OBSERVATION OF SPATIAL AND TEMPORAL VARIATIONS IN X-RAY BRIGHT POINT EMERGENCE PATTERNS

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Abstract. Observations of X-ray bright points (XBP) over a six-month interval in 1973 show significant variations in both the number density of XBP as a function of heliographic longitude and in the full Sun average number of XBP from one rotation to the next. The observed increases in XBP emergence are estimated to be quivalent to several large active regions emerging *per day* for several months. The number of XBP emerging at high latitudes also varies, in phase with the low latitude variation and reaches a maximum approximately simultaneous with a major outbreak of active regions. The quantity of magnetic flux emerging in the form of XBP at high latitudes alone is estimated to be as large as the contribution from all active regions.

1. Introduction

Soft X-ray images of the inner corona have revealed the presence of numerous small, pointlike emission features (Vaiana *et al.*, 1970) which we have named X-ray bright points (XBP). They are found to be associated with small, short-lived and rapidly evolving bipolar magnetic field regions having typical total flux 10^{19}–10^{20} Mx (Krieger *et al.*, 1971; Golub *et al.*, 1974; Harvey *et al.*, 1975). In high resolution Hα spectroheliograms they show enhanced brightness typical of emerging flux regions, although they do not seem to exhibit arch filament systems (H. Zirin, 1975, private communication). Several authors have provided theoretical models of the dynamical properties of emerging flux loops as a basis for comparison with the observed properties of XBP (Parker, 1975; Glencross, 1975). In Golub *et al.* (1975) we showed that the number of XBP during one solar rotation in June 1973 showed significant variations as a function of heliographic longitude. This paper will show the variations in XBP emergence patterns during a 6-month period in 1973 and attempt to assess the significance of these variations in terms of quantity of magnetic flux emerging per unit time in comparison to the emergence of active regions and complexes of activity.

The quantity of magnetic flux brought to the solar surface by XBP can be estimated in two ways. First, we can attribute a typical value of magnetic flux to an average XBP and multiply this value by the number of points emerging per unit time

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within the area of interest. Alternatively, we can use a determination of the lifetime spectrum $N(t)$ of XBP combined with some relationship between magnetic flux and lifetime to obtain a flux spectrum $N(\phi)$, giving the number of regions emerging per unit time having a quantity ϕ of magnetic flux. The total flux brought to the surface will then be

$$\phi_{\text{Tot}} = \int \phi N(\phi) \, \mathrm{d}\phi.$$

There exists a growing body of evidence that the lifetime of a bipolar magnetic region is proportional to the quantity of magnetic flux it brings to the solar surface. Active regions living 10–100 days contain 10^{21}–10^{22} Mx of flux (Sheeley, 1966), with the shorter-lived regions containing lesser amounts of flux. Ephemeral active regions with a mean lifetime of one day or less contain $\approx 10^{20}$ Mx (Harvey *et al.*, 1975) and there is some evidence that XBP living only a few hours contain as little as 2–3×10^{19} Mx of magnetic flux (J. Harvey, 1976, private communication). Born (1974), in a study of emerging flux regions living from several hours to several days deduced a similar relationship between lifetimes of arch filament systems and the quantity of magnetic flux emerging.

In Golub *et al.* (1976) we examined the distribution of lifetimes for all compact X-ray features on the disk in several high time resolution data sets. Among other results we found that XBP at high latitudes have the same distribution of lifetimes as those near the equator, except for a very small number of long-lived low latitude features. The separation between the broadly distributed XBP and the equatorial confinement of active regions occurs at ≈ 2-day lifetime. From the equality of lifetime distributions for high and low latitude features living 2 days or less we infer that the amount of magnetic flux brought to the solar surface in a random sample of N high latitude XBP is the same as in an equally large sample of low latitude XBP. Put less formally, this says that a 'typical' XBP at high or low solar latitude will contain a characteristic quantity of magnetic flux, ϕ_{BP}. Moreover, if we combine the observed distribution of lifetimes with the estimates of magnetic flux discussed above we find that the spectrum of emerging magnetic flux on the Sun is dominated by small, short-lived regions.

Our previous observation of the XBP longitude distribution has been extended to include six complete and two partial solar rotations. We find first that significant nonuniformities, of spatial extent $60°$–$120°$ are seen on most rotations. Moreover, the average full disk number of XBP varies throughout the observing period with minima in June and November of 1973 and a maximum in August. The full disk number of XBP averaged over each rotation increases by almost a factor of two between Carrington rotations 1602 and 1604.

We will also present observations of XBP emergence at high latitudes during the eight rotations. The emergence of magnetic flux at high latitudes was implied in

earlier discussions of XBP latitude distributions (Golub *et al.*, 1974; Golub *et al.*, 1975; Harvey *et al.*, 1975). In this paper we will show variations of a factor of two in the number of XBP emerging per unit time at high latitudes, in both Northern and Southern hemispheres during the six months of observation. A conservative estimate of the magnitude of the flux emergence *at high latitudes alone* during this period is an amount equivalent to one major active region emerging per day in each hemisphere.

2. Analysis Techniques

Heliographic distributions of XBP density were obtained by counting the number of bright points seen on each of 127 X-ray images, spread more or less uniformly over six months of observation. For each exposure, the heliocentric positions of the points were transformed into a Carrington coordinate system. Because of the difficulty in determining extreme east–west positions and possible visibility effects associated with limb brightening, neither the longitudes nor the bright points further than $\pm 70°$ from central meridian were counted. The area obscured by active regions was outlined on each exposure and a proportionate amount subtracted from each longitude slice. For example (see Section 3), the longitude slice $160°–180°$ on rotation 1604 was within 70° of central meridian on six exposures but obscuration by active regions reduced the effective count to 5.1 observations. The observed total of 48 bright points for the six observations leads to a number density of 48/5.1 bright points per observation for the $20°$ longitude interval $160°–180°$.

The counting was performed by placing the transparancies on a light table in a windowless room with the overhead lights turned off. An opaque sheet with a 6-inch hole was placed on the light table and the 4-inch diameter solar disk centered in the hole. Finally, a transparent acetate sheet with a Stoneyhurst coordinate disk drawn on it was placed over the image so that bright point coordinates could be recorded. Stoneyhurst disks of the appropriate solar B angle, to an accuracy of 1°, were used for each image. The east–west readings were later converted to Carrington longitude by simple addition to or subtraction from the longitude of central meridian at the time of the exposure.

The photographic materials used for this study were so-called 'internegs', which are second generation enlarged positive transparencies produced directly from the flight film on Kodak Professional Copy film 4125 (Haggerty *et al.*, 1974). An alternative material was a third generation positive, produced by vacuum contact from the interneg onto a high quality direct duplicating film. The advantage of the latter material is that it is more durable than the 4125 and replacement of a damaged transparency does not involve a reuse of the flight film. Visual inspection showed no detectable difference in the number of bright points counted on the same images using the two different materials.

The choice of filter and exposure duration for the bright point counting was determined by the following criteria:

(1) Bright points are cool relative to such coronal features as active regions and interconnecting loops (Golub *et al.*, 1974). It is therefore necessary to use a filter which transmits the long wavelength portion of the solar X-ray spectrum, corresponding to the temperature range in which bright points are found. Within the S-054 passband the primary contributors to the coronal spectrum at log $T = 6.2$ are the resonance, forbidden and intercombination lines of O VII at 21.6, 21.8, 22.1 Å and lines of Si X at 45.8, 47, 48, 50.6 Å (Tucker and Koren, 1971; Vaiana *et al.*, 1974).

Three of the six S-054 filters are suitable candidates for bright point studies: filter 2, 32 micron Teflon (CF_2), bandpass 2–14, 19–22 Å; filter 3, 'blank', 2–32, 44–54 Å. The 'blank' consists of 1400 Å of aluminium deposited on an 80% transmitting nickel mesh, acting as a prefilter at the entrance aperture to the telescope, plus a magazine window consisting of 2000 Å of aluminium on a one micron polypropylene base. This material is included in the optical path of all of the other filters. We also considered filter 4, 5.7 μ parylene, bandpass 2–18, 44–47 Å.

(2) Observations through the filter had to be performed routinely throughout the mission and occasionally at a frequency high compared with the typical bright point lifetime of eight hours. During periods of manned operation filters 2 and 3 were used routinely in a synoptic program executed twice per day. During the unmanned periods between missions only filter 3 (and a beryllium filter) were used. In addition, filter 3 was considered a 'prime' filter for the S-054 observations and was used extensively in almost all of the observing programs. In particular, several programs involving extended observations at frequencies of one hour, ten minutes and 90 seconds were essential for the analysis herein reported.

(3) The choice of exposure duration is a crucial question involving several compromises. Ideally, one would prefer to use a long exposure in filter 3, in order to observe the maximum number of points. For some portions of this study such a procedure was used. However, for studies of bright point distributions, especially those involving questions of the uniformity of the distribution across the solar surface, the physical properties of the corona and the behavior of photographic emulsions cause severe biases in long exposure images.

The major source of bias is the reduced visibility of an XBP when it is viewed through an overlying structure. An over-simplified argument which still shows the essential point is the following: Suppose that an XBP causes E_b erg cm^{-2} to be deposited on the film. Assuming that this energy produces a photographic density in the linear region of the H and D curve, the density is

$$D_b = \gamma \log E_b + k,$$

where γ and k are constants. Now, if the same XBP is viewed through two different structures of energy E_1 and E_2 the resultant increases in photographic densities at the XBP are:

$$\Delta D_1 = \gamma \log \frac{E_b + E_1}{E_1} = \gamma \log \left(1 + \frac{E_b}{E_1} \right)$$

$$\Delta D_2 = \gamma \log \left(1 + \frac{E_b}{E_2} \right)$$

If, for instance, $E_2 = 5E_1$ and $E_1 = E_b$ which are commonly encountered values in the corona, e.g., across the boundary of a coronal hole we find

$$\Delta D_1 = \gamma \log 4 = 0.60 \gamma$$

$$\Delta D_2 = \gamma \log 1.2 = 0.08 \gamma$$

or $\Delta D_1 \approx 7.5 \, \Delta D_2$. This type of bias is so extreme that we have been forced to use short exposure images, in which only the largest and brightest XBP are visible but the film response is nearly linear rather than logarithmic. The photographic density added by an XBP is then approximately independent of the background density.

A more detailed calculation, using our laboratory measurements of film response and approximate values of X-ray emissivity for bright points and large scale structures is shown in Figure 1. The solid curves show ΔD (in PDS microdensitometer
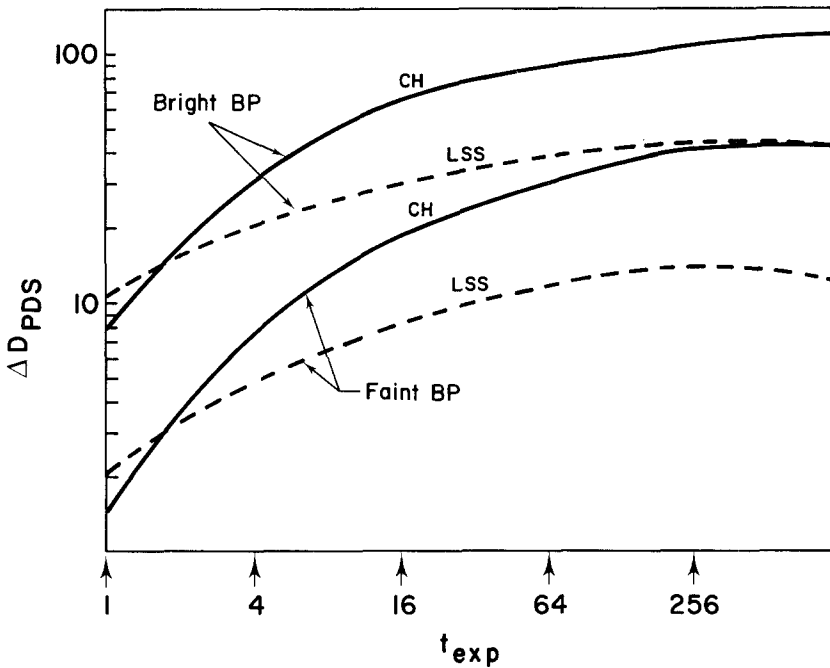

Fig. 1. Calculated photographic density (in PDS microdensitometer units) above background of typical bright and faint XBP's located in coronal holes (solid lines) and under large scale coronal structures (dashed lines), as a function of exposure duration.

units) vs. exposure time for a bright and a faint XBP in a typical coronal hole. The dotted curves show the added density for the same two points observed through a typical overlying coronal structure. The exposure times available in our data are indicated by arrows along the abscissa. As described above, we see that the visibility of XBP in coronal holes on long exposure images is much higher than that of XBP against background structures. However, as we go to shorter exposures differences in visibility become smaller until, in this calculation, the curves actually cross at an exposure time of 2 seconds. The exact point at which the curves cross depends on many factors, such as film fogging, brightness of background structures and relative X-ray emission wavelengths of the superposed features. In addition, we have not included any estimates of the effect of size on visibility, although large faint features are sometimes more easily recognized than small bright ones. However, this analysis indicates that the use of short exposures will enormously reduce the bias in visibility, probably to the level of 30% or less.

From the exposure durations available in the S-054 data, we therefore chose the 4-second filter-3 exposures for the distribution studies. Of course, the number of points visible also decreases with decreasing exposure time. There is also some indication that the visibility begins to decrease if the exposure time becomes too long. Approximately 25% of all bright points visible on a 256-second exposure are visible on these images, typically 20–40 points. Examination of the XBP number density in coronal holes indicates that ≈ 10 times as many XBP should be visible on the 256-second exposure compared with the 4-second exposure. Presumably, most of these are obscured by overlying structures. The average lifetime of the XBP visible on the 4-second exposures is 4 hours, although the same points viewed on 256-second exposures have an average lifetime of 15 hours. The longer exposures have a greater effective sensitivity so that more of the light curve can be seen, thus lengthening the observed lifetime.

The question of counting variations between different observers and in the same observer at different times was examined in a number of ways, summarized in Table I. The only systematic effect found was a slight tendency to count more bright points

TABLE I

Possible sources of systematic errors in XBP counting, methods used for checking and sizes of errors from each source

Bias	Checking technique	Errors
Different observer	Recount same pictures, two or more observers	$\pm 10\%$
Same observer, different times	Recount same pictures, several days later	$\pm 10\%$
Up–down bias	Invert pictures and recount	$+5\%$
Left–right bias	Reverse pictures and recount	None found ($<5\%$)

at the top than at the bottom of a photograph. No other systematic effects were found and the random errors shown are small compared to the statistical uncertainties in the data. That is, if we assume that bright points occur independently of each other, then a full disk count of 25 bright points implies a statistical uncertainty of $\sqrt{25}$ or 20%, which is larger than the typical random differences found between different observers or in recounts by the same observer.

3. The Data

The longitude distributions of XBP from 28 May to 27 November, 1973 are shown in Figure 2. The data have been divided into 27 day groupings, except for the first and last rotations which are somewhat shorter. As described in Section 2 the longitude positions of XBP on each photograph were transformed to the Carrington system by noting the central meridian longitude at the time of the exposure. The 27 day groupings used here correspond to the usual Carrington rotation numbers. The ordinate scale in Figure 2 indicates the average number of XBP per observation, in each 20° longitude slice (see Section 2).

The longitude distributions show first that there are large variations from one location on the Sun to another in the number density of XBP, and second that the variations are not random but rather appear to form large scale patterns. The overall pattern on five of the six complete rotations is above average on one hemisphere and below average on the other. More detailed data were available for the first rotation (Golub *et al.*, 1975) in which the 'high' hemisphere was resolved into two peaks of $\approx 30°$ half width. The 'low' portion showed a smooth lower than average behavior over $\approx 100°$ in longitude. The extreme range of number density between the high and low bins in a rotation is about a factor of three, with the 20° binning used here.

The significance of the deviations from uniformity in the XBP longitude distributions can be quantified using a χ^2 test. For each rotation we have 18 data points corresponding to the average number of XBP per observation per 20° longitude interval. If we then find the average of these 18 points and compare it to the deviations from the average, we have a measure of the uniformity of the distribution in that rotation. The χ^2 is then defined as

$$\chi^2 = \sum_{i=1}^{18} \frac{[x_i - \bar{x}]^2}{\sigma_i^2},$$

where $\bar{x}$ = average number density

        x_i = ith value of no. density

        σ_i = statistical uncertainty in x_i.

We then use a χ^2 table to find $P(\chi^2)$, the probability that uniformly distributed data will by chance deviate from uniformity at least as much as the sample under consideration. Note that with eighteen data points and a one-parameter ($\bar{x}$) fit the applicable number of degrees of freedom is 17.
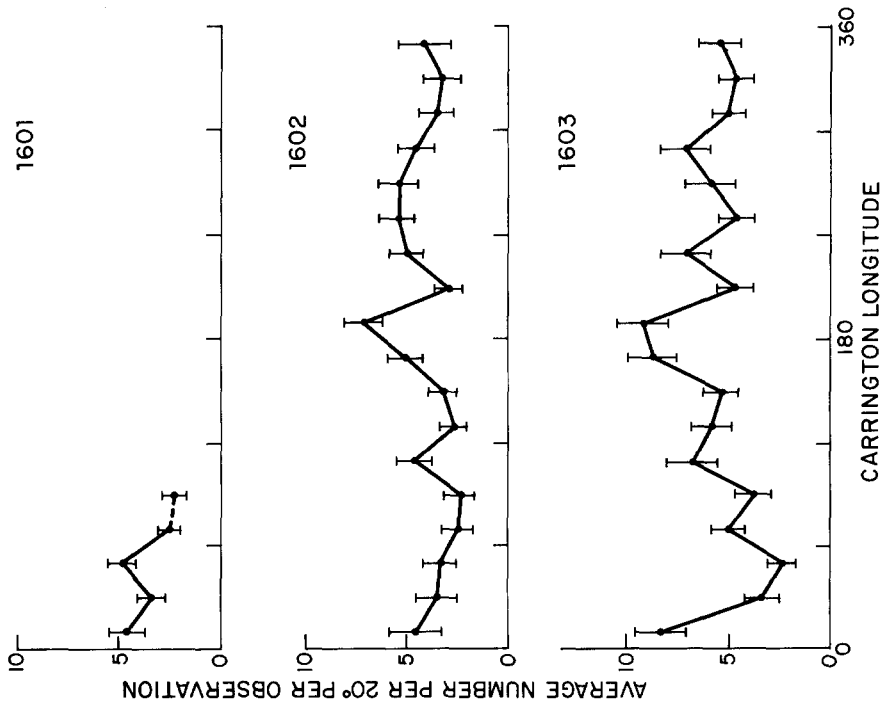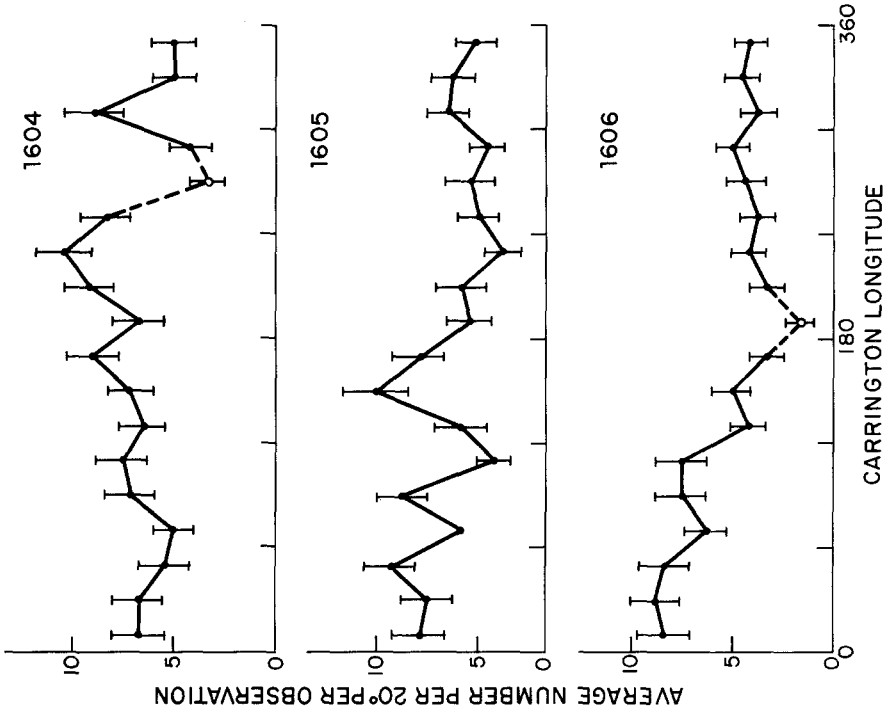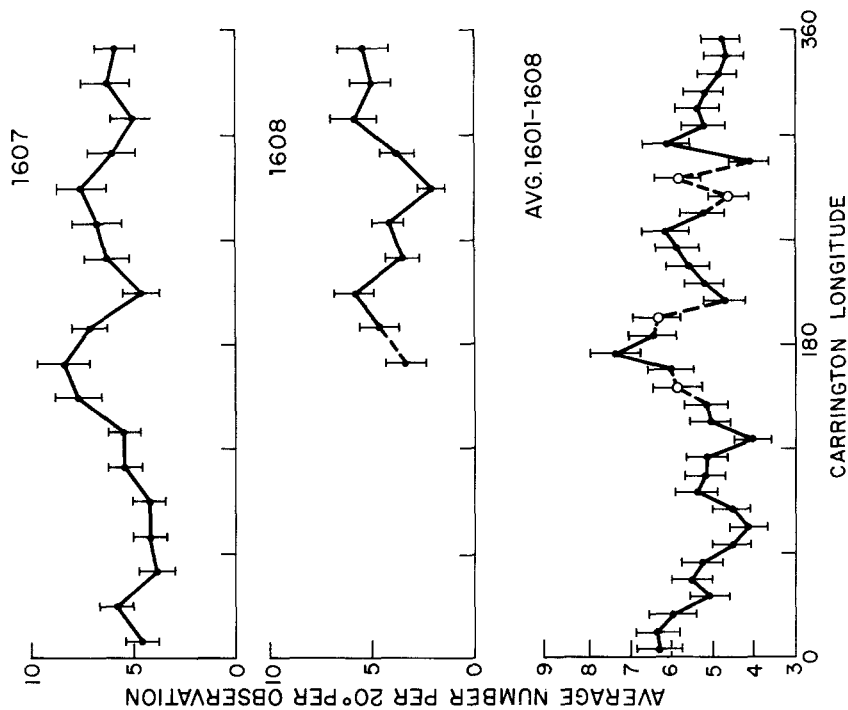
Fig. 2. Average number density (number per unit area) of XBP as a function of longitude for Carrington rotations 1601–1608. Data is divided into 20° longitude intervals, each of which was observed for several days during its disk passage. Open circles connected by dashed lines indicate longitudes for which the correction for obscuration by active regions raised the value of number density by 20% or more.

The results are shown in Table II. All of the six complete rotations have an exceedingly small probability of matching a uniform distribution, generally less than 0.1 %. Only rotation 1608 has an acceptable confidence level for uniformity and it was not observed for the full rotation. This test confirms in a dramatic way that the nonuniformities seen in Figure 2 are indeed significant and the changes from one rotation to another are real.

TABLE II

Probability that the observed nonuniformities in XBP longitude distributions are due to random statistical fluctuations

Rot. No. (1973)	χ^2	n_D	$P(\chi^2)$
1601	9.7	3	10^{-2}
1602	52.4	17	10^{-6}
1603	67.8	17	10^{-9}
1604	35.0	16	5×10^{-3}
1605	40.2	17	10^{-3}
1606	55.6	16	10^{-7}
1607	27.9	17	0.05
1608	13.5	9	0.14

The enormously high statistical sensitivity is due to the very large number of XBP present on the Sun. We counted typically 500 XBP per rotation, a small fraction of the total number which could have been counted. Even so, we observed typically 30 XBP per 20° longitude interval, which may be compared with the average of about 15 AR which emerged over the entire Sun per rotation. A three standard deviation change in XBP number density *in one longitude slice* would typically be $3 \times \sqrt{30}$ or about 55 % of the average number. But the *full Sun* AR number would have to change $3 \times \sqrt{15}$ or 85 % in order to produce the same statistical significance. This comparison is crucial in explaining why many of the variations in magnetic flux emergence patterns herein described cannot be found through the traditional type of active region study.

The short lifetime of XBP means that every day of observation provides a new and presumably independent data set. By comparing photos taken 24 hours apart we do indeed find that approximately 95 % of the XBP are replaced from one day to the next on the 4-second exposures. It is therefore of some interest to examine the variation in full disk XBP number count at a time resolution of 1–2 days in order to determine the randomness of flux emergence patterns. We would expect that the variations observed in the longitude distributions would be reflected in the full disk data, i.e., a more active longitude near CMP would increase the number count. If the emergence
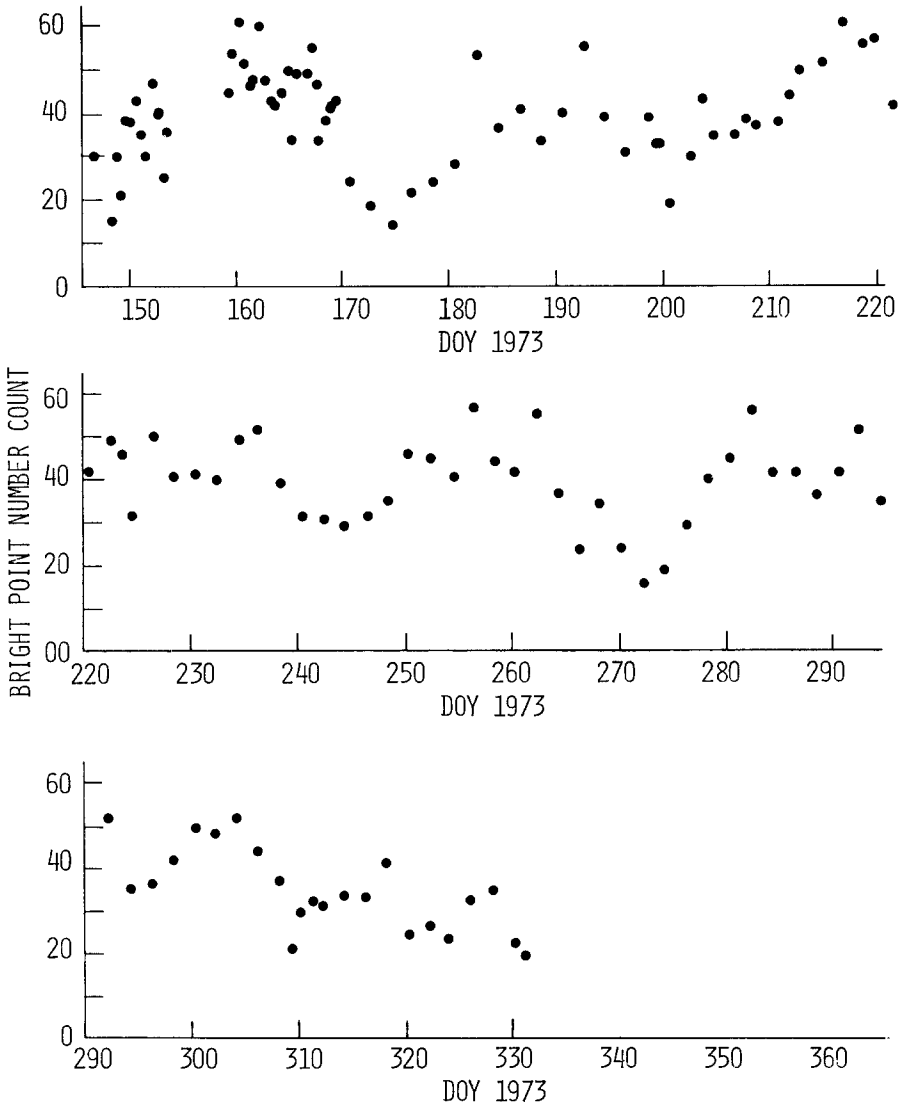
Fig. 3. Number of XBP observed on full disk images (four-second exposures) from 28 May to 27 November, 1973.

patterns are persistent, then a smooth variation in daily number count would be seen and would imply that the driving mechanism which generates the XBP at a particular region on the Sun has some permanence to it.

The observed daily number count for XBP visible within ±70° of central meridian on 4-second filter 3 exposures is shown in Figure 3. These data were obtained with the same photographs from which the longitude distributions were derived. The spacing

between photos is generally two days, except in June when the spacing is twelve hours. The existence of enhanced and suppressed longitudes is seen as an increase and decrease in full disk number as the different longitudes rotate into view. For example, the enhancements observed in the first three rotations would be near CMP on DOY 157–166, 184–192 and 211–220, and the minima would be near CMP on days 143– 148, 172–176 and 200–204. The average number of XBP observed during these two sets of days (when data are available) are 48.9 ± 1.3 and 25.8 ± 1.8, roughly a factor of two difference.

In addition to the longitude enhancements and the variations in distribution patterns, we find that the average number of XBP observed per rotation shows significant and non-random variations. Table III gives the average full disk number of XBP for each of the eight rotations (4-second exposures). The average values for the first and last rotations are small and nearly equal. However, during the intervening months the number of XBP rises dramatically before returning to the lower value. The magnitude of the increase reaches 60% of the initial value, far greater than the effect of active region obscuration which caused a maximum 10% correction on the fifth rotation. Therefore, even with no correction for the presence of active regions we find variations of up to 50% in the monthly average full disk XBP number.

TABLE III

Average full disk number of XBP, peak XBP number density and peak Zürich sunspot number for Carrington rotations 1601–1608

Rot. No.	Average number XBP	Peak number XBP[a]	Peak R_z[b]
1601*	32 ± 3	4.8 ± 0.8	32
1602	36 ± 2	6.8 ± 0.8	75
1603	49 ± 2	8.8 ± 1.2	57
1604	61 ± 3	10.0 ± 1.3	42
1605	55 ± 2	9.6 ± 1.5	130
1606	48 ± 2	8.4 ± 1.2	80
1607	49 ± 2	8.2 ± 1.1	65
1608*	37 ± 3	5.7 ± 1.0	62

* Partial rotations.
[a] Peak value in a 20° interval for that rotation (see Figure 2).
[b] From *Solar Geophysical Data* No. 357, 6 (1974).

The observed variations are not restricted to low latitudes, appearing even more dramatically in the data for XBP at latitudes greater than 30° from the equator. The behavior of low and high latitude points is shown in Figure 4, which shows the averages per rotation of Table III split into the two latitude categories. We see that the high latitude points show a systematic up and down behavior, with variations
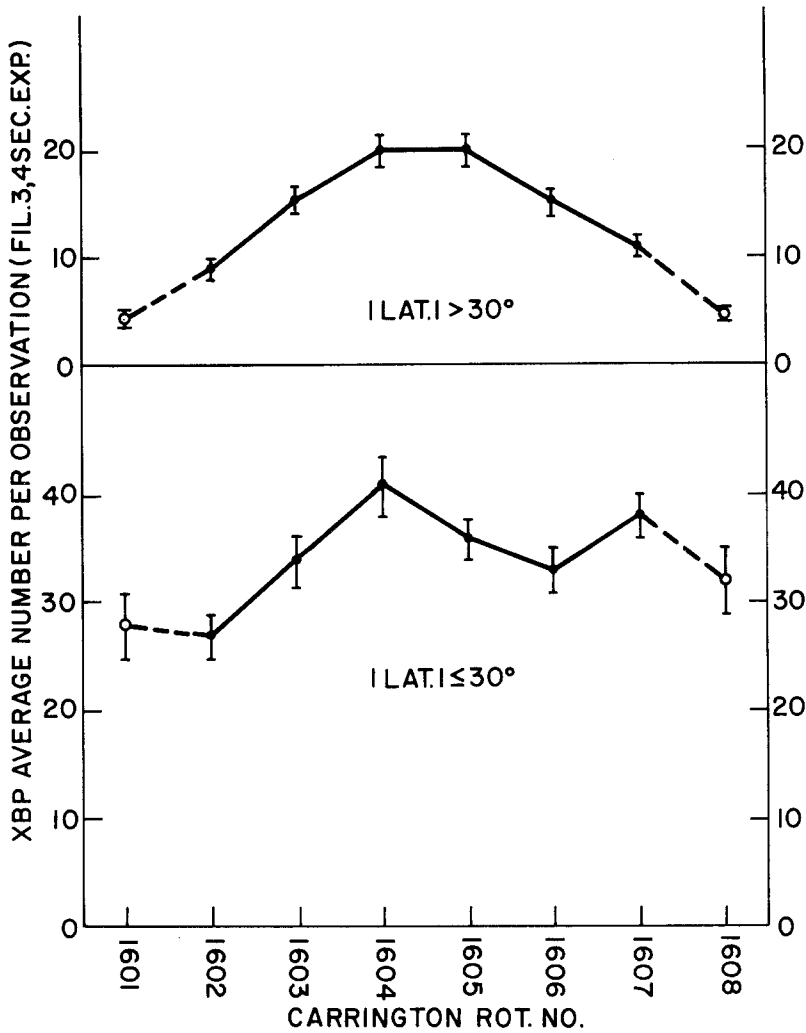
Fig. 4. Average number of XBP observed on four-second exposures (see text) during each Carrington rotation 1601–1608. Data have been separated into low and high latitude bins, with north and south latitudes combined.

greater than a factor of two. Moreover, the variation at high latitudes is smoother than the low latitude variation and peaks in the August–September period, approximately coincident with the one major outbreak of activity during the Skylab period as shown by the peak Zurich sunspot number per rotation, listed in Table III (*Solar Geophysical Data*, 1974). We have checked the northern and southern high latitude numbers independently and find the same behavior in both.

It appears therefore, that an 'event' was observed of approximately six month duration. The event consisted of an increase by 60% in the average number of XBP

on the Sun during each rotation followed by a decrease to the original level. Both high and low latitudes participated, roughly simultaneously and with approximately the same magnitude change. Whether the high or low state was 'normal', or whether the event represents a cyclical or repetitive process, we cannot determine due to the short length of the data base.

4. Discussion

As described in the Introduction, there are in practice two ways to determine the amount of magnetic flux being brought to the solar surface in the form of XBP. The most straightforward method is to determine a characteristic value for the quantity of magnetic flux contained in a typical XBP and to multiply this value by the number of points emerging per unit time within the area of interest.

Comparison of X-ray photographs with high resolution magnetograms shows that XBP contain quantities of magnetic flux in the range of 10^{19}–10^{20} Mx (Harvey *et al.*, 1975; J. W. Harvey, 1976, private communication). The value of flux most often encountered is approximately 2–5×10^{19} Mx when 64-second exposures in filter 3 (see Section II) are used to locate the XBP. In order to be conservative in our estimate we will use 2×10^{19} Mx as a characteristic value.

The number of XBP present on the disk may be obtained by a simple scaling, described in Golub *et al.* (1974). The relative increase in the number of XBP observed in going from a 4-second to a 64-second exposure is slightly greater than a factor of ten, in areas of the Sun where overlying structures do not obscure the observations. The number of XBP present on the disk at a given time is therefore taken to be ten times the number counted on the 4-second exposure, as presented in Figure 3. This yields numbers in the range 200–600 and agrees with estimates obtained with the Harvard College Observatory XUV instrument on Skylab (J. G. Timothy, 1975, private communication). The number of points emerging per unit time is then obtained by solving the equation

$$\frac{dN}{dt} = -\alpha N + \beta$$

for β (Golub, 1976). If we assume that the full disk number changes slowly with respect to the characteristic XBP lifetime of ≈ 8 hours then we may set $dN/dt = 0$ to obtain

$$\beta = \alpha N.$$

The number of XBP emerging per unit time within the area of interest is just a multiple α of the number present at that time. The constant α is seen to be $\approx 24/8 = 3$ if we convert to number emerging per day.

Applying these calculations to the full disk observations of Figure 3, we find that

the quantity of magnetic flux emerging per day in the form of XBP ranges between 1.2×10^{22} and 3.6×10^{22} Mx. If we consider only the XBP at high latitudes (Figure 4) we estimate that 6×10^{21} to 1.2×10^{22} Mx per day emerged at latitudes greater than $30°$.

The number of active regions emerging per day during the Skylab period, as indicated by assignment of McMath numbers, was approximately one per day. A typical active region, which develops sunspots and lives a solar rotation or longer, contains approximately 10^{22} Mx of magnetic flux (Sheeley, 1966). This value may be taken as an upper limit for calculating active region flux emergence during the Skylab period since the great majority of active regions during that time lived only one week or less and so presumably contained lesser amounts of magnetic flux. We therefore estimate that an average of no more than 10^{22} Mx of magnetic flux per day emerged in the form of active regions during the Skylab period. Comparing this number to the calculations for XBP, we find that XBP contributed one to four times as much as did the active regions. Moreover, the amount of flux emerging in XBP *at high latitudes alone* is equal to the contribution from active regions. This number includes only the visible disk and should therefore be multiplied by two to get the full Sun number, from which we estimate that the amount of magnetic flux brought to the solar surface by XBP at latitudes greater than $30°$ from the equator is equivalent to one active region per day emerging in each hemisphere.

In Golub *et al.* (1975) we discussed the possible interpretation of the XBP latitude distribution in terms of two components, one uniformly distributed over the disk and another concentrated into two active latitude belts. Both components contained approximately the same number of XBP, so that one-fourth of all XBP occurred at latitudes greater than $30°$ from the equator. For the remaining three-fourths which occurred within $30°$ of the equator, one in three was attributed to the uniform component and the remainder to the AR-like component.

We may apply this two-component interpretation to the variations seen in Figure 4 by simply extrapolating the uniform component from high latitudes to low, i.e., by subtracting the high latitude from the low latitude data. (It is convenient that the observed break in the latitude distribution occurs at $\sim \pm 30°$, because this latitude divides the solar surface area exactly in half.) The result is that the low latitude variation can be explained as a change in the uniform component alone, while the AR-like component remains constant to within the statistical uncertainties in the data. One data point, on rotation 1607 would be $\approx 3\sigma$ above the average.

Before believing this result, we should point out a major source of possible error. In Section II we described the method used to correct the observations for obscuration by large active regions. As discussed in Section III, this correction amounted to no more than 10% for computation of the full disk number density of XBP. However, the more restricted AR-like sample discussed above is more severely affected by the active region correction, since almost all active regions large enough to obscure significant areas of the solar surface occurred within $\pm 30°$ of the equator. The

magnitude of the AR obscuration correction, if it could be determined for the fictitious XBP sample under consideration, would be 30–40%. Moreover, we have shown that the overall XBP variation is roughly in phase with the emergence of activity, so that a 30–40% increase in the AR-like component of the bright point distribution could be masked by the presence of larger active regions and a gross underestimation of the area obscured by each region. Such a variation, however, is still smaller than the factor of two change seen at high latitudes.

5. Summary

We have examined the heliocentric number density distributions of X-ray bright points (XBP) from 28 May to 27 November, 1973. There exist statistically significant variations in this quantity as a function of solar longitude at all times and major variations in the average number density from one rotation to the next throughout the six-month interval. The number density as a function of longitude is not consistent with a uniform distribution on any of the six complete solar rotations observed.

   Observations of the full disk number of XBP repeated at intervals of 1–2 days show that the enhancements at restricted longitudes (30°–60° in extent) are persistent during their days of disk passage. The presence of an enhanced longitude on the disk raises the full disk XBP number count, typically by a factor of two compared with the count observed in the presence of a depressed longitude.

   A conservative estimate of the quantity of magnetic flux emerging on the Sun in the form of XBP is one to four times the amount emerging in the form of active regions. Moreover, this quantity shows at least a 50% variation during the course of the eight solar rotations observed. A peak in the XBP emergence occurs approximately simultaneous with a major outbreak of active regions.

   The variation as a function of time in XBP emergence is also observed at high solar latitudes. The high latitude number density of XBP averaged over each rotation varies by a factor of two during the six-month period. The peak quantity of magnetic flux brought to the surface at high latitudes alone is estimated to be equivalent to one AR emerging per day in each hemisphere.

   These observations indicate that solar activity is not restricted to active regions and the active region latitudes. The familiar active regions seem to form only a small part of a larger picture of magnetic flux emergence on the Sun. This expanded view of solar activity reveals a highly dynamic behavior even during a relatively short period in the declining phase of a solar cycle. We believe that an understanding of dynamo mechanisms and the solar dynamo in particular will require a more complete characterization of solar activity and the variations in this activity throughout an entire cycle.

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