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TIME DELAYS BETWEEN DECIMETRIC TYPE-III-RD BURSTS AND ASSOCIATED HARD X-RAYS

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RESUMEN. En julio de 1987, se efectuaron radio observaciones en 1.6 GHz usando la antena de 13.7-m de Itapetinga con un tiempo de resolución de 3 ms. Las observaciones en rayos-X fueron obtenidas del HXRBS en SMM. Comparaciones de observaciones de 1.6 GHz con espectro dinámico en el intervalo de (1000 - 100) MHz y rayos-X duros muestran los siguientes resultados: i) en 12 casos, identificamos la continuación de brotes de tipo III-RD hasta 1.6 GHz. ii) Por primera vez, hemos identificado picos de rayos-X demorados en comparación con el brote decimétrico tipo III-RD. Estos retardos son más largos - 1 s - que lo esperado (∿ 100 ms) y han sido interpretados suponiendo que la emisión decimétrica es la 2a. armónica y está causada por el borde delantero del excitador, mientras que los picos de los rayos-X han sido atribuídos a la entrada completa del excitador dentro de la región que produce los rayos-X.

ABSTRACT. In July, 1985 radio observations were made at 1.6 GHz using 13.7 m Itapetinga antenna with time resolution of 3 ms. The hard X-ray observations were obtained from HXRBS on SMM. Comparison of 1.6 GHz observations with dynamic spectra in the frequency range of (1000 - 100) MHz and hard X-rays shows the following results: i) In 12 cases, we identify continuation of type III-RD bursts up to 1.6 GHz suggesting presence of type III-RD bursts at 1.6 GHz. ii) For the first time, we have idetified hard X-ray peaks delayed in comparison to decimetric type III-RD bursts.

These dalays are longer - 1 s - than expected (~ 100 ms) and have been interpreted assuming that the decimetric emission is at 2 nd harmonic and caused by the leading edge of the exciter, whereas peaks of X-rays have been attributed to entire entry of the exciter into the X-ray producing region.

Key words: SUN BURSTS — SUN-FLARES

I. INTRODUCTION

Reverse slope type-III-RD- bursts occur rarely in meter wavelength (La Bonte, 1976). There are very few investigations of joint studies of meter wave type III-RD burst and associated hard X-rays (Crannel et al. 1978). In most of the attempts made so far (Benz et al., 1983, Dennis et al., 1984) there were ambiguities as to which of several X-ray spikes are correlated with given decimetric type III-bursts. Recently, Stahli and Benz (1987) have observed type III like structures in microwave frequency, (5705 - 3100) MHz range and attributed their origin to beam plasma interaction at 2nd harmonic.

For the first time we have investigated high sensitivity high time resolution 1.6 GHz observations with dynamic spectra in the frequency range of (1000 - 100) MHz, which suggest that the observed bursts at 1.6 GHz are extensions of the type III-RD bursts observed up to 1000 MHz, thus providing for the first time an apportunity to investigate decimeter type

III-RD bursts and associated hard X-rays. These investigations have shown one to one correlated X-rays and decimetric type III-RD bursts for the first time.

II. INSTRUMENTATION

The decimetric, 1.6 GHz observations were carried out using 13,7 m Itapetinga antenna with time resolution of 3 ms with absolute time accurancy better than 100 ms in the month of July 1985 (Sawant et al., 1987).

Spectral observations in the frequency range of (1000 - 100) MHz were obtained from Zurich, with time resolution 0.25 s and with absolute time accuracy of better than 0.2s. X-ray observations in the energy range of 30 to 527 KeV were obtained from Solar Maximum Mission satellite with time resolution of .128 s.

III. INVESTIGATIONS OF X-RAY AND 1.6 GHz BURSTS

On July 9, 1985 during 16 48:17 - 16 54:03 UT, 43 bursts at 1.6 GHz with total duration of each of the burst of about 0.3 to 0.5 s were observed. During this interval "DEADLUS" spectroscope observed 20 structures. Most of them can be classified as type III-RD bursts and continued beyond the frequency range 1000 MHz of the spectroscope. Out of 15 bursts, 12 can be identified at 1.6 GHz within 0.2s. (Table I). From 16:46: - 16:54:40 UT, X-ray data were available with time resolution of 0.128 s. Fig. 1 shows spectroscopic, fixed frequency 1.6 GHz and hard X-ray observations.

Table 1. Timings of spectroscopic and associated decimetric bursts.

NR.	TIME UT OF SPECTROSCOPIC (2000-200) MHz BURSTS	FREQUENCY MIN |MHz|	MAX |MHz|	DRIFT |MHz/s|	TIME UT OF ONE OF THE CLOSELY ASSOCIATED PEAK OF 1663 MHz
1	1646:45.5	480	600	1 100	
2	1646:50.3	450	710	> + 800	
3	1646:53.2	500	600	400	
4	1647:56.3	420	>1.000	-500	16 47:56.4
5	1648:13.3	650	>1.000	> 400	16 48:13.9
6	1648:15.4	420	>1.000	1 000	16 48:16.
7	1648:32.2	370	>1.000	+1 000	
8	1648:36.5	340	>1.000	1 000	16 48:36.9
9	1648:43.2	560	>1.000	-	16 48:43.2
10	1648:46.0	610	970	-	
11	1648:52.6	450	>1.000	> 1 000	16 48:53
12	1648:56.8	520	>1.000	-	16 48:57.5
13	1648:58.8	580	>1.000	-	16 48:58.6
14	1649:05.5	560	>1.000	>1 000	16 48:05.2
15	1649:06.5	560	>1.000	+1 000	16 49:06.8
16	1649:08.8	610	>1.000	-	16 49:09.1
17	1649:11.8	500	>1.000	+1 200	16 49:11.8
18	1649:17.8	780	950	-	
19	1651:13.0	560	>1.000	+1 200	
20	1651:23.8	620	>1.000	+1 200	16 51:23.8

In Fig. 1 arrows indicate investigated group of decimetric, 1.6 GHz bursts associated with reverse type III bursts in the frequency range of (1000 - 100) MHz and associated hard X-rays . In these investigations we found twelve X-ray peaks delayed in comparison with decimetric 1.6 GHz, burst peaks by 0.3 - 1.2s as shown in Fig 2. Detailed investigation of one of the group is given below.

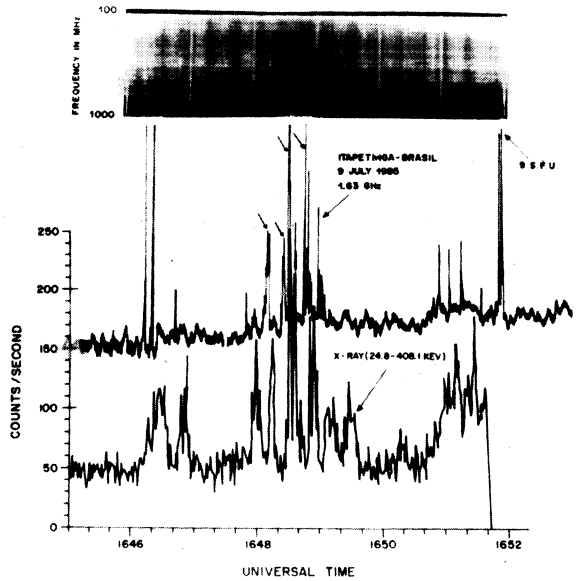

Fig. 1. Radio and X-ray data. TOP: Dynamic radio spectrum of the bursts recorded by DEADALUS analogue spectrometer. The thick vertical lines are minute marks. The horizontal white lines are local interference at fixed frequencies. MIDDLE: Time profile of 1663 MHz observation recorded at Itapetinga. BOTTON: X-ray count rate measured with the HXRBS on SMM. After 51:41 UT, there is satellite night.

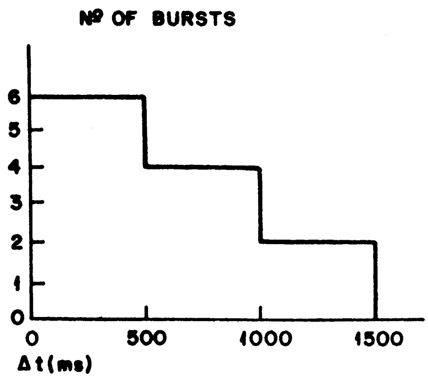

Fig. 2. Histogram of observed time delays between decimetric type III-RS bursts peak and of associated hard X-ray peak.

GROUP 1 (16:48:28 - 16:48:33) UT:

Decimetric 1.6 GHz bursts started arownd 16:48:28 UT and continued up to 16 48:33 UT with three peaks are shown in Fig. 3. X-ray burst also started arownd 16:48:28 UT and also showed three peaks. Associated decimetric burst n^{o} 7 of Table 1 extended beyond 1000 MHz. Fig. 3(a, b) shows that peaks of decimetric, 1.6 GHz burst are leading in comparison to eak of hard X-ray in the range of 0.4 to 1.2 s and are one to one correlated. Cross-rrelation analysis shown in Fig. 4 shows that one the avarage, decimetric burst peaks are eadind X-ray peaks by ~ 0.6 s.

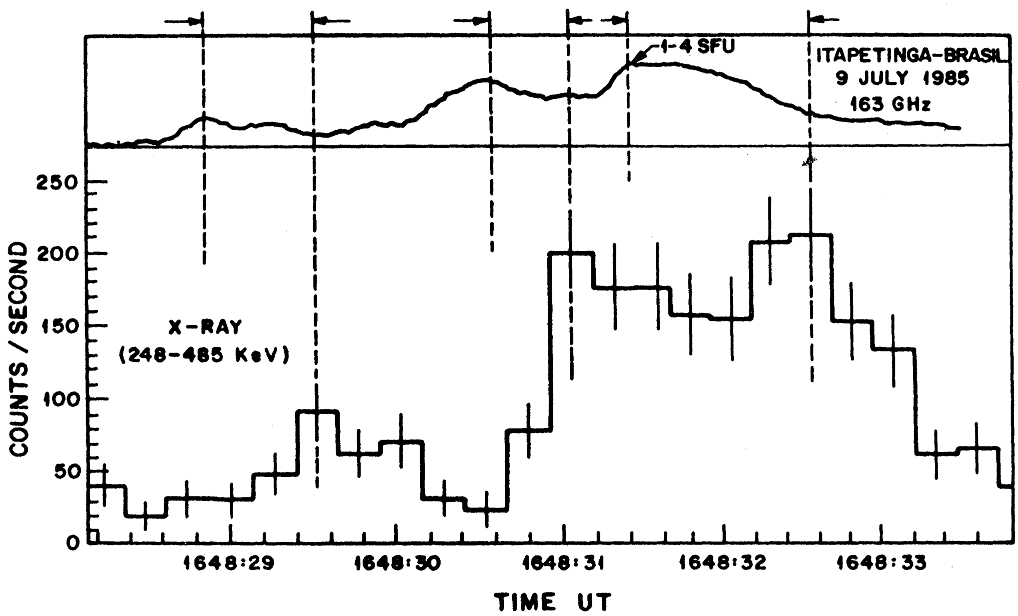

Fig. 3(a,b). Time profile of 1663 MHz bursts (a) and associated hard X-rays (b), the error bars on X-ray count rates are $\pm\sigma$ obtained from the r.m.s. for each interval of 0.128 s.

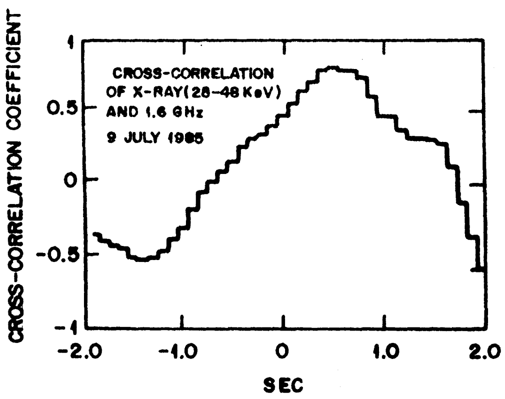

Fig. 4. Cross correlation of decimetric burst and X-rays, that of Gi. 3(a,b) showing the delays of the order of 0.640 s.

V. DISCUSSIONS

Detailed temporal investigations of 1.6 GHz bursts such as rise time (160 ± 25 ms) ecay time (138 ± 35 ms) and time coincidence with reverse slope type III burts in dynamic pectra suggest that observed bursts at 1.6 GHz are type III-RD bursts (Sawant et al., 1990).

Generally decimetric emission, 1.6 GHz, is at 2 nd harmonic (Stahli and Benz, 987), corresponding to electron density of 7.9 x 10^9 cm^{-3} at height of about 10^4 km above hotosphere according to ten times Bumbach Allen's density height model. X-rays are generated ostly at an altitude of ~ 2500 km above photosphere (Kane, 1983).

Thus the difference in height level of emission of decimetric type III-RD bursts and that of hard X-rays is of about 10^4 km.

The estimated drift rate of type III-RD burst below 1000 MHz is ≧ 1000 MHz/sec and we assume it to continue to be the same up to 1.6 GHz. This drift rate corresponds to an exciter velocity of 0.5 c, where c is velocity of light.

Thus, estimated time delays between type III-RD bursts and X-ray peak is of the order of 0.1s, assuming that type III-RD burst is produced at height corresponding to density of 7×10^9 m^{-3} and X-ray are produced after travelling a distance of 10^4 km toward photosphere by the electron exciter beam with velocity of 0.5 C.

Thus the sign of the time delay is correct i.e the peaks of type III-RD burst are observed earliar compared to peaks of hard X-rays. However observed time delays are one order magnitude larger than expected. This can be explained as follows.

As the beam of the electrons travels toward photosphere, leading edge of the exciter produces type III-RD bursts and the rest of the electron beam contributes to negligible radio emission, whereas start of X-ray is produced by the leading edge of electron beam and total entry of the electron beam in to X-ray target region produces peak of X-ray. Thus depending upon the velocity and the length of exciter larger, delays are understandable.

V. CONCLUSIONS

1. Type III-RD bursts have been shown to exist around 1.6 GHz for the first time.

2. Unambiguous one to one correlation between hard X-rays and type III-RD bursts has been shown.

3. Larger time delays between type III-RD bursts and hard X-rays are explained by the fact that type III-RD burts are produced by the leading edge of the exciter at 2nd harmonic whereas X-ray peck is produced by the bulk of the electron exciter beam.

REFERENCES

Dennis, B.R.; Benz, A.O. Ronieri. and Simnet G.M. 1984, Sol. Phys 90, 383.
Kane, S.R. 1983, Sol. Phys. 86 355.
La Bonte, B., 1976, Sol Phys. 50 201
Sawant, H.S., Costa, J.E.R., Trevisan R.H.; Lettari, C.J.B.,
Kaufmann, P. 1987, Sol. Phys. 111 189.
Sawant H.S., Lattari, C.J.B., Benz, A. and Dennis, B. 1990. Sol. Phys. (Submitted).
Stahli, M and Benz, A.O., 1987. Astro. Astrophys. 329, 967.

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