LATITUDINAL VARIATIONS OF LINE-OF-SIGHT VELOCITY OSCILLATIONS IN THE PHOTOSPHERE, CHROMOSPHERE AND PROMINENCES

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Abstract. By studying time variations in line-of-sight velocity in prominences, we found that the velocity oscillations with periods over 40 min have a reasonably well-marked dependence of the period length on the heliolatitude. Simultaneous observations of line-of-sight velocities in the photosphere and chromosphere showed that quasi-hourly oscillation periods at these levels of the solar atmosphere and in prominences have a similar latitudinal behaviour. Thus, the photosphere, chromosphere and prominences should be regarded as a unified oscillatory system.

1. Introduction

Where fundamental problems of the solar interior and differential rotation are involved, reliable experimental data on latitudinal variations of physical plasma parameters, the geometrical size of solar features, and on their behaviour during the course of the evolution of a solar cycle, are of significant importance. Directly or indirectly, observational data make it possible to come nearer to realistic models.

In early 1980s we detected long-period Doppler velocity oscillations (Bashkirtsev, Kobanov, and Mashnich, 1982, 1983; Bashkirtsev and Mashnich, 1984) that attracted the attention of investigators. More recently similar oscillations were found to exist in the quiet solar chromosphere (Bashkirtsev, Kobanov, and Mashnich, 1987). It has been found experimentally that the long-period oscillations in the chromosphere, as in prominences, are horizontal.

Concerning the origin of the oscillations in prominences, we have searched for peculiarities in the oscillation parameters depending on the phase of solar activity cycle, and on the position of prominences relative to zones of activity. The study revealed a reasonably clear heliolatitudinal dependence of the value of the line-of-sight velocity oscillation period in prominences (Bashkirtsev and Mashnich, 1993). Line-of-sight velocity observations in prominences covering the period 1981–1991 were used in our investigation.

By investigating the line-of-sight velocity time variations in prominences, we interpreted the oscillations with periods over 40 min to be forced ones, assuming that the source of such oscillations resides in layers of the solar atmosphere below the prominence. If this is the case, then latitudinal characteristics of quasi-hourly

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oscillations must be revealed at least in visible layers of the solar atmosphere. The present results were derived from studies of the heliolatitudinal dependence of oscillation parameters in the photosphere and chromosphere.

2. Observations

The objective of the observing program was to show the presence or absence of the heliolatitudinal dependence of the quasi-hourly oscillation period in the quiet solar atmosphere. Doppler velocity variations were recorded near the latitudes 0°, 15°–25°, 40°–50°. At these latitudes we detected deviations from the mean value of the quasi-hourly oscillation periods in prominences. It is known that short-period oscillations (3–5 mHz) are vertical ones; therefore, the amplitude of such oscillations decreases from the disk center to the limb. The behaviour characteristic for the quasi-hourly oscillations of the chromosphere is the reverse: at the center of the solar disk they are virtually lacking, and their amplitude increases with the distance from the center to the limb. Based on these factors we used regions of the quiet Sun at the longitude of about 40° in our observations.

The observations were made at the Sayan Solar Observatory with the horizontal solar telescope during August–September 1995 and in July 1996. A high-precision differential method for measuring line-of-sight velocities involved the use of a solar magnetograph. The concept of the instrument for such measurements was described in a paper by Kobanov (1983). Using an additional photomultiplier we carried out measurements simultaneously in the photosphere (λ485.74 nm, Ni I) and the chromosphere (λ486.13 nm, Hβ), with a $2'' \times 8''$ entrance slit and a spectrograph dispersion of 3.12 mm Å^{-1}.

The solar image was kept stable on the spectrograph slit by means of the photoelectric guider; solar rotation was automatically compensated for. With allowance made for distorting factors, line-of-sight velocity measurements were made to an accuracy better than 20 m s^{-1}. Areas were selected for observations in white light and light reflected from the spectrograph mirror slit and passing through the Halle Hα-filter. The length of one recording was typically more than 120 min; hence, during the daytime we were able to take one recording for each of the latitudes, provided that weather conditions allowed. Such a length of a recording gives sufficient spectral resolution. Figure 1 shows a typical example of the Doppler velocity variations in the photosphere and chromosphere. From this figure one notices that the amplitude of the short-period (3–5 min) oscillations, especially in the chromosphere, exceeds that of the quasi-hourly oscillations. A spectral analysis supports these initial estimates. The amplitude of the quasi-hourly oscillations, as a rule, did not exceed 100 m s^{-1} in the photosphere, and 250 m s^{-1} in the chromosphere. The parabolic trend was subtracted from time sequences; after that, the method of correloperiodogram analysis (Kopecký and Kuklin, 1971) was used to calculate line-of-sight velocity oscillation spectra. The power spectra of the

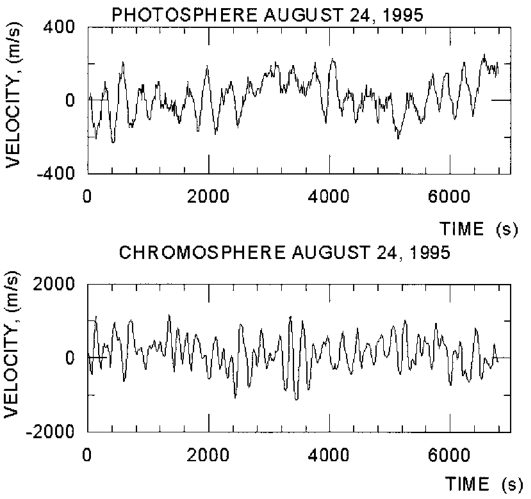

Figure 1. Time series of the Doppler velocity variations in the photosphere (λ485.74 nm, Ni I) and chromosphere (λ486.13 nm, Hβ) simultaneously observed 24 August 1995 at the latitude $\varphi = 4^\circ$ and longitude $\lambda = 40^\circ$.

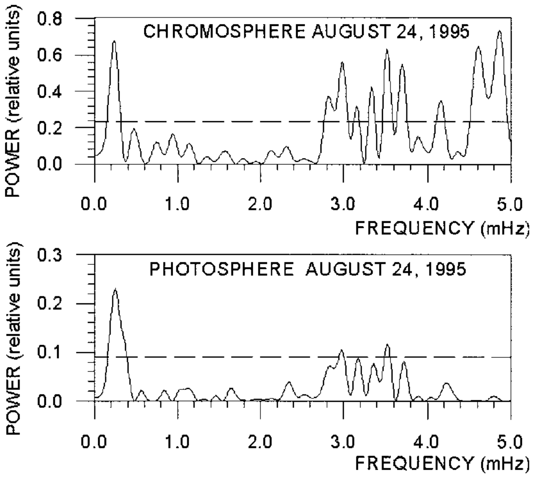

Figure 2. The power spectra of the Doppler velocity variations in the photosphere (λ485.74 nm, Ni I) and chromosphere (λ486.13 nm, Hβ). The maximum oscillation period in the photosphere is equal to $P = 67^{\mathrm{m}} \pm 19^{\mathrm{m}}$, amplitude 59 m s^{-1} and in the chromosphere $P = 69^{\mathrm{m}} \pm 21^{\mathrm{m}}$, amplitude 153 m s^{-1}. The dashed lines mark the 99% confidence level.

Doppler velocity variations in the photosphere and chromosphere corresponding to the registrations in Figure 1 are shown in Figure 2. The accuracy of determining the period P, as shown by Djurovich and Pâquet (1994), is better than $P^2/2T$, where T is the length of a time sequence. For example, when $T = 2P$, the error in determining the period does not exceed $P/4$.

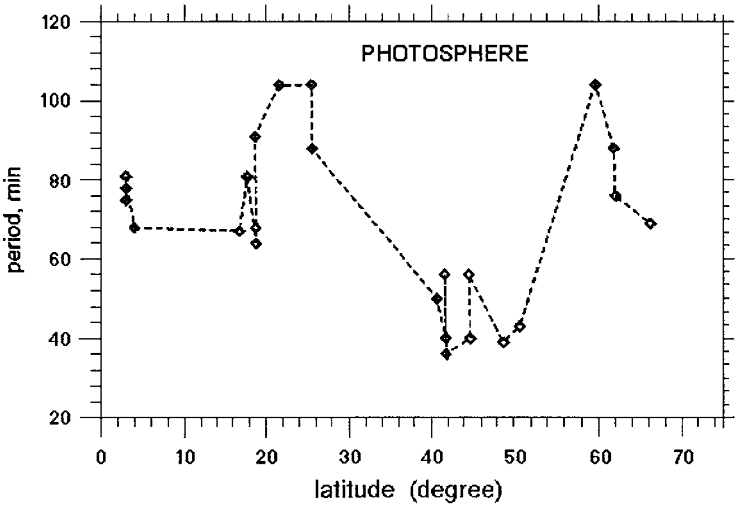

Figure 3. Latitudinal variations of the quasi-hourly oscillation period for the photosphere.

3. Results and Discussion

Figure 3 shows the latitudinal variations of the value of the period for the photosphere and Figure 4 refers to the chromosphere. For comparison, Figure 5 shows the latitudinal variations for the photosphere (dashed line), the chromosphere (dash-dotted line), and prominences (solid line). Even with a small samples, all dependencies reveal deviations from the mean value of the period to maximum values at latitudes of about 25°, and to minimum values at the latitudes 45°–50°.

The quasi-hourly oscillations observed in prominences are interpreted in earlier publications (Balthasar, Stellmacher, and Wiehr, 1988) as eigen-oscillations caused by the geometry and physical conditions of the prominence itself. However, the coincidence of the latitudinal dependencies of the oscillation period at different levels in the solar atmosphere, as is evident from Figure 5, suggests that the quasi-hourly oscillations in prominences may represent forced ones. The photosphere, chromosphere and prominences should be regarded as a unified oscillatory system when frequencies below 1 mHz are concerned.

We shall not attempt to explain the presence of maxima and minima of the quasi-hourly oscillation period at certain latitudes, based on a small amount (28 data sets) of observational data. It should be noted that some investigations revealed variations of different physical parameters of solar plasma with the latitude. A few examples are given below.

It is known that the solar magnetic field in the corona has a latitudinal zonal structure. Using data on the structure of coronal magnetic field Makarov (1983, 1984) showed that at maximum activity each solar hemisphere exhibits two global neutral lines of magnetic field at the latitudes 20° and 40° and one line near the equator. In a series of papers of different authors, addressing the observed fre-

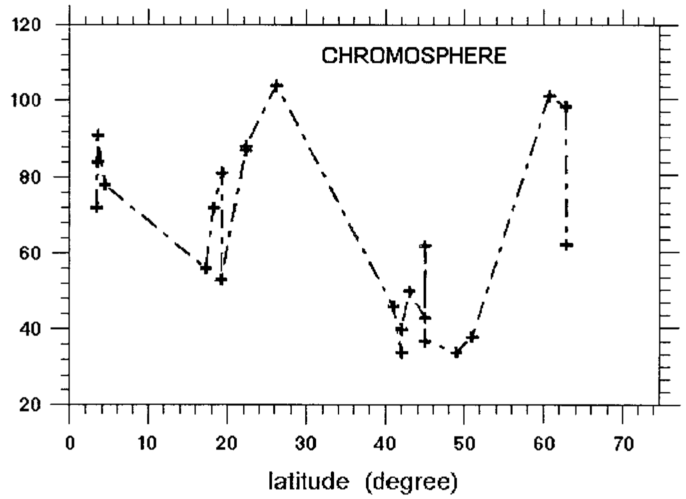

Figure 4. Latitudinal variations of the quasi-hourly oscillation period for the chromosphere.

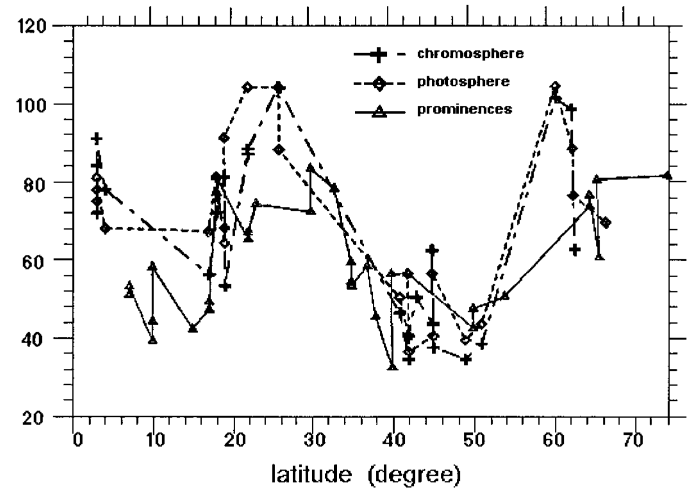

Figure 5. A comparison of the latitudinal variations of oscillations in the photosphere, chromosphere and prominences.

quency splittings of the p modes, variations in the internal angular rotation velocity were calculated depending on the latitude and solar radius. Rhodes *et al.* (1990) compared the variations in inner angular rotation velocity depending on the latitude and solar radius, from observational data obtained at different observatories. A good agreement of results was found, and it was shown that the variations in inner angular velocity of the Sun for $r = (0.6 - 0.95)R_\odot$ behave differently for the equatorial, middle and near polar latitudes. Rimmele and Schröter (1989), using maps of line-of-sight velocities of the photosphere near the solar limb, found that the mean size of the supergranulation cells varies with the heliolatitude, showing a statistically significant minimum at the midlatitudes. Our result on the latitudinal variations of the value of the oscillation period in the photosphere, chromosphere and prominences is important for understanding the origin of prominences.

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