ON THE THERMALISATION OF FLARE-TIME ENERGETIC ELECTRONS OBSERVED AT RADIO AND X-RAY WAVELENGTHS

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ABSTRACT

An interesting microwave event at 2800 MHz was recorded at Ahmedabad on September 19, 1977 at 1026 UT at the same time as the H-Alpha solar flare of importance 3B. The microwave burst was of impulsive nature, with as many as twenty impulses in seventy minutes with a quasi-periodicity of 1 to 5 minutes. An X-ray burst recorded by GOES Satellite in 1-8A band showed at the same time a smooth soft X-ray profile with apparently no sign of hard X-ray bursts. This indicates that the acceleration of discrete electron streams which produced impulsive microwave bursts was not sufficient to produce the hard X-ray component but got thermalised to produce soft X-ray emission, with a gradual rise and a slow decay covering a long duration of more than 2½ hours.

INTRODUCTION

A Dicke type microwave radiometer operating at 2800 MHz is in operation at Ahmedabad to record the daily solar radio flux with an accuracy of ± 3 per cent. Region 889 (McMath 14943, N08, L = 197, Class/area E/730 on 13 September 1977) on the solar disk became active on 16 September 1977. A major flare of optical importance 3B took place at 1026 UT on 19 September 1977 from Region 889 which was recorded at Ahmedabad as a complex microwave event in all its details.

Figure 1 shows the complex microwave event which started exactly at 1026 UT as that of the optical flare reported in the Solar Geophysical Data Report, Boulder, Colorado, USA. We can distinguish in Figure 1 as many as 20 microwave impulsive bursts, within a span of 70 minutes, beginning 1026 UT and each having a duration of about 1 to 5 minutes. The largest burst occurred at 1105 UT with a peak flux of ~1252 sfu which is comparable with 1100 sfu at 2700 MHz observed at Sagamore Hill in USA (1 sfu = 10^{-22} Wm^{-2} Hz^{-1}). The X-ray flux in 1-8A band observed by GOES-2 satellite started rising at 0950 UT and again

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at 1016 UT, reaching maximum at 1052 UT with a peak flux of 2 x 10^{-4} ergs/cm^2/sec as shown in Figure 1.

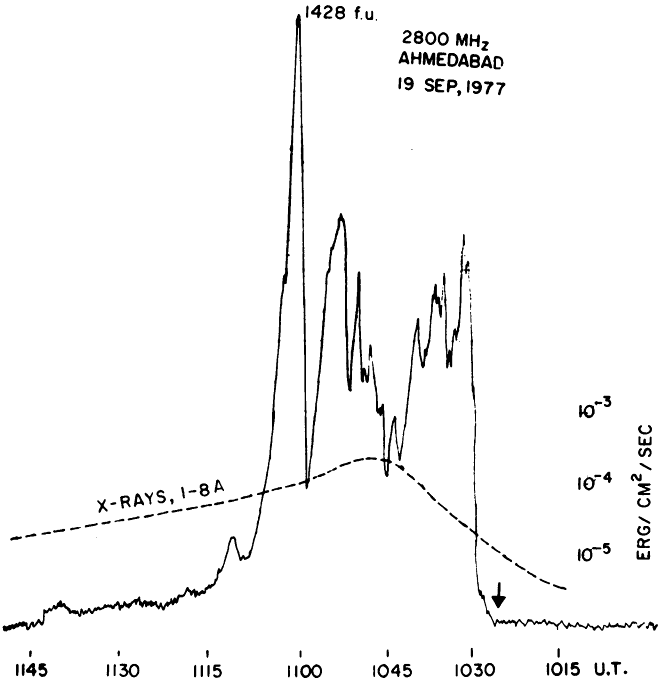

Figure 1. Microwave bursts at 2800 MHz showing quasi-periodicity. Associated X-ray flare is shown by broken line.

INTERPRETATION

The interesting feature regarding the flare on 19 September 1977 is that it displayed strong impulsive phenomenon in the microwave radiation. It is known that hard X-ray bursts are almost associated with microwave impulsive bursts and are of very short duration in flares (~10-50 sec.). The hard X-rays occur mostly after the onset of the soft X-ray emission (Kane, 1969). It is found that the soft X-ray emission starts earlier than the hard X-ray and microwave bursts (Švestka, 1975). It appears that since only soft X-rays were recorded during the event at 1026 UT on 19 September 1977, the non-thermal electrons got quickly thermalised due to collisions with the ambient plasma as they plunged along magnetic flux tube to lower levels.

Another fact which strengthens our conclusion regarding the X-ray emission on 19 September as being due to a single thermal enhancement is that the soft X-ray flux decayed very slowly (more than 2½ hours) as compared to the microwave event (~70 min). The impulsive nature of microwave bursts is indicative of acceleration of discrete electron streams whereas the smooth profile of soft X-rays indicates thermalization of electrons. The emission measure required for soft X-ray burst is $\sim 10^{50}$ cm^{-3} and the electron temperature $\sim 10^{7}$ K (DeFeiter, 1975; Švestka, 1975). For impulsive microwave bursts and hard X-rays, these values will be comparatively higher depending on the intensity of the flaring region.

CONCLUSION

It is difficult to say whether the observed periodicities are truly periodic phenomena representing acceleration of electron streams successively or are due to random flaring of several bright points within the disturbed region. This microwave event which showed strong impulsive behaviour had no counterpart in hard X-rays. Such a situation could be understood if the non-thermal electrons responsible for microwave emission got thermalized by collisions with the ambient plasma as is borne out by the absence of hard X-rays.

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REFERENCES

DeFeiter, L. D.: 1975, Solar Gamma, X- and EUV Radiation, S. R. Kane (Ed.), D. Reidel Publ. Co., Dordrecht-Holland, pp. 283-294.

Kane, S. R.: 1975, Solar Gamma, X- and EUV Radiation, S. R. Kane (Ed.), Dordrecht-Holland, pp. 385-409.

Švestka, Z.: 1975, Solar Gamma, X- and EUV Radiation, S. R. Kane (Ed.), D. Reidel Publ. Co., Holland, pp. 427-439.

DISCUSSION

Haug: You assume that the nonthermal electrons responsible for the impulsive microwave emission have been thermalized quickly by collisions in the ambient plasma. Why is there no hard X-ray production in these collisions?

Degaonkar: Maybe part of the non-thermal electron flux escaped from the apex of the flux tube and part got thermalized. Since the flux of soft X-rays was not very large, and hard X-rays were not produced, I feel that the thermalization might have taken place by electron collisions with ambient electrons and not with dense matter, which is necessary for production of hard X-rays.

Tandon: Would you comment on a wide time lag between the soft X-ray peak and the maximum peak of microwaves at 2800 MHz?

Degaonkar: The time lag could be due to the different production locations of microwaves and X-rays or there might be fresh generation of microwaves without further enhancements in X-rays. We are looking into this problem further.

Hoyng: Have you actually observed that hard X-rays were absent?

Degaonkar: I have not seen anybody reporting to have observed hard X-rays on that day. I don't know if there was any difficulty in measuring it, which is unlikely.

Kahler: The 1-8A X-ray flux is only a little more than 10^{-4} erg cm^{-2} sec^{-1} at the event peak. This seems to be an unusually small event considering the size of the microwave burst.

Degaonkar: I agree. That is why this event appears to be uncommon. The peak X-ray flux is 2 x 10^{-4} erg cm^{-2} s^{-1}; but the impulsive microwave burst is quite strong.