ASSOCIATION OF FLARING X-RAY BRIGHT POINTS WITH TYPE III BURSTS

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ABSTRACT

Using the swept-frequency radio observations obtained at the Clark Lake Radio Observatory and the X-ray photographs taken by the S-054 experiment aboard Skylab, we have searched for type III bursts associated with X-ray bright point (XBP) flares. Using temporal as well as spatial criteria for the association, we have found four such events over a period of 43 days. The time period was selected in such a way that the level of flare and radio activity was low in order to minimize the chance coincidences. The detection of type III bursts from the flaring XBPs is of great interest, since it identifies them with the flare process, of which XBP flares are thought to be the simplest form.

Subject headings: sun: flares — sun: radio radiation — sun: X-rays

I. INTRODUCTION

Solar X-ray bright points (XBPs) are compact emitting regions associated with bipolar magnetic fields. Their properties have been discussed by Golub et al. (1974) and Golub et al. (1977). At any one time there appear to be a few hundred XBPs present on the Sun. Their lifetimes range from a few hours to several days, although only a small number appear to last over two days (Golub et al. 1977). They seem to carry a large fraction of the magnetic flux which emerges to the solar surface.

About 10% of the XBPs exhibit a type of sudden, substantial increase in surface brightness which in larger regions would be termed flaring. No observations of their radio counterparts were made with high-resolution radio telescopes during the Skylab period. Because of the possibility that these events are the manifestation of the flare process in its simplest form, their study is potentially important for understanding the basic flare mechanism. An attempt was made to detect microwave emission (9.4 cm-λ) from flaring XBPs using the 46 m radio telescope of the Algonquin Radio Observatory in conjunction with the X-ray observations from OSO 8 (Avery et al. 1977). Observations over an extended period of more than 50 hours revealed only one radio event which might have been associated with a flaring XBP. Due to ambiguities in the OSO 8 data, Avery et al. (1977) were unable to confirm with certainty the correspondence in position between the possible flaring XBP and the microwave burst source.

It is clear that single-dish telescopes with typical resolutions of a few minutes of arc are not suitable for studying this kind of spatial association; one really needs two-dimensional arrays with resolution of a few seconds of arc to establish precisely this spatial association. However, one can study the radio counterparts of the flaring bright points by using temporal association. These flares appear to be impulsive in nature, lasting only 2–3 minutes. They have been observed at their onset or during their maximum phase with the Skylab S-054 soft X-ray telescope of AS&E. Because of the characteristics of these events it is logical to look for radio emissions arising from the passage of nonthermal electrons through the corona, such as type III bursts. Several hundred flaring bright points were recorded by the S-054 telescope aboard Skylab. Some of these occurred during the observing periods at the Clark Lake Radio Observatory. Using the CLRO interferometer data, we have looked for and measured the positions of short-lived type III bursts at the time of the flaring bright points. The spatial resolution of the X-ray photographs is much higher than that of the radio observations. We used the radio positions to eliminate only the type III bursts that coincided in time with flaring XBPs, but occurred at distant locations. In this Letter we report the results of a search for type III bursts associated with XBPs during part of the Skylab period.

II. THE OBSERVATIONS

The X-ray photographs used in this study were taken by the S-054 telescope aboard Skylab. The characteristics of the instrument were described by Vaiana et al. (1976). The telescope collected over 30,000 broad-band soft X-ray filtergrams in the 2–32 and 44–45 Å wavelength ranges during the period 1973 May to 1974 January. A subset of the full data base, consisting of all 64 s Sun-centered exposures in the broadest band filter,
was used in locating the bright point flares. Data with arcsec resolution were recorded over the full solar disk in each exposure.

Two-dimensional radio positions of the burst sources were obtained at the CLRO, operated by the University of Maryland. During the Skylab mission both the Teepee Tee arrays and the log-periodic array (LPA) were in operation. The Teepee Tee arrays operate in the 20–110 MHz range, and the LPA in the 20–65 MHz frequency range. The time resolution of both instruments was 1 s. The coverage in the N-S direction was always provided by the south arm of the Teepee Tee array, with an angular resolution of approximately 6' at 100 MHz and 15' at 40 MHz. The coverage in the E-W direction was provided either by the E-W arm of the Teepee Tee, or by the LPA. The angular resolution of these instruments was approximately 6' and 5' at 60 MHz, and 18' and 15' at 20 MHz, respectively. The LPA was less sensitive than the south arm of the Teepee Tee; consequently, when E-W observations were taken with this instrument some of the weakest bursts were only recorded by the south arm of the Teepee Tee array. Only one-dimensional (N-S) positions are available for these bursts.

The search for type III bursts associated with flaring XBPs was limited to two periods during the Skylab mission. The first of these extended from 1973 June 17 to August 14. Two brief periods (1973 July 6–8 and July 22–24) were excluded from our study. Radio storms, or frequent type III activity, took place on these dates and would have made the identification of LPA was less sensitive than the south arm of the Teepee Tee array at some frequencies.

The type III bursts observed in association with the Skylab mission were limited to two periods during the Skylab mission. The first of these extended from 1973 June 17 to August 14. Two brief periods (1973 July 6–8 and July 22–24) were excluded from our study. Radio storms, or frequent type III activity, took place on these dates and would have made the identification of these dates and would have made the identification of LPA was less sensitive than the south arm of the Teepee Tee array at some frequencies. These bursts were observed only at a frequency of ∼31 MHz. They were followed by several other type III's between 2007 and 2016. Only N-S positions were available for this event. The dynamic spectra of the bursts are shown in Figure 1a (Plate L15), and the position of the radio source which was much larger in extent. In addition to the four type III bursts which we were able to associate with XBPs, a fifth type III was simultaneous in time, but did not coincide in space with a flaring XBP. Interestingly, this XBP flare was observed at 21°26' on 1973 September 10, simultaneously with one of the type III associated flaring XBPs. It was located at heliocentric coordinates S10, east limb, and is well visible on Figure 2c (Plate L19). Due to the lack of coincidence in their positions, no association between the type III and XBP flare could be established.

We now discuss each XBP flare associated type III burst event and the reliability of the association in each case.

a) The Event of 1973 June 22

The XBP flare occurred at 20°02' UT at heliocentric coordinates N40, CMP. Weak radio bursts occurred at 20°01°19' and 20°02°25' UT. These bursts were observed only at a frequency of ∼31 MHz. They were followed by several other type III's between 20°07° and 20°16°. Only N-S positions were available for this event. The dynamic spectra of the bursts are shown in Figure 1a (Plate L15), and the position of the radio source at 20°02°25' is shown in Figure 2a (Plate L17), superposed on the S-054 X-ray photograph of the disk. The flaring XBP is shown by the arrow.

Type III activity was low at the time of the event. No bursts were observed at Clark Lake on either 1973 June 21 or 23. A second weak group of type III's occurred on June 22, between 20°30° and 20°43° UT. An important F flare was reported to have started at 20°10° UT in the plage region McMath 12390 (Solar Geophysical Data, 1973 December). The flare reached maximum at 20°10° UT. Since the Hα flare occurred shortly after the XBP flare, it is possible that the type III group was associated with the Hα flare rather than with the XBP brightening. The positional information available to us does not permit a clear-cut association one way or the other. Consequently, the association of the type III burst with the XBP flare may not be regarded as definitive in this case.

b) The Event of 1973 July 12

The S-054 photograph taken at 22°29° UT indicated the presence of a flaring XBP at heliocentric coordinates N30, E50. A very weak type III burst was observed with the south arm of the Teepee Tee array at 22°30°15'. The dynamic spectrum of this event is shown in Figure 1b (Plate L16), the type III burst was...
Fig. 1.—Swept frequency records, showing the type III bursts which occurred (a) on 1973 June 22 and (b) on 1973 July 12. The arrows indicate the type III burst.

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Fig. 2.—Flaring XBPs described in the text are indicated by the arrows. (a) 1973 June 22; (b) 1973 July 12; (c) 1973 September 10; (d) 1973 September 13. For (a), (b), and (d) the solid lines indicate the extension of the radio source and the dashed line its approximate centroid. For (c) the cross indicates the approximate centroid of the radio source, the solid line its extension at 50 MHz, and the dashed line its extension at 30 MHz.

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observed in the 31–37 MHz range only. The flaring XBP and the position of the associated one-dimensional radio source are shown in Figure 2b (Plate L18).

We believe this event to be the best example of a correlation between a flaring XBP and a type III burst, for the following reasons: The type III burst (which occurred within a minute of the time of the S-054 picture of the flaring XBP) was the only one observed during the 5 day period July 10–15. Only two unconfirmed subflares have been reported in the Solar Geophysical Data for July 12. Both of these occurred in the region McMath 12417, which at the time was passing the west limb. The flare which occurred closest in time to the type III burst of interest took place on July 13 at about 03h51m UT, at heliocentric coordinates S11, W11 in McMath region 12428. It is clear that the type III burst could not have been associated with any of these subflares.

We wish to emphasize again that the fact that the type III burst was observed only over a limited range of frequencies does not mean that it occurred only at those frequencies. The gain of the instrument varied over the observed frequency band, and the burst may have been simply too weak to be detected outside the 30–40 MHz range.

c) The Events of 1973 September 10 and 13

Flaring XBP's were observed simultaneously with type III bursts on 1973 September 10 and 13. The flaring XBP of September 10 was located at heliocentric coordinates E0, N70; it was observed at 21h26m UT. The two-dimensional radio position of the associated type III source is shown superposed on the S-054 photographs in Figure 2c. The burst was weak, it was observed in the frequency range 25–50 MHz, and its duration was about 6 s. Some flare activity was observed on the disk on this day. The Hα flare which occurred closest in time to the event described by us was observed to start at 20h24m UT and reached maximum at 20h27m; it was a subflare which occurred in McMath region 12513 at heliocentric coordinates S10, W34 (Solar Geophysical Data). Seven type III bursts were observed on September 10 at CLRO; the observations started at 13h47m UT and ended at 23h43m UT. The type III burst which occurred simultaneously with the flaring XBP was the last one, the others were observed between 19h54m and 20h35m UT.

The 13 September 1973 XBP flare occurred at 20h47m UT. The flaring XBP and the position of the type III source are shown in Figure 2d (Plate L20). The type III burst was weak; it was observed in the 51–62 MHz range. Two other type III bursts were observed on this day, at 20h04m and 20h57m UT. The type III burst source observed at 20h04m was confined almost entirely to the southern solar hemisphere; the centroid of the burst which occurred at 20h57m was located off the west limb, 1.7 R⊙ from the center of the disk. Flare activity was low on this day; in particular, no flare was reported during the 6 hours preceding or following the flaring XBP type III event. We believe that both the September 10 and 13 events are good examples of type III bursts being associated with flaring XBP's.

III. Discussion

We have searched for the association of flaring XBP's with type III bursts in the meter-decameter range. In a total of approximately 430 hours of observations, four events were found where a type III burst occurred within a minute of the XBP flare. In all four cases, the XBP flare underlay the associated type III source. We feel certain that three of these four associations are genuine; in the fourth case the type III burst may have been associated with a small Hα flare which occurred simultaneously with the X-ray event. Since 29 flaring XBP's were observed during the period of observations, the above figure represents an approximately 10% association. It has been suggested by Avery et al. (1977) that the XBP's which occur close to the equator and which appear to be slightly longer lived may produce more intense flares, and consequently these may be the ones that are associated with radio bursts. The small number of bursts observed by us does not seem to bear out this suggestion. The positions of type III-associated flaring XBP's ranged from about 10° to 70° heliocentric latitude. All type III bursts observed in association with the flaring XBP's were weak. Unfortunately, no flux density is available for any of the bursts, as no intensity calibrations were taken at the time of the observations. However, the simple detection of type III bursts from the flaring XBP's is interesting, because it identifies them with the basic flare process where plasma radiation takes place. The energetic electrons produced during the XBP flare are expected to be trapped in the loop, giving rise to microwave emission. Occasionally, these energetic electrons appear to have access to open field lines above or near the XBP, giving rise to the observed type III bursts. One would therefore expect a closer correlation of the XBP's with microwave emission than with type III bursts. No microwave emission was reported by patrol instruments in association with any of the events discussed by us. The detection of the microwave emission must require radio telescopes with much larger collecting areas and higher spatial resolutions than those of patrol instruments, since the microwave emission originating from the flaring XBP's is probably weak. We note that of the four XBP's discussed by us two occurred in coronal holes. The other two took place near active-region loop complexes.

Parker (1975) suggested that XBP's are the result of elementary magnetic flux tubes rising through the solar atmosphere by magnetic buoyancy. As the flux tube rises, its feet are twisted by photospheric motions. The azimuthal field accumulates at the apex of the twisted loop. After the twist exceeds a certain critical value there is no equilibrium possible, and the XBP becomes unstable so that the kinked fields are dissipated through...
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Fig. 2d
rapid reconnection. It has been estimated that approximately $3 \times 10^{27}$ ergs of magnetic energy may be carried to the top of the loop by the azimuthal fields (Parker 1975). The total radiative flux released during an XBP flare is estimated to be $U_R \approx 3 \times 10^{27}$ ergs, and the magnitude of the conductive flux is likely to be similar. On the other hand, the total energy contained in type III exciters has been estimated to be of the order of $10^{25}$--$10^{26}$ ergs (e.g., Lin and Hudson 1971). The energy release in the form of type III bursts is therefore a small fraction of the total energy released during the XBP flare, as is the case for ordinary Hα flares.

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