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Photospheric flows around a quiescent filament and CALAS first results

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Abstract. The horizontal photospheric flows below and around a filament are one of the components in the formation and evolution of filaments. Few studies have been done so far because this requires multiwalength time sequences with high spatial resolution. We present observations obtained in 2004 during the international JOP 178 campaign in which eleven instruments were involved, from space and ground based observatories. Several supergranulation cells are crossing the Polarity Inversion Line (PIL) allowing the transport of magnetic flux through the PIL, in particular the parasitic polarities. Before the filament eruptive phase, parasitic and normal polarities are swept by a continuous diverging horizontal flow located in the filament gap where the disappearance of the filament starts. In the future, observations at high spatial resolution on a large field-of-view would be very useful to study filaments, as they are very large structures. We also present the first images obtained with the use of our new 14 MPixel camera CALAS (CAmera for the LArge Scales of the Solar Surface) ($10' \times 6.7'$) . These are the first large-scale and high-resolution images of the solar surface ever made.

Key words. – The Sun: atmosphere - The Sun: Filaments - The Sun: granulation – The Sun: magnetic fields

1. Introduction

Filaments (prominences seen on the limb) which are common solar features always occur along lines where the underlying photospheric magnetic field changes sign. They represent regions where magnetic fields are interacting with the plasma in a subtle way in the different parts of the solar atmosphere. The filaments are structures of the solar corona which are anchored in the solar photosphere by footpoints. Because of the high turbulence of the photosphere (convection motions) several theorical works propose models for the formation of filaments based on converging motions (Van Ballegooijen & Martens 1989; Choe et al. 1992; Ridgway & Priest 1993). Knowledge of photospheric motions over a long time span is needed to understand the action of the plasma on the filament.

In this paper we present the study of a filament observed during a JOP 178 campaign

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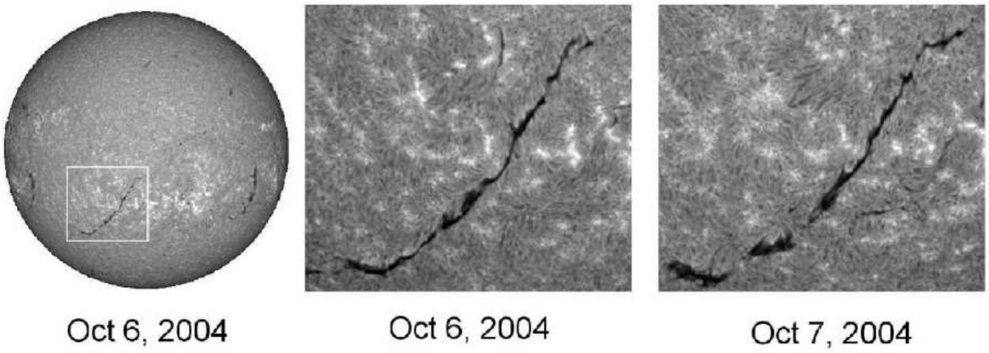

Fig. 1. Position of the target observed by ISOON on October 6 2004 and the filament evolution between October 6 and 7 2004.

over a large field of view with high spatial resolution. The description of horizontal photospheric flows below and around the filament is illustrated and formation of parasitic polarities is discussed.

We present also the photospheric and chromospheric context of the filament eruption on October 7, 2004.

2. Photospheric flows around a quiescent filament

The data used here come from a combination of ground and space based telescopes on October 6, 7 and 8, 2004 during a JOP 178 campaign (http://bass2000.bagn.obs-mip.fr/jop178/index.html). The target was a quiescent filament seen in Fig. 1 at solar coordinates S16E11 (on Oct 6). This target was observed by the Dutch Open Telescope (DOT), THEMIS, the Meudon Solar Tower (MST), The Dunn Solar telescope (DST), the Improved Solar Observing Optical Network (ISOON), TRACE and SOHO/MDI/EIT. These instruments followed this target and observed its eruption on October 7 around 16:30 UT.

Fig. 2 shows a mosaic at 8:50 UT of the $H\alpha$ filament structure that was observed in the southern solar hemisphere (S16E11) on October 6, 2004 during the decaying phase of the solar cycle. This filament has a sinistral chirality which is a normal configuration in that hemisphere. The smallest chromospheric features on the image show that the angular resolution is around $0.5''$ over the field of view of $95''\times323''$. The $5''$ radius circles indicate the region of apparent foot points. Following passive scalars, like corks, over a long time scale enables the formation of a network at supergranular scale. Fig. 3 shows the cork trajectories due to horizontal velocities during 5 hours superimposed on the location of the filament. The horizontal velocity amplitude lies between 0 and 1.2 km/s with a peak of the distribution at 0.3 km/s. We observe that the corks are expulsed from diverging cells with size from meso− to super−granular scales as expected. Some of these cork trajectories cross the filament in different parts. The field of divergence (Fig. 4) does not exhibit any particular behaviour below the filament, which indicates a similar flow over the field of view. At the photospheric level, the solar granulation does not exhibit any special property below and around the filament. However, several supergranulation cells are seen to cross the PIL as observed by Lin et al. (2005).

Fig. 5 shows the time evolution of the MDI magnetograms between 11:43-16:40 UT, in the SE extremity of the filament where the filament begins its eruption. We observe two magnetic structures, indicated by arrows on Fig. 5, moving with the photospheric flows towards opposite polarities. These structures disappear between 16:05 and 16:10 UT for the first one (top arrow) and between 16:20 and 16:30 UT for

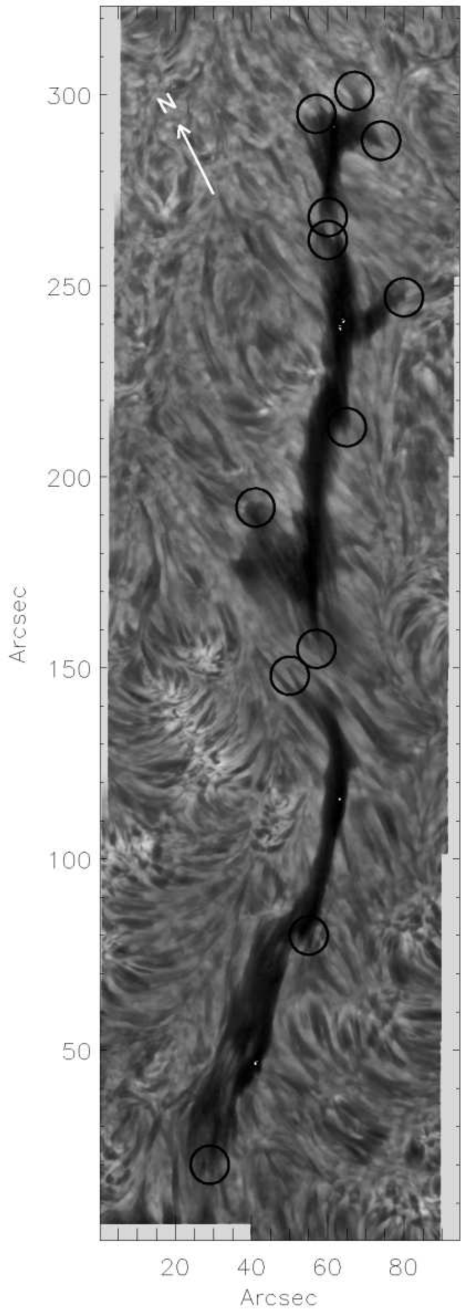

Fig. 2. Mosaic of the filament in $H\alpha$ observed with the DOT, from 6 frames selected, on October 6, 2004 around 8:50 UT. The circles correpond to the footpoints location of the filament. The arrow indicates North direction.

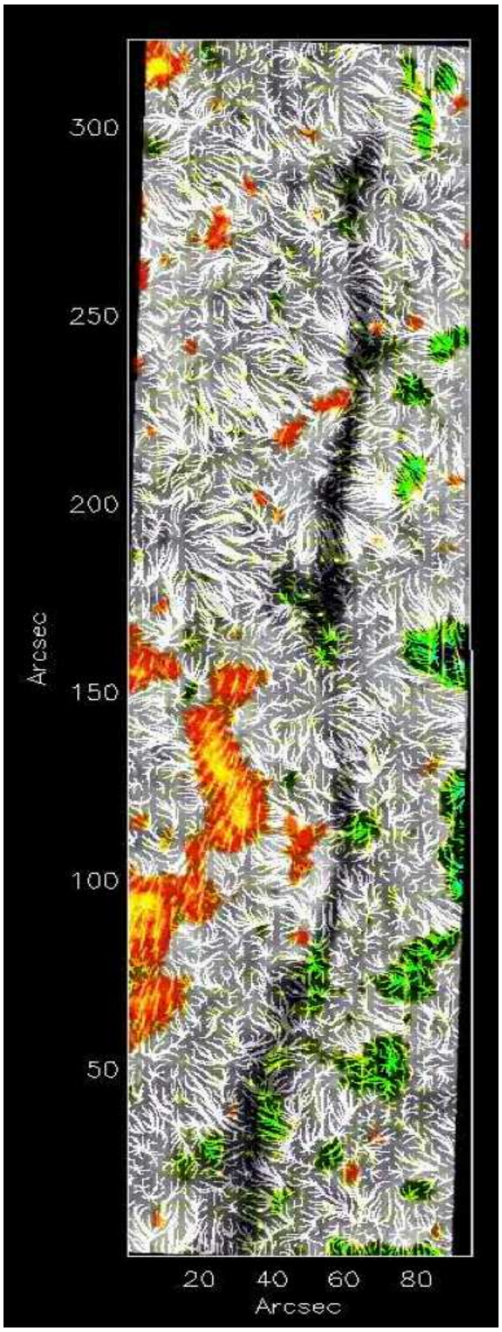

Fig. 3. THEMIS magnetogram on October 6, 2004 and superimposed corks trajectories computed from TRACE data. Longitudinal magnetic field lies between ±447 Gauss. The cold colors green and blue represent the field entering (South) the Sun and the hot colors red and yellow stand for the field going out (North) of the sun. The $H\alpha$ filament observed simultaneously with THEMIS is superimposed.

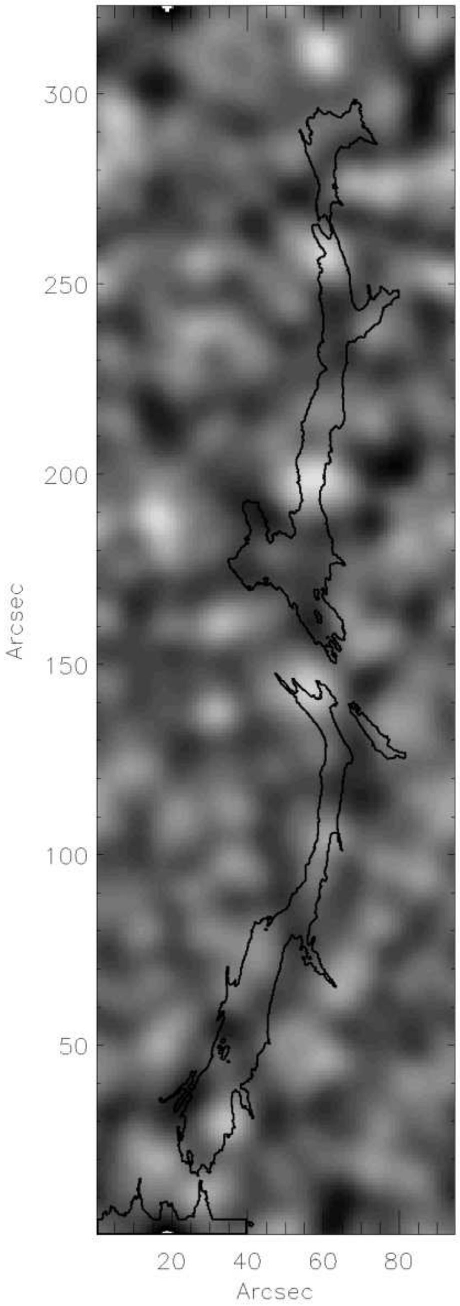

Fig. 4. Divergence map computed from the horizontal photospheric velocities (TRACE data) superimposed on the location of the filament observed with the DOT. Bright are divergent and dark are the convergent flows.

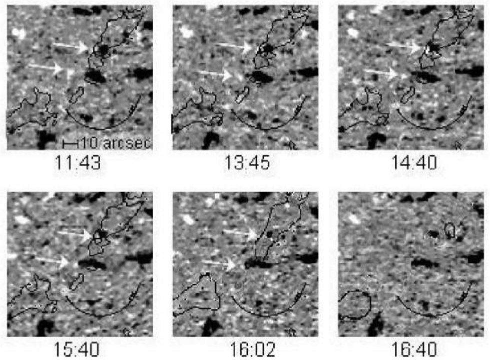

Fig. 5. Longitudinal magnetic field measured by MDI on October 7, 2004 between 11:43-16:40 UT, with the SE extremity of the filament. The arrows indicate the structures which move with the photospheric flows towards opposite polarities. The divergence location is shown by the arch of the circle. North is located at the top of the figure.

the second one (bottom arrow) when they interact with the opposite polarities. These phenomena could be related to the reorganization of the magnetic field and could be a candidate to start the destabilization of the filament which eruption of which starts around 16:30 UT.

3. CALAS first results

3.1. Objectives of the CALAS project

The origin of supergranulation is still much debated. Among various possible approaches, one way to study supergranulation is to observe the horizontal motions of granules. A combination of a very large field-of -view (in order to see as many granules as possible), a very high spatial resolution (to sample granules with a high accuracy) and a high cadence is necessary to study this pattern in detail. Such observations would also be a great asset to study the photospheric field associated to filament as studied in the previous section, because of the usually very large size of filaments. The CALAS project aims at building a complete instrument allowing images, Dopplergrams and magnetograms of the solar surface, installed at the Lunette Jean Rösch, Pic du Midi Observatory (France). In this paper we present the first images obtained with a 14 MPixel camera from the imaging channel. These are the first large-scale and high-resolution images of the solar surface ever made. We also present preliminary results showing the flow field computed on this large field-of view.

3.2. CALAS, the instrument

The camera used for the first observations is a Vector International FCi4-14000, a 14 Mpixel camera using a 24×36 mm CMOS sensor from Cypress/Fill Factory (IBIS4-14000 sensor). The image size is 3048×4560 pixels with a pixel size of 8 μm. We also plan to use a 16 Mpixels camera using an IBIS4-16000 sensor, developed in our laboratory. For this FCi4-14000 we have evaluated the readout noise to 3.3 ADU and the conversion gain to 18.4 electrons/ADU. From the observations we deduced a signal-to-noise ratio around 240 including the photon noise, with a noise around 14 ADU. This range of noise is typical from CMOS cameras and higher than for CCD cameras, however we also benefit from the high reading rate (up to 3.25 frame per second) that will be helpful to reduce the noise with deconvolutions. However the noise level is not as critical as for photometric observations, while our main objective is to characterize the dynamics of supergranulation. This camera is installed at the Lunette Jean Rösch, the 50cm refractor at Pic du Midi Observatory.

3.3. First large-scale and high-resolution images of the photosphere

The large field-of-view in obtained with one single acquisition (no mosaic). The area on the solar surface corresponds to approximately 435000×291500 km^2 (1 pixel = 94 km), which is represented in red on Fig. 6. Fig. 7 shows the image of this large field of view ($10' \times 6.7'$) with high resolution (0.13 ”/pixel) of the solar surface taken on October 28, 2006. A one hour sequence has been acquired both on October 28 and October 29. We obtained a very good time sequence with a homogeneous seeing quality all over the field-of-view. Fig. 8 displays an example extracted from this field ($2' \times 2'$) which shows the quality of the data available on the whole area.

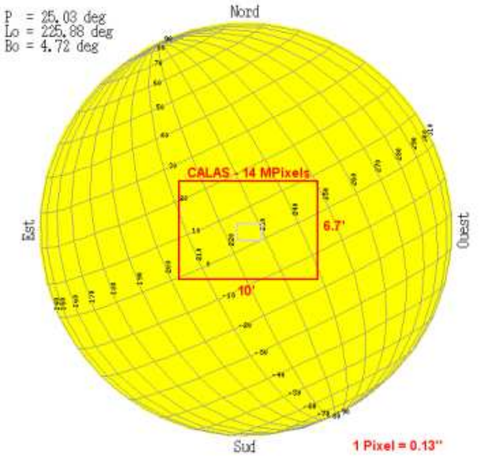

Fig. 6. Location and covered area by our 14 Mpixel camera on solar disk.

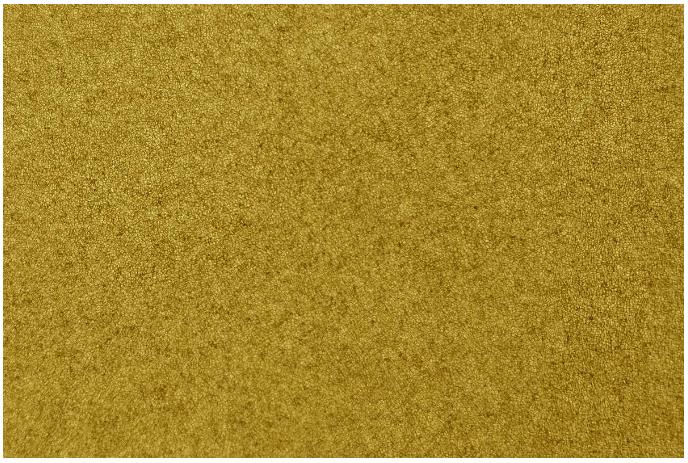

Fig. 7. Solar granulation in 5750 Angs. observed with the LJR (50 cm), on October 28, 2006 over $10' \times 6.7'$ at 9:48 U.T.

This sequence has been recentered and $k-\omega$ filtered, then the flow field has been computed on the whole area. Fig. 9 shows an example of the horizontal flow field over a small area ($18'' \times 18''$) where mesogranulation flows are visible.

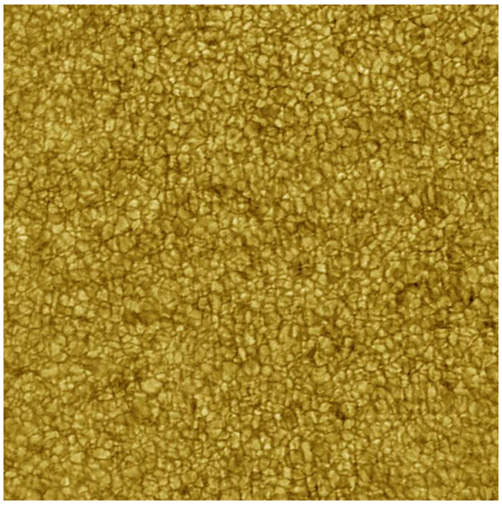

Fig. 8. Full resolution of solar granulation (2′×2′) extracted from Fig. 7.

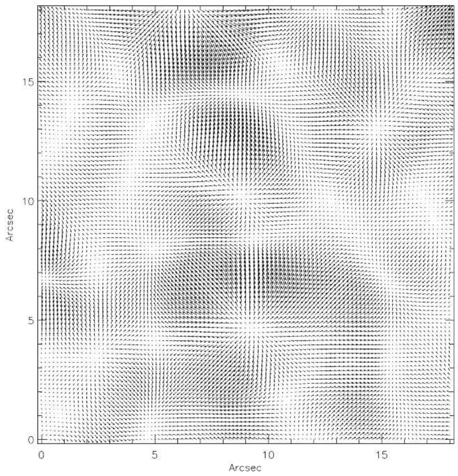

Fig. 9. Horizontal flow field over a small area (18″×18″) showing mesogranulation flows.

4. Conclusions

In this paper we have presented the multi−wavelength observation JOP 178 campaign of a solar filament on October 6, 7 and 8, 2004. From the analysis of the photospheric motion below and around the filament, we derived conclusions which are in agreement with the previous results obtained by Magara & Kitai (1999). Like Magara & Kitai (1999) we do not observe large−scale converging region which could exist along the filament channel for its formation (see Magara & Kitai 1999,for references). We find that the photospheric motions below and in the vicinity of the filament are identical to the remainder of the field-of-view in the quiet sun. We observe that several supergranulation cells cross the Polarity Inversion Line. We confirm that the supergranules can play a role in the transport of the parasitic polarities through the filament for the formation of a barb (footpoint). In particular, we show a detailed example where one sees well the probable formation of a secondary magnetic dip at the location of a footpoint.

Finally, the first time sequences obtained with the new 14 MPixel camera CALAS have demonstrated the possibilities to study the solar surface motions over large field of view with high spatial and temporal resolutions. The first horizontal flows derived from these time sequences are still under processing.

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