Chromospheric Oscillations Observed by SUMER/SOHO

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Abstract.  
We discuss first observations of the temporal behaviour of the hydrogen Lyman lines made by the SUMER/SOHO spectrometer. Using the Ly 5 line, we show here the global oscillatory pattern of the whole line profile for three representative quiet-Sun structures: cell interior, network boundary, and bright network. Mean power spectra for these structures show several maxima, some of which are quite well correlated with the maxima derived from Ca II K$_{2V}$ observations. In the cell interior, the power peak is centred between 4.5–5 mHz. No clear evidence of a 3 minute chromospheric mode was found. In the network, we observe a broad range of frequencies, with a maximum between 2–3 mHz. Lyman lines exhibit certain Doppler shifts and asymmetries, but the oscillatory behaviour is mainly due to the intensity variations which are small compared to the line intensity itself (they reach 10–20 % of the mean line intensity).

1. Introduction

SUMER/SOHO observations in various chromospheric and transition-region emission lines were recently used to study the oscillations in quiet-Sun areas: in cell interiors by Carlsson et al. (1997), in the network by Judge et al. (1997). Gouttebroze et al. (1998) present the mean power spectra averaged over the spectrograph slit which crossed both kinds of structures. The emission lines used for these studies belong to several species in different ionization stages, with the exception of hydrogen. In the spectral range of SUMER, however, one can easily observe the whole hydrogen Lyman series plus the Lyman continuum, and first results of Curdt and Heinzel (1998) clearly indicate intensity oscillations in higher Lyman lines and the continuum. In this paper, we demonstrate several other features of the oscillatory behaviour of the Lyman lines, namely, the variations of the whole line profile and the characteristics of the power spectra for both cell interiors and the network. We use the same time series of 5 June 1997 as studied in Curdt and Heinzel (1998), and the reader is referred to that paper for a description of the observations and the data reduction.
2. Line Profile Variations

In order to see the relationship between brightness variations, Doppler shifts and asymmetries in a Lyman line, we show in Fig. 1 the temporal evolution of the Ly 5 line profile, in three typical quiet-Sun morphological structures (note the different scales of the relative intensity). In the cell interior, we see almost no central reversal for this line (the same applies for higher members of the series) and the intensity oscillations are clearly visible along the whole line profile. However, at certain instances, some small asymmetries are present, depending on the spatial position along the slit. Approaching the network boundary, the line exhibits a rather strong central reversal and asymmetry. This asymmetry changes from red (shown here) to blue when the slit crosses the network. This asymmetry does not seem to affect significantly the periodical variations of the line intensity. The last example shows a strong, almost unreversed, emission in a bright part of the network, with a more dynamical behaviour. We can only speculate that the reversed lines correspond to absorbing features in the network, like dark mottles, while the unreversed bright profile can be related either to bright mottles also seen in the Hα line (Heinzel and Schmieder 1994), or to network bright points. This behaviour seems to have one important consequence: the mean line profile (i.e., cell + network) will be more reversed when we approach the limb; due to projection effects we will see more absorbing mottles. This effect is clearly visible in any spectrum taken near the limb (e.g., Curdt 1997). Note that the data used in this paper correspond to \( \mu = 0.664 \) and thus even the cell profiles can be somewhat contaminated by a projected dark-mottle emission as discussed below.

Another useful visualization of the line-profile oscillations is shown in Fig. 2, where the same data as in Fig. 1a are used (i.e., pixels 25 – 27). Again, basic variations are the brightness oscillations. Variations due to Doppler shifts and certain asymmetries seem to be of a secondary importance. Following the oscillatory pattern from the line centre to the wings, we do not see any significant phase shift. This suggests that the whole line is formed in a region oscillating in phase (we assume that Lyman lines are optically thick).

3. Fourier Power Spectra

In Fig. 3 we plot the results of our preliminary power-spectra analysis, here for the central-pixel intensity of Ly 5. We use the standard Fast Fourier Transform (FFT) technique. The mean power spectrum was obtained by adding the power spectra from individual spatial pixels, but excluding those which are difficult to process by FFT. Therefore, our statistics is very limited and the power spectra are rather noisy. Moreover, we have used a relatively short time series (33 minutes). The power spectra evaluated separately for the cell interior and the network nevertheless exhibit some important features, which agree with other types of observations. In the cell, we can distinguish a peak between 4.5–5 mHz, which corresponds to oscillations with periods above 3 minutes (we do not see any clear evidence of a chromospheric 3 minute mode). While this peak is present in all spatial positions within the cell, another peak around 2 mHz is not – it seems to be a kind of a parasitic signal from dark mottles which
Figure 1. Ly 5 line profile variations.
can be projected over the cell at some spatial positions (note that we are not at the disk centre). The argument for this is that the same peak appears in the power spectrum for the network shown in Fig. 3b. In the network, we see only longer-period oscillations as expected. These results confirm our previous conclusions (Curdt and Heinzel 1998). Several maxima at shorter periods are probably due to noise, although higher-frequency modes, namely in the cells, can also be expected.

By averaging the mean power spectra from both our figures - see dotted line in Fig. 3 - we get a broad peak between 1–6 mHz (using a statistical weight of 2 for cells and of 1 for the network). This qualitatively corresponds to a hump detected for the mean quiet Sun by Gouttebroze et al. (1998). However, their maximum is shifted more towards the shorter periods which we explain by the fact that they have observed at the disk centre, while our mean data seem to be more affected by the network periodicities.

We also want to address the question whether the solar-rotation compensation used by SUMER can cause spurious peaks in the power spectra. The period of our compensation is about 7 minutes (depends on the position on the disk, shortest period is at the disk centre), which corresponds to a frequency of 2.4 mHz and thus might affect the peak of the network oscillations. However, we have made a special test to exclude this: we have summed all spatial pixels along our 115 arcsec long slit (cells + network, both having various periods and phase shifts) and then we performed FFT on such a time series. No maximum was detected at 2.4 mHz.

Finally, let us note that a standard FFT does not seem to be a good tool for studying this kind of oscillations. The reason is that we rather observe wave packets of a finite duration, with phase jumps etc.. A wavelet analysis is thus more appropriate for future detailed studies.

4. Conclusions

Using high-resolution Vacuum-Tower-Telescope (VTT, Tenerife) observations in CaII K$_{2V}$, von Uexküll and Kneer (1995) obtained the average power spectra in the cell interior and the cell boundary (network). Their maximum for the cell interior agrees quite well with our one shown in Fig. 3a. Therefore, we conclude that the oscillations seen in the CaII lines do propagate to higher atmospheric layers and are not fully dissipated in the shocks formed at the lower chromosphere (see the cell-interior modelling of Carlsson and Stein 1997). However, the amplitudes of Lyman-line intensity oscillations are rather small, at least in cell interiors, and the waves seem to be more or less sinusoidal, contrary to what we see in K-grains. As von Uexküll and Kneer (1995), we do not see here any clear evidence for the existence of a 3 minute chromospheric mode. On the other hand, our network periods are longer as compared to CaII K ones, but seem to be consistent with theoretical predictions (see Kalkofen 1999). A very good coincidence between CaII and Lyman lines periodicities in cell interiors is a statistical result. In order to prove a direct correlation for
Figure 2. Contour plot of Ly 5

Figure 3. FFT power spectra.

individual spatially-resolved structures, we plan to organize a joint SUMER-VTT observing campaign.

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