Convective plasma around solar pores

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Abstract

Magnetic structures are commonly observed in the solar photosphere at many different spatial scales, being sunspots and pores the most conspicuous ones. The formation, morphology and evolution of magnetic features are intensely linked to solar activity from the photosphere to the corona. Convective plasma and embedded magnetic field determine the development of different structures but there is not clear consensus from a model explaining the transition from pores into sunspots. Plasma flows in solar active regions can give us a clue on the ongoing processes and interactions leading to the formation of these magnetic structures, i.e. the formation of penumbrae around an umbral core. In the present work we follow the evolution of solar pores from high-resolution time series of images by computing horizontal proper motions. We aim at determine whether or not we find evidences of the presence of strong large outflows around pores, as in the case of sunspots, and how the plasma flows are affected in time by the evolution of the pores.

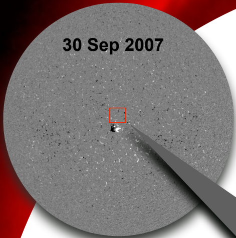


Fig. 1
SOHO (MDI) image showing the region observed on 30 September 2007, corresponding to the emerging flux region NOAA 10971.

Observations

Data were acquired during an observing campaign in September-October 2007 with the cooperation of several European and Japanese institutions and joint observations from various solar telescopes of the Canary Islands Observatories. Coordinated observations with **Hinode** satellite (Kosugi et al., 2007) were performed in the framework of the Hinode Operation Program 14. Images were aligned and subsonic filtered to eliminate p-modes, and residual jittering in the ground-based observations from the Solar Swedish Telescope (**SST**).

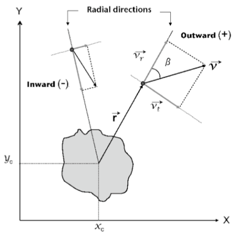


Fig. 2
Sketch showing the projection applied to the velocities around a solar pore centered at *(xc,yc)* with respect to the orthogonal coordinate system X,Y. The figure shows the velocity vectors **v** for two points in the granulation region around the pore (*small black dots*). The projection of **v** along the radial and transversal directions shows the radial v_r and transversal v_t velocity components, respectively.

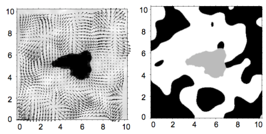
! All coordinates in the figures are in arcsec

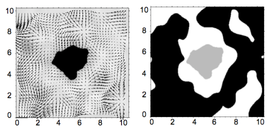
Velocity distribution around solar pores

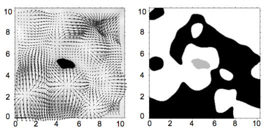
The analysis of the time series of images was based on computing horizontal proper motions by Local Correlation Tracking (LCT); November & Simon (1988), with a Gaussian tracking window (FWHM=1".0). From the velocity fields we can perform a detailed study of the velocity distribution around the solar pores in our FOV. A total of 7 different pore-like structures (labeled from 1 to 7 in the figure on the left) were independently analyzed.

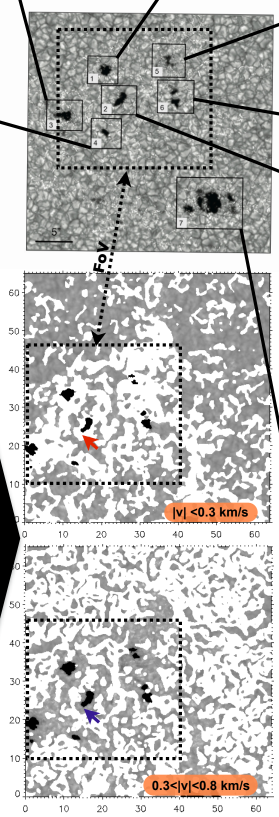
Fig 2 illustrates the projection of velocities into radial and transversal components as a convenient way to compute inward and outward motions surrounding every pore. Because pores in general exhibit their own displacement while embedded in the granulation pattern, the time series were aligned respect to a window framing every pore.

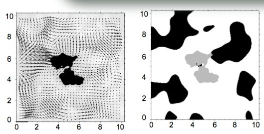
Every pair of figures on the left display the results for the pores 1 to 7 respectively, with the left image being the flow map and the right one a binary mask showing only inward (white) and outward (black) velocity components according to the description in Fig 2.

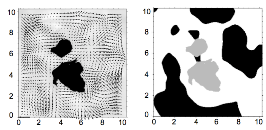


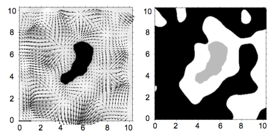












Velocity component
outward
inward

Distribution of horizontal speeds

To study the distribution of horizontal velocities in the whole FOV, we have defined two different intervals depending on the magnitude of the velocity, as follows:

- Low velocity magnitudes < 0.3 km/s
- Medium velocity magnitudes 0.3 - 0.8 km/s

The two figures on the right (see black arrow) show the FOV in which we compute the proper motions. Note that the FOV is slightly shifted down respect to to the one with the labeled pores above them. This is because we are using a longer dataset (50 min) for this computation that does not include pore 7. The background represent the averaged image. The dotted box frames the same region in all the cases as a reference.

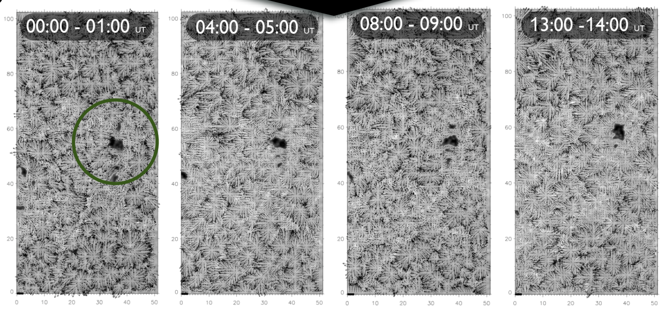
Right-hand figures show the location (white areas) of speeds (velocity magnitudes) within the two different ranges in km/s for the SST data.

Small speeds are mainly grouped in the central part of the FOV, where an intense magnetic activity is detected as evidenced by the high concentration of G-band bright points and faculae present in this region.

Around the pores the velocity magnitudes mainly correspond to the lower range (|**v**|< 0.3 km/s) so that they are surrounded by white areas (e.g location pointed by the red arrow). The areas mapping medium velocity magnitudes are regularly spread out all over the FOV except in the proximity of pores (e.g location pointed by the blue arrow).

Long-term evolution of the velocity field

To investigate how the evolution of the emerging region affects the velocity in the FOV for long periods of time, particularly around pores, we used the Hinode time series corresponding to nearly 18 hours of continuous solar observation. Figure below shows four 1-hour averaged velocity maps. Encircled in green is pore 7 surrounded by some smaller pores, which form a sort of vertical and elongated arrangement. The collection of these pores is evolving in time, and some of them start merging and disappearing. At final stages the image shows the isolated main pore with only a very tiny magnetic companion. We do not detect clear moat-like flows around the pore but velocity components towards the pore in its near vicinity.



References

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Conclusions

The LCT applied to the time series allowed us to track the proper motions of structures in the areas nearby solar pores. Proper motions were tracked for 1-hour periods, but one also for several hours. Derived flow patterns are consistent among each other showing the determinant and overall influence of exploding events in the granulation around the pores and in the whole FOV. Motions toward the pores in their nearest vicinity are dominant. We do not find traces of moat flow. The motions at the periphery of the pores are basically influenced by the external plasma flows deposited by the exploding events, as suggested by other authors (Sobotka 1999, Roudier 2002, Sankarasubramanian 2003). See Vargas Domínguez(2010) for an extended description of the work presented here.