference, most outstanding very close to the solar disk center, is less distinct as one moves away from it. This is an evidence of the verticality of the observed velocity components.

The Evershed flow fits in the negative motion components system, the stability and lifetime of which probably depends on the magnetic field age, intensity and organization. Close to the disk center, we also observed a distinct cellular-like feature, formed from the blue-shifted motion components, with a small area of the weak red-shifted motion components in its center, encircling the dying part of the region's magnetic field. We also show the relationship of the distribution of the active region's magnetic and velocity fields with the structural patterns of the K3 CaII chromosphere. These seemingly trivial relations can reveal the distribution of motions in an active region.

Key words: sunspots, magnetic fields, velocity fields

1 Introduction

Recently the investigation of motions in the photosphere, especially in active regions, has become very topical. Numerous papers concerning the material down-flows in the outer penumbra of sunspots (Schlichenmaier & Schmidt, 2000) and in their vicinity have been published recently (Westendorp Plaza et al., 2001; Zhao et al., 2001; etc.). We measure the Doppler velocities photoelectrically in large areas around sunspots, covering whole sunspot groups, as well as their broad surroundings. Our measurements are made many times per day, over periods of many days, as the studied object and atmospheric conditions permit. We believe that the comparison of the published results mentioned, obtained mostly with a very high spatial resolution, with our photoelectrically measured line-of-sight motions, obtained with a medium spatial resolution (3"–5"), may prove to be, to some degree, inspiring.

Earlier (Bumba & Klvaňa, 1995) we have demonstrated, that some questions concerning the active regions velocity fields can be answered by applying a scanning photoelectric magnetograph with enhanced sensitivity of the Doppler velocity measurements, due to its measuring flexibility and readiness to measure instantaneously and as many times as atmospheric conditions permit. Thus, the scanning photoelectric magnetograph (Klvaňa & Bumba, 1994) enables to collect as large amount of data, as the investigation of the studied object requires. Depending on observational conditions, we are frequently able to measure during the whole passage of the region over the disk.

Moreover, we are getting a more general picture of the whole active region's motion field in its relation to the local magnetic field and its surroundings, and of the dynamics of its development. We have observed that the vertical component of the line-of-sight motions in and around active regions is arranged in a specific way. We are interested in the organizational forms of this local motion field during the process of its penetration into the quiet photosphere (as its disturbance). Namely, some partial results seem to demonstrate a close relation of the degree of the motion organization to the age of the local magnetic field (Bumba et al., 2003).

In July 1994 we measured many times the longitudinal magnetic and Doppler velocity field in active region NOAA 7757 with a leading spot displaying a well-developed Evershed flow and a few fast developing small spots with very short lifetimes, a region 1, which occurred on the visible solar disk in its descending phase of evolution. The whole active region presented interesting motion patterns, demonstrating in the neighborhood of the central meridian the tendency for its red-shifted line-of-sight velocity component, representing there the vertical motion away from the observer, to be organized spatially more markedly and in a certain order (Bumba et al., 2002). The abundant observational data (obtained in many repeated measuring series) and the fact that we observed the region from the time before it passed the disk center until it almost reached the west limb, led us to the evaluation and interpretation of data.

2 Observational data

NOAA 7757 appeared on July 16, 1994 at the east limb, passed through the central meridian on July 22, and was observed for the last time at the west limb on July 28, 1994. Its position was: l = 332°; b = 11° N. Interesting as regards this position is the fact that the spot group met the disk center at a distance of only about 6°. The region reached its maximum evolutionary stage on the invisible side of the Sun. It appeared at the east limb with a fast diminishing following part, seen in white light for the last time on July 19. The leading spot was almost regular with its umbra slightly elongated in the north-south direction. It displayed its descending evolutionary phase during its whole passage across the visible disk. It diminished slowly, but continuously in size. The polarity of its magnetic field was negative. Not far from the center of the disk, the maximal value of its longitudinal component was slightly more than 2200 Gauss (according to the Mt. Wilson Observatory, the intensity reached 2500 Gauss). It changed during the passage over the disk very slowly.

From July 22 to July 25, the reorganization and shortly lasting strengthening of the magnetic field of both polarities led to the formation of a cluster of briefly living pores of both polarities, more numerous in the positive polarity area, with visually measured intensities between 1200 to 1800 Gauss (Mt. Wilson Observatory). This small spot activity was reflected in the reorganization and strengthening of the red-shifted motion components. Our photoelectric observations (made mainly in FeI 5253.47 Å line with a Lande factor of 1.5, and several times in FeI 5123.73 Å line with a Lande factor equal to zero started on July 21, one day before the region's central meridian passage, and were conducted for a period of eight days, till July 28, when the center of the spot was at a distance of about 75° from the disk center. The total number of periods of photoelectric observations we made is 47. But during many periods the measurements were repeated: The region was then scanned from three to eight times during one such measuring period. The total number of obtained measuring sets is thus 81.

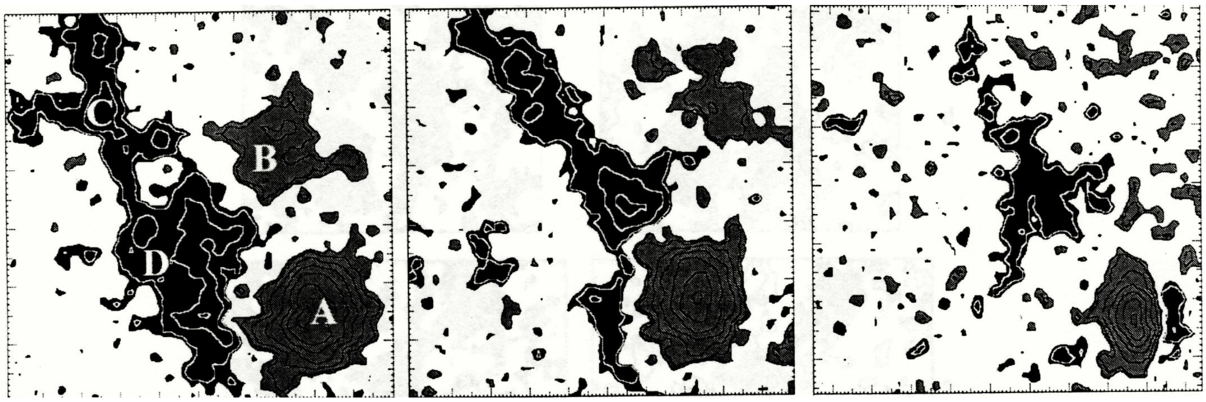

Fig. 1. Maps of the longitudinal magnetic field component. a) July 21, 07:08:17 – 07:28:38 UT b) July 24, c) July 26, 07:05:16 – 07:20:30 UT. The magnetic field intensity values are shown in a logarithmic scale, with the first level at 8 mT. Parts of the leading negative polarity field (grey) are indicated by letters A and B, and parts of the following positive polarity field (black) - by letters C and D

The main aim of the series of repeated measurements was to take into account the effect of five-minute oscillations: every subsequent set of measurements started about 7,5 minutes later than the previous one to provide not only enough time for scanning of a sufficiently large area, but also to get five-minute oscillations exactly in the opposite phase.

The fine-scale (spatial resolution 1.6" × 2.4") and normal mode (spatial resolution 3.2" × 4.8") of scanning were used alternatively during the measurements (Klvana & Bumba, 1994).

The latter mode was also used for taking measurements of larger areas around the group. As always, simultaneously with the measurements of the line-of-sight velocity component with electronically we measured the longitudinal component of the magnetic field and the intensities in the continuum and in the core and wings of the measured line. These data allow us to estimate the spot boundary, etc.

To verify our estimation of the zero-velocity level, the largest area around the studied active region was measured at several distances from the disk center. To construct the velocity map of this area, we took the average velocity of the whole measured area as the reference zero velocity level. (For example, when the center of the spot was about 7^{o} from the disk center on July 22, the measured area (640" * 330") covered a large part of the solar central zone.) We then constructed the velocity maps for the smaller measured area, containing only the leading spot with its closest neighborhood in the same way. The obtained morphologies of the velocity patterns and their amplitudes were compared. They clearly fit together, including the amplitudes, without substantial differences.

For chromospheric observations we used the spectroheliograms obtained at the Astronomical Observatory of the Coimbra University, Coimbra, Portugal. For the comparison we had at our disposal the K3 CaII and $H\alpha$ HI lines for July 21 till 28, 1994, with the exception of July 22 and 24.

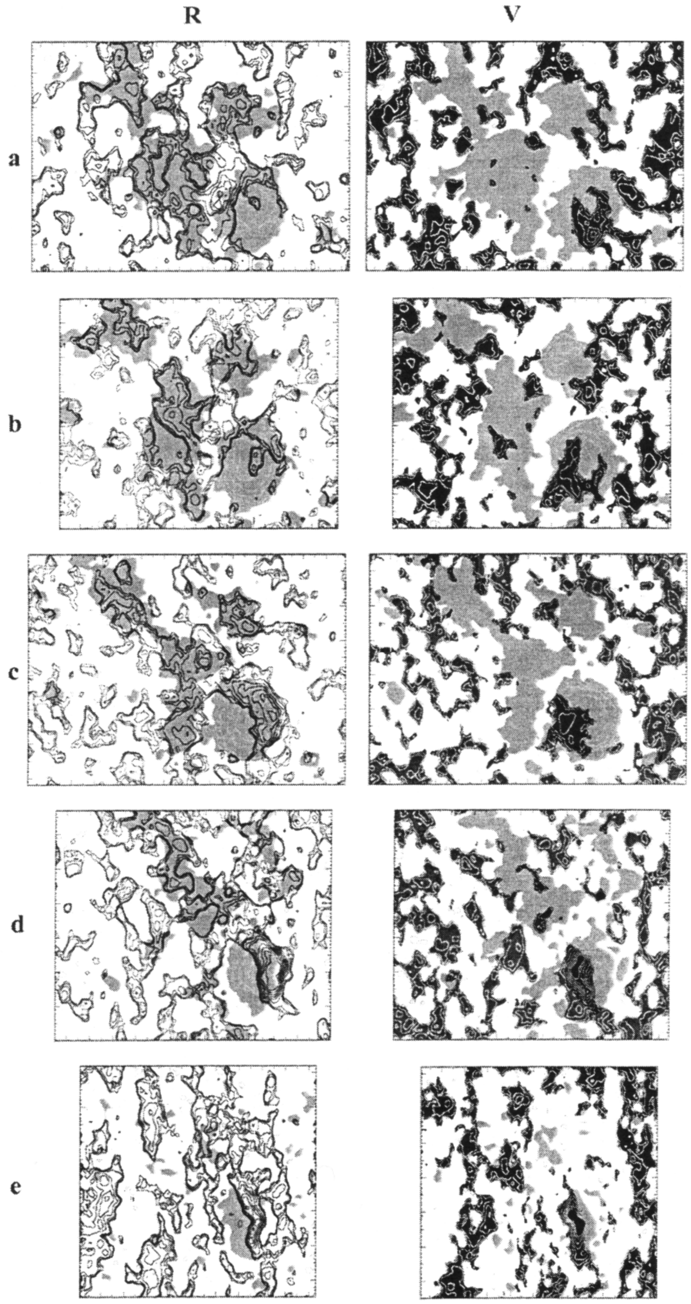

Fig. 2. Maps of the red-shifted (R – to the left) and blue-shifted (V – to the right) line-of-sight velocity components with the indicated magnetic field distribution (in grey, not distinguishing the polarity) in their background. The values of velocities are in ms^{-1}, the first level at $60ms^{-1}$, the second at $120ms^{-1}$, the following levels separated by $100ms^{-1}$. a) July 21, 06:34:08 – 06:51:46 UT; b) July 22, 07:06:45 – 07:17:41 UT; c) July 23, 06:06:31 – 07:14:57 UT; d) July 25, 06:48:30 – 07:02:18 UT; e) July 27, 07:40:06 – 07:55:49 UT

3 The region's (dying) magnetic field

Since the photospheric velocity patterns are closely related to the presence or absence of the local magnetic field, we shall describe briefly the topology and evolutionary dynamics of the region's magnetic field.

The obtained maps of the longitudinal magnetic field component (Fig. 1) clearly demonstrate the fast aging of the field and its dissipation and weakening. Both of its polarities have two parts: the basic one, placed closer to the equator, with stronger intensity, and the second, more northward one, whose intensity is substantially lower, and decreases even faster. In the leading negative polarity field, the strongest part (A) belonging to the main sunspot is less influenced by the aging due to its more concentrated magnetic flux. According to the observations from the Mt. Wilson Observatory, its intensity fell from 2500 to only 2300 Gauss. But the smaller northern part (B) of the leading polarity, with its maximum intensity of about 300 Gauss during the first days of observation, disappeared practically completely already on July 26.

The positive polarity of the following field divided successively into several smaller parts fading away rapidly, and then it split into two main bodies (C and D). Its northeastern portion C disappeared almost completely also on July 26. Its part neighboring on the main spot (D), forming a very weak magnetic gradient with the field of the leader at the beginning, moved even faster away from it, losing its strength in the same way. On July 27, it was last seen in the form of a small island, the intensity of its longitudinal component being of about 200 Gauss, about one spot diameter away from the leading sunspot.

We should mention that during three first days of observations, the region lay very close to the disk center (from about 20^{o}E to about 15^{o}W).

4 The region's velocity field

4.1 Difference in distribution of the blue-shifted and red-shifted line-of-sight motion components in the vicinity of the central meridian

The velocity maps obtained during three days of the region's transition very close to the disk center (Figs 2, 3, 4), show the different organization of areas representing the opposite line-of-sight motion components: the red-shifted motion components are emphasized in the active region's area, while the blue-shifted motion components are emphasized in the surrounding photosphere. The backbone of the region's Doppler velocity patterns is formed by characteristic, semi-regular, mostly cellular-like features of the red-shifted motion velocities, with small areas of weak blue-shifted motion velocities in their centers.

To demonstrate this situation more distinctly and to wipe out the details complicating the picture, we integrated the maps of all measured quantities in a large area around the studied region (about 600" × 250") obtained on July 22, at 9:06:27 9:41:31 UT five times (Fig. 3, left-hand side (A, B)). On the map of the blue-shifted motion components we see a practically empty place without blue-shifted motions in the position of the active region. Contrary to this, on the map of the red-shifted motion components, all of them are concentrated into this space, which coincides with the area covered by the magnetic field.

At this time, the spot's center of gravity was located about 7^{o} from the disk center. This means that line-of-sight motions, visible so well, must contain components which are almost vertical. Simultaneously, also on the integrated map the red-shifted motion components can be seen to be concentrated into three-four cellular-like structures. Among them the feature including the Evershed flow of the main sunspot created the most marked topological unit, the main part of the whole red-shifted motion components body, most regular and stable during the whole time of observation.

With growing distance of the region's velocity field from the disk center, the difference between the distribution and organization of areas occupied by both opposite motion directions is even less distinguishable. We can see this already on the velocity field maps of July 25 (integrated in the same way), when the spot was about 37^o from the disk center (Fig. 3, central part (C, D)). The organizational structures of the line-of-sight velocities of both directions become more and more similar, coming closer to the motion structures observable in the quiet photosphere with its mostly horizontal motions (Fig. 3, the right-hand side (E, F) integrated maps of July 26). V. Bumba, M. Klvana and A. Garcia: Complexity of the Doppler motion field of an active region

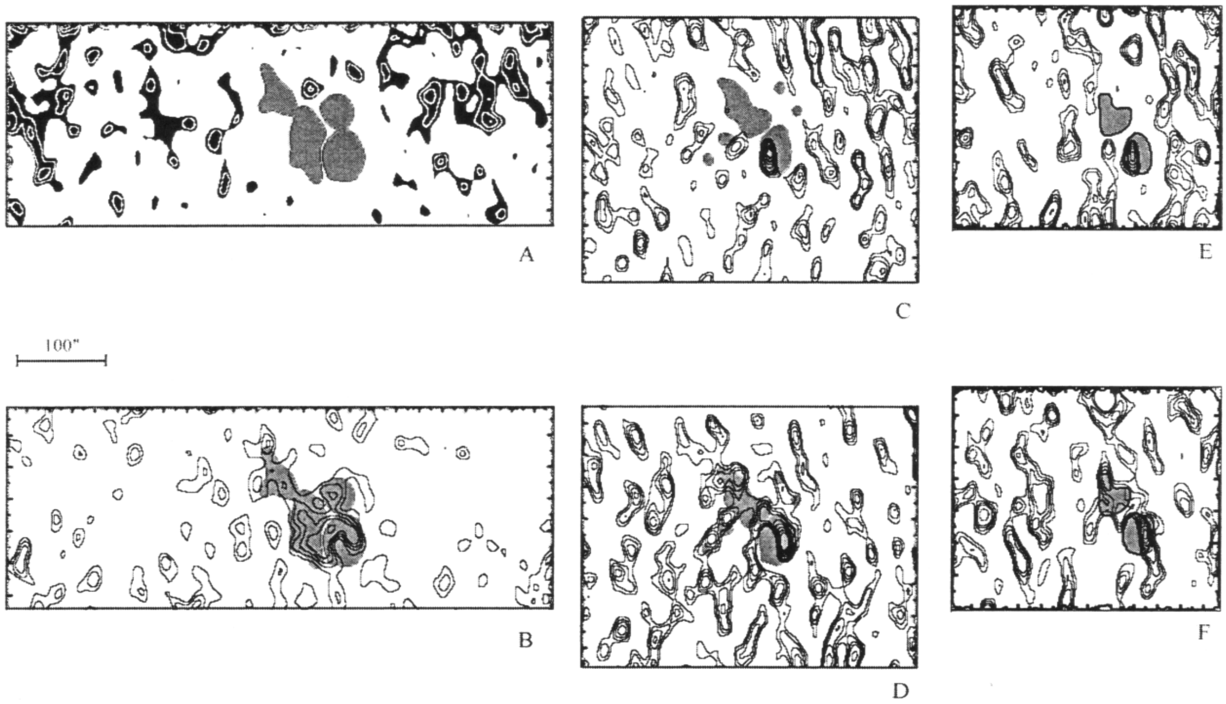

Fig. 3. Maps of the blue-shifted (upper maps A, C, E) and red-shifted (lower maps B, D, F) line-of-sight velocity components in extended surroundings of NOAA 7757, with the indicated magnetic field distribution (in grey) in their background, all maps are integrated five times. A and B: July 22, 1994 (09:06:27 – 09:41:31 UT), with gravity center of the spot of about 7^o from the disk center (northward); C and D: July 25 (07:15:09 – 07:46:29 UT, 38^o); E and F: July 26 (07:29:56 – 07:45:39 UT, $\alpha = 51^o$)

Investigating velocity amplitudes in both directions inside and outside the active region, close to the disk center and far from it, we see the following picture: close to the solar disk center, the line-of-sight velocity amplitudes of both directions outside the active region have values between $150 ms^{-1}$ – $350 ms^{-1}$; inside it, the red-shifted motion amplitudes can be slightly larger (around $400 ms^{-1}$), of course, under the Evershed effect they reach even higher velocities. With increasing distance from the disk center, velocity amplitudes of both directions grow slightly from about $300 ms^{-1}$ to about $600 ms^{-1}$. The amplitudes of the red-shifted velocities inside the region do not differ substantially.

Thus, the main characteristic of the region's Doppler motion field is the strengthening of the red-shifted motion components, their organization into cellularly formed structures, and their best visibility in the center of the disk. This behavior is in contrast to the main characteristic of motions in the surrounding photosphere, which have very small line-of-sight velocity components close to the disk center.

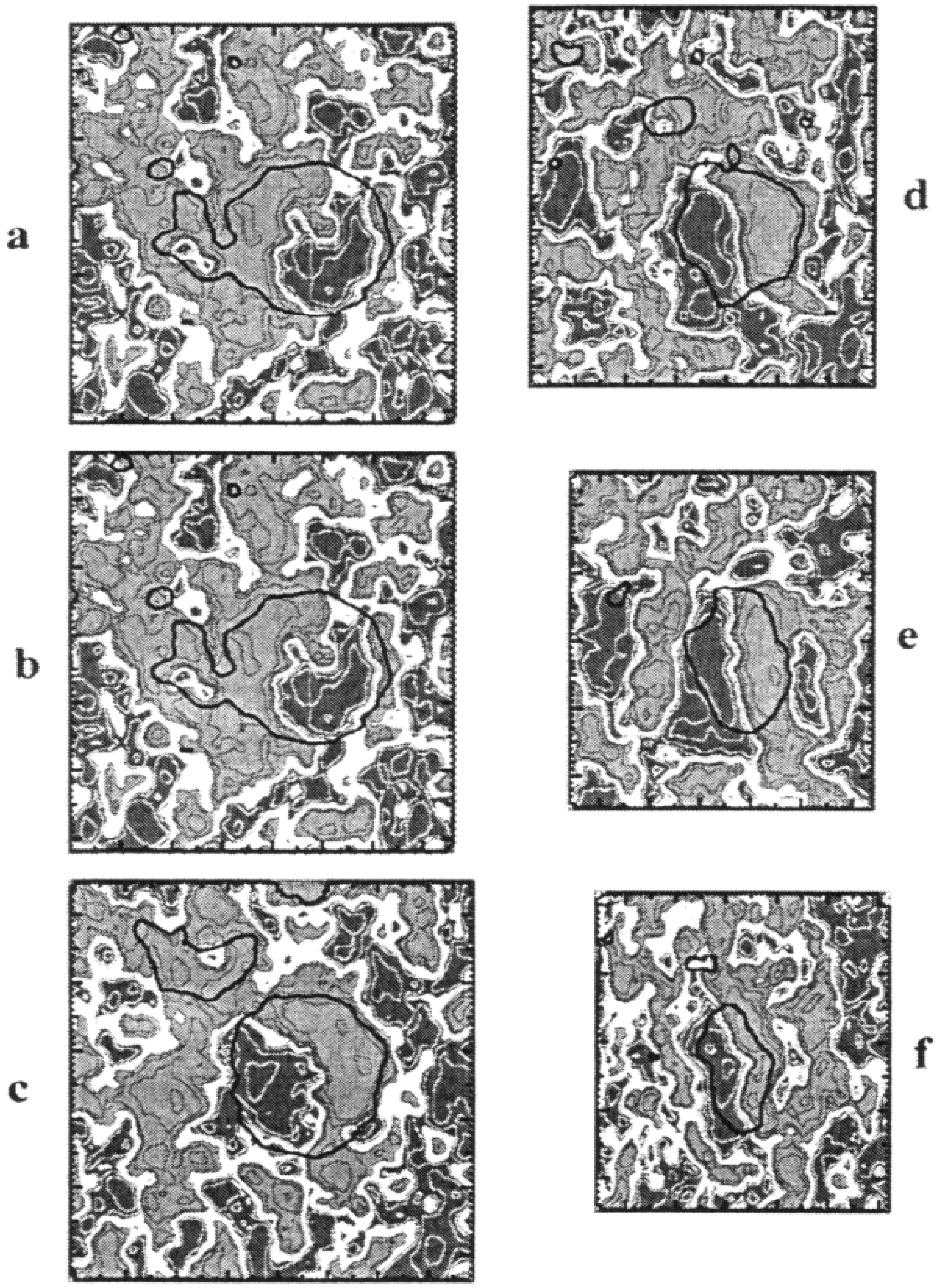

Fig. 4. Line-of-sight velocity maps of the main sunspot (NOAA7757), superimposed by the boundary of the spots in the white light (in a fine-scale mode). Dark are the blue-shifted, grey- the red-shifted velocity components. The velocities are in ms^{-1}, the first level at $60ms^{-1}$. a) July 21, 07:08:17 – 07:28:38 UT; b) July 22, 13:35:20 – 13:43:52 UT; c) July 23, 06:06:31 – 07:14:57 UT; d) July 25, 06:48:30 – 07:02:18 UT; e) July 26, 07:05:16 – 07:20:30 UT; f) July 27, 07:40:06 – 07:55:49 UT

This fact seems to underline the presence of a strong vertical component in the region's line-of-sight motions, while in the quiet photosphere the horizontal motion components predominate, although the vertical component cannot be neglected either (for example, Klvaňa, 1999). The observed similarity of the region's and quiet photosphere's velocity fields closer to the solar limb is an evidence of the presence of the strong horizontal velocity component also in the region's velocity field.

5 The region's velocity field

5.1 The Evershed effect

The boundary of the spot penumbra in the photosphere, defined using the continuum intensity, coincided, during the three days when the spot was the closest to the disk center, with the longitudinal magnetic field intensity level given in our maps by the isogaussline of 40-60 Gauss. Superimposing maps of the isolines of the continuum intensity distribution in the spot, obtained simultaneously in the normal scanning mode, on the line-of-sight velocity maps demonstrates that the Evershed flow exceeds the spot, let us say the penumbra boundary, for a few seconds of arc (Fig. 4). At the same time, we see that the red-shifted velocity components of this normal Evershed effect are closely related with the whole active region's red-shifted line-of-sight motion patterns surrounding them.

The association of the normal Evershed flow system with a more general motion body can be seen practically in the most regular sunspots (for example, Bumba & Klvaňa, 1995; Bumba et al., 1996). Near the solar disk center, these red-shifted velocity patterns encircle the Evershed effect on all sides, its blue-shifted velocity area even from the disk-center side (Fig. 4, and above all, Fig. 5), point to the fact that the Evershed effect motion system, with its still more organized motions (due to the strong concentration of the magnetic field lines), represents a very stable part and life-phase of the region's motion body.

Interpretation of our observational data concerning the regular Evershed effect only, coincides well with the previous results of other authors (for example, Schlichenmaier & Schmidt, 2000; Rimmele, 1995a; Rimmele, 1995b): at first, the motion in the inner penumbra is slightly upwards, then practically horizontal, turning downwards close to the rim of the spot. But this Evershed flow is inserted into a more complicated system of mostly red-shifted motions, best visible close to the disk center with amplitudes smaller than in the Evershed effect and occupying a more extended area, as mentioned above (Figs 4 and 5).

5.2 Topology of the motion patterns of the whole line-of-sight local velocity field

If we investigate the described disk center velocity distribution in even greater detail, we see that the areas of the vertical red-shifted motion components in the southern part of the region's red-shifted motion features body, with the inserted Evershed effect, form the most regular cellular-like structure. Moreover, the circularly formed body of these red-shifted velocity components is surrounded by another circle of blue-shifted velocity component areas in the form of a chain of positive velocity area islands (Fig. 5). The main area of the Evershed blue-shifted velocity components, joining the red-shifted component flow, is attached to the circular pattern from its inner side, but it does not lie in its center. It is placed asymmetrically with respect to the center of this circular feature, merging with the weak middle blue-shifted motions of the circular structure.

While dimension of the diameter of the spot and of the main Evershed flow area is close to the length of the diameter of a supergranule (around 30"-40"), the diameter of the whole circular pattern, formed by the red-shifted velocity distribution, is some 20" larger. And the diameter of the outermost blue-shifted velocity pattern is almost twice as large (again Fig. 5). In the case of NOAA 7757, the leading spot with its Evershed flow system was positioned westward from of the center of the whole pattern, even before the central meridian passage (Fig. 4).

The amplitude of velocities in this extended circular red-shifted vertical motion region is usually substantially smaller than in the Evershed red-shifted motions. On July 22, when the center of the spot is about 7° from the disk center, and while the red-shifted velocity components in the Evershed effect reached 1000ms^{-1}, the maxima of the red-shifted vertical velocity component amplitudes in the rest of the circular feature did not exceed 500ms^{-1}. The blue-shifted velocity component in the Evershed effect reached about 600ms^{-1}, the blue-shifted vertical velocities in the outermost circular chain were 100-200ms^{-1} lower. And while the ratio of the maximal amplitudes in the Evershed flow and in the surrounding motion regions seems to be about 1 : 2 in the neighborhood of the disk center, at larger distances it diminished to about 1 : 4.

Thus, the Evershed effect is formed as a part of a very complicated motion system, occupying an extended area in which the area covered by the red-shifted vertical motions is roughly identical with the area taken by the magnetic field, regardless of its polarity.

The outermost part of the system, indicated by the blue-shifted vertical velocity component, coincided already with the photosphere without strong magnetic fields. Outside the reach of the active region's magnetic field, the red-shifted velocity patterns seem to be less organized, and on the contrary, it is the blue-shifted velocity component that forms the cellular-like features more easily, as we have already once shown in Bumba & Klvaňa (1995).

The best visibility of the described motion patterns dominates during the three days, when the region is the closest to the disk center (Figs 1, 2, 3). This means that the motion must include strong vertically oriented streams, probably also due to the more stable magnetic field body in this evolutionary stage. Although the circular features described can be monitored practically till the last day of observation, with increasing distance from the disk center (more than $30^{o} – 40^{o}$; Figs 2, 3), the motion in both polarities becomes more complicated, and the structures in which they are organized, are mutually more similar and less distinguishable from such structures of the quiet photosphere. Nevertheless, the Evershed effect patterns remain visible in their classical form as far as the limb (Fig. 4).

On the Doppler velocity maps overlapped by the spot contour for July 26 and July 27, when the distance from the disk center increased to about 50^{o} and 65^{o}, respectively, the distribution of the line-of-sight velocity components perpendicular to the direction toward the disk center, is even more periodical in the changing of its red-shifted and blue-shifted velocity areas (Fig. 4). The main Evershed effect itself is preceded and followed by something similar to its mirror images.

In favor of the influence of the evolutionary stage of the region's magnetic field body on the stability and strength of the red-shifted vertical velocity cellular structures, best visible close to the central meridian, speaks the fact that its basic skeleton strengthens and is more distinct in areas, where the reorganizing magnetic field forms new pores or very small sunspots for a short time, adding small portions of new magnetic flux there. This is best seen on the maps obtained on July 22 through July 24, in the middle part of the region, not far from the boundary between the magnetic field polarities (Figs 1 and 2).

5.3 Strengthening of the blue-shifted Doppler motions connected with the dying magnetic field

The less intense islands of the leading negative polarity magnetic field in the northern part (Fig. 1 (B)) of the active region, representing the fast diminishing remnants of an already disappeared small spot (of about 250-350 Gauss intensity), are related with a distinct cellular-like feature of supergranular size (about 40"-60" in diameter), but the periphery of which is now formed of the blue-shifted velocity elements (with the velocity of about 400–500ms^{-1}) and the inner part is filled in by red-shifted motions of the same velocity magnitude (Fig. 6). We have to emphasize that the presented maps were obtained also in the closest neighborhood of the disk center. This again underlines the presence of a strong vertical component in the measured line-of-sight motions. The amplitude of the red-shifted motion component is the smallest during this pattern's central meridian passage. The structure is visible in the motion field as long as its magnetic field is measurable.

We have to state that this organization of motions is exactly the same as in the case of the whole active region. But the blue-shifted cellular-like feature, encircling the diminishing magnetic field, is enhanced and the red-shifted area inside weakened, probably due to the processes accompanying the magnetic field dying.

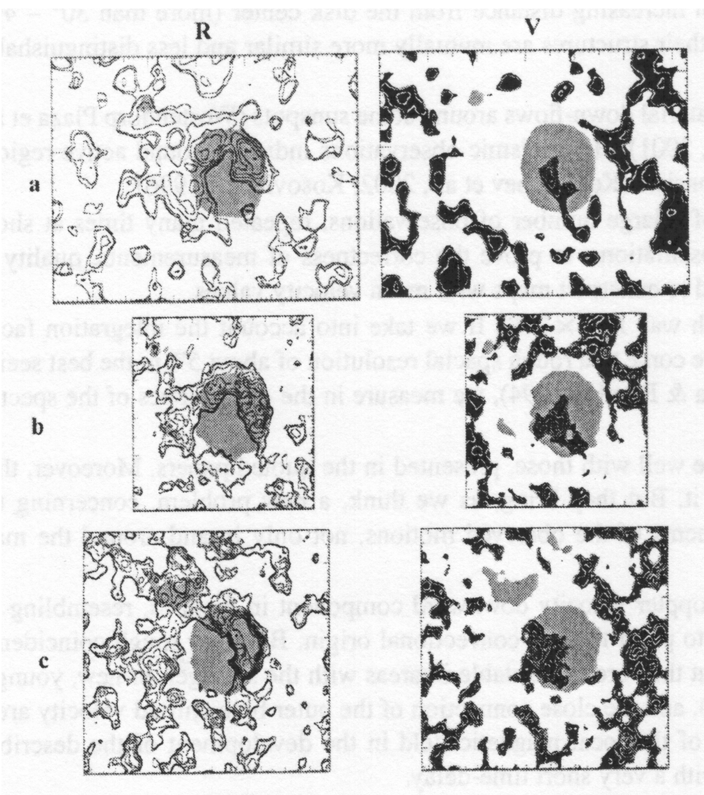

Fig. 5. LEFT – Maps of the red-shifted (R down-flows) and blue-shifted (V up-flows) line-of-sight velocity components in the closest neighborhood of the main sunspot (the area of the spot is indicated in grey in the background of each map), during the time in which the spot was closest to the disk center. a) July 22, 09:06:27 09:41:31 UT, the distance of the spot center from the disk center $\alpha = 6.9^{o}$; b) July 22, 13:35:20 13:43:52 UT, $\alpha = 6.5^{o}$; c) July 23, 06:06:31 07:14:57 UT, $\alpha = 12.0^{o}$. Velocities are (in ms^{-1}), the first level at 60ms^{-1}

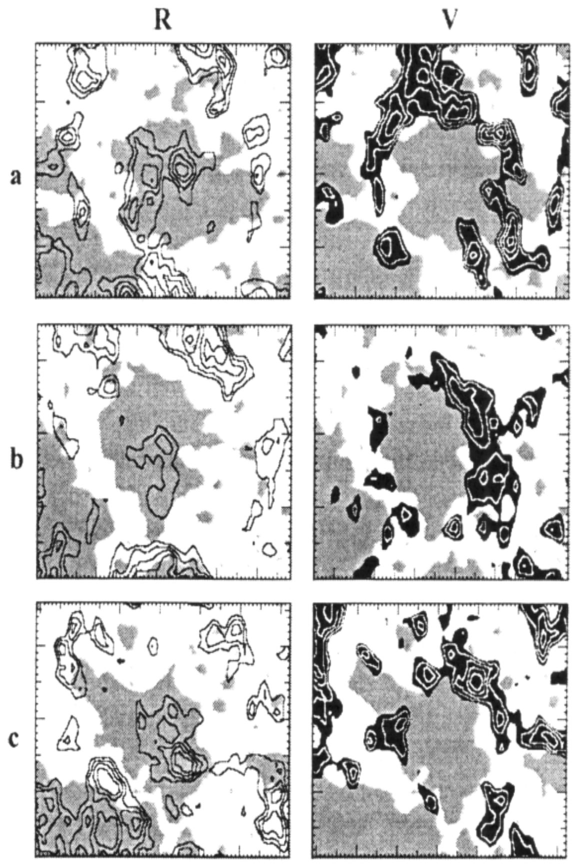

Fig. 6. RIGHT – Maps of the red-shifted (R practically down-flows) to the left, and blue-shifted (V practically up-flows) to the right of the line-of-sight velocity components in the area of the dying magnetic field, indicated in the background in light grey. a) July 21, 06:34:08 06:51:46 UT; b) July 22, 13:35:20 13:43:52 UT; c) July 23, 06:06:31 07:14:57 UT. Velocities in ms^{-1}, the first level at 60 ms^{-1}

The same scheme of distribution or organization of both velocity directions seems to be connected also with the dying body of the region's north-east positive polarity following magnetic field (Fig. 1 (C)), especially since this part of the magnetic field accelerated its aging. In this case, the motion patterns do not have such a well pronounced cellular-like characteristic form, as in the first case, probably also because the maps were measured at greater distances from the disk center. Nevertheless, the distribution of the red-shifted velocity areas, connected with the negative polarity magnetic field dying body, especially at the beginning of the process, is similar to that of the above mentioned dying magnetic field. But with its growing distance from the disk center this similarity becomes lost. Again the red-shifted structures are surrounded by more or less extended islands of the blue-shifted Doppler motions, especially when the region is not as far from the disk center yet. The individual islands of the positive velocity (of about 200-300ms^{-1}) then fit closely to the gulfs of the magnetic field body.

With increasing distance of the region from the disk center, the velocity amplitudes of both directions increase by several hundred ms^{-1}, and the coincidence of the magnetic field and red-shifted motion bodies decreases. The earlier good agreement of their forms is lost; the red-shifted velocity area is more disintegrated. Till July 26, it is still surrounded by islands of blue-shifted motions. But during the last two days, very far from the disk center, no blue-shifted motion components can be seen any more in the relatively extended area around the remnants of the positive magnetic polarity of the following field.

6 Discussion and concluding remarks

Taking into account the obtained results and the results we published earlier (Bumba & Klvaňa, 1995; Bumba et al., 2003), we can conclude: the typical semiregular Doppler velocity field of the quiet, nonmagnetic photosphere is disturbed by the active region's line-of-sight velocity field. Close to the solar disk center, this velocity field displays patterns formed mostly from its red-shifted (away from the observer) orientation, characteristically organized into cellular-like structures. This means that in the area occupied by the local magnetic field, we observe highly concentrated and cellularly organized red-shifted line-of-sight velocity component, filling in this area, while the greatest part of the blue-shifted velocity component surrounds this area, with the exception of cellular-like red-shifted motion structure centers. And how well this organization can be seen, strongly depends on the distance from the disk center. It is best very close to it (up to about 15^{o}-20^{o}). There, we can really speak of the verticality of both line-of-sight velocity components and, therefore, also of an organized downflow. The circular features described can be monitored practically till the last day of observation, but with increasing distance from the disk center (more than 30^{o}-40^{o}), the motion in both polarities becomes more complicated, and their structures are mutually more similar and less distinguishable from Doppler motion structures of the quiet photosphere.

Recently, several papers appeared, describing the strong material downflows around some sunspots (Westendorp Plaza et al., 2001; Schlichenmaier & Schmidt, 2000; Hitzberger & Kneer, 2001). Helioseismic observations indicate around active regions converging downflows, of which the dominant flow pattern consists (Kosovichev et al., 2002; Kosovichev, 1996).

The data from which our results were obtained consist of a large number of observations, repeated many times at short, planned time intervals, enabling to exclude the five-minute oscillations, to prove the correctness of measurements, quality of their repetition, to integrate several velocity maps together, and to construct maps with mean velocity values.

The most used entrance slit aperture of our magnetograph was 1.6"-2.4". If we take into account the integration factor caused by the seeing conditions and the scanning procedure, we come to a rough spatial resolution of about 5", in the best seeing case of about 3". With our relatively wide spectral slit (Klvaňa & Bumba, 1994), we measure in the outer slopes of the spectral line wings.

Taking all this into account, we think that our results agree well with those, presented in the quoted papers. Moreover, they extend their validity to the whole active region and beyond it. But they bring, as we think, a new problem, concerning the magnitude of the ratio of the vertical and horizontal components of the observed motions, not only in and around the main sunspot, but in the whole local motion field.

The concentration and cellular-like organization of the Doppler velocity downward component in features, resembling by their topology, as well as by their sizes, supergranules, seem to point to their convectional origin. But their rough coincidence with the distribution of the region's magnetic field, the fact that they are more stable in areas with the stronger, or new, younger magnetic fields (this situation changes on a timescale of days), and the close connection of the outer blue-shifted velocity areas with the local magnetic field gulfs underline the active role of the local magnetic field in the development of the described situation. The magnetic and motion fields mutually interfere with a very short time-delay.

The coincidence of the distribution of the negative Doppler motion component with the K3 CaII emission in the chromosphere above the studied region (and again, in this way with the region's magnetic field), as well as the agreement of the dark supergranular interiors with the positive Doppler motion components, is not so trivial. It cannot serve just as a diagnostic tool for the photospheric motion distribution. It also poses the question of the general motion organization above an active region, and its possible changes during its various evolutionary stages.

Since the discovery of the Evershed effect in 1909, the general concept of the system of stream-lines in the Evershed effect has not changed essentially. Thanks to the present high spatial resolution, progress has mainly been achieved in linking the individual types of motion mostly with penumbral and other photospheric details, their magnetic field organization, geometry, height in the atmosphere, etc.

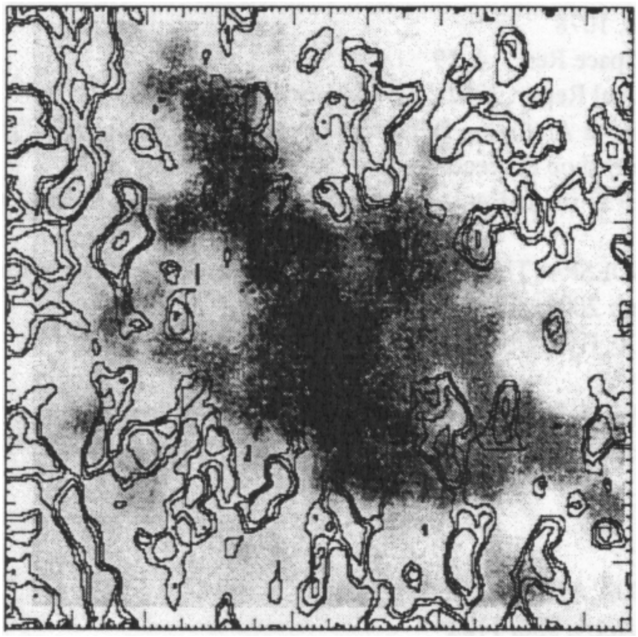

Fig.7. Distribution of the chromospheric emission (K3 CaII) in a negative form and of the photospheric Doppler blue-shifted motions (practically upflows) in NOAA 7757 on July 21, 1994 (08:40:18 - 08:49:44 UT). Velocities are again in ms^{-1}

But we have to remember that the motion field of a sunspot changes substantially with age. Already Abetti (1932) demonstrated the variety of the Evershed flow geometries for different forms and evolutionary stages of sunspots. Forty years ago, investigating spectra taken at the Kitt Peak National Observatory, we showed that in young small spots and pores strong downflows are observed, possibly even from the lower chromosphere. Namely, in most of the numerous small spots, belonging to two young active regions, we observed no, or mostly downward motions, smaller in photospheric lines (from about 0.5 kms^{-1} to about 6 $kms^{-1}$and greater in NaI D lines (10 – 14 kms^{-1} (Bumba, 1967a)).

Recently, several papers studying pore velocity fields have confirmed the existence of the downward motions in some pores and around them (for example, Hitzberger & Kneer, 2001, or Sankarasubramanian & Rimmele, 2003).

We have also to take into account the fact that the formation of a penumbra around the umbra means a crucial point in the development of every mature spot filling in one, or more supergranules (Bumba, 1977b; Bumba, 1973), and that only from this crucial point the normal Evershed effect seems to begin to operate. New theoretical considerations (for example, Hurlburt & Alexander, 2003; Rucklidge, 1995, or Yang et al., 2003) lead to a similar conclusion.

Also the final stages of the functioning of an Evershed effect are not well known, and as we have shown, there exists possibly an inverse flow in dying sunspots and their magnetic field remnants. The observed organization of the line-of-sight motions, oriented oppositely to those observed in the Evershed effect, forming the supergranular-like motion features connected with the dying magnetic field areas, can be roughly taken as an inflow of matter into the area of the vanishing magnetic field from the surrounding photosphere.

To understand the relationship between the magnetic and velocity field of an active region during different stages of its evolution better, we need to investigate more observational data, concerning, at least, several active regions in various evolutionary stages. As we have shown earlier for several large, fast developing, flare active regions, there exists a specific distribution of the line-of-sight motions, connected with the supply of new magnetic flux in areas of the strong magnetic field gradient (Bumba, 1993; Bumba et al., 1996).

But this will be the object of another study, where we would like to demonstrate, on the one hand, the changes of the line-of-sight motion field with age and the importance of six active regions, and on the other, we want to remind of the role of these motions in the formation of the active region's magnetic field. At the same time we would like to discuss the motion distribution from the point of view of the "downward pumping of magnetic flux" (Weiss et al., 2004; Tobias & Weiss, 2004).

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