DYNAMIC BEHAVIORS OF THE QUIET SUN SEEN BY SUMER

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ABSTRACT

The dynamic behaviors of the transition region, including explosive events and oscillations, are studied using spectral observations obtained with the Solar Ultraviolet Measurements of Emitted Radiation spectrograph (SUMER). The spatial stucture and temporal evolution of explosive events are explored with the Si IV 1393 Å line. The time variation of continuum, total intensity, line center displacement and Doppler width of network and internetwork are illustrated using C II and O VI lines near disk center.

Key words: continuum and total intensity; Sun transition region; Oscillations; UV-radiation.

1. INTRODUCTION

The transition region of the Sun is charactersized by small dynamic loop-like structures, whose formation and evolution is intimately coupled to the ever evolving photospheric magnetic fields. The magnetic network is bright and highly variable in all transition region lines. Oscillations of 5-20 min in the network have been frequently reported (e.g. Lites et al.1993). In the internetwork, 3-min are the primary oscillation mode (e.g.Lites et al.1993; Carlsson et al.1997; Krijger et al. 2001). In both network and internetwork regions of high plasma flow suddenly appear for a minutes or so. These so called 'explosive evnets' are thought to be sites of magnetic reconnection (Dere et al.1989; Innes et al.1997). In this paper, we study the temporal and spatial structure of explosive events, and in particular their repetition characteristics. Transitions region oscillations are studied with C II and O VI observations.

2. OBSERVATIONS

Our observations were made with SUMER (Wilhelm et al. 1995; 1997; Lemaire et al. 1997) near disk center on June 1996 during the solar minimum year. SUMER is a high-resolution telescope and spectragraph designed to obtain stigimatic slit images with

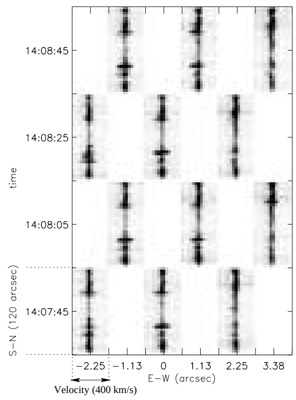

Figure 1. Time and spatial structure of Si IV *1393 Å line during two raster scans. Each raster scan consists of 6 steps in the east-west direction, with a distance of 1.13 arcsec between steps. The exposure time of each image is 5 s, and each raster takes 40 s. First the odd positions were observed (2.25 arcsec between steps) and then the even positions. Thus first the spectra E-W location -2.25, 0 and +2.25 were recorded, followed by the spectra at -1.13, +1.13 and 3.38,etc. The gap locations each raster will be filled with the average of the spectra taken just before and after at the same location. Each unit is 120 arcsec from bottom to top and runs form -200 km s^{-1} (blue shift) on the the left to +200 km s^{-1} on the right.*

spatial and spectra resolution elements of ∼ 1 arcsec and 40 mA (in first order) as well as high temperal resolution over the wavelength range from 465 Å to 1610 Å . Small rasters with many sequences for a half hour at the same region near disk center are used. Figure. 1 shows this type SUMER sequence.

3. RESULTS

3.1. Repetition of explosive events

The SUMER sequence illustrated in Figure. 1 is used with the Si IV 1393 Å line for this study. Explosive events are identified by a flux excess in blue or red

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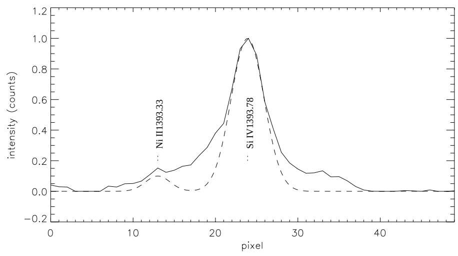

Figure 2. Average quiet Sun emission (dashed line) around the Si IV *1393.78 Å line and an explosive event (solid line). The* Ni II *1393.33 Å line blends with the blue wing about 10 to 11 pixels away from the* Si IV *line center.* Ni II *has a peak intensity about one tenth of the* Si IV *peak.*

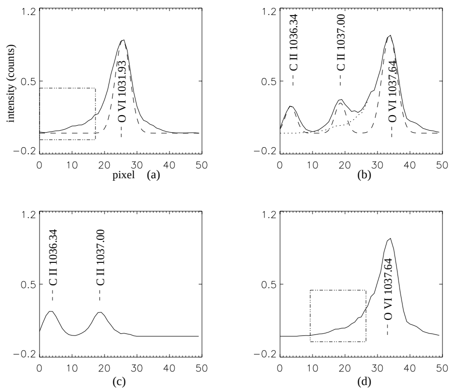

Figure 5. **a and b** : *average quiet Sun emission (dash line) around* O VI *1031.93 Å and 1037.64 Å lines with an explosive event (solid line). Two* C II *1036.34 Å and 1037.00 Å lines blend with blue wing of* O VI *1037.64 Å line.* **c and d** : *separation of the lines when subtituting the blue wing (part in the dot-dot-dash box) of* O VI *1031.93 Å to that of 1037.64 Å .*

wing as showed in Figure. 2. We find that explosive events occur repeatedly at the same location with a median time of 5 minutes between events. Figure. 3 shows the time varation of the Si IV peak intensity and red and blue wing flux excess along the slit (S-N) direction. The E-W development of the two bursts of explosive events are in Figure. 4a and b. The burst displayed in Figure. 4c is the burst with the maximum repetition number of 7. The median time between repetition events is about $\sim$ 5 minutes. The event site movement from west to east is due to the solar ratation (Ning et al.).

3.2. Transition oscillations on the quiet Sun

This study is made with observations of C II and O VI lines with the same small rasters observing sequence as illustrated in Figure. 1. Figure. 5 show the observed lines and their decomposition.

Three wavelength-integrated quantities: the total line intensity I_{total}, Doppler width 2σ and line center displacement λ_c are computed from

$$I_{total} = \int_{\Delta\lambda} (I_\lambda - I_{cont}) d\lambda \quad (1)$$

$$\sigma^2 = \int_{\Delta\lambda} (I_\lambda - I_{cont}) \times (\lambda_c - \lambda)^2 d\lambda / I_{total} \quad (2)$$

$$\lambda_c = \int_{\Delta\lambda} (I_\lambda - I_{cont}) \times \lambda d\lambda / I_{total} \quad (3)$$

where I_{cont} is a background of continuum emission obtained as by interpolating the average counts on either sides of O VI 1031 Å line. All intensity data are given in counts $arcsec^{-2}$ and per exposure time (5 or 10 s dependence on sequence). Doppler width and line center shift displacement are given in units of km s^{-1}.

The time evolution of intensity, shift velocity and Doppler width along slit direction are given in Figures. 6, 7, and 8 respectively. Doppler width presents a smaller value in network than in internetwork on both C II and O VI lines. Figures. 9 and 10 show time variation of intensity, shift velocity and Doppler width along E-W direction in the network and internetwork regions respectively. We found: (1) The Network Bright Points (NBPs), continuum (λ=1031 Å here) participates 5-min oscillations in the transition network regions; the continuum emission tend to oscillate with 3-min in the transition internetwork regions. (2) 3-min line center shift velocity oscillates on the quiet Sun, both transition network and internetwork regions. However, Lites et al. (1993) founded the long-period (in excess of 5-min) chromosphere network oscillations are prominent in both H_3 velocity and intensity. Carlsson et al. (1997) founded that only 3-min oscillates in the upper chromoshpere internetwork.

4. CONCLUSION

From the observations, we draw the following conclusions:
(1). The explosive events repeat with a median time of 5 minutes between events.
(2). The NBPs, continuum (λ=1031 Å here) participates 5-min oscillations in the transition network regions; but continuum emission tend to oscillate with 3-min in the transition internetwork regions. 3-min line center shift velocity oscillates on the quiet Sun, both transition network and internetwork regions. Network has a smaller Doppler width of C II and O VI lines than internetwork.

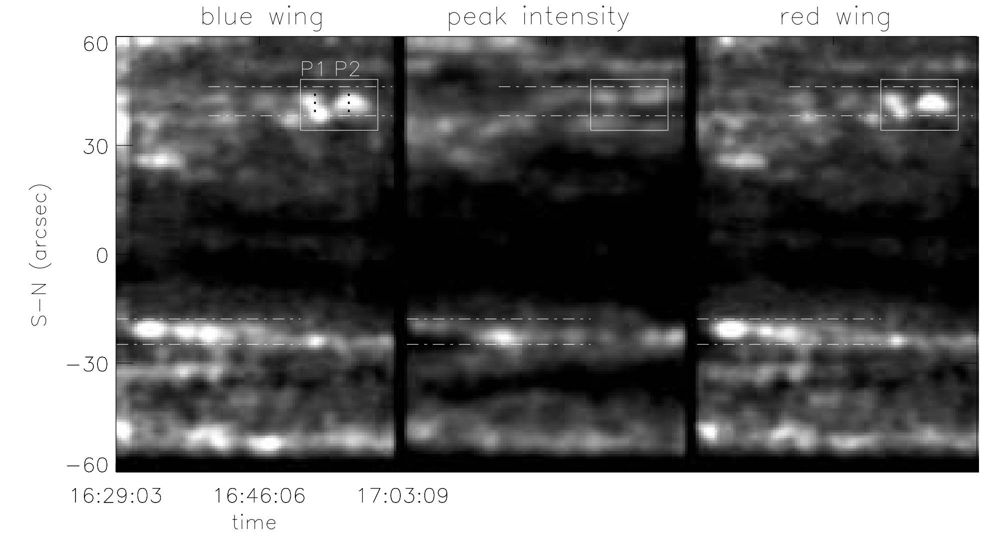

Figure 3. Time variation of blue wing, peak and red wing intensity during a half hour observation period, after binning over ∼ 8 arcsec in the E-W direction. The E-W behaviors of the two explosive event sites bounded by white dash-dot lines is shown in Figure. 4a and b.

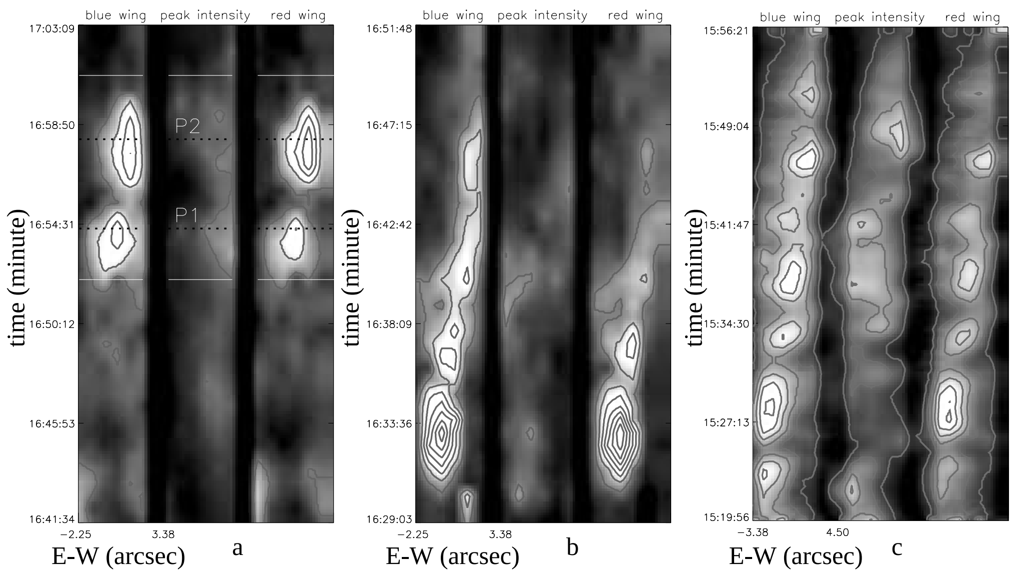

Figure 4. Examples of re-occuring explosive events. The east to west movement is due to solar rotation (1 arcsec/6 minute). The events in (a) are the northern events. The four events in (b) are the southern string of bright events between dot dashed lines in Figure. 3, and the site in (c) is the one with maximum number of 7 repetitions in our dataset.

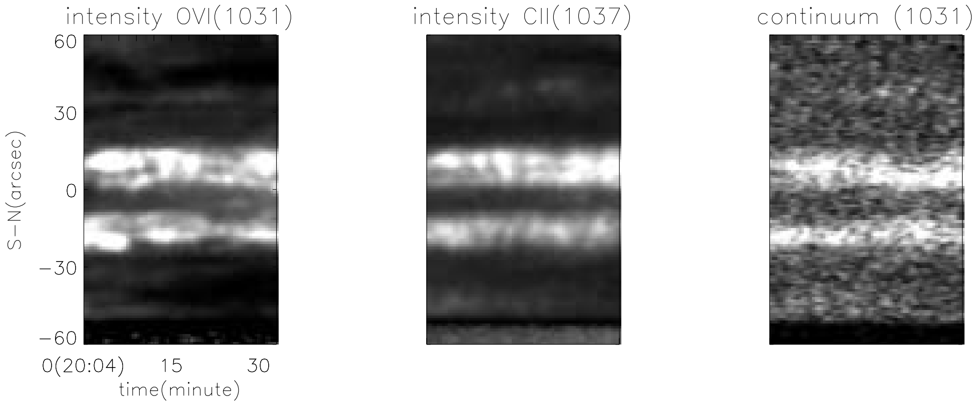

Figure 6. Time variation of O VI *1031.93 Å and* C II *1037.00 Å total intensity and continuum emission (λ=1031 Å) after binning in the E-W direction. Network regions show the NBPs oscillation with 5 minutes.*

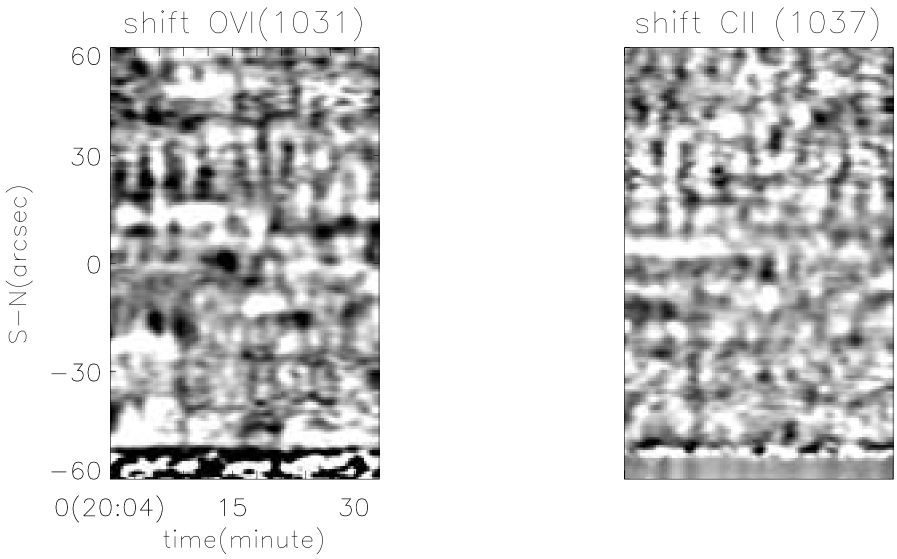

Figure 7. Time variation of O VI *1031 Å and* C II *1037 Å line center shift velocities along slit after binned the E-W direction. The average shift velocity is from -2 km s^{-1} (blue shift) to +2 km s^{-1} (red shift).*

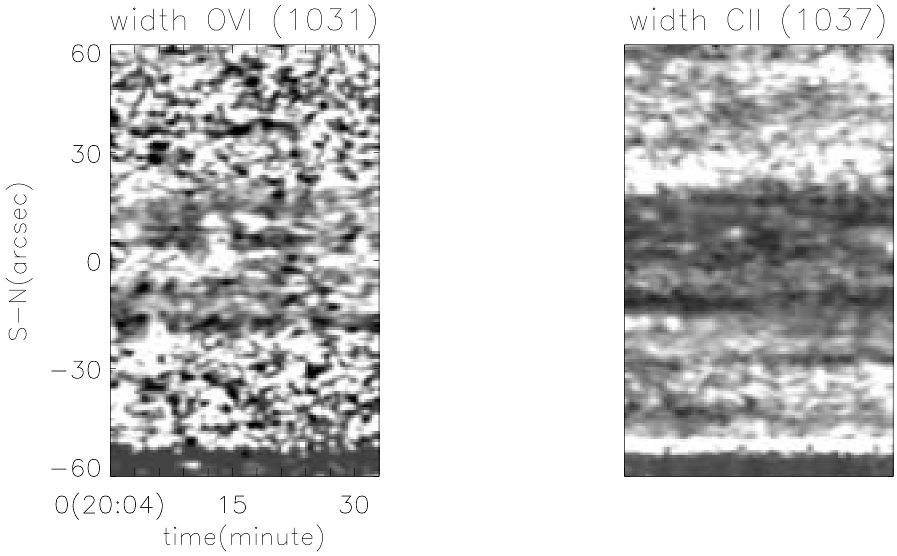

Figure 8. Time variation of O VI *1031 Å and* C II *1037 Å Doppler width along slit after binned the E-W direction.*

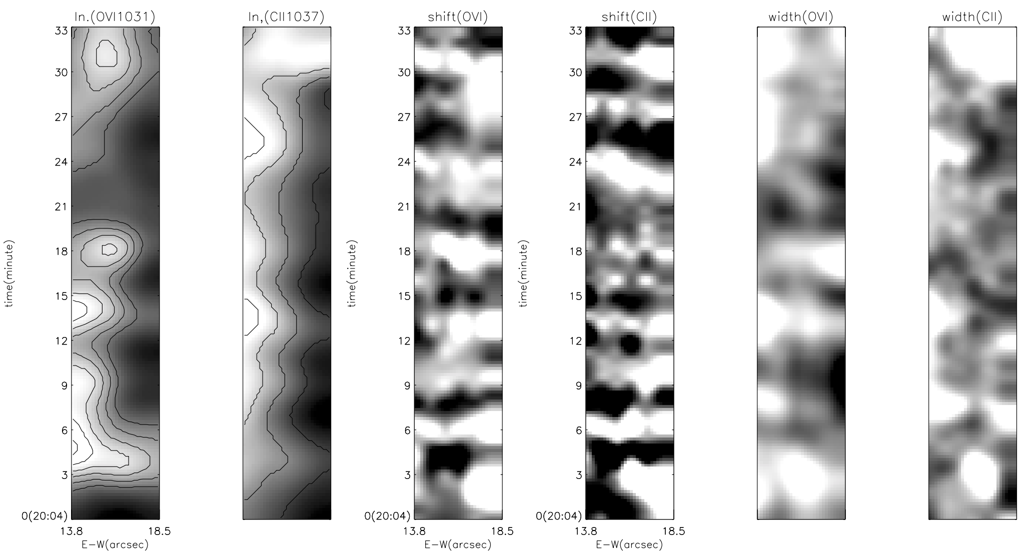

Figure 9. Time variation of O VI *1031 Å and* C II *1037 Å intensity, Doppler width and line center shift velocity in north network region in Figure. 6 after binned the S-N direction, pixels between 0-20. The positive is red shift.*

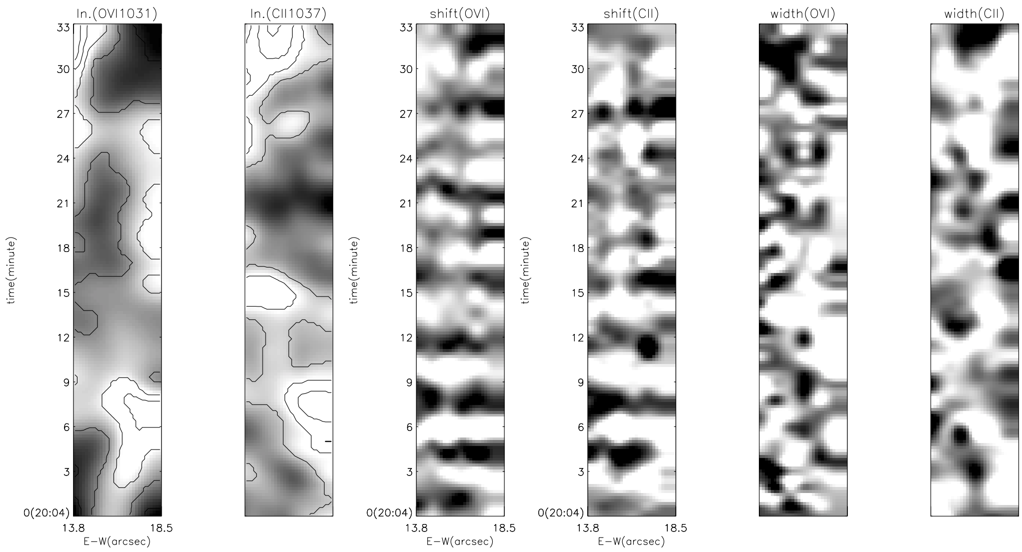

Figure 10. Time variation of O VI *1031 Å and* C II *1037 Å line intensities and line center shift velocities at the internetwork, after binned the S-N direction pixels between 25-30.*

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