by Wiehr et al. (1988), is found in prominence-C at 23-28” (f_0=1.01 mHz) and in prominence-F at 35-41” (f_0=0.834 mHz).

6. Discussion

The deduced periods refer to a highly accurate spatial location of the prominence both, perpendicular and parallel to the spectrograph slit. The data establish a general existence of periods near one hour and near 20 min, but not near 12 min. A certain ‘grouping’ of periods near 3.5, 4.1, 5.3, 8.2, and 9.4 min is only slightly indicated, in agreement with Wiehr et al. (1989) who find the 3 and 5 min periods only occasionally. The majority of periods show a large variation between different prominences and within one prominence. The oscillations often last only a few periods and have spatial extents of a few arcsec (see Figure 3).

This is not surprising when considering that essential parameters determining the oscillation, such as magnetic field, density and geometry, exhibit significant variations in space as well as with time (see e.g. Balthasar & Wiehr 1994). In addition, evolutionary changes and drifts of prominence structures may simulate quasi-oscillatory motions. A comparison with theory may thus only be allowed for highly stable prominences.

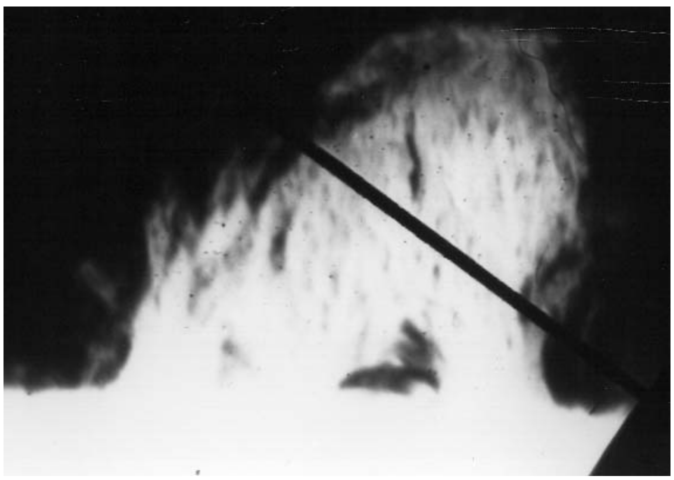

Fig. 6. H_α slitjaw images of a prominence with an enlarged space between the vertical thread structures being a typical candidate for a vertically upward moving disturbance with high Doppler shifts at its borders

7. Repeated disturbances

Such a candidate was the prominence at W40N, observed on July, 31 (A) and August, 3 (B and C). However, even this apparently stable prominence repeatedly exhibited disturbances of the kind described by Stellmacher & Wiehr (1973): a region of low (or absent?) emission moved almost radially through the prominence body showing occasionally Doppler shifts at its boundaries (e.g. locations 37” and 42” in Figure 3). Such events occured in that W40N-prominence on July, 31 (A), August, 3 (B and C), and also on August 1, where no time series but only a few spectra could be taken between clouds. Prominence-G exhibited similar events. Interestingly, both prominences were of the same ’hedgerow type’ (cf. Figure 6) as that observed by Stellmacher & Wiehr (1973).

The repetitive character of such events as well as the temporal variation of the Doppler velocities at their boundaries may simulate quasi oscillatory motion. Hence, also for such apparently ‘quiescent’ prominences, evolutionary variations are hardly separable from pure internal oscillations. These, instead, require a statistical analysis from a large number of observations. A corresponding observing routine has been started at the Locarno observatory.

Acknowledgements. The Gregory-Coudé Telescope is operated by the ’Fondazione Istituto Ricerche Solari Locarno’(FIRSOL). The ’limb guider’ was realized at the FH-Wiesbaden in course of a Diploma work by D.Thomas.

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far not been reported in former papers. A possible occurrence of power maxima due to the usual ‘global’ correlation is thus not yet considered.

4. Data reduction

Our spectra were corrected for the dark and the gain matrices, and the superposed straylight aureole was subtracted. The thus obtained time series of Ca^+ 8542 emission spectra were displayed as a movie. Figure 2, containing a sample of 12, i.e. each tenth, of the total of 120 spectra of prominence-A, gives an impression of what the movie clearly shows: a ’snake like winding’ of the emission streak with time, but also ‘lateral’ motions at the boundaries where structures separate from the main prominence body.

For a quantitative analysis, Gaussian profiles were fitted to the emissions. This yields for each spectrum the spatial variation of central wavelength and maximum line intensity along the slit. The temporal and spatial variation of the Doppler shifts given in Figure 3 shows the oscillations indicated in Figure 2 and well visible in the movie. Figure 3 also shows that some oscillations do not last over the total time interval and cover restricted spatial areas of a few arcsec.

Finally, the power as a function of the time frequency was determined for locations of pronounced emission after suitable spatial averaging (Figure 4). Instead of the commonly applied Fourier analysis, we computed the Power spectra by means of a Lomb normalized periodogram (see e.g. Press et al. 1988). This algorithm also works for unevenly sampled data with time interruptions (as introduced by small cirrus clouds for prominence-C and by hardware failures for prominence-D), and furthermore allows for a much improved frequency resolution.

5. Results

For selected spatial regions with sufficiently high emission, the power spectra averaged over several rows are given in Figure 5. Significant power maxima from this figure, summarized in Table 2, show the known period near one hour for prominences A and D, both being observed over a sufficiently long time interval of 2 hours. Since the other time sequences are not long enough for a detection of these periods, our data agree with a general existence of long periods in prominences (cf. Wiehr et al. 1984; Bashkirtsev & Mashnich 1983, 1984).

Table 2 shows that for all prominences, except B, periods tend to group near 20 min, a value which Wiehr et al. (1989) found in nearly all of their observations. Periods between 3 and 10 min are slightly indicated in all observations with small cycle times, i.e. not in prominences A and D. Allthough the significance of those power maxima hardly exceeds the 90% level, their ‘grouping’ near periods of 3.5, 4.1, 5.3, 8.2, and 9.4 min may be a hint for their reliability. Prominence-A shows periods near half an hour, which still existed three days later (prominence-B), indicating a long lifetime. Indication for harmonic frequencies, as reported by Balthasar et al. (1988) and

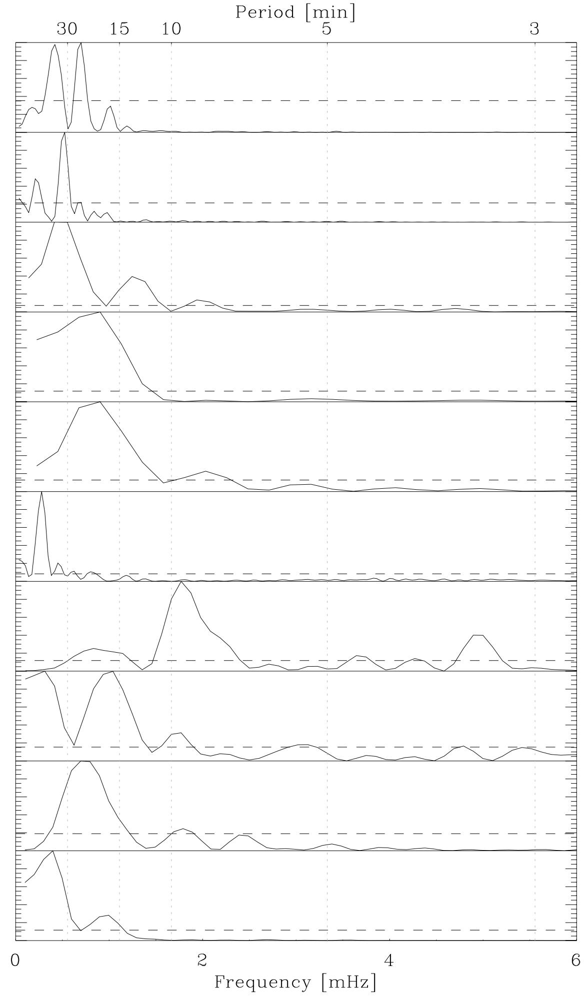

Fig. 5. Power of the Doppler shifts as a function of frequency at the locations of prominent Ca^+ 8542 emission maxima in prominence A (22-30; 48-54), B (73-76), C (5-8; 23-28), D (33-39), E (30-35; 51-57) and F (35-41; 51-60). The dashed lines mark the 90 percent confidence level.

Table 2. Doppler periods in the spatial ranges from Figure 5

pr. No.	loc. ["]	periods [min]						
A	22-30	100	42	24.4	16.5	14	–	–
A	48-54	79.5	33	24.4	20	17	–	–
D	33-39	62	37	27	21	14	–	–
B	73-76	36	13	–	8.3	5.3	4.1	3.6
C	5-8	–	20	–	–	5.3	–	3.5
C	23-28	–	20	–	8.2	5.4	4.1	3.4
E	30-35	–	20	9.4	5.2	4.5	3.9	3.4
E	51-57	–	17	9.6	5.4	4.4	4.0	3.5
F	35-41	–	23	9.3	6.8	5.0	4.2	3.8
F	51-60	45	17	–	–	–	–	–

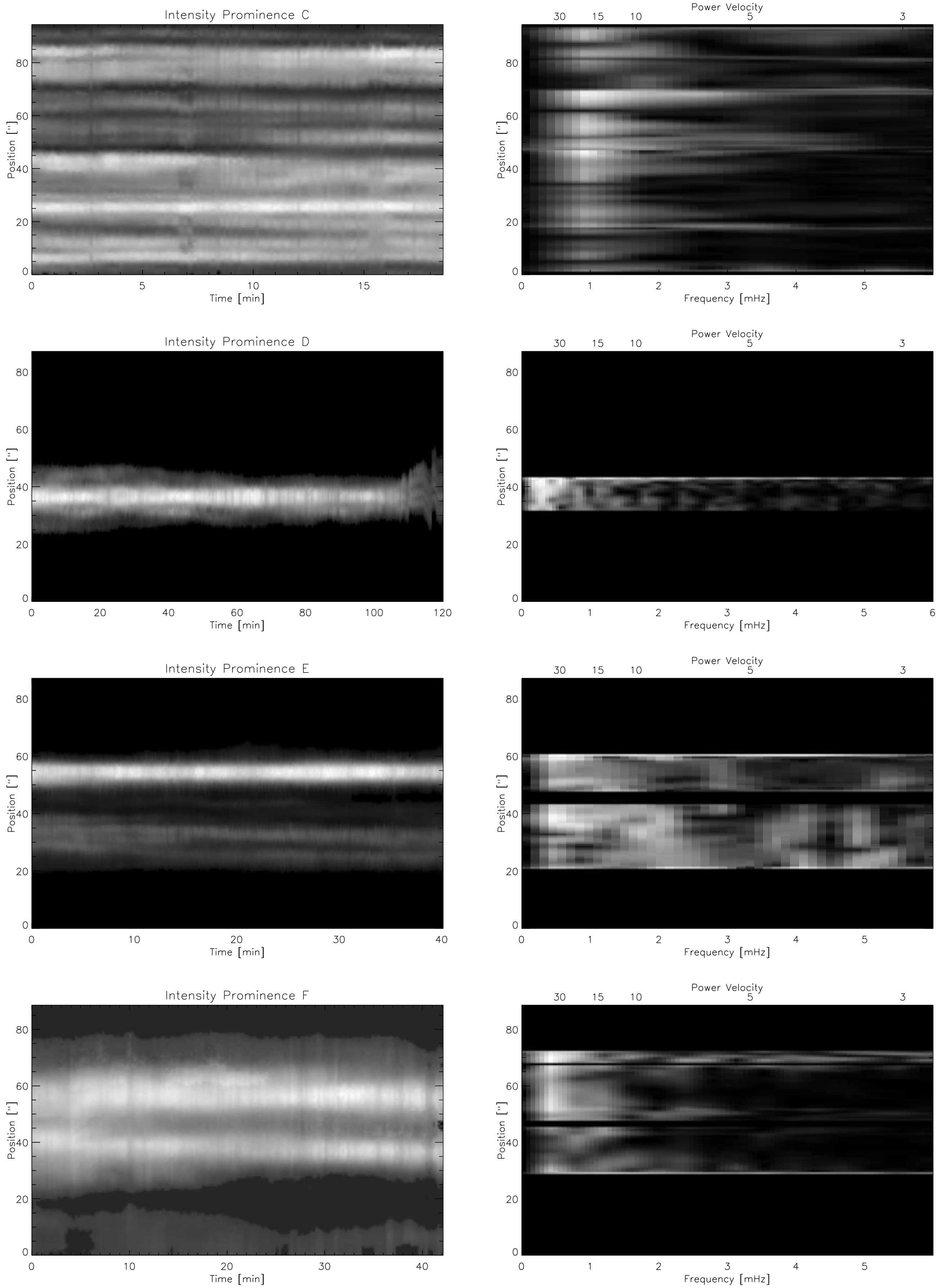

Fig. 4. Power as a function of frequency (abscissa) and location along the slit (ordinate) of Doppler shift together with the time variation of the central intensity (left panel) for the prominences C, D, E, and F

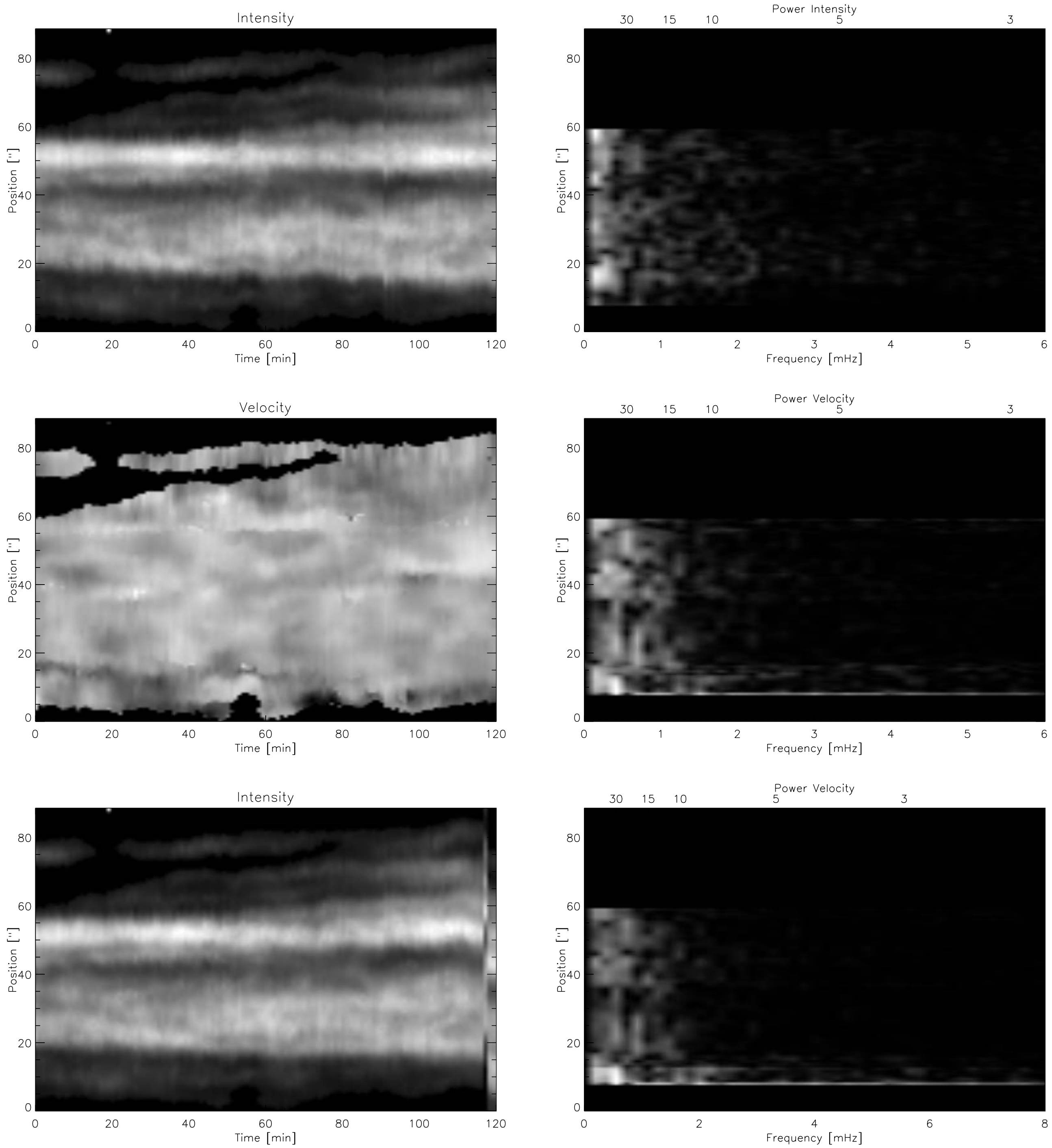

Fig. 3. Temporal (abscissa) and spatial (ordinate) variation of the Doppler shift and central Ca^+ 8542 intensity (left panels) together with the corresponding power distribution (right panels) in prominence-A. The two intensity distributions (lower left) differ by the correlation procedures which are applied to locations 50-53 (upper), resp. 20-28 arcsec

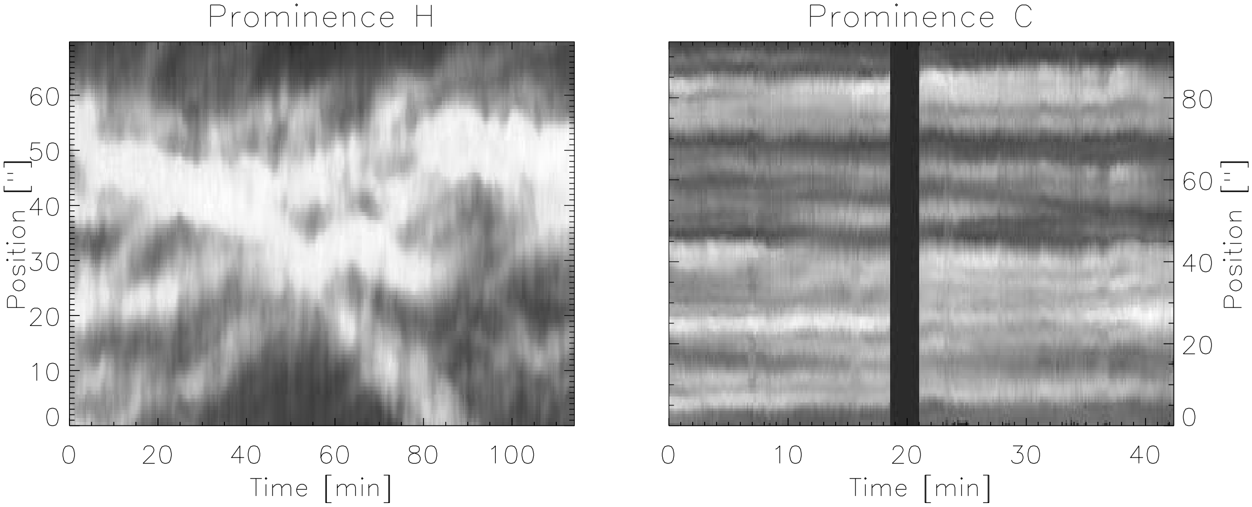

Fig. 1. Time variation of the spatial intensity distribution (along the slit) of the Ca^+ 8542 emission in prominence-H (left panel), showing strong lateral motions and evolutionary changes which make guiding on the slit as difficult as a spatial correlation during data reduction; right: prominence-C showing significant evolutionary variations

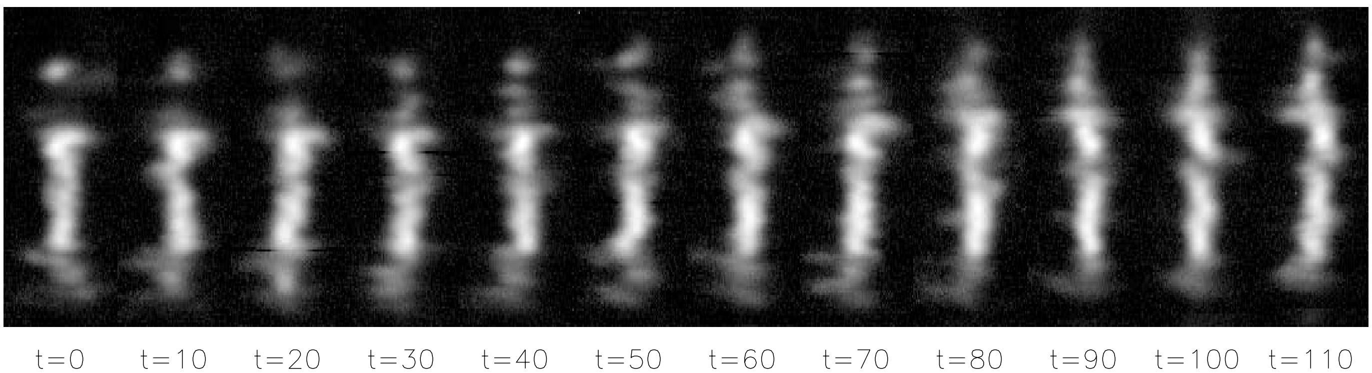

Fig. 2. Time series of the Ca^+ 8542 emissions for 12 of the total of 120 spectra observed in prominence-A.

Table 1. Characteristic parameters of the prominences observed

prom	location	date	t_{tot}[min]	Δt_{rep}[sec]
A	W40N	31.7.	120	60
B	W40N	03.8.	30	6.5
C	W40N	03.8.	19	8
D	E17N	04.8.	120	20
E	W50S	04.8.	40	7.5
F	E42S	13.8.	42	15
G	E40S	14.8.	240	15
H	W20N	16.8.	115	15

very effectively drifts of the limb perpendicular to the slit with an accuracy of about one arcsecond.

3. Spatial correlation in the slit direction

Guiding in the direction of the slit turns out to be rather difficult if individual prominence structures exhibit motions or evolutionary changes (as decay or birth). This is most impressively seen in the intensity variation of prominence-H (Figure 1). Such prominences are not only hard to be guided on the slit, but also the numerical correlation procedure in the slit direction is almost impossible. A 'global' correlation of the total spatial intensity distribution in the spectra may introduce arbitrary lateral shifts, the correlation of one single structure may yield unrealistic shifts of the neighbouring structures.

On the other side, Doppler measurement at a fixed spatial location are senseless for emission structures which drift away or decay, since Doppler shifts are only defined at locations with significant emissions. The determination of Doppler oscillations in such structures would require their 'stretching' by a local correlation procedure, individually applied to each intensity maximum. To our knowledge, such a local correlation has so

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Problems in measuring prominence oscillations

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Received , accepted

Abstract. Time variations of Doppler shifts of the Ca^+ 8542 Å emission in quiescent solar prominences have been measured. A new type of 'limb guider' assures a highly constant distance of the spectrograph slit from the solar limb and furthermore removes low frequency image motion in the direction perpendicular to the slit.

Remaining image motion along the slit is usually removed by a correlation of subsequent spectra. This procedure, however, cannot be applied globally to the whole spatial height in the spectra if individual structures exhibit lateral motions along the slit or even decay or arise during the observation. We therefore correlate defined individual emission maxima from successive spectra.

The finally obtained power spectra show oscillations with a variety of periods at restricted locations. The data favour the known general presence of periods near 20 and 60 min, however they give only slight indication for 'typical' periods near 3 and 5 min.

Key words: sun – prominences – oscillations

1. Introduction

The physical conditions of cool solar prominences embedded in hot coronal surrounding is not yet understood. Numerical calculations (e.g. by Joarder & Roberts 1993) show that prominence oscillations may be driven by magnetic, pressure, and gravity forces. They manifest as internal, external, and hybrid modes (Oliver et al. 1993). This division disappears if the prominence–corona transition region, PCTR, is smooth (Oliver & Ballester 1995). In case of a sharp PCTR, internal prominence oscillations can be detected only if the PCTR is optically thin (Oliver & Ballester 1996).

Hence, the determination of oscillatory modes in prominences gives important physical information. Existing observations (an extended list of references is given by Oliver & Ballester 1995) point to a large variety of periods. Even two simultaneously used telescopes give no coherent results (Balthasar et al. 1993). A possible reason is imperfect guiding of the prominence on the spectrograph slit (cf. Balthasar & Wiehr 1994), since the observer may tend to apply corrections in constant time intervals given by the telescope's drift.

This can be avoided by an automatic guider which stabilizes the image perpendicular to the spectrograph slit, whereas drifts parallel to the slit can be removed in the spectra. Such a 'one-dimensional limb guider' has been realized at the engineer's college, FH Wiesbaden, and was first applied for the present observations. The aim of this paper is to check the existence of 'typical' periods from observations of several prominences guided on the slit with exceptional high spatial accuracy.

2. Observations

Using the evacuated Gregory-Coudé Telescope (⌀=45 cm; f=25 m; Wiehr et al., 1980) of the 'Istituto Ricerche Solari' near Locarno/Switzerland (Bianda & Wiehr 1994), several prominences were observed on July 31, August 3, 4, 13, 14, 16, 1996, cf. Table 1. The emission line Ca^+8542 has been used because of its narrow width (due to μ_{Ca} = 40) and comparatively large brightness as well as the low straylight aureole and the better seeing in the IR. The 600×400 pixel CCD, covering 107"×3 Å, was binned to 150×200 pixels, corresponding to a pixel size of 0.7"×14.5 mÅ. This spatial scale is adapted to the slit width of correspondingly 1.5", required for an acceptable integration time of 2 sec. Depending on the temporal stability of the individual prominences, time series up to 2 hours were taken with cycle times between 6.5 and 60 sec, cf. Table 1.

A 'one-dimensional' guiding perpendicular to the slit is realized by a plan-parallel glass-plate directly fixed to the axis of a stepping motor. It is driven by a photo-diode monitoring the white light limb which is oriented parallel to the slit by means of a Dove prism. A second photo-diode inside the solar disc gives a reference intensity accounting for transparency variations. This prototype of a limb-guider is still limited to a few Hertz thus removing only low frequency image motion, but

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