COINCIDENCE IN SUBFLARE ONSETS IN THE OCTOBER 1979 COMPLEX OF ACTIVITY

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Received 19 September 1984

ABSTRACT. In the October 1979 activity complex, the coincidences of the onsets of subflares, observed in various parts of the activity complex, were statistically proved to be real. The occurrence of subflare pairs from Bou 2030 and 2032, for which the subflare onset times differ by less than 5 minutes (Tab. 2) is statistically significant. The increased coincidence in the occurrence of subflare pairs, differing in onset by 5 minutes or less, was not permanent. The coincidence was only observed on Oct. 6 and 7, 1979 during the transit of the activity complex across the solar disk (SMY - SERF target). The result obtained for the October 1979 activity complex agrees with the present idea of multiple energy release during the impulsive phase of solar flares.

СОВПАДЕНИЕ НАЧАЛ СУБВСПЫШЕК В КОМПЛЕКСЕ АКТИВНОСТИ ОКТЯБРЯ 1979 Г. Реальность совпадения начал субвспышек была потверждена статистическим путем для субвспышек, которые наблюдались в разных местонахождениях комплекса активности октября 1979 г. Статистически значительная встречаемость паров субвспышек в областях Боу 2030 и Боу 2032 была найдена для тех случаев, когда разница начал субвспышек была меньше чем 5 минут (Таб. 2). Повышенное совпадение в наличии субвспышек с разницей 5 минут не имело постоянный характер. Во время перехода комплекса активности по диску Солнца повышение числа совпадений существовало только 6-го и 7-го октября 1979 г. Результат полученный для комплекса активности октября 1979 г. находится в согласии со сегодняшним взглядом о многократном выделении энергии во время импульсной фазы вспышек.

KOINCIDENCIA V ZAČIATKOCH SUBERUPCIÍ POZOROVANÝCH V KOMPLEXE AKTIVITY Z OKTÓBRA 1979. V komplexe aktivity z októbra 1979 bola štatisticky potvrdená reálnosť koincidencie začiatkov suberupcií, pozorovaných v rôznych lokalitách komplexu aktivity. Štatisticky významný je výskyt tých párov suberupcií z Bou 2030 a 2032, pre ktoré rozdiel časov začiatkov suberupcií je menší ako 5 minút (Tab. 2). Zvýšená koincidencia vo výskyte o 5 minút sa líšiacich párov suberupcií nemala trvalý charakter. Z celého tranzitu komplexu aktivity cez slnečný disk (objekt SERF, SMY) bola zistená iba pre 6. a 7. október 1979. Výsledok obdržaný pre komplex aktivity z októbra 1979 je v zhode so súčasnou predstavou o viacnásobnom uvoľnení energie počas impulznej fázy erupcií.

1. INTRODUCTION

Syrovatsky (1981) generalized the conditions which lead to sudden dissipation of the magnetic field in magnetized plasma. High electrical conductivity and non-uniform plasma motion generate singular current sheets. The validity of these conditions has been verified in laboratory as well as astrophysical plasma (Bulanov et al., 1984). The current sheets form the substance of flare processes.

Indirect indications of the existence of current sheets in the solar atmosphere are responsible for flare forecasting being only in its initial stage. Observational data indicate the recurrence and homology of the spatial, spectral and quantitative characteristics of flares which were generated in a particular region of the Sun. Based on the similarity of repeated flares, one is justified in assuming a slow change in the morphology of the magnetic field of a particular active region. Essentially, the method of verifying the pre-flare and post-flare situation of the magnetic field is employed (Martin, 1980). This method requires the following:

- detailed data on the evolution of active regions with good time-space resolution, and
- a comparison of generalized theoretical models with various observed flare patterns.

The pre-flare situation is identified with the state of metastable equilibrium of the current sheet, generated in a non-potential magnetic field. Apart from one of the instabilities of the current sheet, the triggering mechanism of a flare could also be an external agent. The possibility of causal dependence of so-called sympathetic flares, the first flare stimulating the generation of the second, has been discussed since the 1940´s.

Some authors (Pikelner et al., 1975, Friedman et al., 1968, Altyntsev et al., 1977) consider the flare process to be an extensive development of instabilities occurring simultaneously in various places of the current sheet. Syrovatsky (1969, 1972) considered the flare to be a manifestation of the decay of the current sheet as a whole. From this point of view, the occurrence of recurrent and homologous flares (Ellison et al., 1960) is interesting.

The October 1979 complex of activity contained two active regions, Bou

2030 and 2032, which were close to each other (15^{o}). Bou 2032 represented a magnetically complex group containing a delta configuration. Bou 2030 represented a relatively magnetically simple bipolar region, characterized by a conspicuous increase of flare activity on Oct. 6, 1979.

The October complex of activity (or more precisely Bou 2032) was selected as a SERF target during the Solar Maximum Year (SMY). Thanks to internationally coordinated observations of the complex, detailed data were obtained and published on the flare activity in Bou 2030 and 2032 (Antalová et al., 1985, Bhatnagar et al., 1981, Dezső et al., 1981, Felli et al., 1981, Ishkov et al., 1981, Merkulenko et al., 1983, Stepanov et al., 1981).

From the point of view of the flare build-up study, two data are particularly important:

1. The flare with the greatest importance were generated in the magnetically complex group Bou 2032 (Antalová et al., 1985).

2. The enhanced flare activity in Bou 2030 occurred in the interval from Oct. 5 to 7, 1979.

The purpose of this paper is to analyse the published observational material with regard to the quasi-simultaneous occurrence of flares in the individual parts of the complex, to clarify the relation between the flares observed simultaneously, to determine the degree of autonomy of the individual active regions in the activity complex, and to deliberate the possible existence of the assumed sympathetic flares (causally dependent), as well as of the quasi-simultaneous (quasi-synchronous) flares.

2. ANALYSIS OF OBSERVATIONAL MATERIAL

The general evolution of the October 1979 complex of activity and its flare activity were discussed by Antalová et al. (1985). The Bou 2032 group had a globally conspicuous predominance in the production of X-ray and radio flares of high importance as compared to group Bou 2030 (ratio of flares 7:3).

A review of the daily occurrence of flares in the individual active regions of the October complex was obtained from the flare patrol service data, published in SGD 439, Part II.

With a view to the large difference in the magnetic morphologies of groups Bou 2032 and Bou 2030, the question arose of the occurrence frequency of flares and their importance in the individual groups. A high flare effectivity of group Bou 2032 and a low effectivity of group Bou 2030 was expected. Antalová et al. (1985) found, contrary to expectations, that group Bou 2030 equaled Bou 2032 in flare production on Oct. 5 to 7, 1979.

The markedly preferred Bou 2032 group of the October 1979 activity complex created conditions suitable for studying the mutual independence of regions in flare production. Ishkov et al. (1981) pointed out a sequence of three large flares which were observed at intervals of 40 minutes in the activity complex on Oct. 6, 1979. There were observed following flares: 06:21 UT -

2N, 07:00 UT - 2N and 07:38 UT - 1B. With a view to the interval of 40 mins between the flares, they can hardly be considered sympathetic. The 40-minute reccurrence in the flare series of Oct. 6, 1979 is evidence of rapid accumulation of energy and generation of instabilities in the complex on the day involved.

The observational material was processed statistically with regard to the non-random coincidence in the flare occurrence in Bou 2030 and 2032. Of the total number of 72 flares, observed in the activity complex between Oct. 5 and 7, 1979 (SGD 439, Part II), only those pairs of flares from Bou 2030 and 2032, whose onsets in H-alpha differ by less than 30 minutes, were included in Tab. 1. If the observation of the flare onset was lacking, the difference in the times of the maximum intensities of the H-alpha flares was taken into account. The following reasons were responsible for limiting the time interval to 30 mins and less: Fritzová - Švestková et al. (1976) found that the pairs of flares from two close active regions (up to 30^{o}) occurred more frequently than one would expect from probability calculus, provided the difference in the times of their onsets is less than 30 mins. Pairs, which show a difference in the onset times of more than 30 mins, occurred in numbers comparable with the number of randomly expected pairs.

Table 1

List of H-alpha flare pairs observed in the ARs of the October 1979 complex of activity with differences in onset time lesser than 30 minutes

No	Beg (UT)	Max (UT)	End (UT)	Imp	AR	Ref	Δt (min)
			October 05, 1979				
1	05:55	06:01	06:09	SB	2030	SGD, B	6
	-	06:07	06:15	-	2032	B	
	05:51	06:23	07:56	1-/1		SID	
2	08:12E	-	08:34D	SF	2032	SGD	19
	08:31E	08:32	08:40	SN	2030	SGD	
	08:24	08:34	09:00	1-/5		SID	
3	16:07	16:09	16:12	SF	2030	SGD	12
	16:19	16:29	17:06	SF	2032	SGD	
	16:57	17:01	17:06	SF	2030	SGD	
4	20:53	20:57	21:26	SN	2032	SGD	26
	21:19	21:24	21:28	SF	2030	SGD	
5	21:41E	22:05	22:16	SF	2030	SGD	4
	22:03	22:09	22:45	SN	2032	SGD	
	22:18	22:31	23:06	SN	2030	SGD	
	22:27	22:31	22:31D	1-/1	2030	SID	

Table 1 continued

6	23:46	23:49	23:55	SF	2032	SGD	1
	23:47	23:49	00:04	SN	2030	SGD	
			October 06, 1979				
7	04:56	05:02	05:33	SN	2030	A	1
	04:57	05:02	-	SB	2032	A	
	05:02	05:08	05:53	1-/3		SID	
8	06:59	07:00	07:06	SB	2030	A	3
	06:59	07:03	07:30	2B	2032	SGD	
	06:56	07:03	07:27	1-/1		SID	
9	11:09	11:13	11:24	SB	2032	SGD	5
	11:14	-	-	1N	2030	A	
	11:10	11:18	11:40	1-/5		SID	
10	14:28	-	14:43	SN	2030	SGD	0
	14:28	-	14:40	SF	2032	SGD	
11	19:55	19:59	20:08	SN	16350	SGD	2
	19:57	19:59	20:12	SN	2030	SGD	
			October 07, 1979				
12	04:50	05:02	05:30	1N	2032	SGD	27
	05:17	05:23	05:37	SN	2030	SGD	
13	07:01	07:10	07:27	SN	2030	SGD	20
	07:21	07:24	07:35D	SN	2032	SGD	
	07:33	07:35	07:35D	SN	16350	SGD	
	07:55	08:10	08:15D	1B	2030	SGD	
14	07:55	08:10	08:44	1B	2030	A	0
	07:55	-	08:05	SB	2032	A	
15	13:10	13:21	13:37	SF	16350	SGD	8
	13:26E	13:29	13:35D	SF	2030	SGD	
16	12:08	12:13	12:22	SF	2032	SGD	19
	12:27	12:28	12:51	SF	16350	SGD	
17	14:05	14:13	14:35D	1B	2032	SGD	4
	14:14	14:17	14:42	SN	2030	SGD	
18	21:12	21:22	21:46	SN	2030	SGD	24
	21:36	21:45	21:59	SN	2032	SGD	
			October 08, 1979				
19	00:17	00:27	01:02	1N	2030	SGD	8
	00:25	-	01:32	SN	16350	SGD	
20	07:13	07:16	07:32	SN	2030	SGD	7
	07:20E	-	08:00D	SF	16350	SGD	
21	10:18E	-	10:40	SF	16350	SGD	12
	10:30	-	10:40	SF	2032	SGD	

As can be seen from column 5 of Tab. 1, most selected flare pairs were subflares (SF, SN, SB). The H-alpha data on flares are supplemented in Tab. 1 by SID data (SGD 424, Part I). X-ray data, in this case, are only available for large flares (Antalová et al., 1985).

The random number of quasi-simultaneous occurrences of flares in two different active regions can be calculated with the aid of the probability calculus. This is a problem analogous to the coincidence between pulses in two-channel electronic circuits (Evans, 1955, Fritzová-Švestková et al., 1976). The computation can be carried out provided the interval T , in which N_1 flares were observed in the first and N_2 flares in the second active region, is sufficiently long.

Table 2

Comparison of the statistical expected and observed pairs of subflares in Bou 2030 and 2032

Day	T (hours)	flares in	N_1 2030	N_2 2032	t	Obs pairs	Exp pairs	O/E
Oct. 05	22		10	13				
					diff 30^m	7	5.9	1.2
					10^m	2	2.0	1.0
					05^m	2	1.0	2.0
Oct. 06	24		11	13				
					30^m	4	6.0	0.7
					10^m	4	2.0	2.0
					05^m	4	1.0	4.0
Oct. 07	24		11	7				
					30^m	5	3.2	1.6
					10^m	2	1.1	1.8
					05^m	2	0.5	4.0

Using the random coincidence formulas, published Fritzová-Švestková et al. (1976), the numbers of randomly expected pairs of flares on Oct. 5 to 7, 1979 were computed. The computations were carried out for flare pairs observed with an onset time difference of 30, 10 and 5 minutes in regions Bou 2030 and 2032 for each day. The results of the computation of the randomly expected pairs, which should occur within the whole interval T , are given in column 6 of Tab. 2. The randomly expected pairs in interval T are compared with the number of actually observed pairs, the required time differences of 5, 10 and 30 minutes being preserved.

3. RESULTS

1) The most conspicuous differences between the number of randomly expected and actually observed flare pairs were found for the 5-minute lag. On Oct. 6 and 7, this category displayed an excess of observed pairs as compared to the number of pairs randomly expected in groups Bou 2030 and 2032.

2) The result ad 1), referring to one activity complex (October 1979) and to data not particularly statistically significant (72 flares) is in good qualitative agreement with

a) the result of Fritzová-Švestková et al. (1976) who processed abundant material related to many close active regions;

b) with the results of the behaviour of impulsive phases of isolated flares. The analysis of hard X-ray bursts indicates that at least 40% of the flares display multiple peaks observed in various places of the active region with a lag of a few minutes (2-5). This is evidence of multiple energy release in the region during the flare (Fárník et al., 1983, Kattenberg et al., 1983, Duijveman et al., 1983, Dwivedi et al., 1984, de Jager et al., 1984, Tandberg-Hansen et al., 1984).

Considering the fact that flares may also be generated in the marginal parts of an active region (Antalová et al., 1984), it is only natural to expect that, in close active regions, flares with multiple peaks may be generated, whose flare knots are in both active regions simultaneously.

3) The complete list of flares observed in the October 1979 complex of activity indicates that the individual active regions retained their autonomy, limited by the degree of their development, during the transit of the complex across the disk. Between Oct. 6 and 7, the interaction between Bou 2030 and 2032 increased and this was reflected in the larger number of actually observed quasi-simultaneous subflare pairs (lag of 5 minutes and less).

4) On Oct. 6 and 7, the October 1979 complex of activity displayed a well defined location of flare generation. The preferred location of flare onsets in Bou 2030 was the neighbourhood of the trailing sunspot of the group. In Bou 2032, an important part was played by the delta-configuration region. Both localities of flare generation support the conclusions concerning the effect of new magnetic fields in creating a suitable pre-flare situation (Martin et al., 1983, 1984, Priest, 1984).

5) For the purpose of short-range forecasts (2-4 days) of flares, expected in a particular active region, it is important to distinguish the contribution of a new magnetic field of opposite polarity to the increase in flare activity in the region, as well as the appurtenance of the active region to the complex of activity (Antalová, 1967).

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