



The Extreme Downflow in the Umbral Light Bridge of the sunspot

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ABSTRACT

Sunspots are the most readily visible manifestations of the interaction of the solar magnetic field with the solar atmosphere and the most prominent tracers of solar magnetic activity.

Results of the recent studies based on observation from Hinoddetectedthe presence of extremedownflows in a sunspot light bridgeup to 7.2 km s^{-1} which is exceed the speed of sound in solar photosphere of about 6 km s^{-1} .

The convective downflows and upflows are associated with a strong horizontal outflow directed radially outwards from the sunspot centre. These horizontal flows constitute the famous and mysterious Evershed effect.

In the present paperwe studied the asymmetries and wavelength shifts of the FeI lines at 630.25 nm to detect the exiting of the extreme downflows in the sunspot light bridge.

Our analysis reveals the presence of extreme downflows in the umbra light bridge of the sunspot of more than 10 km s^{-1} .

Keywords

Sun; sunspot; solar granulation; redshift.



COUNCIL FOR INNOVATIVE RESEARCH

Peer Review Research Publishing System

Journal: Journal of Advances in Physics

Vol 4, No. 2

editor@cirjap.com, japeditor@gmail.com

www.cirjap.com

INTRODUCTION:

The structure and dynamics of sunspots remain some of the most controversial topics in the surface of the sun. Sunspots are associated with strong magnetic field concentrations that appear in the atmosphere and present typical size of 1200km.

High spatial resolution images of the solar photosphere shows the granulation phenomena. The solar granulation is the smallest motion resolved on the surface of the sun; it consists of small regions of hot rising material (a granule) surrounded by relatively thin regions of cooler falling material. A granular cell thus consists of a hot, slowly rising, central region, and a cooler, more rapidly falling into deeper regions. Typical horizontal and vertical velocities are of about 1 kms^{-1} - 2 kms^{-1} . [1]

Most studies concentrated on changing of the continuum intensity and the bisectors lines shapes with Doppler shifts when changing from high to low spatial resolution. [2]

The line bisector is the loci of points midway between equal-intensity points on either side of the line. The bisector thus divides the absorption line into two halves of equal equivalent width and shows the apparent radial velocity at each depth in the line.

Fig. 1 show asymmetry and wavelength -shift spectral lines of the solar granulation. [3]

The white-light image of solar granulation is shown on the left part of the figure. The spectral lines profiles in the central panel observed under high spatial resolution. The solid curve in the right part of the figure illustrates the resulting line profile averaging over many granules for observations under low spatial resolution.

The resulting line profile in Fig.1 is asymmetric and blueshifted. The type of line asymmetry is indicated by the bisector shape which is characteristic of the letter 'C'.

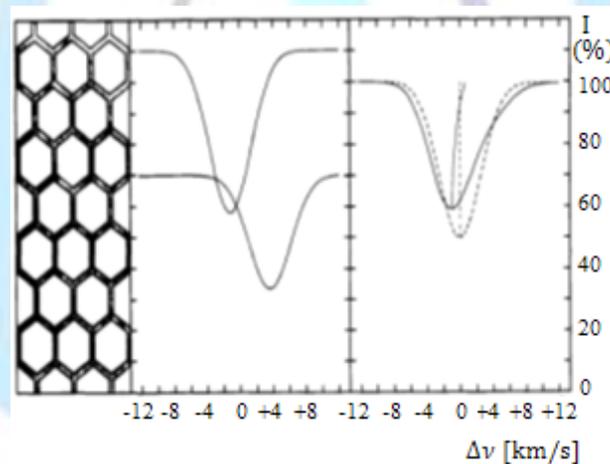


Fig. (1):The spectral line asymmetries and wavelength shifts caused by convection.

DATA ANALYSIS AND DISCUSSION:

In this section we will explain the observational data analyzing for the spectral line FeI at 6301.5 \AA .

We analyzed a standard FITS array data of the solar images in the left part of Fig. 2(a). The data is a 3D cube of dimension (984, 972, 25) includes (x, y, λ). We first normalized the intensity value to its maximum value to get the intensity line profile in Fig. 2(b).

Asymmetry and shifts of the bisectors lines profiles at different intensity levels have been studied to investigate the strong downflows in the umbra of the sunspot.

We measured the lines bisectors at intensity levels from 0.1 to 0.9.

The bisector is constructed by measuring the average Doppler shifts at each level. [4, 5, 6]

We studied the bisector line profiles for intensity levels between 0.1 and 0.8. For higher intensity levels the line shapes becomes unreliable due to the proximity to the continuum level.

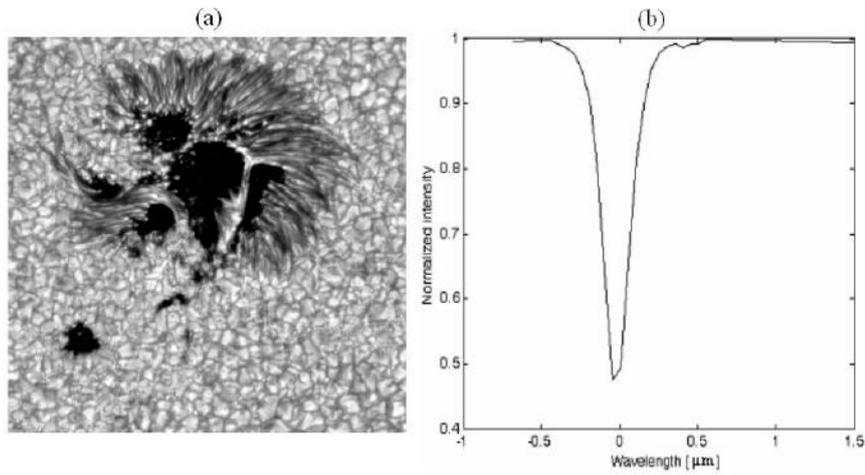


Fig.(2):The left panel displays Doppler map of a sunspot and their surroundings. The right panel displays the intensity line profile for Fe I line at 6301.5 Å.

Analyzing of the bisectors lines profiles at a selected area of the quiet sun shows the usual correlation between the intensity and Doppler velocity as illustrates in Fig. 3.

Fig.3 shows the Doppler velocity distribution of the granules – intergranules regions at the selected area of the sun. We notice that granules with mean positive Doppler velocity up to 1 km s^{-1} (redshift- downflows) while the mean negative Doppler velocity of about -4 km s^{-1} in the (blueshift - upflows) granules.

It is easy to see that the redshifted downflows have low continuum intensity.

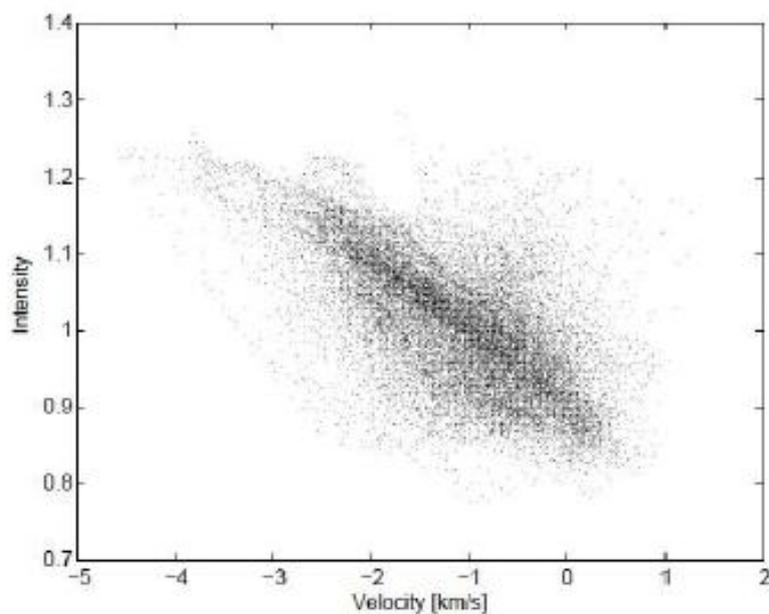


Fig.(3). Continuum intensity as a function of Doppler velocity for the (6301.5 Å line of Fe I).

The resolved profiles of 150 lines at a sub image of size 100x50 pixels on the quiet sun area are shown in Fig. 4.

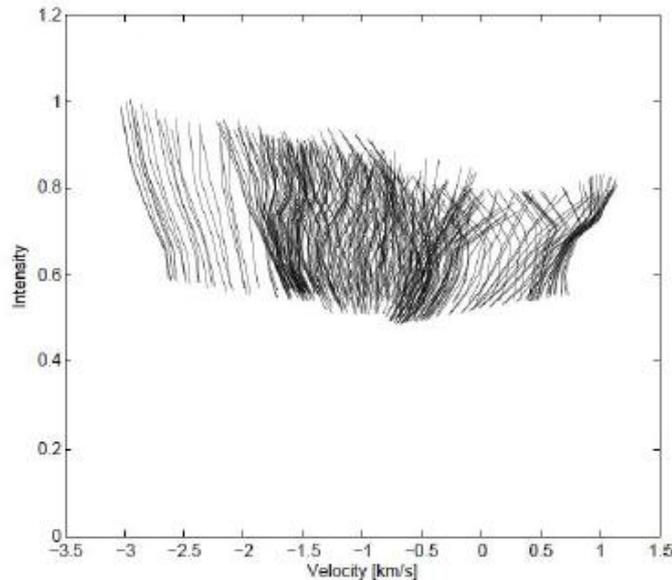


Fig. (4): quiet sun bisectors for a pixel column of 150 pixels. Brighter blueshifted upflows tend to have higher intensity and negative velocities than dimmer intergranules lanes. Also the line shapes vary systematically with distance from granule center.

The bisector profiles in Fig. 4 have different asymmetries and shifts. The lines look stronger and have higher continuum intensity in the blue-shifted granules lanes compared with the red-shifted intergranules. Doppler velocity is less than -2.5 km s^{-1} in the granules - upflows but it is more than 1 km s^{-1} in the intergranules - downflows regions.

The bisector lines in Fig. 4 have symmetric shape tend to the blue-shifted and red-shifted according to their origination in the granules-intergranules regions. The profiles are much less curved in the intergranular - downflows, although there is a sharp shift toward the red near the continuum intensity in some profiles. In this study we have further explored that the red wings of the line profiles are more stable than the blue wings in the regions of transition from granules to intergranular. On the average Doppler velocity is low in the granular - upflows and high in the intergranular - downflows regions.

Doppler velocity of the intergranular - downflows will be increased and reaches a value of more than 10 km s^{-1} in the umbral light bridge of the sunspot as shown in Fig. 5.

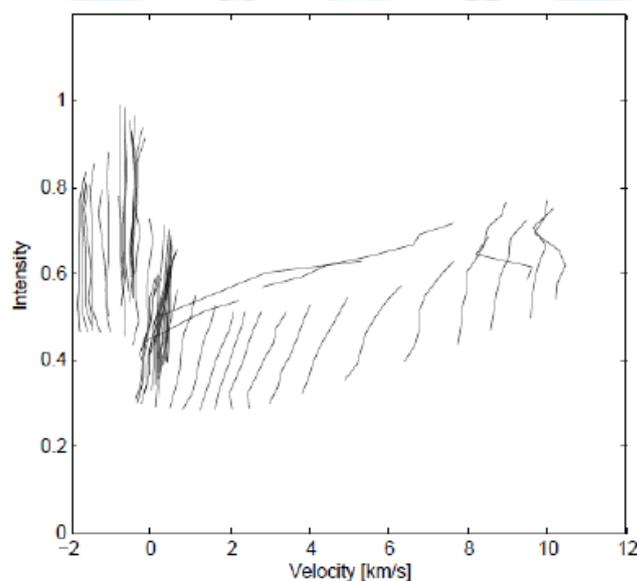


Fig.(5): The lines bisectors across the light bridge in the umbra of the sunspot. Very high downflows velocities are seen at the umbral of the light bridge.

Fig. 5 illustrates the shape of umbral bisectors of $\text{FeI}6301.5\text{\AA}$. We see clearly changes in the resulting lines between the upflows and downflows regions. The line is much less convex in the upflowing granules at the



high continuum intensity. Doppler shift will be increased gradually in direction of the intergranular downflowing and the lines profiles shows deviate from the usual shape when the velocity is exceed 8 km s^{-1} . This result demonstrates the exiting of strong downflows exceed 10 km s^{-1} in the umbral light bridge of the sunspot.

CONCLUSIONS:

Our present analysis of the Fe I line 6301.5 \AA summarized as follows:

- 1- On the quiet sun there is a linear correlation between the continuum intensity and Doppler shift. The speed of the blueshifted upflows of about -4 km s^{-1} , and redshifted downflows up to 1 km s^{-1} .
- 2- The bisectors behavior on the quiet sun exhibit reversal increase of the shift with the bisector intensity toward \wedge -shaped and \vee -shaped. But the lines are stronger in the blueshifted upflows.
- 3- The lines profiles show stronger asymmetries in regions of the redshifted downflows comparable with regions of the blueshifted upflows. Moreover the bisectors shape close to a straight line in some regions of the light bridge and there is no clear noticeable shift especially at the blueshifted upflows.
- 4- The intensity of the most extreme downflows is slightly higher than these of less shifted in the surroundings. But in general the bisectors shape in the umbral light bridge of the sunspot is similar to those on the quiet sun.
- 5- It was also found that the larger shifts associated with the strong downflows of more than 10 km s^{-1} on the edge of the umbral light bridge of the sunspot.

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