

CDAW08, Oct.14-17
Nobeyama Radio Obs.

Group2: 大型フレア電波源の空間構
造及びその時間発展

Member:

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Introduction

- リムほどスペクトルsoft、強度小
(Kosugi1985)電波放射の発生頻度の経度依存性はない。強度もない。
- 高周波数はリム付近の発生頻度大(Silva & Valente 2002)、
- 高周波数はリムほどduration大
- リムほどスペクトル硬い,どの周波数でもリムほど強度大(数値計算)

Motivation

- 強度、スペクトル、偏光度の空間構造(画像解析)の経度依存性を調べる。⇒観測者の視線方向と磁力線のなす角とから、放射電子ピッチ角分布を推定する。(空間分解された画像は今まで用いられていない⇒footpointかloop-topか判別できる)
- ディスク=loop-topメインか？
- リム=footpointメインか？
- フレア前半と後半で変わる？
- 解析候補イベントリスト
- 空間スケール大きめ(M以上フレア) + 南中時刻付近⇒空間分解能高い(26event)
- 強度強いので越石プログラム多用か？

Event List

(RHESSI era)

	Date	Dur.(sec)	GOES	Bright.(K)	F9.4G	F35G	Position.
(1)	2005-12-02	2499	M6.5	5.1e7	1017	551	E17
(2)	2005-08-25	2173	M6.4	1.1e8	2335	4385	E82
(3)	2005-07-27	6239	M3.7	3.9e7	1424	342	E91
(4)	2004-11-03	5224	M1.6	5.4e7	2893	1099	E46
(5)	2004-07-16	4224	X1.3	1.2e8	1348	1549	E39
(6)	2004-07-15	4023	X1.8	7.2e7	760	424	E52
(7)	2003-10-24	3481	M7.6	2.4e7	3986	3878	E69
(8)	2003-04-23	2796	M5.1	8.7e7	1402	531	W16
(9)	2002-11-10	1848	M2.4	8.8e6	506	86	W37
(10)	2002-07-29	1487	M4.8	7.1e6	298	61	W13
(11)	2002-07-18	1015	M2.2	1.4e8	1468	1438	W27
(12)	2002-04-21	10064	X1.5	2.7e7	2479	39	W78
(13)	2002-03-14	3800	M5.7	5.3e7	1482	428	E23

(S18-N19)

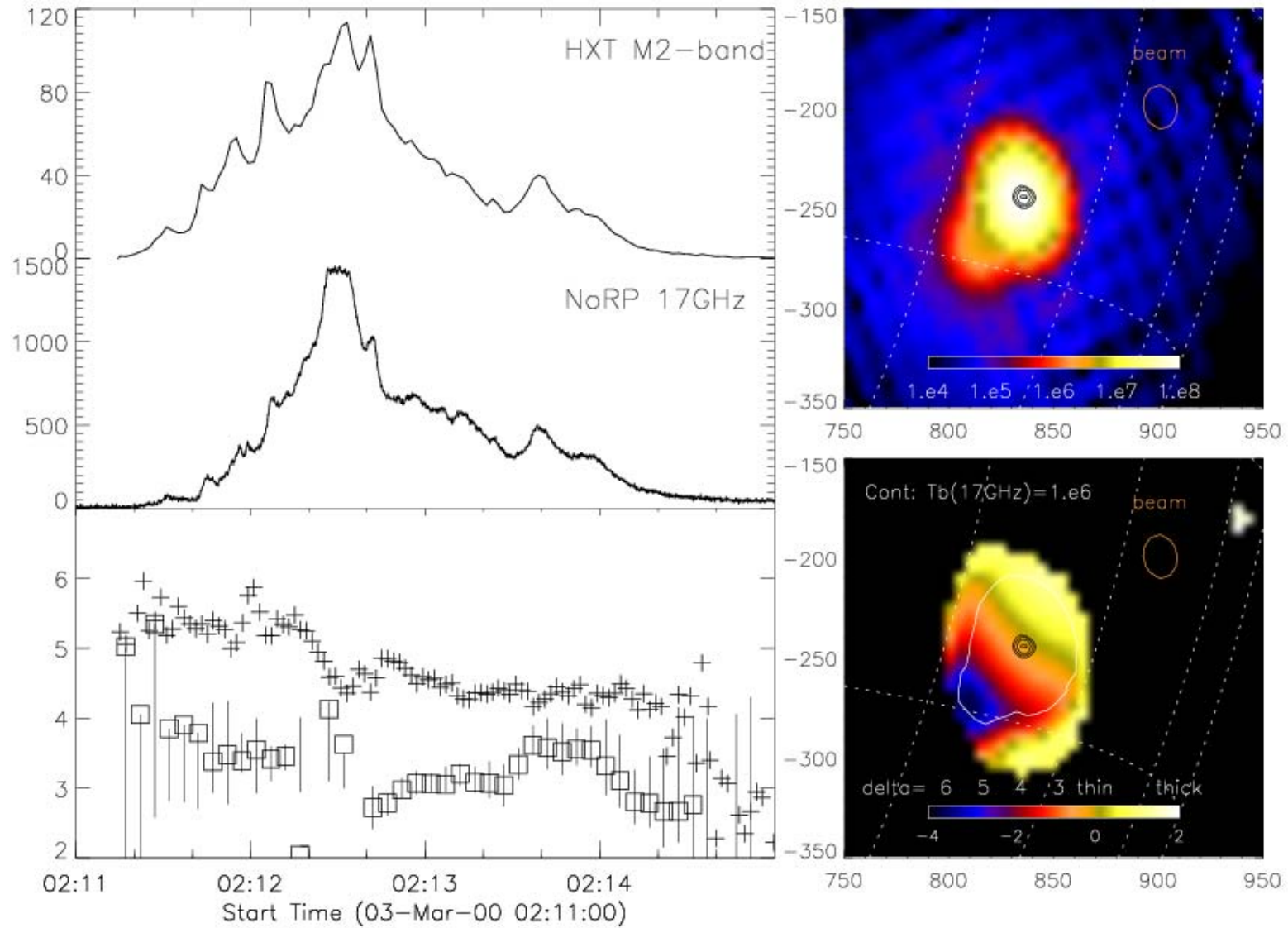
Event List

(Yohkoh era)

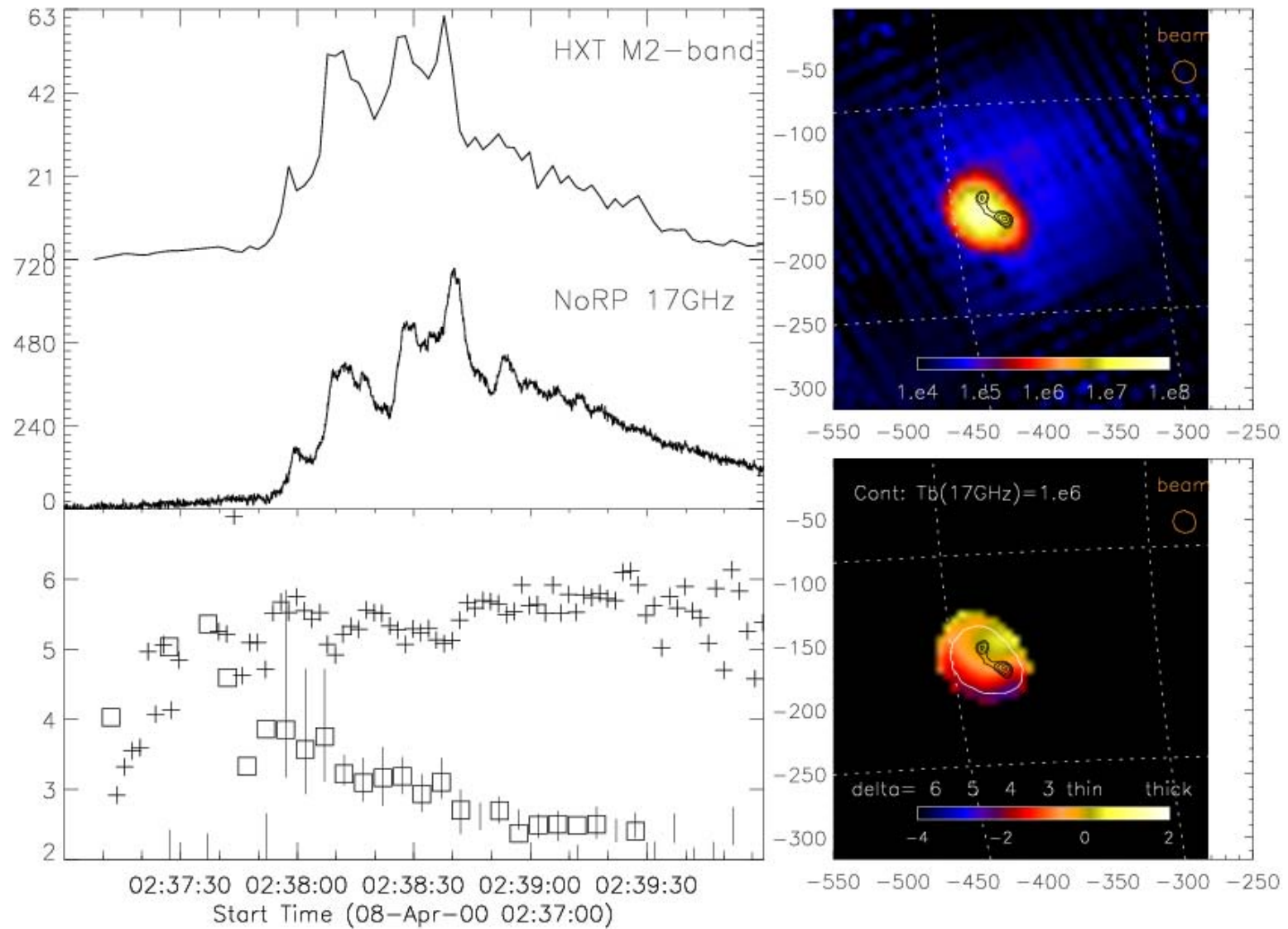
	Date	Dur.(sec)	GOES	Bright.(K)	F9.4G	F35G	Position.
(1')	2000-03-03	1619	M3.8	1.2e8	906	763	W63
(2')	2000-04-08	2318	M2.0	7.8e7	646	314	E28
(3')	2000-07-25	930	M8.0	1.1e8	2360	619	W05
(4')	2000-09-16	6117	M5.9	6.0e7	2818	619	W05
(5')	2000-10-29	3175	M4.4	3.9e7	1694	366	E34
(6')	2000-11-25	7140	M8.2	4.0e7	3089	865	E46
(7')	2001-09-25	2798	M7.6	1.6e7	720	122	E01

(S21-N14)

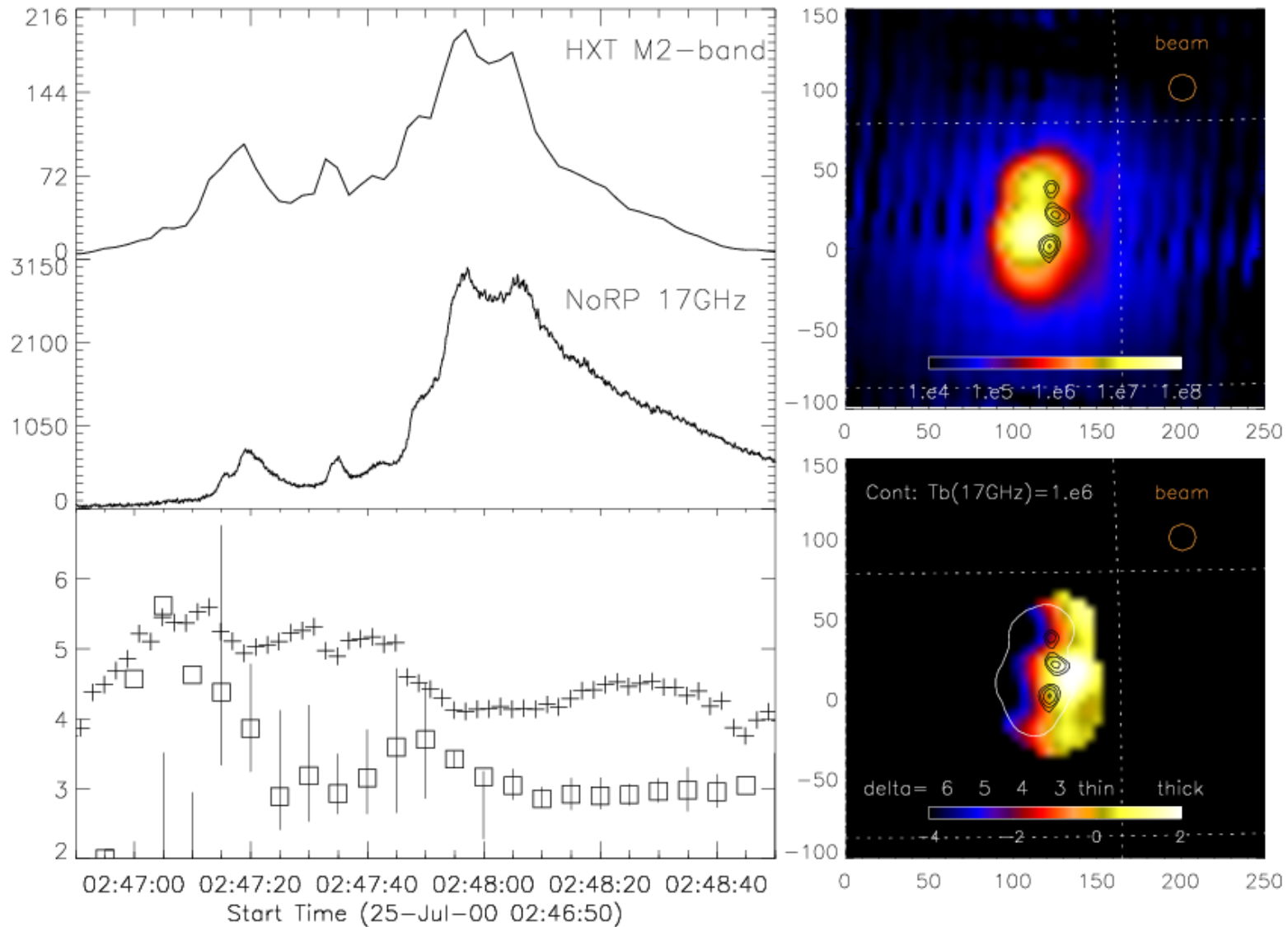
2000 Mar 03 02:11:00 UT (EVENT1')



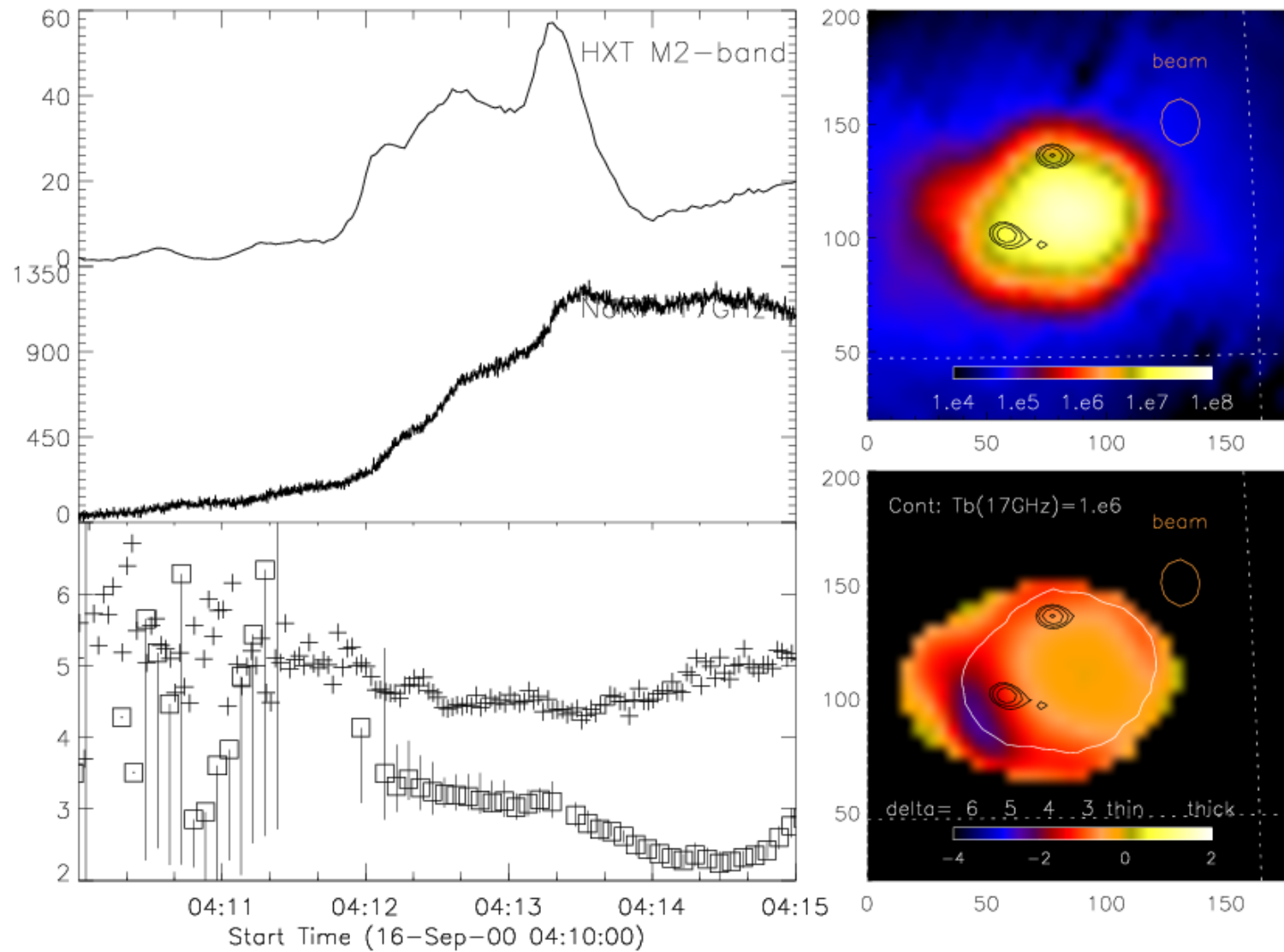
2000 Apr 08 02:37:00 UT (EVENT2')



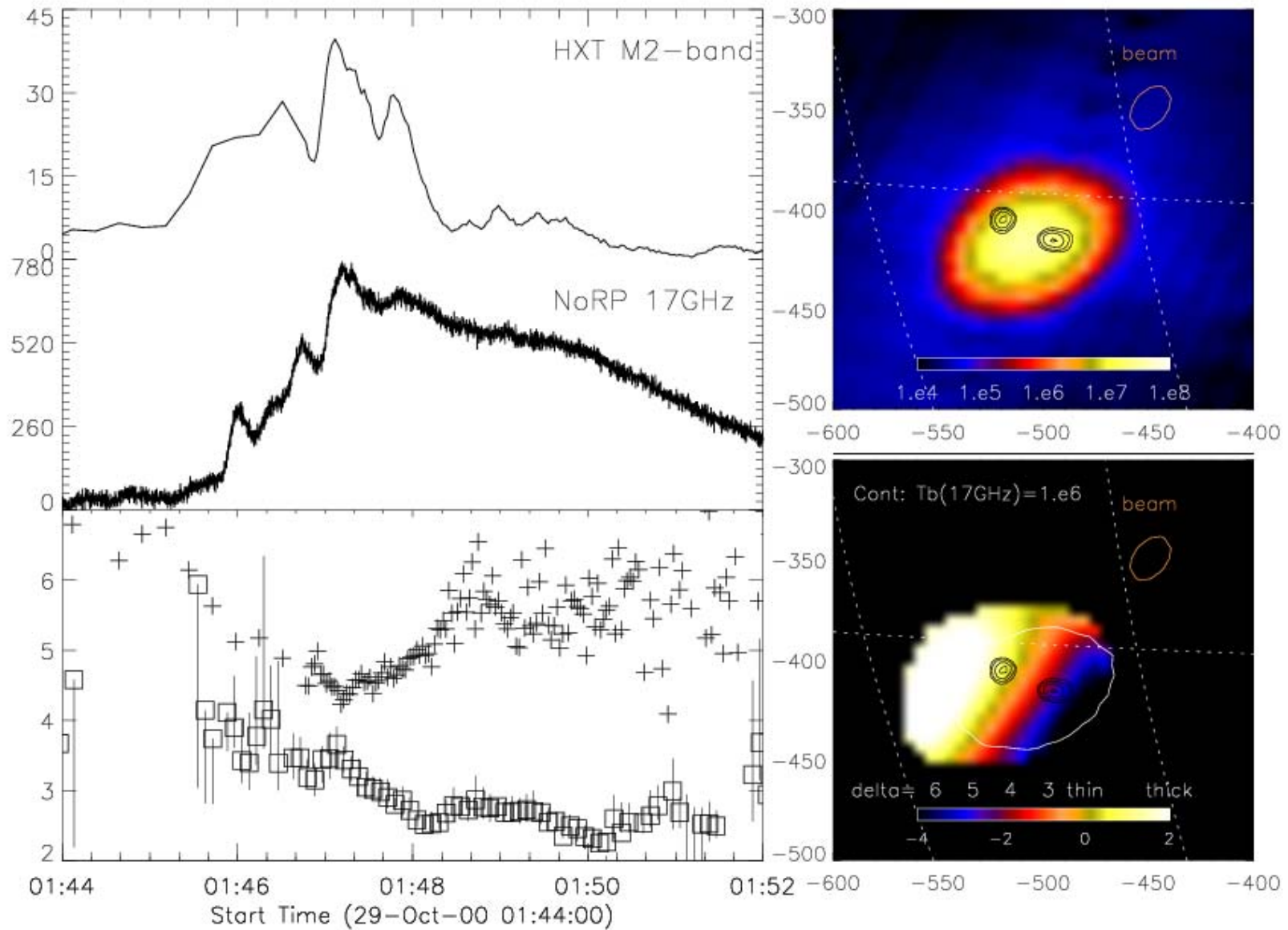
2000 Jul 25 02:46:50 UT (EVENT3')



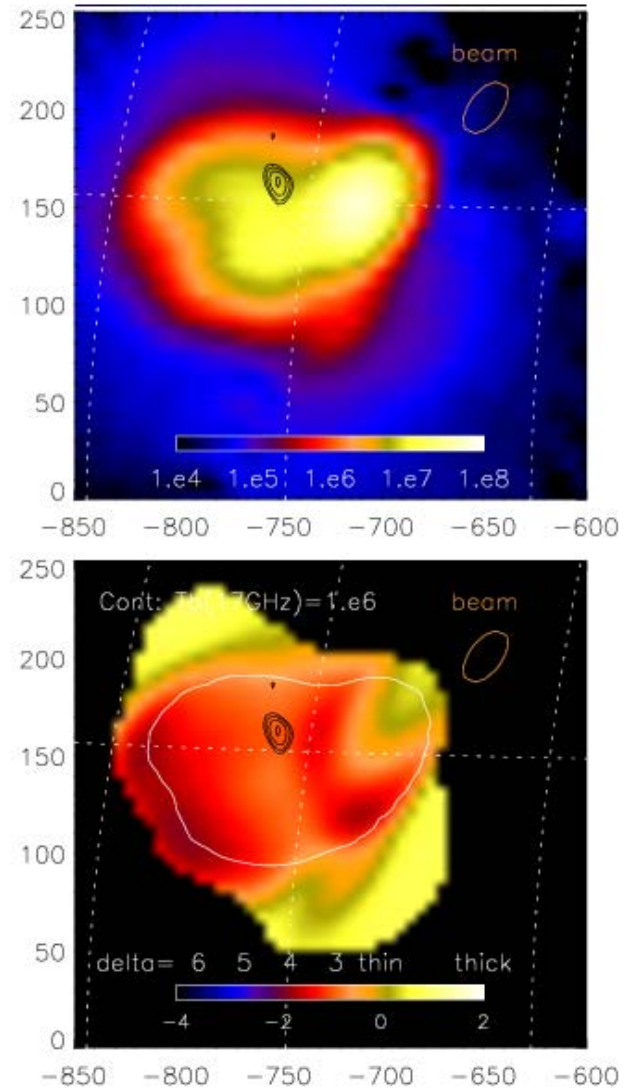
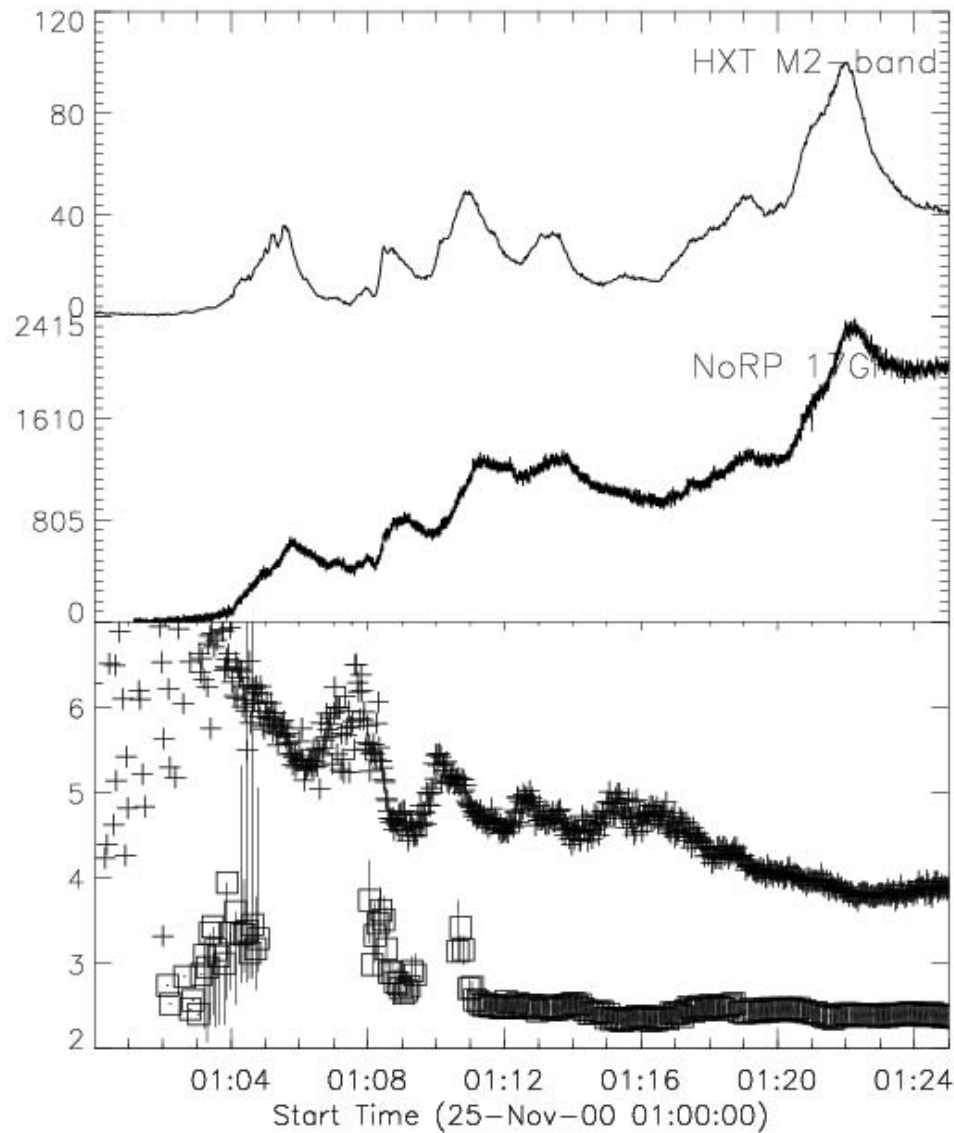
2000 Sep 16 04:10:00 UT (EVENT4')



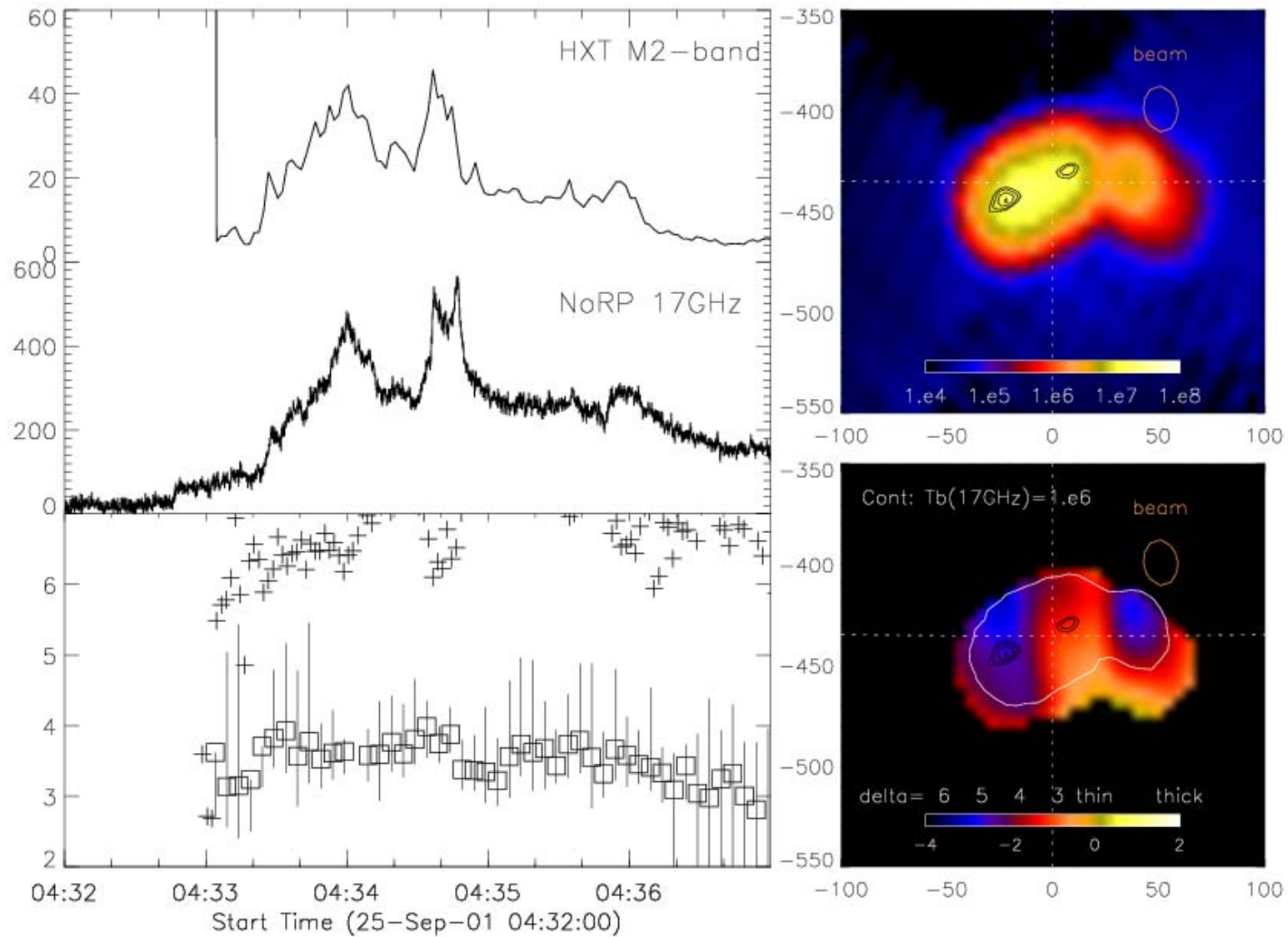
2000 Oct 29 01:44:00 UT (EVENT5')



2000 Nov 25 01:00:00 UT (EVENT6')



2001 Sep 25 04:32:00 UT (EVENT7')



Event List

(Yohkoh era)

Date	radio(17G) source	α (17G/34G ratio)		Remark
Limb付近				
(1') 2000-03-03	foot-point (?)	-1	-1	
(6') 2000-11-25	foot-point	-2	-1, -1	
Disk付近				
(2') 2000-04-08	loop-top	-2	-0.5, -0.5	
(3') 2000-07-25	loop-top (?)	-1.5	-0.5, -1	
(4') 2000-09-16	loop-top	-1	-2, -2	
(5') 2000-10-29	loop-top	-1.5	-2, 0	
(7') 2001-09-25	loop-top	-1.5	-3, -1	
		(loop-top)	(foot point)	

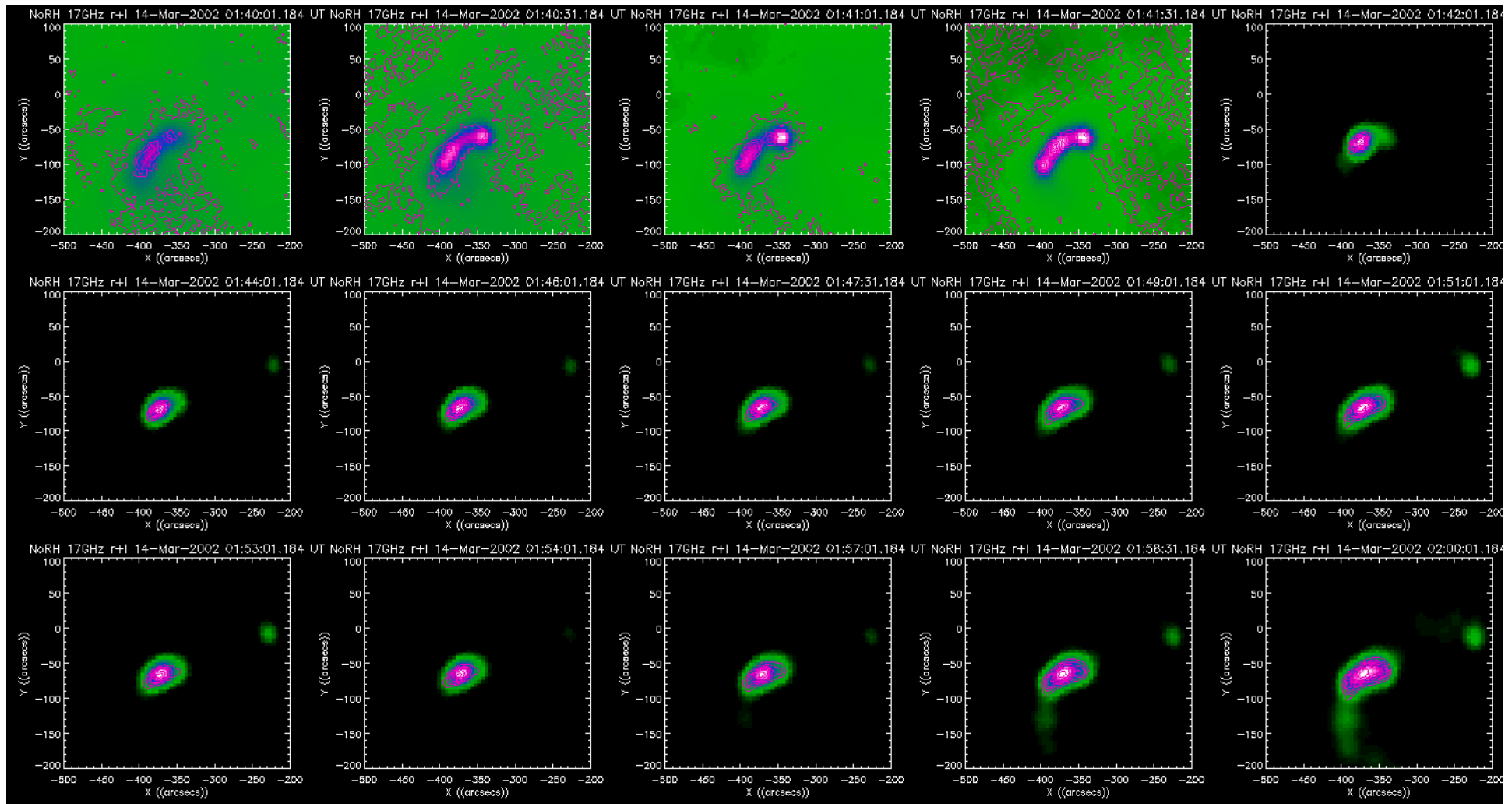
Event List

(RHESSI era)

	Date	Dur.(sec)	GOES	Bright.(K)	F9.4G	F35G	Position.
(1)	2005-12-02	2499	M6.5	5.1e7	1017	551	E17
(2)	2005-08-25	2173	M6.4	1.1e8	2335	4385	E82
(3)	2005-07-27	6239	M3.7	3.9e7	1424	342	E91
(4)	2004-11-03	5224	M1.6	5.4e7	2893	1099	E46
(5)	2004-07-16	4224	X1.3	1.2e8	1348	1549	E39
(6)	2004-07-15	4023	X1.8	7.2e7	760	424	E52
(7)	2003-10-24	3481	M7.6	2.4e7	3986	3878	E69
(8)	2003-04-23	2796	M5.1	8.7e7	1402	531	W16
(9)	2002-11-10	1848	M2.4	8.8e6	506	86	W37
(10)	2002-07-29	1487	M4.8	7.1e6	298	61	W13
(11)	2002-07-18	1015	M2.2	1.4e8	1468	1438	W27
(12)	2002-04-21	10064	X1.5	2.7e7	2479	39	W78
(13)	2002-03-14	3800	M5.7	5.3e7	1482	428	E23

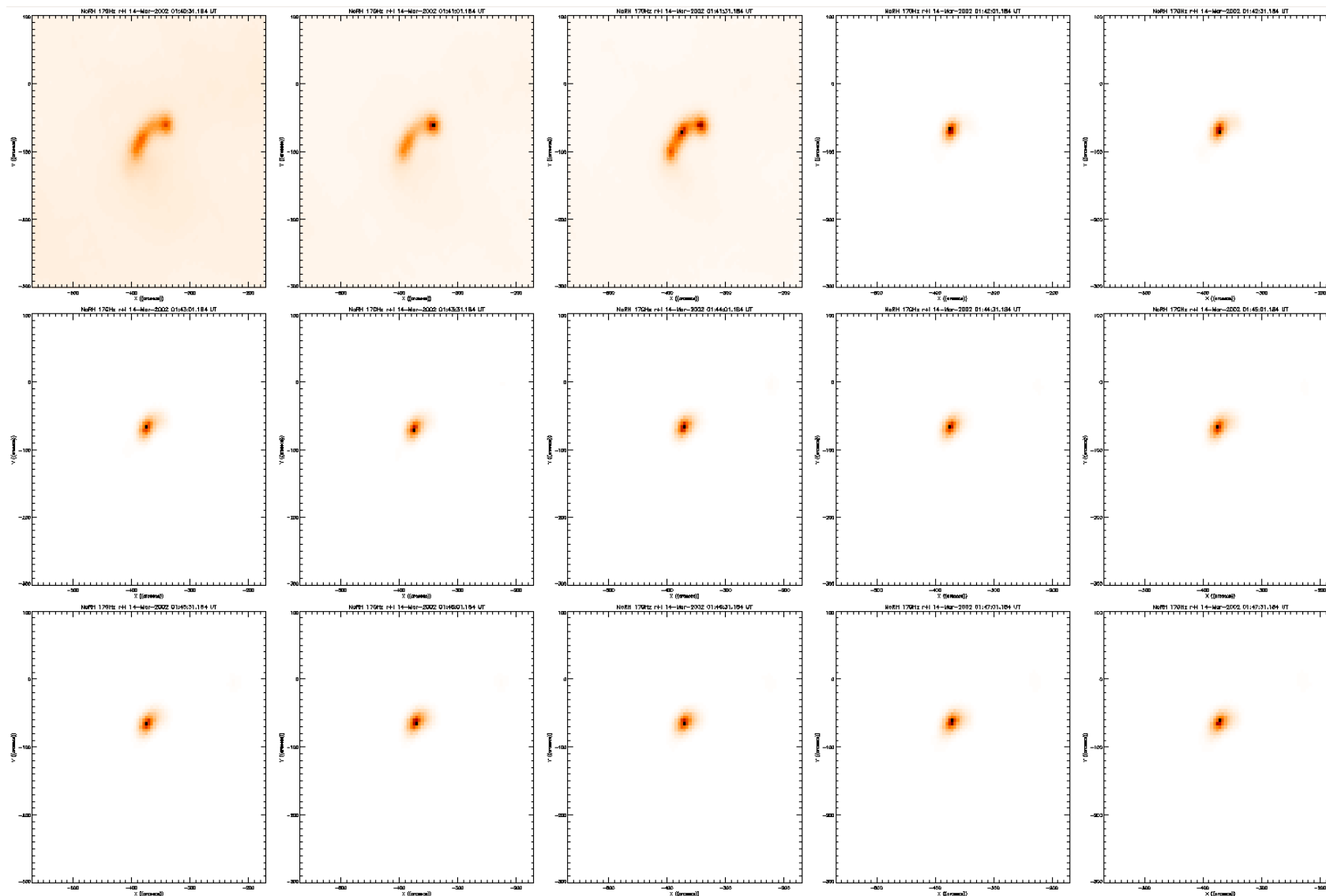
(S18-N19)

2002 Mar 14 01:43:46UT(Event1)



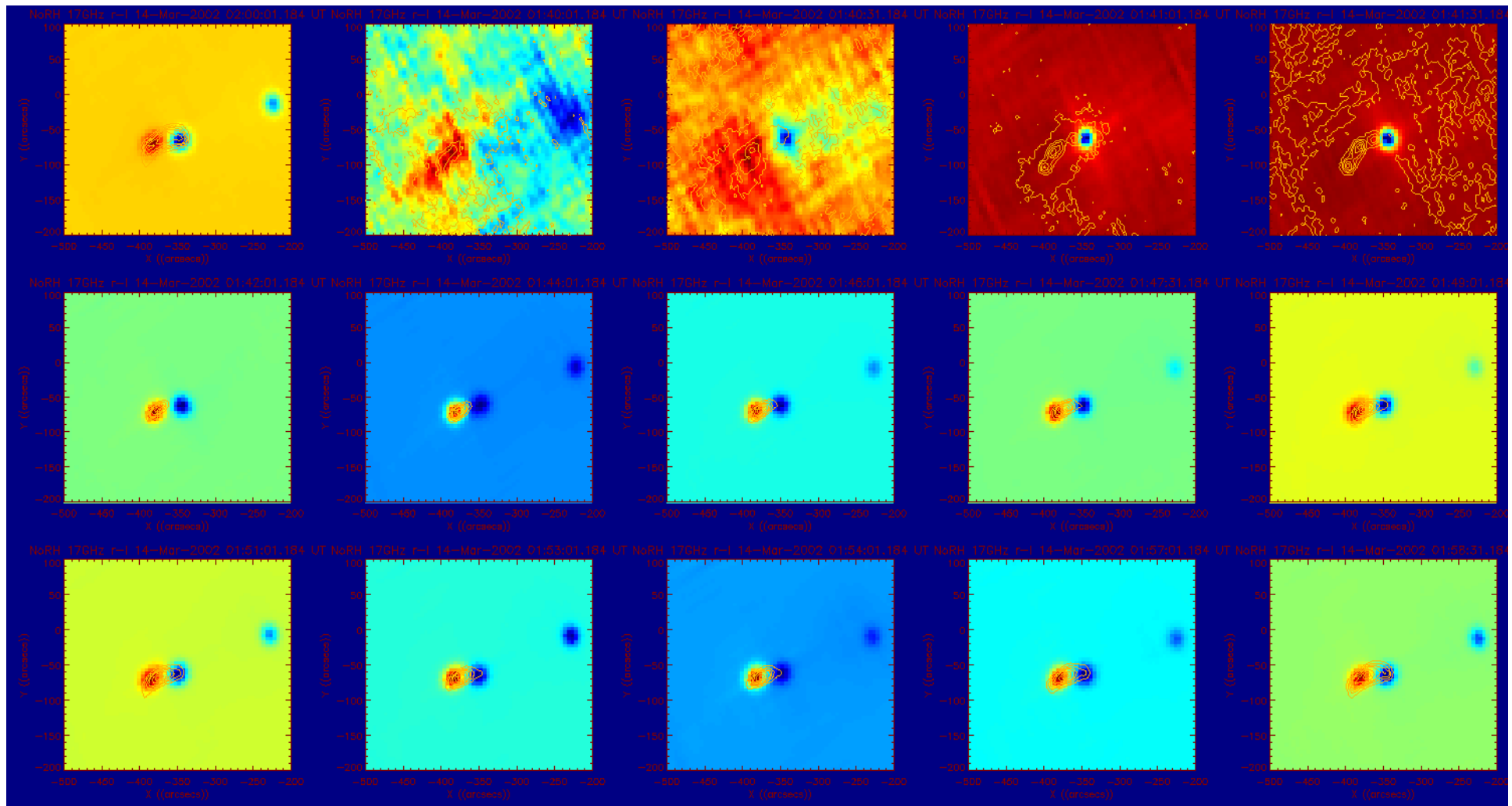
Heliog17G +34G contour

2002 Mar 14 01:43:46UT(Event1)



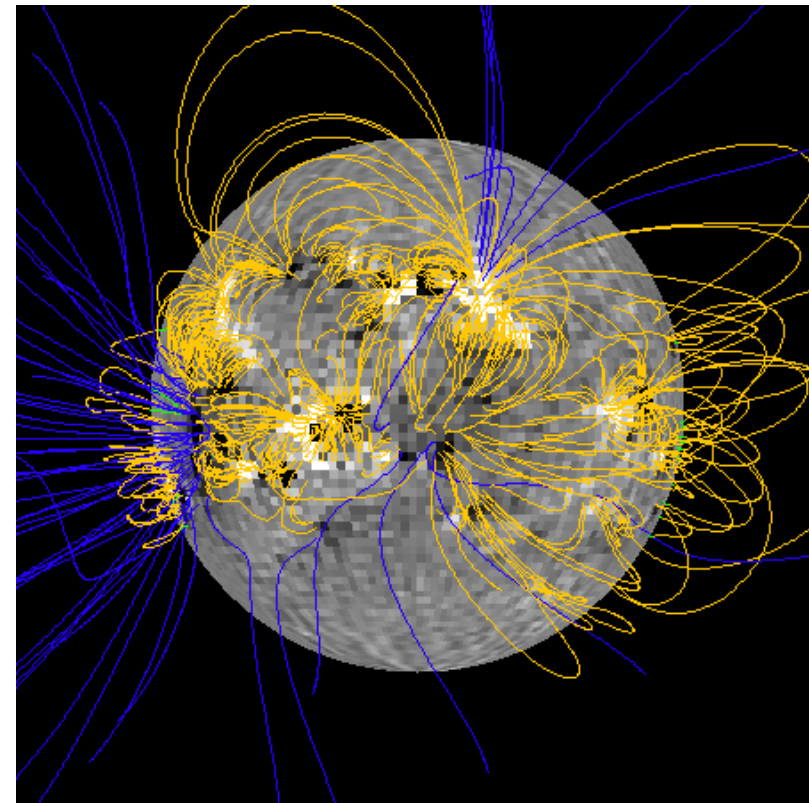
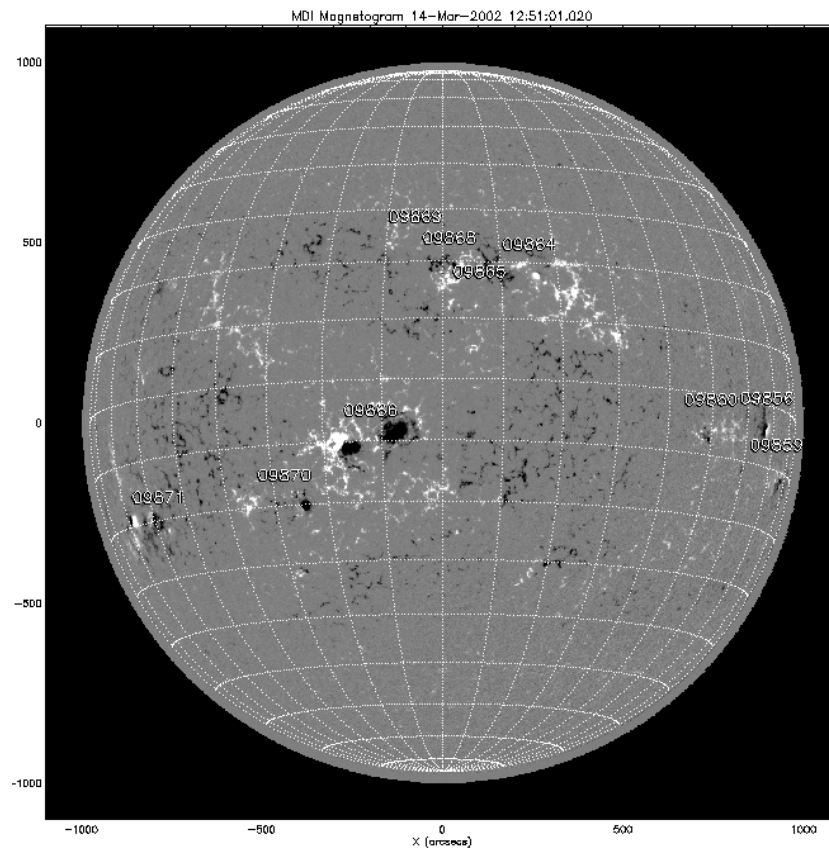
Helix17G

2002 Mar 14 01:43:46UT(Event1)



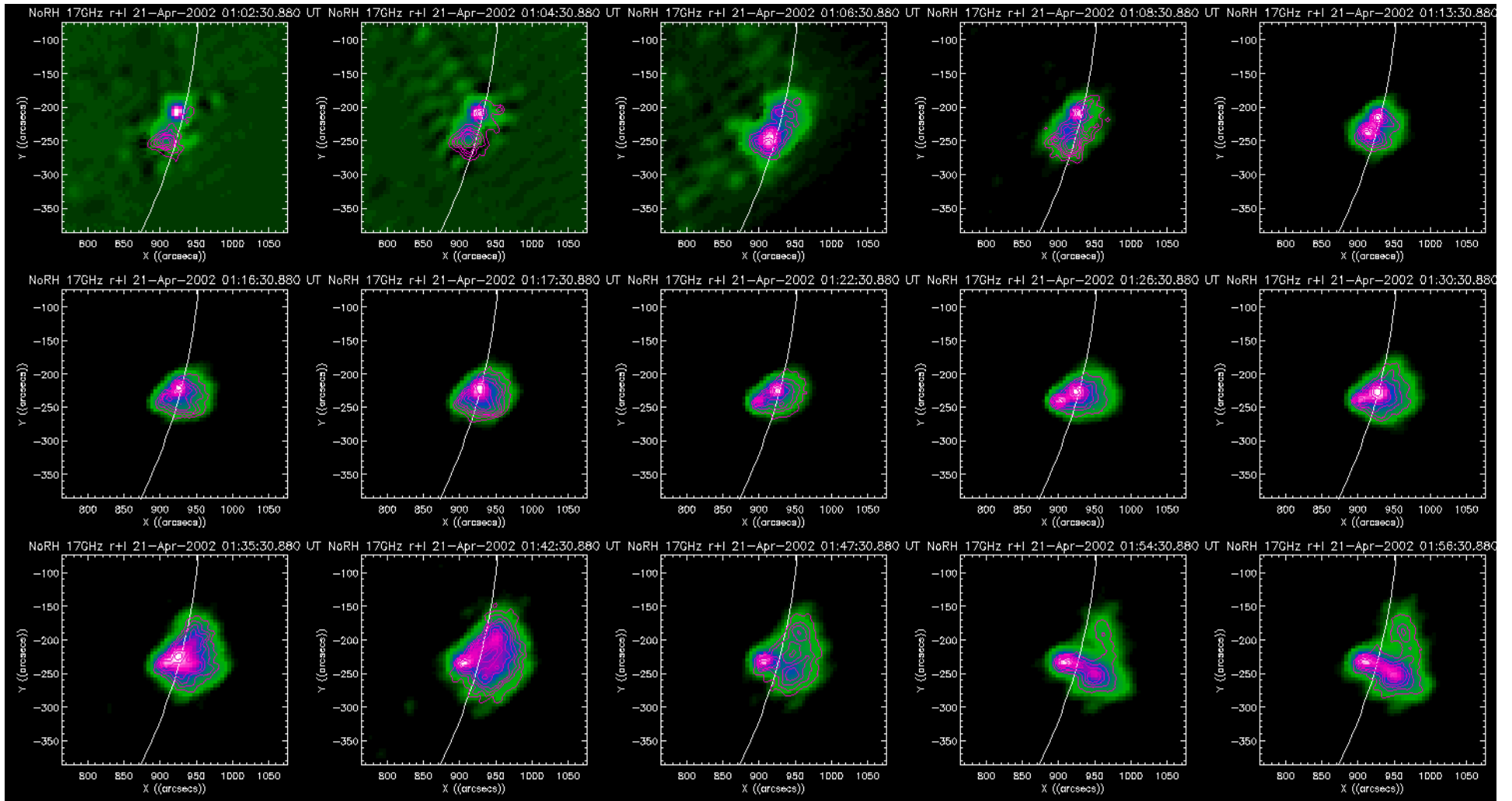
HelioG 17G偏光 +34G contour

2002 Mar 14 01:43:46UT(Event1)



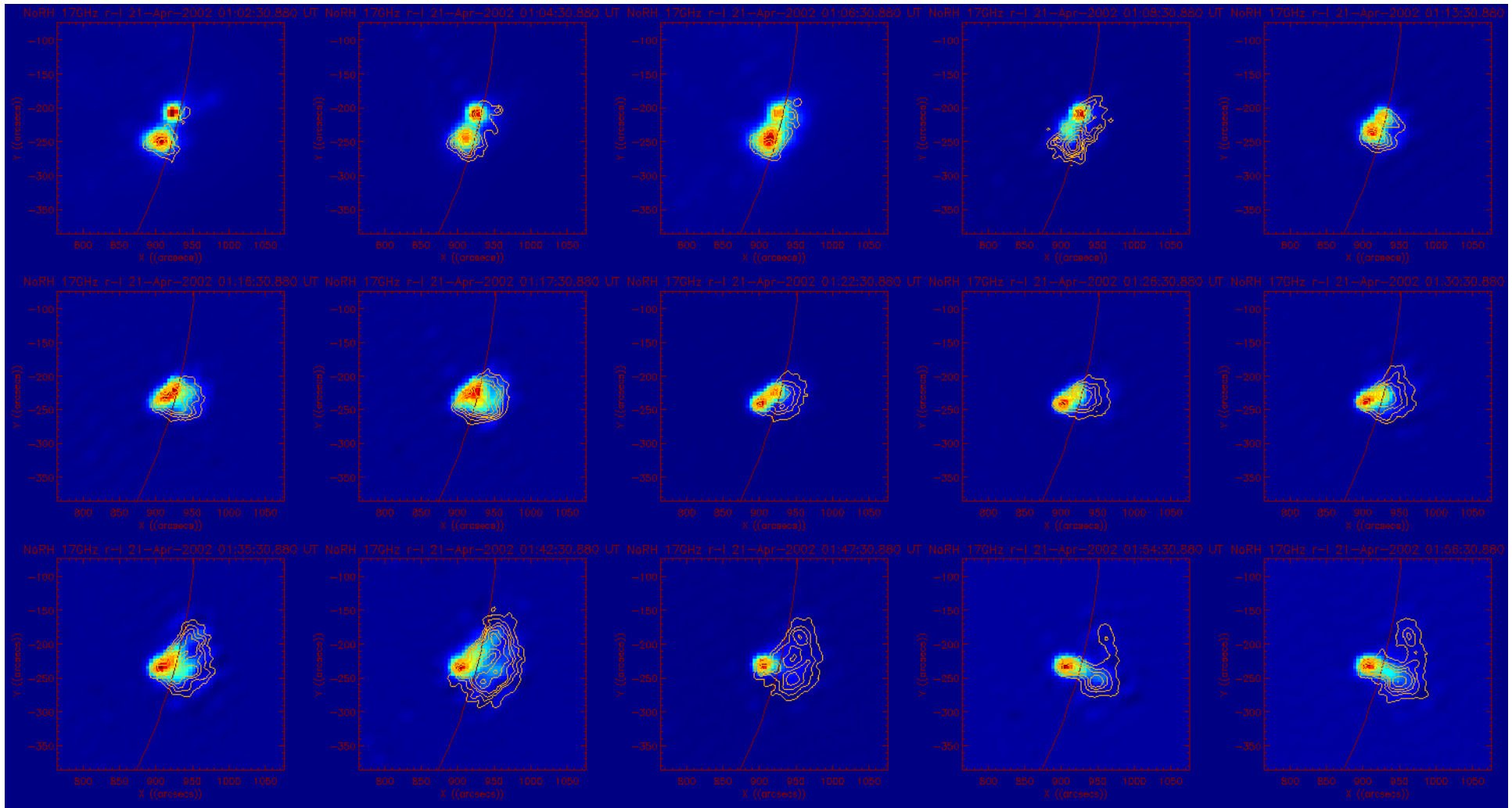
SOHO/MDI + potential field

2002 Apr 21 01:15:20UT(Event2)



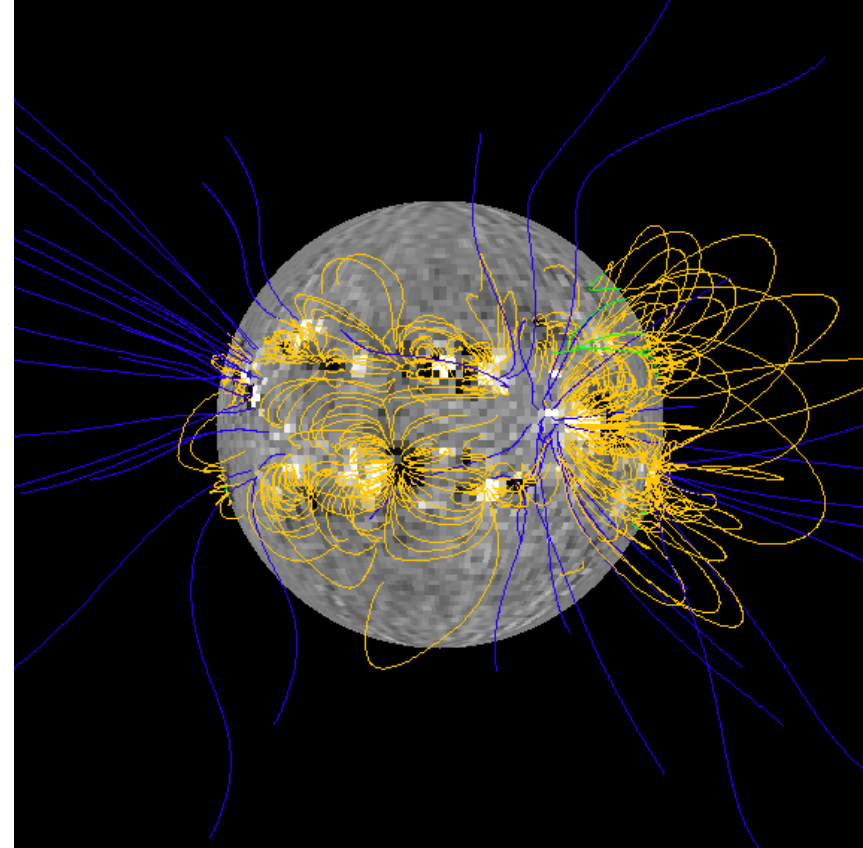
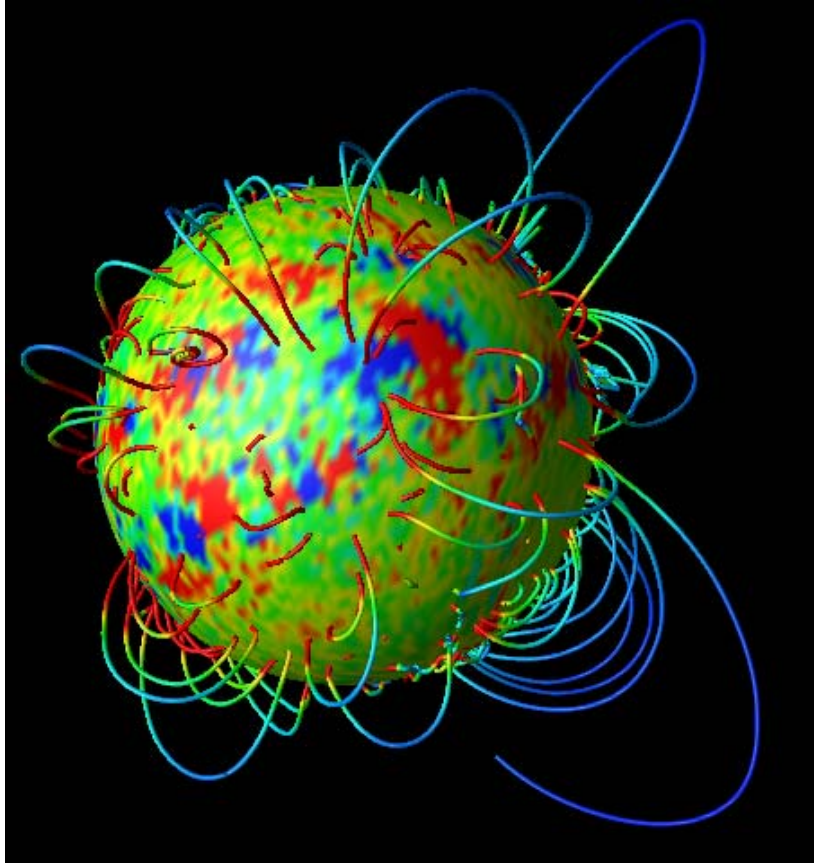
Heliog17G +34G contour

2002 Apr 21 01:15:20UT(Event2)



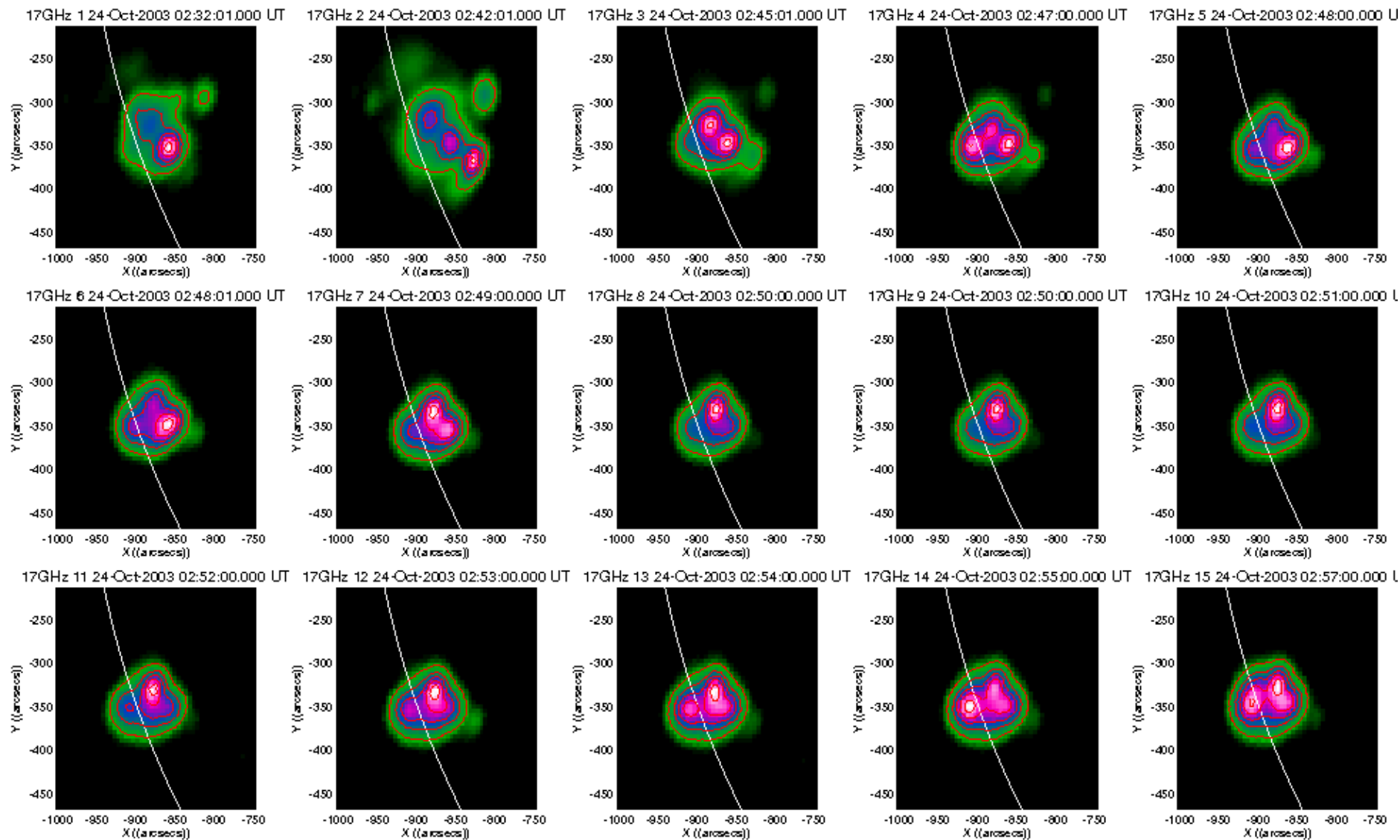
Heliog 17G偏光 +34G contour

2002 Apr 21 01:15:20UT(Event2)



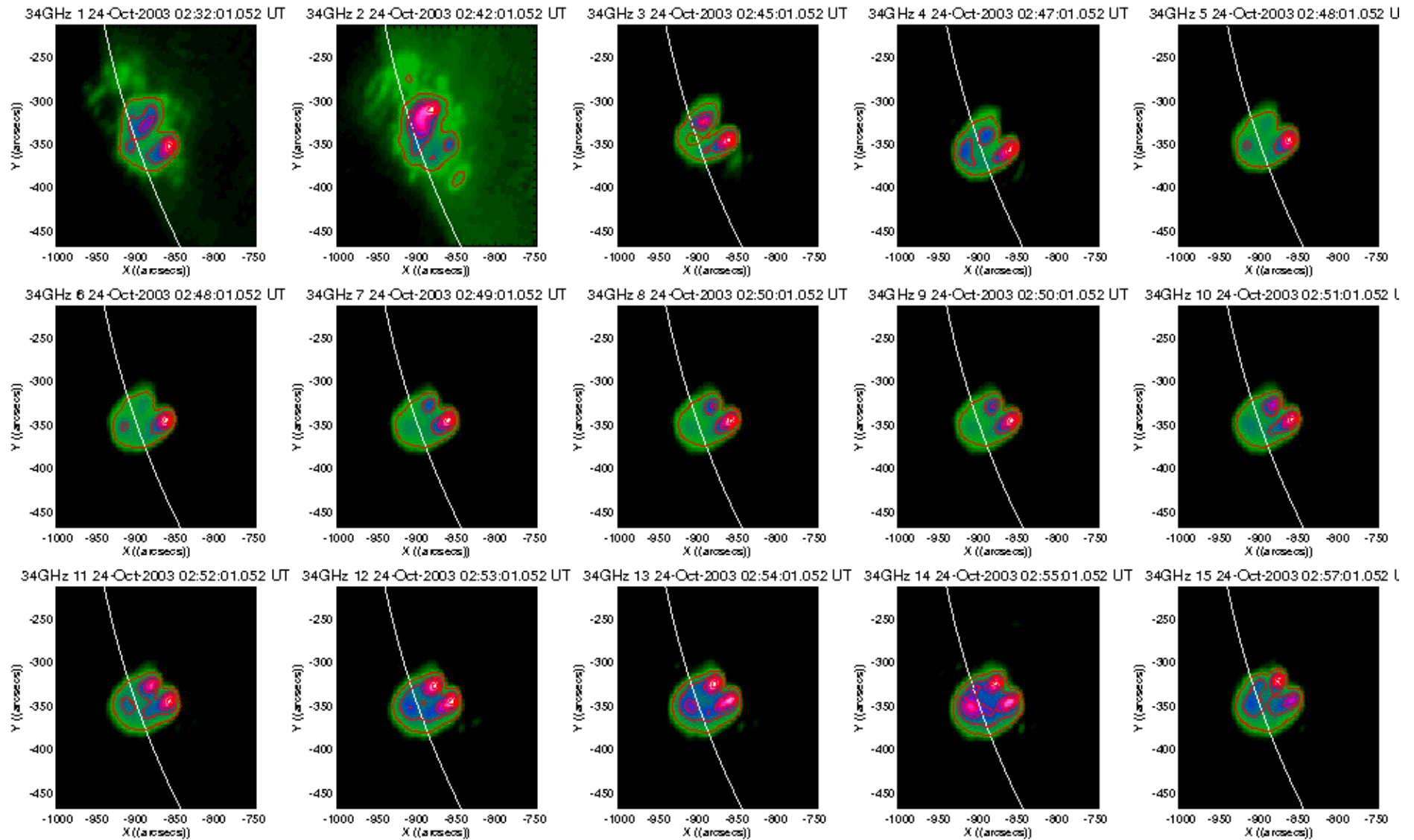
potential field

2003 Oct 24 02:46:14UT(Event3)



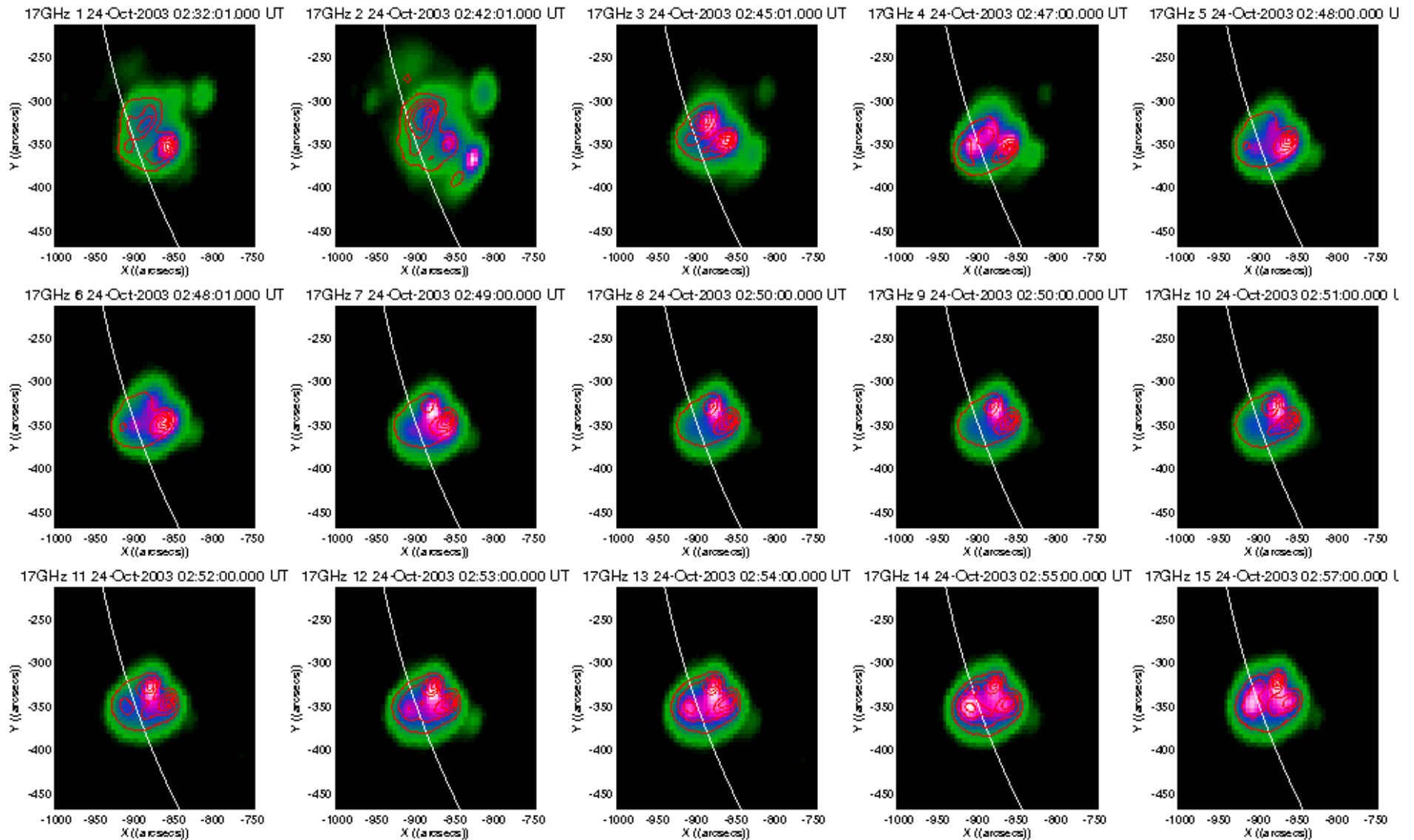
Heliog 17G

2003 Oct 24 02:46:14UT(Event3)



Heliog 34G

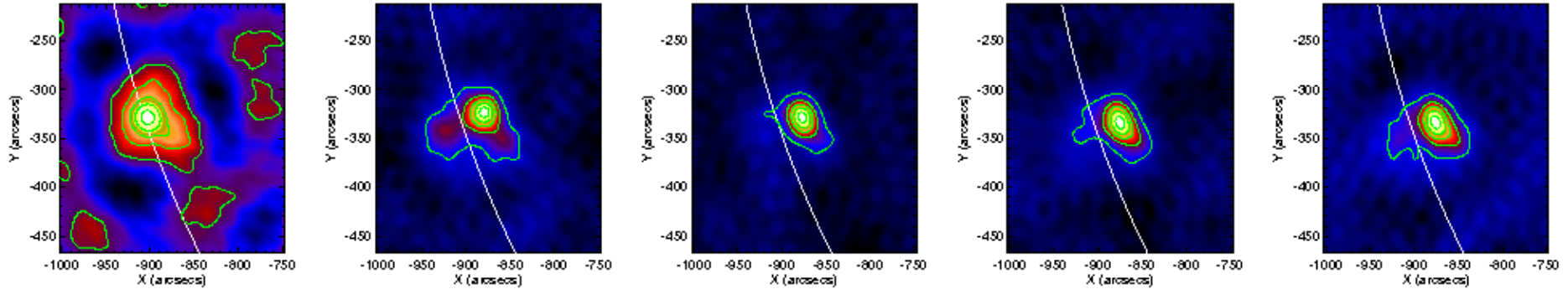
2003 Oct 24 02:46:14UT(Event3)



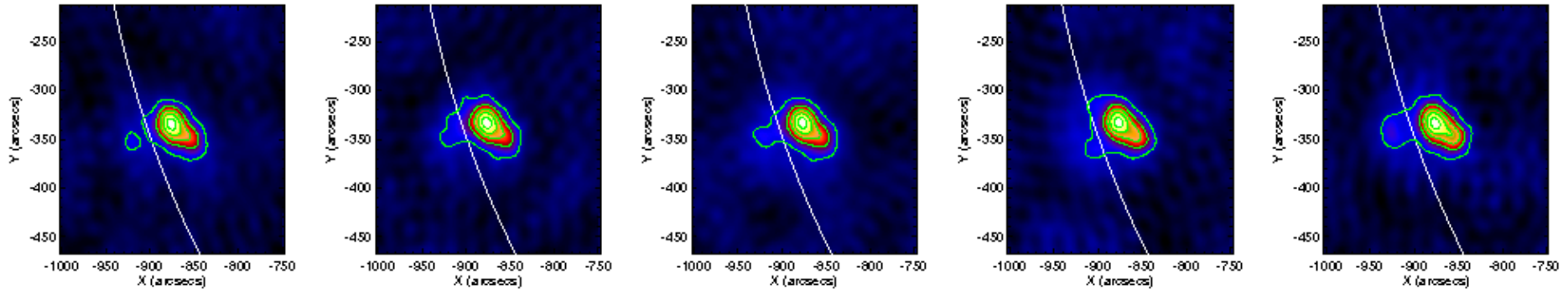
Helix 17+34G

2003 Oct 24 02:46:14UT(Event3)

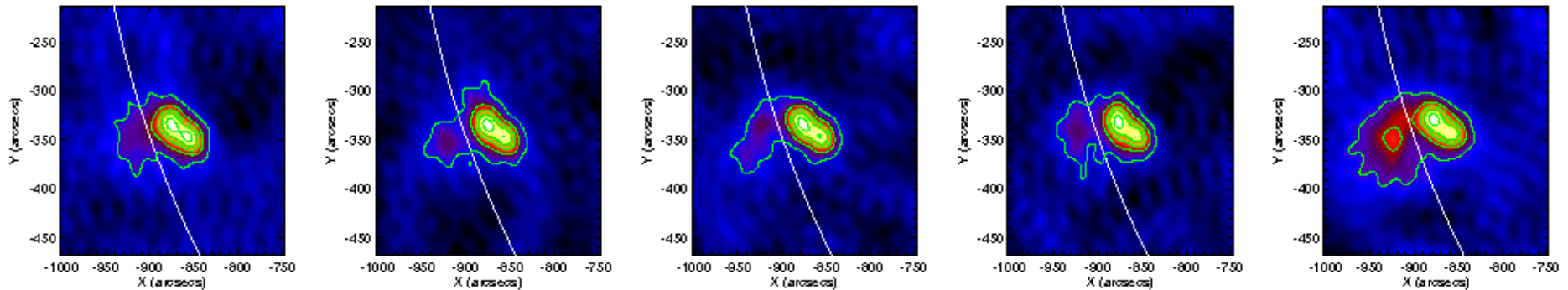
RHESSI 1 24-Oct-2003 02:32:09.000 UT RHESSI 2 24-Oct-2003 02:42:29.000 UT RHESSI 3 24-Oct-2003 02:45:29.000 UT RHESSI 4 24-Oct-2003 02:46:41.000 UT RHESSI 5 24-Oct-2003 02:47:45.000 L



RHESSI 6 24-Oct-2003 02:48:25.000 UT RHESSI 7 24-Oct-2003 02:48:57.000 UT RHESSI 8 24-Oct-2003 02:49:37.000 UT RHESSI 9 24-Oct-2003 02:50:17.000 UT RHESSI 10 24-Oct-2003 02:51:05.000

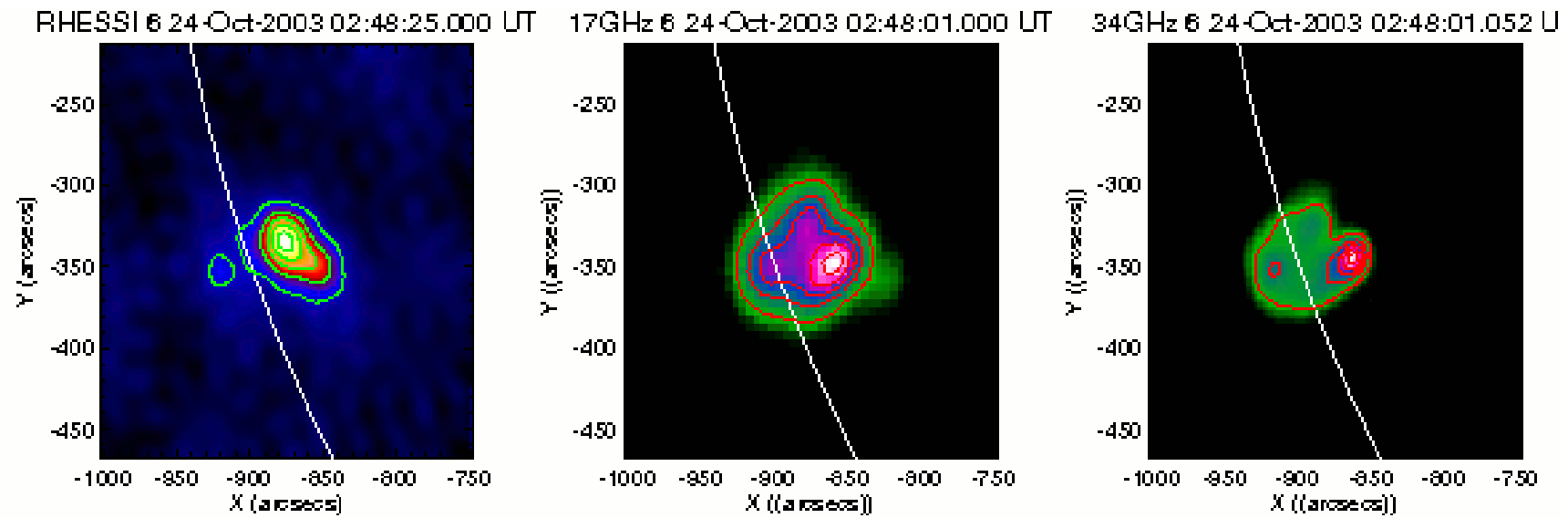


RHESSI 11 24-Oct-2003 02:51:49.000 UT RHESSI 12 24-Oct-2003 02:52:41.000 UT RHESSI 13 24-Oct-2003 02:53:41.000 UT RHESSI 14 24-Oct-2003 02:55:17.000 UT RHESSI 15 24-Oct-2003 02:56:57.000

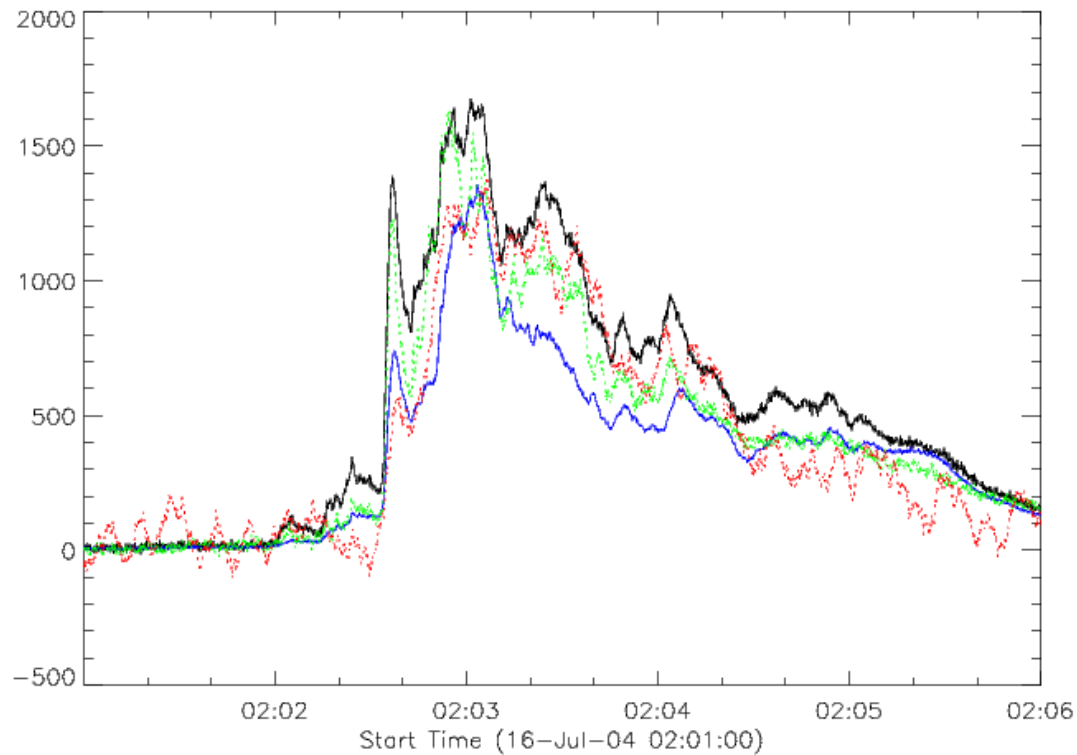


RHESSI

2003 Oct 24 02:46:14UT(Event3)

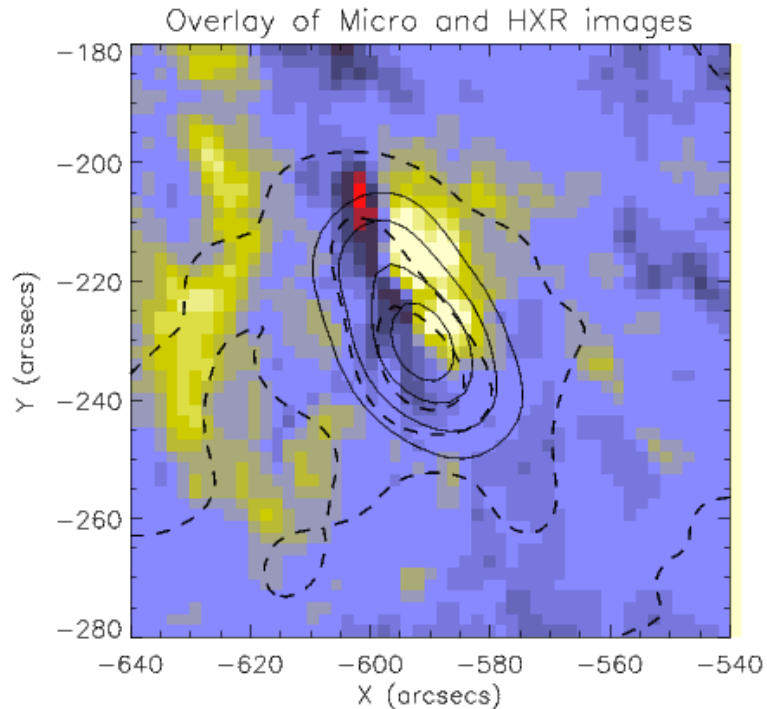


2004 July 16 02:03:34UT(Event4)



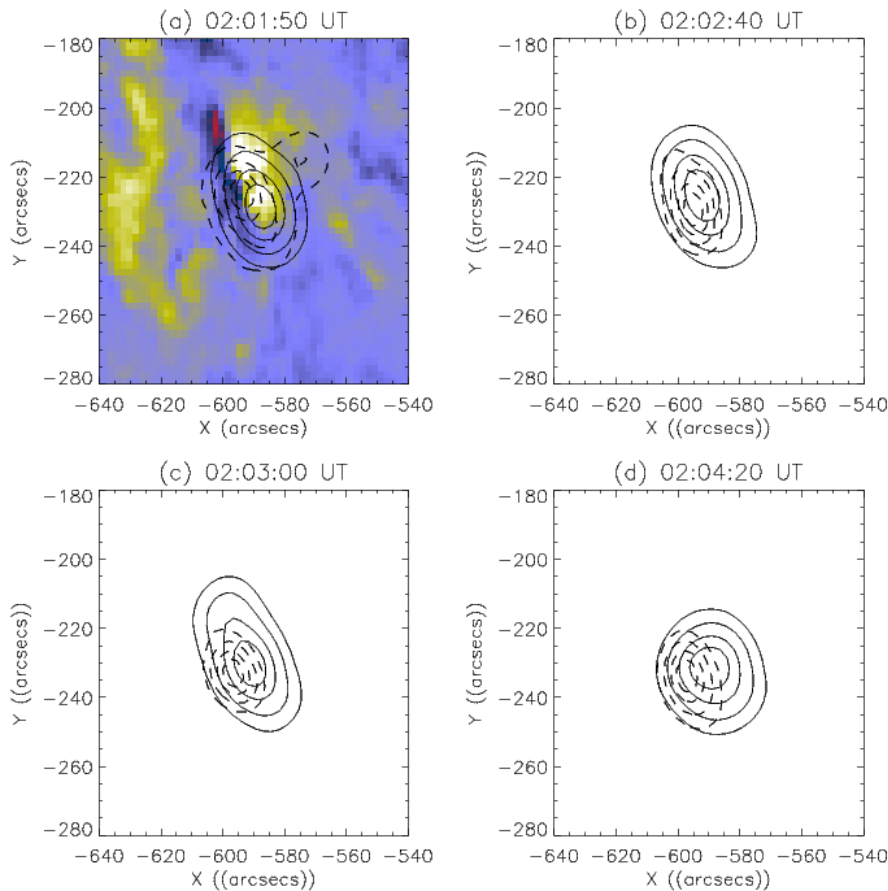
The microwave time profile at 9.4 (blue), 17 (black), 35 (green), and 80 GHz (red). The spectrum is flat between 10 and 80 GHz.

2004 July 16 02:03:34UT(Event4)



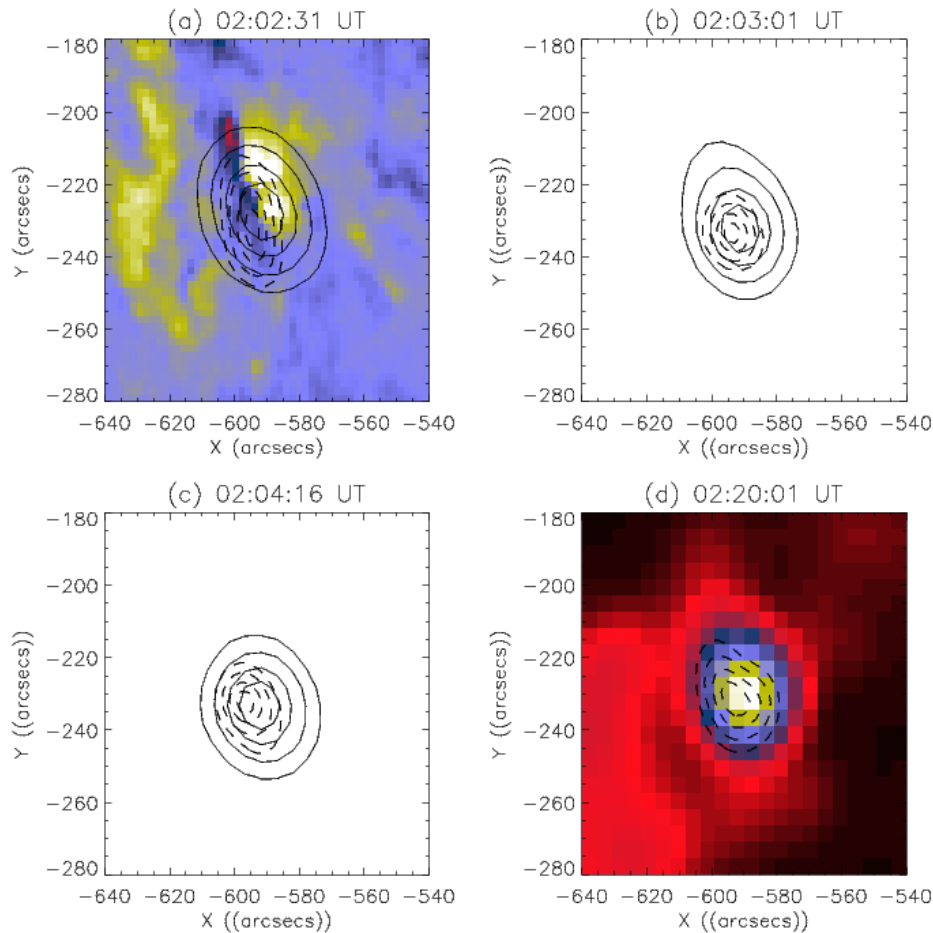
17 GHz images are synthesized by Fujiki program (better spatial resolution). The 17 GHz sources in the impulsive phase are located along the magnetic neutral line while the 34 GHz sources are smaller and located slightly on the west side of the corresponding 17 GHz source.

2004 July 16 02:03:34UT(Event4)



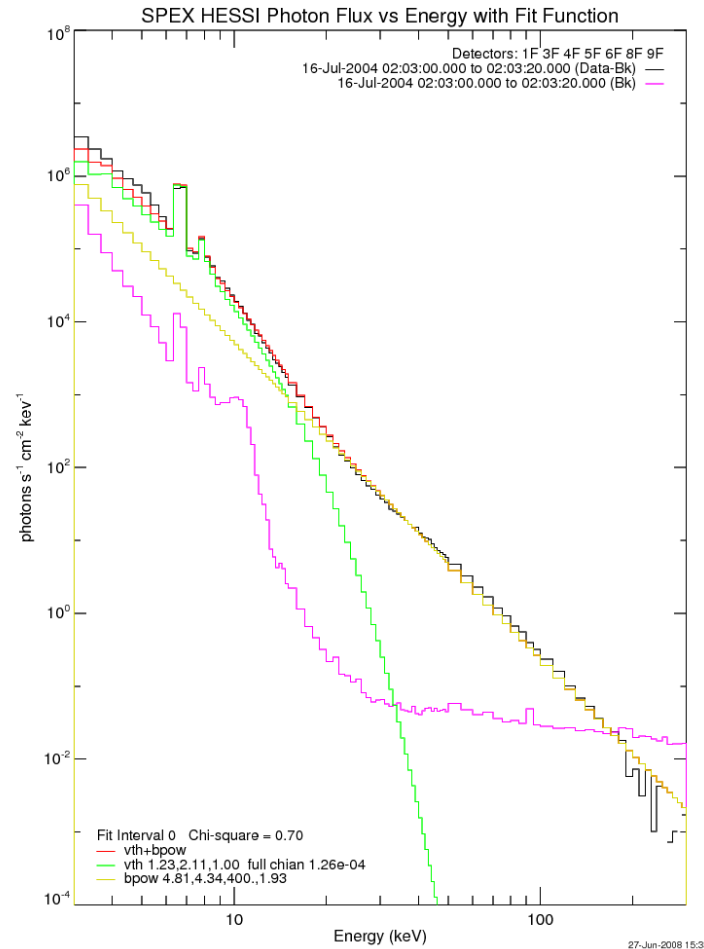
The time development of 17 and 34 GHz sources are shown at typical times of 02:02:31 (precursor), 02:03:01 (impulsive peak), 02:04:16 (impulsive decay time), and 02:20:01 UT (gradual thermal phase). Microwave sources are stationally located at the almost same location. In the gradual thermal phase, a large arcade structure develops and slightly bright sources at 17 and 34 GHz can be seen at the same location as ones in the impulsive phase which corresponds to the footpoints of the large arcade structure. The background image is SOHO/MDI image.

2004 July 16 02:03:34UT(Event4)



Overlay of 17 GHz and HXR sources.
17 GHz source: 02:03:00 UT
HXR source: 02:03 -0204 UT
(around the impulsive peak)
Contour level: 0.1, 0.25, 0.5, 0.75 of
each peak brightness.
50 % level of the HXR source shows
good agreement with that of the 17
GHz source, being located along the
magnetic neutral line.
Probably the HXR source seems to
be located slightly above the 17 GHz
source.

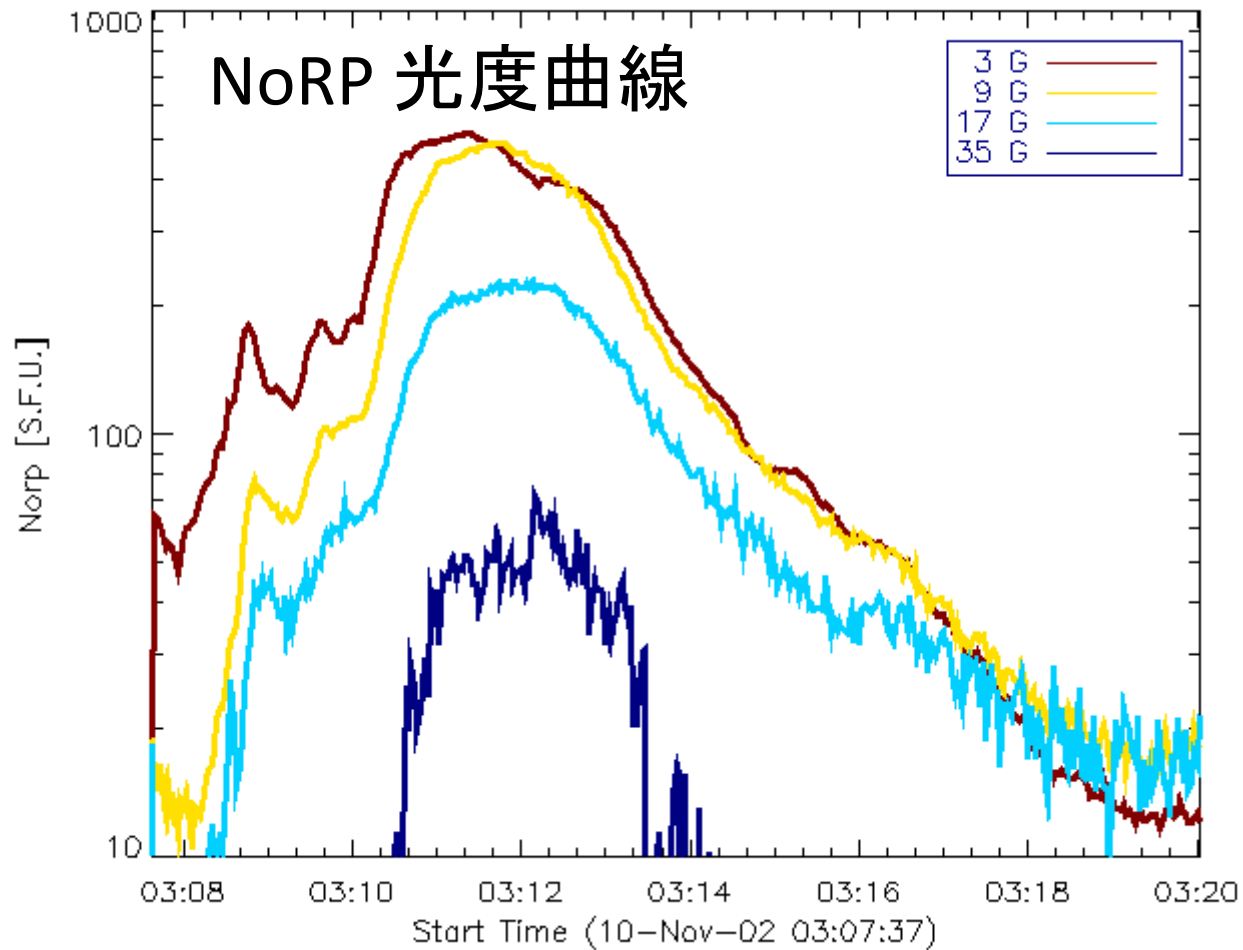
2004 July 16 02:03:34UT(Event4)



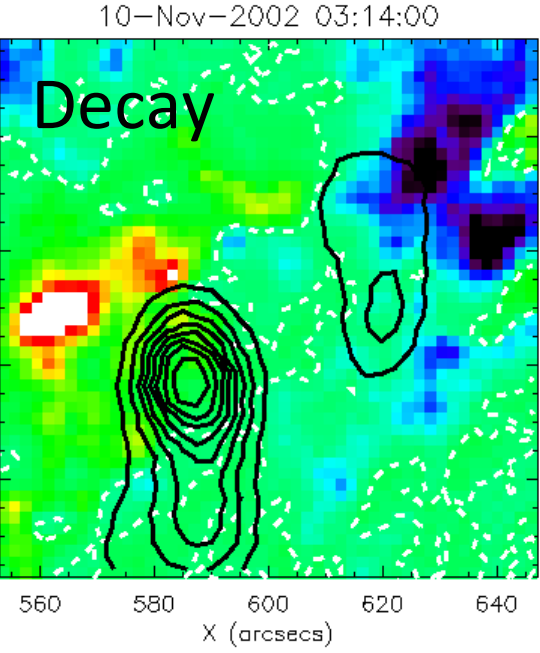
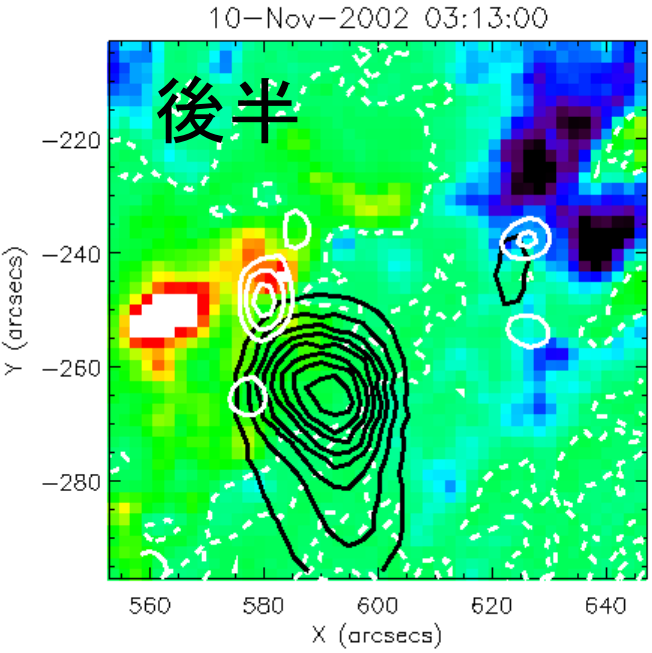
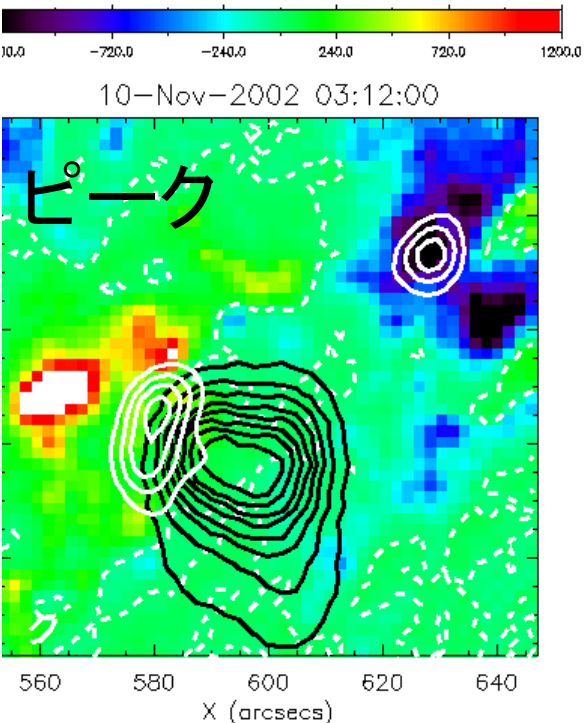
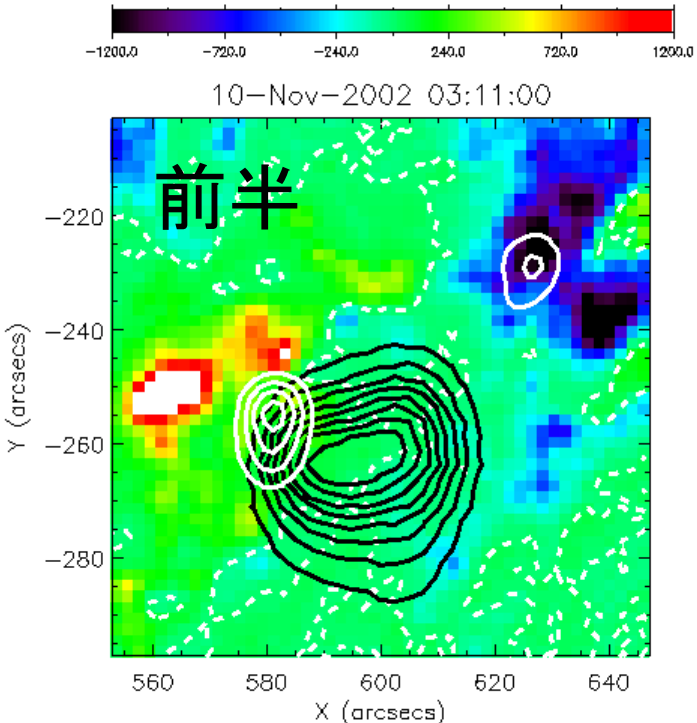
The HXR spectrum is fitted by one power-law
above 25 keV. Power law index = 4.3

2002 Nov 10 03:11:47UT(Event5)

2002/11/10: M2.4 西經37度(中間)



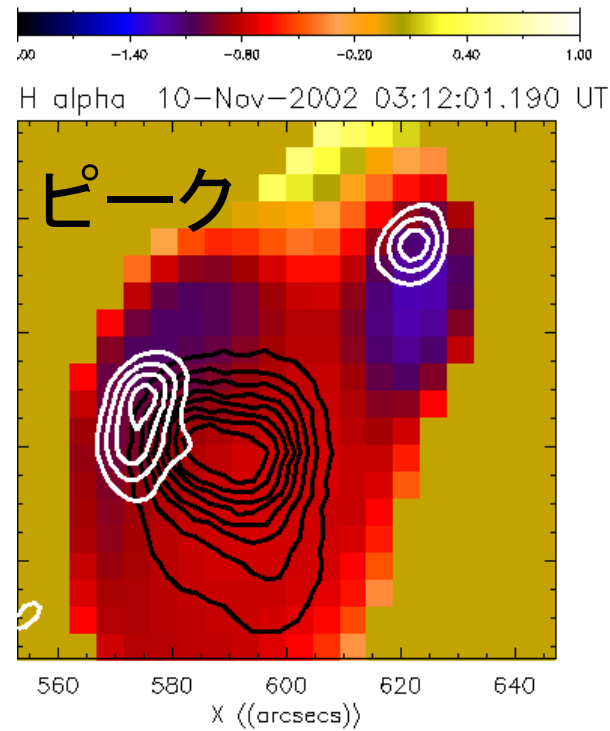
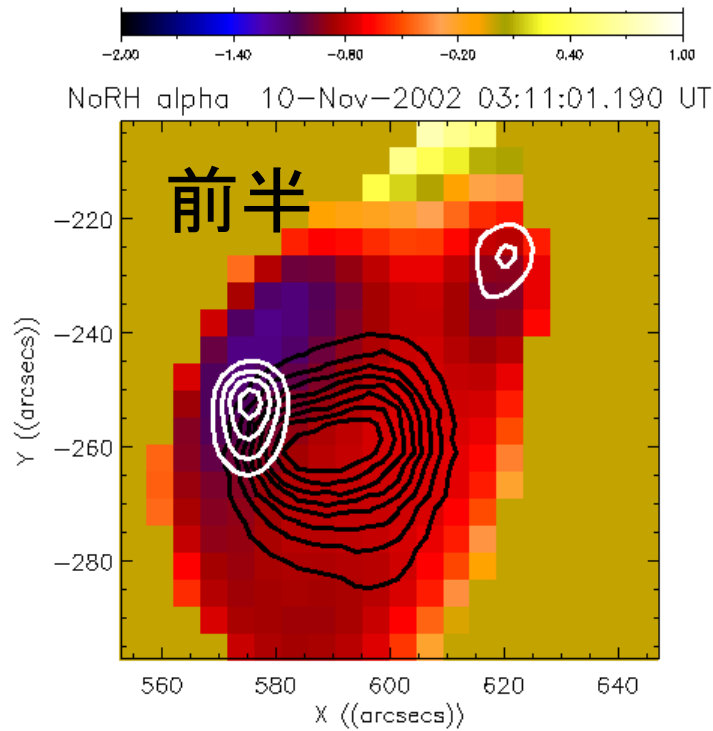
(Event5)



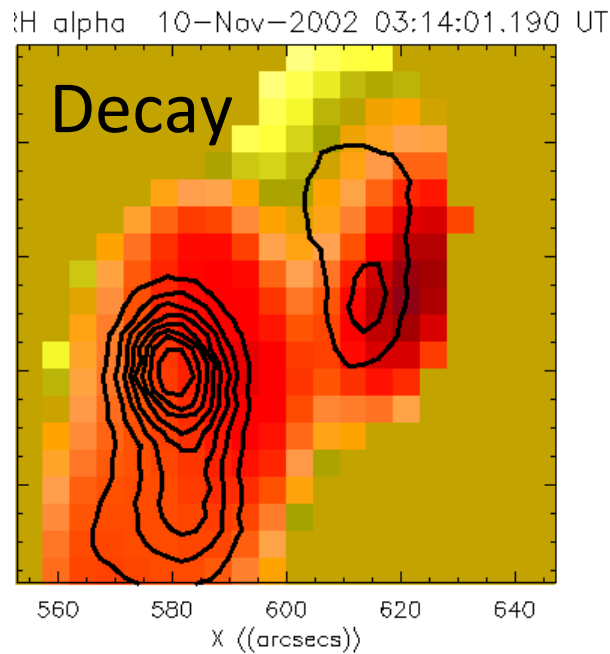
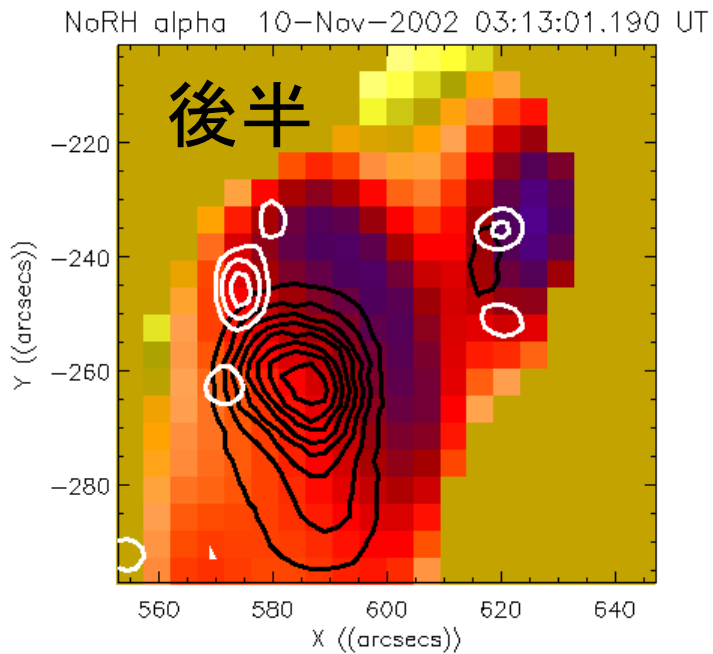
カラー:MDI
黒等高線:34G
白等高線:50-100 keV
白点線:磁気中性線

- ループトップ電波源
- Decay phaseの電波ソース意味不明

(Event5)



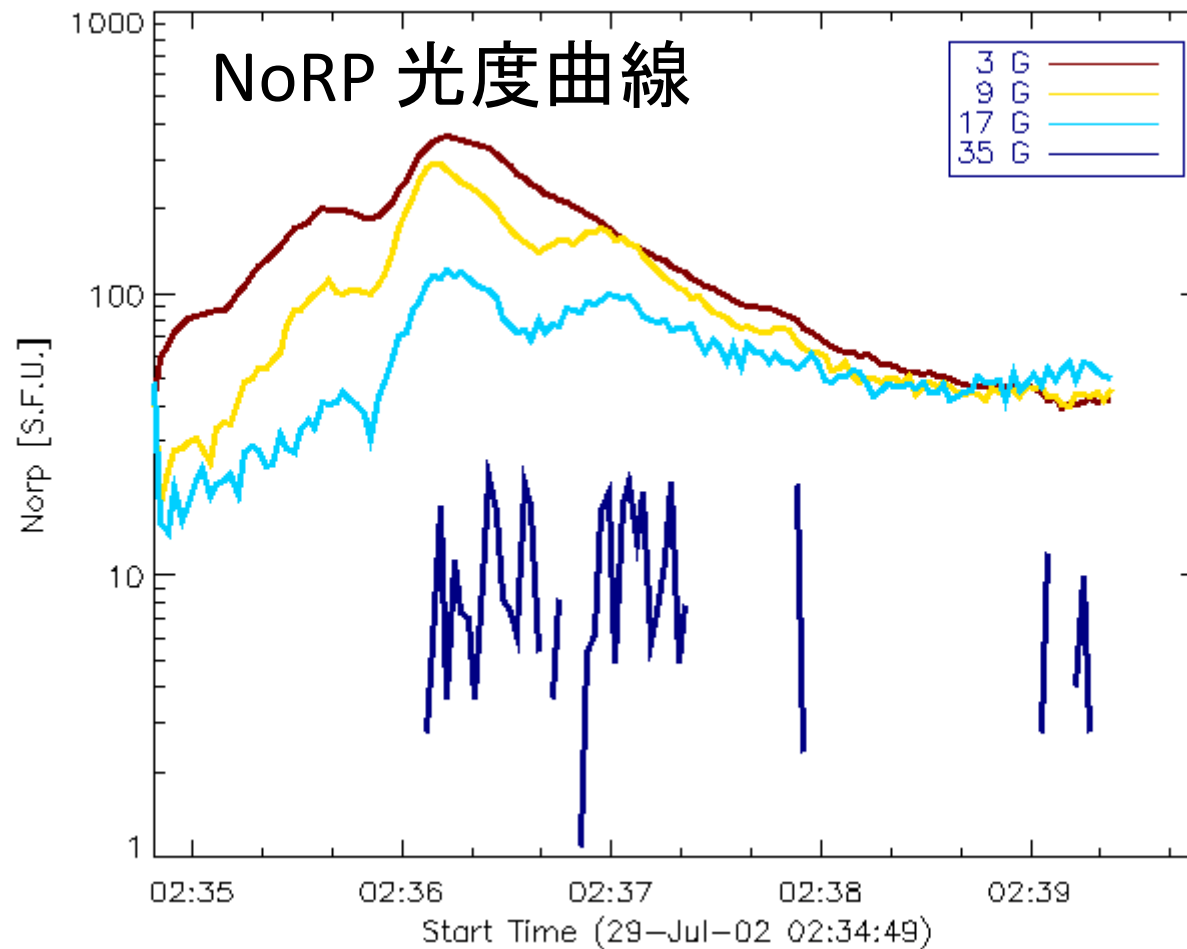
α -map
等高線はさっきのと同じ



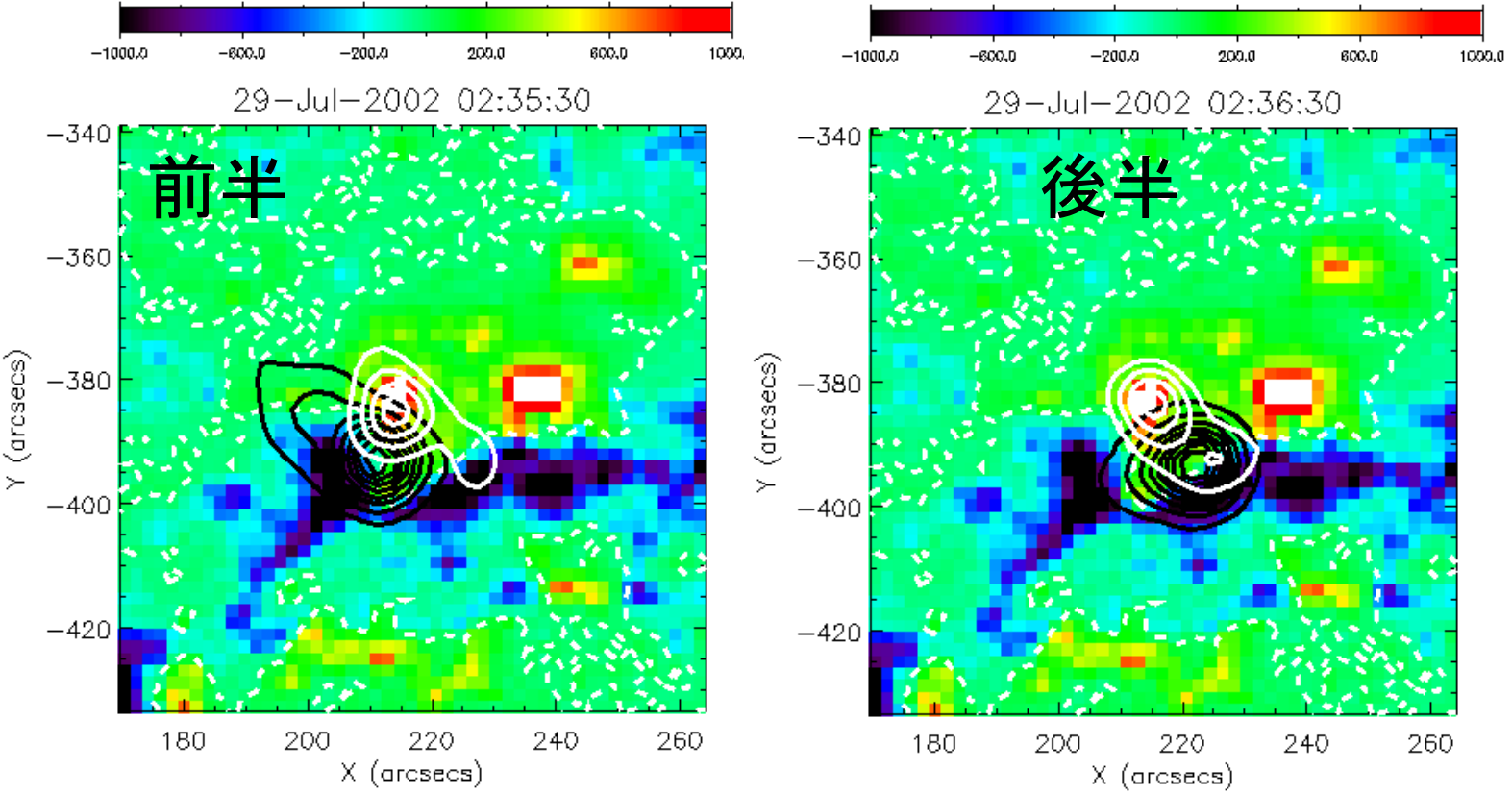
少なくとも前半
半~ピークは、
footpoint-soft,
loop-top-hard

2002 Jul 29 02:36:21UT (Event6)

2002/07/29: M4.8 西経13度(ディスク)



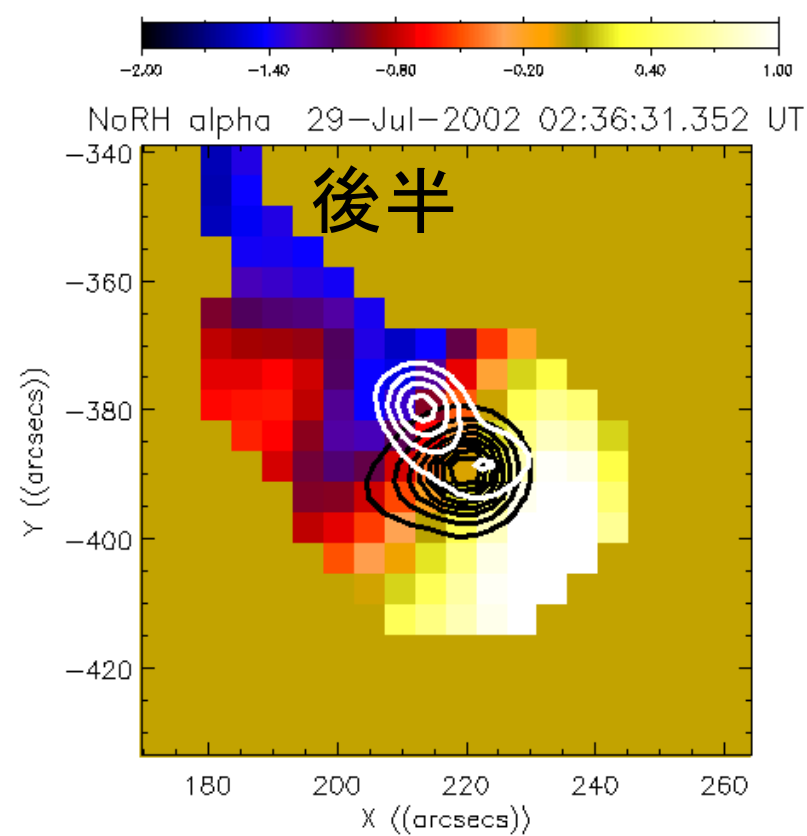
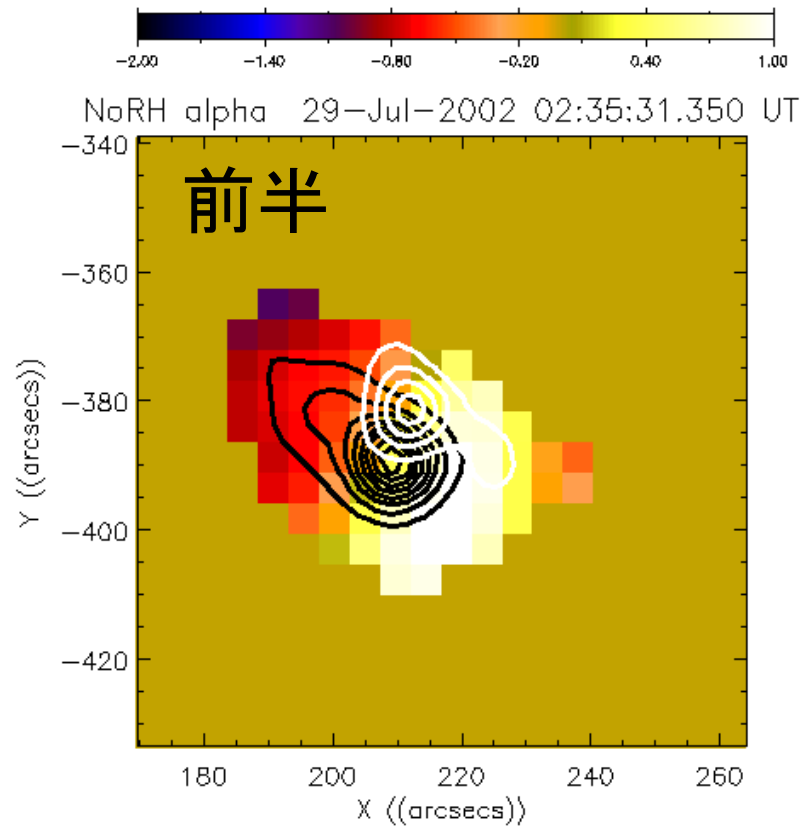
(Event6)



カラー: MDI
黒等高線: 34G
白等高線: 50-100 keV
白点線: 磁気中性線

- アーケードトップ電波源
- ソースが時間と共に東(= $-v \times B$ 方向)に移動

(Event6)



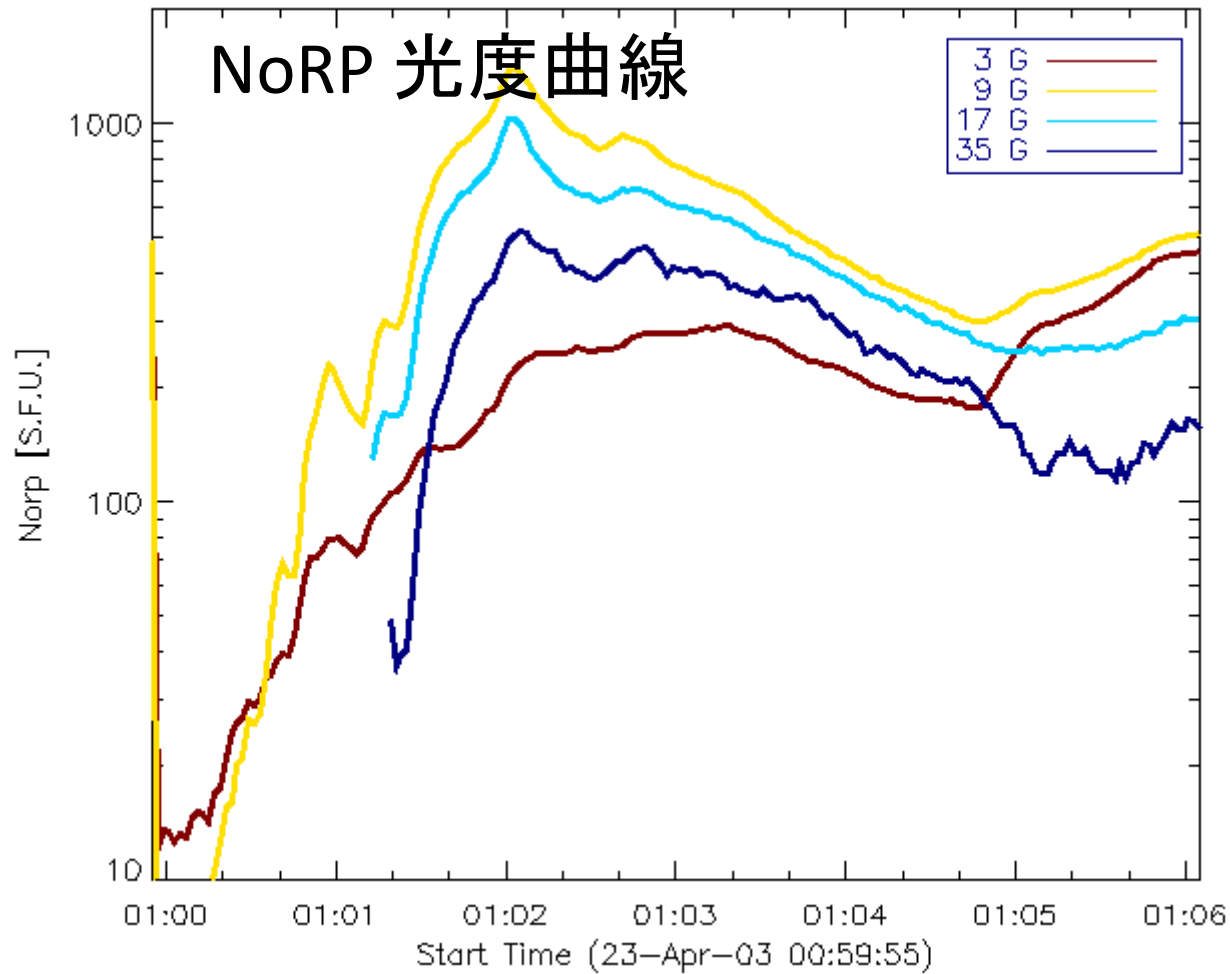
α -map

等高線はさっきのと同じ

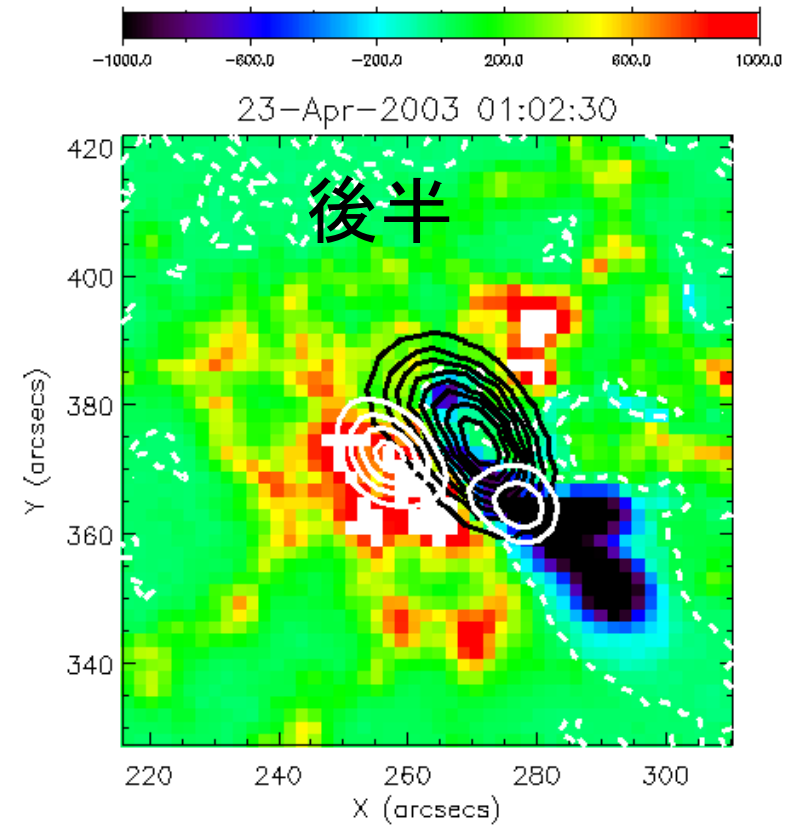
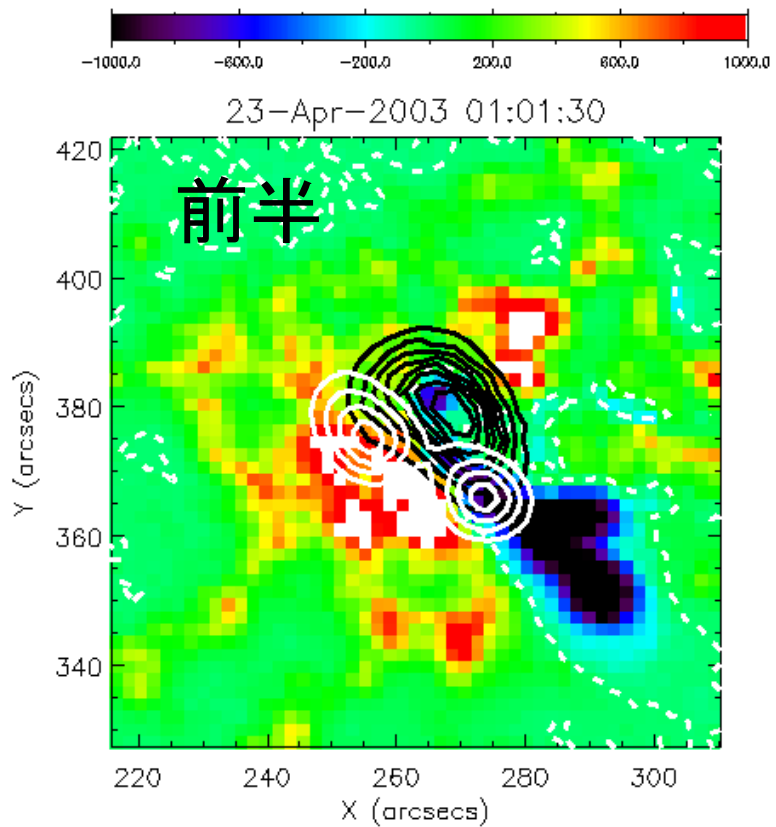
footpoint-soft, loop-top-hard と言える??

2003 Apr 23 01:01:59UT(Event7)

2003/04/23: M5.1 西経16度(ディスク)



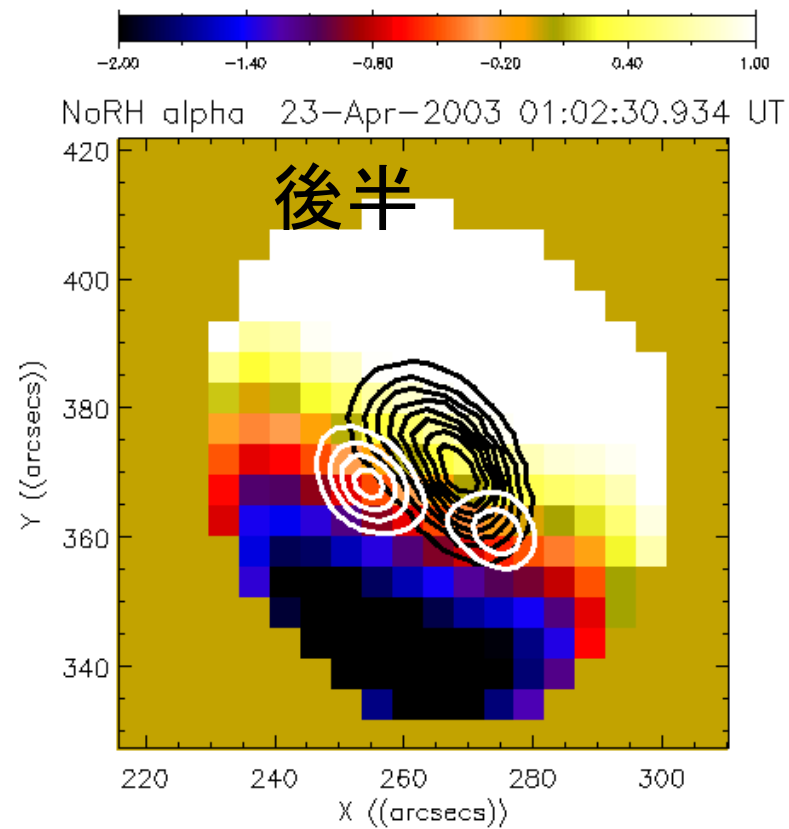
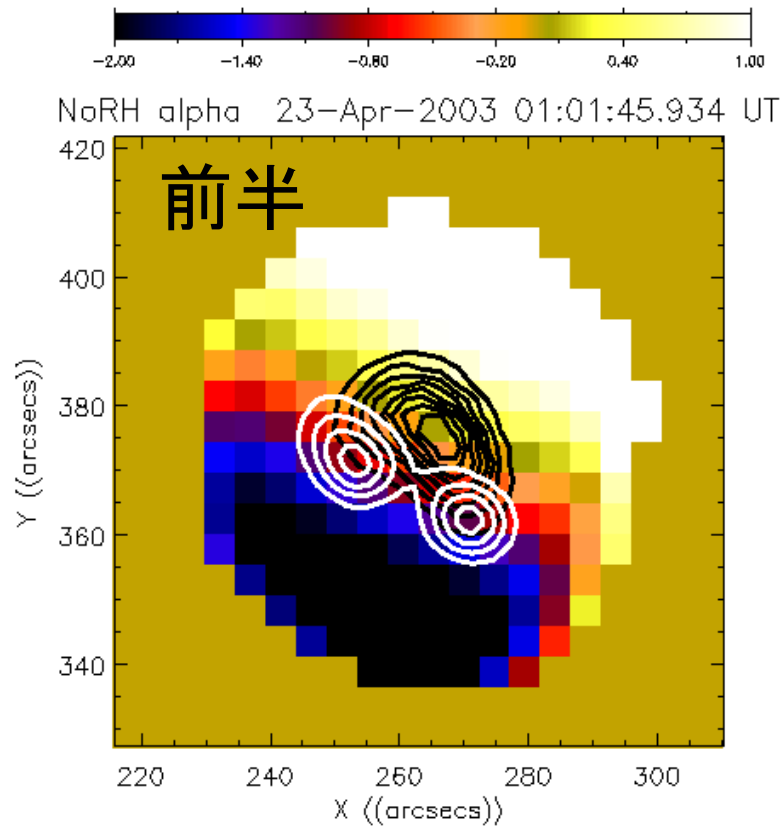
(Event7)



カラー:MDI
黒等高線:34G
白等高線:50-100 keV
白点線:磁気中性線

- ループトップ電波源
- といいながらも、ピークのループ内位置は時々刻々少し変化(左上=>右下)
- X線源=> 超シア構造
- 時間と共にほんの少しリラックス

(Event7)



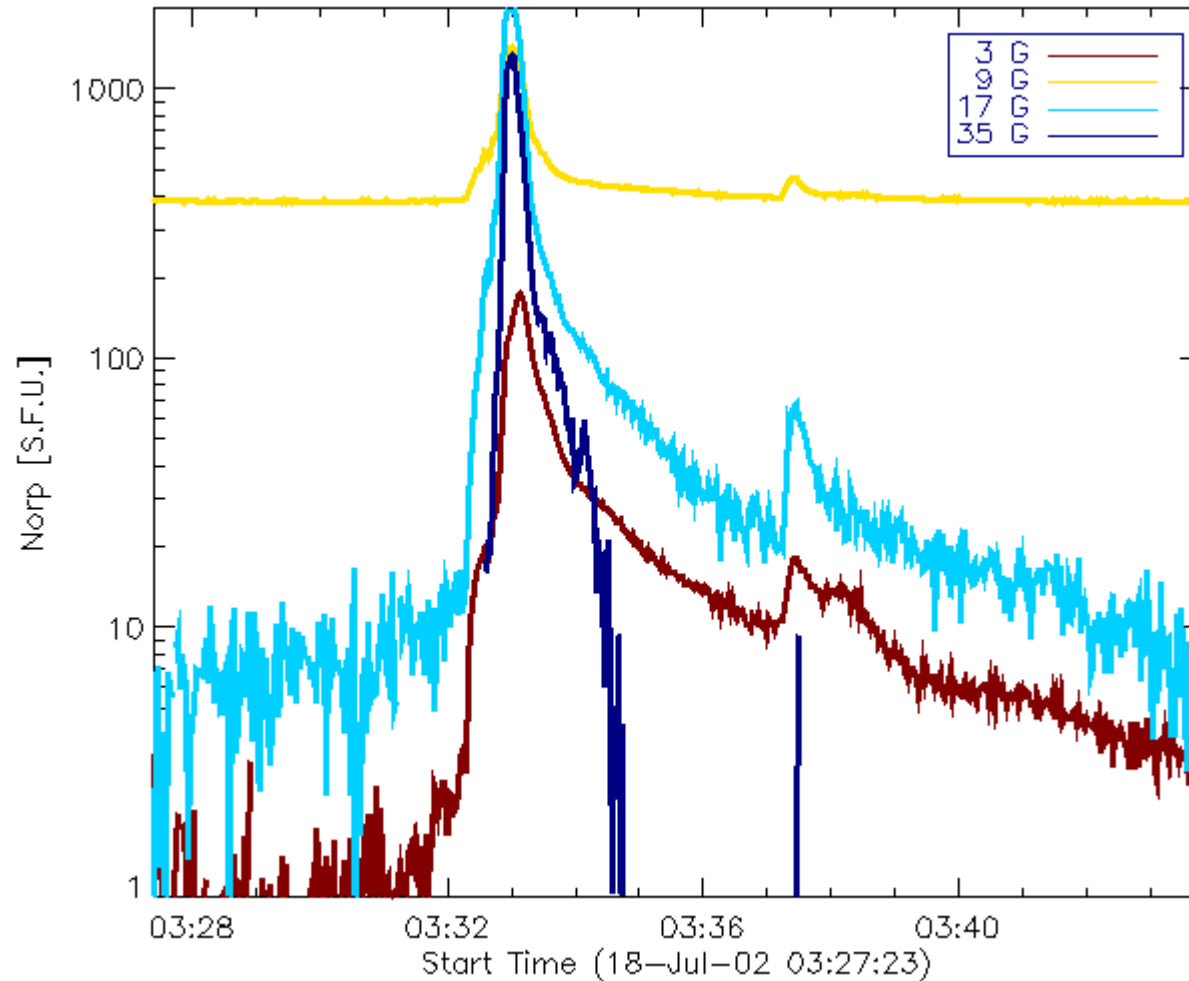
α -map

等高線はさっきのと同じ

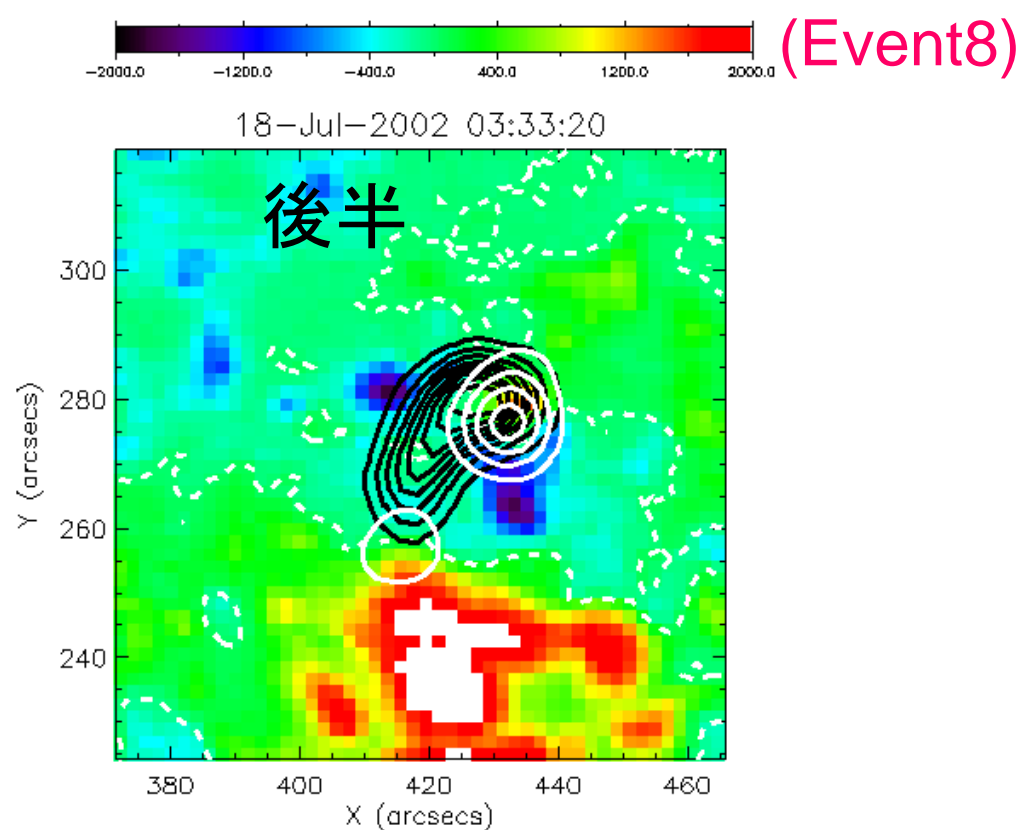
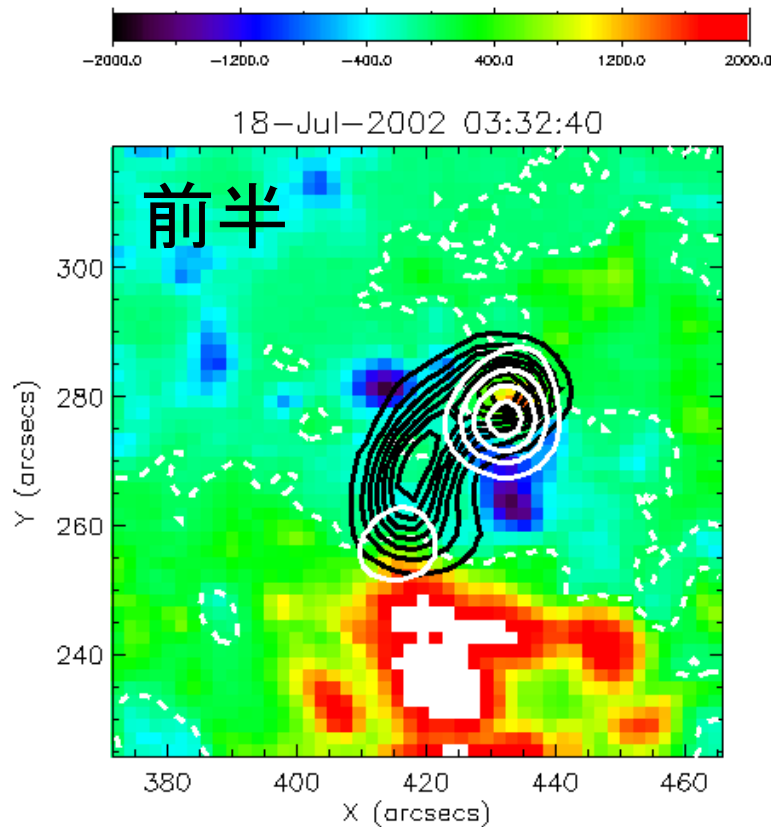
結構はっきりとfootpoint-soft, loop-top-hard

2002 Jul 18 03:32:53UT (Event8)

2002/07/18: M2.2 西経27度(ディスク)



NoRP 光度曲線
9.4 G 未キャリブ



カラー: MDI

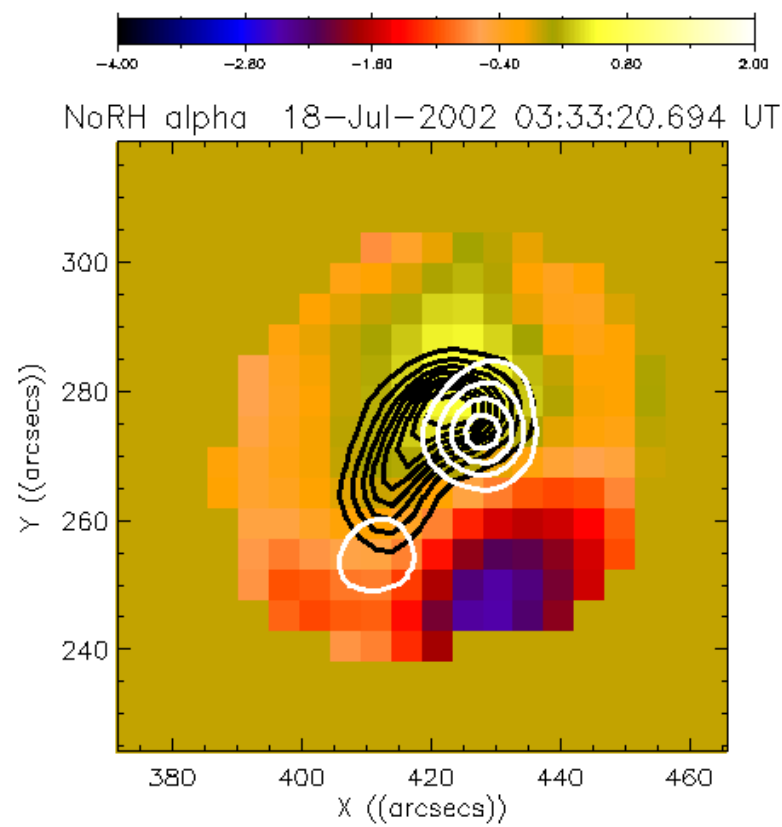
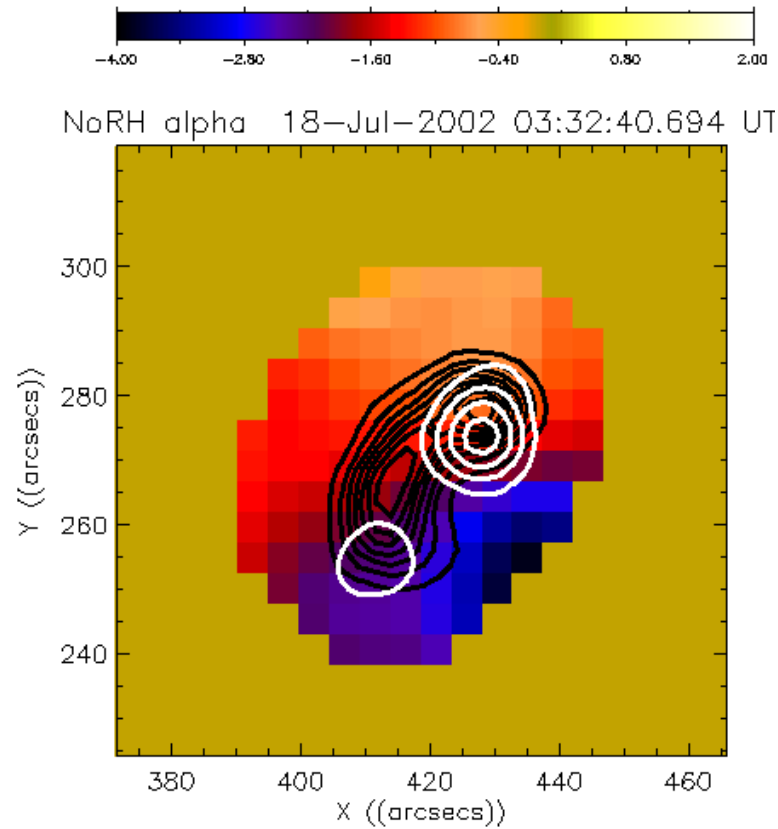
黒等高線: 34G

白等高線: 50-100 keV

白点線: 磁気中性線

- **ループトップ+レッグ**電波源
- といいながらも、ピークのループ内位置は時々刻々少し変化(下=>上)
- 磁場が非常に強い(>3kG黒点)=> M2.2クラスで輝度温度>1億度

(Event8)



α -map

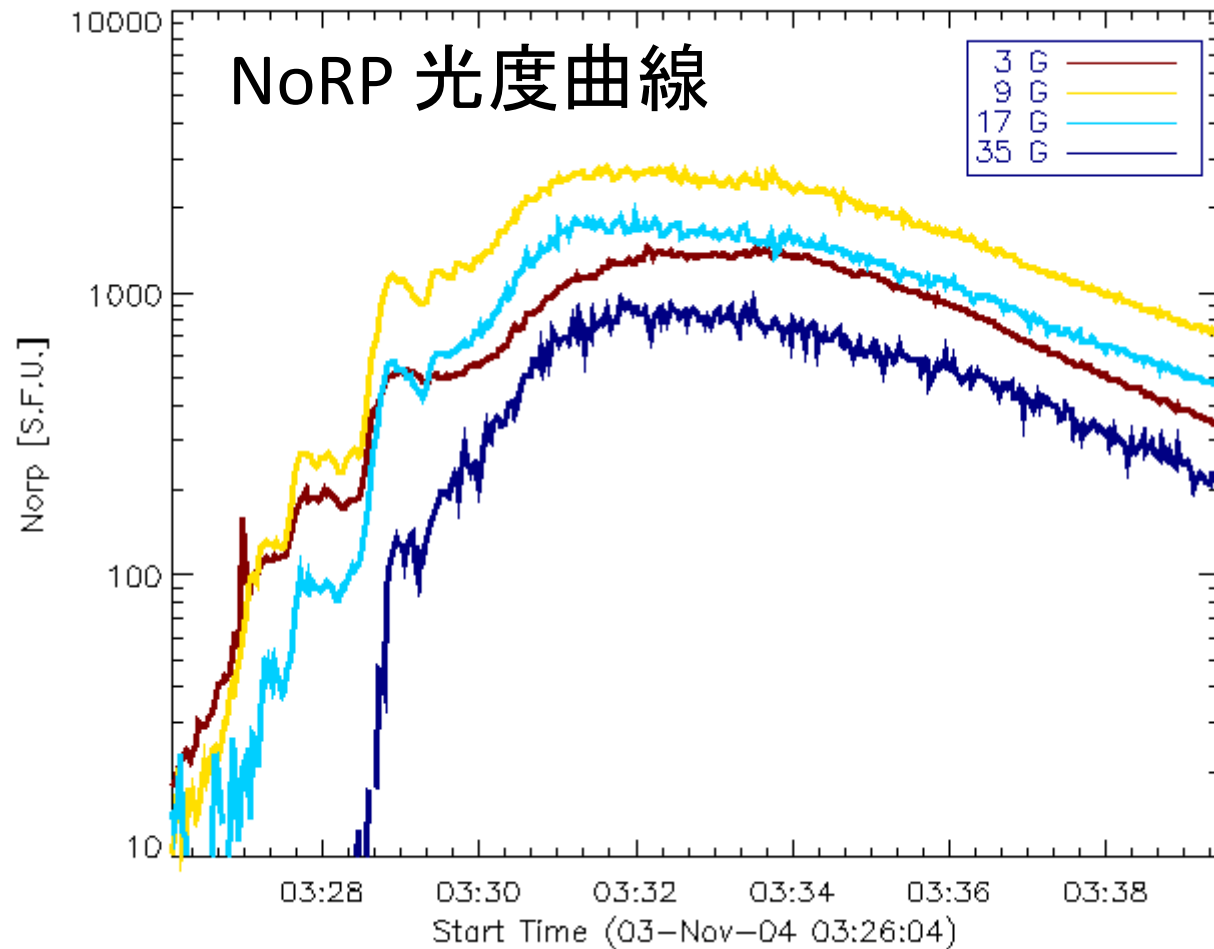
等高線はさっきのと同じ

footpoint-soft, loop-top-hard

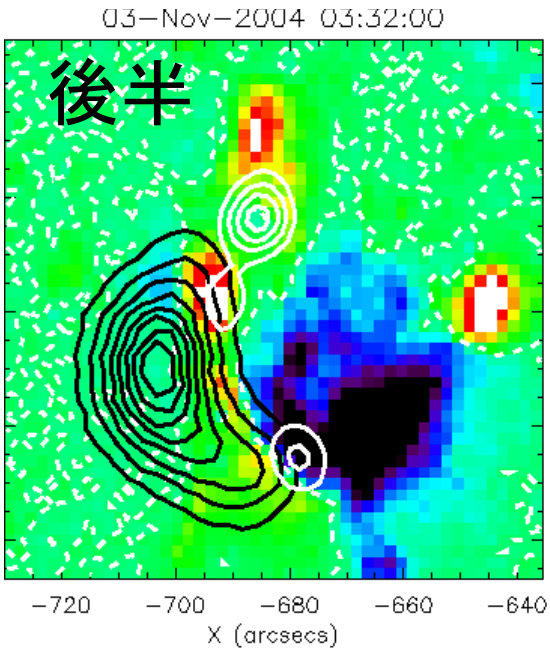
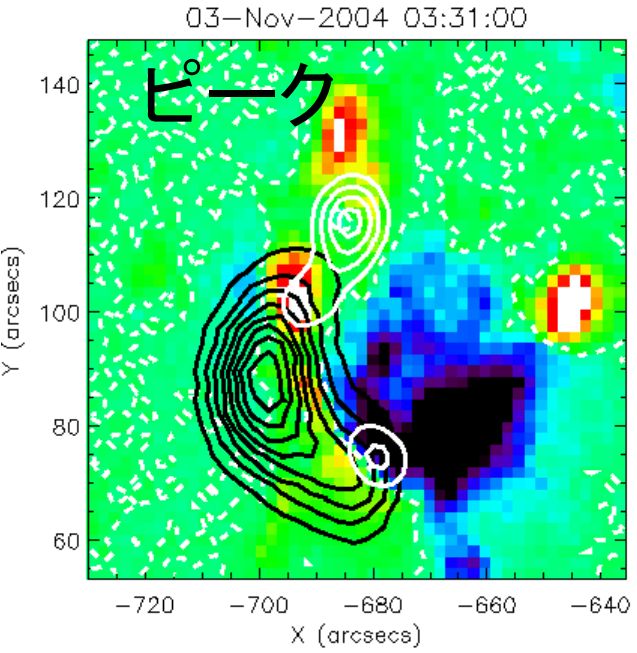
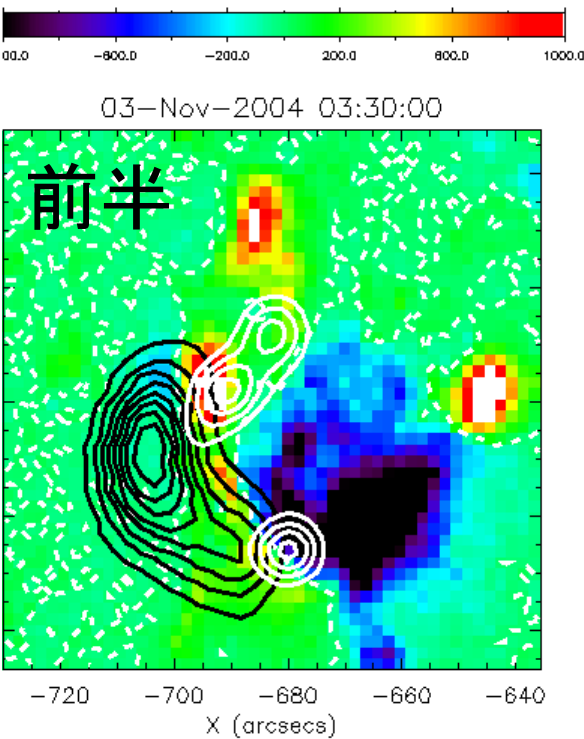
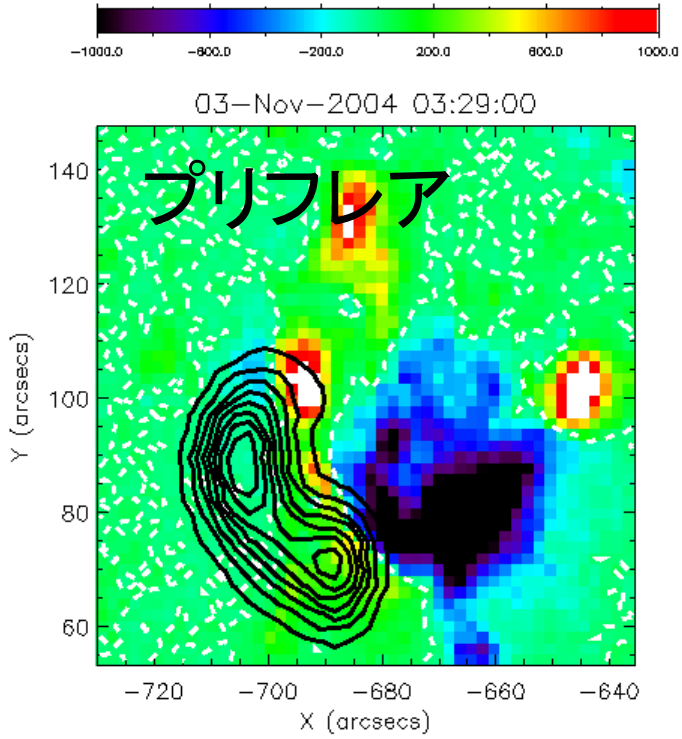
北のfootpointが南のfootpointよりハード

2004 Nov 03 03:30:32UT (Event9)

2004/11/03: M5.1 東經46度(中間)



(Event9)

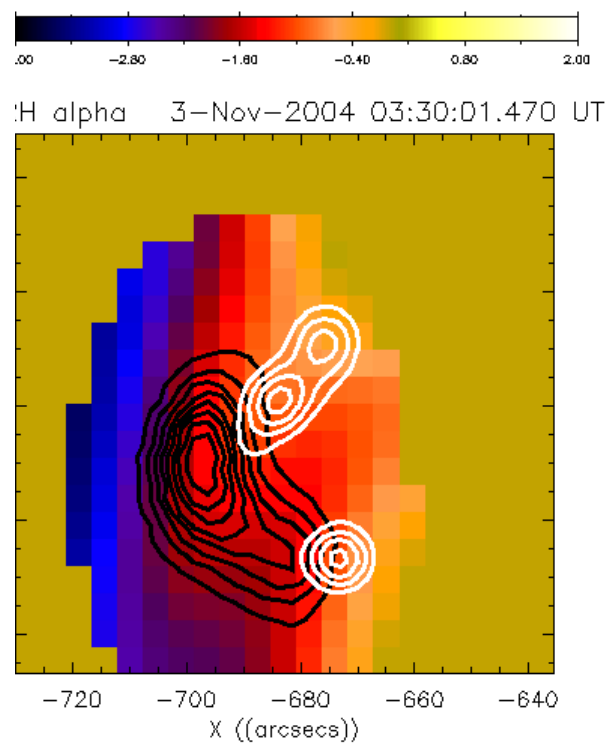
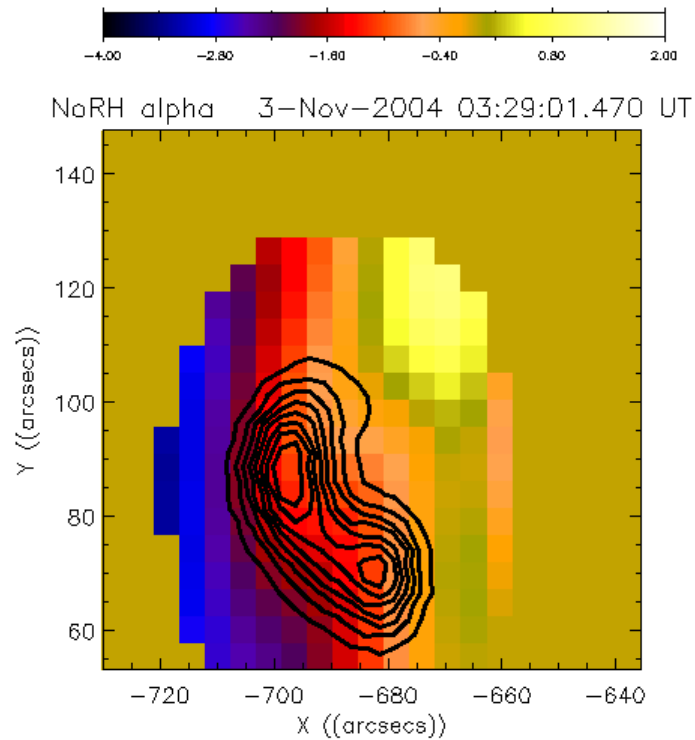


カラー:MDI
 黒等高線:34G
 白等高線:50-100 keV
 白点線:磁気中性線

- プリフレア時に
**フットポイント電
 波源**が見える
- が、メインは常
 に**ループトップ
 電波源**

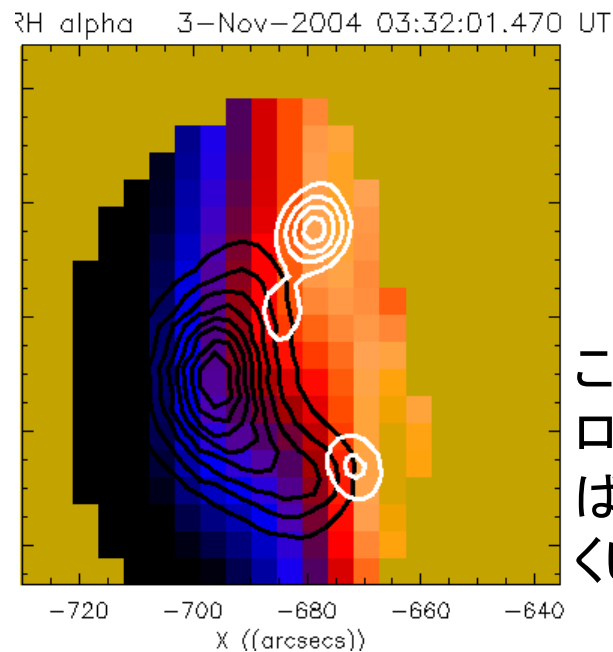
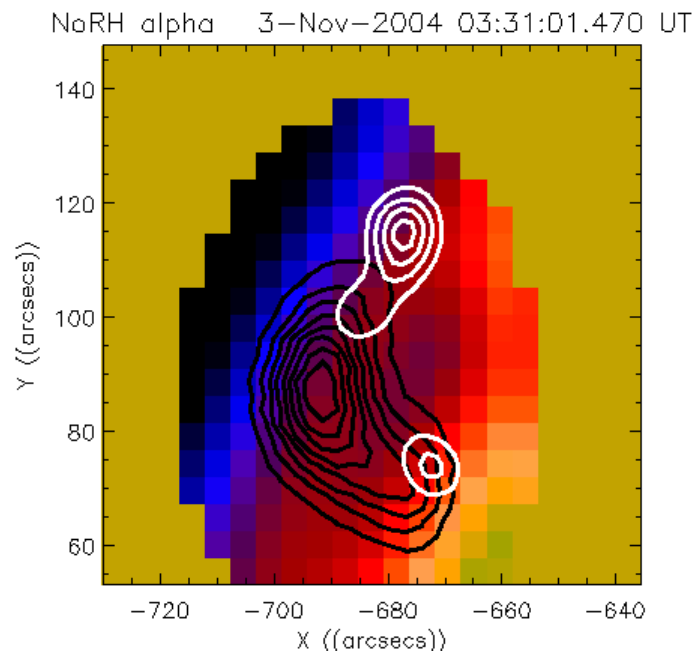
このフレアはバーストプ
 ログラムを用いなければ
 ならないが、まだ上手
 くない

(Event9)



α -map
等高線はさっき
のと同じ

**footpoint-HARD,
loop-top-
SOFT???**



バーストプログラ
ムで精査すべし

このフレアはバーストプ
ログラムを用いなけれ
ばならないが、まだ上手
くない

結論・解釈・今後

- 経度13-46度の5イベントについて、電波放射分布の顕著な経度依存性は見られない
- いずれもループトップがメイン(Kosugi 1985 を支持) => 磁力線垂直方向の加速 and/or トラップを意味
- 時間変化の詳細解析が必要
- 例えば、ループに沿った強度分布が時間変化するイベントが結構ある
- 加速機構やループ内輸送・拡散タイムスケールの時間変化を調べられるか

Event List

(RHESSI era)

Date	radio(17G) source	α (17G/34G ratio)	
Limb付近イベント			
(4) 2003-10-24	footpoint \Rightarrow loop-top		
(9) 2002-04-21	footpoint \Rightarrow loop-top		
Disk付近イベント			
((1)) 2005-12-02			
(2) 2004-11-03	(footpoint \Rightarrow)loop-top (?)	Soft	Hard (Burst?)
(3) 2004-07-16	loop-top		
(5) 2003-04-23	loop-top (top \Rightarrow bottom)	Hard	Soft
(6) 2002-11-10	loop-top	Hard	Soft
(7) 2002-07-29	loop-top	Hard	Soft
(8) 2002-07-18	loop-top+leg	Hard	Soft
(10) 2002-03-14	footpoint \Rightarrow loop-top		
		(loop-top)	(foot point)

Event List

(Yohkoh era)

Date	radio(17G) source	α (17G/34G ratio)		Remark
Limb付近				
(1') 2000-03-03	foot-point (?)	-1	-1	
(6') 2000-11-25	foot-point	-2	-1, -1	
Disk付近				
(2') 2000-04-08	loop-top	-2	-0.5, -0.5	
(3') 2000-07-25	loop-top (?)	-1.5	-0.5, -1	
(4') 2000-09-16	loop-top	-1	-2, -2	
(5') 2000-10-29	loop-top	-1.5	-2, 0	
(7') 2001-09-25	loop-top	-1.5	-3, -1	
		(loop-top)	(foot point)	

結果

- Foot-point HXR sourceとradio source一致しない。
- ほとんど(ピーク時)はloop-topで観測。(加速された粒子が観測されている。
 - (1)HXRで100keVのcounter part観測されているから
 - (2)turning frequency小, $F_{17\text{GHz}} > F_{34\text{GHz}}$ なのでoptically thin \Rightarrow nonthermalと考えられる
 - (3)Brightness e_6 - $e_7 \Rightarrow$ synchrotronからしか放射されない。
- Early phase radio source移動
(foot-point \Rightarrow loop-topへ、foot-pointは減光している(?))
*Heliogのdynamic range 1/1000,
Brightness $\sim e_7 \rightarrow$ foot-point e_4 他の光球面と同じとこまで見えるのに観測されていないから)
- Post flare phaseはまだよく解析できていない。ぼんやり広がっているような。

- 電波イベントのsourceの一の経度依存性なさそう。
⇒ディスク、リムで変化がないのでloop-topソースじゃないかと考えられる。Kosugi1985を支持する結果。実際、画像合成した結果はloop-top sourceがディスクでもリムでも多い。
- Loop-top: hard, foot-point: softとなる結果もあれば、loop-top: soft, foot-point: hardとなる結果も1例観測された(ただし、Burstで画像解析した結果、Hanaokaに比べ温度が4000万度低かった。これが影響している可能性があり、さらなる解析必要)。
- 大フレア中の空間構造・時間発展が解析可能になった。
今後さらに解析を進めていく必要がある。
- Loop-topにpitch angleの大きな($V \perp$ の大きな)粒子(Nonthermal electron)が多く存在していることを示唆しているのではないか。