A COMPARISON BETWEEN BRIGHT POINTS IN A CORONAL HOLE AND
A QUIET-SUN REGION

SHADIA RIFAI HABBAL, JAMES F. DOWDY, JR.,1 AND GEORGE L. WITHBROE
Harvard-Smithsonian Center for Astrophysics
Received 1989 July 19; accepted 1989 September 16

ABSTRACT

We compare the morphological structure and temporal behavior of the emission from coronal bright points in a coronal hole and a quiet region, using data from the Harvard EUV experiment on Skylab. We find that, in both regions, coronal bright points are located at network boundaries and cover a range of sizes from 10' to 40' in linear extent. In a given bright point, the peaks of emission in the six different lines, measured simultaneously through the same instrument slit, are not always cospatial, implying that bright points consist of a complex of small-scale loops at different temperatures. The intensity of bright points in both regions is also characterized by a significant temporal variability in all the wavelengths measured. This variability exhibits no regular periodicity. Yet the ratio of the varying (ac) to the constant (dc) components of the emission, in all the bright points studied, has a local maximum at 1-2 × 10^5 K which coincides with the peak of the radiative loss function, and another local maximum at Mg x (1.4 × 10^6 K). We find that coronal bright points in a coronal hole or a quiet region are indistinguishable structures, and therefore conclude that they are independent of the underlying background corona.

Subject headings: hydromagnetics — Sun: corona — Sun: magnetic fields — ultraviolet: general

I. INTRODUCTION

The interest in the study of coronal bright points stems from the belief that they could be an important indicator of coronal heating processes (see, for example, Habbal and Withbroe 1981; Waldron and Mullan 1987). Typically 10'-40' in spatial extent, bright points are characterized by enhanced coronal emission, observed at X-ray, EUV, and radio wavelengths, above the background quiet Sun (Golub et al. 1974; Marsh, Hurford, and Zirin 1980; Habbal and Withbroe 1981; Habbal et al. 1986; Gary and Zirin 1988). High-resolution X-ray images show them as consisting of an arcade of miniature loop-like structures, reminiscent of small active regions (Sheeley and Golub 1979), and exhibiting occasional flaring activity. The likelihood of a closed magnetic field structure is further supported by their association with magnetic bipolar regions (Golub et al. 1974) developing more often in regions of canceling magnetic flux than emerging flux (Harvey 1985; Habbal and Harvey 1988). They are also characterized by a short lifetime: a few hours as opposed to days for active regions.

The most distinctive property of coronal bright points, however, is the prominent spatial and temporal variability of their emission over the course of their lifetime (Sheeley and Golub 1979; Habbal and Withbroe 1981; Habbal and Harvey 1988). The variability is chaotic in nature with no obvious systematic pattern. Furthermore, the variations at different temperatures in the bright points are not always correlated on a time scale of minutes (Habbal and Withbroe 1981; Habbal and Harvey 1988). Habbal and Withbroe (1981) attributed the changes in EUV emission to intermittent heating, possibly correlated with changes in magnetic field topologies over scales of a few arcsecs or less. This is supported by radio observations where the observed variability in the radio emission could be attributed to fluctuations in the pressure, conductive flux, and the strength and direction of the magnetic field (Habbal et al. 1986).

The purpose of this study is to compare the observational properties of coronal bright points in coronal holes with those in the quiet Sun. Bright points remain somewhat of an enigma. They are clearly manifestations of local intermittent heating, but their connection to the global coronal heating remains ambiguous. The interaction of bright points, if any, with the large-scale magnetic field structure could be clarified by comparing the properties of coronal bright points in coronal holes with those in the quiet Sun. The two regions differ in their large-scale magnetic field structure. The data used in this study were selected from observations acquired by the Harvard EUV spectrometer/spectroheliometer on Skylab (§II). The results are given in §III followed by a discussion in §IV and concluding remarks in §V.

II. DESCRIPTION OF THE DATA

The data consist of measurements made using a photoelectric detection system capable of monitoring simultaneously, through the same slit of the spectrograph, intensities from spectral lines formed in the chromosphere, chromospheric-coronal transition region, and corona (Reeves, Huber, and Timothy 1977; Reeves et al. 1977). The simultaneity of the observations at these different temperatures and the exact spatial registration at the different heights in the atmosphere make these data unique. Within a spacecraft orbit, up to 10 scans of a 5' × 5' field of view were obtained every 5.5 minutes with a spatial resolution of 5'. For the purpose of this study, we selected three consecutive orbits for each region. The number of 5.5 minute scans, within each orbit, varied from 5 to 10 depending on the quality of the data. Both regions were at Sun center.

III. RESULTS

a) Morphological Structure

Figures 1 and 2 (Plates 6-7) show the 5' × 5' field of view of the coronal hole region and the quiet region at coronal

HABBAL, DOWDY, AND WITHBROE

(Mg x 625 Å at 1.4 × 10^6 K) and transition region (C iii 977 Å at 9 × 10^4 K) temperatures. By coronal bright points we mean compact bright features in Mg x. In the quiet region, they are identified as structures where the Mg x emission is at least a factor of 2 higher than the surrounding. They are readily detected in the coronal hole where the background Mg x emission is weak. Thus defined, they are identified by circles in these figures.

To make the presentation in this paper more tractable we selected three typical examples in each region, labeled A1–A2, B, and C in the quiet-Sun region and 1, 6, and 7 in the coronal hole (these latter numbers correspond to the labels used by Habbal and Withbroe 1981 in their earlier study of bright points in a coronal hole).

The details of the structures of five individual bright points are shown in Figures 3–7 (Plates 8–12). The scale in these figures is magnified over those shown in Figures 1 and 2. The morphological properties of both coronal hole and quiet-Sun bright points can be summarized as follows:

1. Coronal bright points in both regions cover a range of sizes, from 10" to 40" in linear extent, or 75 to 450 arcsec^2 in area (see Table 1).

2. By comparing Mg x to C iii in both Figures 1 and 2, one can see that Mg x bright points are apparent in C iii and lie within the C iii network. (This was first reported by Egamberdiev 1983, who compared X-ray images of the Sun from Skylab with Ca ii K and Hz spectroheliograms.)

3. Some very strong C iii bright points have no significant Mg x emission, while some weaker ones have a strong Mg x counterpart. Furthermore, the number of network bright points which show no corresponding enhancement in Mg x emission is larger than the number of those with corresponding coronal emission. This is shown again by comparing Mg x to C iii in Figures 1 and 2.

4. The distribution of intensity over the area of a bright point is not uniform (see Figs. 3–7). Furthermore, the areal size of a bright point varies in time (see, for example, BP 7 in a coronal hole, Fig. 5, or BP C in the quiet region, Fig. 7).

5. Often a bright point has more than one local intensity maximum concentrated in the smallest resolution element of 5" × 5" (see BP 1 in C iii [5:23 UT] or Mg x [5:29 UT], Fig. 3; BP C in Mg x [2:09 UT], Fig. 7). These peaks do not persist in the same location for very long (see the time sequence of BP A1–A2 in C iii, Fig. 6). They often pop up in different parts within the bright point boundary over the course of the observing. They can also fade and reappear in the same location in time steps as short as our temporal resolution of 5.5 minutes (see BP1 in C iii [5:23, 5:35 UT], Fig. 3).

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>EXAMPLES OF SIZE DISTRIBUTION OF EUV BRIGHT POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Bright Points</td>
</tr>
<tr>
<td>Quiet-Sun</td>
<td>A2</td>
</tr>
<tr>
<td></td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Coronal hole</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

6. The brightest pixels are often, but not always, spatially coincident in all lines (compare Mg x with C iii in Figs. 3–7).

7. Bright points sometimes emerge as clusters. There is some correlation between the temporal behavior of these neighbors implying a magnetic link between them. One example is BP A1–A2 in Figure 6, which appears to be formed of two distinct, yet interacting structures which brighten together. Another example is BP 5 (Fig. 4) which appears as a flaring bright point, i.e., a very bright source in Mg x at 5:35 UT only. At 5:40 UT the bright source disappears, but faint Mg x emission appears in a source 40" away from the source of the "flare." Note that these two sources are faint but visible in C iii throughout the sequence shown, and that the C iii emission at the location of the flare brightens prior to the Mg x emission.

8. Finally, the distribution of sizes of bright points, as well as their spatial abundance, is the same in a coronal hole and a quiet region (compare the number of sources with bright Mg x emission in Figs. 1 and 2).

Thus, within the limits of the spatial resolution of the instrument, the morphological properties of bright points are the same whether in a quiet region or in a coronal hole.

b) Temporal Variability of the Emission

The temporal behavior of bright points, as shown in the preceding examples, strongly suggests that the energy source to the bright points is highly variable. Because the bright points have on average a lifetime of a few hours, we assume that there are two components to the energy source: a steady one and, superimposed on it, a variable one. To establish a more quantitative measure of the variable component of the emission in each wavelength, we introduce the quantity,

\[ \frac{ac}{dc} = \frac{\sqrt{\text{rms}^2 - \sigma^2}}{\bar{I} - \sqrt{\text{rms}^2 - \sigma^2}}. \]  

(1)

For each bright point, \( \bar{I} \) is the average over all the scans in one orbit, of the total intensity per scan, \( I_i \), at a given wavelength, i.e.,

\[ \bar{I} = \frac{\sum_i I_i}{N}, \]  

(2)

where \( N \) is the total number of scans in an orbit, and \( i = 1, N \). To compute the total intensity per scan, \( I_i \), we fixed the area of a bright point in Mg x throughout the three orbits. The bright point area defined in Mg x was then used to define the bright points in lower temperature lines. We also corrected for solar rotation. The quantity \( \sigma \) in equation (1) is the intrinsic variability expected from photon counting statistics, and is given by

\[ \sigma = \sqrt{\bar{I}}. \]  

(3)

The quantity \( \text{rms} \) in equation (1) is a measure of the variability of the intensity about the mean, \( \bar{I} \), in a given orbit, and is given by

\[ \text{rms} = \sqrt{\frac{\sum_i (I_i - \bar{I})^2}{N}}. \]  

(4)

The quantity \( \frac{ac}{dc} \) is independent of the strength of the emitting line. It is a measure of the relative magnitude of the fluctuations in intensity with respect to the mean intensity in a given orbit.

We compare, in Figures 8–14, the changes in time of the total intensity \( I_i \) for the six wavelengths, in the bright points

© American Astronomical Society • Provided by the NASA Astrophysics Data System
studied. For each wavelength, the logarithmic scale for \( I \) is the same; this provides a simple visual comparison of the changes in the different lines. The expected statistical fluctuations in the data (\( \pm \sigma \)) are smaller than the size of the data points. Data points are not connected when one or more rasters are missing from a sequence. We also show in these figures the changes of the corresponding ac/dc parameter as a function of temperature and time (i.e., for the three consecutive orbits studied). Since the quiet-Sun emission in Mg x has a contribution from the overlying large-scale coronal structure, we corrected for that contribution. To estimate the background emission we took the mean intensity from an area with no bright points and found it to be 15 counts pixel\(^{-1}\). This number was then subtracted from the Mg x emission in the pixels forming the quiet-Sun bright points. The effect of this correction is shown in the additional plot labeled ac/dc\(^x\) versus temperature. The results of our analysis can be summarized as follows:

1. The intensity in the different emission lines exhibits significant temporal fluctuations in two forms: short-term fluctuations from one 5.5 minute scan to the next, and more gradual fluctuations over 20–30 minutes. Yet there is no characteristic periodicity for these variations in any of the bright points studied.

2. The short-term variations in the different lines are not always correlated. What correlation exists occurs between lines formed in the transition region (from \( 4 \times 10^4 \) to \( 5 \times 10^5 \) K, C ii to O iv lines). On longer time scales, a stronger correlation exists for the variation of the mean emission as a function of orbit between the different wavelengths.

3. The most striking characteristic common to all the bright points is the existence of a distinct local peak around \( 1–2 \times 10^5 \) K in the ac/dc parameter. This peak averages around 0.2 for quiet-Sun bright points, with one example (BP C, Fig. 14, 2nd orbit) reaching 0.6. For coronal hole bright points the peak ac/dc at \( 10^5 \) K covers a range of 0.1–0.4.

4. An additional peak at Mg x appears in some orbits in the ac/dc parameter in the coronal hole bright points. This peak reaches up to 0.7 in BP 7 (Fig. 10, 1st orbit). (Although not
shown, this peak reaches 1 in the flaring bright point BP 5.)

For the quiet-Sun bright points, the Mg x appears in the
corrected ac/dc* curves ranging from 0.1 to 0.6.

5. The relative magnitude of the ac/dc peaks at $10^5$ and $10^6$
K can vary significantly in either separate bright points or a
given bright point throughout the three orbits. For example,
all three coronal hole bright points in orbit 2 have approxi-
mately the same ac/dc = 0.2 at $10^5$ K but different Mg x ac/dc
peaks: BP 7 (Fig. 10) has a peak value of 0.2, BP 1 (Fig. 8) of
0.3, and BP 6 (Fig. 9) has no Mg x peak. In a given bright point
BP 6, the peak value at $10^5$ K is the same in orbits 2 and 3, but
different at $10^6$ K in these orbits.

6. There is generally not a correlation between the magni-
tude of the ac/dc peaks and the mean intensity in a given orbit.
For example, the ac/dc curve can remain the same, while $I$
changes by a factor of 2 (e.g., BP B, Fig. 13). On the other hand,
ac/dc can change by a factor of 3, while $I$ remains the same in
two consecutive orbits (see, for example, the change in O IV in
BP C from orbit 1 to 2, Fig. 14, and BP 1 between orbit 1 and
2, Fig. 8). Exceptions do exist, however. For BP 7 (Fig. 10) the
ac/dc parameter follows that of $I$.

7. The value of the peaks in ac/dc around $10^5$ K or $10^6$ is
independent of the size of the bright points.

In summary, bright points in a coronal hole and a quiet
region show the same qualitative behavior in the temporal
variability of their emission. Specifically, the ac/dc parameter
shows the same characteristic behavior as a function of tem-
perature for bright points in both regions, with two distinct
peaks around $10^5$ and $10^6$ K.

IV. DISCUSSION

Given the lack of any periodicity in the temporal variability
of the EUV emissions from bright points, it is somewhat sur-
prising that any systematic trend actually exists, such as the
distinct peaks in the ac/dc parameter at $10^5$ K and at coronal
temperatures (see Figs. 8–14). The variation of the emission is
linked to the energy balance in the magnetic structures forming
the bright points. There are two likely energy sinks: radiation
and thermal conduction. The nature of the energy source is
unknown; it is probably magnetic in origin. The heating is
variable, as evidenced by the temporal variability of the emis-
sion from bright points. The cooling rate of the plasma deter-

© American Astronomical Society • Provided by the NASA Astrophysics Data System
mines the response time to this variable energy input. To compute this response time, let us consider the characteristic times associated with cooling due to thermal conduction, \( \tau_c \), or radiation, \( \tau_R \). By equating the time change of the internal energy to energy loss by thermal conduction or radiation we find

\[
\tau_c = 5 \times 10^{-10} n_e L^2 T^{-5/2},
\]

\[
\tau_R = 2 \times 10^{-16} T_e \frac{1}{n_e \Phi(T)},
\]

where \( T_e \) and \( n_e \) are the electron temperature and density, respectively, \( L \) is the characteristic length at the height of formation of the line, and \( \Phi(T) \) the radiative loss function. The net cooling time is then given by

\[
\tau_{tot} = \frac{\tau_c \tau_R}{\tau_c + \tau_R}.
\]

For the assumed mean temperatures of the lines we used their peak temperature of formation. We assumed a constant pressure in the transition region and coronal heights of \( n_e T_e = 2 \times 10^{15} \text{cm}^{-3} \text{K} \) (Withbroe and Noyes 1977). Although the pressure in a coronal hole is slightly lower, choosing one value for both regions is a good assumption for the purpose of the following discussion.

The results summarized in Table 2 show that the cooling time scales increase with increasing temperature. To produce a peak in the ac/dc parameter at O IV and Mg X would seem to imply, from the consideration of time scales only, that the energy input has two distinct time scales: a few seconds for O IV, and a few minutes for Mg X. Let us first consider the radiative losses. The radiative loss curve, \( \Phi(T) \) (see Table 2), has a peak \( \sim 10^5 \text{K} \), while the radiative energy loss, \( n_e^2 \Phi(T) \), is a decreasing function of temperature. Surprisingly enough, the ac/dc curve below \( 10^6 \text{K} \) matches the shape of the radiative loss curve \( \Phi(T) \). To achieve this matching we suggest the following: if instead of assuming a constant pressure in a bright point and, therefore, deducing different densities at different temperatures (as in Table 2), we assume that the bright points are formed of different loops with the same density but different temperatures, then the radiative energy loss in these different structures will have the same temperature dependence as.
\[ \Delta t = 5.5 \text{ min} \]

**Fig. 11.**—Same as Fig. 8 for bright point A1 in a quiet region. An additional corrected ac/dc* plot is shown where a correction of 15 counts pixel\(^{-1}\) for the background Mg \(\times\) emission was subtracted from the total intensity of Mg \(\times\) in the computation of ac/dc*.

**Table 2**

**Cooling Times and Radiative Losses for EUV Bright Points with Constant Pressure**

\(p = n_p T = 2 \times 10^{15} \text{ cm}^{-3} \text{ K}\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>C (\text{II})</th>
<th>C (\text{III})</th>
<th>O (\text{IV})</th>
<th>O (\text{VI})</th>
<th>Mg (\times)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T (\text{K}))</td>
<td>(4.5 \times 10^4)</td>
<td>(9 \times 10^4)</td>
<td>(2 \times 10^5)</td>
<td>(3.2 \times 10^5)</td>
<td>(1.4 \times 10^6)</td>
</tr>
<tr>
<td>(\Phi(T))</td>
<td>(2 \times 10^{-22})</td>
<td>(6.3 \times 10^{-22})</td>
<td>(6.3 \times 10^{-22})</td>
<td>(4 \times 10^{-22})</td>
<td>(10^{-22})</td>
</tr>
<tr>
<td>(n_p (\text{cm}^{-3}))</td>
<td>(4.4 \times 10^{10})</td>
<td>(2.2 \times 10^{10})</td>
<td>(10^{10})</td>
<td>(6.2 \times 10^9)</td>
<td>(1.4 \times 10^9)</td>
</tr>
<tr>
<td>(L (\text{cm}))</td>
<td>(2 \times 10^8)</td>
<td>(2 \times 10^8)</td>
<td>(2 \times 10^8)</td>
<td>(2 \times 10^8)</td>
<td>(10^9)</td>
</tr>
<tr>
<td>(\tau_e (\text{s}))</td>
<td>(2.2 \times 10^6)</td>
<td>(1.7 \times 10^5)</td>
<td>(10^4)</td>
<td>(2 \times 10^3)</td>
<td>252</td>
</tr>
<tr>
<td>(\tau_g (\text{s}))</td>
<td>1</td>
<td>1.3</td>
<td>6</td>
<td>26</td>
<td>2 \times 10^3</td>
</tr>
<tr>
<td>(\tau_m (\text{s}))</td>
<td>1</td>
<td>1.3</td>
<td>6</td>
<td>26</td>
<td>252</td>
</tr>
<tr>
<td>(E_R = n_p^2 \Phi(T)) (ergs cm(^{-3}) s(^{-1}))</td>
<td>0.4</td>
<td>0.3</td>
<td>0.06</td>
<td>(1.6 \times 10^{-2})</td>
<td>(2 \times 10^{-4})</td>
</tr>
</tbody>
</table>

* J. Raymond 1989 private communication.
the radiative loss curve. Subsequently the emission below $10^6$ K will have a peak at $10^5$ K as manifested in the ac/dc curve, with the condition that the time scale of the energy input be less than the shortest cooling time of a few seconds. At higher temperatures, greater than a few $\times 10^5$ K, where the conductive losses overcome the radiative losses, the increase in the ac/dc variable follows the increase in the conductive losses with temperature, with the condition that the energy input time scale be less than a few minutes.

Based on the above considerations of the cooling time scales, the temperature dependences of the energy loss mechanisms, and the morphological structure of bright points, we propose the following scenario: bright points are formed of a complex of loop structures at different temperatures. These structures would be a subset of the small-scale cool loops that form the network boundary as proposed by Dowdy, Rabin, and Moore (1986). Such a temperature distribution would explain the two distinct peaks in the ac/dc parameter and also the lack of spatial correlation between the peak emission at coronal and transition region temperatures observed in many cases.

To achieve this selective distribution of temperatures we envision the following scenario: the interaction of the magnetic field lines in the network with the field from the individual poles of emerging bipole produces frequent recombinations in very localized regions, the energy of which could provide the variable heat input and heat the atmosphere to different temperatures. This picture is consistent with the finding that bright points are formed in the network boundary as described earlier, and where the canceling of magnetic flux between emerging bipole and the network field is most likely to occur (Harvey 1985). Furthermore, those magnetic interactions are also very likely to produce MHD waves. In particular, if fast mode MHD waves are produced, they have the unique property of preferentially heating the atmosphere in selective regions depending on the density and magnetic field distribution (Habbal, Leer, and Holzer 1979). The matching between $\dot{I}$, the average intensity of emission in an orbit, in all the lines indicates that there is a correlation between the heating processes at these respective temperatures. The nonuniform distribution of temperatures within bright point loops could be an indirect manifestation of heating by these waves in a region with a complex small-scale magnetic field structure. The smallest characteristic cooling times which are determined by the radiative losses (see Table 2) then place an upper limit on the
time scale of the intermittent heating mechanisms suggested above, typically a few seconds.

We have concentrated in the above discussion on the interpretation of the temporal variability of the morphological structure and the emission, as well as the peaks in the ac/dc curve. In our qualitative explanation of these results we ignored the origin of the steady component of the heating, which we designated as dc, which in turn could be related to the lifetime of a bright point. If this steady component is independent of the global coronal heating, as our observations strongly indicate, the above scenario could account for this component if we have a component of the heating mechanism with a time scale longer than the longest cooling time of a few minutes. Hence we speculate that there is evidence for a spectrum of frequencies in the heating mechanisms in bright points with characteristic time scales ranging from seconds to minutes. Clearly more detailed theoretical modeling of energy balance models with intermittent heating mechanisms are necessary before we can satisfactorily account for these observational results.

The field strength (of which we have no direct measure in these data) most likely plays an important role in selecting the sites where bright points reaching coronal temperatures are actually formed. From radio measurements Habball et al. (1986) have inferred field strengths ~100 G at transition region/coronal heights. It is plausible that indeed the field must exceed a certain threshold value, undetermined at present, to produce what are commonly known as X-ray or EUV bright points and that it is only in these regions of the network boundary that coronal bright points are formed.

V. CONCLUSION

We have concentrated in this study on the comparison of the observational properties of coronal bright points in a coronal hole and a quiet region, using the data from the Harvard EUV experiment on Skylab. The uniqueness of the data stems from the simultaneity of the data acquisition in six different wavelengths scanning the chromosphere to coronal temperatures. The two regions chosen differ only in the large scale structure of the overlying magnetic field.

We have limited our study to coronal bright points, i.e., to those magnetic structures that reach coronal temperatures. We found that, in both a coronal hole and a quiet region, there are fewer bright points that reach coronal temperatures than those
at transition region temperatures. Therefore, if transition region temperatures are used as proxies for network bright points they cannot be used as a proxy for coronal emission.

We have also inferred from the data that coronal bright points consist of closed magnetic field structures located in the network boundary. The occasional lack of spatial correspondence between regions of peak emission at coronal and transition region temperatures strongly suggest that they are complex structures, most likely in the form of groups of loop arcades, covering a spectrum of sizes, ranging from 10° to 40°, and temperatures.

Despite the seeming chaotic behavior in the temporal variability of the emission from bright points, there is a distinct pattern in the dependence of the ac/dc parameter on temperature whether bright points are in a coronal hole or a quiet region. This parameter, defined as the ratio of the variable to the steady component of the emission, exhibits two distinct peaks, one at transition region temperatures ~2 × 10^5 K, and the other at coronal temperatures. These two temperature regions correspond, respectively, to the peaks in the radiative efficiency of the ions and the conductive losses. Magnetic reconnection on a time scale of a few seconds, produced by the interaction of separate poles of emerging bipolar features with the more “established” magnetic field in the network boundary, could account for the temporal variability of the emission and these two distinct peaks. These reconnection sites would subsequently produce fast mode MHD waves which, given some critical plasma parameters, in particular density and magnetic field strength, would contribute to the heating of the plasma and variability of the emission at coronal temperatures.

The similarity of the morphological structure of bright points and the temporal variability of their emission in a coronal hole and a quiet region suggest that their distinctive properties are independent of the structure of the overlying large-scale magnetic field. It seems therefore plausible that the dynamic nature of the emission from bright points is strictly determined by the properties of the small-scale magnetic field, in particular its strength and complexity, rather than the large-scale magnetic field structure.

We are very grateful to A. Accomazzi and E. Grace for their help with the image processing of the halftone images.
Esser’s comments on an early version of the manuscript are appreciated. J. F. D. extends his thanks to the staff of the Solar and Stellar Physics division at the Center for Astrophysics for their hospitality during his visit. S. R. H.’s work was funded by NASA grants NAGW-249 and NAG5-1032. The NASA Solar Physics Branch of the Space Physics Division, the Air Force Geophysical Laboratory through its Solar Physics Branch of the Space Physics Division, as well as the Visiting Scientist Program of the Smithsonian Astrophysical Observatory, provided support for J. F. D.

REFERENCES


SHADIA RIFAI HABBAL and GEORGE L. WITHBROE: Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138

© American Astronomical Society • Provided by the NASA Astrophysics Data System
Fig. 1.—EUV spectroheliograms of a 5' × 5' area of a coronal hole at Sun center in Mg x (625 Å) at 1.4 × 10^6 K, and C iii (977 Å) at 9 × 10^6 K. The coronal hole, distinguishable by the lack of Mg x emission, is surrounded by quiet regions with two small active regions in the west. Bright points in the coronal hole only are circled. The data were taken 1973 August 21 at 5:35 UT. The spatial resolution is 5'.

HABBAL, DOWDY, AND WITHBROE (see 352, 333)
Fig. 2.—Same as Fig. 1 for a quiet region at Sun center taken 1973 November 11 at 1:52 UT. There are two small active regions in the west also in these data.

Haiman, Dowdy, and Withbroe (see §2, 313)
FIG. 3.—A time sequence showing bright point 1, in a coronal hole, magnified over the scale shown in Fig. 1. The upper panels are in Mg x, the lower ones in C III.

HABRAL, DOWDY, AND WITHBROE (see 352, 334)
FLARING BRIGHT POINT IN A CORONAL HOLE
AUG 21, 1973

MG X

C III

5:24  5:29  5:35  5:40 UT

Fig. 4.—Same as Fig. 3 for bright point 5, the flaring bright point, in a coronal hole

Habbal, Dowdy, and Withbroe (see 352, 334)
Fig. 5.—Same as Fig. 3 for bright point 7 in a coronal hole

HABBAL, DOWDY, AND WITHBROE (see 352, 334)
FIG. 6.—Same as Fig. 3 for bright points A1 and A2 (labeled bright point A in this figure) in the quiet Sun

HABBAL, DOWDY, AND WILBROROE (see 352, 334)
Fig. 7.—Same as Fig. 3 for bright points C in the quiet Sun

HABBAL, DOWDY, AND WITDBOE (see 352, 334)