NETWORK AND INTERNETWORK PROPERTIES AT PHOTOSPHERIC AND CHROMOSPHERIC LEVELS

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ABSTRACT. We use coordinated observations between ground-based observatories (NSO/Sacramento Peak) and the Michelson Doppler Interferometer onboard SOHO to analyze the characteristics of Network Bright Points (NBPs) at different atmospheric heights and compare them with those of the surrounding internetwork areas.

We improve on the existing statistics using a sample of 11 NBPs, and the same number of "test" internetwork areas, defined in a comparable way. The method we adopted to study the temporal evolution of NBPs insures that each bright structure is properly followed in time and position at each height.

1. Observations and Data Reduction

In this paper we use high spatial resolution observations obtained in August 1996 during a coordinated observing program between the "R.B. Dunn" Solar Telescope at NSO/Sacramento Peak and the Solar and Heliospheric Observatory (SOHO). The observing setup is described in detail in Cauzzi et al. (1997, 1999).

Monochromatic intensity images were obtained with the tunable Universal Birefringent Filter with a temporal resolution of 12 s (NaD_2, Hα, Hα-1.5 Å, white-light), and with the Zeiss Filter with a temporal resolution of 3 s (Hα+1.5 Å). Onboard SOHO, the Michelson Doppler Imager (MDI, Scherrer *et al.*, 1995) acquired data with an image scale of 0.605″/pixel. Maps of continuum intensity, line-of-sight velocity and longitudinal magnetic flux were obtained in the NiI 6768 Å line at a rate of one per minute for several hours. The velocity images were available with a binned 2×2 format. All these different spectral signatures allow a good coverage of the whole photospheric - chromospheric region.

We analyze here ground-based data obtained on August 15th, 1996, from 15:15 to 16:05 UT with constant good seeing conditions (better than 1″). The MDI data were considered for the longer interval 14-17 UT. At any given time the alignment among the images acquired with different instruments is better than about 1″. We refer to Cauzzi *et al.* (2000) for details on FOV overlay and data reduction procedures.

To study the temporal development of the NBPs, we computed the light curves for the bright points at each wavelength or signature. The curves for each NBP were obtained by selecting an area that contained the bright point throughout the whole observing period (even if it moved spatially), and then averaging, for each time, over all the pixels whose intensity exceeded a threshold value. This procedure guarantees that the structure is properly followed in time, avoiding the loss of relevant pixels, or the inclusion of spurious ones. We also computed the light curves of 11 areas randomly selected in the quiet regions of the FOV, and of size comparable to that of the NBPs (about $3'' \times 3''$). No threshold was applied for their computation. These quiet areas should represent the so-called internetwork regions, which appear field-free at MDI sensitivity.

A search for possible periodicities in the fluctuations of the NBPs light curves was performed using temporal power spectra. First, the light curves were detrended using a smoothing window of 600 s. Then, a power spectrum was computed for each light curve of the 11 NBPs and of the 11 internetwork areas. To analyze the differences between these two atmospheric components, we averaged separately the power spectra over all of the NBPs and over all of the quiet regions. In Fig. 1 we show some of these averaged curves.

The phase difference (Φ) and the coherence (C) spectra have also been computed for several signatures pairs to search for propagating chracteristics of (possible) waves. For each pair, the NBPs always show a coherence lower than the internetwork, pointing out the effect ofthe magnetic field on the wave propagation regime.

2. Discussion

We discuss the results of our analysis separately for photospheric and chromospheric signatures.

At photospheric levels: The power spectra computed for photospheric signatures do not show any difference between network and internetwork, within the limits of sensitivity and accuracy of the instruments used (see Fig. 1 a-b-d). The white-light and Hαred wing power spectra peak at low frequency around 1.5 mHz, while at higher frequencies they display a decay generally explained with the stochastic variations of the granulation. The phase difference between Hα red wing and white light images ($\Delta h \leq 100$ km) in the internetwork, is $5\,\deg - -10\,\deg$ in the frequency window 1.5 – 2.5 mHz, with a coherence higher than 0.95 (see Fig. 2). A phase lag of this amplitude and sign has been found by Rutten (2000) in the internetwork between the intensity of two UV continua. The persistence of this phase value ($C > 0.95$) suggests the presence of oscillations, that in this range of temporal frequencies and at a spatial frequency of 3 Mm^{-1}, might be interpreted as downward directed gravity waves.

The power spectrum of the magnetic flux variations is considered only for NBPs because in the internetwork areas the noise is too high to reliably measure the magnetic field. The peak around 1.5 mHz indicates the long term variations of the magnetic field, while the small but significant peak around 3 mHz (corresponding to 5 minutes oscillations) might indicate the presence of MHD waves, related to the acoustic waves well visible in the velocity power spectrum (see Fig. 1-d). The analysis of the phase relation between the magnetic flux and velocity could clarify the nature of the waves. In our case, the phase difference and coherence spectra between magnetic flux and velocity (B$-$V) for the NBPs indicate a very low correlation between the two signals so we cannot conclude anything on the presence of MHD waves within the network points.

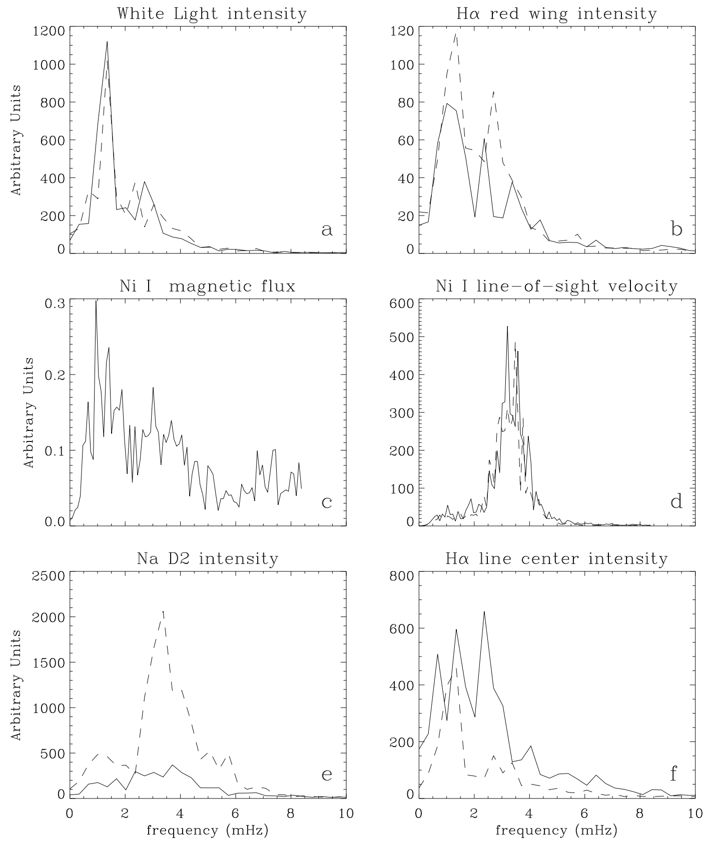

Fig. 1. Average power spectra in arbitrary units. Solid line indicates NBPs and dashed line internetwork regions.

At chromospheric levels: Network and internetwork areas have a rather different behaviour in the power spectra. In the low chromospheric levels, where NaD_2 originates, the NBPs power spectrum is compressed at all frequencies if compared to the internetwork, while in the high chromosphere, where Hα originates, the power of NBPs is higher than the one of internetwork. This opposite effect may be an indication that the magnetic field disturbs and reduces the amplitude of oscillations already present in the low chromosphere while it assumes a leading rôle in the high chromosphere. In particular, the oscillations present in network points seem to change regime with respect to both the photosphere and the high chromosphere in the layers contributing to the NaD_2 emission.

The power spectrum of Hα intensity in NBPs has the more relevant peak at 2.2 mHz (7 minutes oscillations). The other peaks at lower frequencies cannot be considered

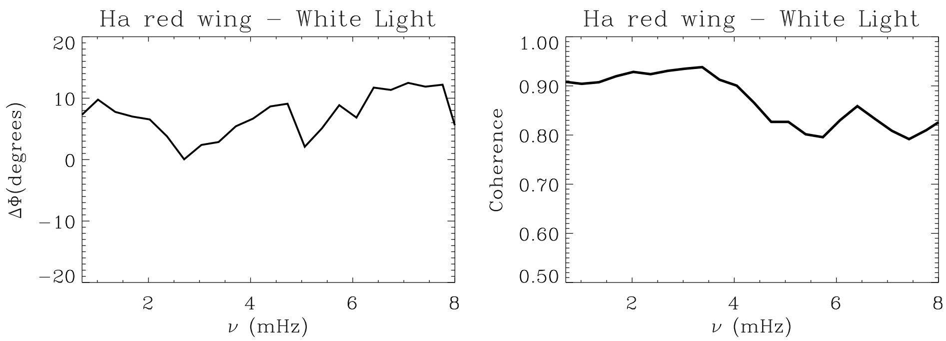

Fig. 2. Phase difference (left) and coherence (right) spectra for the Hα red wing – white light pair.

because the one at 0.6 mHz is related to the duration of the observations and the second at 1.3 mHz is strongly affected by the smoothing window. The 7 minutes oscillations are not correlated with the photospheric fluctuations, as indicated by the very low coherence measured between the Hα core and the blue and red wings. We can then confirm, using a larger sample of NBPs, the presence of the peak found by Lites et al. (1993) around 2 mHz in the power spectrum of K3 velocity fluctuations for a single network point. Kalkofen (1997) and Hasan & Kalkofen (1999) proposed an explanation for this peak in terms of transverse magneto-acoustic waves in magnetic flux tubes, excited by granular buffeting in the solar photosphere. In their model the low coherence between photospheric and chromospheric signatures can be explained by a partial conversion of the transverse waves to longitudinal modes in the higher chromosphere.

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