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Hα Intensity Oscillations in Large Flares

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Abstract. We reinvestigate the problem of Hα intensity oscillations in large flares, particularly those classified as X-class flares. We have used high spatial and temporal resolution digital observations obtained from Udaipur Solar Observatory during the period 1998–2006 and selected several events. Normalized Lomb–Scargle periodogram method for spectral analysis was used to study the oscillatory power in quiet and active chromospheric locations, including the flare ribbons.

Key words. Sun: oscillations, chromosphere, flares.

1. Introduction

Hα intensity oscillation was detected many decades ago by several workers, e.g., Jensen & Orral (1963) and Elliott (1969) who reported chromospheric oscillations with a period of 120–130s. More recently, Jain & Tripathy (1998) and Wang *et al.* (2000) amongst others showed the influence of flares on the chromospheric oscillations. Considering a variety of contradictory results obtained by earlier workers, we reinvestigate the problem of oscillations in the quiet, active and flaring locations in the chromosphere.

2. The observational data

The Hα data of solar flares used for this study were obtained by the 6-inch aperture Spar telescope of Udaipur Solar Observatory in the observational period 04:00–12:00 UT of USO time window. The data have spatial and temporal resolution of the order of 2–3 arcsec and 3s–60s in different datasets. The selection of data was carried out essentially with two criteria: (i) energetic flares belonging to X-class, and (ii) flares occurring in the location between $\pm 50^\circ$ in longitude and $\pm 20^\circ$ in latitude, so that the projection effects may be neglected (Venkatakrishnan & Allen Gary 1989).

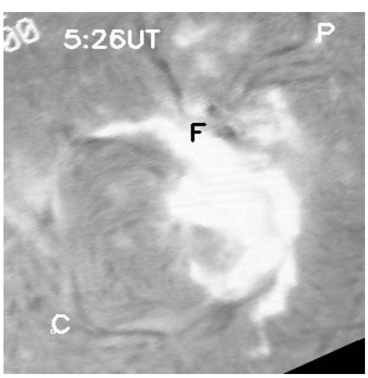
3. Data analysis

From the large set of available images, we selected the best images taken at good seeing conditions. Standard image processing steps were then applied on the selected images. The effects of guiding and image motion were reduced by registering the images. To remove effects of varying observing conditions during the observations we normalized the images.

The relative intensities at quiet (C), plage (P) and flare ribbon (F) points were calculated by taking 8×8 matrix in each frame. These locations were carefully selected using movies of the respective events. The tracking errors and atmospheric seeing effects do not allow use of smaller windows, while larger windows would tend to dilute the net intensity. The power spectrum of these relative intensities were estimated using Lomb (1976) method for data sampled at uneven intervals. Jian *et al.* (2007) have recently used this method for spectral analysis of VLBI observational data, and investigated the problem of appearance of spurious signal in the data with unequally spaced sampling.

4. Results and conclusion

The Hα filtergrams for three of the selected flares observed on 28 November 98 (X3.3/3N), 10 April 01 (X2.3/3B) and 26 October 03 (X1.2/1N) were analyzed. Hα intensity flare images at maximum phase for the 10 April 01 event is shown in Fig. 1(a). The three positions corresponding to the flare ribbon, plage region and quiet chromospheric region are denoted by F, P and C in the Hα filtergram over which we obtained relative intensity profiles as shown in Fig. 1(b), alongwith their respective power spectra in Fig. 2(a–c). The power spectrum of the 10 April 01 flare shows periodicity at 3.3 mHz in quiet chromosphere and in the plage. The peak at 3.3 mHz corresponds to 5-min oscillation in the chromosphere. The power spectrum for the 26 October 03 and 28 November 98 events show dominant peaks at 3.3 mHz indicating the existence of 5-min oscillation in the quiet chromosphere, with other significant peaks at 2.5 and 4.6 mHz. The significant peaks at the plage locations were also found at 3.3 mHz. We found that the amplitudes of some peaks, which were prominent in the quiet chromosphere, reduced in the flare. The other significant peaks at 1 mHz in quiet, plage and flare locations correspond to a spurious large period oscillation perhaps appearing as the artifact of Lomb's method (Jian *et al.* 2007), and is not of interest.

(a)


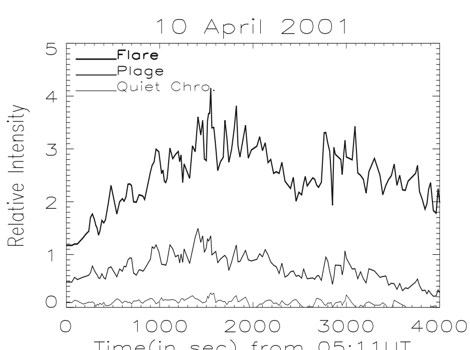
(b)


Figure 1. **(a)** Hα intensity flare images at maximum phase – 10 April 01 event. The points F, P and C denote flare ribbon, plage and quiet chromospheric positions over which we obtained relative intensity profiles. **(b)** Hα intensity profiles at three positions F, P and C.

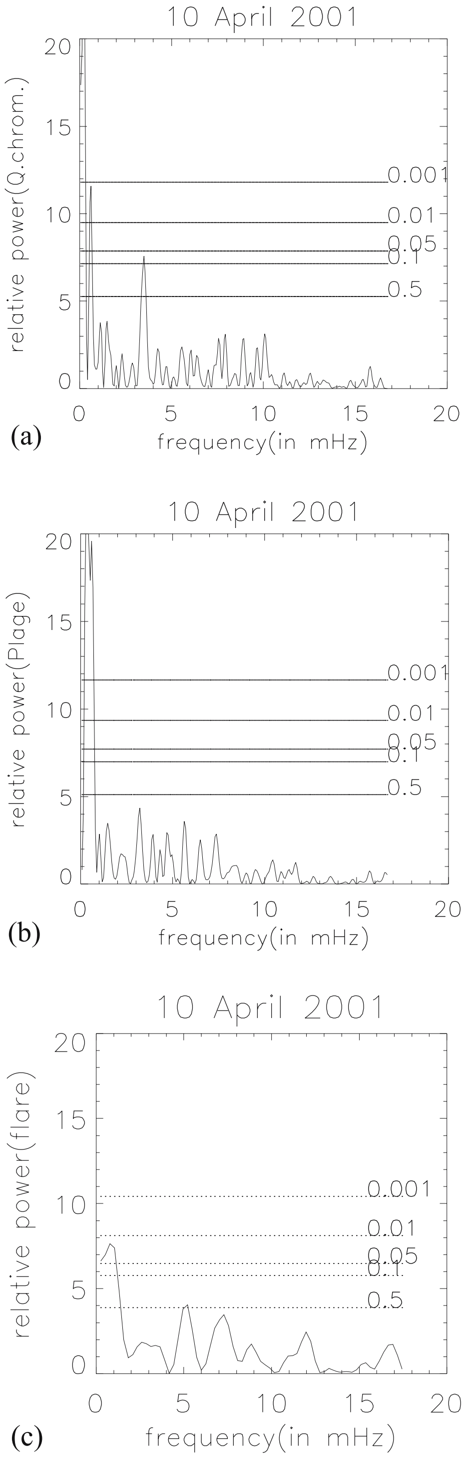


Figure 2. Power spectra corresponding to time profiles at (a) quiet location (reference) 'C', (b) plage 'P', and (c) flare 'F' marked in Fig. 1(a).

In summary, we arrived at the following inferences from Hα intensity measurement of these events. The results obtained from the analysis of the six flares are still not conclusive enough and do not consistently provide the 3- and 5-minute oscillations at all the locations observed in Hα. However, there are varying levels of detection of these oscillations in individual events, viz.,

- 3- and 5-minute oscillations are present in quiet chromosphere in all the cases alongwith some additional periodicities as reported by earlier researchers.
- These oscillations are modified in the flare locations as found in some cases.
- Nearly the same periodicities are found in plage as in the quiet chromosphere but with reduced amplitude.

We plan to enhance our sample of flares by including M-class flares of significant importance in optical class, such as 1B and larger, in order to increase the statistical significance of the results obtained in this study.

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