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Observations of density fluctuations in a quiescent prominence

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Abstract. Density fluctuations in a torsional quiescent prominence were studied with Solar Optical Telescope on board of Hinode satellite. Continuous observations were made in Ca II H line from ~15:00 UT May 03, 2008; the observational duration was $\sim$ 1hr with a cadence time $\sim 30s$. The emission intensity along the prominence axis as functions of altitudes and time shows fluctuations in brightness with local peaks in Fourier power spectra, indicating the presence of periods and intervallic displacements to be $3 \sim 11$ min and $2 \sim 7$ Mm respectively and statistically significant peaks at $368 \pm 63s$ & 620 ± 41 s, and 3.3 ± 0.6 Mm regime. The distance is the line of sight projection. These intensity disturbances may perhaps be caused by density fluctuations originated from compressional waves in which the possible origin could be the combinations of p-mode oscillations induced at the surface and twisting of the flux tube.

Keywords. Sun: prominences.

1. Introduction

Solar prominences are thin elongated clouds made of mostly ionized gas with typical temperatures $4800 \sim 6000$K and plasma densities $10^{10} cm^{-3} \sim 10^{11} cm^{-3}$(Zirin 1988). Surrounded is a corona with temperatures and densities higher and lower by order of 2 respectively. They are invisible in the continuum, but may be seen in any strong emission lines. If they are spotted at the solar limb, they appear brighter against the dark space and they are called prominences. They appear dark on the disk due to background radiations from the photosphere; they are called solar filaments. In general, prominences are categorized in two kinds: Quiescent (long-lived) filaments and Active (transient, eruptions, flare-associated) filaments (Zirin 1988).

A comprehensive overview of the oscillations in prominences is given by (Mackay *et al.* 2010). Solar prominences are subject to various types of oscillatory motions. Oscillations are mainly detected from periodic Doppler shifts from spectral lines. Space-Time sliced intensity images laid side by side is another detection technique. In the present paper, study of emission intensity disturbances within a torsional quiescent prominence is shown.

2. Observation

Analysis is based upon Hinode telescope observations of quiescent prominence located at east limb at $\sim -25°$ latitude. The data was taken on May 03, 2008 from 15:00 UT for ~1 hr with a cadence of ~30s. The images consist of 1024×1024 pixels in Ca II H (396.8 nm) line with a bandwidth 0.3 nm and the pixel size $\sim$ 80km. The present paper focused on the prominence shown in Fig. 1, in particular, the left flux tube. The detection technique is to obtain averaged emission intensity integrated along the line of sight near the flux tube axis. The results were converted by fast fourier transform for determinations of any intervallic fluctuations. Daily images of full disk H alpha from Solar

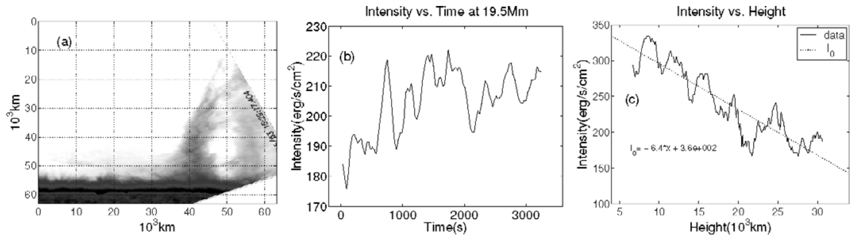

Figure 1. (a)Prominence image at Ca II H line taken on May 03 15:29 UT. The color was inverted and the contrast was enhanced. This image consists of 512 × 512 pixels. (b)Temporal evolution. Distance is approximated from photosphere. (c)Spatial displacement at 14:49:19

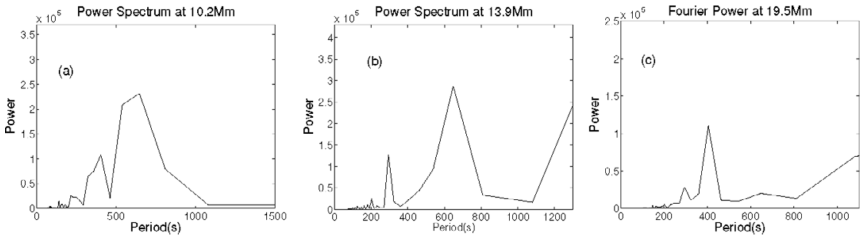

Figure 2. (a)∼(c) Power spectra at different altitudes.

Magnetic Activity Research Telescope (SMART) showed this prominence appeared from west limb around Apr 20, surviving all time before it came to east limb where observations of Hinode took place.

3. Results and analysis

Movies of the prominence showed moving features, partially brighter than ambient, at ∼15:05:08 UT, appearing from near the apex moving in torsional motions toward the left foot point of Fig. 1a and disappearing behind the tube at ∼15:10:18 UT. The line of sight projection speed was determined by tracking the flow; it is estimated 10 ∼ 13 km/s. Several other flows are seen but a much smaller scale. If one supposed these flow directions represent the magnetic field line, then the pitch angle $\tan^{-1}(B_\phi/B_z)$ (in usual cylindrical coordinates with z along the tube axis) seems to be higher at a foot point and decrease at higher altitudes which is seen from movies. Only downflows were observed in view of the left flux tube. Fig. 1 also shows plasma fluids escaping into outer space from near left foot point.

Fig. 1b & 1c show temporal evolutions and spatial displacements at ∼19.7 Mm and 14:49:19 UT respectively(approximated from the photosphere). Fig. 2 shows power spectra of temporal evolutions at three different heights. Table 1 summarizes intervallic displacements measured from power spectra at different time. Fourier power spectra indicate local peaks in periods and intervallic displacements to be 3 ∼ 11min and 2 ∼ 7 Mm respectively and statistically significant peaks at $368 \pm 63s$ & 620 ± 41s, and 3.3 ± 0.6 Mm regime.

Because the intensity and density are correlated, the quasi-periodic and intervallic fluctuations in intensity could be a signature of compressional waves. However, this wave like phenomena did not clearly show signs of drifting, signifying that these intervallic fluctuations might represent near stationary waves rather than propagating. The origin of the stationary-like wave could possibly be due to the twisting of the flux rope. According to Zhugzhda (Zhugzhda 1996), the torsional velocity v_ϕ and the magnetic field B_ϕ are

Table 1. Summary of intervallic displacement

Time (UT)	Intervallic displacement ($10^3 km$)	Power (10^5)
14:49:17	3.0 ± 0.2	27
15:02:19	2.5 ± 0.2	7.4
15:10:18	4.0 ± 0.7	10
	6.8 ± 1.0	73
15:16:48	3.6 ± 0.5	9.0
	2.0 ± 0.2	7.8
15:28:47	3.5 ± 0.1	55
15:34:20	3.2 ± 0.8	6.3

related to the longitudinal component υ_z and B_z by the following.

$$\frac{\partial}{\partial t}\left(\frac{B_\phi}{B_z}\right) + \frac{\partial}{\partial z}\left(\upsilon_z \frac{B_\phi}{B_z}\right) = \frac{\partial \upsilon_\phi}{\partial B_z} \tag{3.1}$$

If the equilibrium value $B_{\phi,0}$ is non-zero, the torsional components give rise to density perturbations and longitudinal flows. If the above case is considered, observations of such emission intensity oscillations could provide information about the magnetic field strength based from theoretical studies. The moving features discussed earlier are perhaps an indication of mass flows because they were isolated and appear irregularly. As was discussed, only downflows seem to occur in this flux tube. In this sense, the other foot point carries out the upflows and represents continuous supplies of chromospheric materials. This process might be a part of maintenances and stabilities of quiescent prominences.

Other things to note is the intensity I_0 almost decreases linearly with increasing heights. This slow decline in density may be related to its long-lived, continuous mass flows, or combinations of both.

4. Discussion and conclusion

The present paper discovered periods near ∼6 min and ∼11 min regime. The fact that measurements yield two frequencies might be because the oscillation from twist is accompanied by upward acoustic waves initiated by photospheric motions at the foot point. A number of papers discuss its presence of 5 min global photospheric oscillations generated by p-mode waves. Slow magnetoacoustic waves in coronal loops appear to be created by p-mode (De Mootel *et al.* 2000); likewise, continuous fluctuations in density suggest that these wave like phenomena may also be induced by p-mode oscillations. Shorter and longer periods could be the consequence of p-mode and twist respectively. Although the dominant period is 5 min, Garcia *et al.* have identified 10 modes above ∼666 s seen by GOLF (Garcia *et al.* 2001), possibly implying the coupling of other periods as well. However, we emphasize that transverse waves are not due to p-mode oscillations, but by some other means (e.g. microflares) because the oscillations are generally damped and cease after few cycles (Mackay *et al.* 2010). Because of the quasi-periodic fluctuations in intensity, we rather not disregard the approach the there are MHD waves in this prominence.

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