

VELOCITY AND MAGNETIC FIELD STRUCTURE IN THE VICINITY OF H α FILAMENTS

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The measurements of the velocity fields in the photosphere in the vicinity of H α filaments are analyzed. It is shown that the filaments lie mainly above the blue shift regions (the regions of upward motion) in the photosphere often near the velocity inversion line. The relationship is considered between the velocity field structure on the one hand and the type of the filament on another.

1. Introduction

The analysis of the velocity and magnetic field distribution near H α filaments may clarify some questions associated with their formation, stability and energy build-up. A vast literature is devoted to this problem (e.g. see the review by Schmieder, 1989). However most of the papers deal with the velocity field structure near the filaments in the chromosphere (in H α) or in the transition zone between the corona and the prominence (in CIV and SiIV lines – see, for the instance, Kucera et al., 1999). As far as we know, it is only in works by Martres, Rayrole, and Soru-Escout, 1976, Martres et al, 1981, and the research team of IZMIRAN (Ioshpa et al, 1986, Ioshpa and Kulikova, 1994, 1995) were studied the velocity fields in the photosphere under the filaments. Meanwhile there are reasons to suggest a certain relationship between the character of the velocity structure in the photosphere and the location of the filament. First, it is well known that the filaments usually lie above the neutral line of the longitudinal magnetic field. Second, they are connected with the photosphere by so called "feet", where, according to some observations, the chromospheric matter moves up or down (e.g. see Kubota and Uesugi, 1986). Third, there is some evidence that the 5-minute photospheric oscillations in the filament location zone are weakened (Martres, Rayrole, and Soru-Escout, 1976).

Ioshpa and Kulikova, 1995 analyzed the structure of the photospheric velocities under three filaments observed on the Solar Tower Telescope of IZMIRAN in 1991-1992. Two filaments were similar by their morphologic properties and were located in the vicinity of active regions with high spotting activity. The third filament was located in an old faculae region with relatively weak magnetic fields. The authors arrived at the conclusion that the stable parts of the filaments were located above the boundary between the

regions of upward and downward motion of the photospheric matter.

After some modifications of the instrument had been made to increase the sensitivity of the velocity measurements (see Section 2), we decided to continue these investigations. In this paper, we analyze the velocity and magnetic structure in the photosphere near three H α filaments observed in June – August 1999.

2. Observation instruments and method

All measurements were made on Solar Tower Telescope of IZMIRAN with the aid of a Babcock-type solar scanning longitudinal magnetograph and an integral-interference spectrometer (tachometer) (Ioshpa and Kogevatov, 1991) working simultaneously in two different lines – the magnetograph in FeI 5253 Å (Lande factor $g = 1.25$) and the tachometer in FeI 5576 Å (nonmagnetic, $g=0$). The latter was based on the Fabri-Perot interferometer stabilized by the quantum frequency standard. The observations had a spatial resolution of 5". A preliminary filtration of the spectral lines was carried out with a second-order diffraction spectrograph with a linear dispersion of 0.9 Å/mm. The sensitivity of magnetic field measurements was about 5-10 G. The sensitivity of velocity measurements with the tachometer was 10 m/s. As shown by estimates, the formation heights of these two spectral lines differ by about 20 km.

As mentioned in Section 1, our instrument experienced some modifications that allowed us to increase the reliability of the obtained results. We shall describe them briefly.

1. It is well known that the line-of-sight velocity measured with a magnetograph contains usually spurious Doppler shifts due to the spectrum motions in the spectrograph. For example, the spectrograph of the IZMIRAN Solar Tower Telescope gives spurious line shifts equivalent to approximately 100 m/s. Therefore the radial velocities determined with a magnetograph use to display an error comparable with the measured velocities themselves. That's why a new system for compensation of the spectral line shift in the spectrograph was worked out and was introduced in operation in the magnetograph channel in 1998 (Kogevatov, Kulikova, and Cheragin, 1998). As a result, the accuracy of velocity measurements with a scanning magnetograph increased by an order of magnitude and became comparable with the accuracy of velocity measurements with a tachometer (10 m/s). It

allowed us to obtain simultaneously two velocity maps in two lines with approximately the same sensitivity. It also gave us also an additional way to check the correctness of the velocity results.

2) As before (Ioshpa and Kulikova, 1995), the distribution of magnetic fields and line-of-sight velocities in the vicinity of filaments was obtained by step-by-step scanning over the region under consideration. However in 1996, a new scanning system program was put in operation that allowed compensation of the 5-min velocity oscillations. Every 2.5 min, the system brought the solar image to the initial point, and the measurements were repeated. So, every point of the solar image was passed twice during 2.5 min. The scanning rate was $5\frac{1}{2}$ /s. The distance between the scans was usually $5\frac{1}{2}$. The full time necessary to produce one map was 25-30 min.

To take into account the trend of the line-of-sight velocity due to the image motion in the course of scanning, as well as the possible apparatus trend, a low-frequency filtration of the records was performed by subtracting the constant and the linear components. The value of the velocity averaged over the entire investigated region was taken for the null point. The accuracy of determining the null-point was 20-40 m/s. As shown by the analysis, the shift of the velocity null-point by such a value did not noticeably affect either the velocity distribution pattern, or the position of the velocity inversion line relative to the filament (within a given spatial resolution).

The records of the line-of-sight velocity and the magnetic field were supplemented by simultaneous $H\alpha$ filtergrams taken in the light reflected from the entrance slit of the spectrograph.

3. Observation and analysis

We present here the 1999 observations in the photosphere under three filaments. Two filaments were similar by their morphologic properties and were located in the old faculae regions, the third filament was located in the vicinity of active regions characterized by high spot activity.

a) The first filament was a long one and extended by about 400 arcsec approximately along the 25°S solar parallel. We observed it during 6 days from June 11 to 16. Fig.1 represent the $H\alpha$ images of this filament (Big Bear Obs. pictures taken from Internet) and the respective velocity maps for 11, 13 and 14 June. The filament positions taken from our simultaneously obtained filtergrams are marked with black circles. The rectangles on the $H\alpha$ images in Fig.1 are roughly correspond to the spatial position of the velocity maps and marked with the same figures. The velocity isolines plotted at 100 m/s steps are solid for the upward motion (blue

shift), and hatched for the downward motion (red shift).

The longitudinal position of the middle part of this filament on June 11 was about 30°E . We can see that the eastern part of the filament lies near the inversion velocity line (not under it), but predominantly in the blue shift region. The western part of the filament moves away from the inversion line and is positioned entirely in the blue region. On the contrary, the locations of the most legs and the east end of the filament correspond to the red shift regions (set against them). The velocity maps of June 13 give an impression that the red shift regions are divided by a blue shift corridor with the filament lying above it. On June 14, the eastern part of the filament erupted, but its western part (except the legs) remained lying under the blue shift region near the inversion line. On the following days (June 15 and 16), the same tendency of the filament position kept invariable in spite of a very unstable behaviour of the filament itself and the velocity field structure as a whole.

b) The second filament under discussion was also long and stretched along the 25°N solar parallel by approximately 400 arcsec. The western end of the filament was directed towards the sunspot. We observed the magnetic and velocity structure in the photosphere during several days – June 29 and July 1-3. The middle part of the filament was near the central meridian 1 July. The filament in $H\alpha$ (Big Bear Obs.) and the velocity maps for this day is shown in Fig.2.

The analysis of the maps shows that the tendency mentioned above keeps, i.e. most part of the filament lies in the region of upflow of the photospheric matter, whereas most of its feet and the ends are located in the downflow region or come close to it. For example, the narrow eastern part of the filament on the fig.2 lies in the upflow region but the western part with its ragged southern boundary with many small legs - in the downflow region.

c) The third filament under consideration was lying to the West of AR 8598 ($\text{N}23^\circ$) observed during the joint observation campaign of late June 1999 coordinated by Dr. Gary. The filament resembled an arc morphologically connected with the spot in the western part of AR (see $H\alpha$ images for 24 and 26 June of the filament on Fig. 3). We observed this filament from June 23 till June 28. The velocity maps for June 24 and 26 are also shown on Fig 3. As seen from the $H\alpha$ picture, the filament consisted of two branches that joined in the plage region at the top of the arch, where they got alternatively connected and disconnected. The general velocity structure did not change all over the observation

interval: the branches of the filament stayed all the time in the upflow regions bounding the downflow corridor. Only the southern ends of the filament and the top of the arch, where the filament branches disconnected, were located in the downflow region.

4. Conclusion

The analysis of observations brings us to the following conclusions:

1) Not only the magnetic but the velocity field structure in the photosphere are closely related to the position of the filament.

2) To judge from the results discussed in this paper, as well as in (Ioshpa and Kulikova, 1995), the filament of both types (old quiescent and those associated with active regions) have the tendency to lie above the upward motion regions being sometimes shifted to the inversion velocity line.

The filaments position above blue shift regions seems more pronounced in relatively stable narrow and clearly defined parts of the filaments associated with active regions. The quiescent old ragged filaments with a lot of legs may have the same tendency, but it is not as clearly pronounced, since the feet and the ends of the filament usually reside in the downflow region. Some of our maps show that the filament lies in a kind of corridor the blue shift (upflow) region forms between two red shift (downflow) regions.

3) The feet and the ends of the filament usually go into (or rest on) the matter downflow region.

4) The plage regions in the vicinity of filaments are characterized by a downward motion of the matter (e.g. see Fig.3. for the filament observed on 24 and 26 July).

All these results agree on the whole with the $H\alpha$ and CIV observations of the velocity field structure in the chromosphere (Schmieder, 1989; Engvold, Tandberg-Hanssen, and Reichman, 1985). They imply that the upward motion of the matter begins in the photosphere and continues in higher layers of the solar atmosphere. It would be reasonable to ask what significance this fact might have for the matter supply to the filament and for its stabilization over the photosphere.

It is possible that the matter upflow under the filament may play an important role in its stabilization. Though the location of the filament at the top of the magnetic arch (as in the classical Kiepenhahn-Schluter model) is corroborated by some magnetic field observations, the well known instability of such structure leaves place to some doubt. According this model the magnetic arch sags under the weight of the filament, and the latter is supported by tension. However this structure is subject to interchange and flute instability that develops as the filament matter

leaks by gravity through the field lines. The dynamic pressure of the upward flow may stabilize the situation. In those places where the upflow is absent or is changed by a downflow, the filament matter can move downwards to form the "feet".

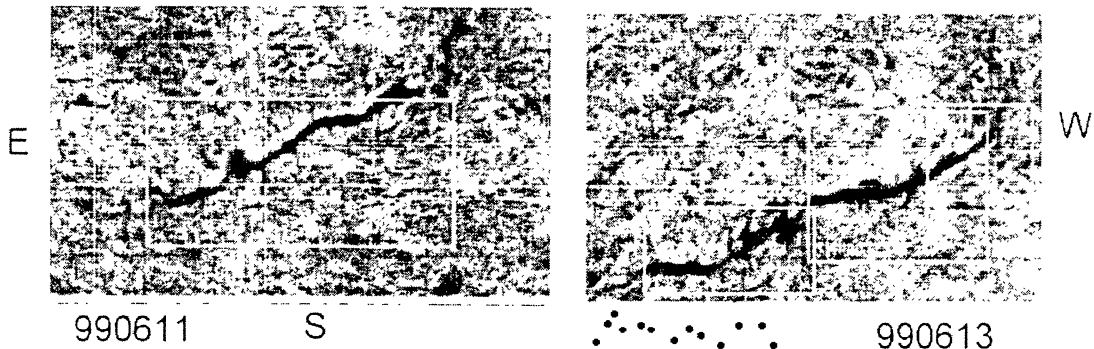
Somewhat less probable that the upflow may supply matter to the body of the filament. This idea conflicts with our understanding of the magnetic structure - it requires an effective leakage of matter upwards across the field lines.

Acknowledgment

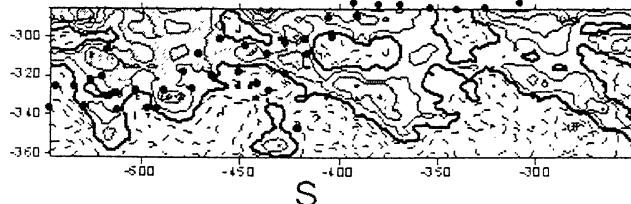
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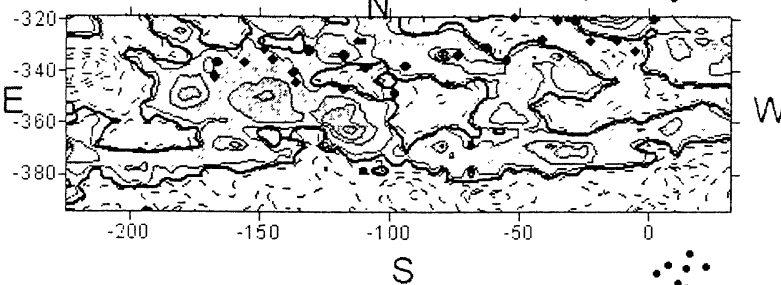
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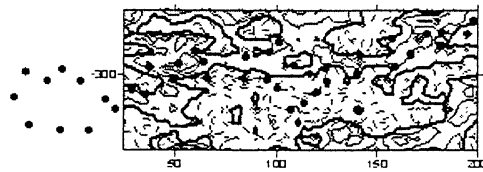
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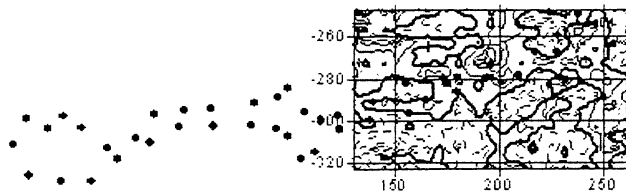
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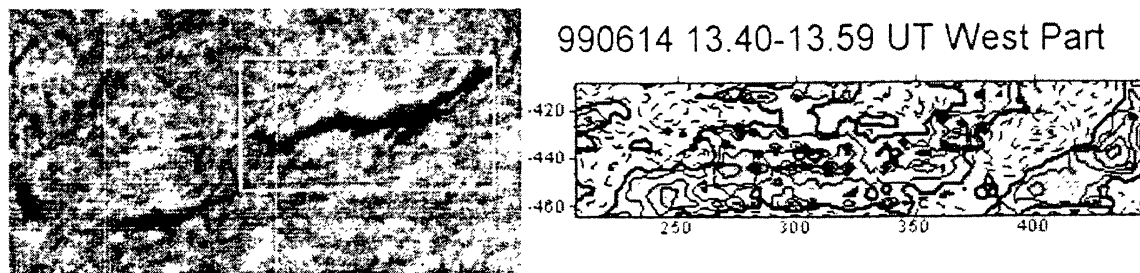


Fig. 1. $H\alpha$ images of the filament (Big Bear) and velocity maps for June 11, 13, and 14, 1999. The rectangles on the $H\alpha$ images correspond to the observed regions on the velocity maps. The dark regions on the velocity maps with solid isolines correspond to the upflow regions, the light ones with the hatched isolines - to the downflow regions. The dark circles show schematically the position of the filament. The scale on the velocity maps is given in arcsec.

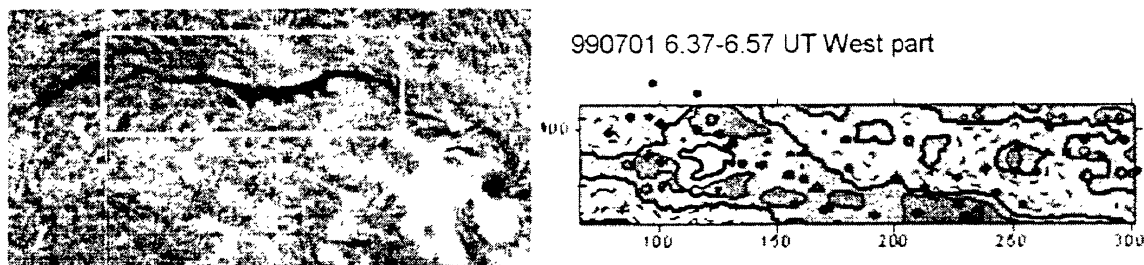


Fig. 2. $H\alpha$ images and the corresponding velocity map for July 1, 1999. The conventions are the same as in Fig. 1.

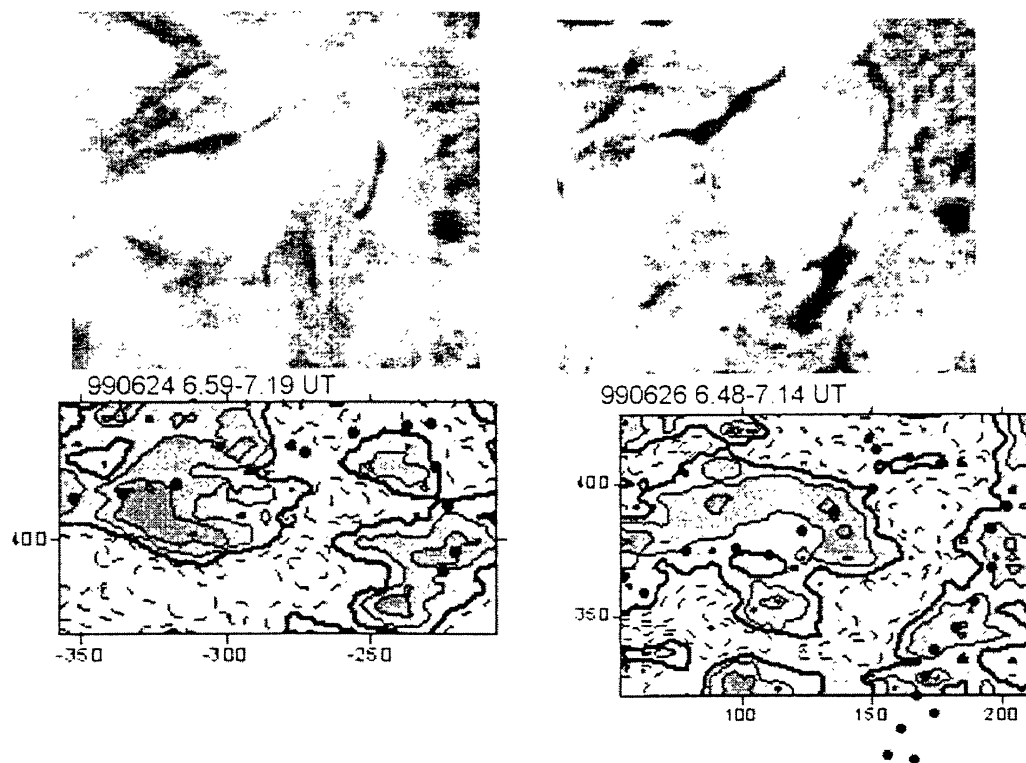


Fig. 3. H α images and the corresponding velocity maps for June 24 and 26, 1999. The conventions are the same as in Fig. 1