COMPARATIVE STUDY OF THE FLARE-BURST ASSOCIATION FOR POST-MAXIMUM PERIODS OF CONSECUTIVE SOLAR CYCLES

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СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ СВЯЗИ ВСПЫШКА-ВСПЛЕСК ДЛЯ ПЕРИОДОВ ПОСЛЕ МАКСИМУМОВ ПОСЛЕДОВАТЕЛЬНЫХ СОЛНЕЧНЫХ ЦИКЛОВ

Случаи появления микроволновых всплесков связанных со вспышками, а также спектры максимального потока исследовались зависимости от фазы до и после максимума соответствующих вспышек при двух последовательных солнечных циклах, т.е. 1969—72 и 1980—82. Были получены следующие результаты:
I. Около 76% всплесков связанных со вспышками появлялись на фазе до максимума а остающиеся 24% после максимума, независимо от класса вспышки, интенсивности или площади в 20 солнечном цикле, в то время как в 21 цикле эти значения были 65% и 35%.
II. Всплески с импульсным и постепенным подъемом и спадом были относительно более обильными в до-максимумных фазах вспышек для 20 цикла, в то время как импульсные, сложные и простые всплески были более обильными в 21 цикле.
III. Спектры максимального потока импульсных всплесков были в основном типа обратного U и GRF всплески были прибывающими с частотой для 20 цикла. Для 21 цикла спектры импульсных всплесков были в основном возрастающего и обратного U типов, в то время как сложные и простые типы были в основном типа обратного U.

Occurrences of flare-associated microwave bursts as well as peak flux spectra have been examined in relation to the pre- and post-maximum phases of the respective flares during the post-maximum period of two consecutive solar cycles, i.e. 1969—72 and 1980—82. Results obtained are:
(i) About 76% of the flare-associated bursts occur in the pre-maximum phase and the remaining 24% occur in the post-maximum phase irrespective of the flare classification, intensity-wise or area-wise, for the 20th solar cycle, whereas these values are 65% and 35% for the 21st cycle.
(ii) Impulsive and gradual rise and fall bursts are relatively more abundant in the pre-maximum phase of flares for the 20th cycle, whereas impulsive, complex and simple bursts are more abundant in the 21st cycle.
(iii) Peak flux spectra of impulsive bursts are mainly of the inverted-U type and CRF bursts are of the increasing with frequency type for the 20th cycle. For the 21st cycle the spectra of impulsive bursts are mainly of the increasing and inverted-U type, whereas those of the complex and simple types are mainly of the inverted-U type.

1. Introduction

In our earlier papers (S. K. Sarkar et al., 1975; Das Gupta et al., 1975) some studies have been made of the occurrences of the flare-associated microwave bursts as well as of their peak flux and energy excess spectra in relation to the pre- and post-maximum phases of the lifetime of the respective flares during the period 1967—72 (the post-maximum phase of the twentieth solar cycle). In the mean time the data of solar microwave bursts and Hα-flares have been obtained for the post-maximum phase of the 21st solar cycle which embraces much more solar activity with some peculiarities inherent in it compared to that of the previous one. This has prompted us to make a comparative study of the distribution and spectral nature of the microwave bursts occurring in the pre-maximum and postmaximum phases of the associated Hα-flares for the two successive post-maximum phases of the solar cycles.

2. Relevant Data and Analyses

In the present analysis group reports of isolated and confirmed flares with durations greater than 10 min have been taken into consideration. In order to minimise the error of calibration and to have round the clock observations, microwave burst data

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recorded at 1415, 2695, 4995, 8800 and 15400 HMz by the Sagamore Hill and Manila Observatories, at 2800 MHz by the Ottawa Observatory as well as those at 1000, 2000, 3750, 9400 MHz by the Toyokawa Observatory have been considered. Both the flare and microwave burst data have been collected from the Solar Geophysical Data Bulletins issued by NOAA, U.S.A. A microwave burst is said to be associated with a Hα-flare when it occurred within the actual lifetime of the flare. The present analysis included the data of both Hα-flares and microwave bursts observed during the successive post-maximum periods 1969–72 and 1980–82 of the 20th and 21st solar cycles, respectively, which have been chosen because most intensive centimetric and metric bursts tend to occur in the descending and ascending phases of the solar cycle and avoiding the peak phase (Takakura and Ono, 1962).

The relative percentage distribution of the flare-related microwave bursts in the pre-maximum phase (the interval between the time of start and peak of the flare) and post-maximum phase (the interval between the time of peak and end of the same flare) was determined after grouping the flares according to the dual importance scheme. This has been done for the flares which occurred during the post-maximum period of the 20th as well as 21st solar cycles. These results are displayed side by side in Tab. I.

Table I

Percentage distribution of flare-associated microwave bursts in the two consecutive cycles

Flare-classes	Percentage distribution for			
	20th cycle in flare phase		21st cycle in flare phase	
	Pre-max	Post-max	Pre-max	Post-max
Sb	77·9	22·1	65·4	34·6
1b	80·0	20·0	67·8	31·2
Sn	77·1	22·9	66·4	34·6
In	76·1	23·3	64·2	35·8
Sf	73·0	27·0	62·8	37·2
'bright'	77·7	22·3	66·0	34·0
'normal'	76·7	23·3	66·0	34·0
'faint'	72·6	27·4	61·0	39·0
'subflare'	76·7	23·3	65·0	35·0
Class I	77·5	22·5	65·2	34·8

The table shows that in the 20th cycle 76·5% of the flare-associated microwave bursts occur in the pre-maximum phase, whereas the remaining 23·5% occur in the post-maximum phase of flare. According to the observations in the 21st cycle the respective figures stand as 64·9% and 35·1%.

The distribution of flare-related microwave bursts classified according to their morphological character in the two phases of flares for the post-maximum period of the aforesaid two solar cycles has also been examined, the results being shown in Tab. II.

Table II

Distribution of different morphological types of microwave bursts in relation to the two phases of flares for two successive cycles

Morphological type	Percentage occurrence for			
	20th cycle in flare phase		21st cycle in flare phase	
	Pre-max	Post-max	Pre-max	Post-max
Impulsive (1, 2, 3, 4)	51·9	34·8	27·5	18·7
Gradual rise and fall (20, 22)	30·1	28·9	17·7	11·9
Complex (45, 46)	6·1	3·1	18·5	12·6
Post burst increase (29)	1·3	19·2	3·1	23·5
Simple (5)	5·3	3·9	19·0	11·2
Spike (8)	1·3	2·7	3·4	4·9
Others	4·0	7·4	10·7	17·2

The results indicate that in the 20th solar cycle Impulsive and GRF types of microwave bursts mostly occurred in the pre-maximum phase of the flare, whereas in the 21st cycle, Impulsive, GRF, complex and simple bursts constituted the major group. Considering the post-maximum phase of flare it may be said that the occurrence of Impulsive, GRF and PBI morphological types are predominant in the 20th cycle, while there is no such preferencial occurrence of any morphological type in the 21st cycle, as the complex and simple bursts show a sharp increase in number in this cycle compared to that in the previous one.

The spectral nature of multifrequency events has been evaluated after considering the bursts that were observed during the post-maximum periods of both the 20th and 21st cycles. The spectral nature has been designated according to the standard classification in vogue. Table III displays the results. As most of the multifrequency bursts occurred in the pre-maximum phase of flares, the aforesaid percentage distribution for the post-maximum phase of flares has not been adhered to.

The results of Tab. III indicate that the percentage

Table III

Spectral percentage distribution of multifrequency bursts for the two cycles

Spectral type	Percentage distribution of spectral type for the post-maximum period of	
	20th cycle	21st cycle
Increasing	30·3	27·9
Decreasing	12·4	8·2
U	4·5	24·0
Inverted U	41·5	29·5
Complex	11·3	10·4

occurrences of microwave bursts with increasing type of spectra are nearly equal to each other in both the solar cycles. The bursts with the U-type of spectral nature have shown a sharp increase in number which nearly compensates the fall in the occurrences of bursts with Inverted-U spectral characters in the 21st solar cycle compared to that in the previous one.

Since the multifrequency microwave bursts in the pre-maximum phase were found to be mainly Impulsive and GRF in the 20th cycle and Impulsive, complex and simple types in the 21st cycle, only the spectral analysis of the aforesaid types of bursts was carried out. The comparative study is shown in Tab. IV and Fig. 1.

The results indicate that in the 20th solar cycle the impulsive bursts occurring in the pre-maximum phase generally have the Inverted-U and Increasing type of spectral nature, while GRF bursts have the Increasing type of spectra. During the post-maximum period of the 21st solar cycle, Impulsive bursts with the Increasing and Inverted-U type, complex bursts with the U and Inverted U-type and simple bursts with the Increasing and Inverted U type of spectra are generally observed.

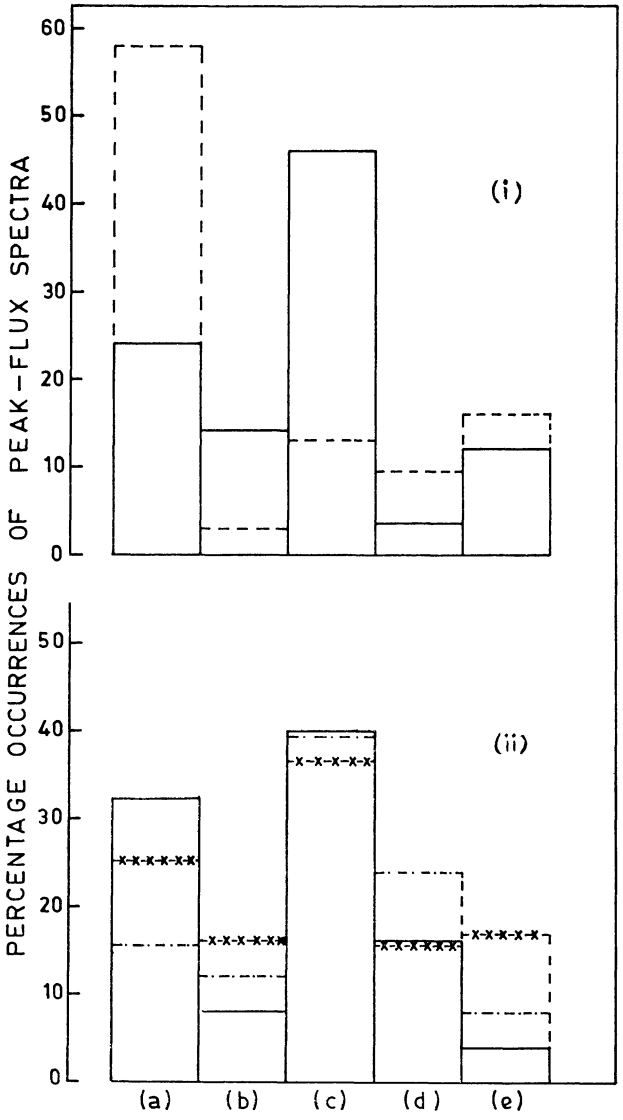

Fig. 1. Histograms showing the percentage occurrences of different spectral types. a) Increasing with frequency, b) Decreasing with frequency, c) Inverted U, d) U, and e) Complex (or Zig Zag) of Impulsive (——— line), GRF (— — — line), Complex (— . — . — line) and Simple (—x —x — line) types of microwave bursts for (i) 20th and (ii) 21st solar cycles.

Table IV

Spectral percentage distribution of different morphological bursts for post-maximum periods of two solar cycles

Spectral nature	Percentage occurrence in				
	20th solar cycle for bursts of type		21st solar cycle for bursts of type		
	Impulsive	GRF	Impulsive	Complex	Simple
Increasing	23·8	58·1	32·0	15·5	25·0
Decreasing	14·3	13·2	8·0	12·1	15·9
U	3·4	9·7	16·0	24·1	15·9
Inverted-U	46·3	12·9	40·0	39·7	36·4
Complex	12·2	16·1	4·0	8·6	16·8

3. Conslusion

The foregoing analysis which encompasses the comparative study of the flare associated microwave bursts for two consecutive cycles throws some light on the physical conditions of the solar atmosphere during the evolution of microwave bursts. As the peak of the 21st solar cycle is more pronounced compared to that of the 20th cycle, the relative sunspot number is obviously larger in the present cycle indicating greater solar activity. During the period of greater solar activity the occurrences of microwave bursts in the post maximum phases of flares have been found to increase as it is evident from Tab. I. Considering the morphology of the microwave bursts it is observed that the occurrences of complex and simple types of bursts have shown a preponderance in the current cycle too.

Earlier observations (Neupert, 1968) indicate that the number of soft X-ray emission maxima is greater in the post-maximum phases shown in the pre-maximum phases of flares. The soft X-ray emission is assumed to arise from the heating of flare plasma, the heating being possibly due to high energy particle collision losses and plasma waves which raise the temperature of the source region to some tens of millions of degrees.

Since the sunspot activity is higher in the current post-maximum period of the solar cycle, it is likely that flare occurrence is higher, as a consequenee of which the formation of coronal condensations due to plasma compression (Zheleznyakov, 1970) is highly probable. As a result of this the occurrence of microwave bursts in the post-maximum phases of flares in the recent cycle may increase. Following the argument behind the development of the soft X-ray emission it may be presumed that simple and complex bursts are generated due to the thermal emission of heated plasma.

From the spectral study on microwave bursts it has been found that bursts with U type spectra have increased considerably in the post-maximum period of the 21st solar cycle. U-shaped spectra are generated by the optically thin synchrotron radiation at lower frequencies relativistic electrons being accelerated by shock waves produced after the violent explosion of a flare (Castelli and Aarons, 1968; Das and DasGupta, 1983) which is obvious during the period of high solar activity.

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