Reverse Drift Bursts in the 0.8-4.5 GHz Band and their Relation to X-Rays

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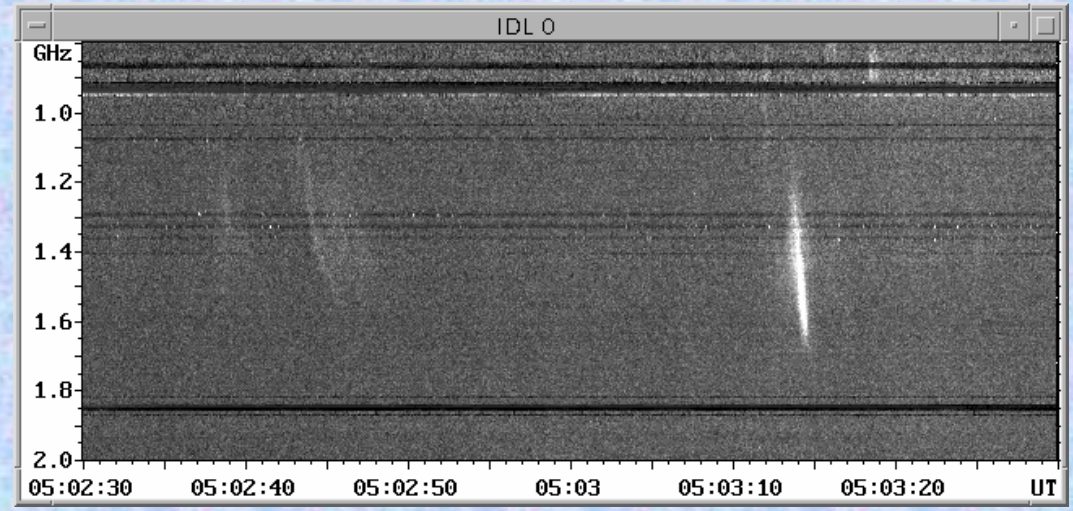
Aim of the study:

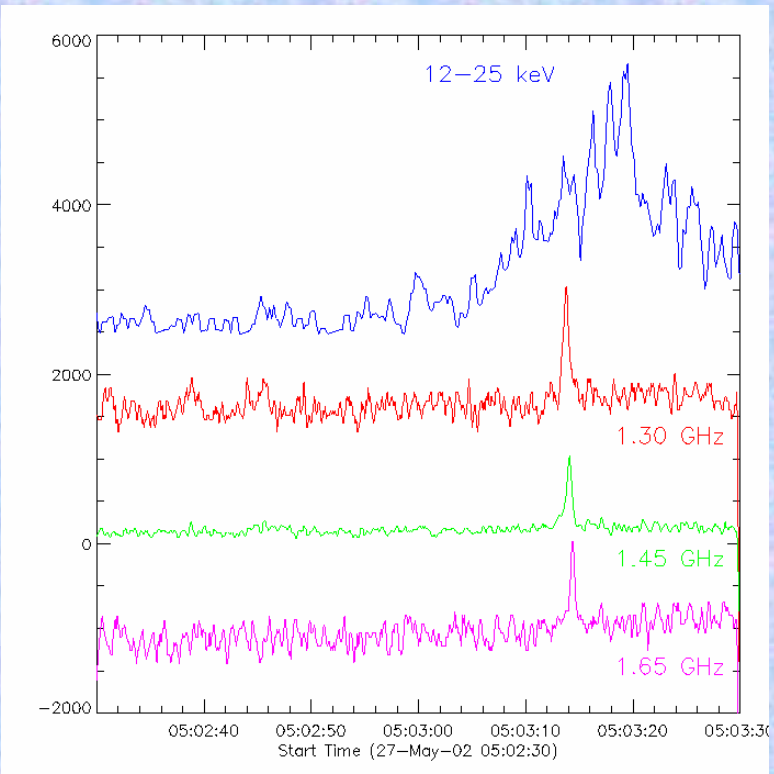
- To look for any relation between Reverse Drift Bursts (RDBs) observed in 0.8-4.5 GHz range and X-rays (especially above 12 keV), to describe the relation or to deny it.
- It was supposed that RDBs are radio manifestation of beams of energetic electrons moving downward to chromosphere and causing radio emission through plasma emission mechanism. The same electrons produce hard X-rays upon arrival into dense layers. We tried to show or to deny one-to-one correlation between the RDBs and hard X-ray peaks.
- If the correlation is found we would like to measure the time delay between RDB and X-ray peak.
- It is known that some RDBs have a very high frequency drift and its determination requires high temporal resolution of radio spectra (it is due to a very steep gradient of plasma density in the source region and high velocity of the beam, about c/3) and others have a much slower drift and their origin may be different. We tried to look for any differences in X-ray emission (like different time relation or changes in X-ray source position or shape) between the two basic groups of RDBs.
- If possible, we would like to describe a few “typical” features of different RDB+X-ray events and to try to “classify” them.

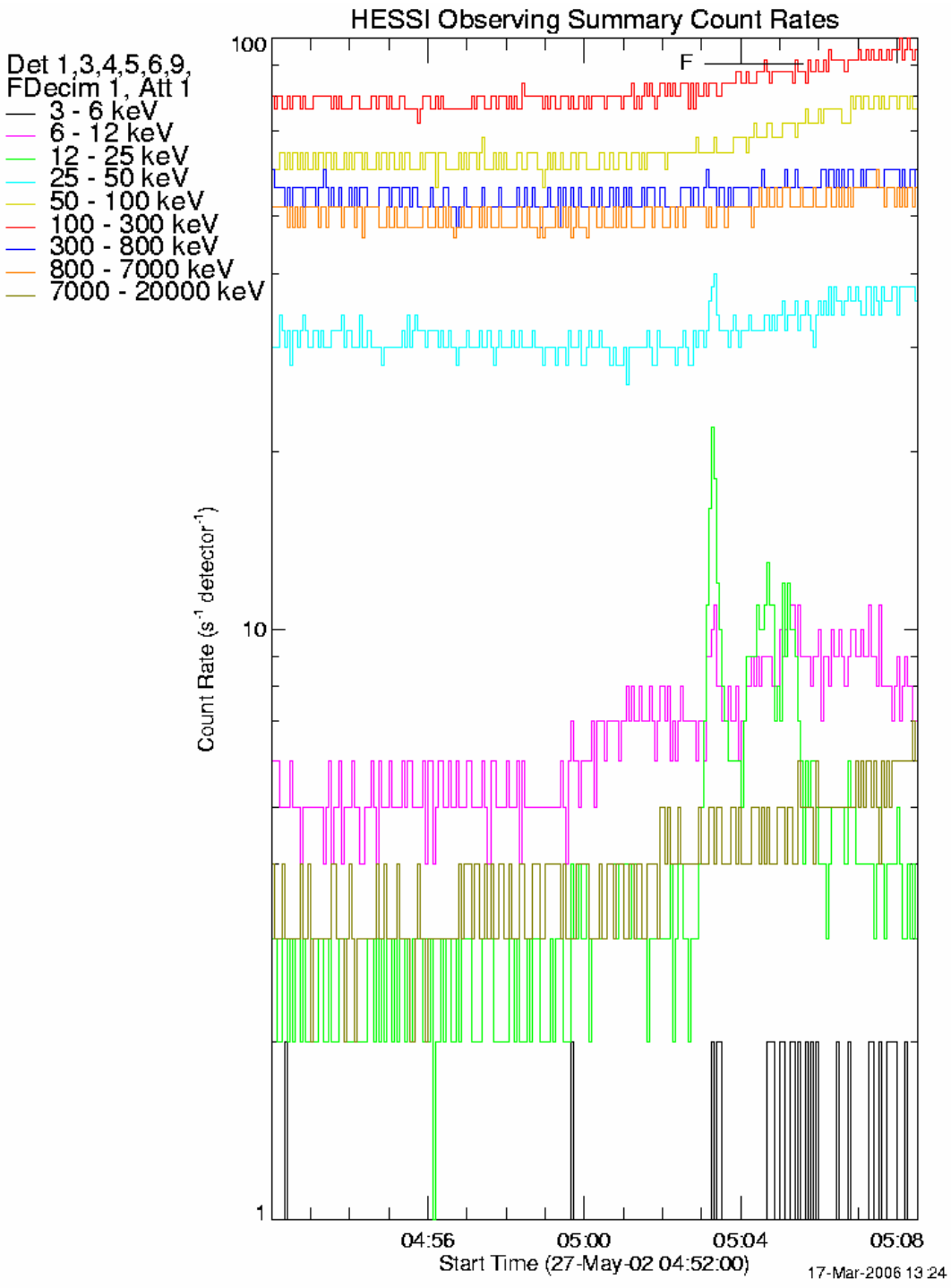
Table of RDB events (Ondřejov spectrograph) for which RHESSI observations are available

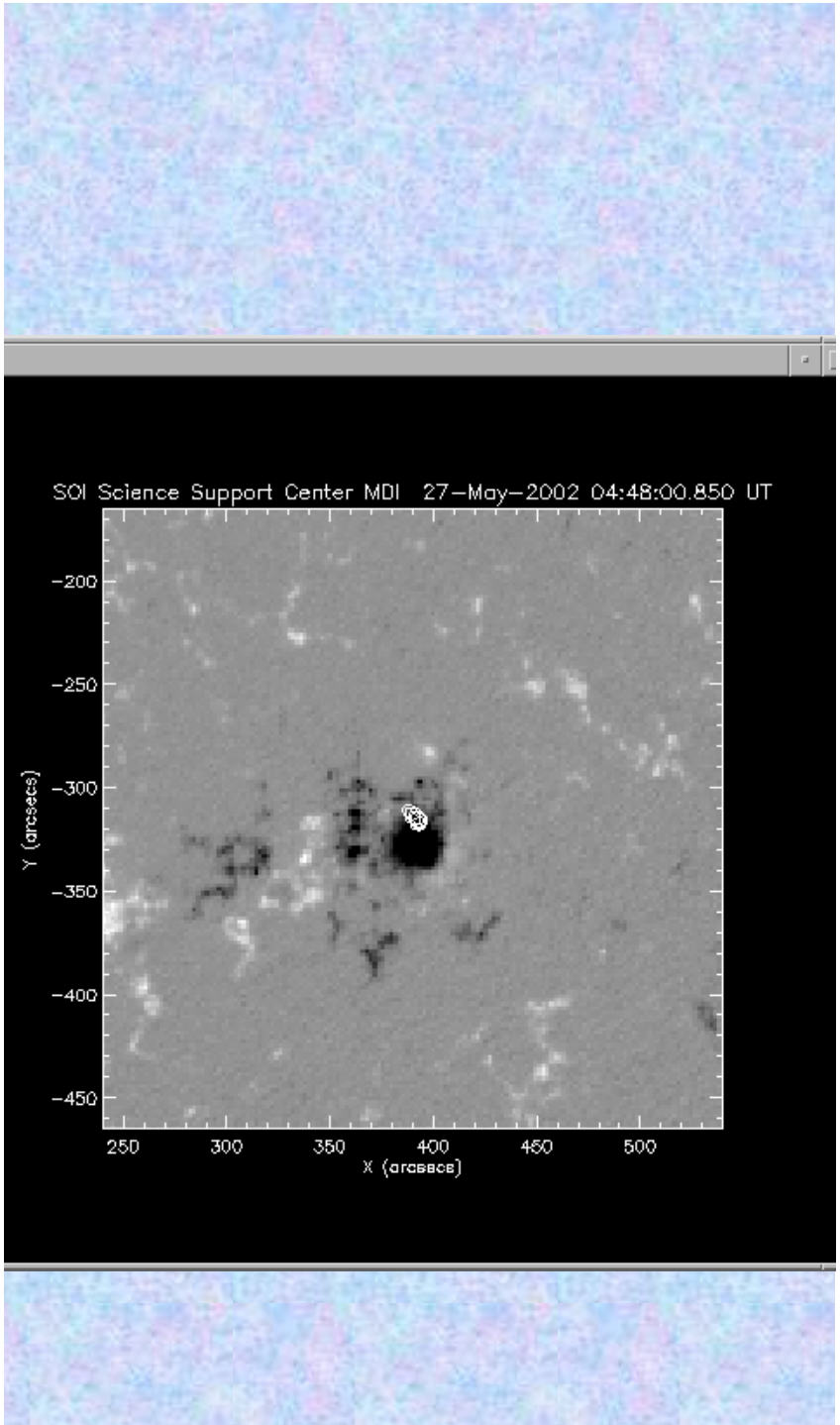
No.	Date	Time Interval of RDBs (UT)	Frequency Drift (MHz s^{-1})	GOES Flare Start	Max	End	GOES Class
1.	30 Mar 02	06:49:30-:50:10	600	06:20	07:08	08:40	C9.0
2.	10 Apr 02	12:27:30-:29:20	1100	12:15	12:32	18:00	M9.0
3.	11 May 02	11:32:00-:32:30	>1000	11:20	11:32	12:30	M1.5
4.	27 May 02	05:02:30-:03:30	750	05:00	05:07	05:20	C1.1
5.	30 Jul 02	07:37:20-:38:00	1500	17:10	17:38	18:20	C2.3
6.	14 Aug 02	17:07:35-:08:00	70	17:05	17:15	17:30	C1.3
7.	31 Aug 02	14:20:20-:21:00	>5000	14:17	14:22	14:32	C5.0
8.	01 Sep 02	09:31:30-:31:50	2400	09:30	09:32	09:40	C7.3
9.	25 Oct 02	07:02:10-:02:40	1500	07:01	07:02	07:14	C4.0
10.	21 Nov 02	12:43:20-:44:20	800	12:42	12:46	12:56	C1.0
11.	10 Mar 03	10:02:45-:03:25	1600	10:01	10:05	10:22	C1.3
12.	15 Mar 03	10:39:10-:39:40	630	10:02	10:10	10:50	M0.0
13.	09 Jun 03	16:28:20-:29:00	800	16:25	16:29	16:45	C6.8
14.	10 Aug 03	10:15:10-:16:30	420	10:00	10:20	10:50	C3.5
15.	28 Oct 03	11:01:25-:01:40	620	09:30	11:08	21:00	X17.2
16.	31 Oct 03	11:22:00-:22:07	2800	11:10	11:13	11:40	C3.0
17.	23 Jul 04	06:44:50-:45:00	240	06:41	06:48	07:15	C2.1
18.	26 Jul 04	05:39:00-:41:00	48	05:36	05:52	06:45	M1.4
19.	03 Dec 04	13:04:55-:05:27	600	13:02	13:08	13:40	B8.0
20.	11 Apr 05	07:51:20-:51:40	600	07:51	07:52	07:54	B1.2
21.	09 May 05	10:45:30-:46:00	600	10:30	11:03	11:40	C9.0
22.	01 Aug 05	13:28:10-:29:10	920	13:07	13:50	19:00	M1.1

First example of an event with a single well defined “fast” RDB on 27 May 02






HESSI Observing Summary Count Rates
Det 1,3,4,5,6,9,
FDecim 1, Att 1
3 - 6 keV
6 - 12 keV
12 - 25 keV
25 - 50 keV
50 - 100 keV
100 - 300 keV
300 - 800 keV
800 - 7000 keV
7000 - 20000 keV
F
100
10
1
Count Rate (s-1 detector-1)
04:56
05:00
05:04
05:08
Start Time (27-May-02 04:52:00)
17-Mar-2006 13:24

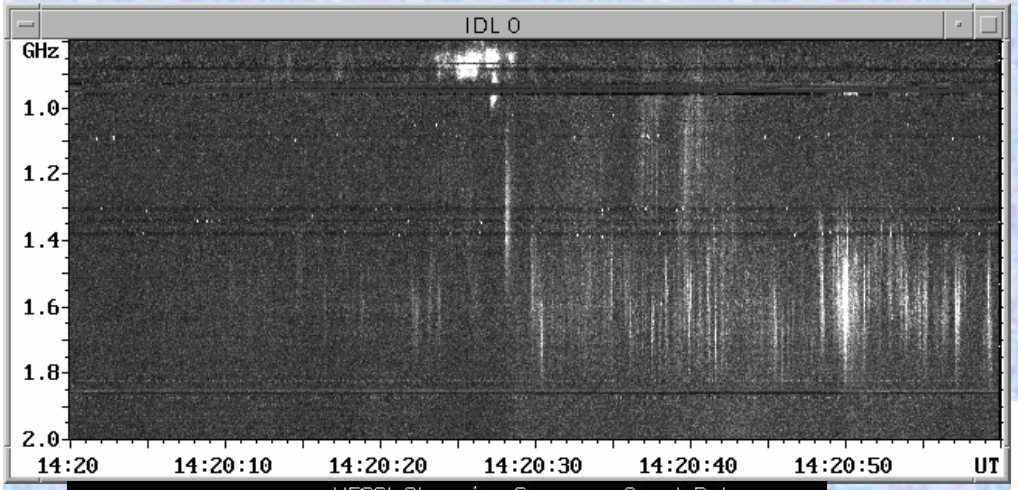

SOI Science Support Center MDI 27-May-2002 04:48:00.850 UT
-200
-250
-300
-350
-400
-450
Y (arcsecs)
250
300
350
400
450
500
X (arcsecs)

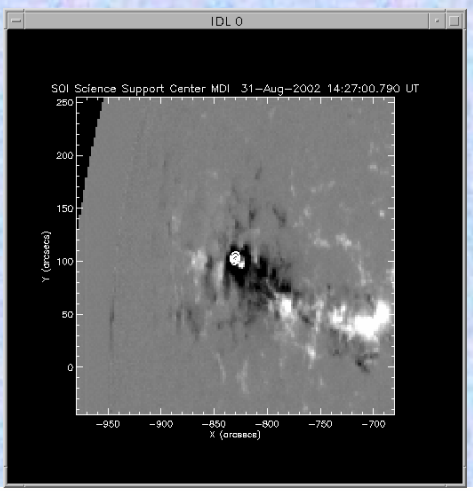
Typical features of many events in our data set:

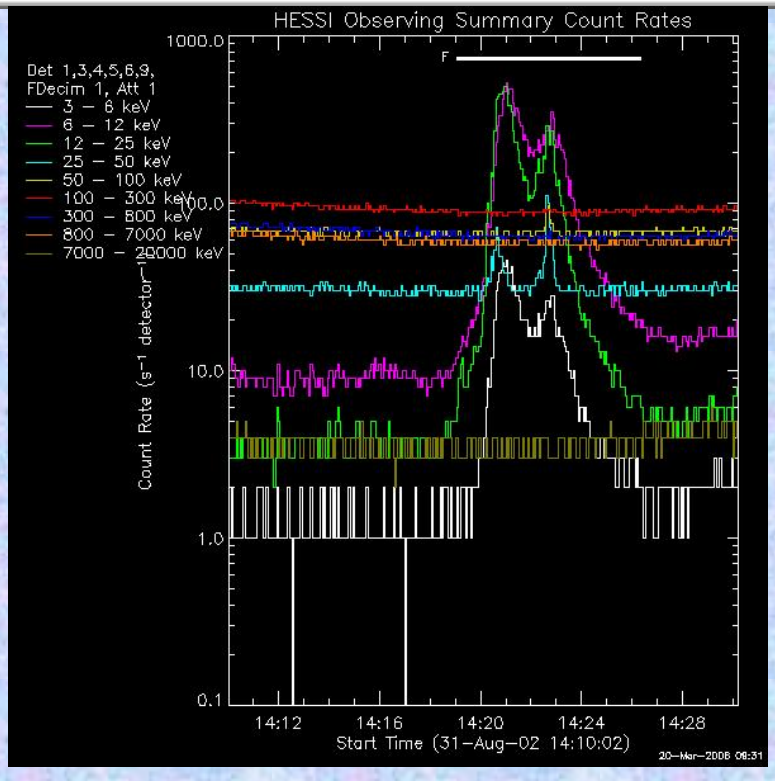
*** very weak hard X-ray emission, short and nearly symmetrical profile**
*** compact hard X-ray source**
*** soft X-ray importance C**
*** high frequency drift**
*** RDBs during the rise phase in RHESSI flux**
*** RDBs are nearly always observed during the hard X-ray burst but it seems to be impossible to make a reliable temporal correlation of an RDB and a sub-peak in the X-ray flux**

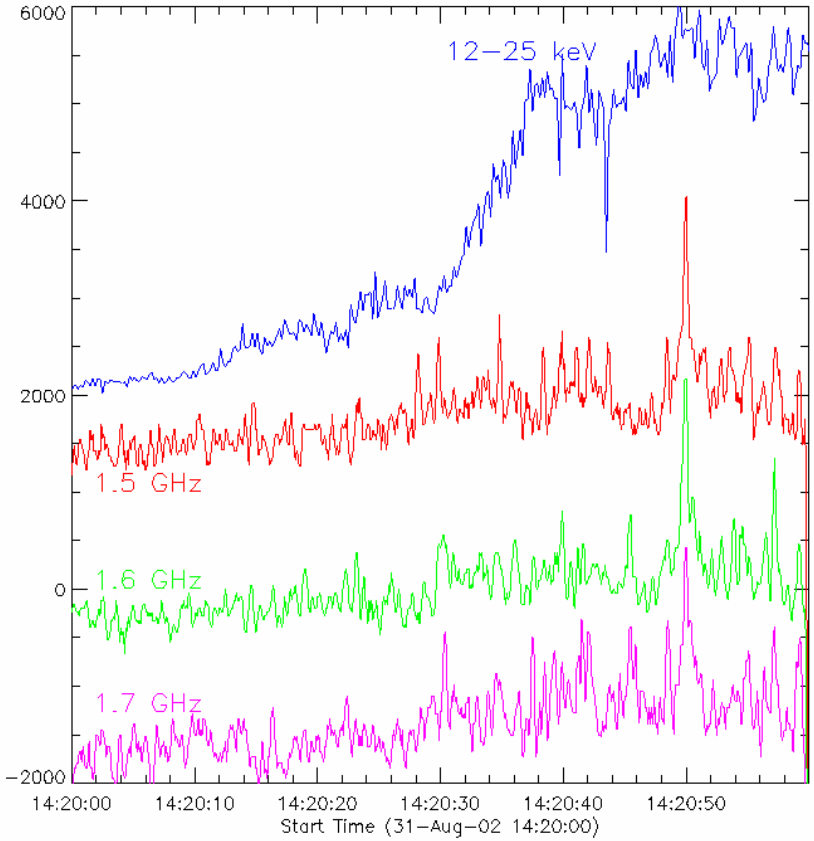
A few other examples:

31 AUGUST 2002

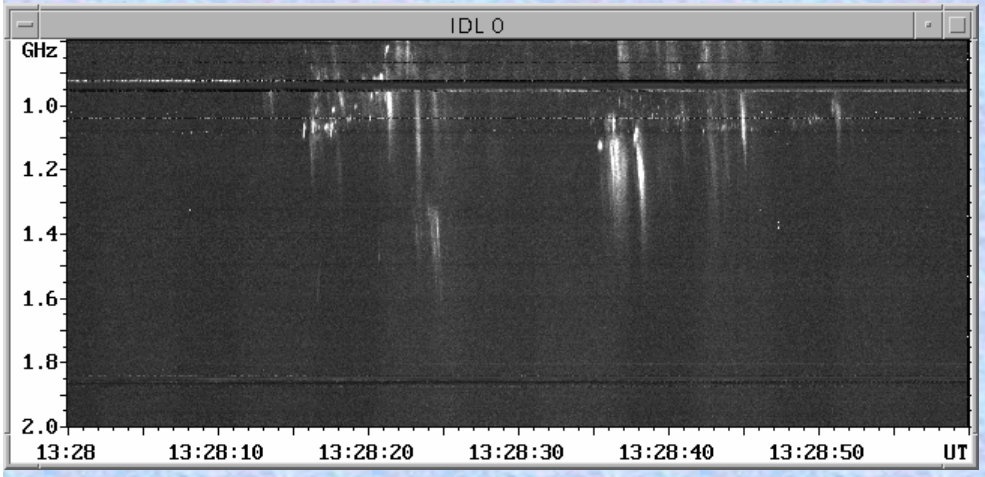


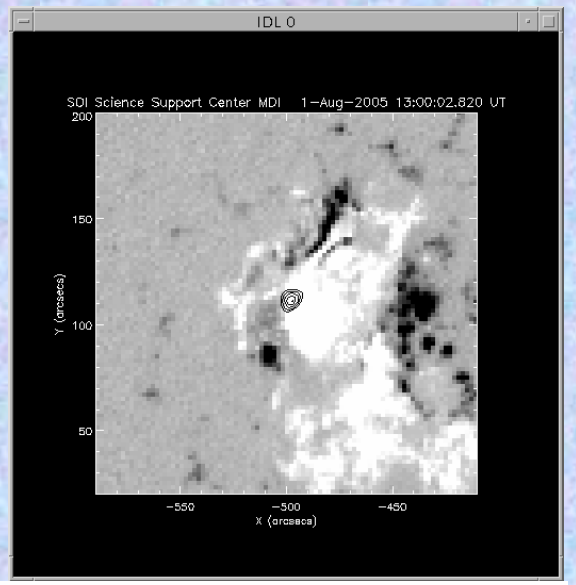


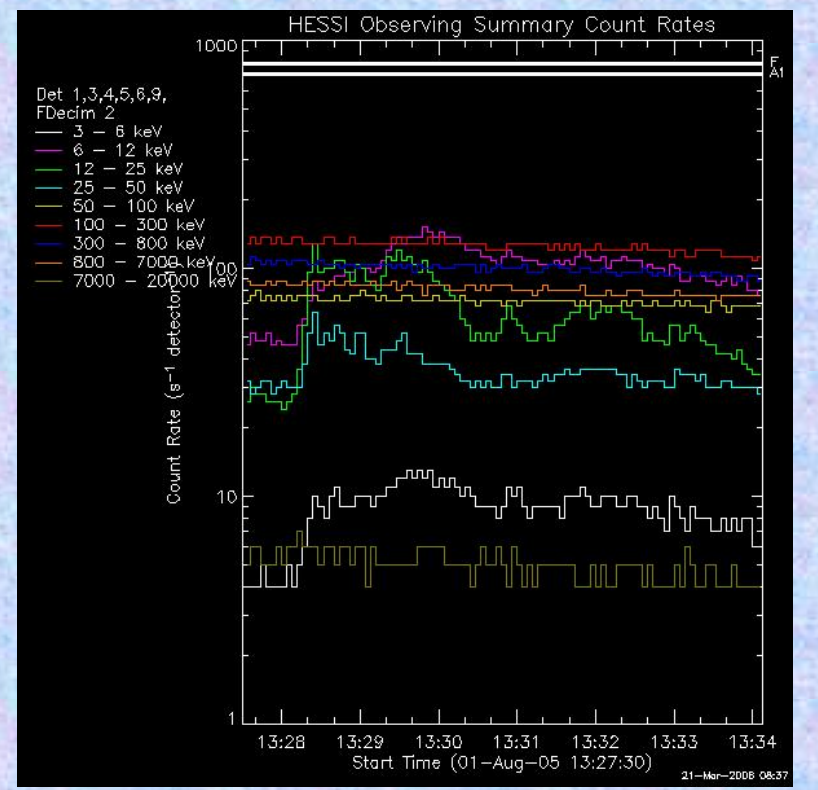


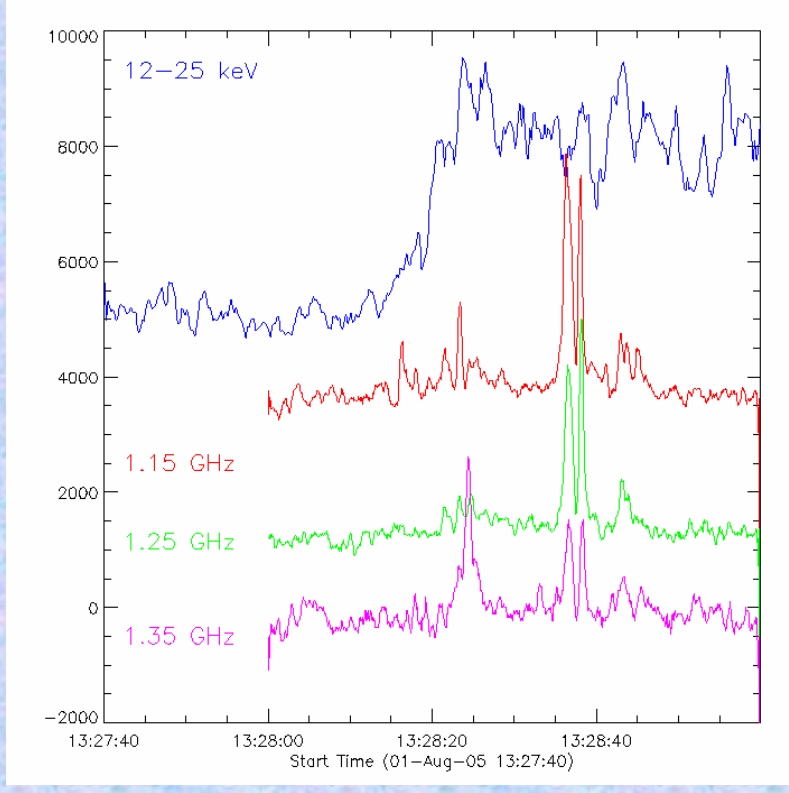


01 AUGUST 2005

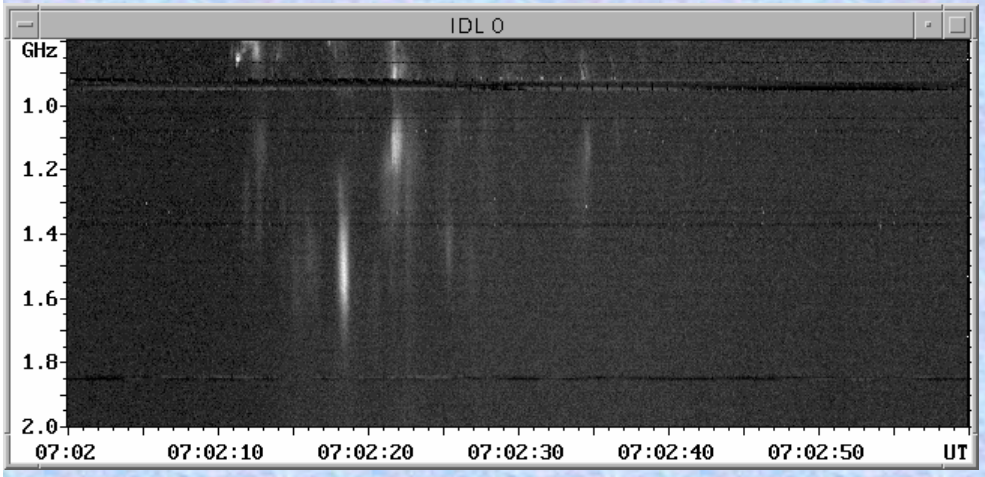


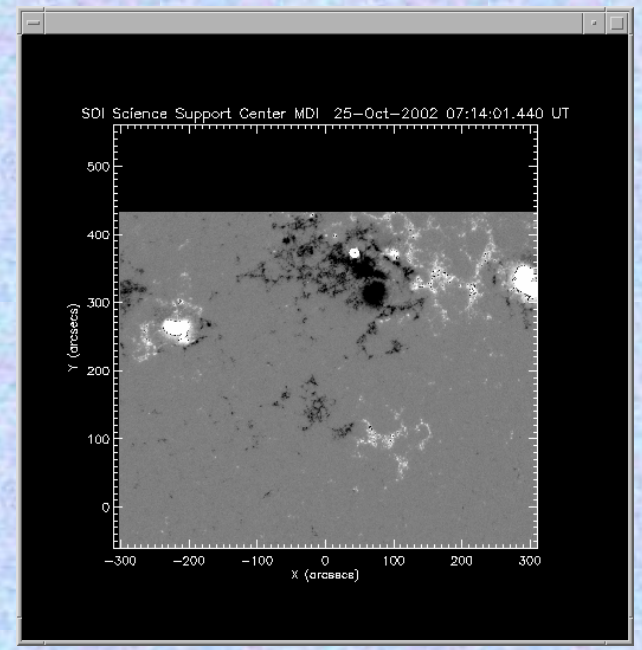


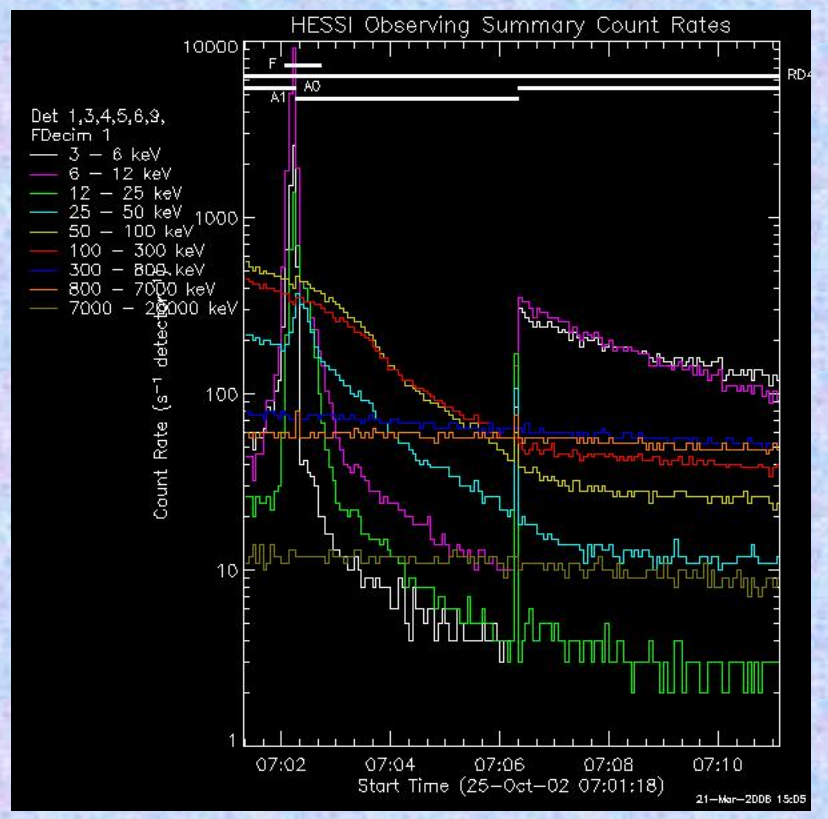


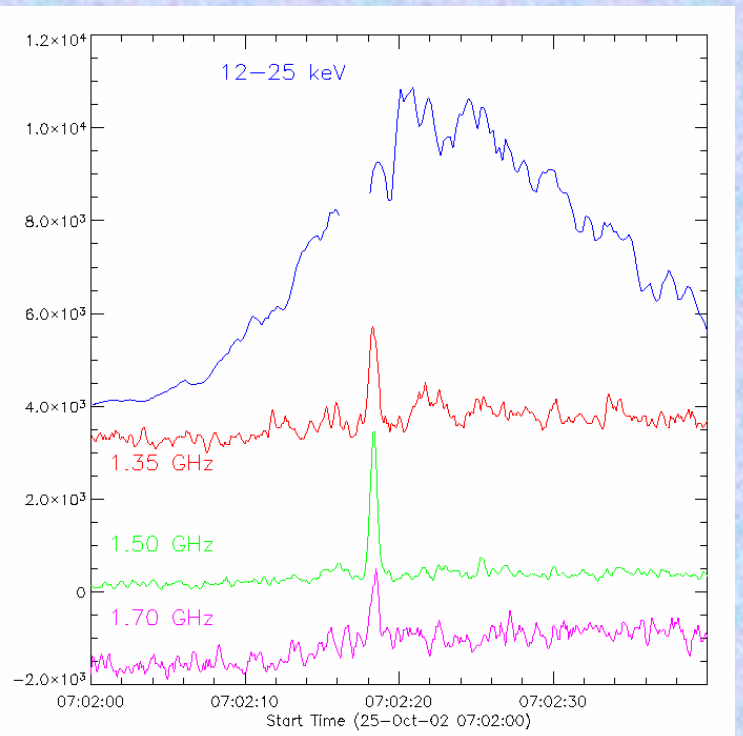


25 OCTOBER 2002

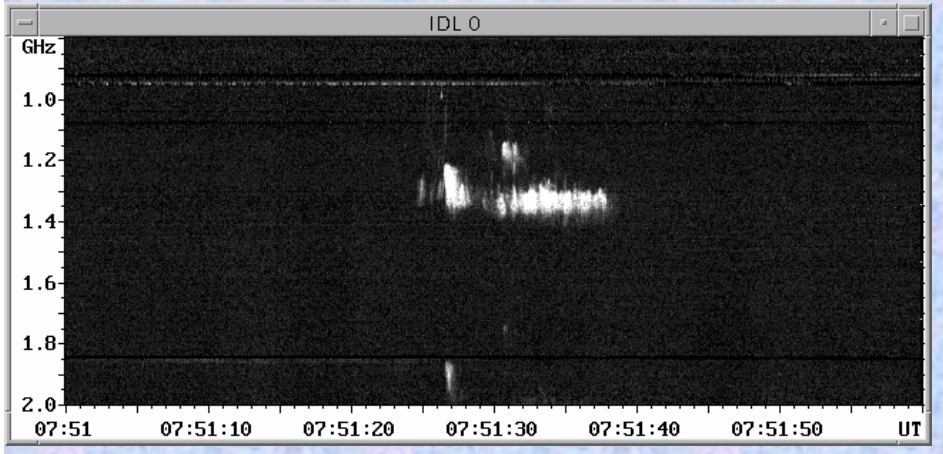


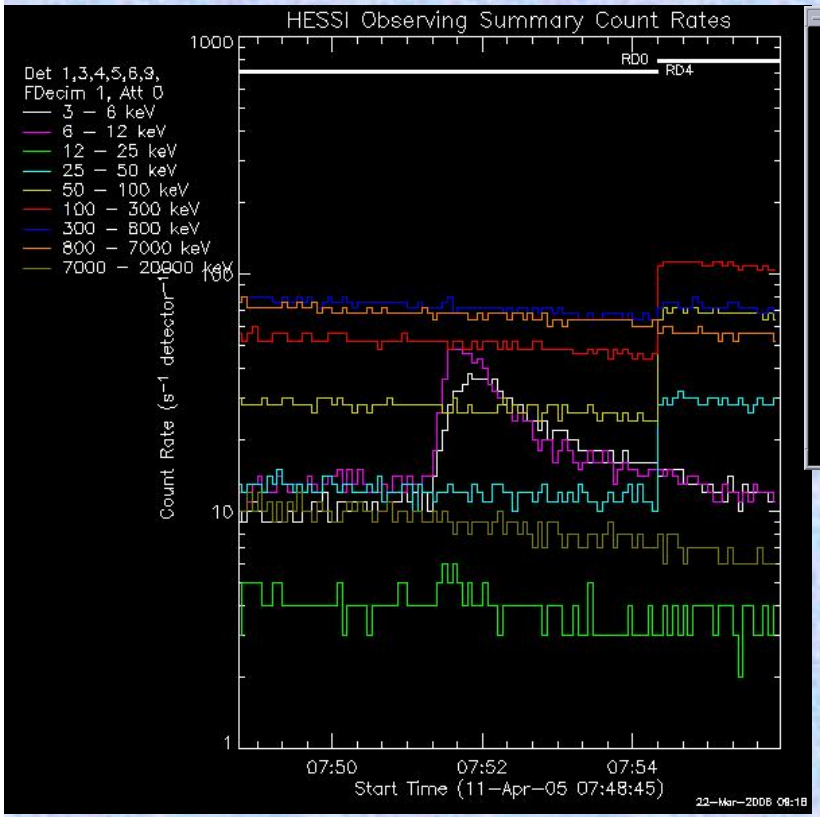


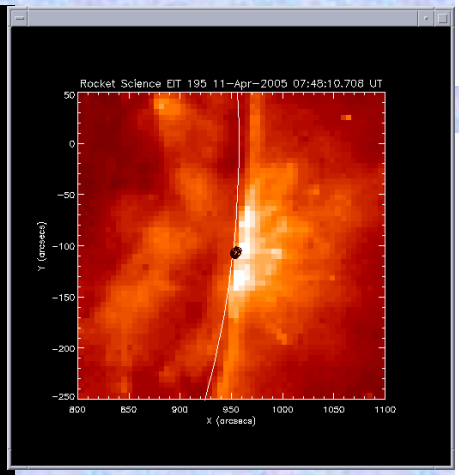


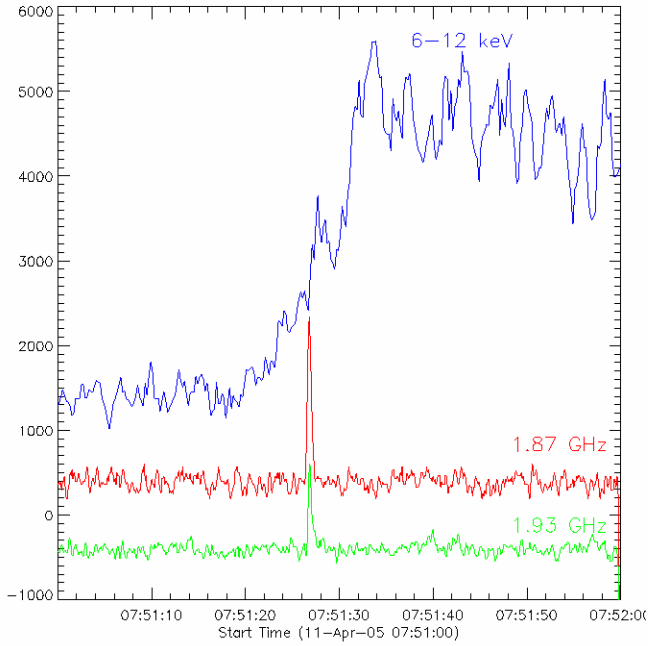


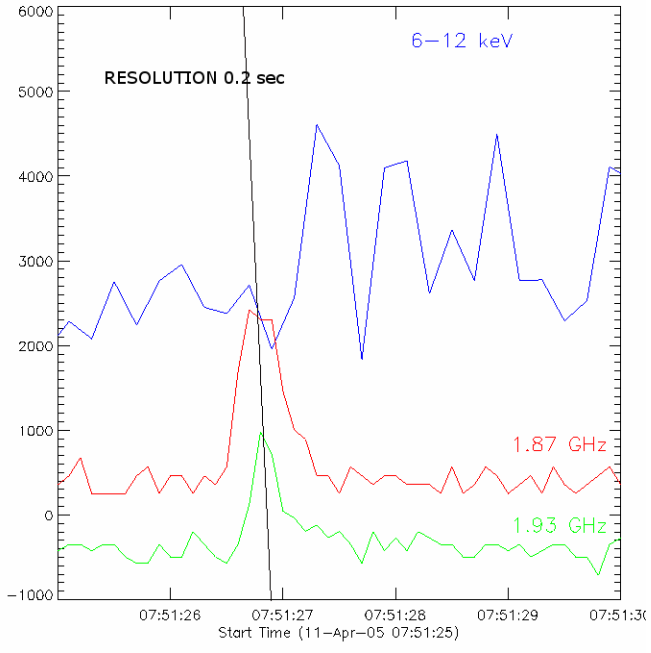
11 APRIL 2005



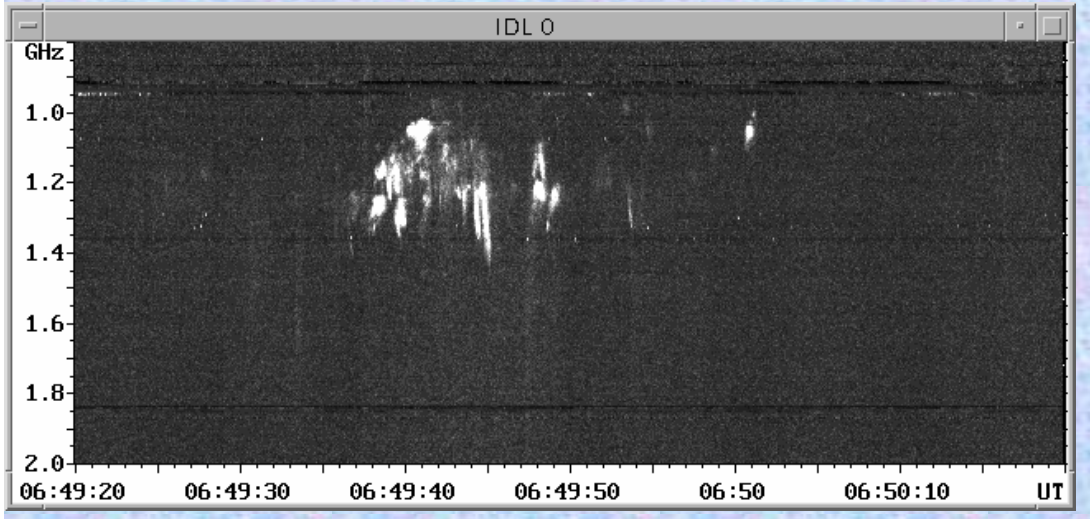


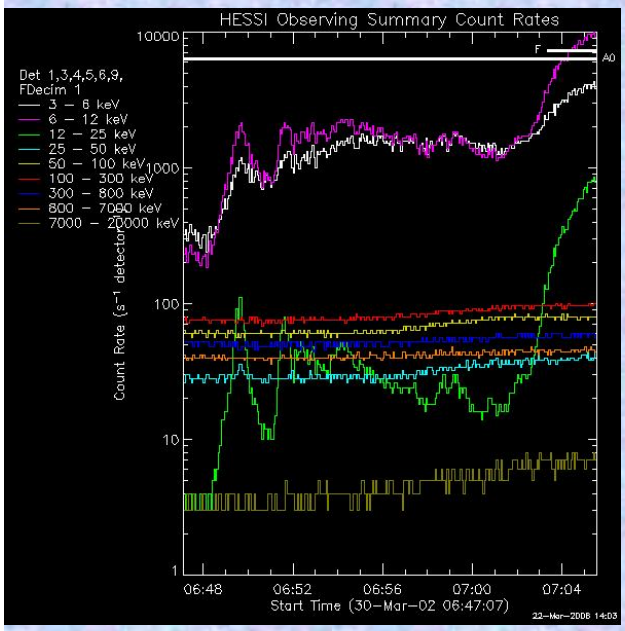


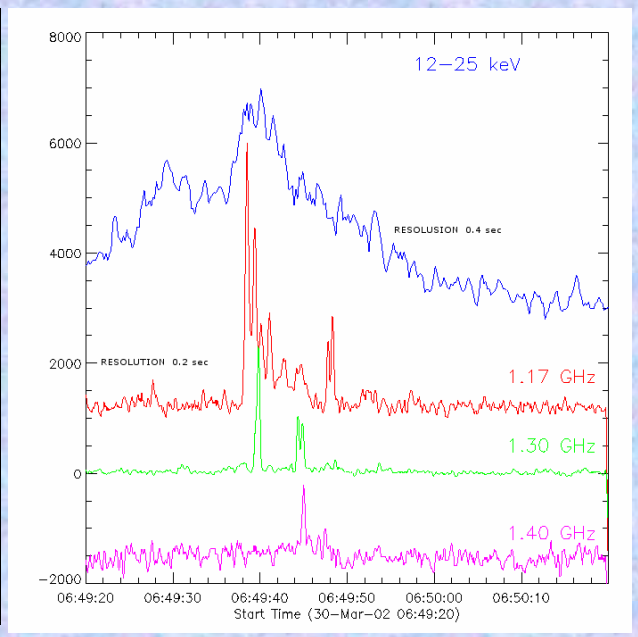


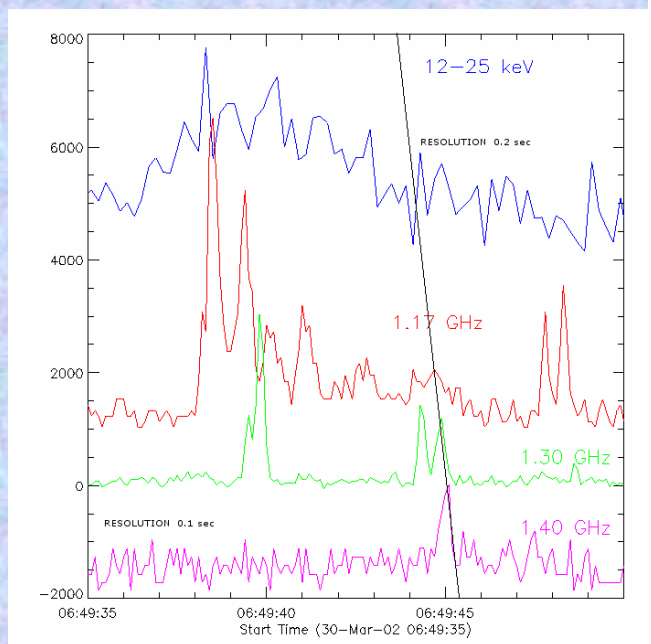


30 MARCH 2002





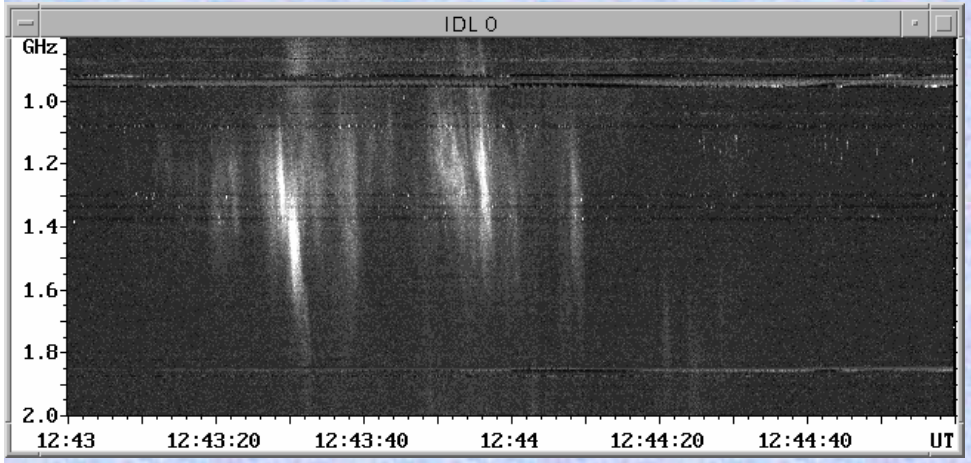


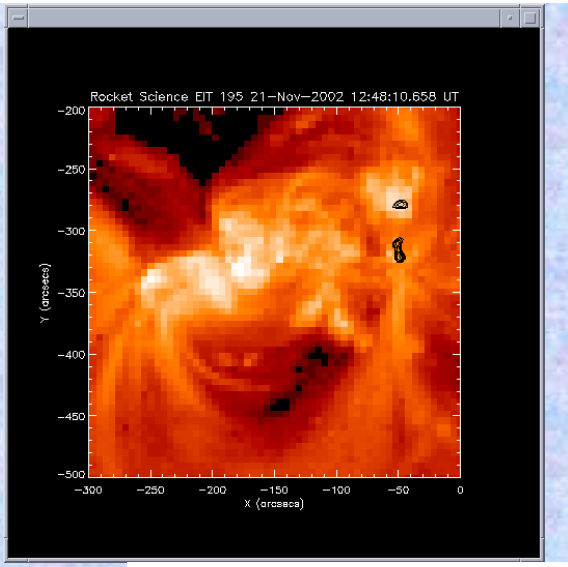


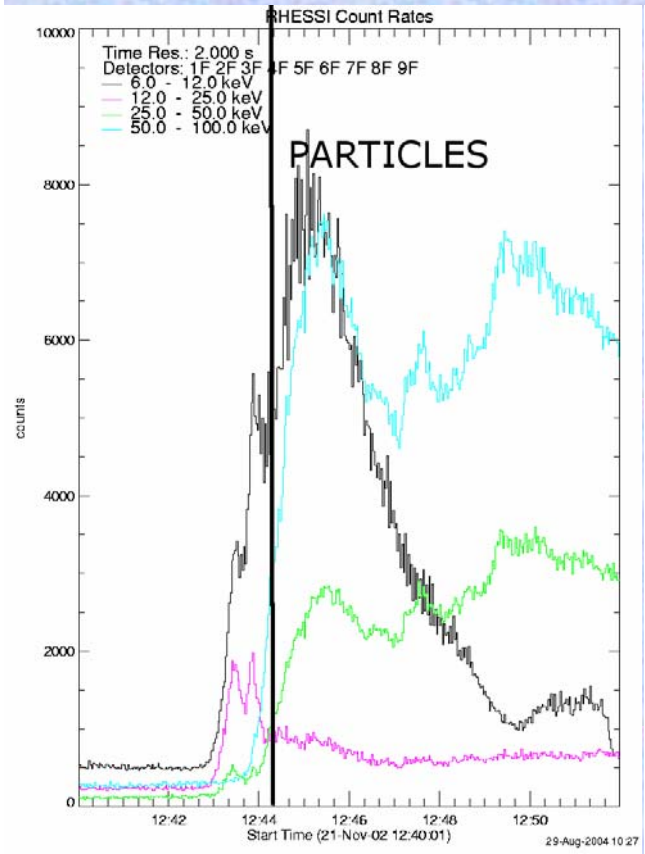
As a small sub-group of the previous events we found relatively “fast” RDBs which were accompanied by multiple sources X-ray emission.
Some changes of the X-ray sources are observed during the RDB observation.

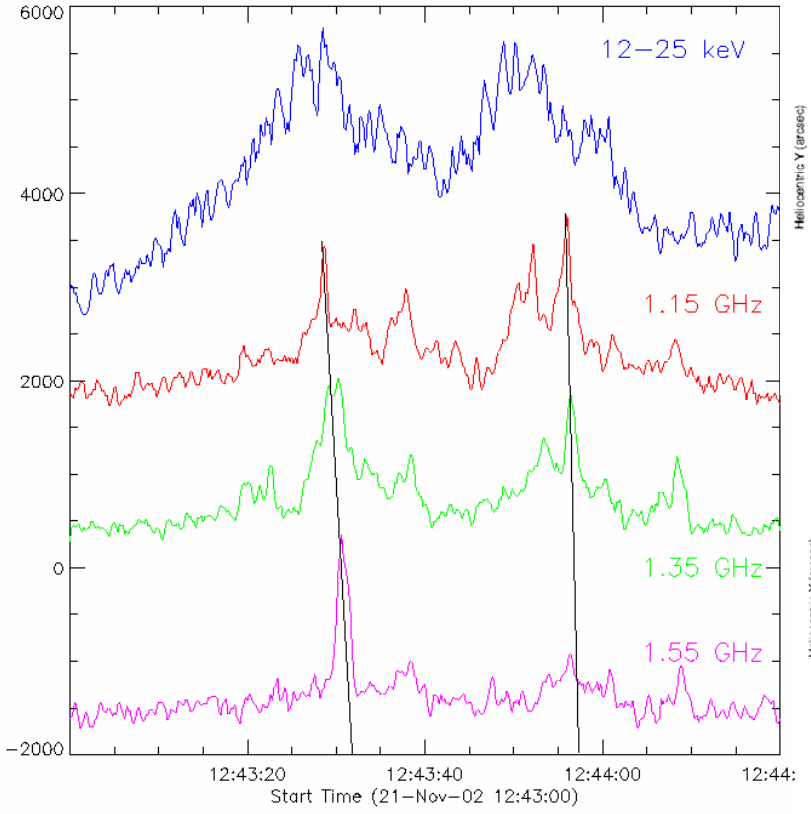
We can show a few examples:

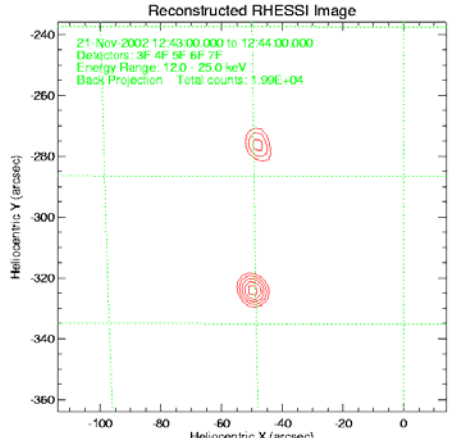
21 NOVEMBER 2002

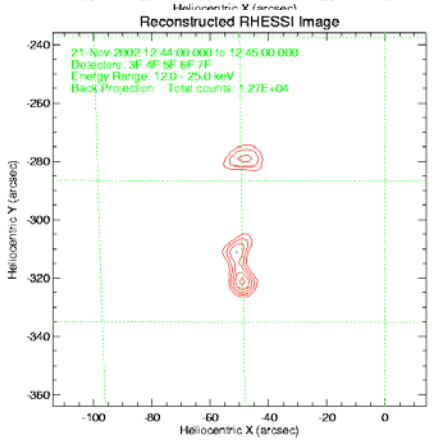




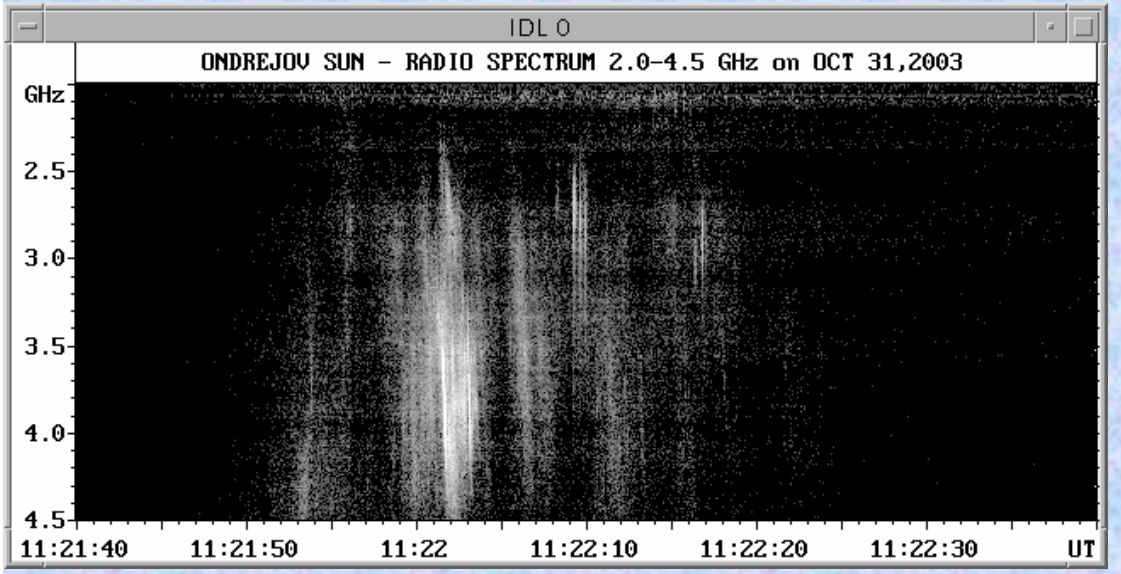


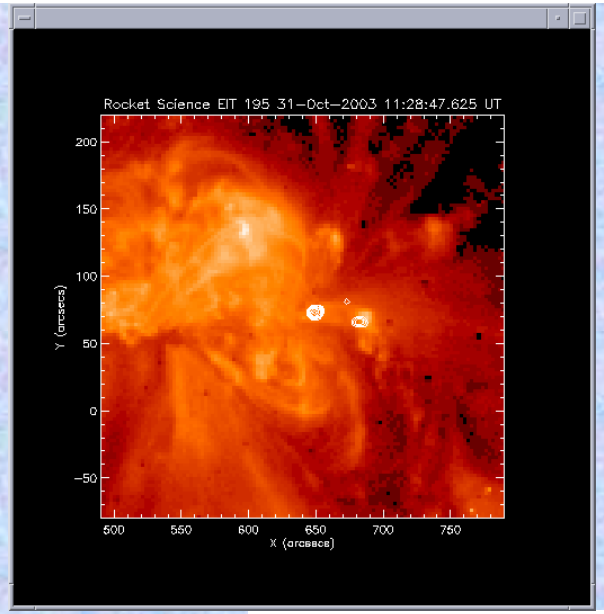


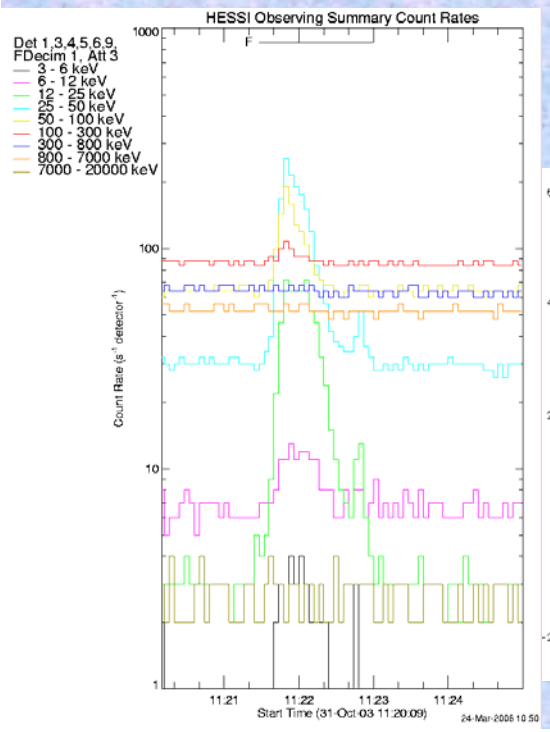


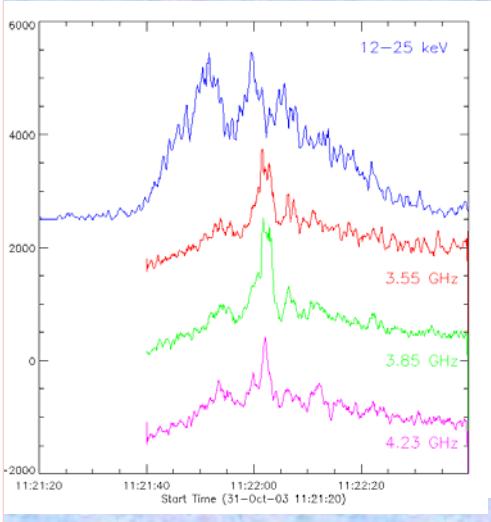


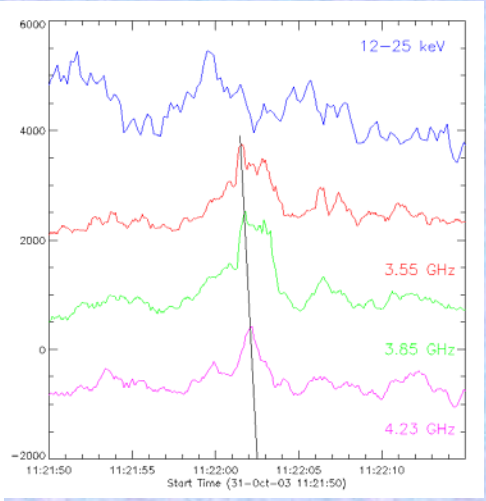
31 OCTOBER 2003

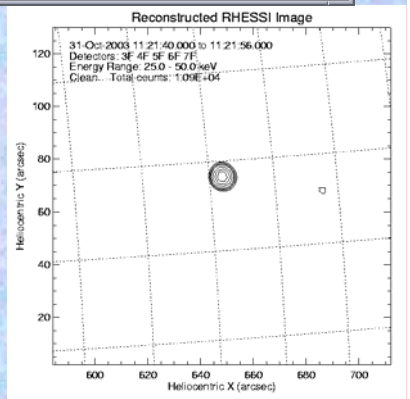


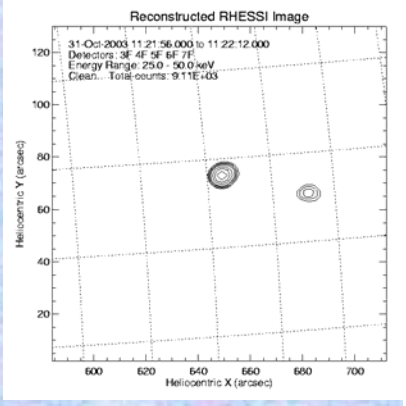








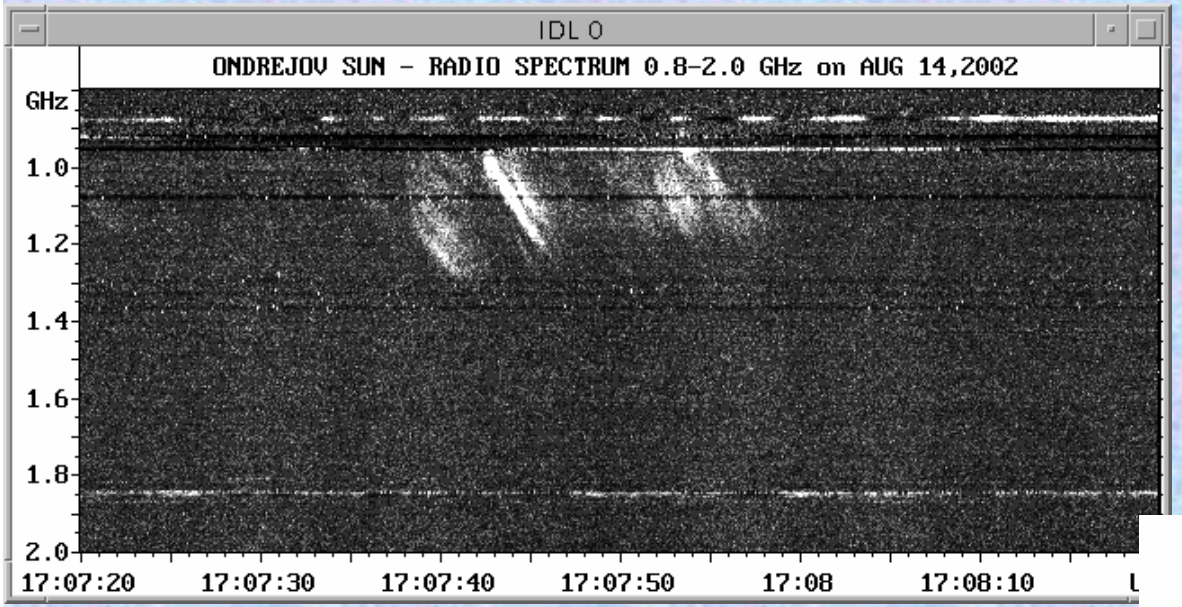


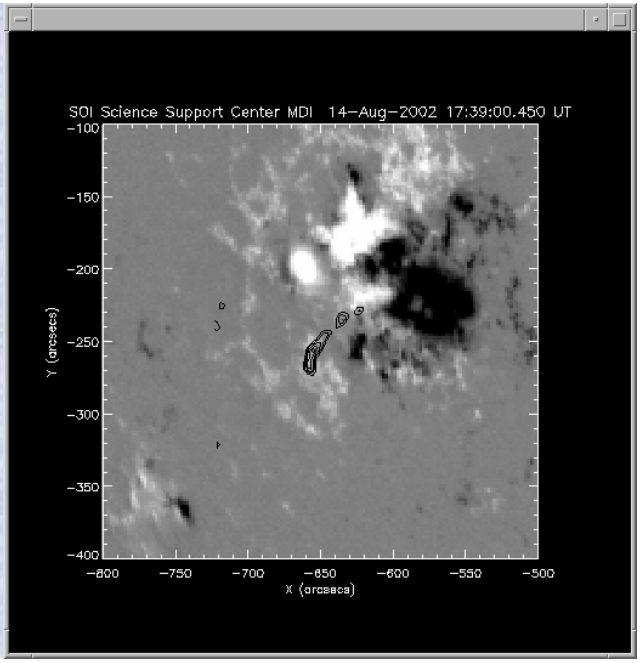


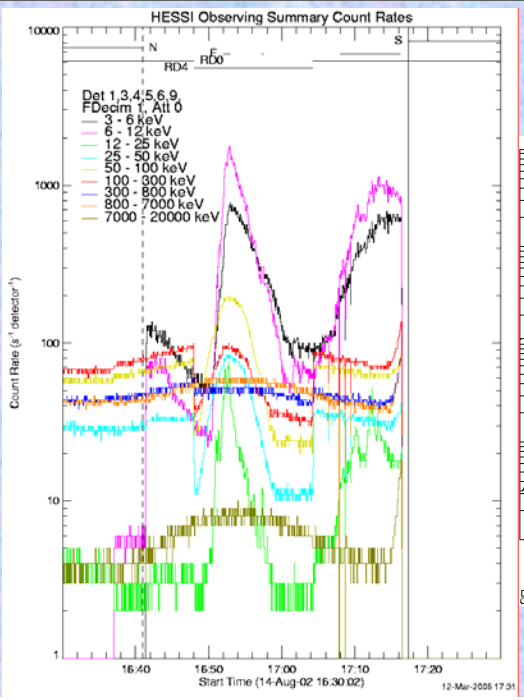
Another group of RDBs are those events where RDBs have an extremely slow frequency drift. These events seem to be accompanied by multi-source X-ray emission, not so impulsive as in the first group. During RDBs observation the shape of the corresponding X-ray source may change or expand. It seems also that the X-ray emission is not so hard and impulsive but the events have higher GOES soft X-ray importance. The RDBs “driver”may be different, i.e. instead of fast electron beams a shock disturbance.

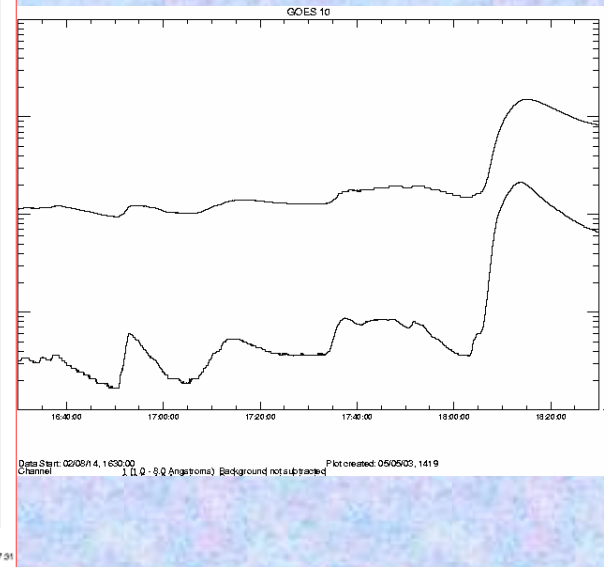
A few examples :

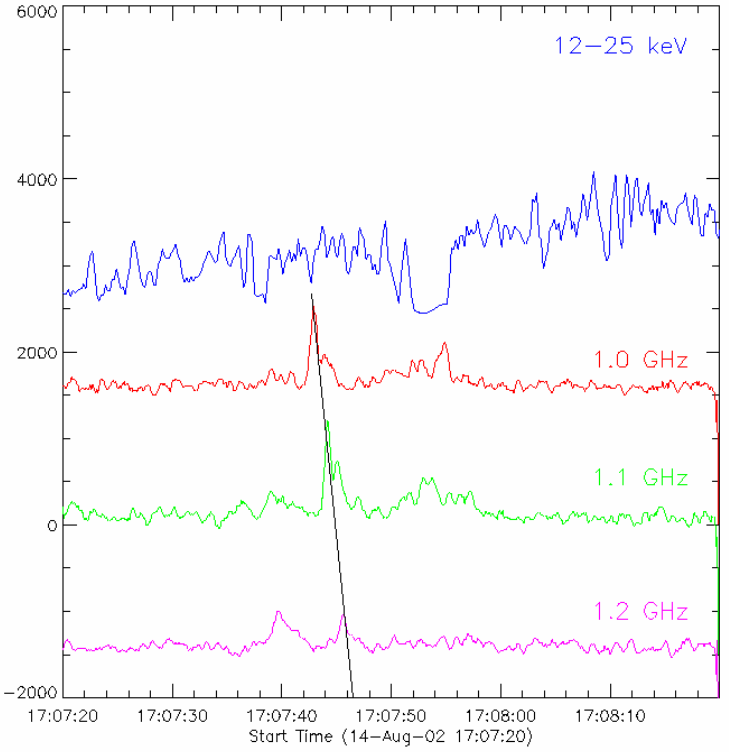
14 AUGUST 2002



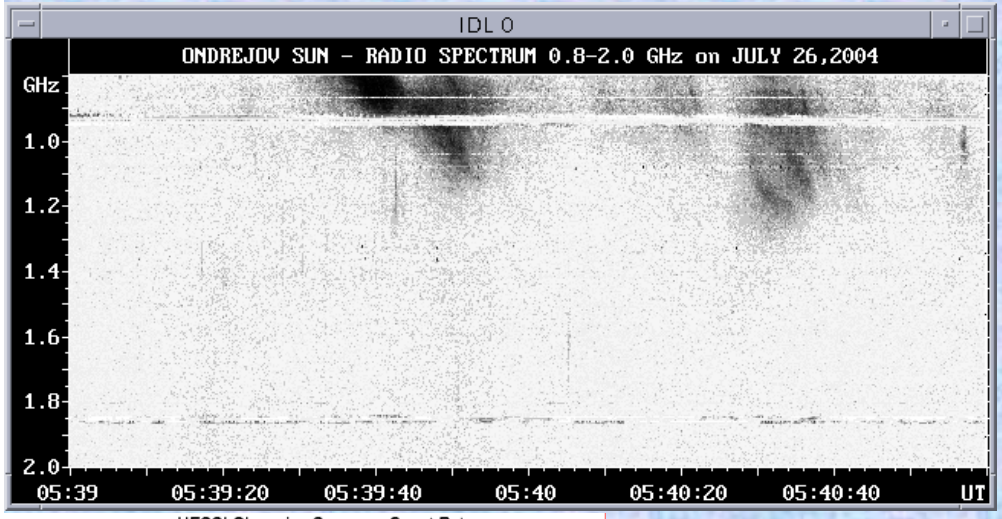


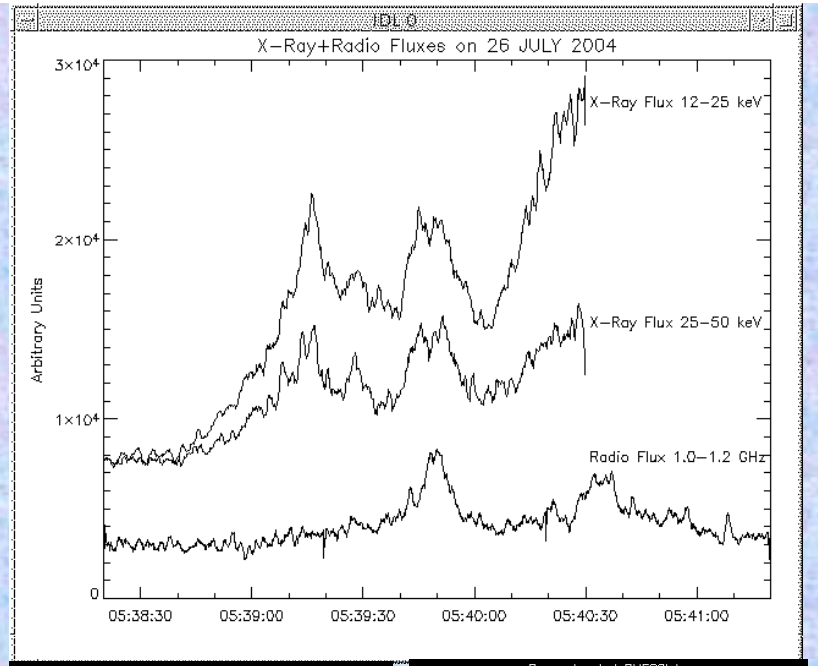


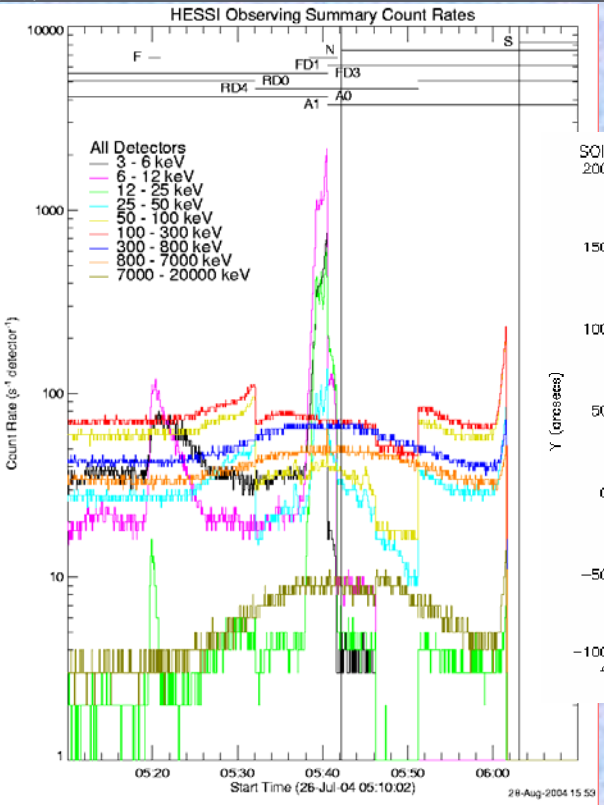


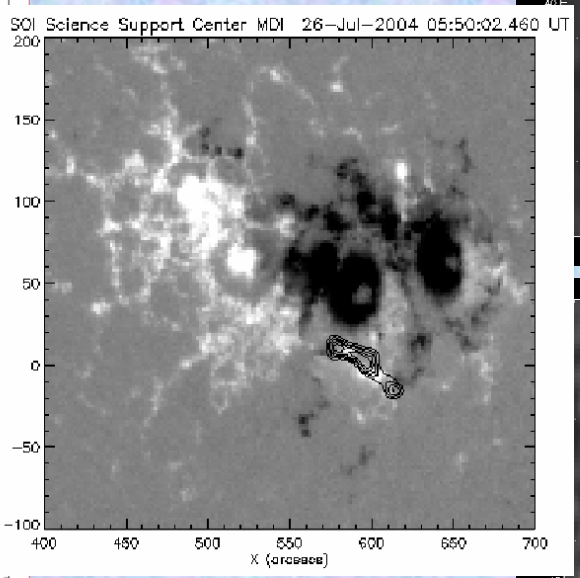


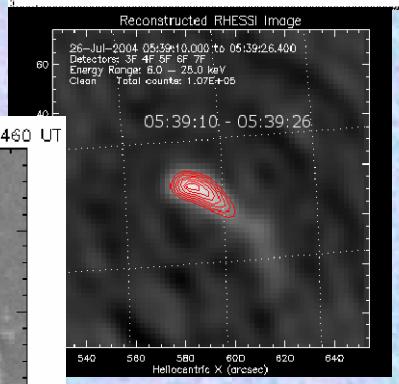
26 JULY 2004

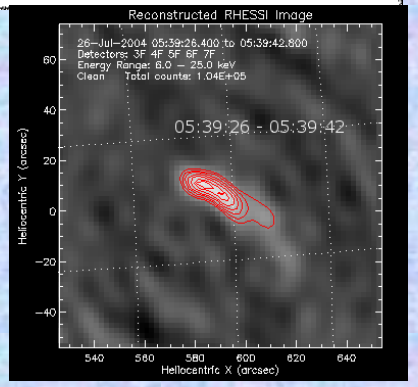

IDL 0
ONDREJOV SUN - RADIO SPECTRUM 0.8-2.0 GHz on JULY 26,2004
GHz
1.0
1.2
1.4
1.6
1.8
2.0
05:39
05:39:20
05:39:40
05:40
05:40:20
05:40:40
UT

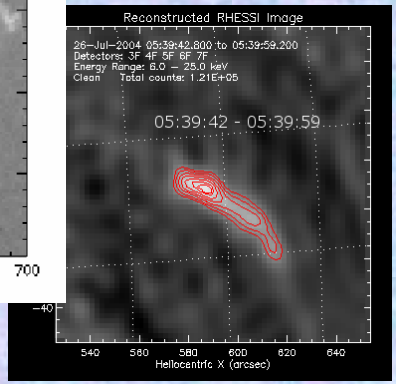

IDL 0
X-Ray+Radio Fluxes on 26 JULY 2004
3×10⁴
2×10⁴
1×10⁴
0
Arbitrary Units
X-Ray Flux 12-25 keV
X-Ray Flux 25-50 keV
Radio Flux 1.0-1.2 GHz
05:38:30
05:39:00
05:39:30
05:40:00
05:40:30
05:41:00

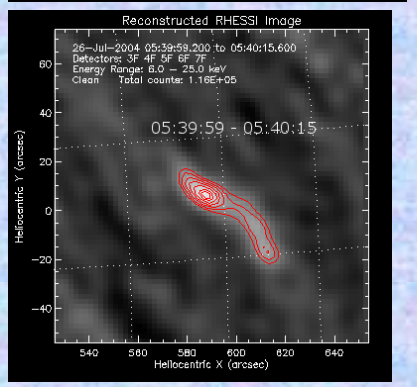

HESSI Observing Summary Count Rates
All Detectors
3 - 6 keV
6 - 12 keV
12 - 25 keV
25 - 50 keV
50 - 100 keV
100 - 300 keV
300 - 800 keV
800 - 7000 keV
7000 - 20000 keV
Count Rate (s⁻¹ detector⁻¹)
Start Time (26-Jul-04 05:10:02)
28-Aug-2004 15:59


SOI Science Support Center MDI 26-Jul-2004 05:50:02.460 UT
Y (arcsecs)
X (arcsecs)

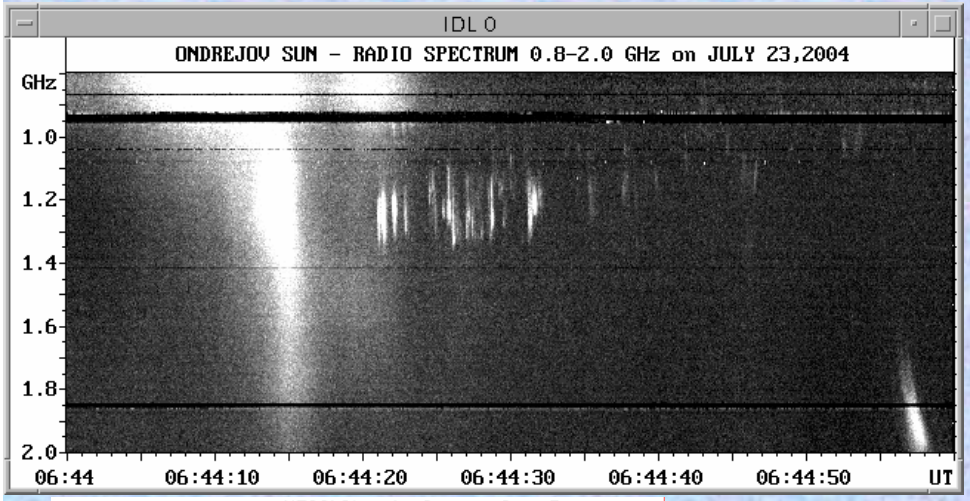

Reconstructed RHESSI Image
05:39:10 - 05:39:26
Heliocentric X (arcsec)

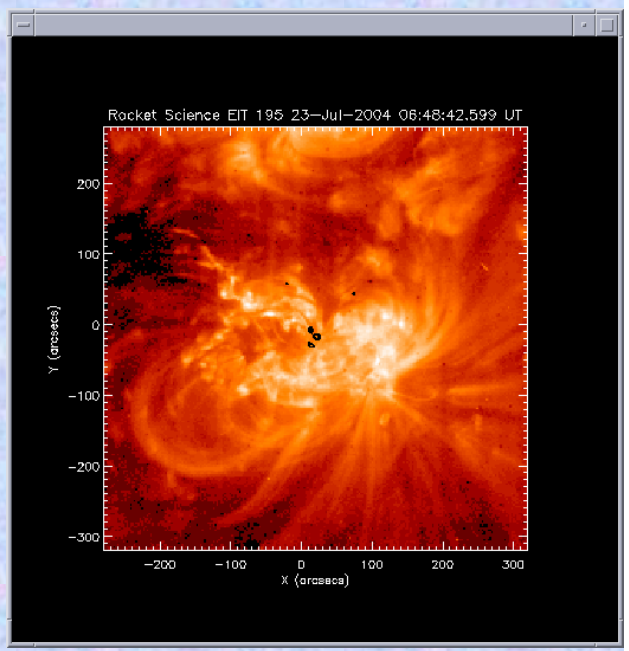

Reconstructed RHESSI Image
05:39:26 - 05:39:42
Heliocentric Y (arcsec)
Heliocentric X (arcsec)

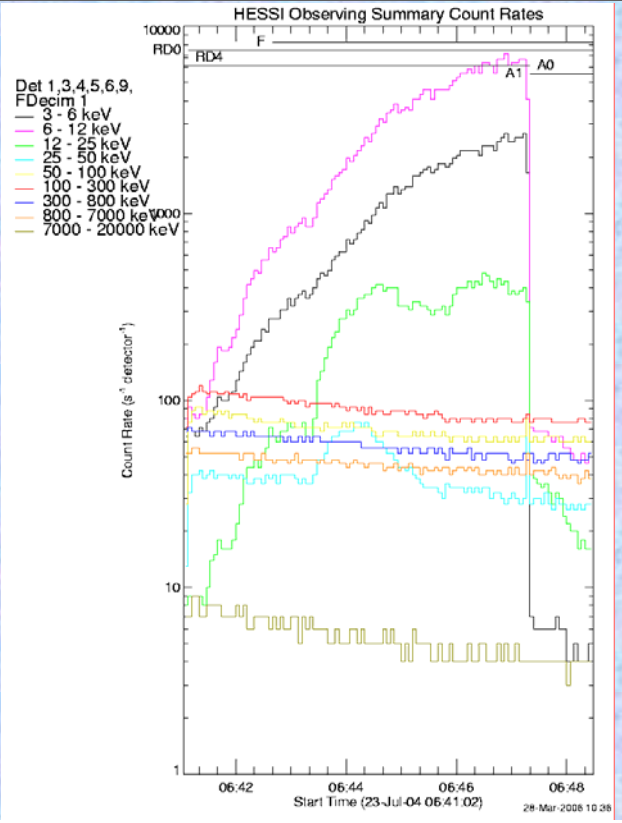

Reconstructed RHESSI Image
05:39:42 - 05:39:59
Heliocentric X (arcsec)

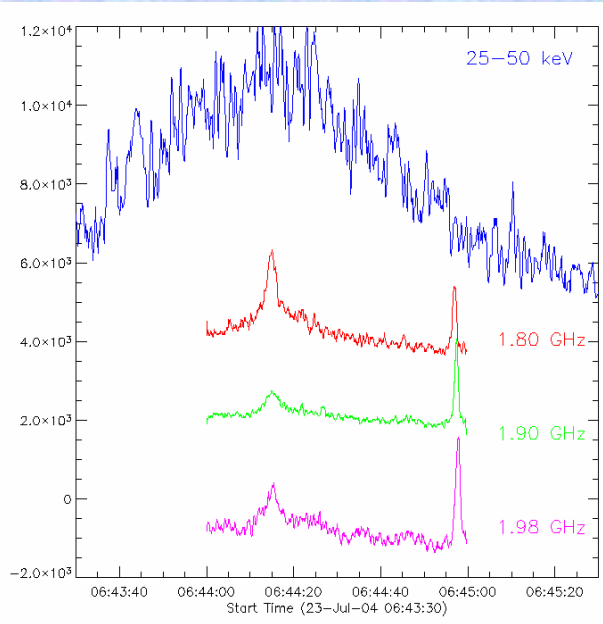

Reconstructed RHESSI Image
05:39:59 - 05:40:15
Heliocentric Y (arcsec)
Heliocentric X (arcsec)

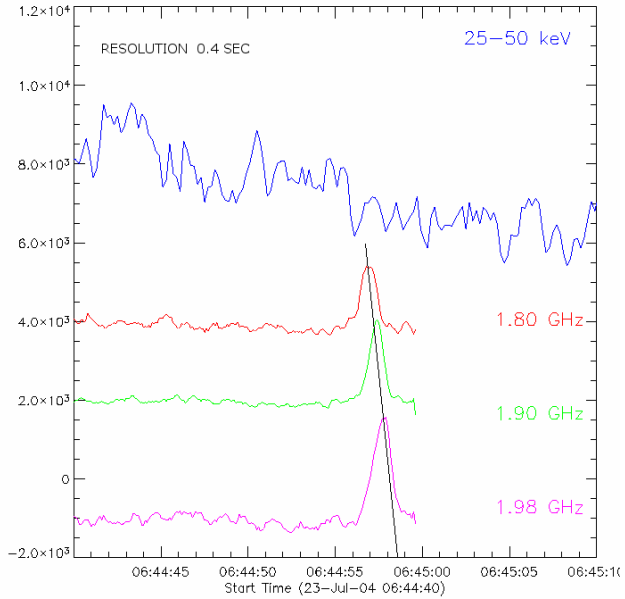
23 JULY 2004


IDL 0
ONDREJOV SUN - RADIO SPECTRUM 0.8-2.0 GHz on JULY 23,2004
GHz
1.0
1.2
1.4
1.6
1.8
2.0
06:44
06:44:10
06:44:20
06:44:30
06:44:40
06:44:50
UT

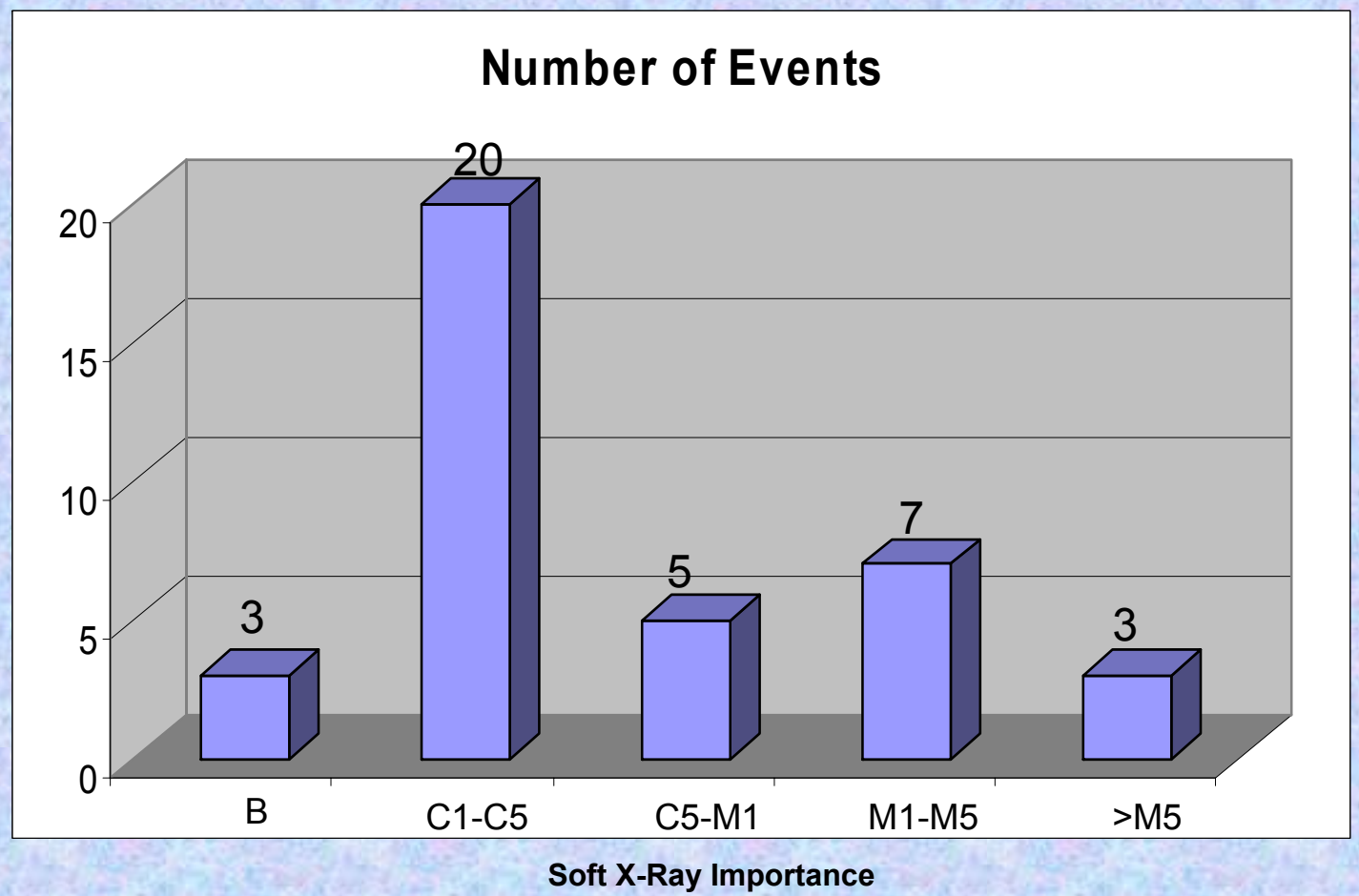

Rocket Science EIT 195 23-Jul-2004 06:48:42.599 UT
Y (arcsecs)
X (arcsecs)
200
100
0
-100
-200
-300
-200
-100
0
100
200
300


HESSI Observing Summary Count Rates
Det 1,3,4,5,6,9,
FDecim 1
3 - 6 keV
6 - 12 keV
12 - 25 keV
25 - 50 keV
50 - 100 keV
100 - 300 keV
300 - 800 keV
800 - 7000 keV
7000 - 20000 keV
RD0
RD4
F
A1
A0
Count Rate (s⁻¹ detector⁻¹)
10000
1000
100
10
1
06:42
06:44
06:46
06:48
Start Time (23-Jul-04 06:41:02)
28-Mar-2008 10:38


25-50 keV
1.80 GHz
1.90 GHz
1.98 GHz
1.2×10⁴
1.0×10⁴
8.0×10³
6.0×10³
4.0×10³
2.0×10³
0
-2.0×10³
06:43:40
06:44:00
06:44:20
06:44:40
06:45:00
06:45:20
Start Time (23-Jul-04 06:43:30)


RESOLUTION 0.4 SEC
25-50 keV
1.80 GHz
1.90 GHz
1.98 GHz
1.2×10⁴
1.0×10⁴
8.0×10³
6.0×10³
4.0×10³
2.0×10³
0
-2.0×10³
06:44:45
06:44:50
06:44:55
06:45:00
06:45:05
Start Time (23-Jul-04 06:44:40)

GOES Soft X-Ray Importance versus RDBs Observation



CONCLUSIONS

- Reverse Drift Bursts are mostly observed during the rise (flash) phase of hard X-ray emission.
- It seems that RDBs with high frequency drift are mostly accompanied by compact X-ray sources.
- There are also events with high frequency drift RDBs and with multiple X-ray sources which may change shape or intensity during the RDB observation.
- In some cases the frequency drift of the observed RDBs was very small. Here the radio emission might be a result of a downward moving shock front.
- In the frequency range below 1.4 GHz Aschwanden et al. found in 26 % of studied 882 events correspondence between individual X-ray peaks and type III radio bursts (including RDBs). The relative timing between HXR pulses and radio bursts was found with a coincidence of <0.1 s in statistical average.

  In the range above 1 GHz we did not find any such one-to-one relation between individual X-ray peaks (sub-peaks) and individual RDBs on the time scale of the order of 1 s.
- GOES importance versus RDBs shows that RDBs are preferably observed during flares with lower soft X-ray importance. The reason is unclear so far.