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Oscillations and Heating in Chromospheric Fine Scale Structures

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Abstract. We have analyzed a 35-min-long time sequence of spectra obtained simultaneously in CaII H-line, NaI D1 and D2 lines, and in strong and weak FeI lines in a quiet region at the center of the solar disc under high spatial, spectral, and temporal resolution using the VTT of NSO/Sac Peak. We derived the line profile at the sites of a large number of bright points and network elements, and extracted the various line profile parameters. The important results emerged from this analysis are: (i) The bright points and network elements exhibit 3-min and 5-7 min periodicity in their intensity oscillations respectively; (ii) The bright points are grouped into three classes according to their dynamical behavior, and it is surmised that the differences in their behavior are directly related to the inner network photospheric magnetic points to which they have been observed to bear a spatial correspondence; (iii) The period of intensity oscillations decreases outward from the low photosphere (5-min) to the middle chromosphere (3-min); (iv) The evidence for the existence of the constant period of oscillations in bright points with their brightness and the different period from network oscillations suggests that the mode of heating mechanism may be identical (by 3-min period waves) for all classes of bright points and it may be an entirely different mechanism (5-7 min period waves) in the case of network elements; (v) The physical process behind the cause for the bright points may be due to the interference of these 3-min period waves, and the 3-min bright points may be magnetic in origin.(vi) According to the current models, the energy transported by these 3-min period waves at the sites of the bright points can account for a substantial fraction of the radiative loss from the quiet chromosphere.

1. Introduction

One of the major problems of solar physics is to understand the way the chromosphere and the corona are heated and supported by the non-radiative energy from the layers below. Biermann (1948) and Schwarzchild (1948) have suggested that the outer atmosphere heated by acoustic waves generated in the hydrogen convection zone. In 1949, Schatzman has shown that the acoustic waves will be converted into shock waves and will dissipate the energy in the chromosphere and corona. Observational evidence has come from a famous total solar eclipse of February 25, 1952 with the flash spectra which led to the first models of the chromosphere based on excellent observations. Since then several theories attempted to explain the heating mechanism.

The most suited lines for the observations of middle and upper chromosphere in the visible region are MgI b1, H-alpha and H and K lines of CaII. The CaII H and K lines are resonance and collisionally controlled lines and are very sensitive to the variations in temperature and the magnetic field strength, therefore they are excellent indicators of the chromospheric structural changes related to solar magnetic activity. Using these lines, the chromospheric oscillations and heating at the sites of different chromospheric features can be studied in great detail. At high resolution CaII H and K spectroheliograms show the different chromospheric features, namely, the plages, network elements and intranetwork bright points. They are seen in emission and have a one-to-one correspondence with the underlying photospheric magnetic fields (Leighton, 1961, Skumanich, Smythe, & Frazier 1975; Sivaraman & Livingston 1982; Nindos & Zirin 1998). Thus the non-radiative heating seen as excess emission occurs only in regions associated with magnetic fields, irrespective of the size of the chromospheric structures. These features will contribute in the variations of total K- emission flux, in the heating of the chromosphere and in the variations of UV irradiance variability (Lean 1987; Foukal & Lean 1988; Kariyappa 1993; Kariyappa & Sivaraman, 1994; Kariyappa, Sivaraman, & Anandaram 1994; Kariyappa et al. 1995; Kariyappa 1994, 1996; Kariyappa & Pap 1996; Kariyappa & Kneer 1998; Kariyappa 1998).

Jensen and Orrall (1963) have shown observationally that the chromosphere oscillating with a period of 180-200 sec. Observations of high temporal, spatial, and long-time sequence of spectra of CaII H and K lines show that waves with a 3-min period transport, and dissipate a large amount of energy, and heat the chromosphere at the sites of the bright points (Punetha 1974; Liu 1975; Cram & Dame 1983). Although these observations provide an overall understanding of the oscillations and heating, some of the important problems remain unanswered.

2. A Brief Summary on Observations and Analysis

We made an attempt to solve some of the problems in using a 35-min time sequence of spectra obtained (Beckers et al. 1972) at the VTT of NSO/Sac Peak simultaneously in CaII H line, NaI D1 and D2 lines and large number of FeI lines at the center of the solar disc in a quiet region. The spatial resolution is about 1 arc sec or better and the time resolution is 12 sec. We derived the absolute line profiles for 30 bright points and 2 network locations and extracted the line profile parameters and plotted them as a function of time in order to obtain their light curves. More details on the reduction of the spectra are presented in Kariyappa et al.(1994); Kariyappa(1994,1996), and further data handling will also be described below, together with the results.

3. Results and Discussion

The bright points can be grouped into three classes depending on the brightness enhancement during their dynamical evolution. The differences in their behavior are directly linked with the inner network photospheric magnetic points to which they have been observed to bear a spatial correspondence. The light curves of the bright points give the impression that the "main pulse", which is the upward propagating disturbance carrying energy, throws the medium within the bright point into a resonant mode of oscillation that is seen as the follower pulses. The mechanical energy transported by the main pulses at the sites of the bright points over the entire visible solar surface can account for a substantial fraction of the radiative loss from the quiet chromosphere, according to the current models. The bright points can provide 50% of the energy required to heat the quiet chromosphere. This together with the contribution from the network can account for the energy requirement of the quiet chromosphere (Kariyappa, et al. 1994). The bright points are associated with 3-min periodicity, whereas the network elements exhibit 5-7 min periodicity in their intensity oscillations (Kariyappa 1994, See histogram and power spectra plots in Figures 2, 3, 5 and 6). We have analyzed the line profiles of NaI D1 and D2 , large number of strong and weak FeI lines together with the CaII H line obtained simultaneously. All these lines are forming at different heights in the solar atmosphere ranging from the low photosphere to the middle chromosphere. We examined the central intensities of these lines at the sites of the bright points and found that the period of intensity oscillations in the chromospheric bright points decreases outward from the low photosphere (5-min) to the middle chromosphere (3-min) (Kariyappa 1996, See Fig.6 and Table II).

We have derived the period of oscillations using power spectrum analysis and the peak intensity value of H2V for the main and follower pulses separately from the time series plots (Kariyappa et al. 1994, Kariyappa 1994) for all the 3 classes of bright points. In addition, we estimated the average peak intensity value of H2V of all the main and follower pulses for all the 3 classes of bright points. We have plotted in Fig. 1 the intensity of the main pulse and an average intensity of the main and follower pulses against the period of intensity oscillations, respectively.

We have examined the behavior of intensity oscillations at the sites of the bright points for the 35-min duration and we find that the amplitude of the intensity of the main and follower pulses of variety of bright points decay exponentially with time. We derived the decay rate from the exponential curves and plotted in Fig. 2, the decay rate versus the intensity of the main pulse and an average intensity of the main and follower pulses respectively. It is clearly seen from Fig.1 that the period of intensity oscillations seen at the sites of a variety of bright points in the interior of supergranulation cells is *independent* of their intensity enhancements.

In addition, the amplitudes of the main and follower pulses of a variety of bright points decay exponentially with time. Fig.2 clearly shows that the decay rate is also *constant* with their brightness. In other words, the wave period and the intensity amplitude are *uncorrelated* and the decay rate of the intensity is exponential and is *independent* of the intensity amplitude. We find evidence for a of constant period of the oscillations in bright points with their brightness and the different period from network oscillations. This suggests that the heating mechanism may be identical (by 3-min wave period) for all classes of bright points and it may be an entirely different mechanism (5-7 min wave period) in the case of network elements. This result will answer the question raised

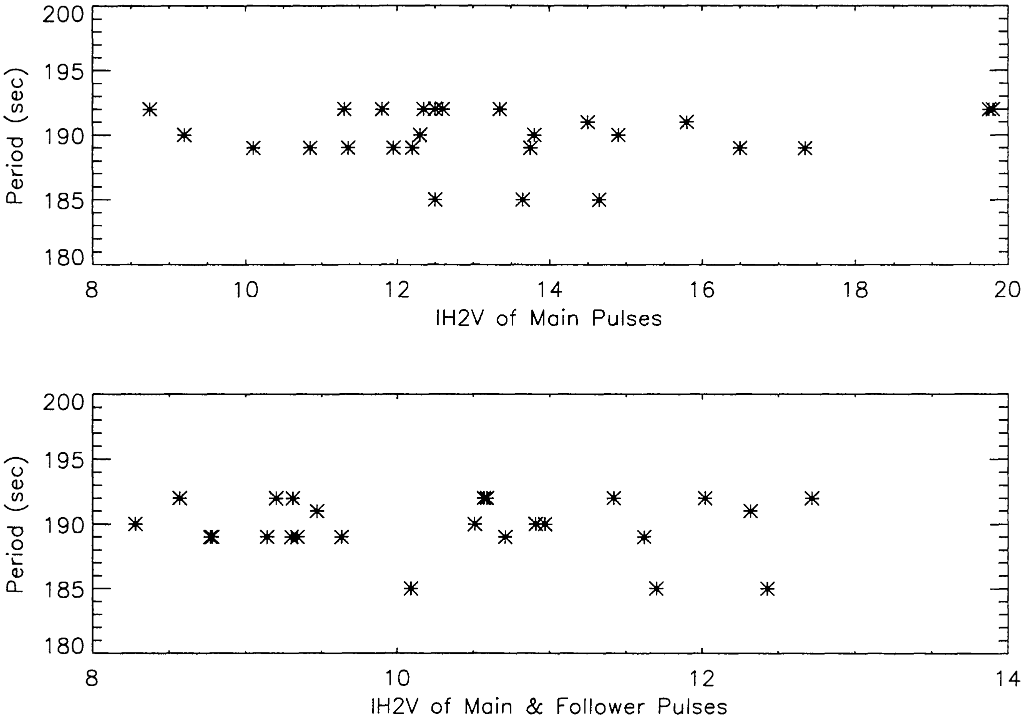

Figure 1. Variation of the period of intensity oscillations with the peak value of I_{H2V} of the main pulses (top) and the average peak value of I_{H2V} of the main and follower pulses (bottom) of all the classes of bright points. The correlation coefficient (r) is 0.12.

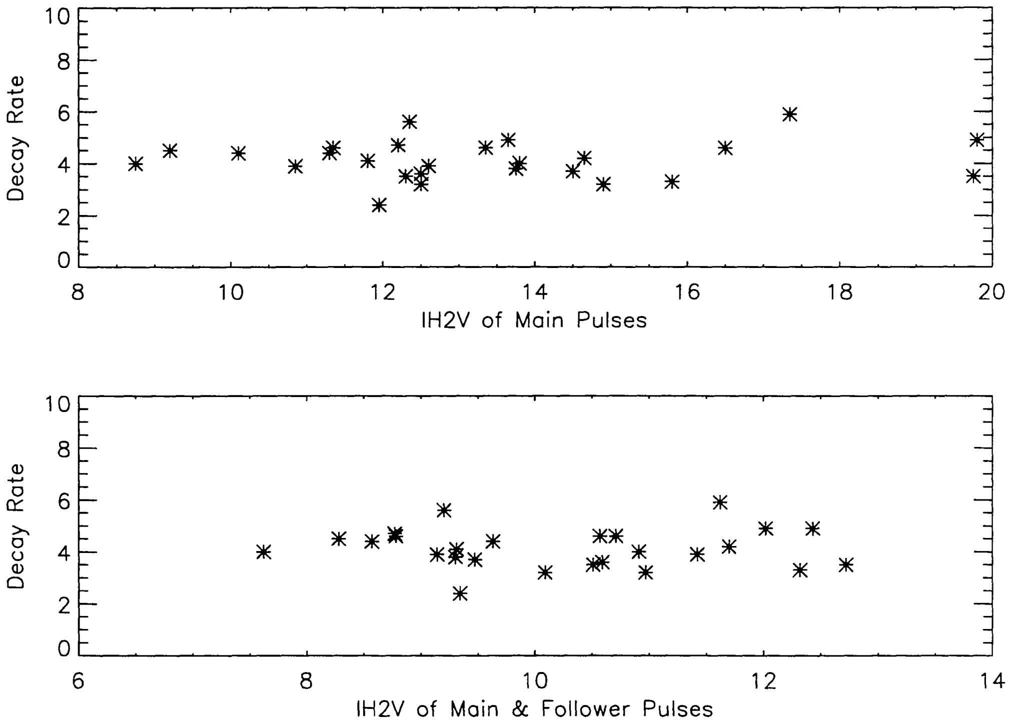

Figure 2. Variation of the decay rate in amplitudes of the pulses with the peak value of I_{H2V} of the main pulses (top) and the average peak value of I_{H2V} of the main and follower pulses (bottom) of all the classes of bright points. The correlation coefficient (r) is 0.05. The y-axis values will be multiple of 10^{-4} in % of the continuum per sec.

by Kalkofen (1989), whether the layers in the network elements and the bright points are heated in the same way. The physical process behind the cause for the bright points may be due to the interference of these 3-min period waves, and the 3-min bright points may be magnetic in origin.

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