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FINE STRUCTURE OSCILLATIONS OF A QUIESCENT PROMINENCE

PLAMEN NIKOLOV[1], TANYU BONEV[1], NIKOLA PETROV[1], PAWEL RUDAWY[2], BOGDAN ROMPOLT[2], PETAR DUCHLEV[1]

[1]*Institute of Astronomy, Bulgarian Academy of Sciences*
[2]*Astronomical Institute of Wroclaw University*
E-mail: pnikolov@astro.bas.bg, tbonev@astro.bas.bg, nikipetrov@yahoo.com, rudawy@astro.uni.wroc.pl, rompolt@astro.uni.wroc.pl, duchlev@astro.bas.bg

Abstract. High resolution H-alpha spectrum observations of a quiescent prominence (QP) obtained at Pic du Midi Observatory are digitized and studied. The long time series ($\sim$ 2.5 hours) of spectrograms reveal similar periods of oscillations from different parts of the prominence body. The computed line-of-sight velocities of the fine structure exhibit no changes of the amplitudes with time. The analyzed fine structures represent kink-mode oscillations of average periods.

1. INTRODUCTION

The average duration of a stable magnetic configuration that supports quiescent prominences (QPs) is about 3 hours. Observations of such prominences on the solar limb are a good base for exploring the periodic changes in their fine structure. Disturbances of the prominence plasma magnetic fields may readily produce quasi-oscillatory motions of local parts or even of the whole prominence (Wiehr, 2004).

When such prominences are observed on the solar disk as filaments the Doppler shift measurements indicate both upward and downward line of sight directed plasma motions. Internal motions in QPs have been long time under study but there is still little knowledge about their origin, behavior, and range of velocities (Petrov, 2007). Pettit (1932) has found, from time sequences of filtergrams, plasma velocities of 5 to 10 km/s. The H-alpha high-resolution observations of Yi (1992) have given velocities of about ± 1 km/s.

There is a big amount of observations implying oscillations in QPs, and cyclic velocity and intensity changes are a commonplace there. The oscillations have a large range of periods, of the order from $3 \div 5$ min up to one hour. High-resolution observations of quiescent filaments (QFs) show oscillations that are strongly tied to their fine threads (Yi, Engvold, and Keil, 1991). High resolution H-alpha spectral observations often present non attenuation periodicity changes of line of sight (l.o.s.) velocities with period 50-60 min (Petrov, 1997; Dermenjiev, 2001). For observations longer than 2.5 hours some investigations show similar periods with attenuation amplitudes (Wiehr, 2004; Terradas, 2002).

2. DATA SET AND DATA REDUCTION

We examine the structure and the l.o.s velocity variations of a QP on the base of high resolution H-alpha spectra and filtergrams obtained by one of the authors (BR) on October 16, 1977 at Pic du Midi Observatory. The prominence was located at the northeastern (N52-E55) limb, according to Meudon synoptic map for Carrington rotation - 1660 (Fig. 1). The filament lasted for two solar rotations and during the observations it was on its first rotation.

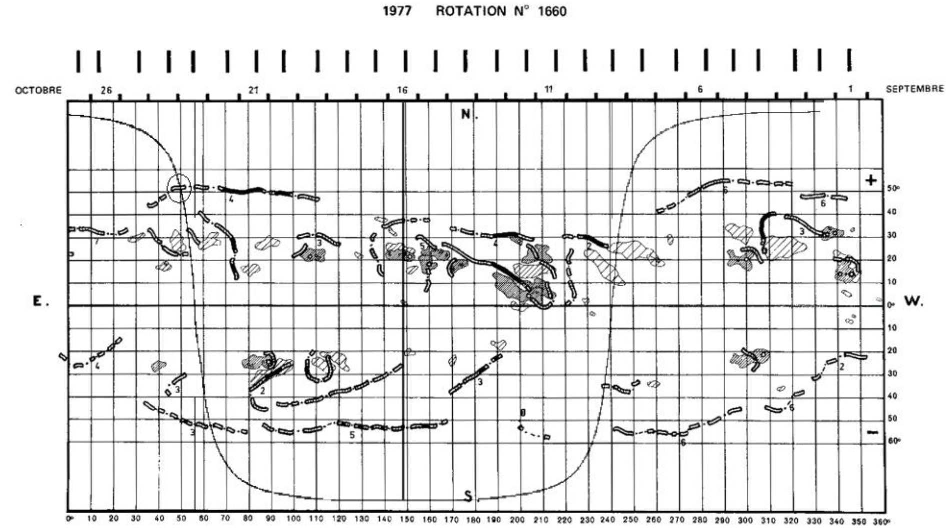

Figure 1: Part of synoptic map and the QP position on the solar limb (MSP, 1977).

The series of high-resolution H-alpha spectra have been recorded on photographic plate using the 11-m solar horizontal telescope equipped with a 9-m spectrograph (Mouradian and Leroy, 1977). A spectroheliosan, developed at the Astronomical Institute of the Wroclaw University, was used for precise positioning of the slit. A slit-jaw unit coupled with an H-alpha camera has provided H-alpha filtergrams together with the actual slit position against the prominence body. The spectra from the QP have been taken with an exposure time of 5 s and 0.75 mm slit width.

The H-alpha filtergrams, presented on Figure 2, show that the QP consists of several arches. Our data include time series of 37 H-alpha spectra at 42 consecutive slit positions on the body of the prominence. For the purpose of this study we took data for two slit positions, 06 and 25, marked on Figure 2. The spectra obtained at position 25 were divided into two subregions, denoted 25a and 25b, respectively. The locations of these positions are chosen according to the quality of the observational data and include all spectra obtained during the observation run. The spectra have been obtained in a time interval of about ∼150 min (from 08:36:50 UT to 11:00:29 UT) with a nearly equal time step of 3.5 min between the consecutive scans.

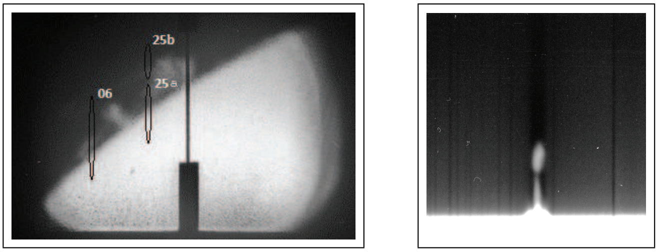

Figure 2: H-alpha filtergrams (left) together with the actual slit position against the prominence body and the respective H-alpha spectrogram, slit position 25 (right) with telluric lines of absorption.

The selected spectra and filtergrams have been digitized with an aperture of 0.016 mm which corresponds to ∼117 km at the QP body. The first step of the data reduction is the proper orientation of the spectral images, i.e. the alignment of the transition line between background and photosphere exactly along the columns of the image. In the second step we derive the dispersion of the spectrograms by use of telluric lines well expressed in the background next to the H_α absorption. The value derived for the inverse linear dispersion is equal to 0.012514 Å/px. We selected the minimum of the teluric H_α absorption to be the zero point for the wavelength mesurements. Profiles of the QP's emission were taken along to the dispersion at different heights, starting 3000 km above the photosphere. The maximum of intensity of each profile was considered as representative for the l.o.s velocity of the QP at the coresponding height. The maxima were derived by fitting the profiles with parabolic fun

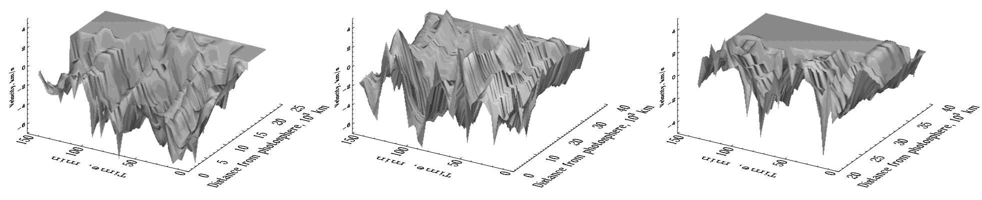

Figure 3: Distribution of l.o.s velocities in space and time for the three slit positions. Left, middle, right: slit position 06, 25a, 25b, respectivelly. The x-axis represents the distance along the slit in 10^3 km and the y-axis shows the time in minutes.

In a third step we corrected for solar rotation (Snodgrass, 1989) under accounting for the QP position on the solar limb. And finally, in a fourth step, all profiles obtained at a given slit position at different times were combined in 3-D maps. These maps, shown in Figure 3, represent the l.o.s. velocity dependence on time at different heights above the photosphere.

3. RESULTS AND DISCUSSIONS

The velocity fluctuations shown in Figure 3 are distributed, with some exceptions, in the range [-5÷5] km/s. The fluctuations exhibit quasi-periodic structure in time but only small variations in space, along the slit. The observed globally coherent structure is a characteristic feature of the kink mode (Van Doorsselaere, 2008).

The variations of l.o.s velocities were measured from the photosphere to distance of up to 50 000 km over a time interval of about 2.5 hours. In order to derive periods of the oscillations we selected those regions along the slit which are characterized with the highest signal-to-noise ratio, extracted the profiles around these positions, calculated average profiles by integration along the space direction, and approximated the averaged profiles with the following function:

$$\mathrm{v} = \mathrm{v}_{mean} + \mathrm{v}_o \ \sin(\omega \mathrm{t} + \phi) + \mathrm{a} \times \mathrm{t},$$

where t is the time, v_{mean} is a constant velocity along the l.o.s., v_o is the amplitude of the periodic variations, ω is the cyclic frequency, and ϕ is the initial phase. The term a × t has been added finally to account for possible constant increase/decrease of the radial velocity.

Figure 4 shows the averaged profiles extracted at the three regions and the best approximations with the function given above. At slit position 06 the velocity variations are characterized by periodic changes superimposed on a gradual constant increase of the mean radial velocity from approximately -6 km/s at the beginning of the series to about -3 km/s, 2.5 hours later. The profiles at positions 25a and 25b are well described by the periodic term only, slightly blue shifted to a constant mean values of -2 km/s, and -1 km/s, respectively.

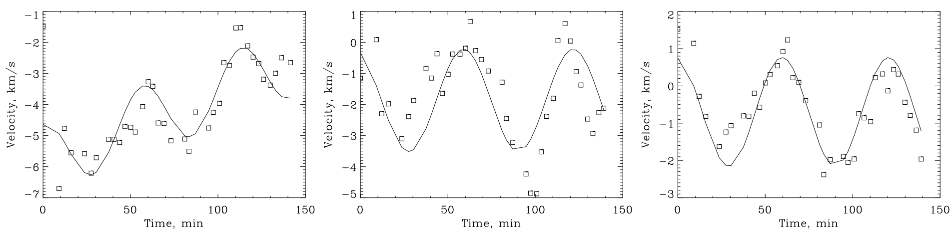

Figure 4: Squares: Measured line of sight velocities of the QP fibril for profiles extracted at slit positions 06 (left), 25a (middle), and 25b (right). Full lines: Fits to the data.

The cyclic frequency derived from the fit of the data obtained at slit position 06 is $\omega = 2\pi/\mathrm{T} = 1.74\mathrm{x}10^{-3}\ \mathrm{s}^{-1}$, which corresponds to a period T=60 min. For slit positions 25a and 25b the frequency derived from the fits is $\omega = 2\pi/\mathrm{T} = 1.69\mathrm{x}10^{-3}\ \mathrm{s}^{-1}$ corresponding to a period of 62 min. Assuming that one period is equivalent to the time interval which is needed for the plasma flow to move along the full length of the arch, we can calculate that length if we know the velocity of the flow. Typical flow velocities are given by Tandberg-Hanssen (1995) and amount to 55 km/s. With the derived periods this yields an arch length of about 200 000 km.

The Doppler shift measured with respect to the averaged H-alpha profile of the chromosphere, indicates cyclic displacement or vibration of the arches, which are typical for kink modes with average periods. The morphological structure of kink modes is presented on Figure 5.

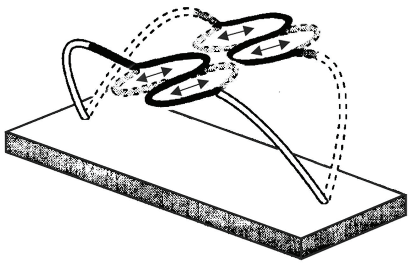

Figure 5: The diagram shows the pattern of kink mode fine structure oscillations of a quiescent prominence.

4. CONCLUSIONS

Three time series of l.o.s velocities of QP were analysed. The variations of l.o.s velocities were measured from the photosphere to distance of up to 50 000 km over a time interval of about 2.5 hours. The changes in velocities are in the range [-5÷5] km/s. From the time sequencies obtained at two different slit positions we found oscillations with periods of about 60 and 62 min. The derived periods in combination with typical flow velocities yield a prominence arch length of about 200 000 km. The results obtained for the observed QP are typical for kink mode oscillations (Wiehr, 2004).

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