MULTI-WAVELENGTH ANALYSIS OF A SOLAR NETWORK REGION

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Abstract. We analyse co-temporal observations of a network region found near the solar disc centre, obtained by the Dutch Open Telescope (DOT) and the Coronal Diagnostic Spectrometer (CDS) on-board SOHO during a coordinated observing campaign in October 2005. DOT obtained images in 5 wavelengths along the Hα profile, while CDS obtained sit-and-stare observations in several EUV spectral lines that span the upper solar atmosphere. After fitting the CDS spectral line profiles we obtained 2-D space-time maps of intensities, Doppler velocities and Doppler widths. We study the appearance of the network region in the different spectral lines and the temporal variations of the obtained physical parameters. We employ a wavelet analysis to examine the existence of oscillations at the network in the different solar layers.

Key words: Sun - network - oscillations

1. Introduction

It is now well established that in the quiet regions of the solar photosphere the magnetic field is mainly concentrated into small flux tubes with field strengths of 1-2 kG (Solanki, 1993), which form patches of magnetic flux concentrations. A strong spatial coincidence exists between these magnetic flux concentrations and the overlying network boundaries. The network persists throughout the chromosphere-corona transition region and the low corona. A clear distinction exists between the network boundaries (NB hereafter) and the cell interiors (IN hereafter) based on different morphological and dynamical characteristics. Obviously, these differences must be reflected in the behaviour of the oscillations observed in these regions. Indeed, several authors have reported that oscillations at the NB have a period close to 5 min whereas the IN seems to oscillate with a period of $\sim$ 3 min (see e.g.
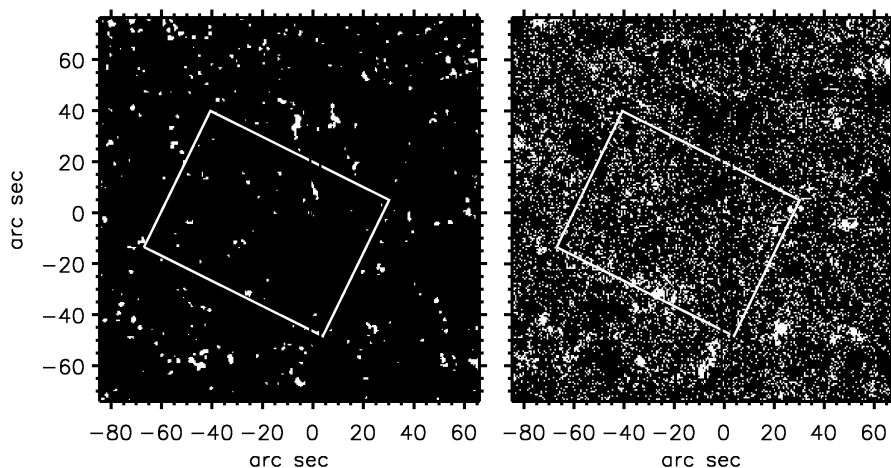
Figure 1: C IV TRACE image (*left*) and MDI magnetogram (*right*) obtained October 14 at 10:15 UT. Solar North is up. The white rectangle inside the images marks the DOT's FOV (pointing to the celestial North), while the two parallel grey lines inside the images mark the location of the sit-and-stare CDS observations.

Deubner and Fleck, 1990). Analysis of the oscillatory behaviour may shed light on the role that waves play in the heating of the outer atmosphere. On the other hand, several structures such as mottles, explosive events, blinkers, network flares, up-flow events have been found to be residing at the network boundaries. For most of these structures magnetic reconnection has been suggested as the driver (e.g. Tziotziou *et al.*, 2003) which also has been considered as one of the coronal heating mechanisms. Therefore, it is not surprising that several studies are devoted to better understand the network phenomena and the structures associated with them.

The aim of this work is to study a network region by using observations obtained both from the ground and space.

2.   Observations and Data Reduction

The analysed data were obtained on October 14, 2005 and consist of time sequences of observations of a quiet region found at the solar disc centre recorded by different instruments. Sequences recorded by the Dutch Open Telescope (DOT) were obtained between 10:15:43 - 10:30:42 UT and consist of 26 speckle reconstructed images taken at a cadence of 35 s and a pixel size
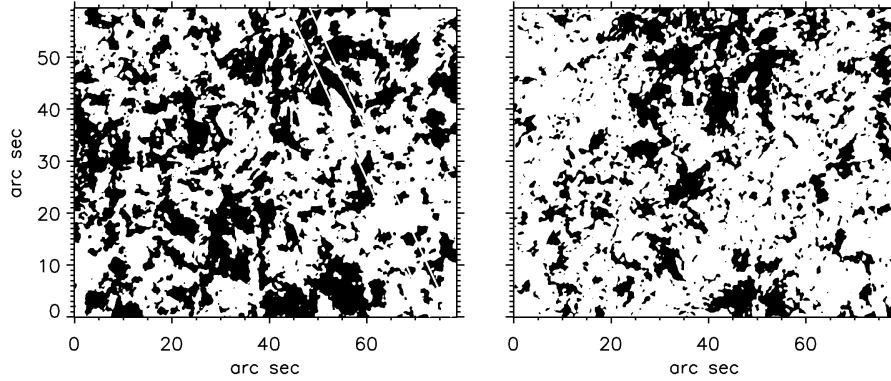
Figure 2: DOT Hα-0.7Å (*left*) and Hα+0.7Å (*right*) images. In the left image the two grey parallel lines mark the CDS slit position of the sit-and-stare observations.

of 0.071″ in 5 wavelengths along the Hα line profile (i.e. at -0.7Å, -0.35Å, line centre, 0.35Å and 0.7Å), in the G-band, in the Ca II H line and in the blue and red continua. TRACE obtained high cadence filter images at 1550Å, 1600Å and 1700Å. CDS using the 4″ × 240″ slit obtained sit-and-stare observations in several spectral lines spanning the upper solar atmosphere. Using the standard CDS software the raw measurements were corrected for flat field, cosmic rays and other instrumental effects. A single Gaussian with a linear background and Poisson statistics were used for fitting each spectral line profile and obtain the peak intensity, the Doppler shift and the Doppler width. MDI obtained high cadence images at its high resolution mode.

Extensive work went into collecting, scaling and co-aligning the various data sets to a common coordinate system (see Figure 1 showing the coalignment of TRACE, MDI and DOT images).

3. Results

3.1. Observational Overview

In the Hα-0.7Å image (Hα blue wing, Figure 2 *left*) the dark streaks are part of the elongated Hα mottles seen better at line centre. Some mottle endings appear extra dark in the blue wing image through Doppler blueshift. Near the mottle endings one can see several bright points. They constitute the magnetic network which partially outlines the boundaries of the supergran-
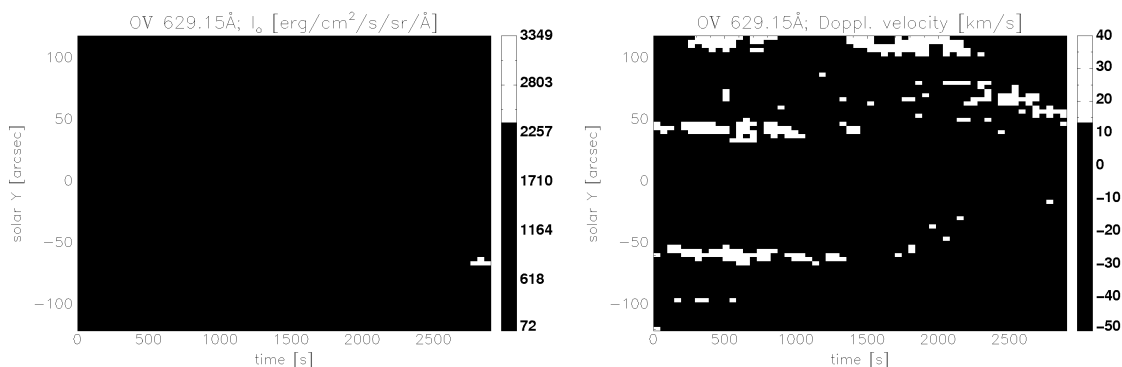
Figure 3: Intensity (*left*) and Doppler velocity (*right*) space-time maps in the O v line from the CDS sit-and-stare observations. The values along the Y-axis give the position along the CDS slit.

ular cells. Intercomparison between the DOT images (Figure 2) and the co-temporal TRACE C IV image and MDI magnetogram (Figure 1) indicates that isolated bright points show up in the regions of relatively stronger magnetic field. Part of the slit (between positions -47″ to 19″ along the slit) of the CDS sit-and-stare observations crosses the DOT's FOV (and, moreover, from -8″ to 19″ crosses the rosette region which is apparent in the upper part of the DOT's FOV and consists of several mottles (see Figure 2).

3.2. WAVELET ANALYSIS

For the study of the temporal variations we are using a wavelet analysis (Torrence and Compo, 1998) which permits not only the determination of any periodic signal but also how this period varies with time. We refer the reader to Tziotziou *et al.* (2004) for a detailed description of the wavelet analysis method, as well as for the methods used for determining the significance of the derived periods.

We choose two regions: one containing several bright points that define the NB and the other at the location where several dark mottles are found corresponding to positions 37″ and 34″ along the slit of the CDS sit-and-stare observations respectively (see Figure 3). Periods lower than 100 s and higher than 500 s have been filtered out. In Figure 4 we show the results of the wavelet analysis for the Hα line centre intensity variations at a fixed location found at the mottles' region and at the network boundaries. The
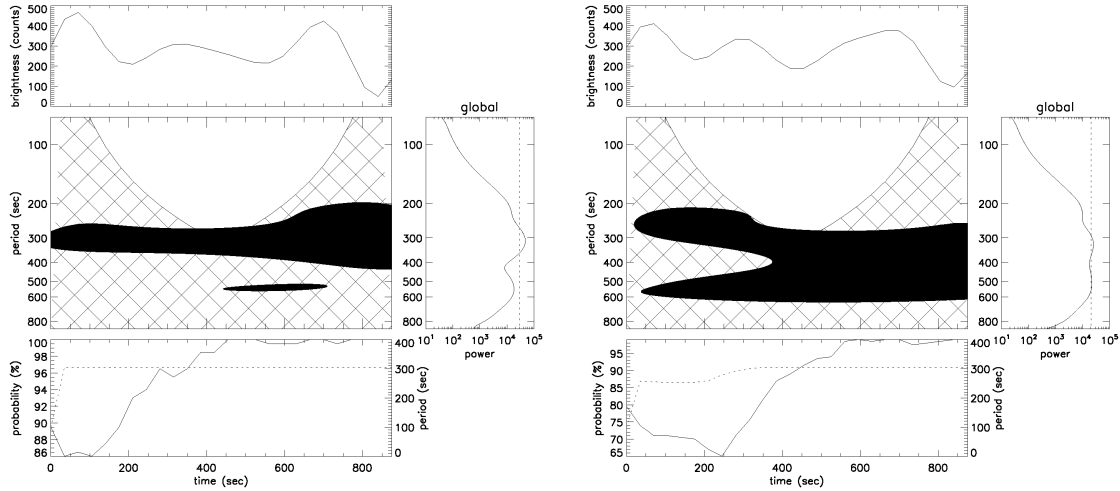
Figure 4: Wavelet analysis at a fixed location in the mottles' region (*left*) and the NB region (*right*) for Hα line-centre intensity variations.
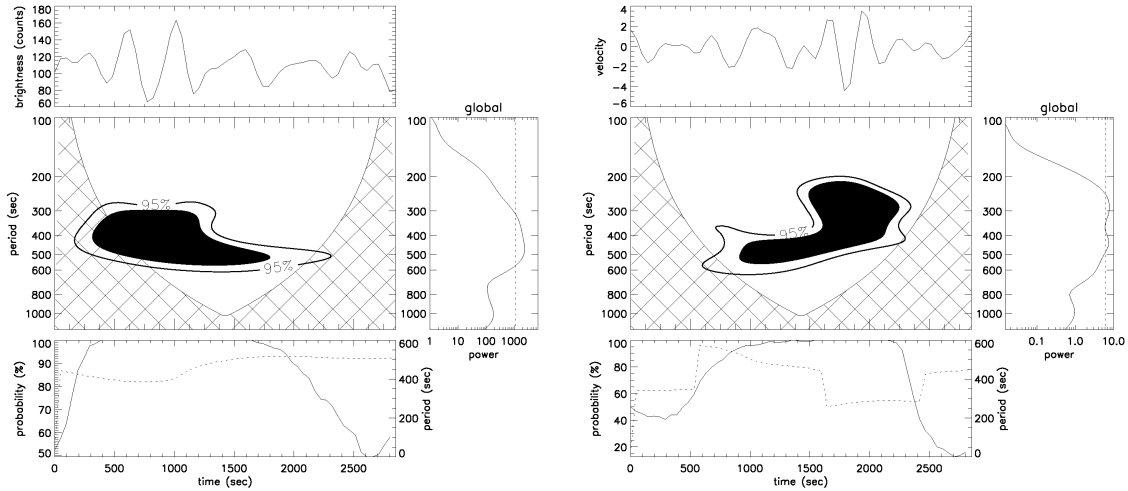

Figure 5: Wavelet analysis at a fixed location in the mottles' region of the O v intensity variations (*left*) and velocity variations (*right*).
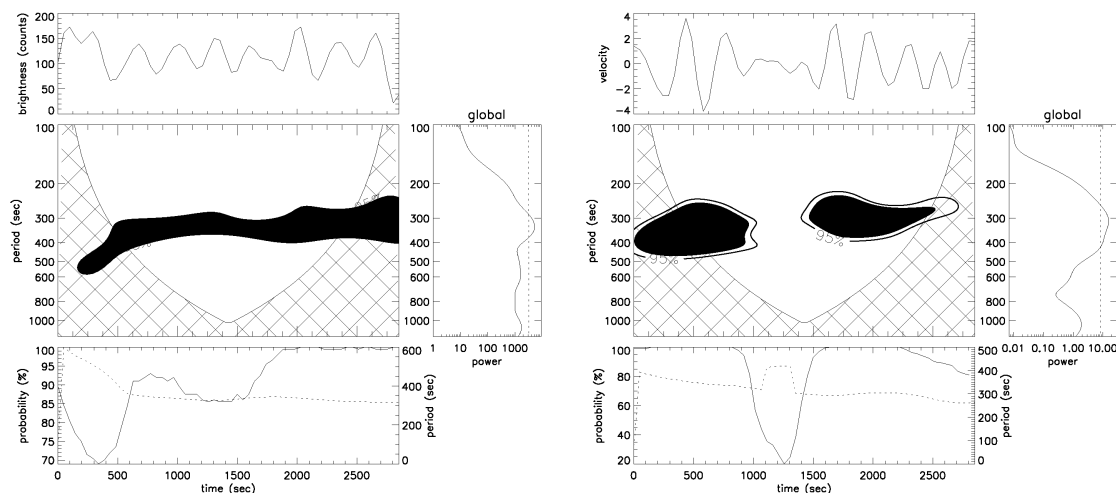
Figure 6: Wavelet analysis at a fixed location in the NB of the O v intensity variations (*left*) and velocity variations (*right*).

middle left panels of the figures show the calculated power spectra as a function of time and period for the variations shown in the top panels. The contours represent the significance level of 95%, which is obtained assuming a Poisson noise spectrum, while the cross-hatched regions below the cone-of-influence line indicate the regions which are subject to edge effects due to zero padding. The middle right panels show the global power spectrum, that is the average of the wavelet power spectrum over time. The dotted line - when present on the global power spectrum – indicates the equivalent global significance level of 95%. Finally the lowest panels show the variations of the probability (solid line, left abscissa) obtained with the randomization method (see Tziotziou *et al.*, 2004) and the equivalent period of the maximum power peak (dotted line, right abscissa) for which this probability was calculated.

The power spectra of the intensity Hα fluctuations for both regions show a peak at ∼5 min. No enhanced power for 3-min oscillations is detectable. This is consistent with previous results giving 5 min oscillations at the NB and also 5 min oscillations at the mottles (see Tziotziou *et al.*, 2004). The results of the wavelet analysis for the O v intensity and velocity variations at the mottles' location are shown in Figure 5 (left and right respectively), while the corresponding variations at a NB location are shown in Figure 6. What is clear from these figures is that there is little difference in the periods
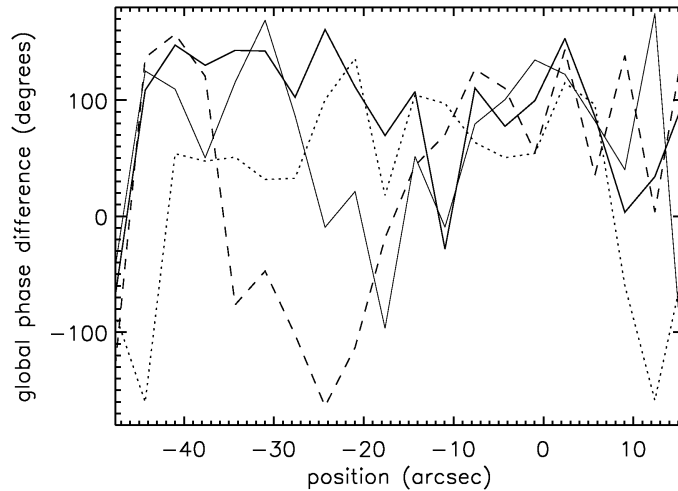
Figure 7: Global phase difference (in degrees) obtained for the period between 200 s and 500 s for which the global power is maximum as a function of position along the CDS slit between the Hα line centre intensity and the He I (thick solid line), O III (thin solid line), O V (dotted line) and Ne V (dashed line) intensities.

of oscillations observed in these two regions. The power of the oscillations is concentrated in the 250 - 450 s range.

In order to look for propagation characteristics of waves at different heights in the solar atmosphere, we computed the phase difference, as well as the phase coherence between the Hα line centre intensity time series and several time series of line intensities observed with CDS. To find the phase difference a cross-wavelet transform is used in the filtered data (see Tziotziou *et al.*, 2005). Then the global phase difference has been obtained for the period between 200 s and 500 s for which the global power is maximum. In Figure 7 we present the global phase difference as a function of position along the CDS slit between the Hα line centre intensity and the He I (thick solid line), O III (thin solid line), O V (dotted line) and Ne V (dashed line) intensities. The calculated global phase coherence gives extremely high values (≥ 0.7), and makes the obtained phase difference values highly significant, strongly suggesting that the observed power is due to oscillations. The positive value of the global phase difference in the mottles' region ($\sim$ -8″ to 0″), as well as in the NB region ($\sim$ 1″ to 8″) between the examined lines indicates the presence of upward propagating waves. It is

also remarkable that its values for the different line pairs and for the rosette region have an almost similar behaviour indicating a clear interconnection between processes in the lower and higher solar atmosphere.

4.   Discussion and Conclusions

The present observations show that there exist intensity as well as velocity oscillations at the network boundaries for a wide range of spectral lines. A wavelet analysis reveals the periods as well as the duration of these oscillations. Our results show that the variations are intermittent, occurring only during part of the full time sequence, while the power is concentrated around 5 min. Judge *et al.* (2001) have conjectured that some of the intermittency can be caused by the interaction of upward propagating waves with the magnetic field. The phase difference analysis between the Hα line, which is a chromospheric line, and the He I line (which is also chromospheric), as well as three transition region lines (O III, O V and Ne V) indicates the presence of upward propagating waves in both mottles and NB locations. Of course, further investigations are needed in order to obtain some concrete conclusions regarding the nature of these waves.

Acknowledgements

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