ON THE SOLAR SURGE ASSOCIATION WITH MICROWAVE AND HARD X-RAY EMISSION BURSTS

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Abstract. It is found that 20% solar surges are associated with microwave bursts (2800–15000 MHz) and also that solar surges are not associated with hard X-ray bursts (17–40 keV).

1. Introduction

The solar surges represent a fast phenomenon in the chromosphere to corona region. A solar surge is some kind of prominence, which occurs in an active region of the Sun. The solar surge appears (in Hα) in the shape of straight or curvilinear spikes and grow upward from the chromosphere with velocities between 50–200 km s^{-1}. After attaining a maximum height (2×10^5 km), the material usually apparently seems to descend along the original trajectory (cf. Švestka, 1976). Surges are seen in emission over the limb and in absorption on the disk. Surges often appear at the same location many times at an average rate of one per hour. Sometimes the ejected material of the surge travels along a spiral or helical path (Dizer, 1968; Verma 1983) and returns to a neighbouring active centre (Macris, 1971; Verma and Pande 1982). In some cases, the surges show an association with the microwave bursts (Swarup *et al.*, 1960; Garczynska *et al.* 1982). Surges are found to be poorly associated with the soft X-ray radiations (Rust *et al.*, 1977) and SIDs (Verma, 1984a). The association of surges with the hard X-ray (HXR) radiation is still not established.

Here, we present a study of the relationship between HXR and microwave bursts with the solar surges.

2. Observational Data and Analysis

The solar surges are regarded as chromospheric mass ejections from the Sun and since 1980 the *Solar Geophysical Data* (SGD) has started publishing the required data in the chapter on 'Mass Ejections from the Sun'. In these SGD reports the duration of occurrence and the location for each surge is given. For microwave burst data corresponding to each solar surge we again used SGD. For HXR data corresponding to each surge we used *Hinotori Satellite Data* (1982, 1983). The HXR data recorded by Hinotori satellite was published by Hinotori HXM/SXT team in four energy channels. The first energy channel counts 17–40 keV photons, the second channel 40–67 keV photons, the third channel 67–152 keV photons, and the fourth cannel 152–359 keV photons. In the present study we used the first channel of HXR data as published by

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Hinotori HXM/SXT team (1982, 1983) because the frequency of events are maximum in this channel. Details about the techniques employed for photon counting in various energy are given in *Hinotori Satellite Data*, Parts I (1982) and II (1983).

In order to study the relationship between the microwave and HXR bursts with solar surges we followed the time correlation procedure used earlier by Swarup *et al.* (1960) and Zirin (1978). We followed this procedure because spatial locations of solar surges are known in Hα but are unknown for the microwave and HXR emissions.

For elucidating the relationships between microwave and HXR emisions with the solar surges, we noted all the solar surges from SGD (1980–1984) along with their duration of occurrence as observed in Hα. We also noted the corresponding microwave bursts from SGD (1980–1984). In the present study we used frequency range between 2800–15000 MHz. In the absence of other dynamic events on the Sun (e.g., flares, eruptive prominence), we noted the microwave radiation observed upto 10 min before the onset of Hα emissions for each surge. In this study we restrict ourself to non-event surges (NES), during the evolution of which no flare or other dynamic events have been observed on the solar disk. After excluding surges corresponding to NFO (no flare observations), FP (flare present on the disk), and SSE (start and end time unknown), we have the non-event surges (NES) as shown in Tables I and II. In Table I, TSR and MES stands for total number of surges recorded and number of surges with microwave bursts. In table II, NHXRO stands for number of surges corresponding to which no HXR observations are available, SHXRO stands for the number of surges with HXR observations available and HXRS stands for the number of surges associated with the HXR bursts.

TABLE I

Association of microwave bursts (2800–15000 MHz) with solar surges

Year	TSR	NFO	FP	SSE	NES	MES
1980	74	04	40	–	30	09
1981	357	56	89	01	211	38
1982	266	48	104	65	49	13
1983[a]	82	14	47	21	10	00

[a] Period of observations: 1 January, 1983–30 June, 1983.

TABLE II

Association of HXR bursts (17–40 keV) with solar surges

Year	NES	NHXRO	SHXRO	HXRS
1981[a]	202	152	50	00
1982[b]	49	41	08	00

[a] Period of observations: 26 February, 1981–15 December, 1981.
[b] Period of observations: 8 January, 1982–30 December, 1982.

2.1. Association between solar surges and microwave bursts

From Table I, it is clear that out of 779 surges recorded throughout the world during the $3\frac{1}{2}$ years period, only 300 NES surges are left for our study after excluding NFO = 122, FP = 280, and SSE = 87. Briefly, we find that corresponding to 300 solar surges during their occurrence in Hα only 60 surges produce microwave bursts (2800–15000 MHz). Out of the 60 surges associated with the microwave emissions, 43 surges produce simple (*s*) type bursts, 8 surges manifest only gradual rise and fall (GRF), 5 surges produce complex bursts (C), 3 surges show pre-burst activity (PRE), and only 1 surge produce series of bursts (SER). The onset time of each microwave burst corresponding to each Hα surge is noted. A histogram is plotted between the times differences in minutes of Hα and microwave emissions during the surges versus the number of surges with microwave emissions. In Figure 1 the horizontal dashed line shows an upper mean level with 95% confidence and only the peaks above the line are considered significant. It is clear from Figure 1 that the microwave emission starts upto 5 min earlier or within 5 min of the start of the surge in Hα and that no significant number of surges show simultaneous emissions (i.e. 0 min).

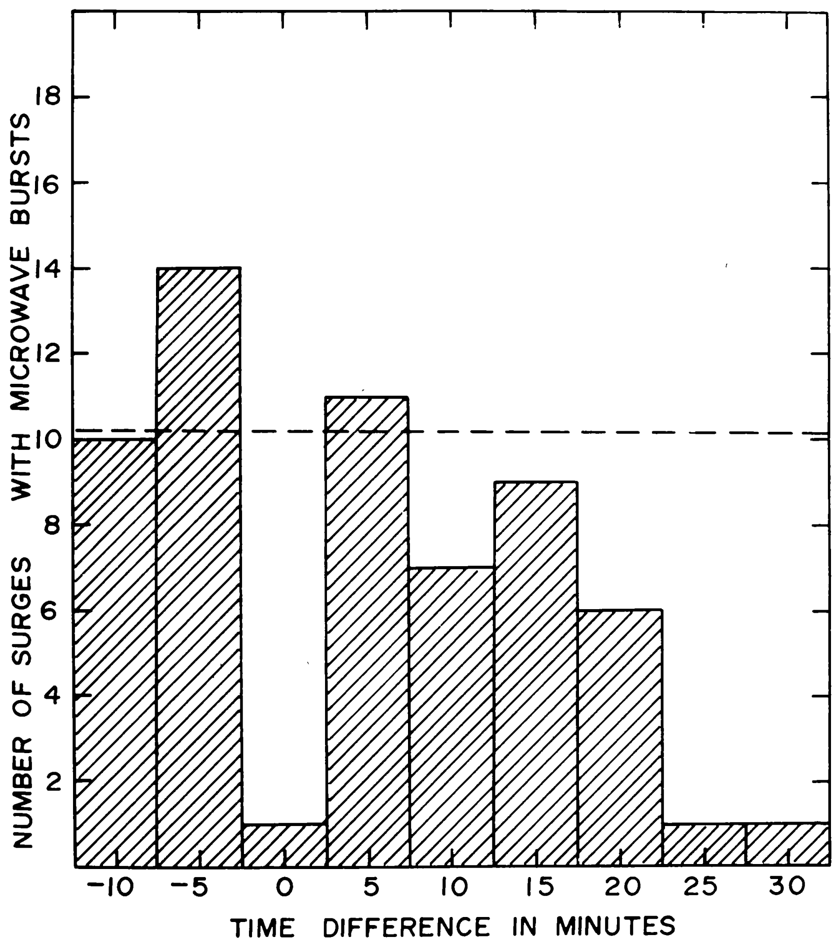

Fig. 1. Plot of time difference in minutes between the onset of Hα and microwave emission bursts during solar surges versus the number of Hα surges with microwave emissions.

2.2. Association of solar surges with HXR bursts

In order to study the relationship between the HXR emissions (17–40 keV) and the solar surgers we used SGD (1981, 1982, and 1983) and *Hinotori Satellite Data* (1982–1983). The period of study for the present study is less than 2 years (Hinotori satellite observation period). In 1981 and 1982, Hinotori satellite recorded HXR profiles during the periods: 26 February, 1981–15 December, 1981 and 8 January, 1982–30 September, 1982. Analysis based on Hα and HXR data of SGD (1981–1983) and Hinotori data (1982–1983) is shown in Table II. This study is limited to the HXR emission data recorded by the Hinotori satellite. From Table II, it is clear that during 1981 and 1982, 50 and 8 solar surges respectively were observed corresponding to which the HXR data (17–40 keV) is available. It is also clear from Table II that solar surges do not produce HXR radiation (17–40 keV) during the interval of their occurrence.

3. Discussions

In the preceding section we have studied the relationships between the solar surges and the microwave and HXR bursts. In the present study we find that 20% solar surges show a fair association with the microwave emission bursts (range 2800–15 000 MHz) and that a majority of these bursts were of simple type(s). Also this association is less pronounced than the findings of Garczynska *et al.* (1982). Solar surges do not show any association with HXR bursts (17–40 keV).

The HXR and microwave radiations are the results of an interaction between the solar atmopshere and the accelerated electrons and other particles produced during some dynamic eruption phenomena (e.g. flare, huge prominence eruption, etc.). The HXR radiation is due to bremsstrahlung of electrons in the ambient plasma and the microwave radiation arises through gyrosynchrotron mechanism (cf. Heyvaerts, 1981; Švestka, 1976). For both the radiations the kinetic energy of accelerated electrons, responsible for the production of HXR and microwave radiation is the important parameter. According to Peterson and Winckler (1959), De Feiter (1975), and Verma (1984b), the kinetic energy of electrons required to produce the HXR bursts ($\sim 10^{29}$ erg s^{-1}) is approximately 10^4 times of those electrons ($\sim 10^{25}$ erg s^{-1}) which are responsible for producing the microwave bursts. The 20% association of the microwave bursts and the negligible association of HXR bursts with the solar surges show that during surge eruption accelerated electrons may attain, kinetic energy up to 10^{25} erg s^{-1}, which is sufficient only for the production of microwave emission. Thus non-production of HXR bursts during the solar surges helps in fixing an upper limit on energy of the electrons referred to above.

From Figure 1 it is obvious that during the occurrence of surge the microwave emissions associated with the solar surges have onsets up to 5 min before and within 5 min of the start of Hα emission. According to Kampfer and Magun (1983) the Hα and the microwave emissions originate in solar atmosphere through different mechanism and from different heights. The Hα emission essentially originates in the lower chromosphere, while the microwaves originate in the upper chromosphere to corona transition region. Observations of microwave bursts which precede the Hα emissions by five minutes suggest that the triggering of the surge occurs in the corona. Similarly when microwave bursts occur after the Hα emission one may infer that the triggering of the surge occurs in the lower chromosphere. Thus, two mechanisms for the production of surges may exist, however, at present there is no evidence in the literature for the first mechanism in which the surge triggering onset occurs in the corona.

The above findings are based on small data base (60 events). So these must be verified on large data base.

4. Conclusions

The results of the present investigation of the association of microwave and HXR burst emissions with the solar surges may be summarised as follows:

(1) 20% of solar surges show association with the microwave bursts (2800–15 000 MHz).

(2) Surges do not show any significant association with the HXR bursts (17–40 keV).

References

De Feiter, L. D.: 1975, in S. R. Kane (ed.), 'Solar Gamma, X- and EUV Radiation', *IAU Symp.* **68**, 283.

Dizer, M.: 1968, *Solar Phys.* **4**, 99.

Garczynska, I. N., Rompolt, B., Benz, A. O. Slottje, C., Tlamicha, A., and Zanelli, A.: 1982, *Solar Phys.* **77**, 177.

Heyvaerts, J.: 1981, in E. R. Priest (ed.), *Solar Flare Magnetohydrodynamics*, Gordan and Breach Science Publ., London, p. 429.

Hinotori Satellite Preliminary Solar Hard X-ray Data: 1982 and 1983, Parts I and II, Hinotori SXT/HXM Team (eds.), Tokyo Astronomical Observatory, Mitaka, Tokyo, Japan.

Kampfer, N. and Magun, A.: 1983, *Astrophyss. J.* **274**, 910.

Macris, C. J.: (1971) in C. J. Macris (ed.), *Physics of the Solar Corona*, D. Reidel Publ. Co., Dordrecht, Holland, p. 68.

Peterson, L. E. and Winckler, J. R.: 1959, *J. Geophys. Res.* **64**, 697.

Rust, D. M., Webb, D. F., and Maccombie, W. 1977, *Solar Phys.* **54**, 53.

Solar Geophysical Data: 1980–1984, Part II, U.S. Department of Commerce, Boulder, Colo., U.S.A.

Švestka, Z.: 1976 *Solar Flares*, D. Reidel Publ. Co. Dordrecht, Holland p. 108.

Swarup, G., Stone, P. H., and Maxwell, A.: 1960 *Astrophys. J.* **131**, 72.

Verma, V. K.: 1983, *Bull. Astron. Soc. India* **11**, 70.

Verma, V. K.: 1984a, *Solar Phys.* **94**, 155.

Verma, V. K.: 1984b, *Indian J. Radio Sp. Phys.* **13**, 159.

Verma, V. K. and Pande, M. C.: 1982, *Bull. Astron. Soc. India* **10**, 211.

Zirin, H.: 1978, *Solar Phys.* **58**, 94.