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CHARACTERISTICS OF BLINKERS OBSERVED WITH CDS

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ABSTRACT

Blinkers are transient brightenings seen in the extreme ultraviolet. They are candidates for microflare activity at transition-region temperatures. We investigate the properties of blinkers detected in quiet-Sun movies obtained with the Coronal Diagnostic Spectrometer (CDS) on the Solar and Heliospheric Observatory (SOHO).

We report on their energy content, size, ratio of maximum to average brightness and duration. The average lifetime of a blinker is about 25 minutes, while the average size is of the order of 6 pixels. They are present in both bright and dark regions. The size and energy of the blinkers are well correlated.

Key words: chromosphere; transition region; corona; blinkers.

1. INTRODUCTION

Harrison (1997) defined the blinker as a phenomenon showing an enhancement of a factor 2-3 in the flux of transition region lines at network junctions, with durations ranging from 1 to 30 min. and averaging 13 min. Their thermal energy content is reported to be on the order of 10^{-6} times that of a 'standard' flare. Walsh et al. (1997) observed blinkers in an active region. We used a similar criterion to the one of Harrison (1997) and applied it to measurements of the O V 629.74 Å line. In our data sets we identified 311 distinct blinkers.

2. OBSERVATIONS

The measurements have been carried out using the Normal Incidence Spectrometer of CDS (Harrison et al. 1995) in its movie mode, i.e. with the $90'' \times 240''$ slit. In this mode a filtergram covering a part of the solar surface corresponding to the slit size is produced in selected spectral lines. Spectral information within each spectral line is lost. The targets were quiet regions at Sun center on 3rd December 1996 and on 6th December 1996. He I 584.33 Å ($2 \cdot 10^4$ K), O V 629.74 Å ($2.5 \cdot 10^5$ K) and Mg IX 368.06 Å (10^6 K) were recorded simultaneously at a cadence of 31 seconds during a total time of 4 hours on each day. The actual exposure time was 25 seconds and the overhead amounted to 6 seconds. In this paper, we concentrate on the analysis of the O V transition region line.

After carrying out the standard reduction procedure - i.e., correcting for bias of detector, calibration, etc.- we used cross-correlations and pointing information provided by the instrument housekeeping data to compensate for solar rotation and changes in the telescope pointing. Therefore, in the reduced time series, each pixel follows the same point on the solar surface during the whole time series. The size of the resulting field of view is $67'' \times 217''$ (40×129 pixels, with the pixel size being $1.68'' \times 1.68''$). We took special care to interpolate over pixels with missing data and pixels contaminated by cosmic rays. Finally, the data were corrected, to first order, for the slow evolution of the geometrical structure of solar features by removing the long-term linear trend. This was done separately for each pixel and spectral line.

3. RESULTS

3.1. Blinker detection

Figure 1 shows an example of the light curve of a single pixel. For each pixel we first determined the groups of time steps for which the intensity was above some threshold, which we have chosen to be 1.6 times the 4 hours averaged intensity for that pixel (c.f. Fig. 1). Each of these groups was "followed" backward and forward in time, until local minima were found which lay below the average intensity. These points are designated as the start and end time of a possible blinker. If one or more blinkers were identified a new averaged intensity was calculated from only those time steps not harbouring a blinker. The procedure of blinker identification was then repeated with the same criterion but with the new (lower) average value until no new blinker was identified. Finally, we determined the standard deviation (σ) of the time-steps not harbouring blinkers and we redetermined the start and end time of each blinker in the same manner as described above, but this time looking for local minima below the final averaged intensity outside of blinkers plus the 1σ standard deviation above this value. In Fig. 1 this criterion leads

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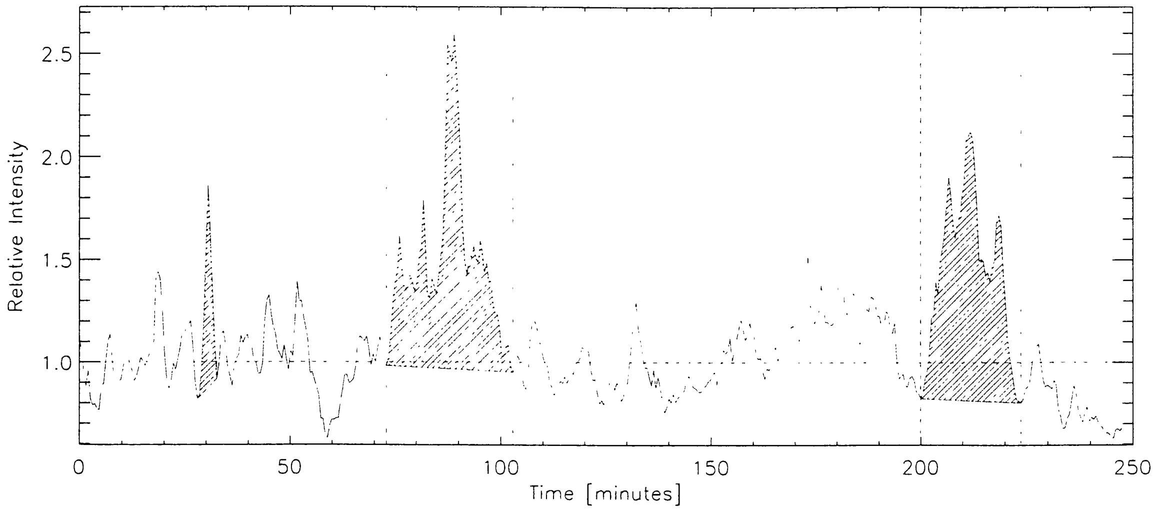

Figure 1. Sample light curve showing 3 blinkers. The horizontal dashed line represents the value of the background intensity after iterative removal of the contribution of the blinkers. The vertical dashed lines represent the start and end times of the 3 blinkers. The shaded regions are proportional to the energies of the blinkers. The vertical axis shows the intensity relative to the intensity averaged over the time when no blinkers were present (horizontal dashed line).

to the identification of 3 blinkers with different durations.

Neighbouring pixels showing "simultaneous" brightenings satisfying the above criterion were finally grouped together. Here "simultaneous" means 80 % of overlap in time. Additionally, we grouped only those pixels for which the blinker start times fell within 4 minutes of each other. The idea behind this criterion is that we expect the underlying physical mechanism (e.g. magnetic reconnection) to affect the surrounding gas relatively quickly (similar start times). However, the cooling time scale over which the parcels of gas cool need not be the same in different pixels.

3.2. Temporal and spatial characteristics of blinkers

The left image of Fig. 2 shows a sample frame of a quiet-Sun CDS movie in O V 629.7 Å at the moment when the number of points showing blinker activity is maximum. The contours outline the points which harbour blinkers at that time. In the right image of Fig. 2 the time-average of the quiet-Sun CDS movie is plotted. The contours depict all the points which brighten sufficiently to be classified as blinkers at some time during the 4 hours of the observations. We see that blinkers are present in bright as well as in dark regions (i.e., in the network and in the intranetwork, respectively).

Figure 3 shows the percentage of pixels in the field of view showing blinkers as a function of time. Since some blinkers started before the beginning or ended after the end of our observations their starting and

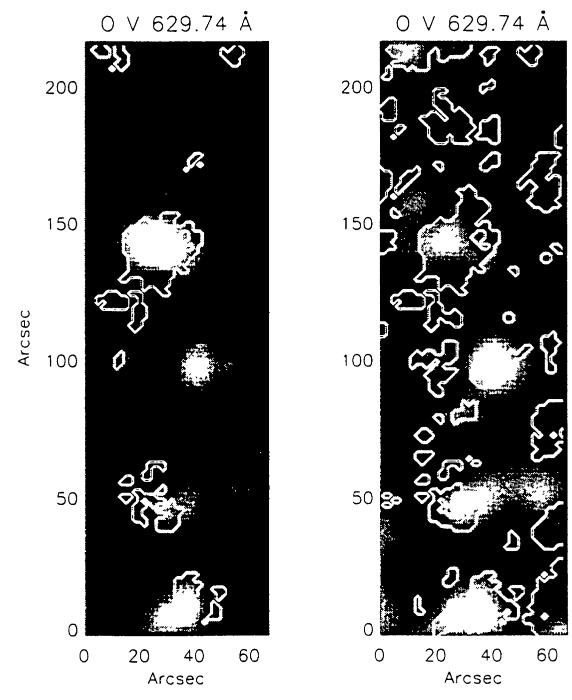

Figure 2. Sample frame (left) and time-average (right) of a quiet-Sun CDS movie in O V 629 Å recorded on 3rd December 1996. The contours on the left frame depict the blinkers present at the time step of greatest blinker activity (corresponding to the plotted frame), while the contours on the right frame depict all the blinkers which are present at some time during the 4 hours of the observations. Brighter areas correspond to higher intensities.

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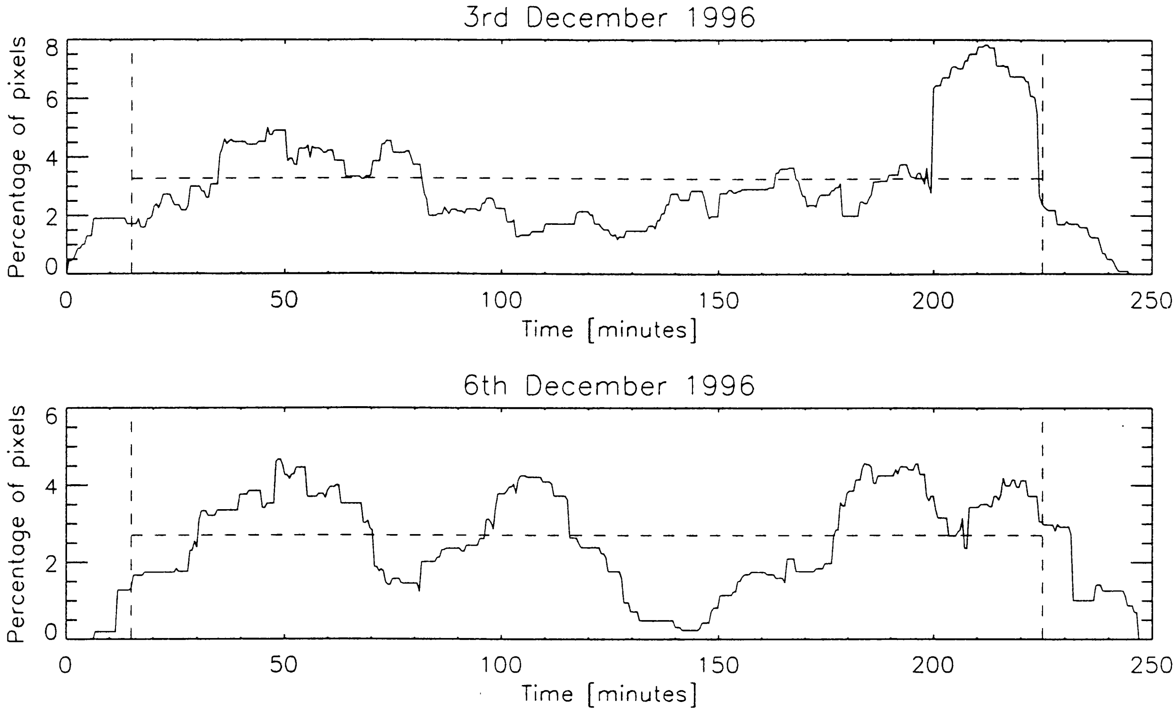

Figure 3. Percentage of pixels showing blinker activity in the field of view as a function of time. The horizontal dashed lines represent the average values of the data between the two vertical dashed lines.

ending times could not be determined and consequently they are not recorded as blinkers. Therefore, the percentage of pixels associated with blinkers is only reliable between the vertical dashed lines. Due to this criterion some of the pixels in Fig. 2 are not shown to harbour a blinker although they underwent considerable brightening. A striking example is the bright blob in the middle of the right frame of Fig. 2. Note that on the left-hand image it is far less bright. The percentage of pixels harbouring blinkers shows large temporal variations (Fig. 3).

We detected 311 blinkers in a total of 29'926 seconds within the field of view ($67'' \times 217''$), or approximately 1.45×10^{-12} events/km^2/sec. The solar surface is 6.00×10^{12} km^2. Thus, 8.75 events per second start over the entire solar surface. With an average duration of 25.03 min. per blinker (see Sect. 3.3), we can expect about 13'000 blinkers, as defined by our criterion, to be present at any moment in time over the entire solar surface. We expect that the different number of blinkers on the solar surface found by Harrison et al. (1999) and us is due to the application of different criteria for their identification.

3.3. Distributions of parameters characterising blinkers

Figure 4 shows histograms of the various parameters characterising the blinkers: energy per blinker, size, ratio of peak intensity to temporally averaged intensity, and duration. The energy for one pixel corresponds to the shaded area under the light curve in Fig. 1. The energy of a blinker is the sum over the energies for all the pixels deemed to belong to this particular blinker. All these values are, of course, dependent on the employed definition of blinkers. The typical duration of a blinker lies between 10 and 35 min, with an average value of 25.03 min. Average values of the other parameters amount to 2.24 for the intensity ratio, 5.87 pixels for the size and 4.92 $\times 10^{-5}$ ergs/cm^2/arcsec^2 for the energy per blinker.

Note that the drop in number of events with short duration (Fig. 4d) may be an artifact of the selected threshold of 1.6 for the intensity ratio (Fig. 4c). The largest blinker has a size of 120 pixels. Only those blinkers whose start and end times fell inside the observing time (first and last time step excluded) were included in the statistical analysis.

We have also investigated the correlations between these parameters. Table 1 gives the cross-correlation coefficients. The intensity is the background intensity as explained in Sec. 3.1. There is a large scatter in values of the correlation coefficients. The size and energy and the ratio and energy are the best correlated, while the duration and size and the intensity and ratio are totally unrelated to each other.

Figure 5 (left) shows a plot of the blinker energy as a function of the size of the blinker. These 2 parameters show a significant correlation as confirmed by the correlation coefficient of 0.89. The solid line is a

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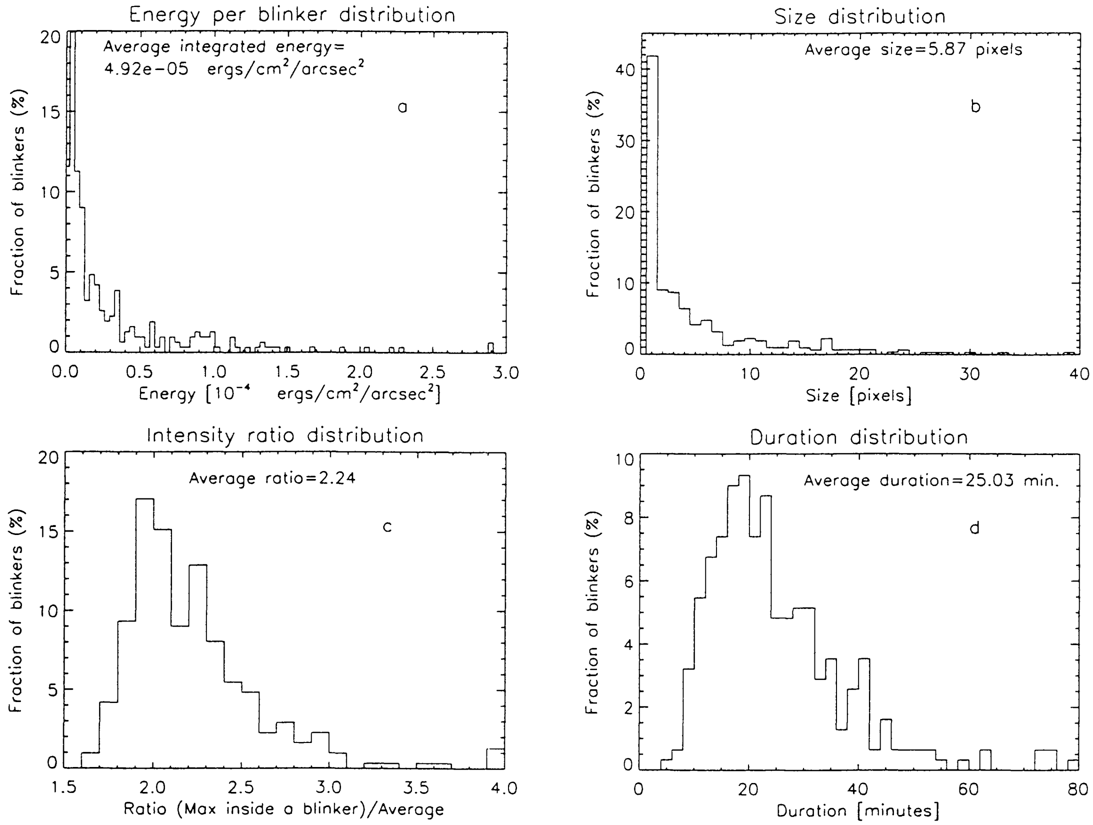

Figure 4. Distributions of energy, size, intensity ratio and duration for the 311 observed blinkers.

linear fit. Figure 5 (right) shows the blinker energy as a function of the region's background intensity averaged during the time without blinker activity for each group of pixels forming a blinker. The solid line is a linear fit. The cross-correlation coefficient between the averaged background intensity and the energy is 0.18.

It has to be remembered that the choice of minimum intensity ratio of 1.6 influences the relevant distributions as well as the cross-correlation coefficients obtained.

4. SUMMARY

In the 2 data time series of images obtained with CDS we detected a total of 311 blinkers in the O V 629.74 Å line. We found that the average lifetime of a blinker is about 25 minutes, its average size is not larger than 6 pixels and its average intensity ratio is 2.24. Blinkers are present in both bright and dark regions. We estimated a rate of 8.75 blinkers starting every second over the entire solar surface, or, about 13'000 blinkers occuring at any given time. The size and energy of blinkers are fairly well correlated. Other pairs of parameters describing the blinkers are not well correlated.

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correlation pair	cross-correlation coefficient	correlation pair	cross-correlation coefficient
energy-duration	0.07	intensity-ratio	0.00
energy-intensity	0.18	intensity-size	0.09
energy-ratio	0.30	intensity-duration	-0.21
energy-size	0.89	ratio-duration	0.24
duration-size	-0.03	ratio-size	0.22

Table 1. Cross-correlation coefficients for different pairs of parameters

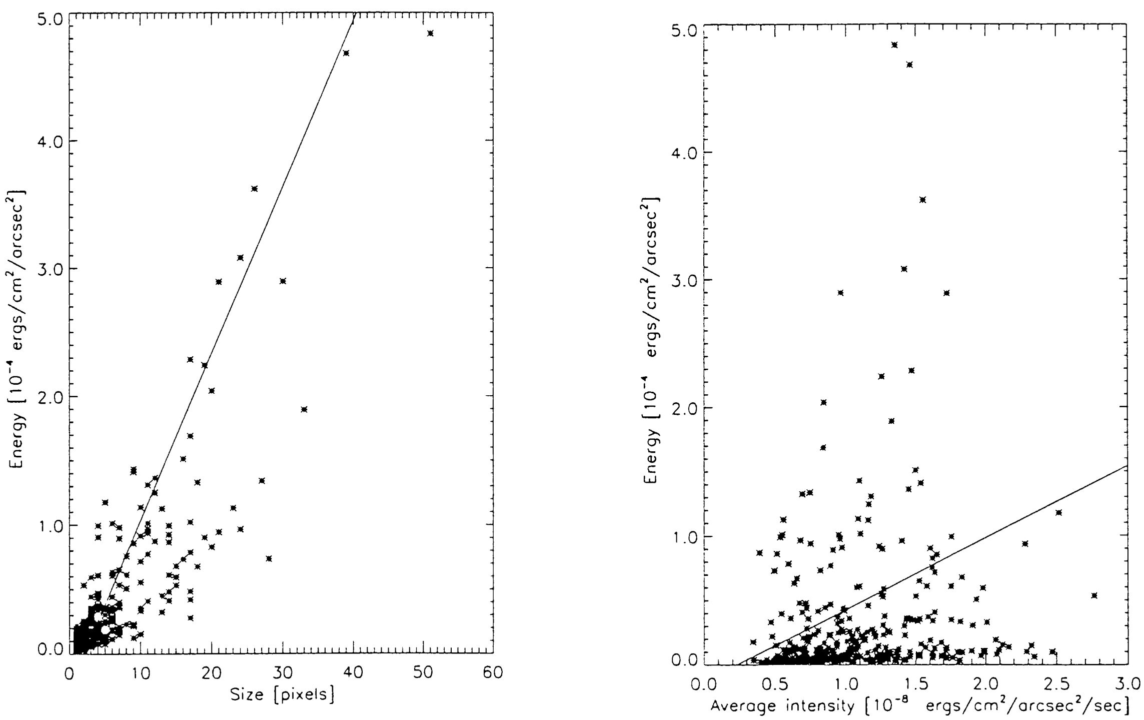

Figure 5. Energy per blinker as a function of the blinker size (left) and energy per blinker as a function of the intensity in the spatial points showing the blinker averaged during the time without blinker activity (right). The solid lines are the linear least-squares fits to the data points.

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