PERIODIC OSCILLATIONS FOUND IN THE VELOCITY FIELD OF A QUIESCENT PROMINENCE

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(Received 27 August, 1985; in final form 15 January, 1986)

Abstract. With the purpose of detecting periodic oscillations or waves in a quiescent prominence, temporal variations of a Ca II K line profile have been studied. The most conspicuous phenomenon found here is the fact that the edge of the prominence showed, over some 20 000 km along the spectrograph-slit, periodic velocity fluctuations of nearly the same phase with periods of 210–240 s and with an amplitude of up to ± 2 km s^{-1}. At other portions, several different periods of peaks (160–400 s) can also be seen in the power spectra, but less distinctly. As to the intensity and the line width, however, no periodic variations have been detected.

1. Introduction

According to many studies published to date, oscillatory phenomena in prominences (including dark filaments) seem to be classified roughly into the following three types. The first is the so-called winking filament which is the most prominent event that has been studied extensively by a number of authors (for instance, Ramsey and Smith, 1965, 1966; Hyder, 1966; Kleczek and Kuperus, 1969; Landman *et al.*, 1977). The second is the long-period line-of-sight velocity oscillation recently found by several authors. Malville and Schindler (1981) detected oscillations of a loop prominence, having a period near 75 min and an amplitude of 1–2 km s^{-1}, approximately 90 min before the onset of a flare. Bashkirtsev *et al.* (1983) and Bashkirtsev and Mashnich (1984) obtained oscillation periods of 42–82 min with amplitudes in excess of 200 m s^{-1} for 15 prominences observed. Wiehr *et al.* (1984) have also obtained similar periods of 50, 60, and 64 min, with amplitudes of 1–2 km s^{-1} for 3 prominences.

The third type is the short-period oscillation for which only very weak evidence has been given. Although it has often been suggested that oscillatory motions can exist in the line-of-sight velocity fields of prominences (for instance, Malville, 1968; Liszka, 1970; Ramsey, 1977), very few studies have been made to detect temporal variations of this type. Vršnak (1984) reported that he found horizontal velocity oscillations of a loop prominence having a period of 8 min, and Wiehr *et al.* (1984) obtained slight indications of short-period oscillations with periods near 3 and 5 min. In studying the small-scale velocity field of a quiescent prominence, Engvold (1981), however, failed to find clear evidence for oscillations or waves. Malherbe *et al.* (1981) reported that the chromospheric oscillations ($P = 240$ s) were almost undetectable in a filament and were reduced around it.

With the purpose of detecting periodic oscillations of this type, we made time series observations of Ca II K line spectra of a quiescent prominence. The purpose of the

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present paper is to describe the procedure and the results of the line profile and the power spectral analyses.

2. Observations

Using the domeless solar telescope and the vertical spectrograph of the Hida Observatory, University of Kyoto, time series observations of a quiescent prominence were carried out on 12 November 1981. Over a 20 min period, 81 frames of Ca II K-line spectra, together with Hα slit jaws monitor pictures, were obtained with a constant interval of 15 s and with a 10 s exposure time. An example of the spectrogram and a monitor picture thus obtained are given in Figure 1.

The prominence was located at a comparatively high latitude in the south–western hemisphere (PA = 249°) well isolated from any active regions. According to *Solar*

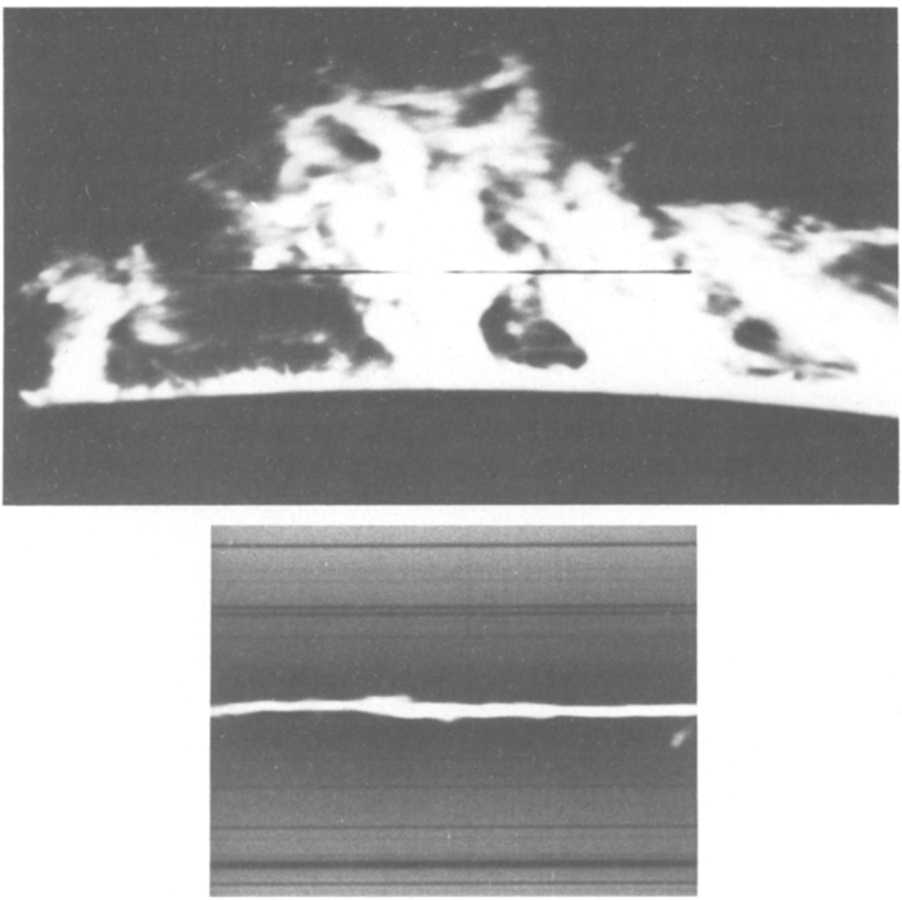

Fig. 1. An example set of slit jaws monitor Hα picture (above) and Ca II K line spectrum (below). During a 20 min period, 81 sets of exposures were made with a constant interval of 15 s.

Geophysical Data, this prominence was long-lived and stable in its global structure. As seen in the spectrogram of Figure 1, however, small-scale Doppler shifted features can be seen. The spectrograph slit, whose length corresponds to about 84 000 km, was situated at around 20 000 km above the solar limb. The dispersion of the spectrograph, determined by the two iron absorption lines (Fe I 3930.308 and 3937.336), is 0.551 Å mm^{-1}.

3. Line Profile Analyses

At ten equally separated points along the slit (interval of successive scans = 8400 km), microphotometric scans, digitizing with an interval of 0.005 mm, were carried out for all 81 frames. After converting the photographic density into intensity using the technique developed by Tsubaki and Engvold (1975), the background sky spectrum was

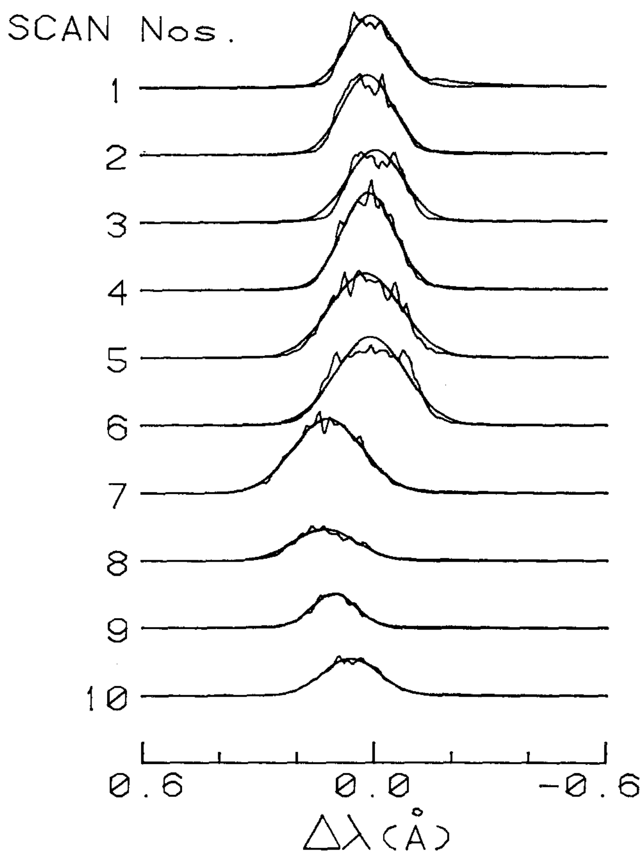

Fig. 2. Typical line profiles of 10 successive scans for a single frame obtained by making least-squares fittings to the Gaussian after subtracting the background sky spectrum. Scan No. 1 corresponds nearly to the right end of the slit seen in Figure 1. Note that the fittings are almost perfect for scans 4, 7, 8, 9, and 10.

subtracted to obtain the real line profile. Here, we assumed that the K_2 and K_3 structures in the background spectrum can be neglected as compared with the much larger emission profile of the prominence itself. That is, the background spectrum to be subtracted was determined by making least-squares fittings to the first-order polynomial at both sides of the emission.

To the real emission profile thus obtained, the technique developed by Tsubaki (1975) has been applied: that is, least-squares fittings to the Gaussian curve have been done to obtain three fundamental quantities (integrated line intensity, Doppler width, and line-of-sight Doppler velocity) as functions both of position along the slit and of time.

In Figure 2, we give as an illustration typical line profiles of 10 successive scans for a single frame. As shown in the figure, the fittings are not very good for scans 1, 2, 3, and 6, but are nearly perfect for the rest. As will be shown below, the periodic oscillations have been found at the edge part of the prominence, corresponding to scans 8, 9, and 10. It can safely be said, therefore, that deviations from the Gaussian seen at several scans will not affect the final results.

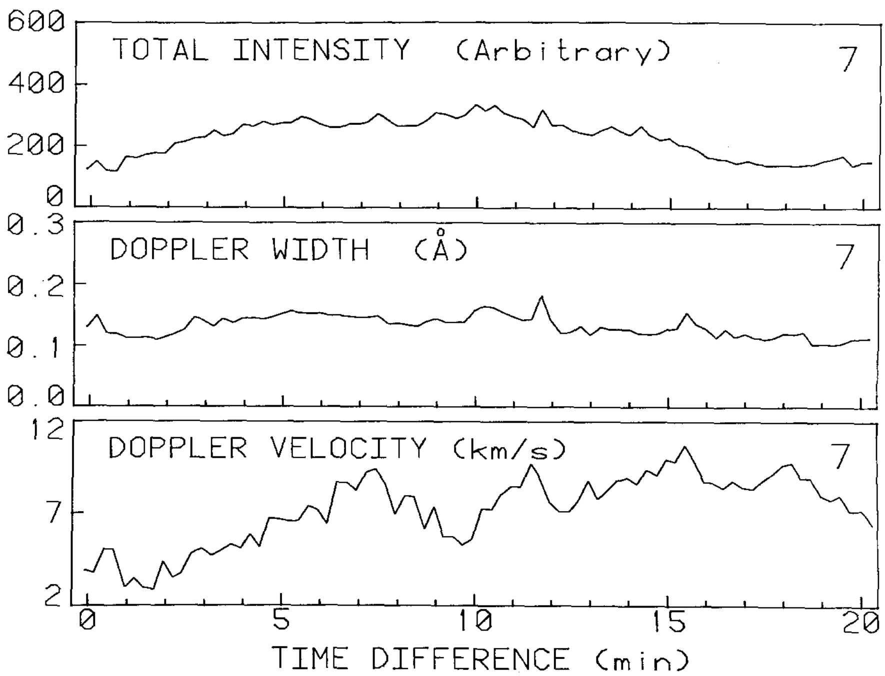

Fig. 3. Example of temporal variations for three physical quantities obtained at scan 7. From top to bottom: total intensity, Doppler width, and Doppler velocity, respectively.

In Figure 3 we show, as an example, a set of temporal variations of the three physical quantities obtained for scan 7. All such drawings, ten sets in total, were carefully inspected and the following preliminary conclusions have been derived. That is, no clear evidence of periodic oscillations has been found for intensity or Doppler width, while the line-of-sight Doppler velocity showed distinct periodic oscillations at several locations. The most prominent are those found at scans 8, 9, and 10 which correspond to the left-hand edge of the prominence (see Figure 1). Temporal variations of Doppler velocity for these three positions are given in Figure 4.

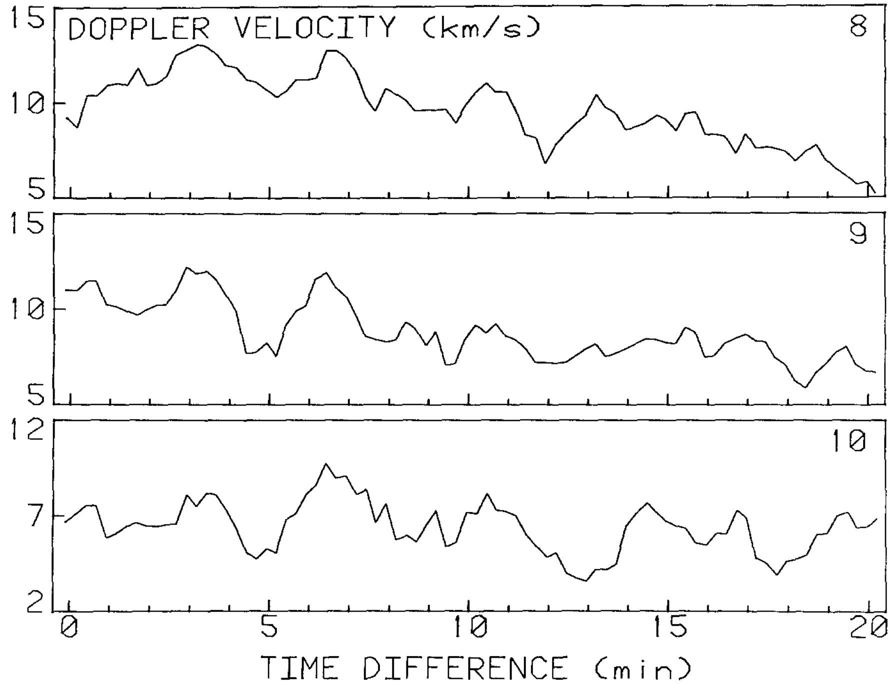

Fig. 4. Temporal variations of Doppler velocity at three successive points corresponding to the left-hand edge of the prominence. The phases of periodic fluctuations are nearly identical, with amplitudes of up to ± 2 km s^{-1}.

As shown in Figure 4, clear periodicity can be seen in all the three positions with amplitudes of up to ± 2 km s^{-1}. The characteristic features of these oscillations are: (1) the oscillating phase is nearly identical for the three locations; and (2) the amplitudes tend to be reduced with the lapse of time, especially for the scans 8 and 9, which suggests the possibility that the present oscillations could be some kind of damped oscillations.

4. Fourier Analyses

To confirm and develop the preliminary conclusions given in the previous section, Fourier analyses or power spectral analyses have been done for the three physical quantities at all ten positions measured. Following the usual method of FFT analysis, smoothings of data points were made at both ends after eliminating drifting low-frequency change by making least-squares fittings to the second-order polynomial. Since the observations were made for a duration of 20 min with an interval of 15 s, we should, hereafter, restrict our argument to those oscillations that show some limited range of period, say 100–600 s. It is also to be noted that the frequency resolution, corresponding to the time duration of 20 min, is 1/20 × 60 Hz, that is, 0.83×10^{-3} Hz.

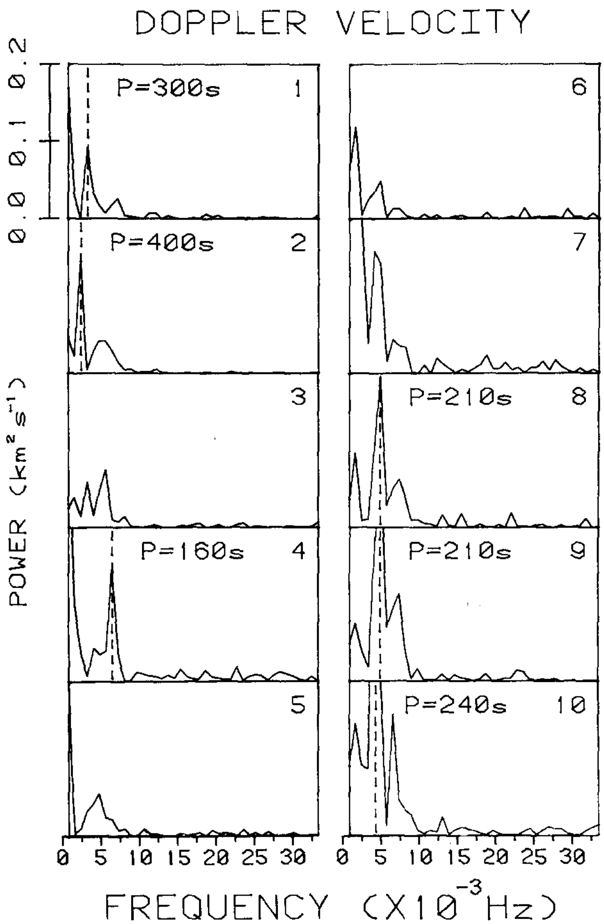

Fig. 5. Power spectra for the line-of-sight Doppler velocity. At the scans 8, 9, and 10, the high power of sharp peaks can clearly be seen with nearly the same periods of 210–240 s, which confirms the evidence for the existence of oscillatory motion at the left-hand edge of the prominence.

In Figure 5, we give the power spectra for the line-of-sight Doppler velocity thus obtained. The conclusions derived from the power spectral analysis can be summarized as follows.

(1) At scans 8, 9, and 10 in Figure 5, the high power of sharp peaks can clearly be seen with nearly the same periods of 210–240 s, thus confirming the preliminary result given in the previous section. Since we can recognize a sign of similar power peak even at the adjacent scan 7, and since the power value seems to increase continuously with scan numbers, we can reach the conclusion that the edge of the studied prominence

showed, over some 20 000 km along the slit, periodic velocity fluctuations of nearly the same phase with periods of 210–240 s and with an amplitude of up to ± 2 km s^{-1}. As mentioned in the previous section, there is a possibility that the present oscillations could be some kind of damped oscillations.

(2) At scans 1, 2, and 4 in Figure 5, comparatively low but sharp peaks with periods of 160–400 s are also visible. Since the line profile fittings were not very good for scans 1 and 2, however, we should not give much meaning to these two scans. As to scan 4, we cannot deny the possibility of the existence of small-scale periodic oscillations since the fitting of line profile was almost perfect, as is shown in Figure 2.

(3) As for the intensity and the line width, no sharp peaks with high powers have been found at any locations in the power spectra, as expected by the visual inspections made in the previous section.

According to the *Solar Geophysical Data*, the studied prominence or the dark filament was composed of a chain of three bodies, elongating along a direction with an angle of some 20 deg to the equator. When the observation was made, the west side body had already set beyond the limb and the mid-point of two others seemed to be just on the limb. The oscillations have been found at the eastern side edge of the middle body. As the angle between the line-of-sight and the average axis of the filament should be nearly 20 deg (since the obliquity of the Sun's axis was very small; that is, Bo = 3°.2), the direction of the present oscillation should be mainly along the filament axis.

The oscillation period, 210–240 s, is nearly the same as that recently found in the inner corona (Tsubaki *et al.*, 1986) and as those detected in the chromospheric level (see, for example, Malherbe *et al.*, 1981). To make any judgement on whether the oscillations found here represent the general property of quiescent prominences or are only a type of activity, further observations are necessary.

Acknowledgements

We are very grateful to Professors Kawaguchi and Kanno of Hida Observatory, and to Professor Hirayama of Tokyo Astronomical Observatory for their stimulated discussion on the problem. One of us (Tsubaki) must express his deepest thanks to Drs Kurokawa and Funakoshi for their kind assistance with the observations at the Domeless Solar Tower.

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