THE CHROMOSPHERIC NETWORK DYNAMICS AS DERIVED FROM THE ANALYSIS OF CA II K AND HE I 1083 NM LINES

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Abstract. We present results of line profile analysis of observations simultaneously performed around the Ca II K and He I (1083 nm) lines, using the Horizontal Spectrograph of the Vacuum Tower Telescope of NSO / SP. From the spectral analysis of a 83 min long sequence of CCD spectra, we derive some dynamical properties of the main components of the quiet chromosphere: i) the magnetic network, ii) the cell interior. We present a whole set of amplitude spectra near 5 and 3 min periods for the two lines; K, and He I velocity spectra extending up to 100 mHz are also considered, for the first time.

1. Introduction

Heating by MHD waves of the chromosphere and the corona is a viable mechanism which nevertheless needs detailed observations for confirmation (Zirker, 1993).

Observations of 5 min and shorter period waves in the corona have already been reported and discussed (Tsubaki, 1977; Koutchmy, Locans and Zhugzda, 1983). Moreover, the topic of chromospheric oscillations is continuously discussed, several groups being involved in both observations and analysis with improved methods; see e.g. Lites et al. (1993), Fleck et al. (1993).

Among the major issues, we note the relevance to the heating problem of the resonance period of the chromosphere near 3 min and the role of the magnetic field in magnetic elements, possibly generated by self-excited dynamos (see Lorrain and Koutchmy 1992) and the occurrence and dissipation of high frequency (HF) waves, especially in the corona.

The observations we consider here were performed in order to analyse the low frequency (LF) period waves as well as the HF waves, from the chromosphere to the corona (Bocchialini et al. 1993a).

Two typical regions of the chromosphere were studied; we called them Active Network (AN) and Quiet Region (QR); the last one was selected as a region free of prominent and/or vertical magnetic field.

We use the sketch presented in Fig. 1 to illustrate the features we want
to discuss, considering the atmospheric properties from the photosphere up to a few thousand km. The cut across the chromosphere presented on Fig. 1 is similar to the ones proposed by Axford (1993) and Koutchmy and Loucif (1992). The heart of the AN is the bottom of the magnetic region, called by Axford the 'furnace', which is believed to be the ultimate source of the fast wind.

2. Observations

The observations have been achieved on March 22, 1993 at the VTT of NSO/SP; the new multi-channel Horizontal Spectrograph developed for the Advanced Stokes Polarimeter of HAO/NSO has been used. The data have been recorded on CCDs, simultaneously in the Ca II K and the He I lines. The final resolutions after all required corrections are: 1.2 arcsec/px and 5.8 pm/px for Ca II K and 16.2 pm/px for He I. The sequence of observations is 5000 sec long and the sampling interval is 5 sec.

We selected two regions: an active network element (AN), which is averaged over 6 arcsec along the 2.3 arcsec slitwidth, and a quiet region (QR), averaged over 3.6 arcsec; we also considered the average region (AV) over the whole 38 sec long slit. More details about the region seen with filtergrams and Hα slit-jaws images, and the data processing are given in Bocchialini et al. (1993a, b).
3. Averaged line profiles in Ca II K and 1083 He I, and interpretation

AN and AV He I line profiles (average over the whole temporal sequence) are presented in Fig. 2a. We found that the average central line depression (1083.035 nm) is 8% of the continuum in AN, 2% in QR and 5% in AV, in good agreement with Giovanelli & Hall (1977). The FWHM is equal to 15±2 km s⁻¹ in AN and AV. The most important result is the extended red wing, in both AN and AV, which suggests a downflow at least in AN; this red component could be due to the same downflow as the one systematically observed in transition region lines.

Ca II K line profiles in AN, QR and AV (obtained over the 5000 sec sequence) are shown in Fig. 2b. Intensities are scaled to White and Suemoto's profiles (1968). The measured FWHM of K₃ is equal to 9±1 km s⁻¹ for the QR and to 8±2 km s⁻¹ for the AV. The AN profile is too asymmetric for this quantity to be measured properly. Assuming that the velocity of AV at line center (K₃) is zero, we measured a velocity of 0.95±0.50 km s⁻¹ (redshift) for AN and of -1.35±0.5 km s⁻¹ (blueshift) for QR. Note that the red-shift shown in K₃ over AN is consistent with what we saw in the 1083 He I line. This suggests that the downflow well observed in transition region lines is also seen in the network, down to layers re-absorbing the Ca II K radiation (K₃).

4. Time series analysis: results and discussions

We performed a Fourier analysis of intensities at selected wavelengths measured on each spectrum along the whole time series.
a) In Ca II K, we first present the temporal intensity variations of $K_{2V}$ and $K_3$, for AN and QR, see Fig. 3. The amplitudes of $K_2$ variations are almost the same for AN and QR; in $K_3$, amplitudes are several times higher in AN than in QR. For AN, the amplitudes in $K_{2V}$ and $K_3$ are quite comparable. In $K_3$, we see about 3 wave trains during the 5000 s sequence.

The temporal variations of $K_3$ Doppler velocity are also presented for both regions. To compute Doppler velocity, we used the fast method based on the subtraction of line wing intensity modulations and subsequent calibration using the average profiles of Fig. 2.

The amplitudes for AN and QR are quite comparable but it clearly appears that the periods of oscillations are different (Fig. 4a, b). This is confirmed by the amplitude spectra at LF (between 0 and 20 mHz), see Fig. 4c: around 3 min there is considerably more power in QR than in AN and the peak is centered around 7 mHz; at 5 min the spectra show similar amplitudes in QR and in AN; let us stress that the large ratio we measured in AN, between 5 min and 3 min oscillations, is in favor of the 5 min periods.

At HF (10 to 100 mHz), the amplitude spectrum in QR is higher than in AN (Fig. 4d); the significance of this result is considered below.

b) In He I, we computed the Doppler velocity near the line center, using the same straightforward method of line wing intensity differences (without assumption on the shape of the line profile). The visual comparison with Ca II K for AN shows an obvious correlation between the velocities observed in $K_3$ and in 1083 He I, the correlation being not obvious for QR. The amplitudes of the oscillations are typically three times higher in QR than in AN (Fig. 5a, b, c) near 5 min periods, and up to 8 times near 3 min periods!

We also present the amplitude spectra of the continuum, near 1083 nm, in AN and QR, to show the excellence of the signal/noise ratio (Fig. 5d) in both AN and QR: 5 min oscillations appear in intensity variations as reported by Koutchmy and Lebecq, 1986 and Title et al., 1990, as well as
Fig. 4. Temporal variations of Ca II K$_3$ velocity (a) in AN, (b) in QR; amplitude spectra of K$_3$ velocity (c) at LF, (d) at HF; full line: AN, dotted line: QR.

Fig. 5. Temporal variations of He I velocity (a) in AN, (b) in QR; (c) amplitude spectra of velocity at low frequency, (d) amplitude spectra of He I continuum; full line: AN, dotted line: QR.

very low frequency fluctuations.

In order to evaluate the results obtained at HF, we also performed an analysis of the spurious velocity signal due to random fluctuations present in our spectra (noise of different origins). We applied the same formula used
Fig. 6. He I amplitude spectra at high frequency (a) in the continuum, (b) in line intensity, (c) in Doppler shift or velocity; (d) amplitude spectra of the noise in simulated Doppler shifts of the pseudo continuum at HF; full line: AN, dotted line: QR. Note that velocity spectra (c) have not been corrected for the noise (d).

to compute the Doppler shifts in the 1083 He I line to the nearby pseudo continuum and obtained the results shown in Fig. 6d for HF.

At high frequency -10 to 100 mHz- the power measured in the continuum intensity, as well as in line intensity, and in velocity, is once again higher in QR, (Fig. 6a, b, c). In the He I line, both QR and AN exhibit HF power which is significantly above the noise level shown in Fig. 6d.

As for seeing effects, they are minimized by an excellent guiding, the compensation for the solar rotation, and essentially the spatial averaging (see §2) performed to improve the signal to noise ratio. We feel confident that seeing effects are negligible, a statement which certainly needs a thorough verification.

5. Conclusions

a) 3 min oscillations are prominent in QR: 3 min waves could be analysed, especially at the highest chromospheric level of He I 1083; in AN, 5 min oscillations are prominent. At HF, some power is observed above the identified noise level in both AN and QR (more in QR).

b) The definite occurrence of 5 min oscillations at the He I level in AN, see Fig. 4c and 5c, as well as the absence of the chromospheric resonance near 3 min (especially if we assume that the small power observed there could
be due to the influence of scattered light) point out to a mechanism of wave propagation in the magnetic region possibly connected with the heating. Further analysis is needed to conclude on that. We are now analysing our time series to look at phase and coherence spectra.

Besides, we also want to add a few recommendations concerning observations with SOHO: SUMER seems to be well-suited to the study of chromospheric regions up to the transition region. The best spatial and temporal resolution should be aimed at, even if during the data processing, addition of pixels in selected regions is performed to improve the signal to noise ratio, as done in the present work. The spectral window should have, as many lines formed at different temperatures as possible. In the 60 - 160 nm range, we suggest the 123.8 - 127.8 nm window where CI, Si I, Si II, C II, C III, N V lines cover temperatures from below $10^4$ K to $1.5 \times 10^5$ K. The suggested observing mode could use the 1”x240” slit, a spatial scan of 4 steps of 0.76” with a dwell time of two seconds, leading to a temporal resolution of 8 s. If possible, all lines pixels should be transmitted (or stored on board), which is the only way of measuring strong asymmetries in line wings. Temporal sequences should be significantly larger than one hour, in order that ”events” (bright points, explosive events) be detected and statistically analysed.

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