INTENSITY OSCILLATIONS IN CHROMOSPHERIC BRIGHT POINTS AND NETWORK ELEMENTS

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Abstract. From a 35-min time series of photographic spectra in the Ca II H-line obtained at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory under high spatial, spectral, and temporal resolution, we have derived a large number of H-line profiles at the sites of the bright points in the interior of the supergranulation cells, and at the network elements, on a quiet region at the centre of the solar disc. It is shown that the bright points are associated with 3-min periodicity in their intensity oscillations whereas the network elements exhibit ~7-min periodicity. It is surmised that the large difference in periods of the intensity oscillations, the strength of the magnetic fields, and the intensity enhancements at the sites of the bright points and the network elements themselves may probably be taken as evidence to argue that the mechanisms of heating in the two cases are dissimilar, irrespective of the sizes of these structures.

1. Introduction

Since its discovery by Leighton (1961), the 5-min oscillation has been the subject of a large number of observational and theoretical investigations. It has been known since the observations of Jensen and Orrall (1963) that the solar chromosphere oscillates with a period of 180–200 s. The Ca II H and K resonance lines have often been used to study the fine structure in the solar chromosphere, and the chromosphere appears highly structured on a two-dimensional image obtained in these lines. The quiet solar chromosphere shows three distinct structures: the network elements marking the boundaries of supergranulation cells; the bright points in the interior of the cells; and the truly quiet chromosphere, also in the cell interior. The network elements and the bright points are seen in emission in the H and K lines. The relative contributions from the network elements and the bright points to the K-emission flux are of the order of 25% and 15%, respectively (Kariyappa and Sivaraman, 1994) and they show a one-to-one correspondence with regions of enhanced photospheric magnetic fields (Skumanich, Smythe, and Frazier, 1975; Sivaraman and Livingston, 1982). Observations of time-sequence spectra of Ca II H and K lines by Liu (1974), Cram and Dame (1983), and Kariyappa, Sivaraman, and Anandaram (1994, henceforth KSA), have shown that waves with a 3-min period transport and dissipate a large amount of energy at the sites of the bright points. The recent review by Rutten and Uitenbroek (1991) gives a comprehensive account of the current status in our knowledge both in observational and theoretical fronts on the K_{2V} (and H_{2V}) bright points.

In our previous paper (KSA), we dealt with the analysis of the H-line profile only at the locations of the bright points within the cell interior. But in the present

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paper, we concentrate on the study of intensity oscillations at the sites of the network elements from an examination of their H-line profiles. We compare the results of the present analysis with the results of the bright points and make an attempt to bring out the differences between the two cases in the period of intensity oscillations, and hence in the heating mechanism.

2. Observations

The data for this study consist of a photographic time sequence of spectra in the H-line region obtained at the Vacuum Tower Telescope (VTT) and the echelle spectrograph of the Sacramento Peak Observatory, on September 13, 1971, and the scheme of observations used here is Program B of the HIRKHAD mode (Beckers *et al.*, 1972) which takes spectra simultaneously in seven lines at a repetition rate of 12 s. The solar rotation was compensated for during the observations. The exposure for each frame was ~3 s, with a dispersion of 12.1 mm Å^{-1} (15th order) in the H-line region. The seeing conditions were exceptionally good during the entire duration of 35 min. With 12 s for each frame we have, in all, 177 frames. The present study deals with the analysis of the H-line at the locations of the network elements compared with the analysis of the bright points.

3. Reduction of the Data

We have chosen 32 locations for a detailed study and designated them as B_1, B_2, $B_3, \ldots, B_{32}$. Of these, 29 locations are in bright points and 3 locations (B_4, B_{18}, B_{25}) are in the network elements. We obtained the digital values of the densities for these locations in all the frames by scanning parallel to the dispersion with the PDS microdensitometer with a projected size of $50\mu \times 200\mu$ for the scanning aperture which corresponds to 0.004132 Å×500 km. We converted the density values first to relative intensity via a photometric calibration and then in terms of the continuum intensity by setting the intensity at λ3966.25 Å on the violet wing of the H-line at 23% of the continuum (White and Suemoto, 1968). Elaborate details are given in our earlier paper (KSA). We have, in all, 5133 photometrically calibrated profiles for the 29 bright points and 531 for the 3 network elements. We derived for each profile the intensity of the emission peak in the violet (I_{H2V}) and made plots of I_{H2V} versus the time covering the duration of the sequence. Further data handling will also be described below, together with the results.

4. Results and Discussions

4.1. INTENSITY OSCILLATIONS IN THE BRIGHT POINTS

We have clearly shown in our previous paper (KSA) that the bright points can be grouped into three classes depending on their dynamical evolution, and these bright points have a period of 190 ∓ 20 s in their brightness oscillations. The bright

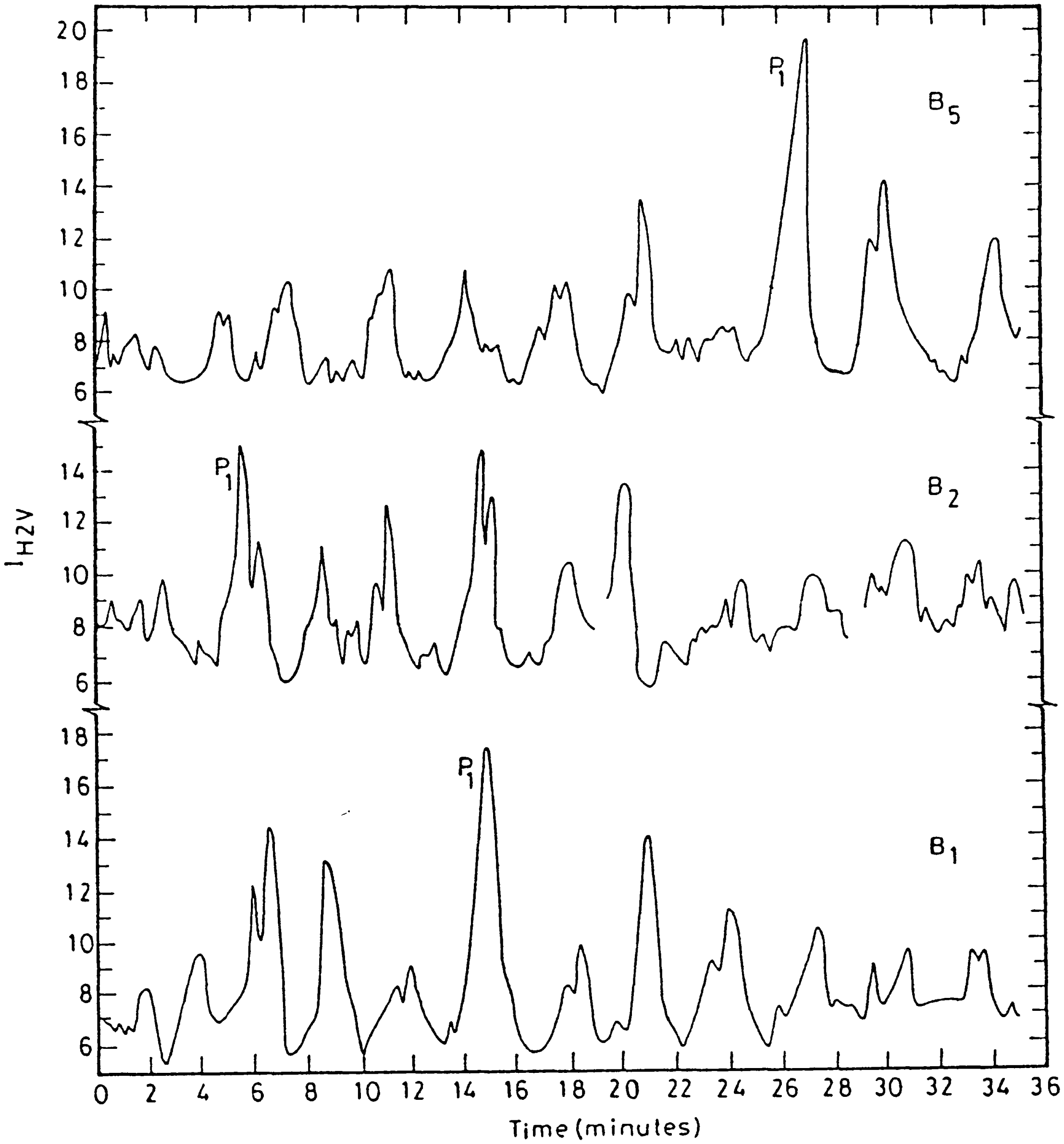

Fig. 1. The variations in intensity of the H_{2V} emission peak (I_{H2V}) of the three bright points (B_1, B_2, and B_5) during the 35-min observations. The main pulse designated as P_1 is 4 to 5 times the normal brightness value and is followed by several pulses with decreasing amplitudes.

points show a large intensity enhancement in H_{2V} at their peak brightness phase, as high as 4 times above the mean ambient level (Figure 1), which corresponds to the undisturbed line profile. We have shown the light curves of B_1, B_2, and B_5 in Figure 1 for the entire 35-min duration of the sequence.

The strong pulse of each bright point in its light curve is designated as 'main pulse' and is indicated as P_1 in Figure 1. Although the main pulse (P_1) is easily identifiable from a look at the I_{H2V} versus time curve it may be worth assigning an objective criterion for identifying the main pulse. On examination of the H-line profiles corresponding to the positions of P_1, it is seen that the ratio of the intensity of the H_{2V} and H_{2R} emission peaks is 2 or higher ($I_{H2V}/I_{H2R} \geq 2$). The main

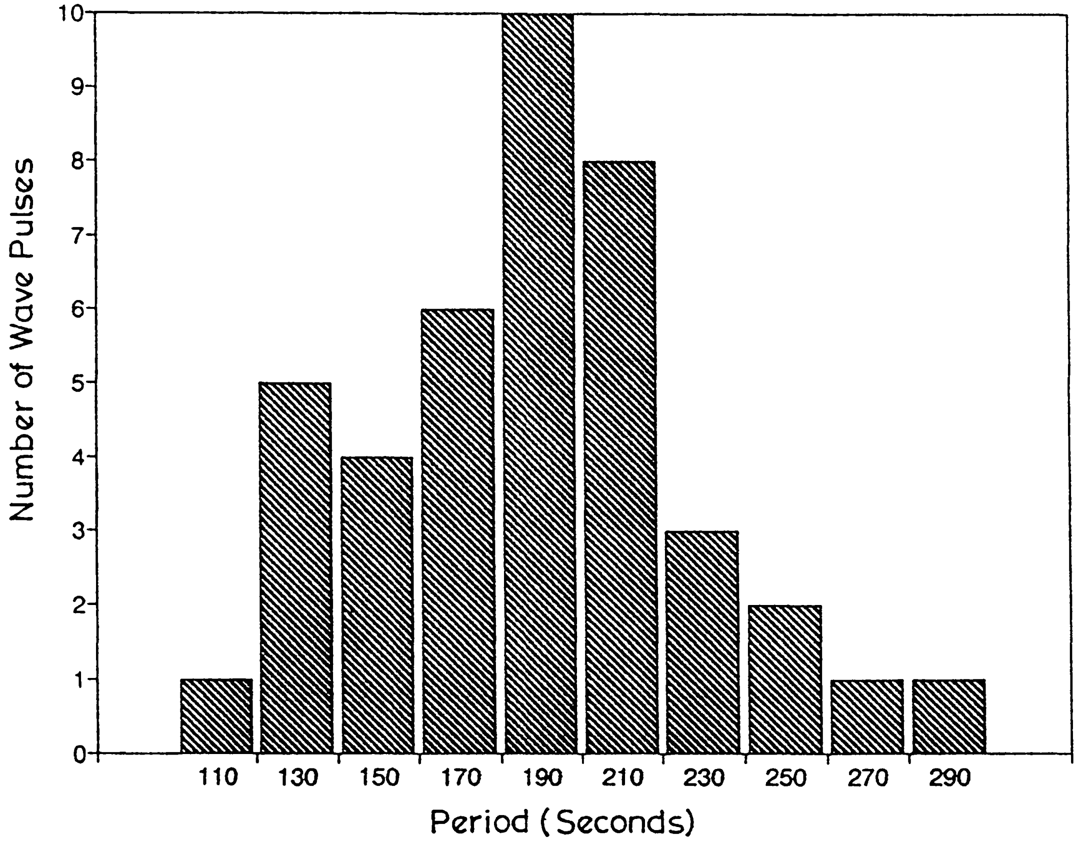

Fig. 2. Histogram plot of the periodicity of oscillations in I_{H2V} of the bright points. There is a sharp peak at 190 s.

pulse as well as the follower pulses, although periodic, do not have sinusoidal shapes, suggesting a nonlinear behaviour. We have evaluated the period of the pulses constituting a wave train by feeding the I_{H2V} digital values (values every 12 s, corresponding to the repetition rate of the frames) to a computer and have measured the time separation between consecutive peaks. The histogram of the periods so derived for the main pulses, as well as for the follower pulses for the 29 bright points, shows that the periods of these brightness oscillations lie in the range 150–210 s, with the peak in the bin 190 ∓ 20 s (Figure 2). We have done a power spectrum analysis for all the 29 bright points and we have shown the power spectrum for the bright point B_1 in Figure 3. Although there are secondary peaks in some cases, one noteworthy point is that the average period falls around 190 ∓ 20 s. The period is almost the same for the pulses in all the bright points (KSA) and thus seems to be independent of the differences in the brightness enhancement, and the main pulse and the follower pulses have also the same period, and a detailed study of this is in progress. Thus, the bright ponts are the sites where intense brightness enhancement is seen, and the brightness oscillates with a period of 3 min (Liu, 1974; Cram and Dame, 1983; Kalkofen, 1989, 1991; and KSA).

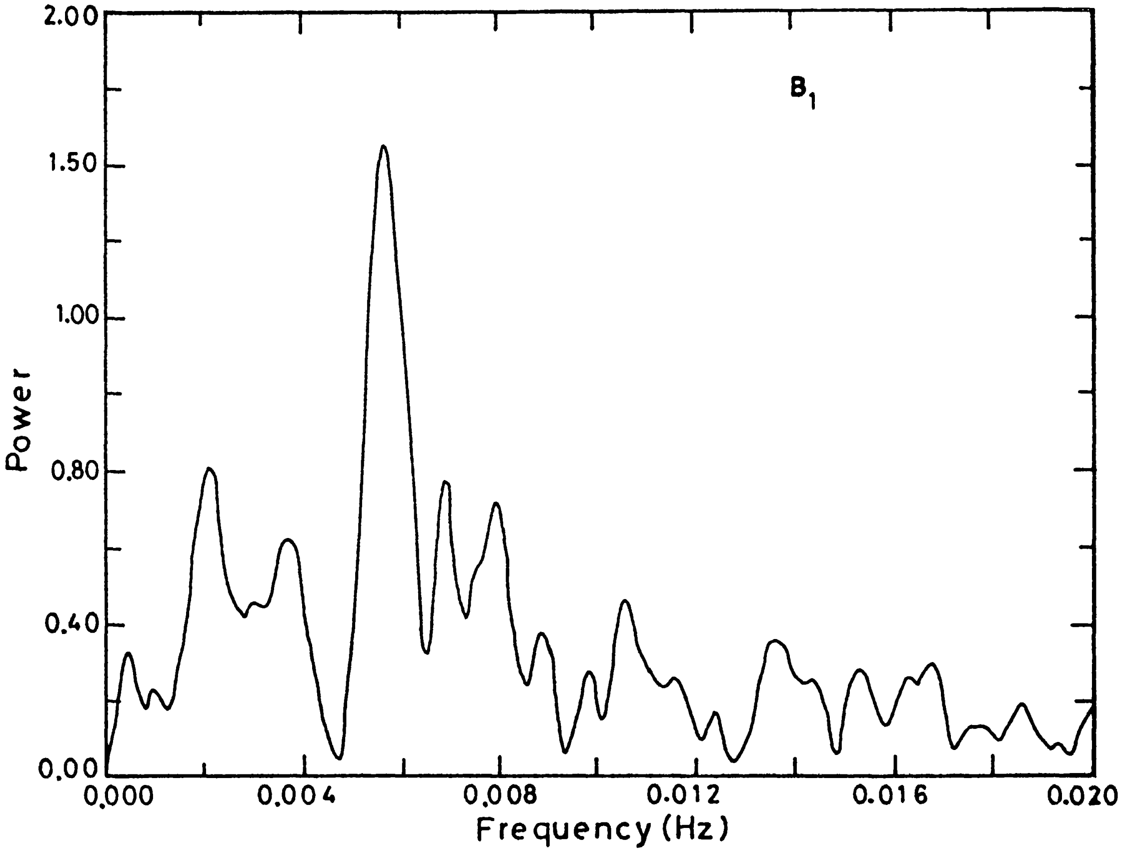

Fig. 3. Power spectrum of a bright point B_1. Notice that the main power is invariably centred around 190 ∓ 20 s.

4.2. INTENSITY OSCILLATIONS IN THE NETWORK ELEMENTS

Among the 32 sample locations we have analyzed, three (B_4, B_{18}, and B_{25}) lie on the network elements. The line profiles for these were reduced in the same way as was done for the inner network bright points (KSA). A plot of I_{H2V} versus time for B_4 and B_{18} is shown in Figure 4. These plots show intensity fluctuations with periods 0.5–1.5 min. Superposed on this is a quasi-sinusoidal pattern with a period of ~7 min. To uncover this period, we applied a 5-point smoothing to the raw I_{H2V} plots of B_4 and B_{18}. The ~7 min oscillations then stand out. These are seen in our histogram plot (Figure 5) where the smaller period dominates because of the larger numbers. We have done a power-spectrum analysis for the network elements, and it is shown for B_{18} in Figure 6. The power spectrum (Figure 6) shows that there is an indication of the presence of a period longer than 7 min, and to confirm this period we need to have a longer duration of observations. It is not clear whether the short excursions seen in the intensity plots of H_{2V} (Figure 4) are significant, and if so whether they represent the ejections of spicules from the network elements. Kuperus and Athay (1967) have suggested that one

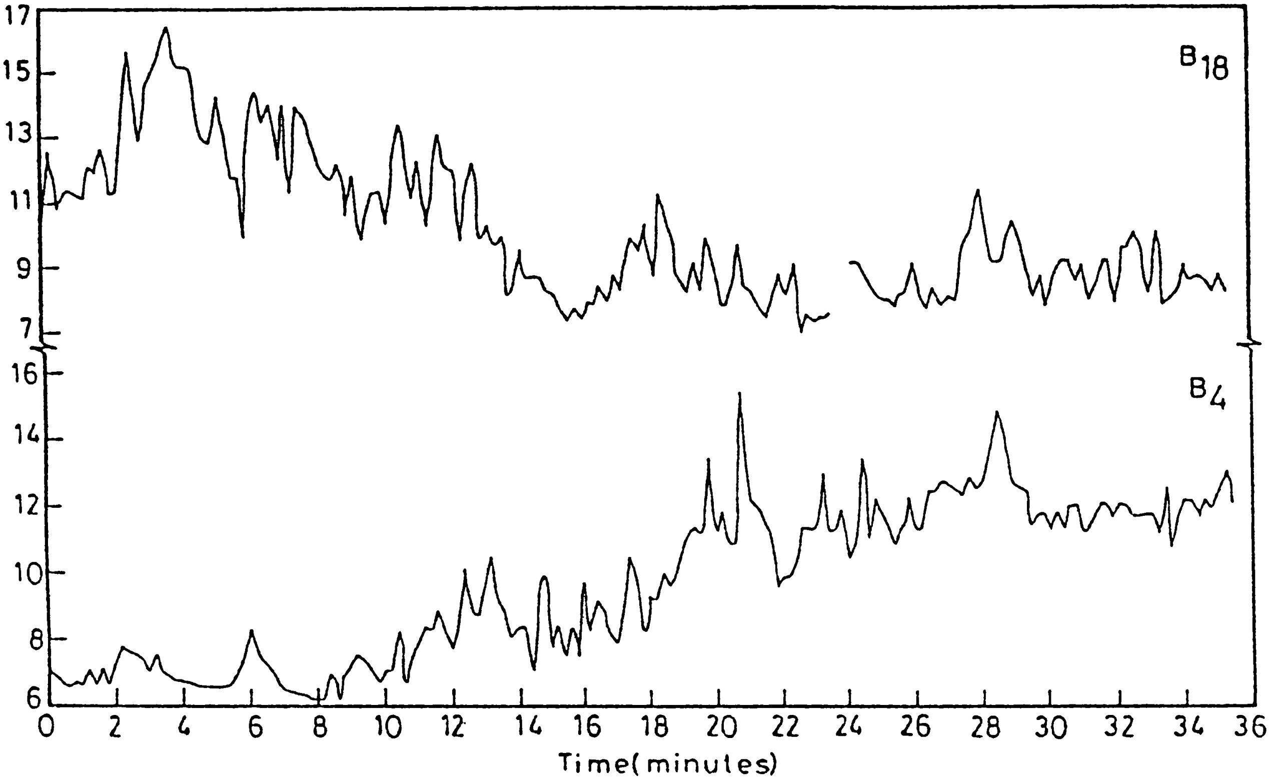

Fig. 4. The temporal variations in I_{H2v} for two locations in the network elements (B_4 and B_{18}).

of the more interesting properties of spicules is their association with the borders of supergranulation and the Calcium network, and this suggests an association between spicules and regions of enhanced vertical magnetic fields. Platov and Shilova (1971) have shown, from a 42-min duration time series of Hα-filtergrams, the existence of vertical oscillations superimposed with those of ~5-min period. But the long-period oscillations (~7 min) appear to be the characteristic of the network elements. Woods and Cram (1981) have shown long-period oscillations ($P \geq 300$ s) seen in the chromospheric parts of the plage where λ8542 is formed. Cram and Dame (1983) also make mention of rapid excursions, and the large period of the oscillations in the network elements. Also they have suggested that the rapid excursions may be associated with the existence of small, high velocity structures (spicules).

Skumanich, Smythe, and Frazier (1975) have shown that there is a one-to-one correspondence between the emission seen in the network elements and areas of enhanced magnetic fields in the underlying photosphere, and the strength of the magnetic field ranges 10–150 G. Sivaraman and Livingston (1982) have shown a similar relation for the bright points, and the magnetic field ranges 10–70 G. Hence, we can conclude from the above studies that the network elements may have an intense magnetic field compared to the bright points. In addition, the network elements are more intense in emission than the bright points (Grossmann-Doerth, Kneer, and von Uexkull, 1974; Kariyappa and Sivaraman, 1994). The conventional

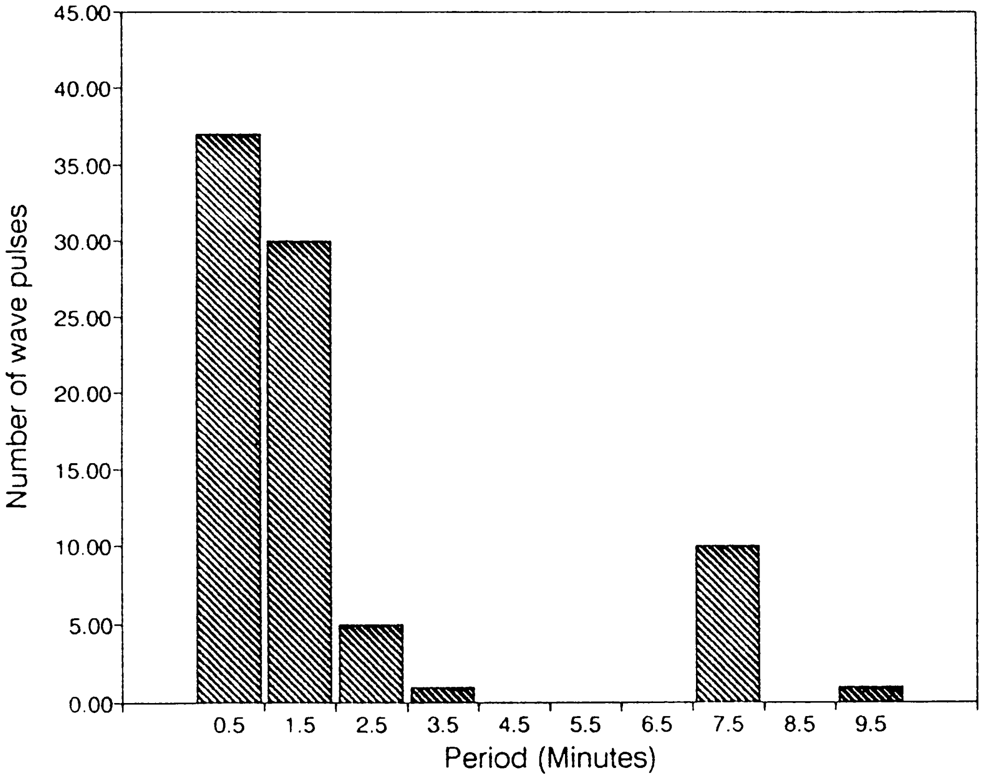

Fig. 5. Histogram plot to illustrate the periodicity of oscillations for the I_{H2V} parameter of the H-line profile for the two network elements. There are two sharp peaks: one around 1 min and the second one around 7 min.

wisdom is that network elements are more closely packed with thin magnetic flux tubes. Thus, the difference in oscillation (dynamical) properties could be due more to the collective behaviour of a large number of tubes as opposed to the dynamical behaviour of a single tube, in the case of the bright points in the cell interior. The large difference in (i) period of the intensity oscillations, (ii) the strength of the magnetic fields, and (iii) the intensity enhancements at the sites of the bright points and network elements themselves may probably be taken as evidence to argue that the mechanisms of heating in the two cases are dissimilar. Also, according to Kalkofen (1989), it is not known whether the layers in the network elements and the bright points are heated in the same way. This suggests that the regions of intense vertical magnetic field strength coincide with regions that are bright in the core of the Ca II H and K lines, indicating non-radiative heating, irrespective of the sizes of these structures, although the physical processes leading to the heating at the microscopic level seem to be different. We are aware that our sample is too small to draw any firm conclusions. Further work on the H-line profiles with more network elements is in progress.

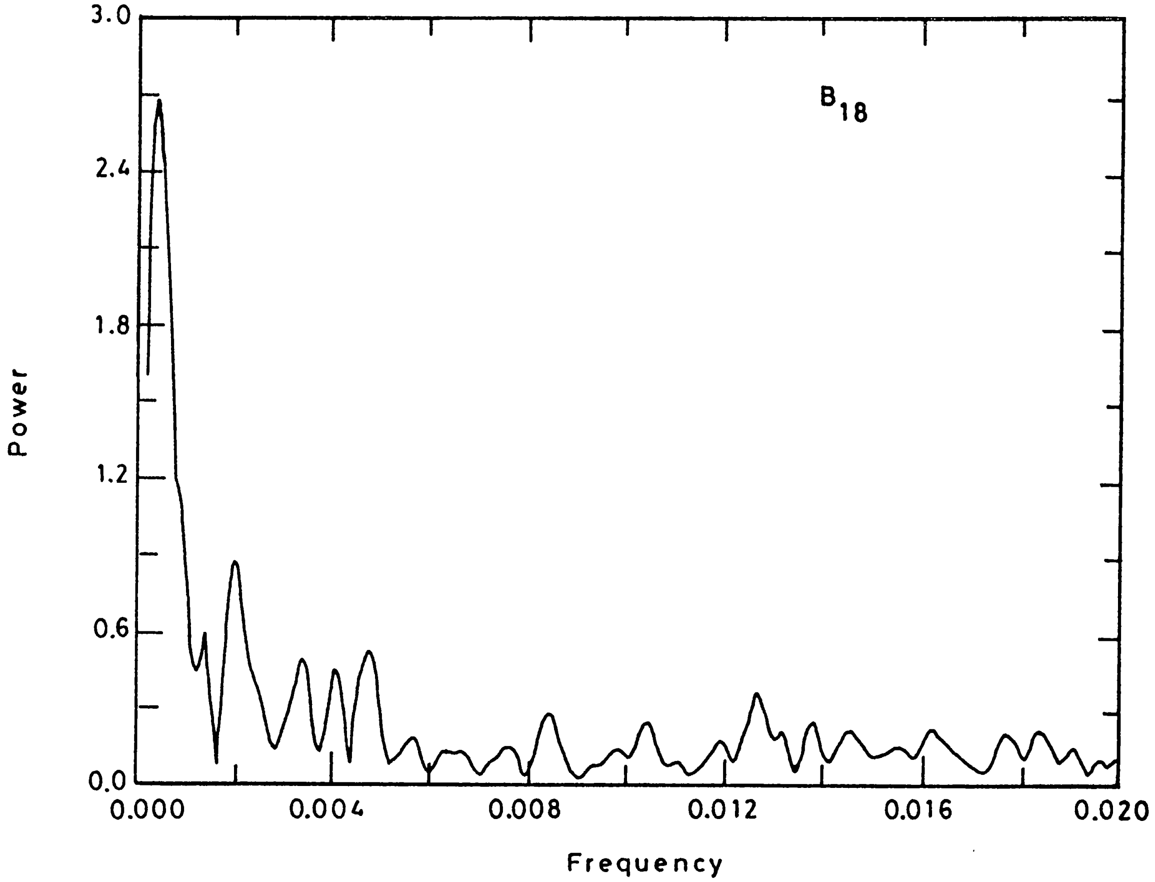

Fig. 6. Power spectrum of a network element B_{18}. Notice the main, powerful peak which may correspond to a longer period apart from a peak present around 7 min.

5. Conclusions

The important conclusions that emerge from this study are the following. The bright points show a 3-min period in intensity oscillations, whereas the network elements exhibit ~7-min periodicity. It is surmised that the large difference in periods of the intensity oscillations, the strength of the magnetic fields, and the intensity enhancements at the sites of the bright points and network elements themselves may probably be taken as evidence to argue that the mechanisms of heating in the two cases are dissimilar. The intensity plots of network elements show an intensity fluctuation with periods of 0.5–1.5 min, and it is not clear whether these short excursions are real, and if so whether this behaviour may be associated with the existence of small, high-velocity structures, namely the spicules, that are evolving rapidly in time.

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