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Observational Searches for Chromospheric g-Mode Oscillations from CaII H-Line Observations

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Abstract. We have used a high spatial and temporal resolution of long time sequence of spectra in CaII H-line obtained at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory on a quiet region at the center of the solar disk over a large number of bright points and network elements to search for atmospheric (chromospheric) g-mode oscillations. An important parameter of the H-line profile, intensity at $H_{2V}(I_{H_{2V}})$, has been derived from a large number of line profiles. We derived the light curves of all the bright points and network elements. The light curves represent the main pulse with large intensity amplitude and followed by several follower pulses with lower intensity amplitudes. The light curves of these bright points would give an impression that one can as well draw curves towards and away from the highest peak (main pulse) showing an exponential growth and decay of the amplitudes. An exponential decaying function has been fitted for all the light curves of the bright points to determine the damping time of the modes that are more or less the same, and one value of the coefficient of exponent can represent reasonably well the decay for all the cases. The FFT analysis of temporal variation of both the bright points and the network elements indicates around 10-min periodicity. We speculate that this longer period of oscillation may be related to chromospheric g-mode oscillations.

Key words. Solar chromosphere: CaII H-line—oscillations chromospheric g-mode.

1. Introduction

It is known that there are two types of gravity waves in the Sun, namely, (i) the internal gravity waves, that are expected to be confined to solar interior, and (ii) the atmospheric gravity waves, which are related to the photosphere, chromosphere, and may be further beyond. Pallé (1991) had discussed in great detail the various methods to search for solar gravity modes. Many authors have claimed, in the past 22 years, to detect internal g-modes in the Sun, but so far, there is no observational evidence. The atmospheric g-modes of small scale may exist, but in the atmosphere the Brunt Vaisala frequency is ≈ 5 mHz and hence one would expect the observed frequencies to be a few mHz. And of course, there would be some very high order atmospheric g-modes with longer periods. There are some observational evidences to show that there is signature of atmospheric gravity waves at the chromospheric level using the time sequence of filtergrams obtained in CaII K and Mg b2 lines (Damé *et al.* 1984; Kneer & von Uexkull 1993).

In this paper, we make an attempt to search for atmospheric (chromospheric) g-modes using the intensity oscillations at the sites of the chromospheric bright points and network elements observed under a high spatial, spectral and temporal resolution in CaII H-line.

2. Data and analysis

The observations were obtained by Sivaraman with the Vacuum Tower Telescope (VTT) using the echelle spectrograph of the Sacramento Peak Observatory on September 13, 1971 under the Program B of the HIRKHAD mode (Beckers *et al.* 1972). We have totally 177 frames for the 35-min duration of observations with a repetition rate of 12 s. We have chosen 29 bright points and 3 network elements and designated them as $B_1, B_2, B_3, \ldots, B_{32}$ (refer Fig. 1 of Kariyappa *et al.* 1994, hereafter KSA). We have derived photometrically calibrated line profiles for all the bright points and network elements. We have measured an important parameter of the line profile, namely, the intensity of the emission peak on the violet side ($I_{H_{2V}}$) for each profile, and plotted $I_{H_{2V}}$ versus time. We have done the power spectrum analysis using FFT for the time series data of the bright point (B_1) and the network (B_4).

3. Results and discussion

In our earlier paper (KSA), we have discussed on the classification of bright points and shown that the bright points can be grouped into three classes (see KSA, Figs. 2 and 3: class I; Fig. 4: class II and Fig. 5: class III) depending on their intensity enhancements

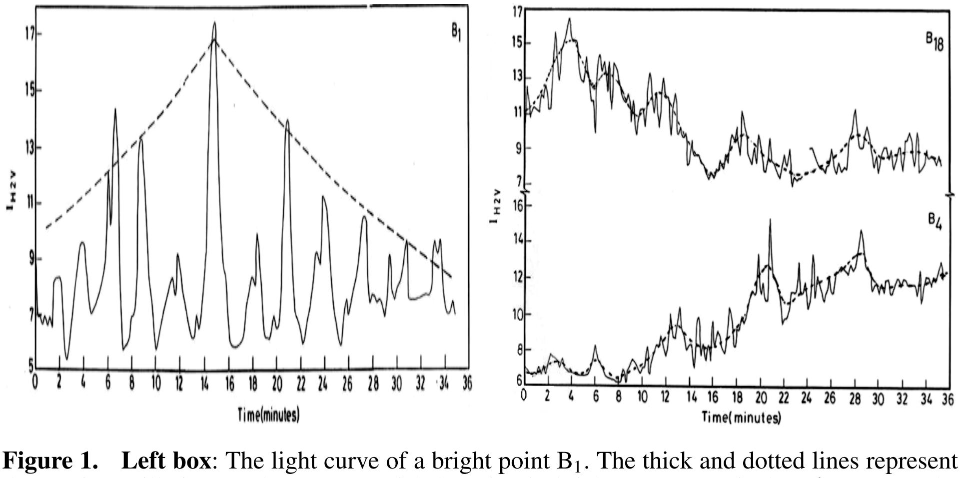

Figure 1. Left box: The light curve of a bright point B_1. The thick and dotted lines represent the 3-min oscillations and an exponential decaying in brightness respectively. **Right box**: The light curves of the two network elements B_4 and B_{18}. The dotted line represents the mean curve of the intensity fluctuations showing 5–7 min periodicity.

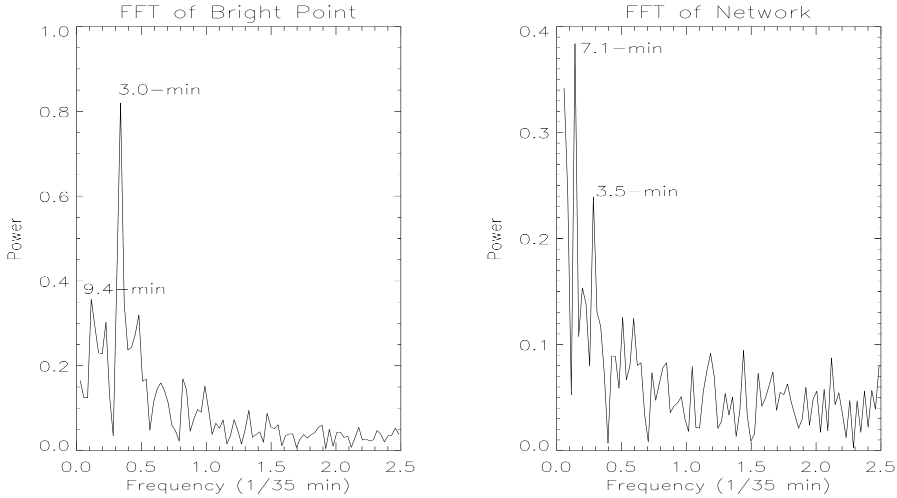

Figure 2. The power spectra of bright point (B_1, left box) and of network (B_4, right box).

during their dynamical evolution. A majority of the class I bright points show a large enhancement of $I_{H_{2V}}$ at their peak brightness phase, as high as 3 times above the mean ambient level (refer Figs. 2 and 3 of KSA), which corresponds to the undisturbed line profile (at time $t = 0$) of Fig. 11 of KSA. Class II bright points show moderate intensity enhancement in $I_{H_{2V}}$ (about twice the mean ambient level) at the peak brightness phase. However, class III bright points show only a marginal increase in $I_{H_{2V}}$ at the brightest phase. All these results suggest that the different classes of bright points may be associated with different strengths of the magnetic field. In the light curves of the bright points, the highest peak in the intensity variation of each bright point is designated as the "main pulse", and marked as P_1 (refer Figs. 2 to 5 of KSA). The main pulse is followed by several pulses with smaller amplitudes and this would give an impression that one can as well draw curves towards the highest peak showing an exponential growth of the amplitudes. We suggest the possibility that the main pulse is followed by several pulses whose amplitudes decay exponentially with time.

In order to know the damping time of the modes, we have fitted exponential function for all the classes of bright points using time series data. The slopes of decay of the curves are more or less the same, and mean value of coefficient of the exponent ($4.14 \times 10^{-4}\ \mathrm{s}^{-1}$) taken for all the 29 bright points can represent reasonably well the decay for all the cases. We have examined the light curves of the bright points obtained by Liu (1974, see Fig. 6) and find that there is a strong main pulse and it is followed by several pulses with exponentially decreasing in their intensity amplitudes. Similarly we have fitted the exponential functions for his light curves of bright points (see his Fig. 6) and found that the slopes of decay are the same for any bright points and the value of coefficient of exponent is found to be $3.5 \times 10^{-4}\ \mathrm{s}^{-1}$. It is clearly seen that there is a good agreement between the coefficient of exponent values derived from both Liu's and the present data. The value of coefficient of exponent represents the damping time of the modes and it is of the order of 40 minutes. For comparison, we have tabulated the exponential functions for the light curves of B_1 and B_5 bright points and for Liu's (1974) bright points in Table 1.

Table 1. Exponential decay in the amplitudes of the follower pulses from the main pulse for the bright points (B_1 and B_5) and Liu's data.

Bright point	Exponential function; $I(t)$
B_1	$16.69 \exp(-5.9 \times 10^{-4} t)$
B_5	$18.89 \exp(-4.9 \times 10^{-4} t)$
Liu bright point 1	$13.95 \exp(-3.4 \times 10^{-4} t)$
Liu bright point 2	$15.47 \exp(-3.6 \times 10^{-4} t)$

We have shown the light curve for the bright point B_1 (not shown for B_5) in the left side box of Fig. 1. It is clearly seen from Fig. 1 (left box) that the bright point shows a 3-min period of intensity oscillations. In the left side box of Fig. 1, the thick line represents the 3-min period of intensity oscillations, whereas the dotted line shows an exponential decaying in brightness. In addition to the light curves of the bright points, we have generated the light curves for the two network elements (B_4, B_{18}) from the same time sequence spectra, and these are shown in the right side box of Fig. 1. We know from the earlier studies (KSA, Kariyappa 1994; Kariyappa *et al.* 2005) that the network elements have different patterns of intensity oscillations showing 5–7 min periodicity (dotted curve in Fig. 1, right box). We have done the power spectrum analysis on the time series data of both bright point and network to look for longer periods of oscillations. In Fig. 2, we have presented the power spectra for B_1 in the left panel and for B_4 in the right panel. One can see from the power spectrum that there is an indication of a longer period of oscillation around 10-min.

We can summarize the preliminary results as follows:

- The chromospheric bright points and network elements exhibit different periodicities (3-min and 5–7 min respectively), but, both of them seem to be also associated with the 10-min longer period of oscillations.
- The light curves of the bright points show an exponential growth and decay of the amplitudes and the damping time of the modes is of the order of 40-min.
- We speculate that the 10-min longer period of oscillations may be related to g-mode oscillations of the chromosphere. These results confirm the earlier findings that there is a signature of gravity waves in the chromosphere (Damé *et al.* 1984; Kneer & von Uexkull 1993) that needs further investigation with a long stretch of observations.

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References

Beckers, J. M., Master, H. A., Mann, G. R., Brown, D. R. 1972, *Solar Phys.*, **25**, 81.
Damé, L., Gouttebroze, P., Malherbe, M. 1984, *Astron. Astrophys.* **130**, 331.

Kariyappa, R. 1994, *Solar Phys.*, **154**, 19.
Kariyappa, R., Sivaraman, K. R., Anadaram, M. N. 1994, *Solar Phys.*, **151**, 243 (KSA).
Kariyappa, R., Satya Narayanan, A., Damé, L. 2005, *Bull. Astron. Soc. India*, **33**, 19.
Kneer, F., von Uexkull, M. 1993, *Astron. Astrophys.*, **274**, 584.
Liu, S.-Y. 1974, *ApJ.*, **189**, 359.
Pallé, P. L. 1991, *Adv. Space Res.*, **11**, 29.