STATISTICAL ANALYSIS OF A BRIGHT POINT OBSERVED SIMULTANEOUSLY IN TWO CHROMOSPHERIC AND TRANSITION REGION LINES BY SUMER

K. Bocchialini¹, J.-C. Vial¹, G. Einaudi²

¹Institut d’Astrophysique Spatiale, Bât. 121, Université Paris XI - CNRS, F-91405 Orsay cedex, France
²Dipartimento di Fisica, Università di Pisa, Piazza Torricelli 2, I-56126 Pisa, Italy

ABSTRACT

Intermittent energetic bursts - as Bright Points - could be the signature of non-observable small scales that are strongly related to the small dissipative coefficients which appear in the MHD equations. A statistical analysis was performed on the integrated intensity measured in a coronal Bright Point, observed by SUMER for more than 3 hours, simultaneously in S VI (944 Å) and Le (937 Å) lines, formed respectively at 10⁴ K and 2 10⁸ K.

The Bright Point was selected in real time using an EIT image in Fe IX/X (171 Å). Its diameter is around 20 arcsec, and is centered in the field-of-view (120° in elevation and 30° in azimuth). The exposure time was 10 s; 100 s were required to build one image, and 112 images, which evidence the bright point evolution, were analysed.

In both SUMER lines, the intensity distributions in the Bright Point exhibit power laws. This result will be discussed as a possible signature of the existence in the Bright Point region of self similar structures with scales much smaller than the instrumental resolution.

Key words: Sun, Bright Point, Statistical Analysis - SOHO.

1. INTRODUCTION

The nature of the energy release in the solar atmosphere remains one of the main unresolved problems in solar physics, though the correlation of activity with the intensity of photospheric magnetic fields seems beyond doubt. This has led to the idea that all of coronal activity might be attributed to the dissipation of magnetic energy, either previously stored in the corona or injected continuously via a flux of waves (Einaudi et al. 1994).

The energy source is well accepted to reside in photospheric motions. The coupling between the photospheric forcing and the coronal dynamics generate highly intermittent spatial concentrations of electric currents exhibiting very small spatial scales due to the weakness of dissipative processes in corona (Einaudi et al. 1996). An observed event in corona would then be the result of the superposition of many not observable elementary events consisting in the disruption of each current sheet with consequent release of magnetic energy.

This scenario has led many people to the use of a statistical approach both in the interpretation of the observations and in the theoretical effort to explain such observations. The reason has been the fact that cellular automaton models (SOC) for magnetic field instabilities (Lu and Hamilton 1991, Lu et al. 1993, Vlahos et al. 1995) have shown the existence of power-law behaviour of energy release in modelling coronal activity. Recently Georgoulis et al. (1997), by concentrating on the overall long-time behaviour of the system, have shown that magnetically forced MHD turbulence results in an energy release with properties analogous to those observed in SOC models, namely the presence of distinct bursts which follow well-defined power laws in terms of total energy content, duration and peak luminosity.

It is important to remark that the comparison of the distributions of observed “events” may be of little meaning. For example, evidence for the existence of magnetic separatrices in some flaring regions (Démoulin et al. 1994) indicates that complexity beyond the simple random braiding of an axial field is necessary for certain classes of solar events to occur.

Stated differently, while for the low-energy activity associated with coronal heating, the integrated energy flux from the photosphere is probably always comparable to the coronal dissipated power, in situ storage may be required for larger flares, marking an important distinction in the dynamics, though not in the dissipation. It is therefore important to study the statistical behaviour of events occurring in the so-called “quiet Sun”, where a large scale magnetic complexity is not likely.

We have applied a statistical approach to the study of bright points. These elementary small magnetic structures have been studied extensively in X-rays Golub et al. (1977), in EUV wavelengths (e.g. Habal and Withbroe 1981) and more recently in the radio range (Kundu et al. 1994). Bright Points can be observed everywhere on the Sun, in coronal holes or in the quiet corona, as small bright areas with sizes generally less than 20000 km; they evolve on timescales of several minutes (Nolte et al. 1979), with lifetimes ranging between about two hours and two days (Harvey 1993). Comparison between magnetograms and X-ray observations showed that bright points coincide with magnetic bipoles (Krieger et al. 1971, Golub et al. 1977).

Using the observations performed in different lines...
formed at different altitudes, with SOHO (Solar and Heliospheric Observatory) and described in Section 2, we show the temporal evolution of a BP (Section 3); a statistical analysis is presented in Section 4, in order to see if self-similar structures with scales smaller than the instrumental resolution could exist in Bright Points (Section 5).

2. OBSERVATIONS

The observations were performed on August 30 1996, between 13:22 UT and 16:43 UT, in the frame of JOP 38. The involved SOHO instruments were EIT (Extreme-uv Imaging Telescope, see Delaboudinière et al. 1995), SUMER (Solar Ultraviolet Measurements of Emitted Radiation, see Wilhelm et al. 1995) and CDS (Coronal Diagnostic Spectrometer, see Harrison et al. 1995). The target, a Bright Point (hereafter BP), was selected in real time from an EIT image in Fe IX/X (171 Å). At the beginning of the sequence, the coordinates of this bright point were (-131°, -60°). Its shape was circular and its diameter was around 20 arcsec.

Figure 1 shows a large field of view (11'x11') containing the observed region obtained with EIT in Fe XV (284 Å) and MDI (on the left). The field-of-view is centered on an active region: EIT exhibits big loops and MDI shows the two opposite polarities of their feet. In the middle of the panel, an enlarged region is displayed, selected from the upper left corner of the large previous f.o.v. A BP, more intense than the background has been selected to be observed with SUMER. MDI shows that the BP is magnetized but in this case the spatial resolution was not good enough to see if different polarities are present in the BP. (New observations are planned, involving MDI in its best resolution configuration.) On the right part of the panel is shown the SUMER f.o.v in S VI (120° in elevation, 30° in azimuth), centered on the BP.

We now concentrate on SUMER observations: After the coordinates selection, SUMER was pointed in real time on the BP which was simultaneously observed in Lyman c (937 Å) and S VI (944 Å), formed respectively at 10^4 K and 2 10^5 K. The spectral window around each line is 1 Å.

The SUMER field of view was centered on the bright point and the solar rotation was compensated on board. The dimensions of the used slit were 1'x120", the step size equal to 3 arcsec and the step number equal to 10. The exposure time was 10 seconds in each line, consequently 100 seconds were required to build one image. The images were corrected from the flatfield effects and from the line distortion.

The integrated intensity was computed over 1 Å (the whole spectral window), in both lines.

3. TIME EVOLUTION OF THE BRIGHT POINT

The temporal evolution of the BP is displayed on Fig. 2, from t=0 to t=3 hours; 100 s separate each frame. The rows are alternatively S VI and Lc. One can see that the BP has the same intensity and geometric variations in both lines, simultaneously. From left to right, and from top to bottom, the intensity is increasing at the beginning, two bright feet seem to appear in the BP, and after a while 3 feet appear. But it is not possible from the available MDI images to check if they correspond to different polarities. The BP lasts around 2 hours, disappears during 2 minutes and is visible again but fainter, and disappears completely 3 hours after the beginning of the observation (which does not correspond to the "birth" of the BP). Note that in the right bottom corner, a new bright point is growing up.

4. STATISTICAL ANALYSIS

The aim of this work is to perform a statistical analysis on the integrated intensity in terms of distribution. We consider all the frames in each line- and we plot in Fig. 3 the number of pixels which have a given intensity as a function of the relative intensity itself. The upper row corresponds to the complete field of view for all the frames. These distributions are fitted with a χ² curve for the lower intensities (intensity is randomly distributed in the field of view); at higher intensities (more than 0.6 arbitrary units in S VI and more than 5 arbitrary units in Lc), the two curves diverge.

If we now concentrate on the BP area (Fig. 3, second row) -we consider here only the frames where the BP is visible- we obtain a distribution which is again fitted with a χ² curve between 0 and 1.6 arbitrary units in S VI and between 0 and 7 arbitrary units in Lc. The fitting curves evidence a threshold which is the limit between the "background" and the "real" structure.

We consider now only the intensities above these thresholds. The third (all frames) and fourth (BP only) rows of Fig. 3 display the logarithm of the
SUMER observations – 30 Aug. 1996

Figure 2. Temporal evolution of the BP, simultaneously in S VI and Ly€. Total duration 3 hours. The rows are alternatively S VI and Ly€.
Figure 3. Intensity distributions in S VI (left) and Le (right). The first row corresponds to the distribution of the intensity of the complete f.o.v for all the frames. The second row shows the distribution of intensity in the bright point (for all the frames where it appears). The third and fourth rows are the log-log distribution of the previous distributions; the power laws are evidenced by the straight lines which are the best linear fits of the curves; their equations are indicated as $y = Az + B$. Solid line: observations, dashed line: $\chi^2$ fit function.
number of pixels with a given intensity as a function of the logarithm of only these intensities which are higher than the threshold. We see that different power laws with different slopes appear in both lines, but the slopes are almost identical in both lines: if we consider the total distribution over all the frames, the slope is equal to -2.18 in S VI and equal to -2.82 in Lc. But if we consider the BP distribution and the highest intensities, steeper slopes appear: -5.26 in S VI and -5.64 in Lc. It seems that the smaller scales we consider, the steeper slopes we obtain. These power laws in the BP distributions could be the signature of the existence of self-similar structures in BP, with scales much smaller than the instrumental resolution.

5. CONCLUSION

The preliminary results of the statistical analysis performed on a Bright Point observed by SUMER simultaneously in S VI and Lc on August 30 1996, was presented. The 3 hours duration of the observation sequence gave us the possibility to follow the time evolution of this small (20") bright, magnetized structure selected in real time from an EIT image. We showed that the behaviour of the BP is very similar in both lines which are formed at different altitudes. Concerning the statistical analysis itself, two cases were studied in both lines: the distribution of the integrated intensity (in arbitrary unit) was plotted (i) considering the complete field of view in all the frames, (ii) considering only the region defined by the BP when the BP exists. The distributions, with an extended tail, were fitted with a χ² curve; a threshold was defined where the distribution and the fit diverge. Below the threshold, the intensities are attributed to the noise, whereas above the threshold, the intensities may be attributed to the fact that no matter where we observe in the solar corona, there exist structures at spatial scales much smaller than the observational resolution which lead to the observed features. Such features may range from big flares to simple coronal heating in terms of the energy involved, but all of them may ultimately be due to different superpositions of current sheets which continuously form and disrupt, consequently releasing magnetic energy. The fact that the response of a portion of the "quiet Sun" is non-gaussian, in the sense that the log-log distribution of the intensity above threshold, in both lines and in cases (i) and (ii), evidences power laws, very similar in both lines, might be the signature of a well defined self-organization of the system in the observed region. It is interesting to notice that the intensity distributions differ substantially depending whether the complete field of view or just the BP are considered. This fact might have to do with the topology of the magnetic field which, according to the magnetograms, seems to have a loop topology more complex in the BP region.

REFERENCES

Harvey K, 1993, Thesis "Magnetic bipole on the Sun", Utrecht University, The Netherlands
Nolette J.T., Solodyna C.V., Gerassimenko M., 1979, Sol. Phys., 63, 113

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