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Pre-pulses: Signature of a Trigger Process in Short (<60 secs) Solar Hard X-Ray Flares

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ABSTRACT

Our continuing study of short solar hard X-ray events (<60 sec duration) from the SMM HXRBS instrument has revealed a unique feature. A well-separated distinctly identifiable, narrow (2-6 sec wide) pulse occurs prior to the start of the longer-flare lasting emission activity. We present light curves of eight events showing this feature. These pre-pulses show symmetrical rise and fall times. We present spectral evolution of the pre-pulses and compare their evolution to that of the main event spectra. We argue for this feature to be the elementary flare burst (de Jager, 1978). These pre-pulses could be a signature of the magnetic reconnection phenomenon discussed by Sturrock et al. (1984).

INTRODUCTION:

The light curves of the hard X-ray emission (20-500 keV) associated with solar flare activity have very complex and diverse characteristics. Their durations extend from a few seconds to tens of minutes. Attempts to classify flares using their light curves to understand the physical processes involved in flare phenomena has been very difficult. Various schemes have been proposed (Heyvaert et al. 1977, Priest 1981, Tanaka 1983, Tsuneta and Tanaka 1987).

Broad classification on the basis of their duration, i.e. short (<few minutes) and long lasting (few minutes to tens of minutes), offers some opportunity to understand flare phenomena - their dynamics and energetics. The short events could be associated with compact flaring active regions while the long-lasting events could be associated with extended active regions. We are studying a subset of short events (< 60 sec) from the SMM/HXRBS data set to evaluate their fine time structure and their spectral evolution. The fine time structure studies involves the search for periodicities or quasiperiodicities and a search for homology in these events (Wiehl & Desai 1983, Desai et al. 1987).

We present in this paper evidence showing a well separated, distinctly identifiable narrow pulse feature prior to the start of longer-lasting hard X-ray flare activity. We have observed a symmetrical nature in the rise and fall times of their light curves and have compared their spectral evolution with that of the later flare activity. We argue that this pre-pulse feature is the true "elementary flare burst" (van Beek, de Feitor and de Jager 1974; de Jager and de Jonge 1978) and is the signature of the magnetic reconnection phenomenon discussed by Sturrock 1984.

DATA:

The SMM Hard X-ray Burst Spectrometer (HXRBS) has recorded about 8000 hard X-ray events over a period of eight years from 1980 to 1988. About 200 of these events have a duration of less than 60 secs and a peak counting rate of >100 counts per second. We present the analysis of ten of these events which show a narrow pulse feature at the beginning of the hard X-ray activity. Table 1 gives the date, time of occurrence, and some parameters of the events.

Table 1

	Date	Time (UT)	Duration (s)	Pre-pulse Peak rate (counts/s)	FWHM of Pre-pulse (s)
1	80/6/9	0251:20	27	800	4.0
2	80/7/5	1010:00	34	200	3.5
3	80/7/9	0145:36	30	400	3.5
4	81/2/7	1505:43	12	340	2.5
5	81/4/25	0046:50	18	600	5.0
6	81/7/10	0655:02	13	550	3.5
7	82/2/11	2351:48	30	420	3.0
8	82/6/12	2015:50	20	300	5.0
9	84/4/29	1736:58	10	800	4.0
10	87/5/26	1701:31	20	200	2.5

Figure 1 shows light curves of the events on June 9, 1980, and July 9, 1980. In both of these events the pre-pulse is clearly identifiable. The June 9 event, with a peak counting rate of 800 counts/s in the pre-pulse, exhibits some fine time structure. The rise at 0251:24 UT is statistically significant. The peak counting rate in the pre-pulse is the same as the peak counting-rate in the later activity. For all but one event this observed feature that the pre-pulse is as intense as the later flare activity is true. In the July 9th event the pre-pulse has a symmetrical structure with equal rise and fall times and shows no indication of any fine time structure. The later activity is more extended in time as compared to the event of June 9.

In Figure 2 we show three events on July 5, 1980, July 17, 1980 and May 26, 1987. These three events are not as intense as the previous two shown in Figure 1. The pre-pulses are also narrower. The pre-pulse to main phase delays in these three events are of the order of half a second. The total duration of flare activity are also very similar, indicating homology for the total flare emission. The event on May 26th, 1987 shows activity with a 12-second delay. For each of these three events the peak counting rate in the pre-pulse in the same as that in the main phase of flare activity.

Figure 3 shows light curves of the events of February 11, 1982 and June 12, 1982. The pre-pulse for the June 12th event is not as intense as the later main phase activity. The main phase activity of the February 11th event is delayed by about 12 seconds. In Figure 4 we show three events where there is only pre-pulse activity.

We have examined the spectral characteristic for the pre-pulse and main phase flare activity and do not find any significant difference between them. Figure 5 shows a light curve of the most intense event, that of June 9, 1980. The spectral index, ν, which results from a power-law fit to the flare data is the same during the pre-pulse and the later main phase activity and has a value of $\nu = 3$.

CONCLUSIONS:

In the events studied here the width of the pre-pulse varies from a couple of seconds to 5 seconds. This feature is quite unique with respect to its location in time, width, and symmetrical rise and fall characteristics. Earlier attempts to identify an "elementary event burst" from entire light curves of extended events could not establish its true characteristics. Our results show that the total energy in the pre-pulse, the "elementary event burst", lies in the range 10^{27} - 10^{28} ergs. This value is consistent with the value derived by Sturrock (1984), cf. 10^{27} -10^{28} ergs, or that of 10^{27} - 10^{29} ergs derived by van Beek et al. (1974).

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Sturrock, P. A., et al., Solar Physics, 94, 341-357, 1984.

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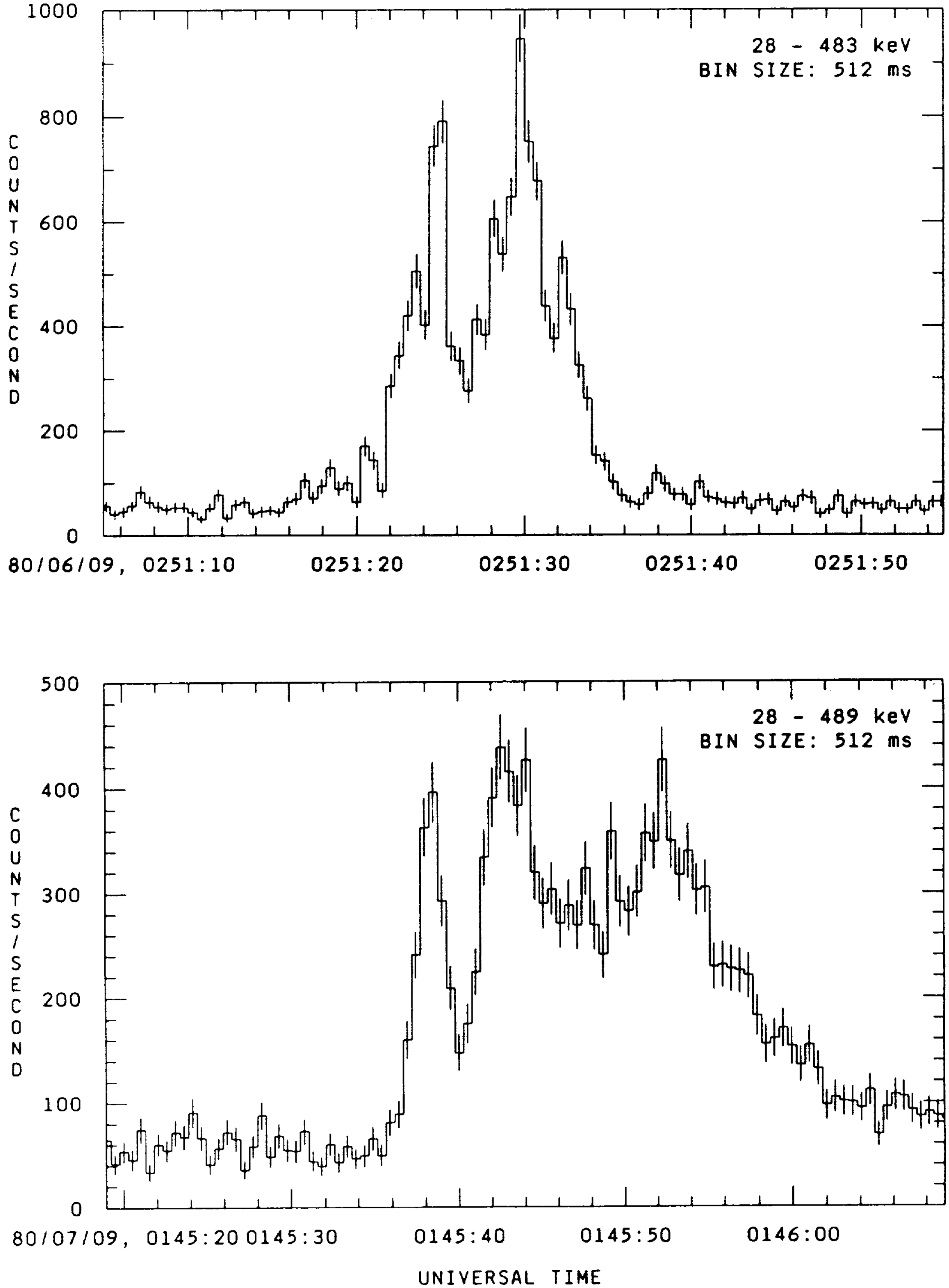


1000
800
600
400
200
0
COUNTS/SECOND
28 - 483 keV
BIN SIZE: 512 ms
80/06/09, 0251:10
0251:20
0251:30
0251:40
0251:50
500
400
300
200
100
0
COUNTS/SECOND
28 - 489 keV
BIN SIZE: 512 ms
80/07/09, 0145:20
0145:30
0145:40
0145:50
0146:00
UNIVERSAL TIME

Fig. 1

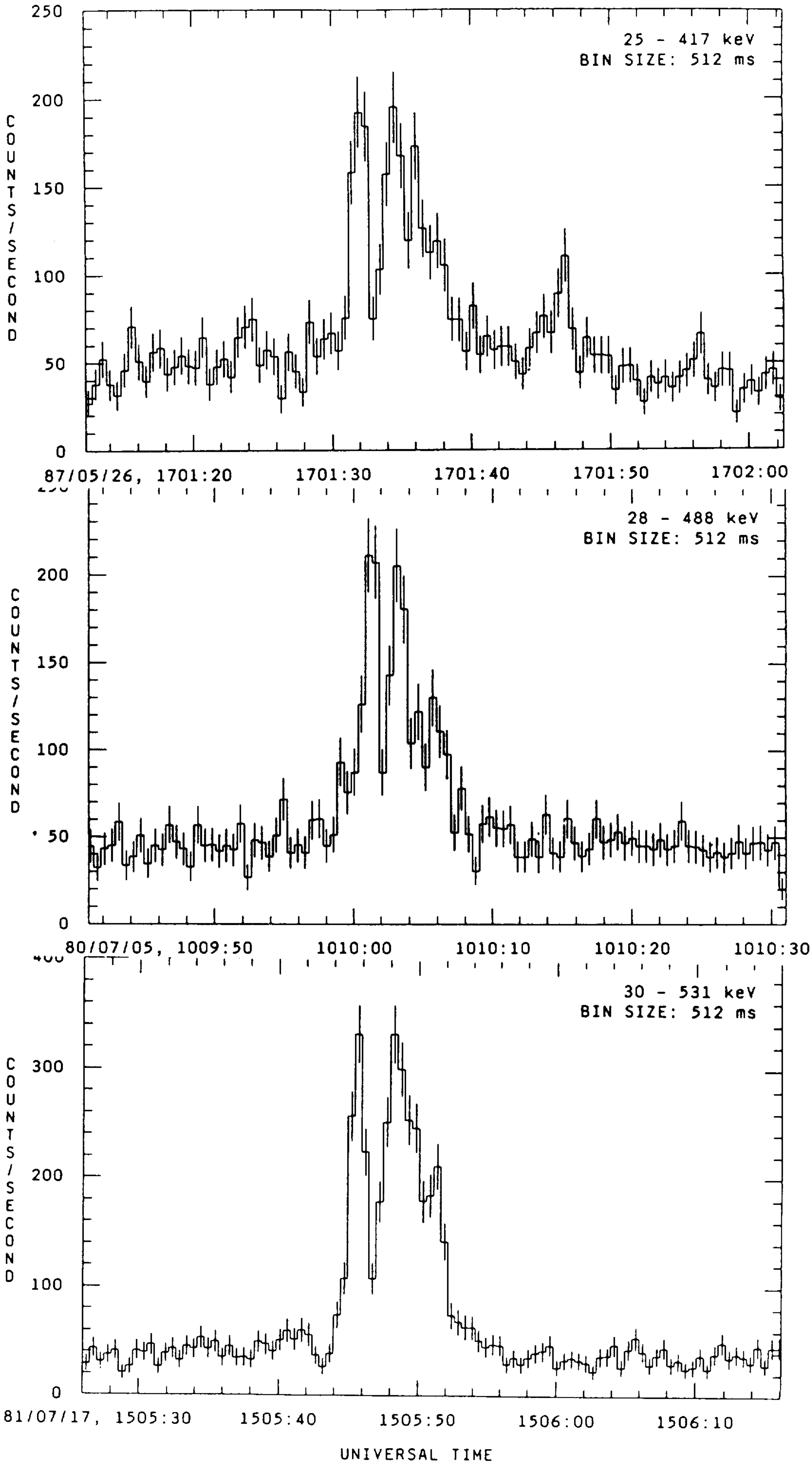
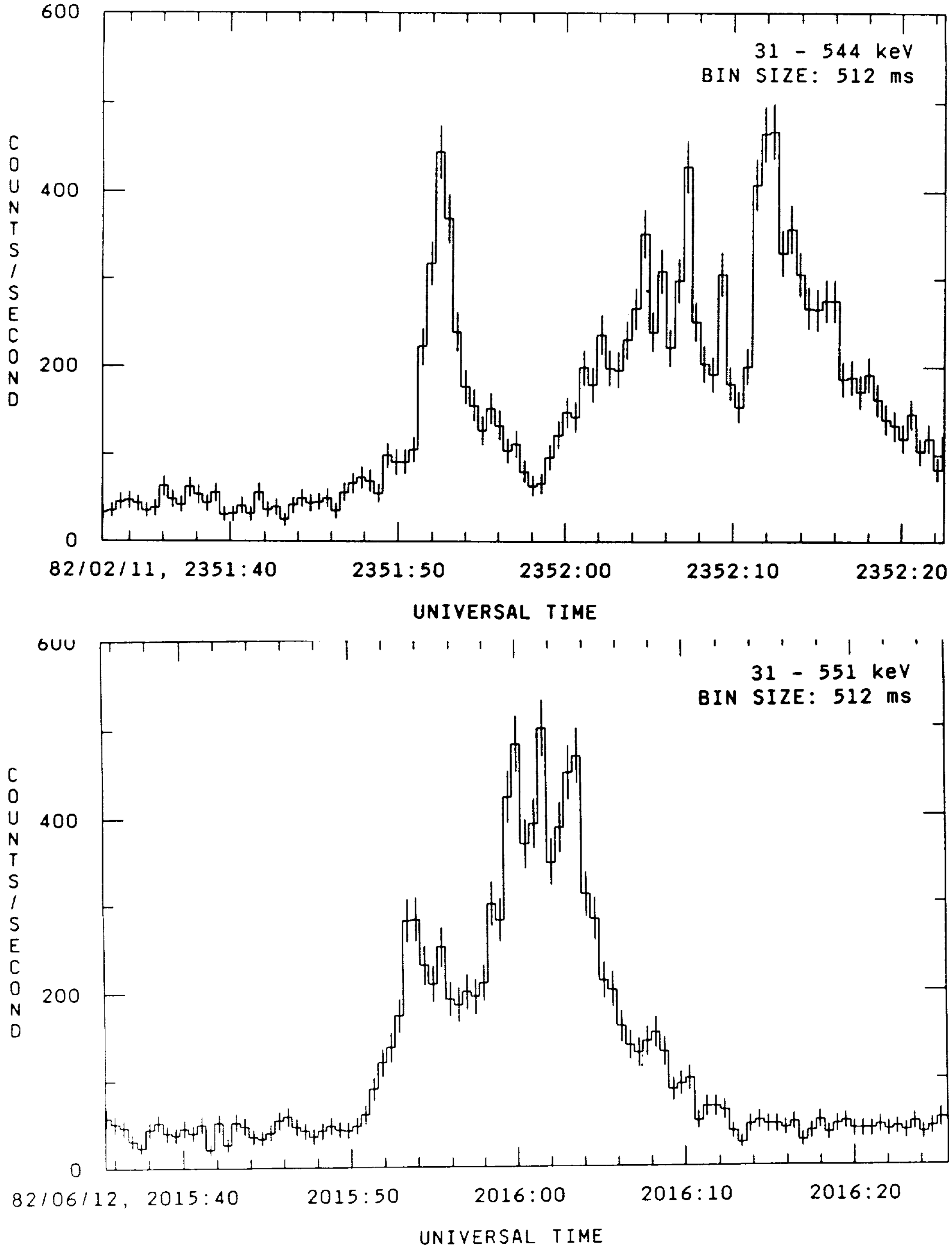
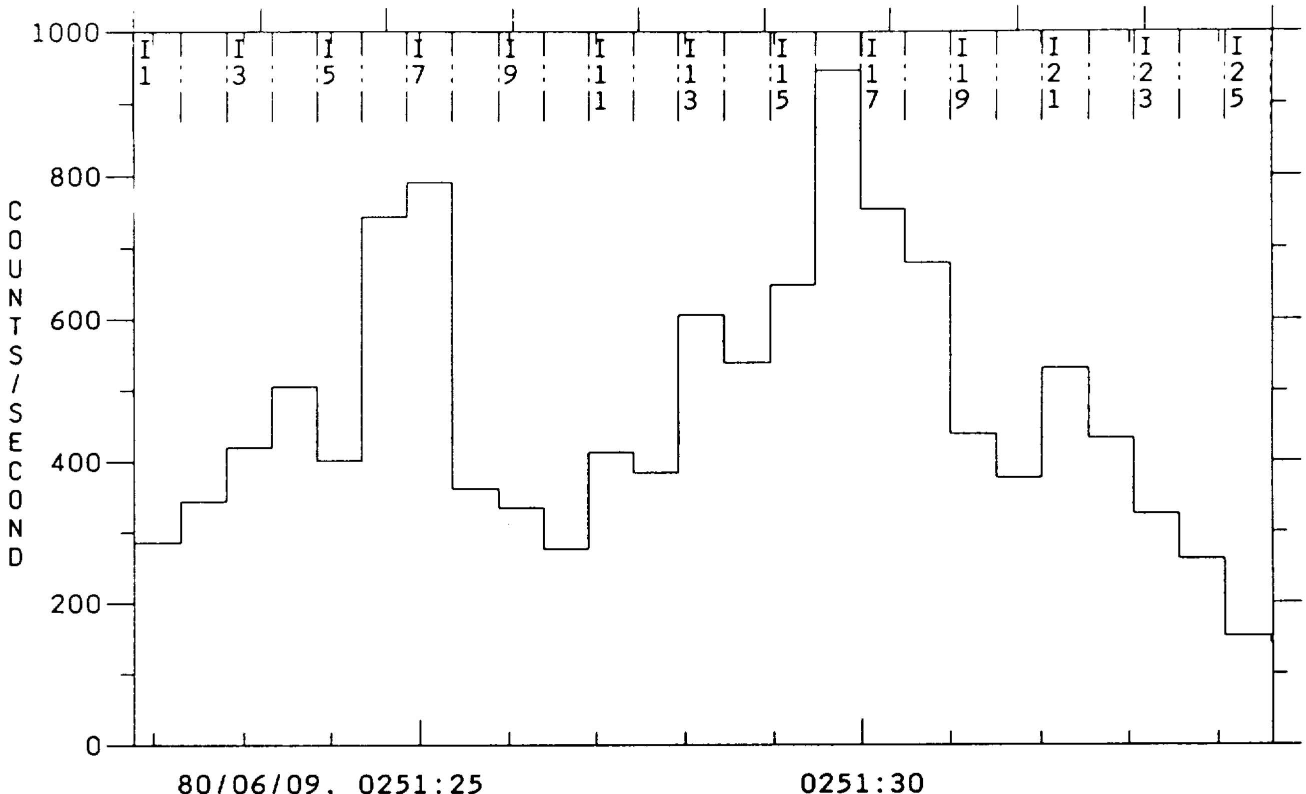

25 - 417 keV
BIN SIZE: 512 ms
COUNTS/SECOND
87/05/26, 1701:20
1701:30
1701:40
1701:50
1702:00
28 - 488 keV
BIN SIZE: 512 ms
COUNTS/SECOND
80/07/05, 1009:50
1010:00
1010:10
1010:20
1010:30
30 - 531 keV
BIN SIZE: 512 ms
COUNTS/SECOND
81/07/17, 1505:30
1505:40
1505:50
1506:00
1506:10
UNIVERSAL TIME

Fig. 2



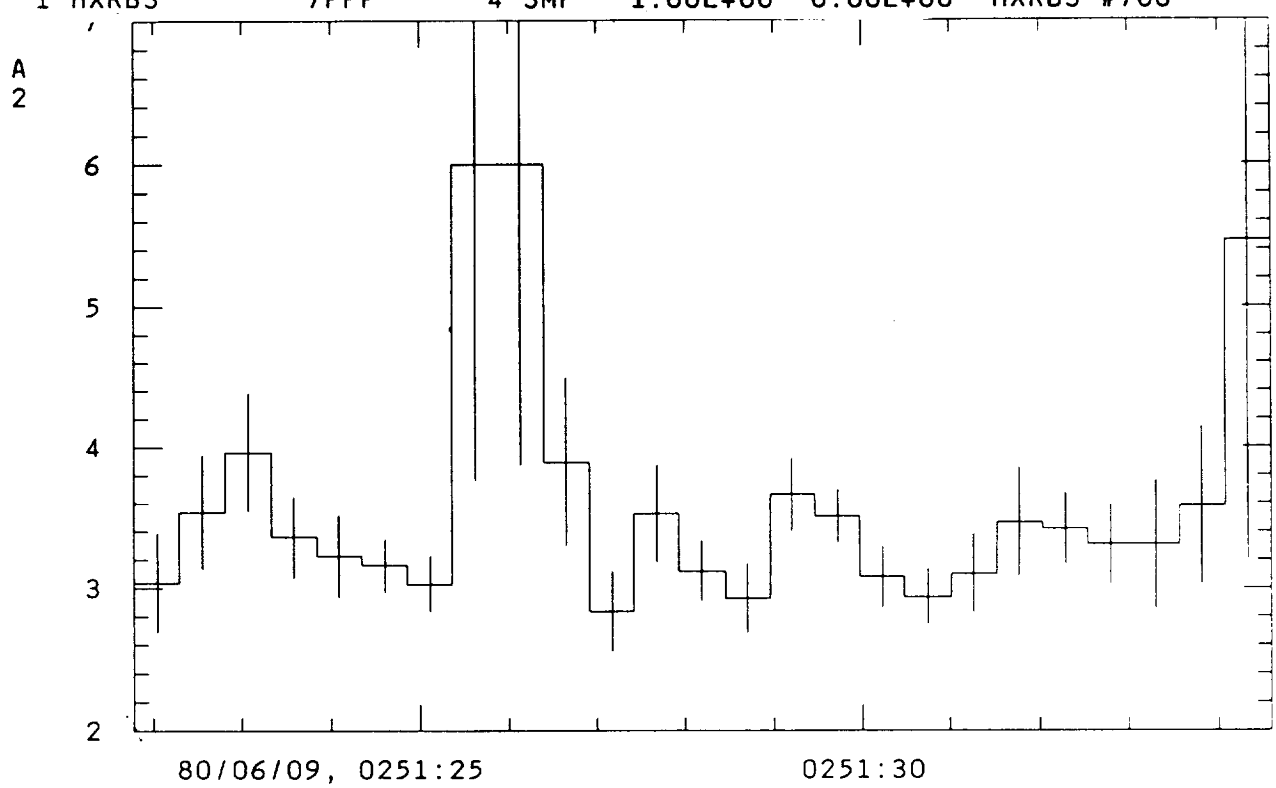
31 - 544 keV
BIN SIZE: 512 ms
COUNTS/SECOND
600
400
200
0
82/02/11, 2351:40
2351:50
2352:00
2352:10
2352:20
UNIVERSAL TIME
31 - 551 keV
BIN SIZE: 512 ms
COUNTS/SECOND
600
400
200
0
82/06/12, 2015:40
2015:50
2016:00
2016:10
2016:20
UNIVERSAL TIME

Fig. 3



BASE:80/06/09,0248:13.883 S:0248:13.883 E:0303:15.131 C:17-MAY-89 17:48

SOURCE:	CHMASK:	ACCUMMODE:	SCALE:	ADD:	LABEL:
1 HXRBS	7FFF	4 SMP	1.00E+00	0.00E+00	HXRBS #706



1POWERL = A1*(E/EM)**(-A2)

80/06/09, 0251:21.787   17-MAY-8906:43:31
START INTERVAL= 1   TOTAL INTERVALS= 25

Fig. 5

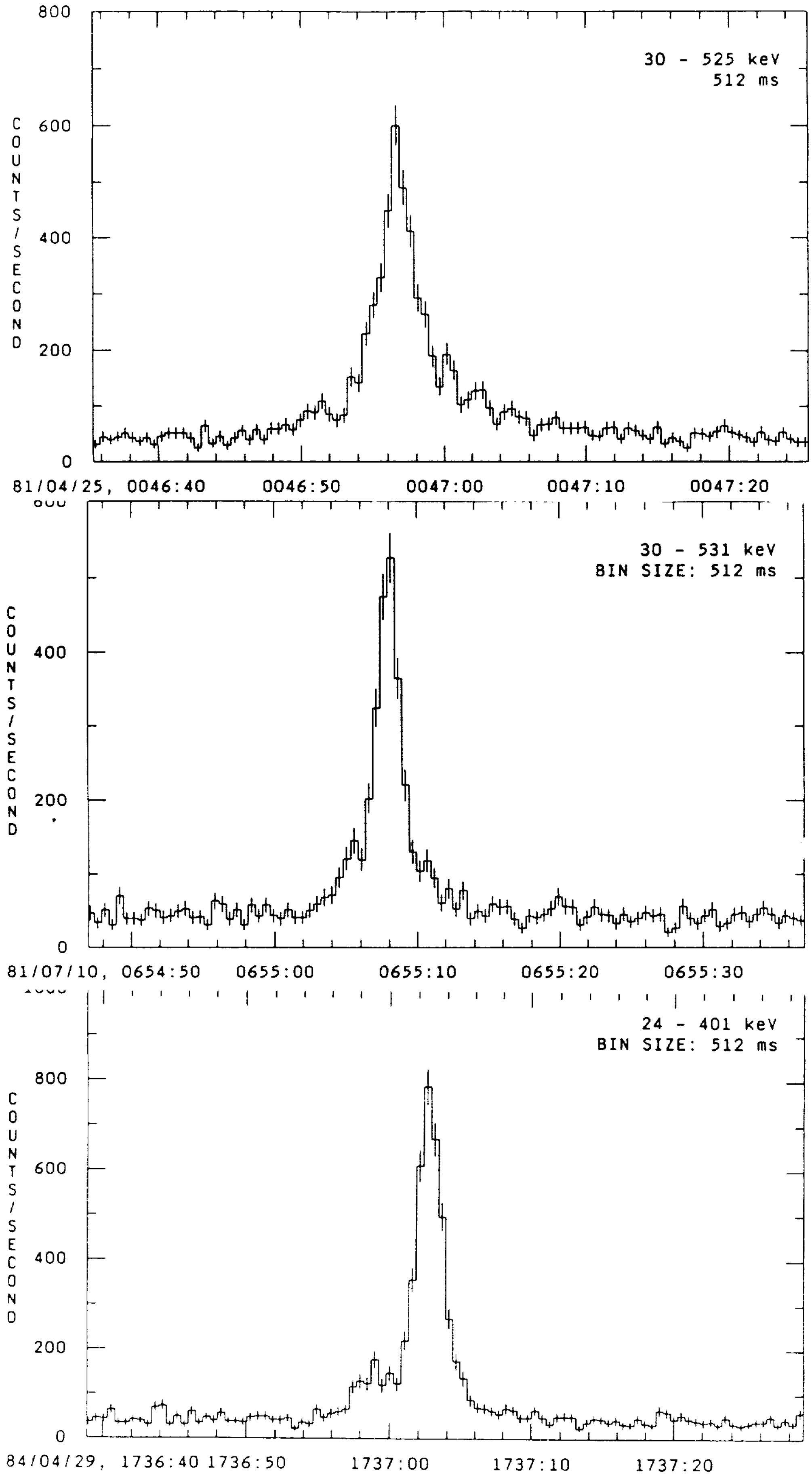

30 - 525 keV
512 ms
COUNTS/SECOND
0
200
400
600
800
81/04/25, 0046:40
0046:50
0047:00
0047:10
0047:20
30 - 531 keV
BIN SIZE: 512 ms
COUNTS/SECOND
0
200
400
81/07/10, 0654:50
0655:00
0655:10
0655:20
0655:30
24 - 401 keV
BIN SIZE: 512 ms
COUNTS/SECOND
0
200
400
600
800
84/04/29, 1736:40 1736:50
1737:00
1737:10
1737:20

Fig. 4