Working Group 3: Radio correlations

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24 Oct 2001

A Cool, Dense Flare

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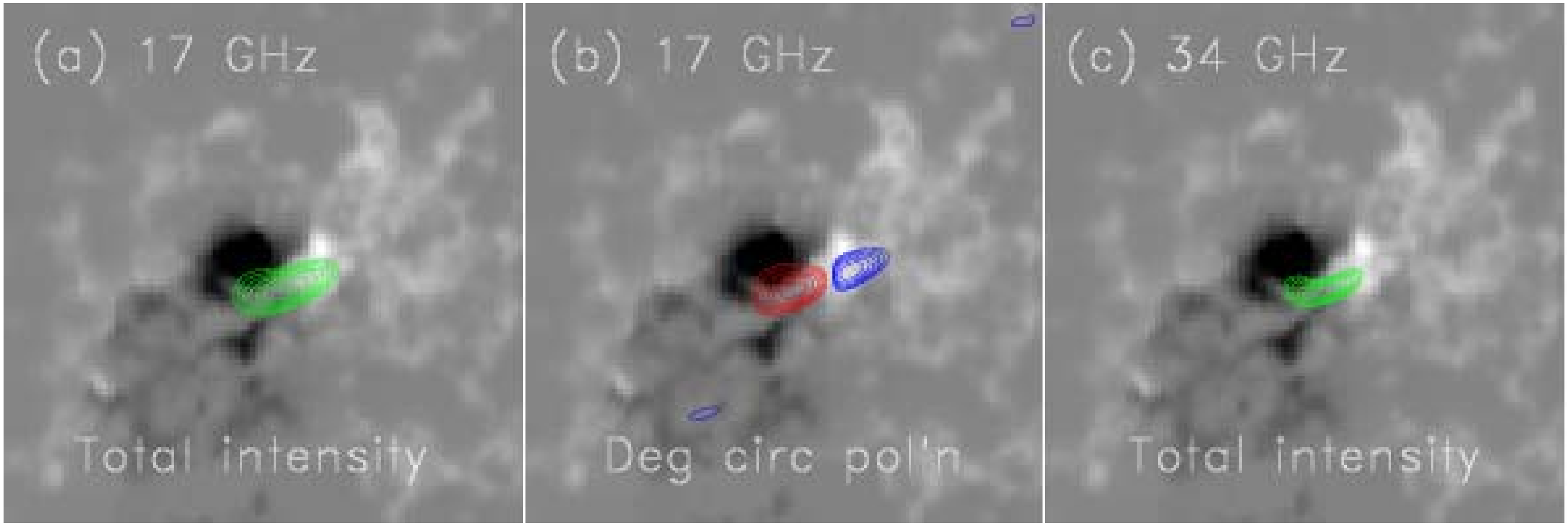
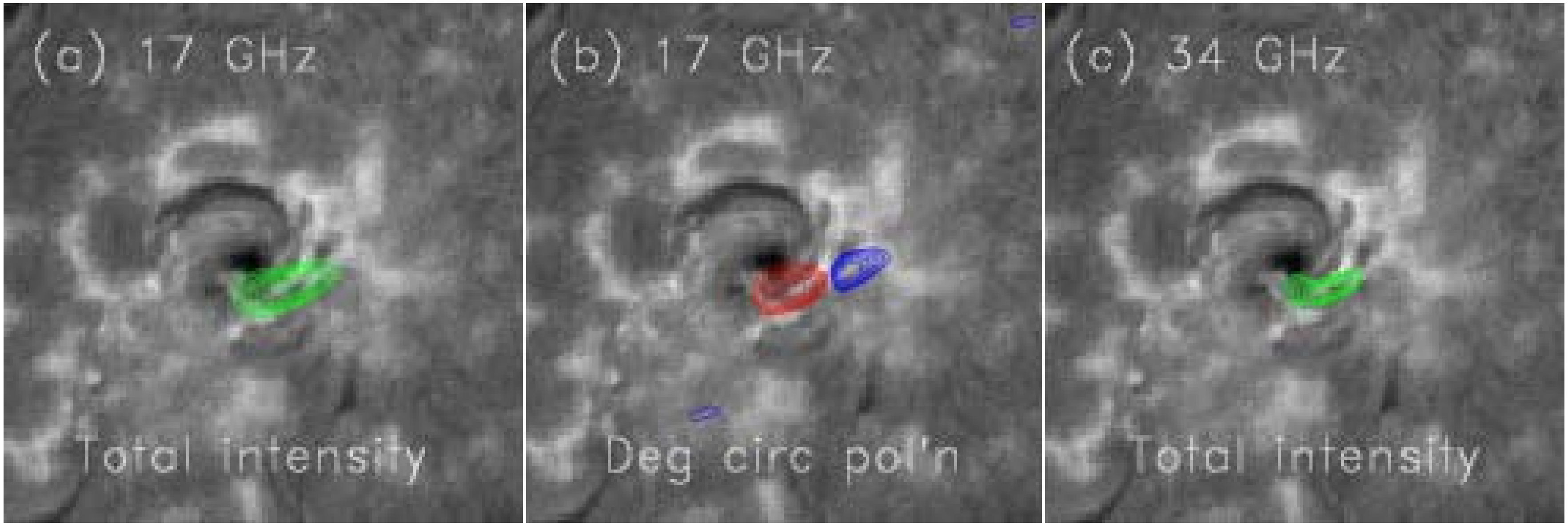
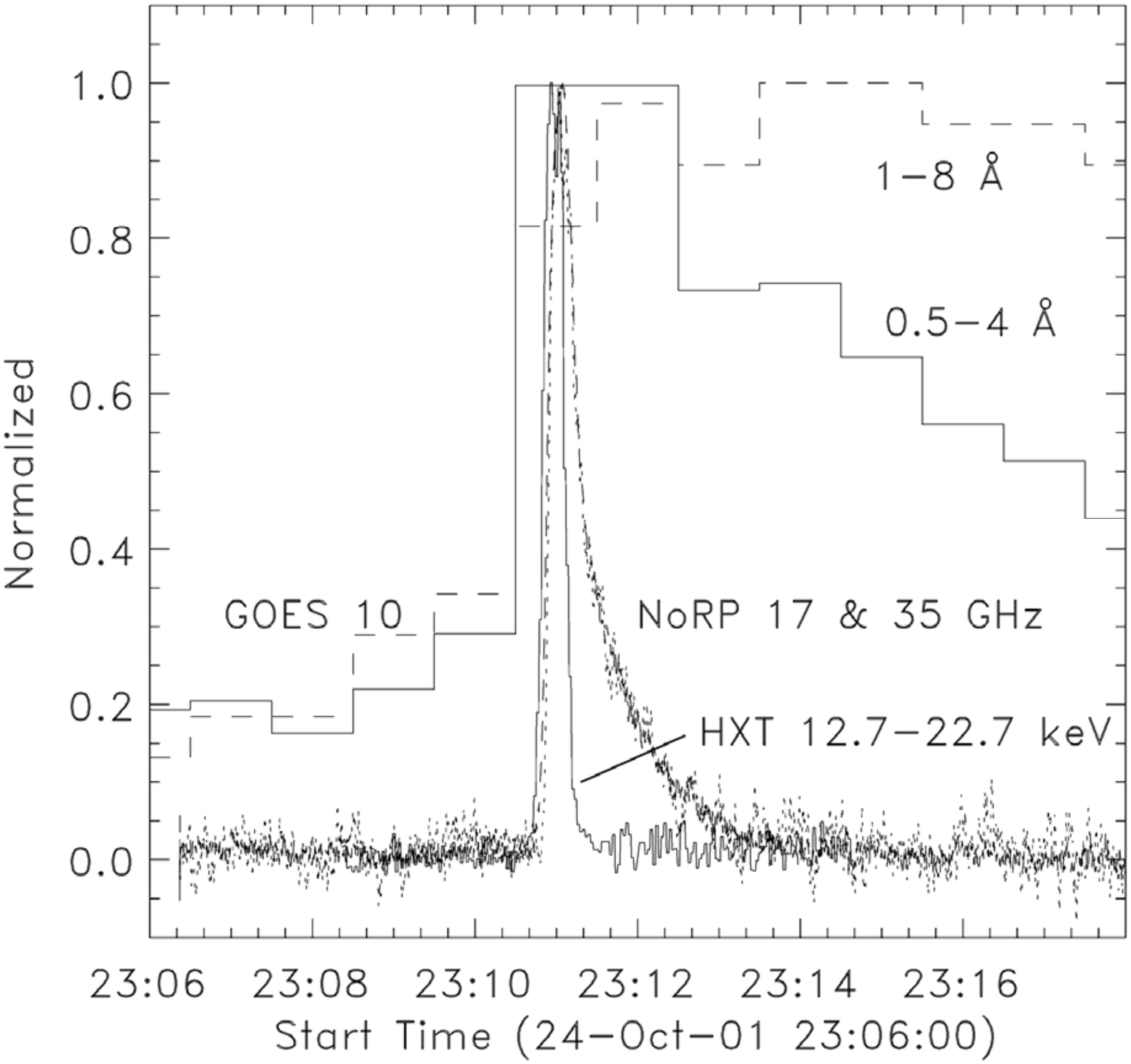
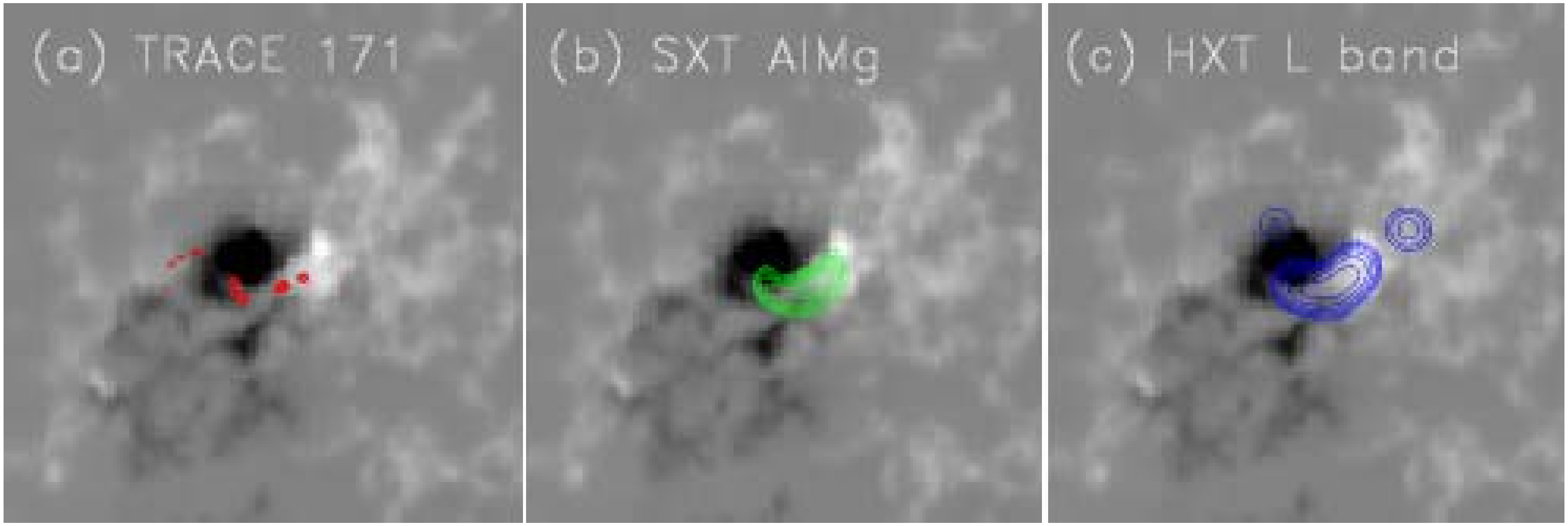
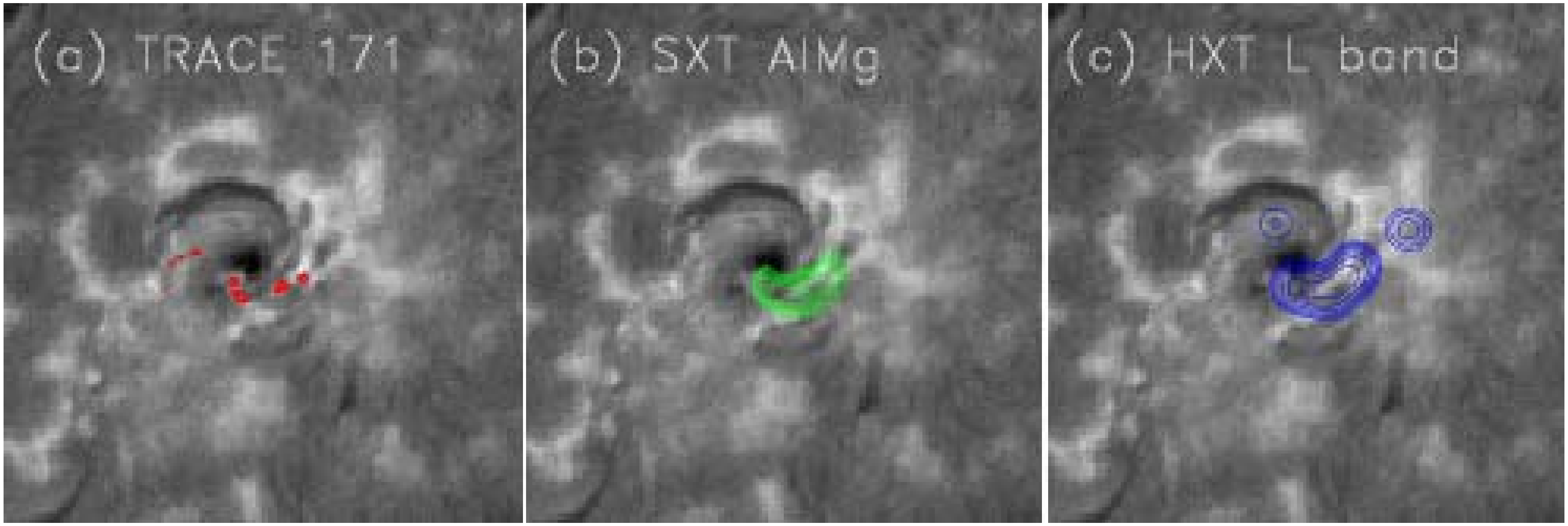
Owens Valley Solar Array*

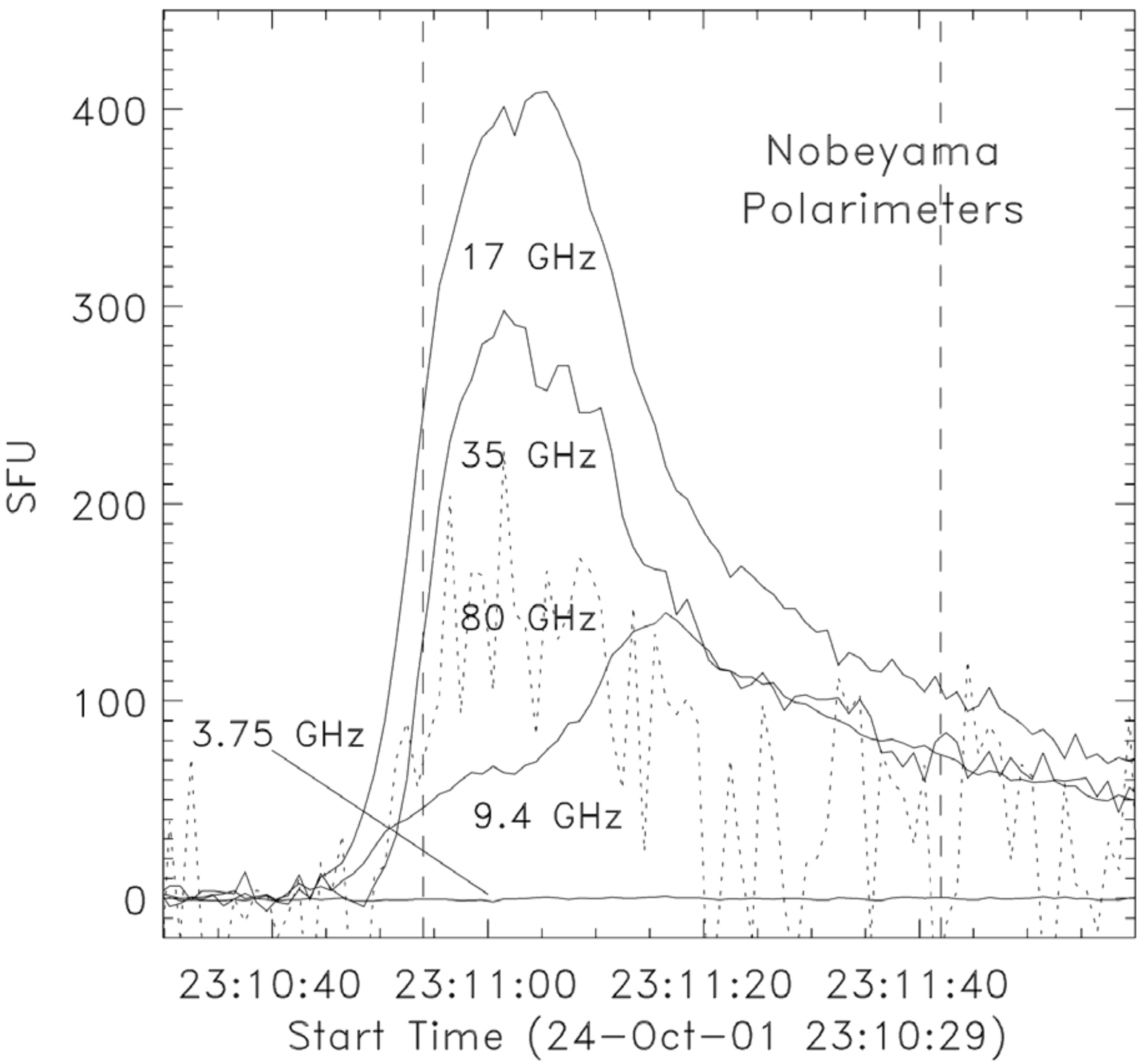

(a) 17 GHz
Total intensity
(b) 17 GHz
Deg circ pol'n
(c) 34 GHz
Total intensity


(a) 17 GHz
Total intensity
(b) 17 GHz
Deg circ pol'n
(c) 34 GHz
Total intensity


1.0
0.8
0.6
0.4
0.2
0.0
Normalized
1-8 Å
0.5-4 Å
GOES 10
NoRP 17 & 35 GHz
HXT 12.7-22.7 keV
23:06
23:08
23:10
23:12
23:14
23:16
Start Time (24-Oct-01 23:06:00)


(a) TRACE 171
(b) SXT AlMg
(c) HXT L band


(a) TRACE 171
(b) SXT AlMg
(c) HXT L band


400
300
200
100
0
SFU
Nobeyama
Polarimeters
17 GHz
35 GHz
80 GHz
3.75 GHz
9.4 GHz
23:10:40
23:11:00
23:11:20
23:11:40
Start Time (24-Oct-01 23:10:29)

Observational Summary

- Impulsive, radio rich flare – little EUV, SXR, HXR
- Low frequency cut-off below ~10 GHz
- Flux maxima delayed with *decreasing* frequency
- Flux decay approx. frequency independent late in event

Interpretation

- Radio emission is due to GS emission from non-thermal distribution of electrons in relatively cool, dense plasma
- Ambient plasma density is high – therefore, Razin suppression is relevant
- Thermal free-free absorption is also important ($\sim n^2 T^{-3/2} \nu^{-2}$)

Include these ingredients in the source function (cf. Ramaty & Petrosian 1972)

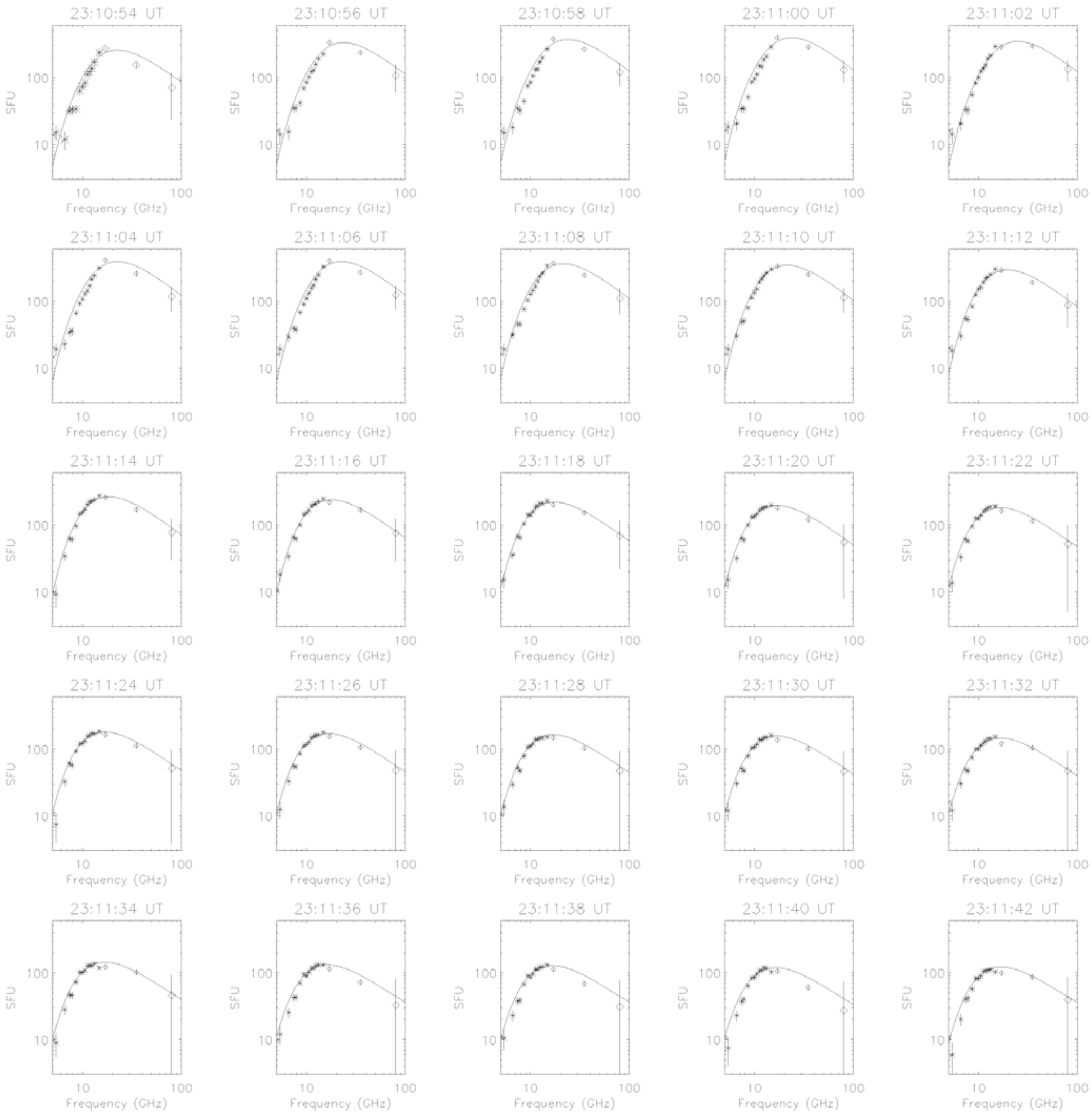
The idea is that energy loss by fast electrons heats the ambient plasma, reducing the free-free opacity with time, thereby accounting for the reverse delay structure.

1 spectrum/
2 sec

2-parameter
fits via χ^2-
minimization

n_{rl}, T

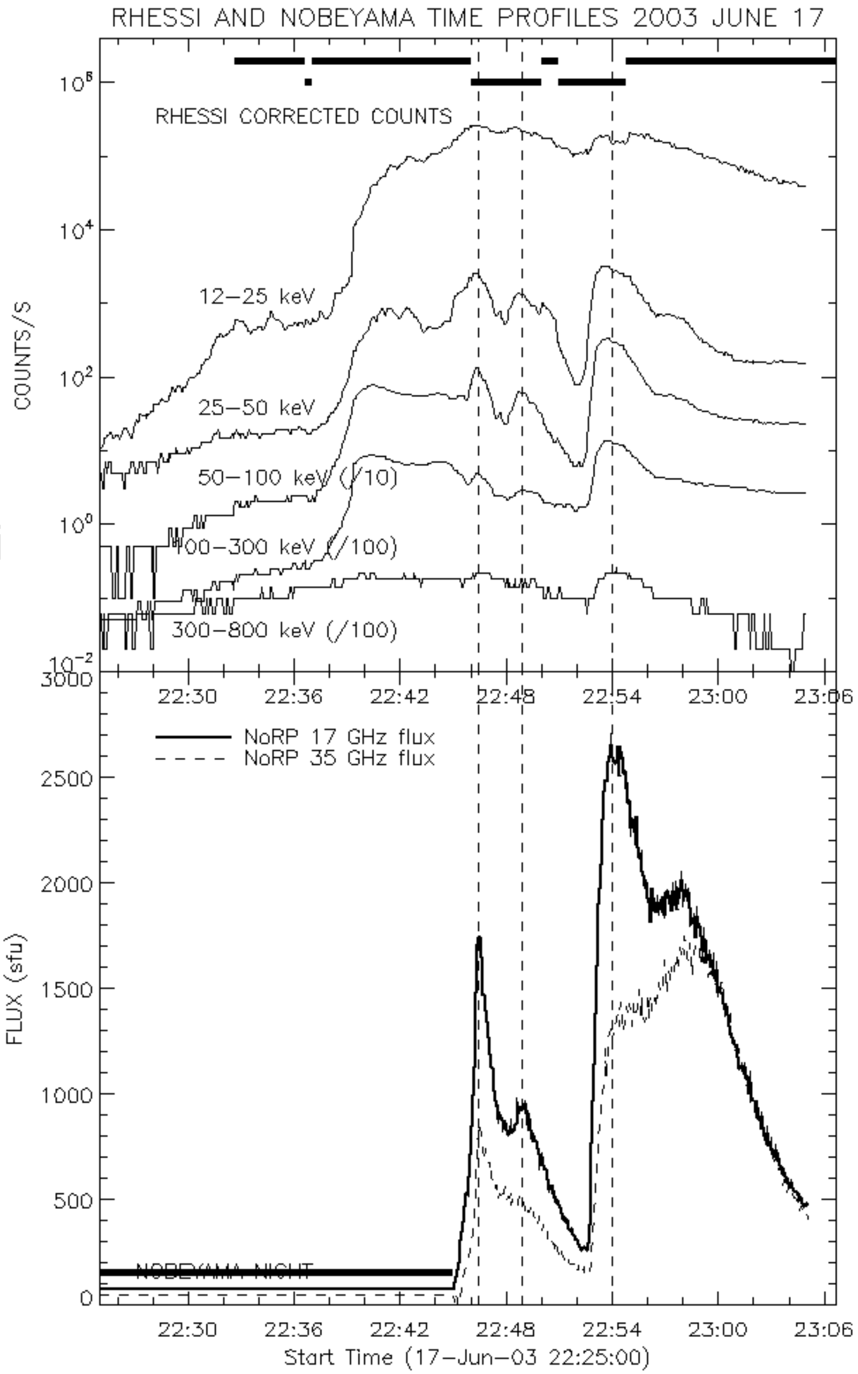
B, θ, n_{th},
A, L, E_1,
E_2, δ
fixed



Microwave and hard X-ray imaging observations of energetic electrons in solar flares: event of 2003 June 17

Kundu, M R., Schmahl, E J, and
White, S M

i



RHESSI light curves (12-800 keV) and radio time profiles

Selected RHESSI 12-25 & 25-50 keV maps in different epochs of the main phase

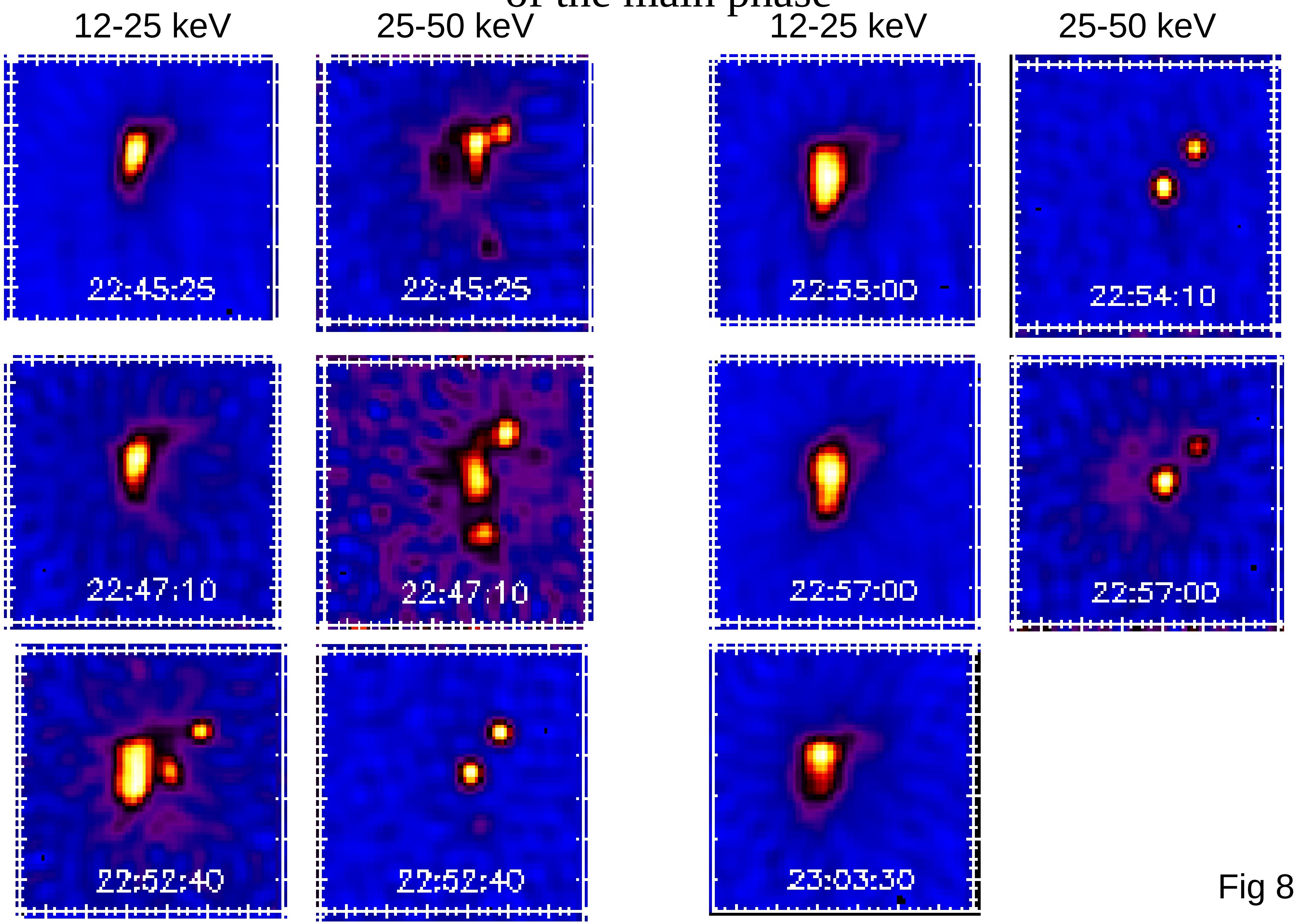
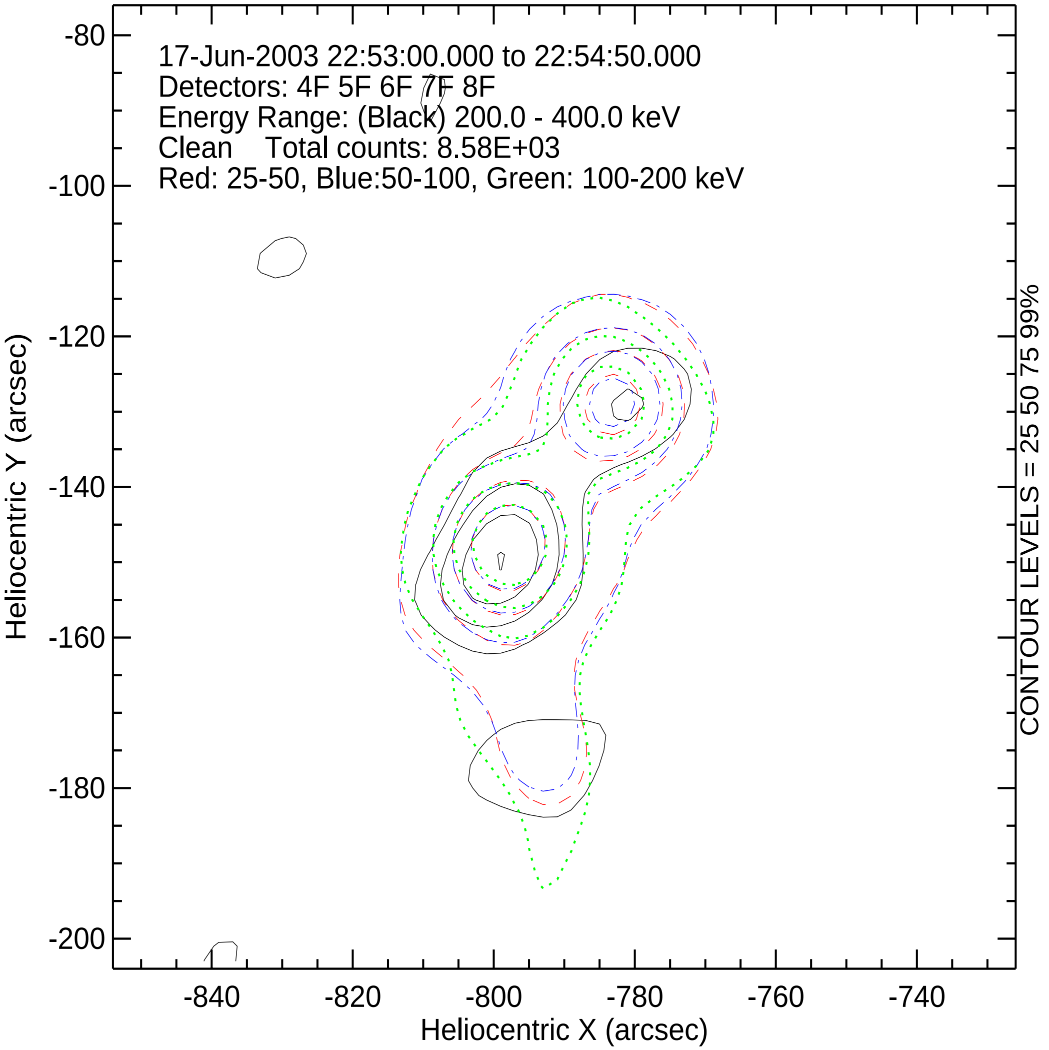


Fig 8a

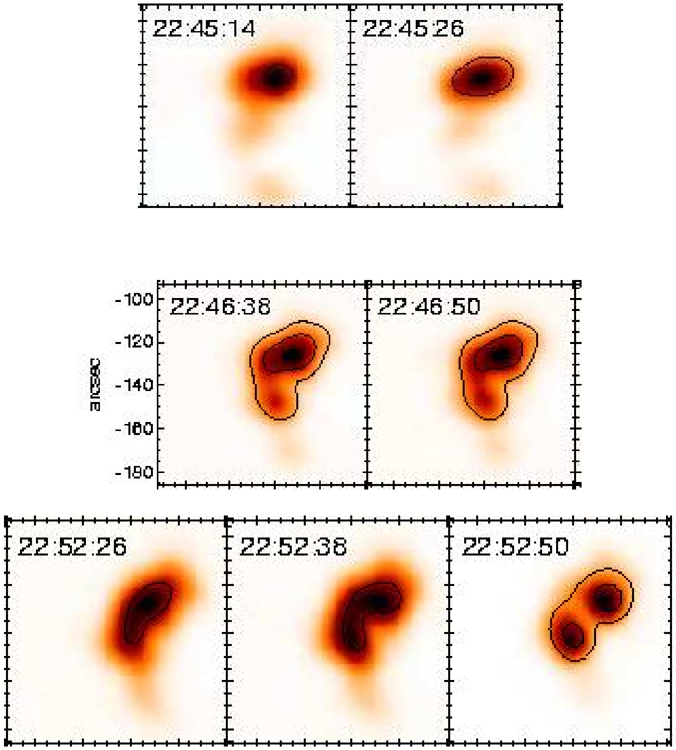
RHESSI 200-400 keV Image along with lower energy maps



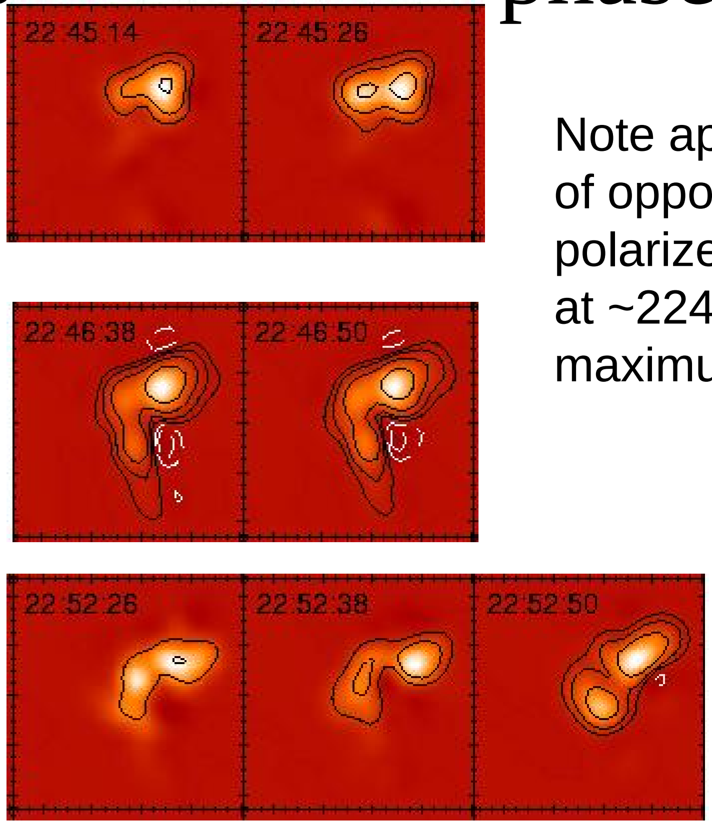
Note that the low energy and high energy sources are co-located

Fig 8b

Selected 17 GHz maps in I and V at different epochs of the main phase



Intensity

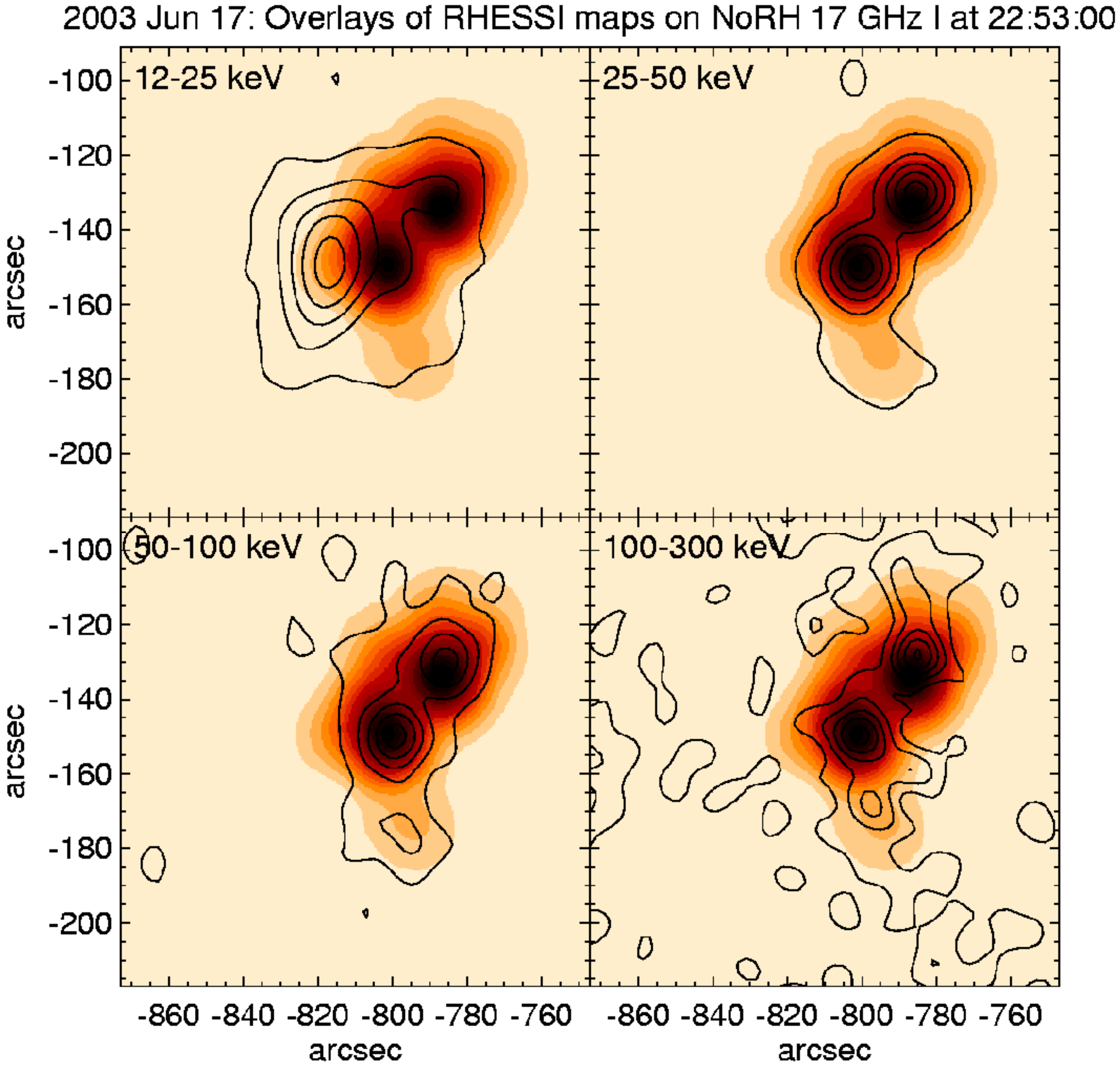


Polarization

Note appearance of oppositely polarized source at ~2246 –- first maximum.

Fig 10a

HXR & 17 GHz I



HXR (contours at
10,30,..,90%)
& 17 GHz I (color)

Note coincidence of HXR & 17 GHz flaring sources

SUMMARY AND CONCLUDING REMARKS

- We discuss a flare of GOES class M6.8 using simultaneous imaging observations by RHESSI in HXR and by NoRH in microwaves.
- The preflare phase was observed well by RHESSI, but not by NoRH due to Nobeyama night time. The important feature of the RHESSI preflare phase is that we observed a TRACE ejecta whose height- time positions were well determined. The trajectory of the absorbing material tracks directly from a 6-25 keV "looptop" source, consistent with the scenario that open field lines extend above a reconnection region near the top of the flare loop, and that material--possibly a plasmoid--is ejected upward from that region.
- Shortly after the ejection, accelerated electrons are beamed downwards from that reconnection region to the footpoints where they appear in hard X-rays with energies > 25 keV.

Coronal connectivity from radio and hard X-ray images

Stephen White

Coronal connectivity

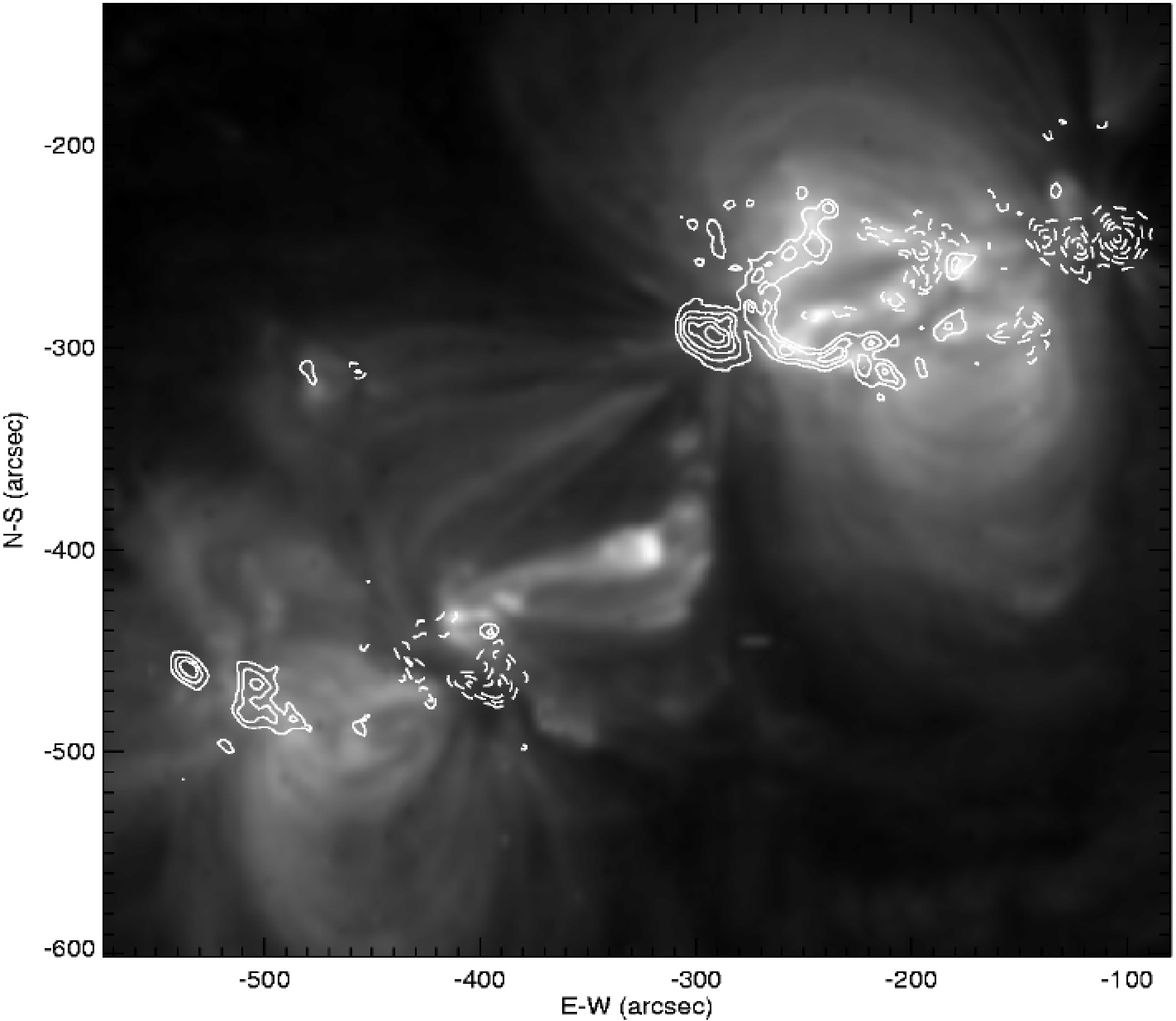
- Due to limited dynamic range, generally assume that one HXR source is a footpoint, two is 2 footpoints, three is 2 footpoints plus loop top: “single-loop paradigm”. Compare soft and hard energy ranges.

- Radio data have more dynamic range and we generally see several sources, even in quite small events

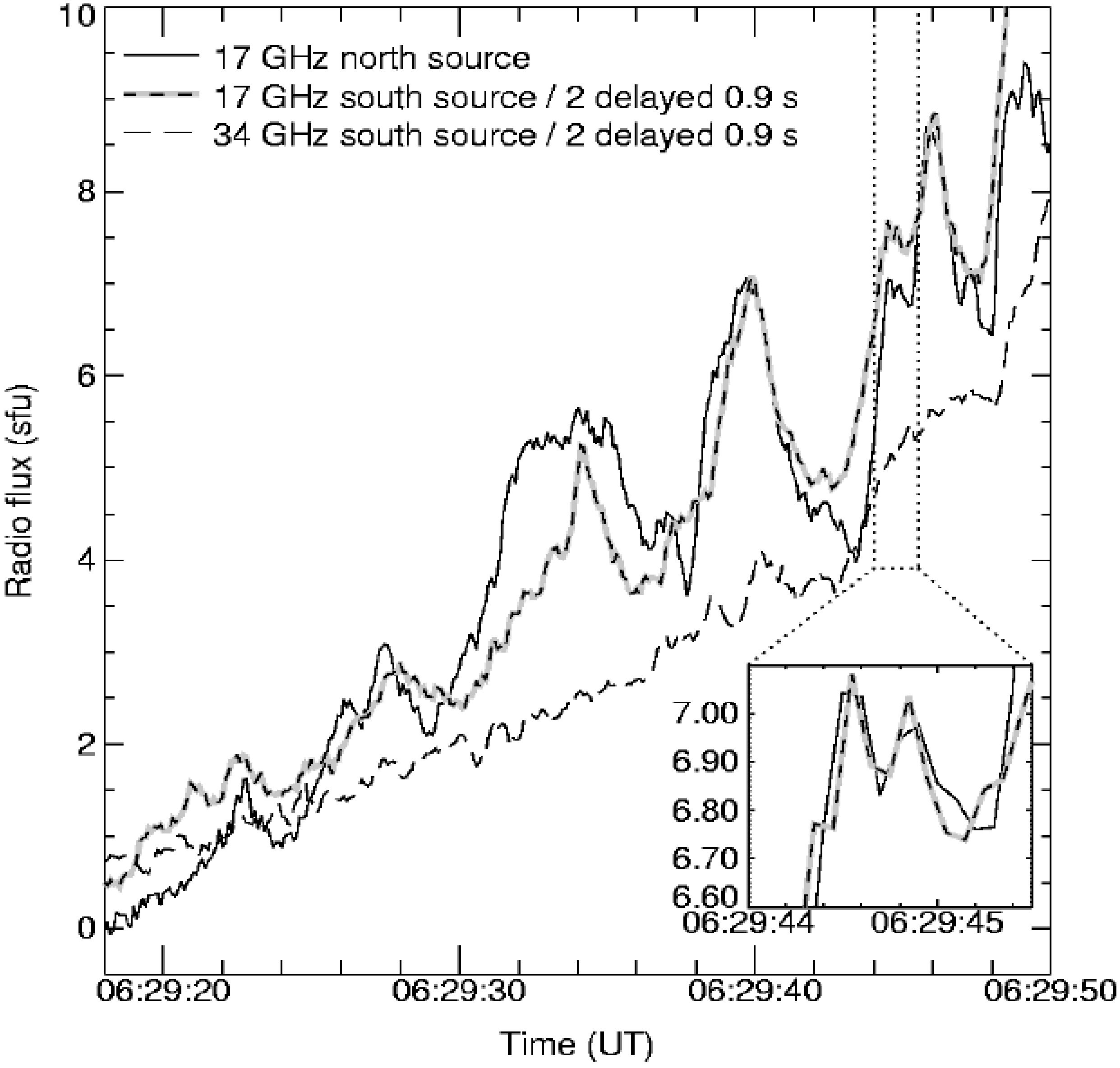
- This offers the opportunity to help with identification of coronal connections of RHESSI sources

- Strongest evidence is correlated fluctuations in connected sources

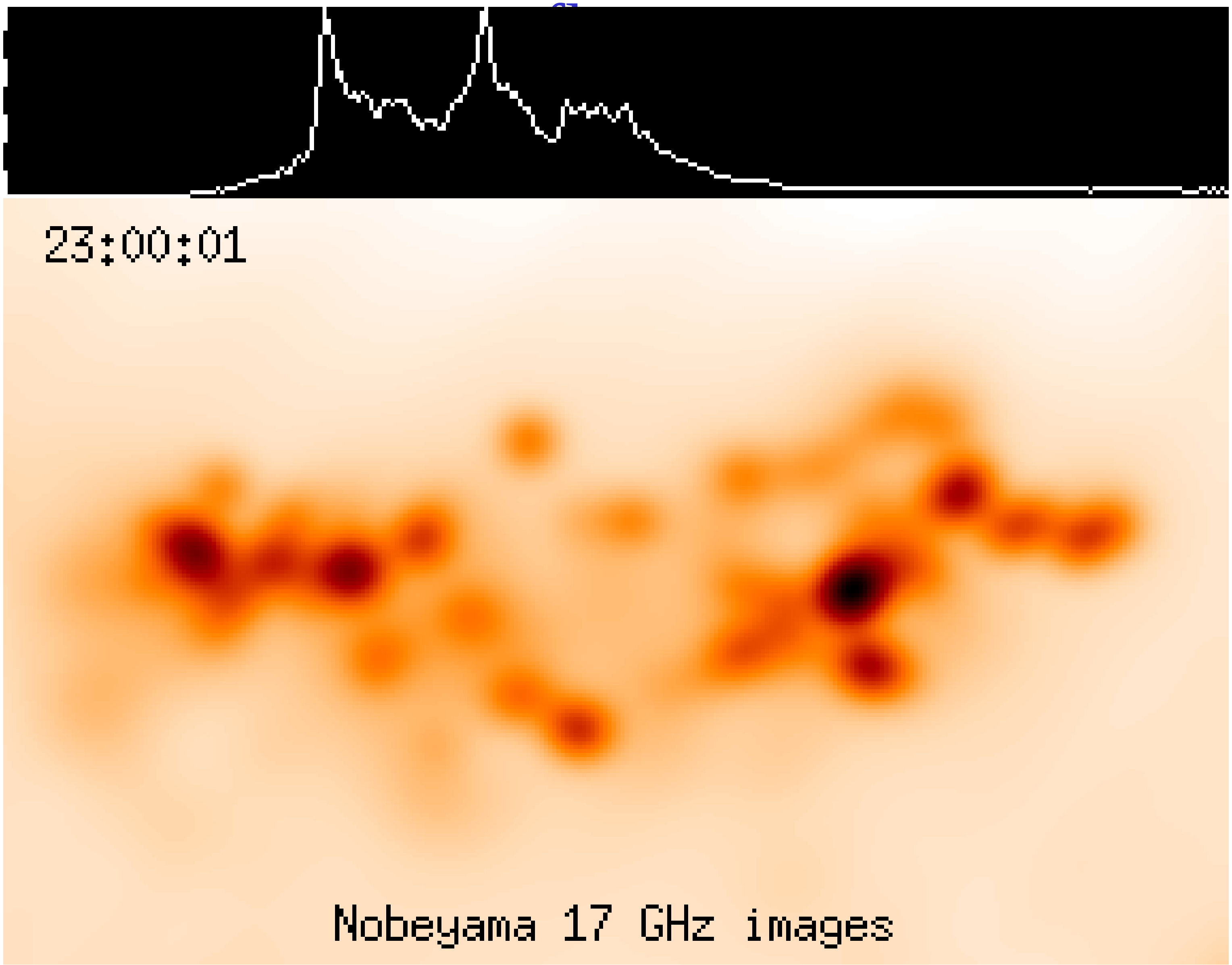
MDI mag field on EIT 284 image



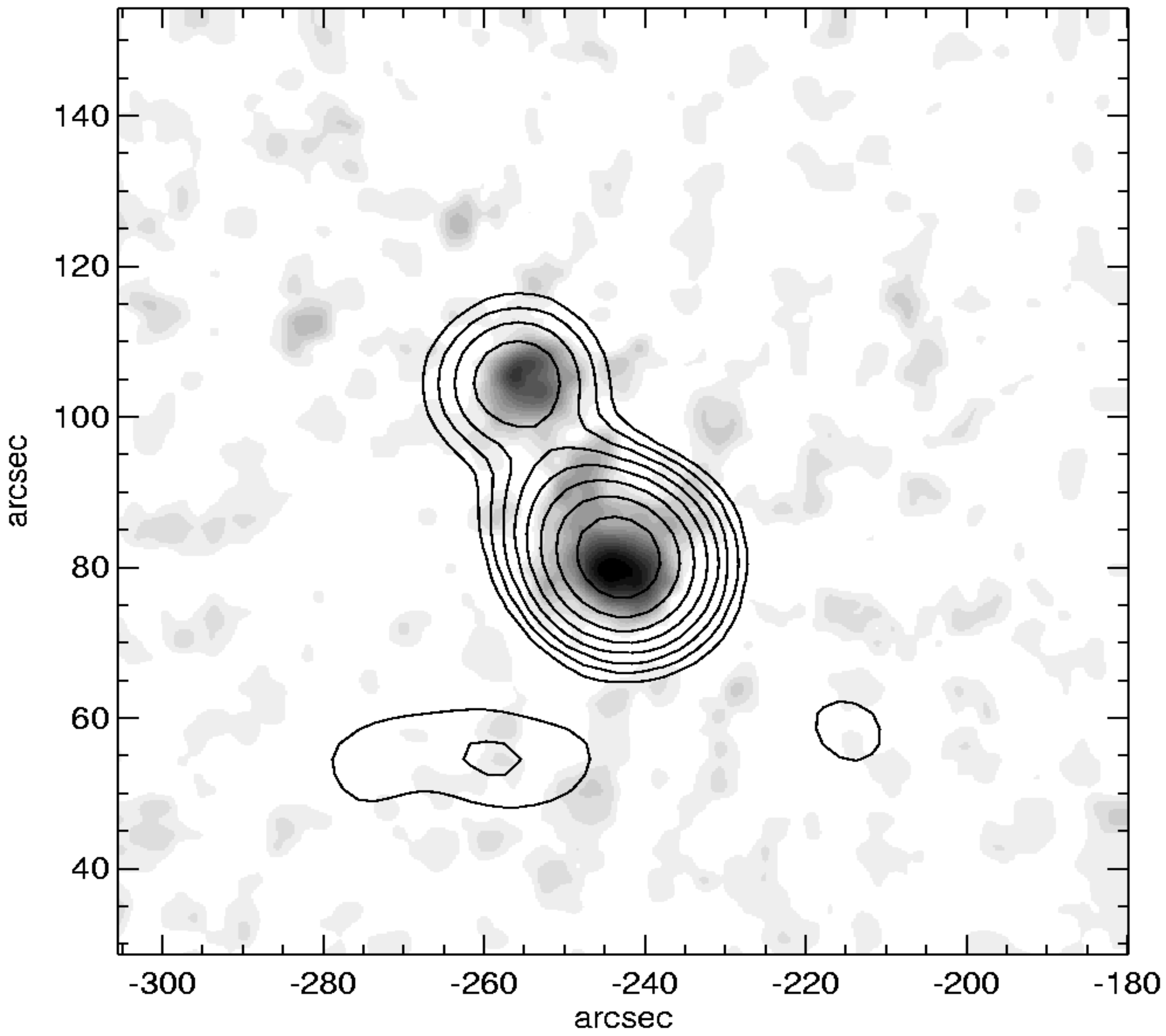
Contours at 15.0,30.0,45.0,60.0,75.0,90.0 percent of 1.76e+03

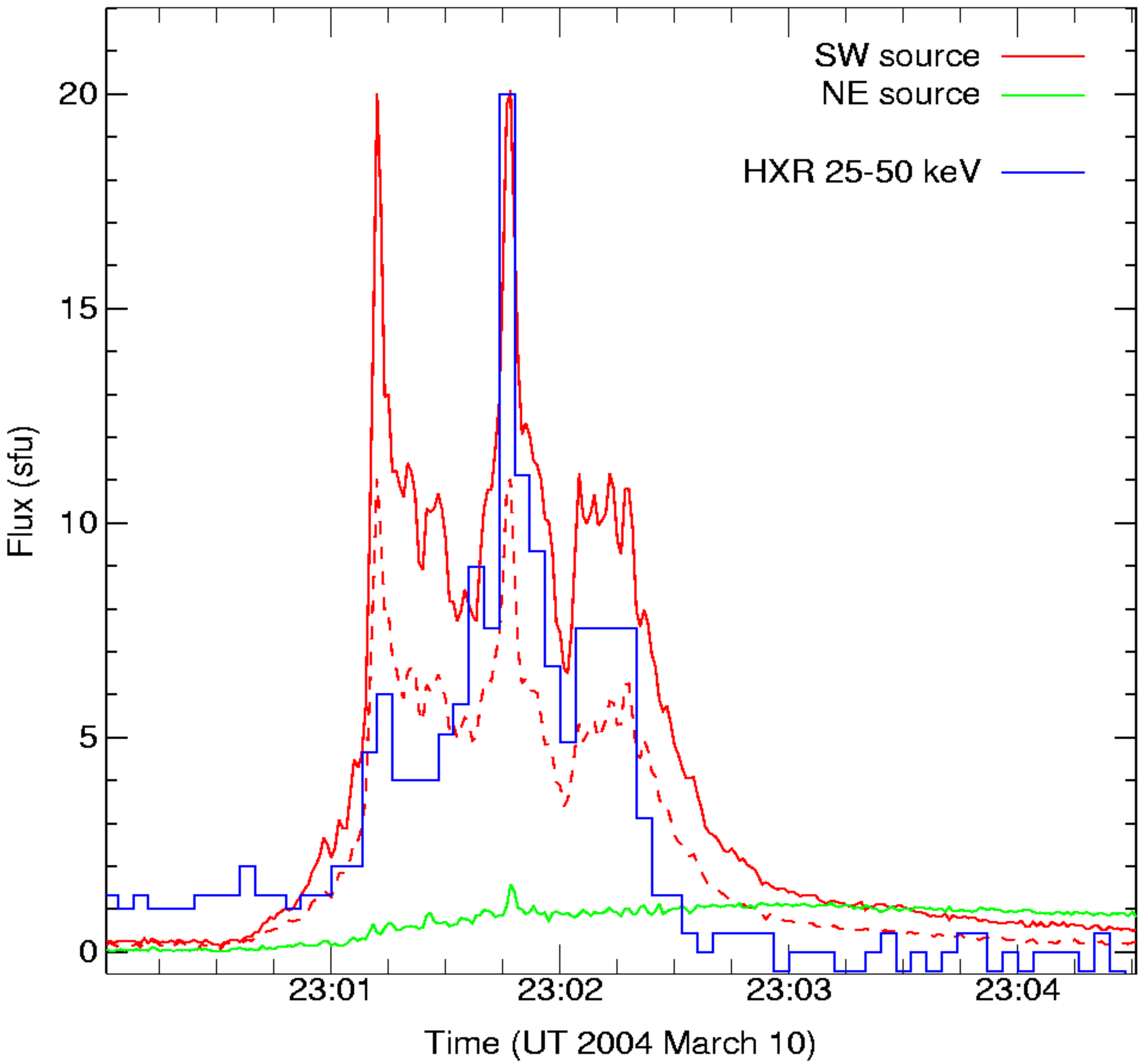


17 GHz north source
17 GHz south source / 2 delayed 0.9 s
34 GHz south source / 2 delayed 0.9 s
Radio flux (sfu)
10
8
6
4
2
0
Time (UT)
06:29:20
06:29:30
06:29:40
06:29:50
7.00
6.90
6.80
6.70
6.60
06:29:44
06:29:45

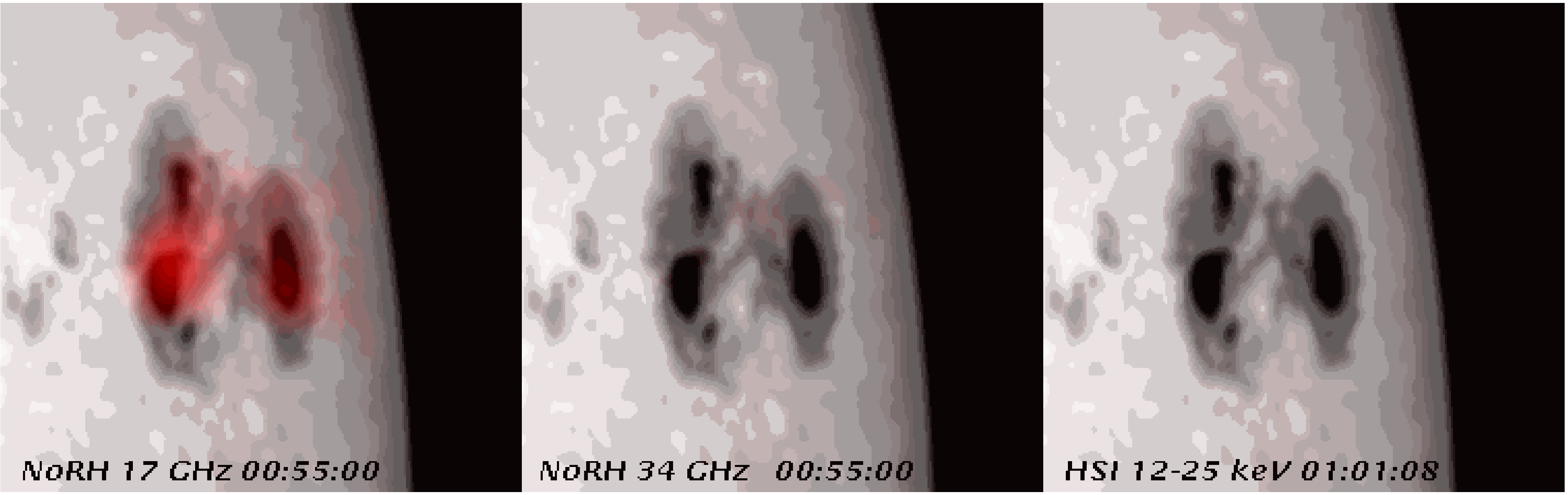

23:00:01
Nobeyama 17 GHz images

NoRH 17 GHz on RHESSI 25-50 keV

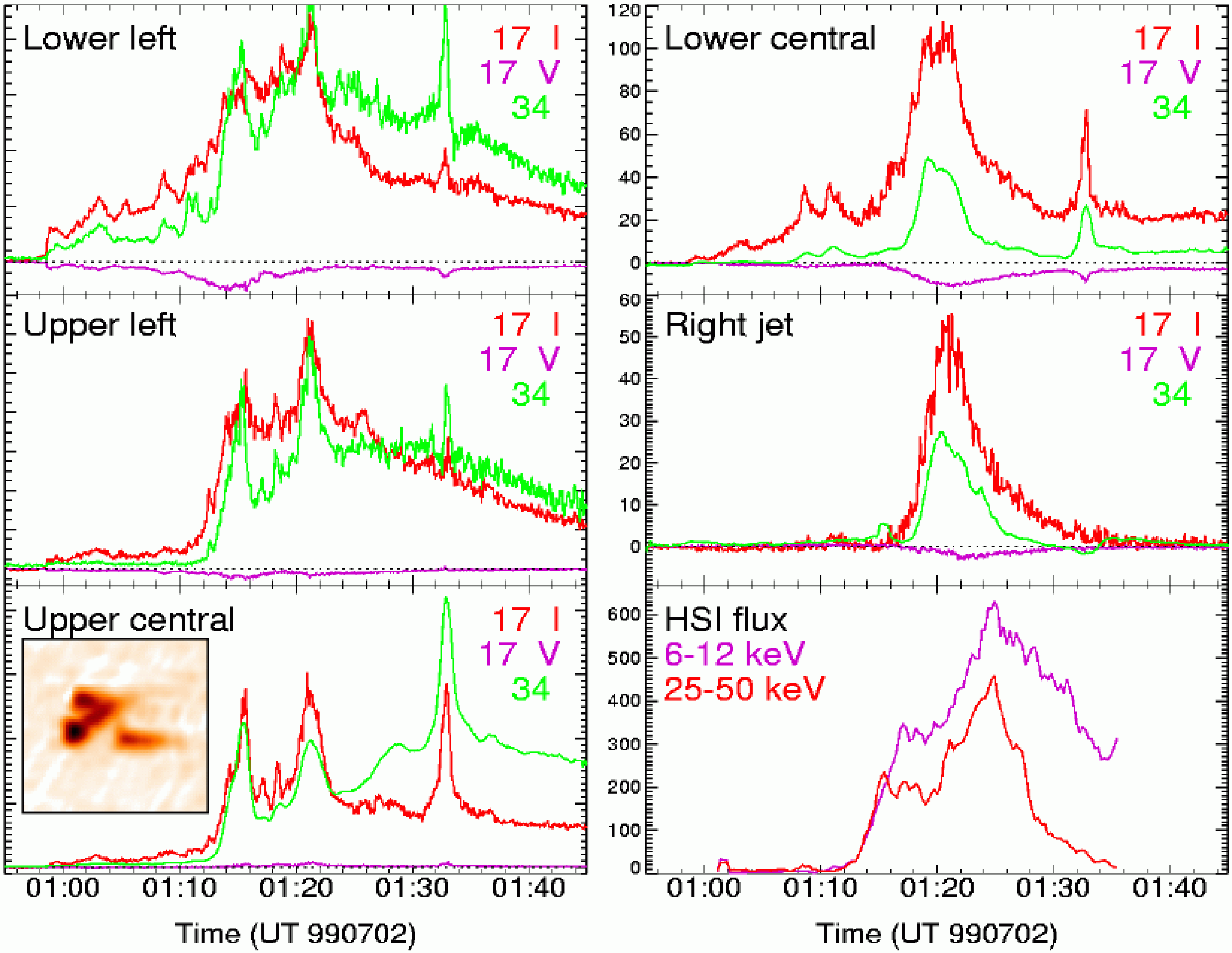



SW source
NE source
HXR 25-50 keV
Flux (sfu)
0
5
10
15
20
23:01
23:02
23:03
23:04
Time (UT 2004 March 10)

2003 Nov 3 flare: 17 + 34 GHz + 12-25 keV



25-50 keV images look like 12-25 keV



Lower left
17 I
17 V
34
Upper left
17 I
17 V
34
Upper central
17 I
17 V
34
Lower central
17 I
17 V
34
Right jet
17 I
17 V
34
HSI flux
6-12 keV
25-50 keV
0
50
100
150
200
0
20
40
60
80
100
120
140
0
100
200
300
400
0
20
40
60
80
100
120
0
10
20
30
40
50
60
0
100
200
300
400
500
600
01:00
01:10
01:20
01:30
01:40
Time (UT 990702)
01:00
01:10
01:20
01:30
01:40
Time (UT 990702)

Joint Discussion: WG2 and WG3

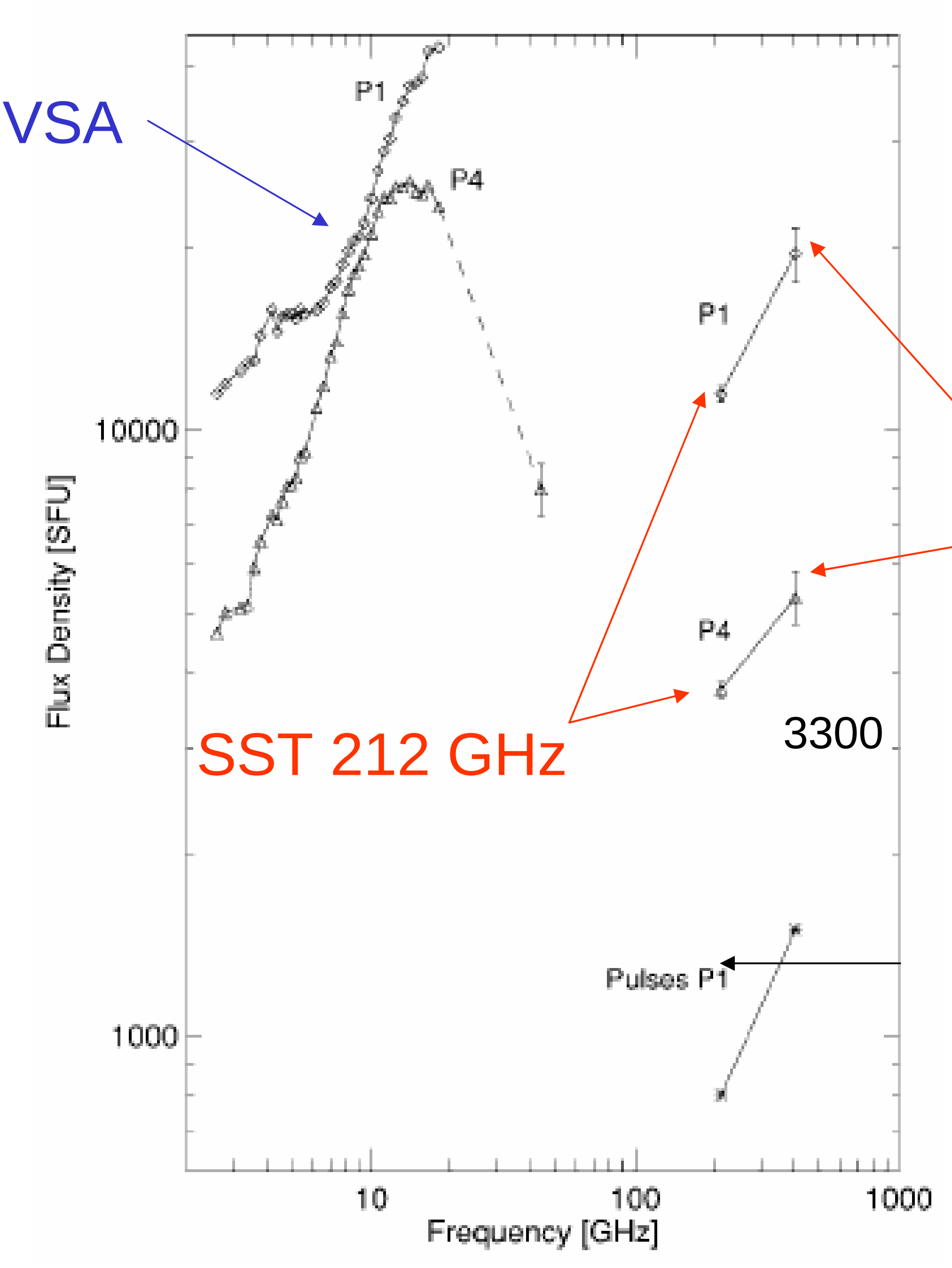
The High Frequency Radio Component in Large Flares

Gerard Trottet: millimeter data, interpretations

Ron Murphy: high-energy pions

Tim Bastian: possibility of a thermal explanation

4 November 2003



OVSA

SST 212 GHz

SST 405 GHz

3300

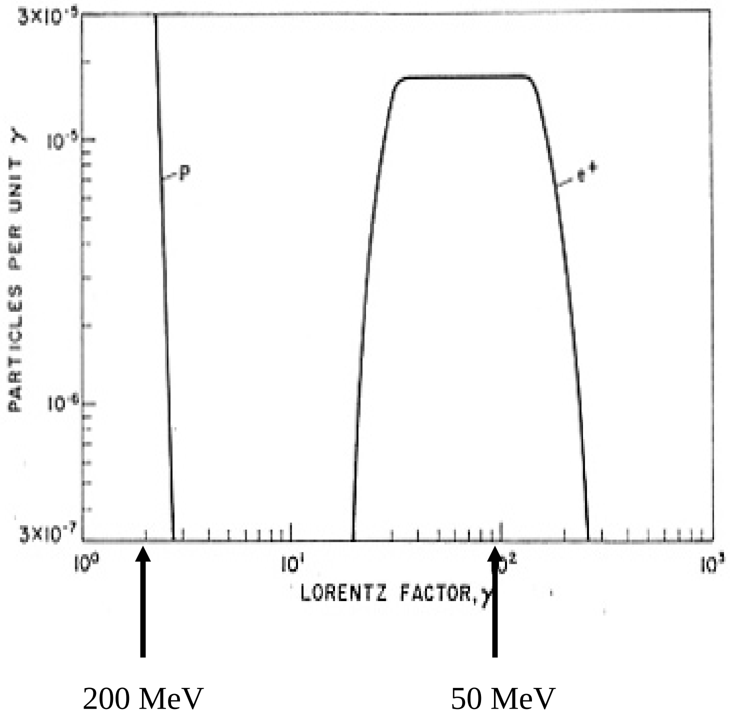
Largest SXR flare recorded: X28, possibly as large as X45 (Neil et al. 2004, Burton et al 2005).

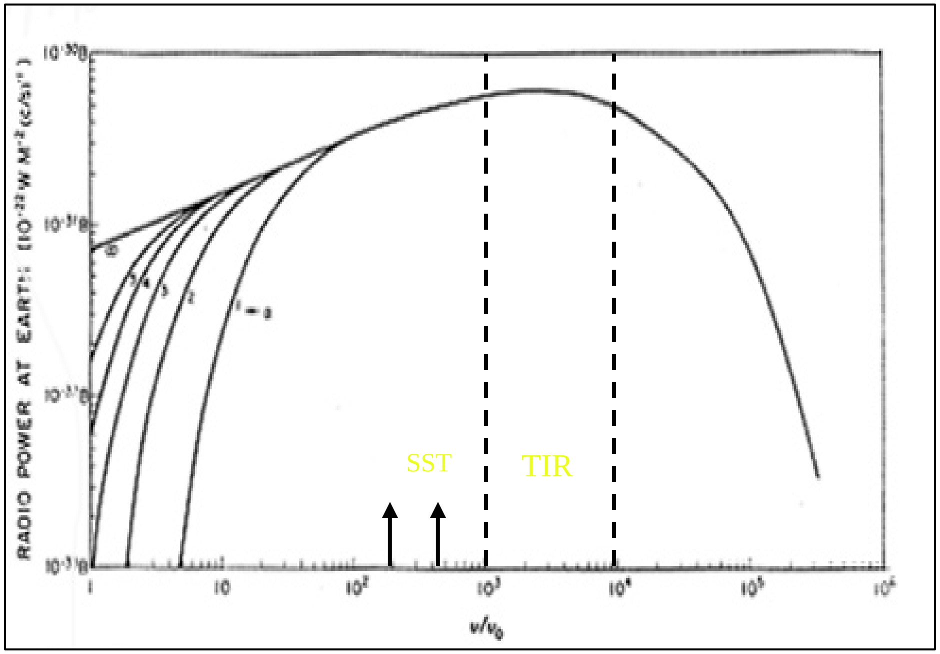
Kaufmann et al. 2004

Increasing spectra above 200 GHz ?

- Optically thick gs. From e^- ⇒ compact and very dense sources with high magnetic field: **unrealistic numbers of high energy electrons!**
- gs. from positrons (Lingenfelter & Ramaty 1967)
- Inverse Compton/gs (Kaufmann et al. 1986)
- Thermal: optically thick free-free emission: **energy deposition in the chromosphere by particles or conduction fronts**

Example of gs from positrons (Lingenfelter & Ramaty 1967)





B=400 G

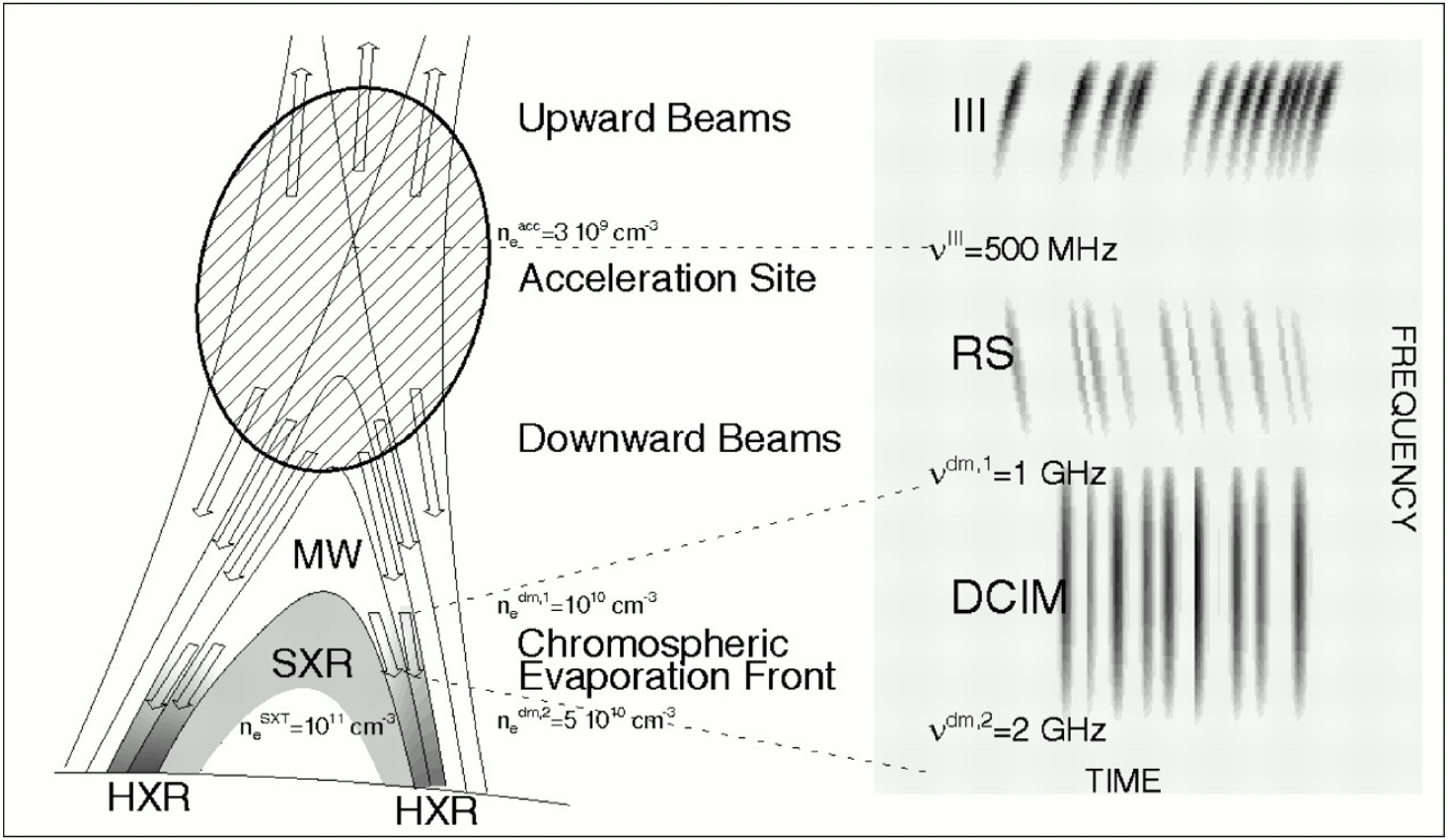
←⮟B➢→

The submm-λ source is manifestly composed of contributions from several sources:

- The SXR-emitting plasma must contribute at least 2000 sfu to each of 212 and 405 GHz
- There is clearly a nonthermal component, estimated to be of order 3300 sfu at 212 GHz and perhaps 1500 sfu at 405 GHz
- The bulk of the remainder could be accounted for by the sum of optically thick and optically thin contributions of material at temperatures from TR to SXR-emitting values.

$$S_\nu = 2k_B \frac{\nu^2}{c^2} \int_{source} d\Omega \int_0^\infty T_{eff} e^{-\tau} d\tau \rightarrow 2k_B \frac{\nu^2}{c^2} \sum_i T_i (1 - e^{-\tau_i}) \Omega_i$$

Electrons going both up and down from energy release site



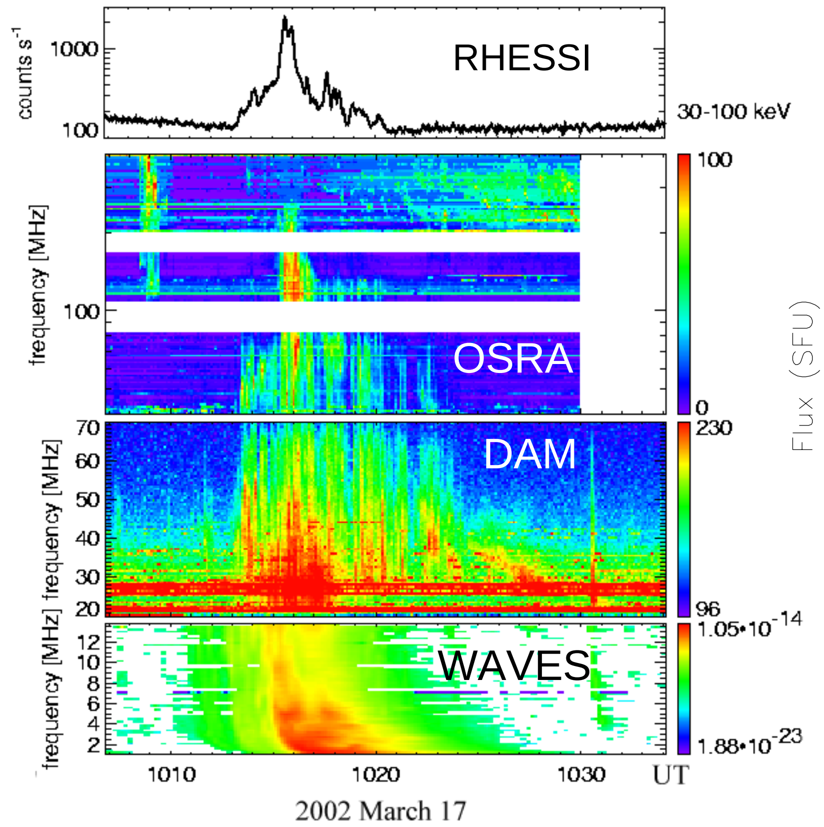
Radio bursts and CME’s

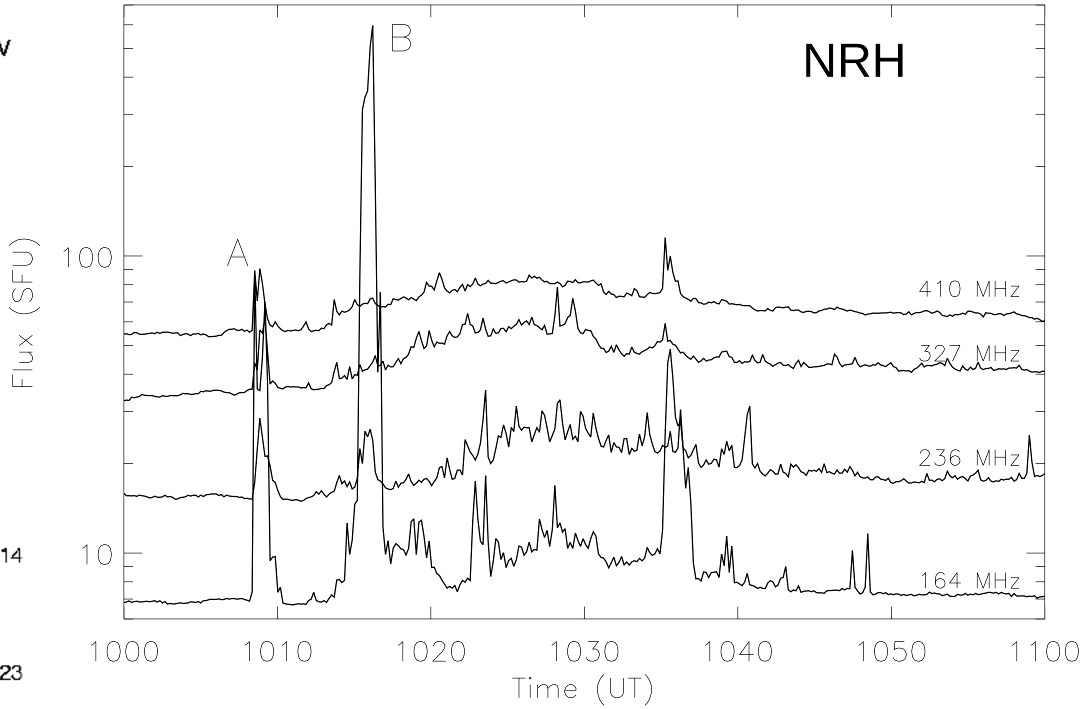
Monique Pick

RHESSI workshop 5-8 April 2006

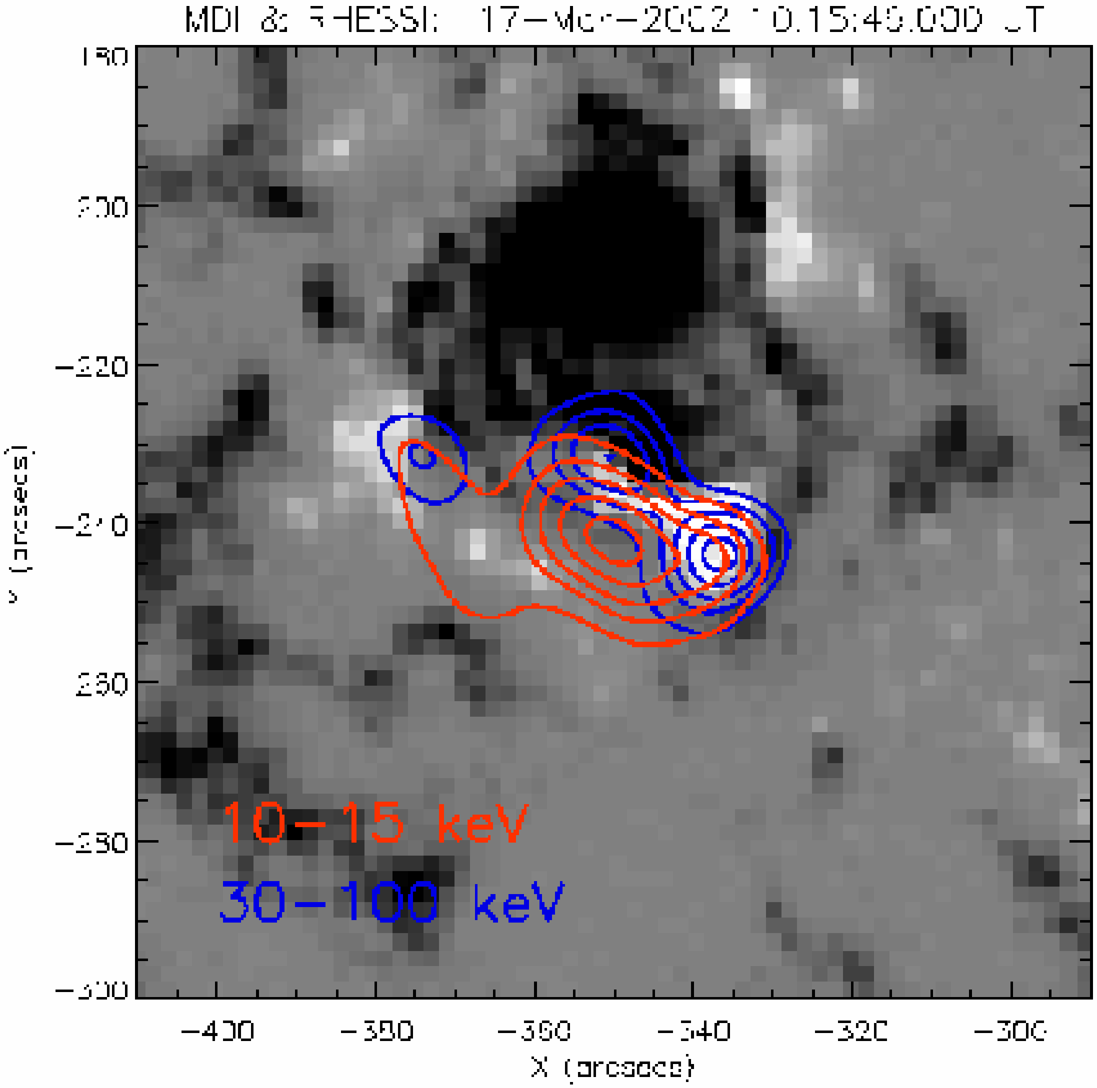
17 March 2002

Y. Yan, M. Pick, M. Wang, S. Krucker, A. Vourlidas





17 March 2002
RHESSI



HXR

West source + polarity

East and middle sources mixed polarity

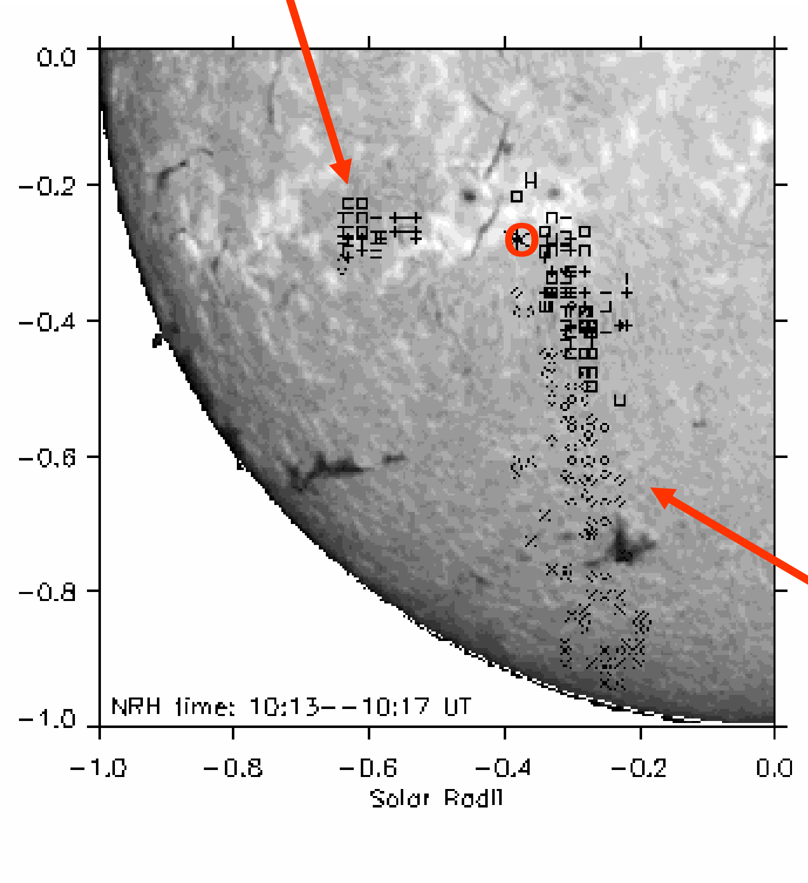
SXR

Outline 2 adjacent loops

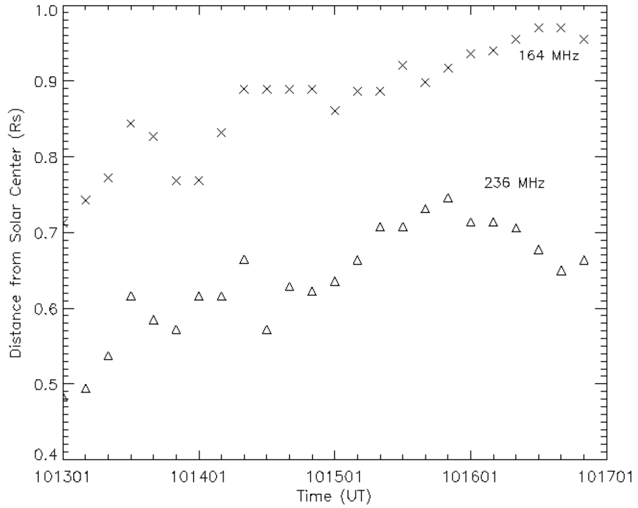
3 HXR sources at foot points

17 March 2002 Event B

Continuum

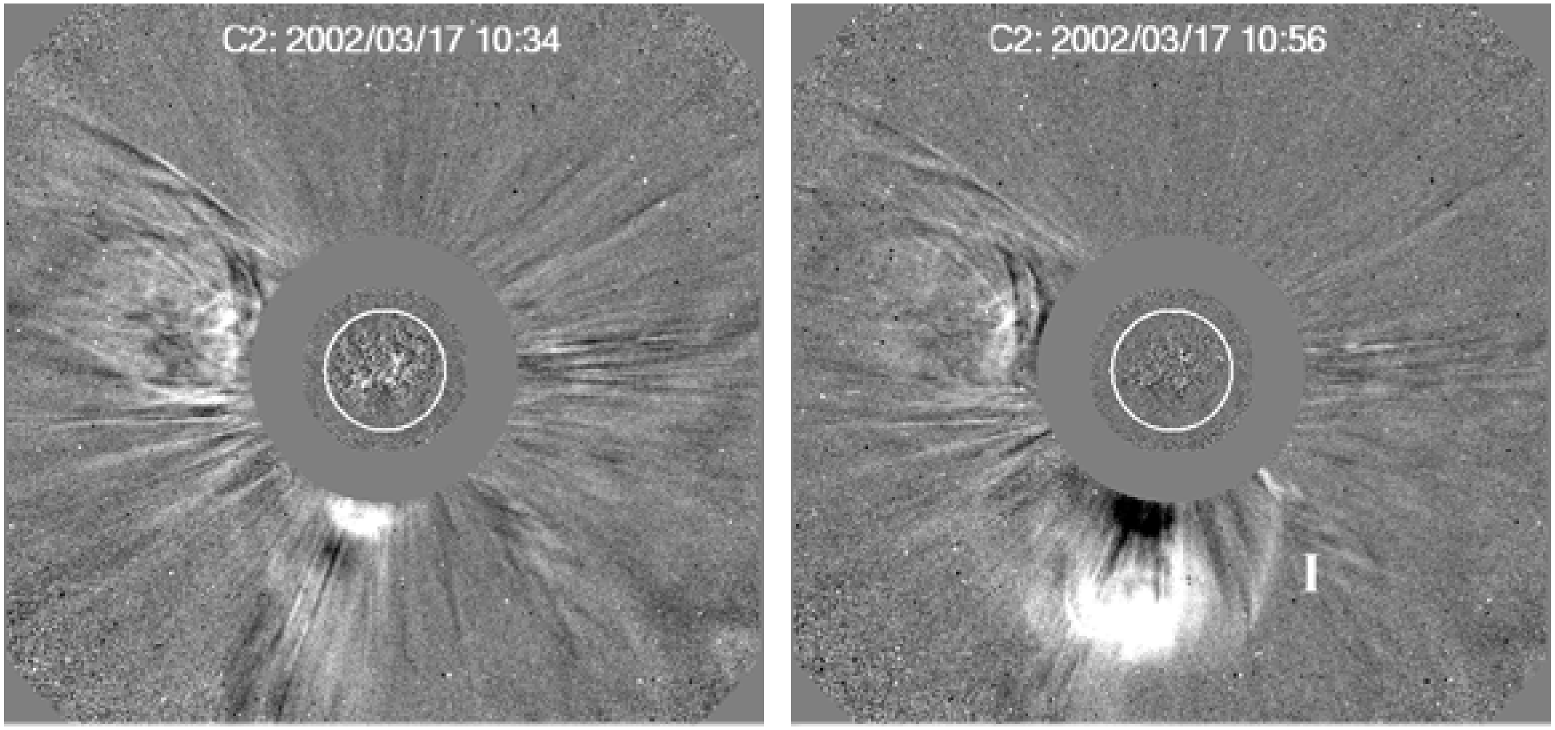


Type III's



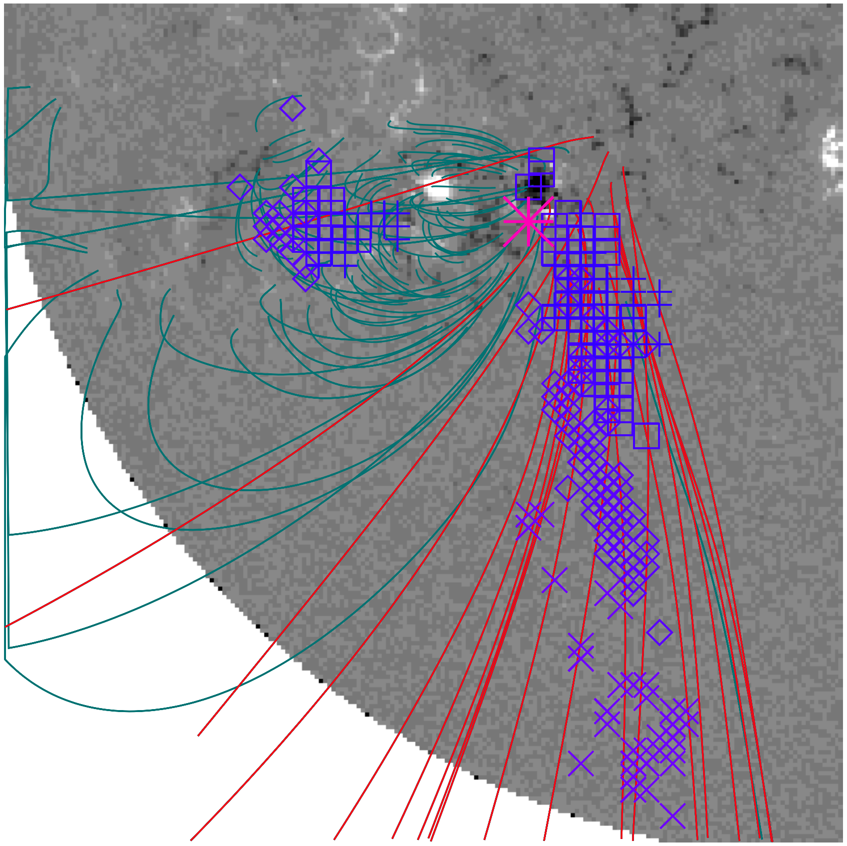
236 MHz

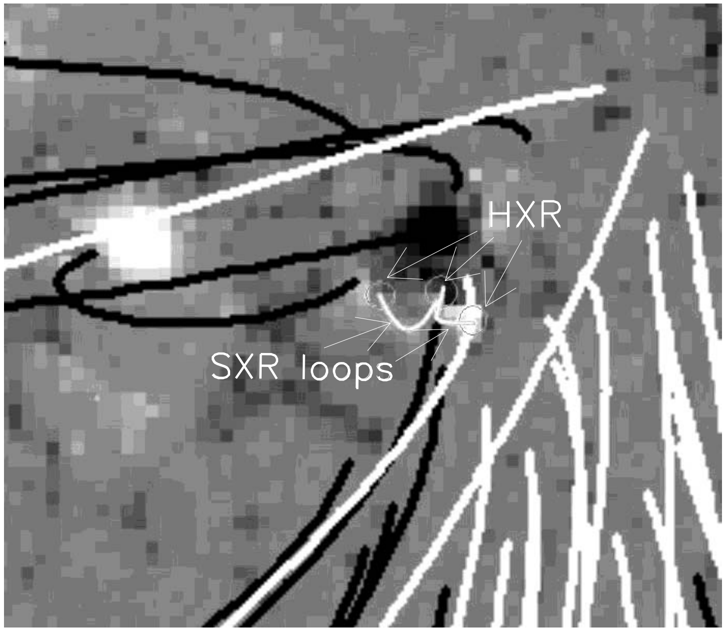
Cadence 1s 600 km/s


C2: 2002/03/17 10:34
C2: 2002/03/17 10:56
I

17 March 2002 Event B

- AR 9871 inside old remnant region
- Inclusion of small interacting loops
- CME above large extrapolated S loops





HXR

- West source + polarity
- East and middle sources mixed polarity

SXR

- Outline 2 adjacent loops « W » shape

HXR and Radio: Temporal relationship

Sprangle &Vlahos, 1993 EM excited by unstable electron distribution inside the flaring loop and excite electrons along Open fields.

17 March 2002

HXR and Type III same electron population

- Small loops emerge(1 or 2) interact with surrounding open field lines
- HXR produced by electrons propagating downward
- Outward electron beams propagate in the interface region between the ascending CME and the neighboring open field lines
- Development of CME → this region becomes highly compressed
- TypeIII 2fp → starting and ending altitudes at each frequency
- Apparent motions of type III bursts increase in density 10 (4 at 164 MHz) Newkirk model

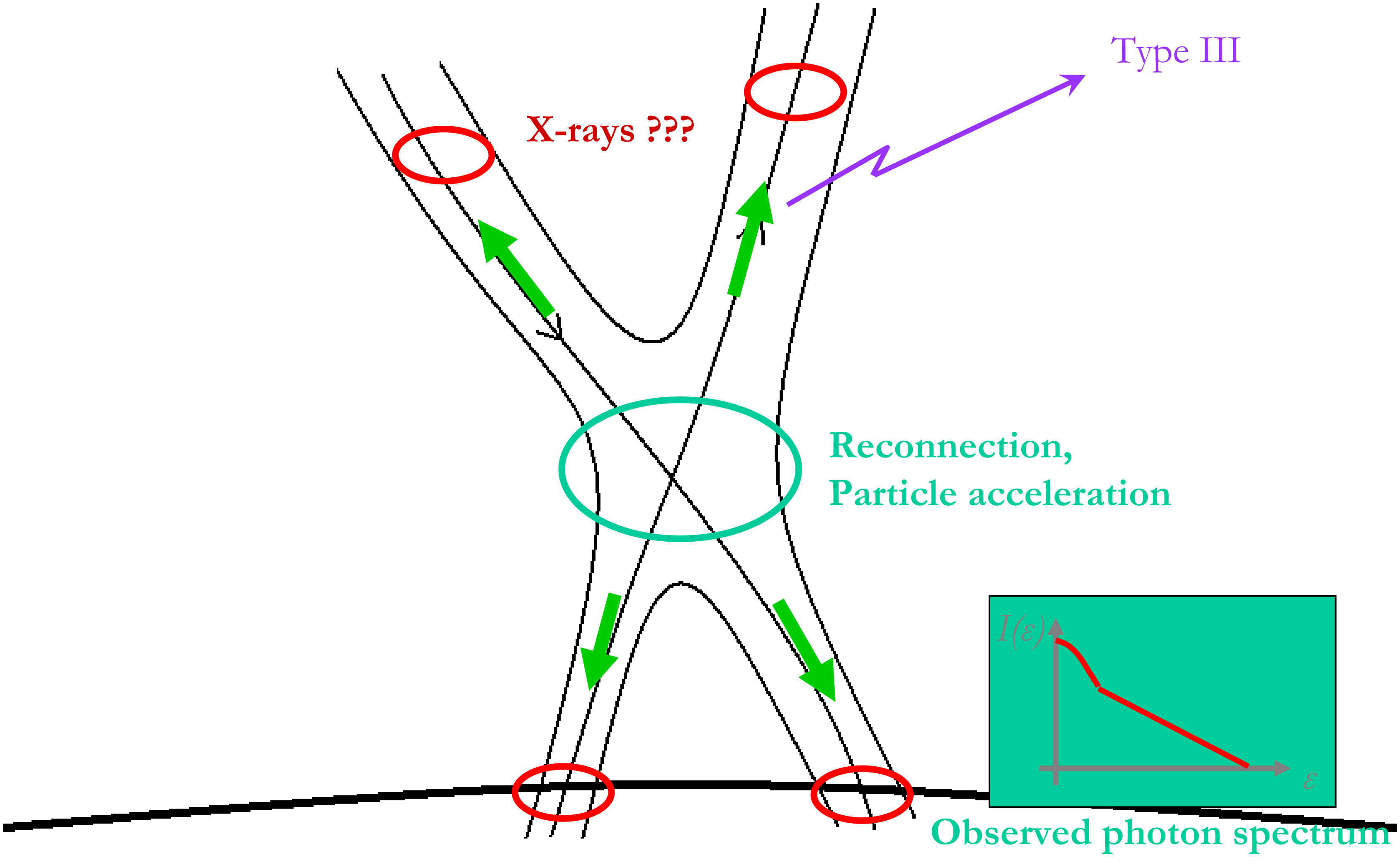
Search for X-ray emission from coronal electron beams associated with type III radio bursts

Pascal Saint-Hilaire, Säm Krucker, Robert P. Lin

Space Sciences Laboratory, University of California, Berkeley

Sixth RHESSI Workshop
Meudon, April 5th, 2006

Standard flare scenario:



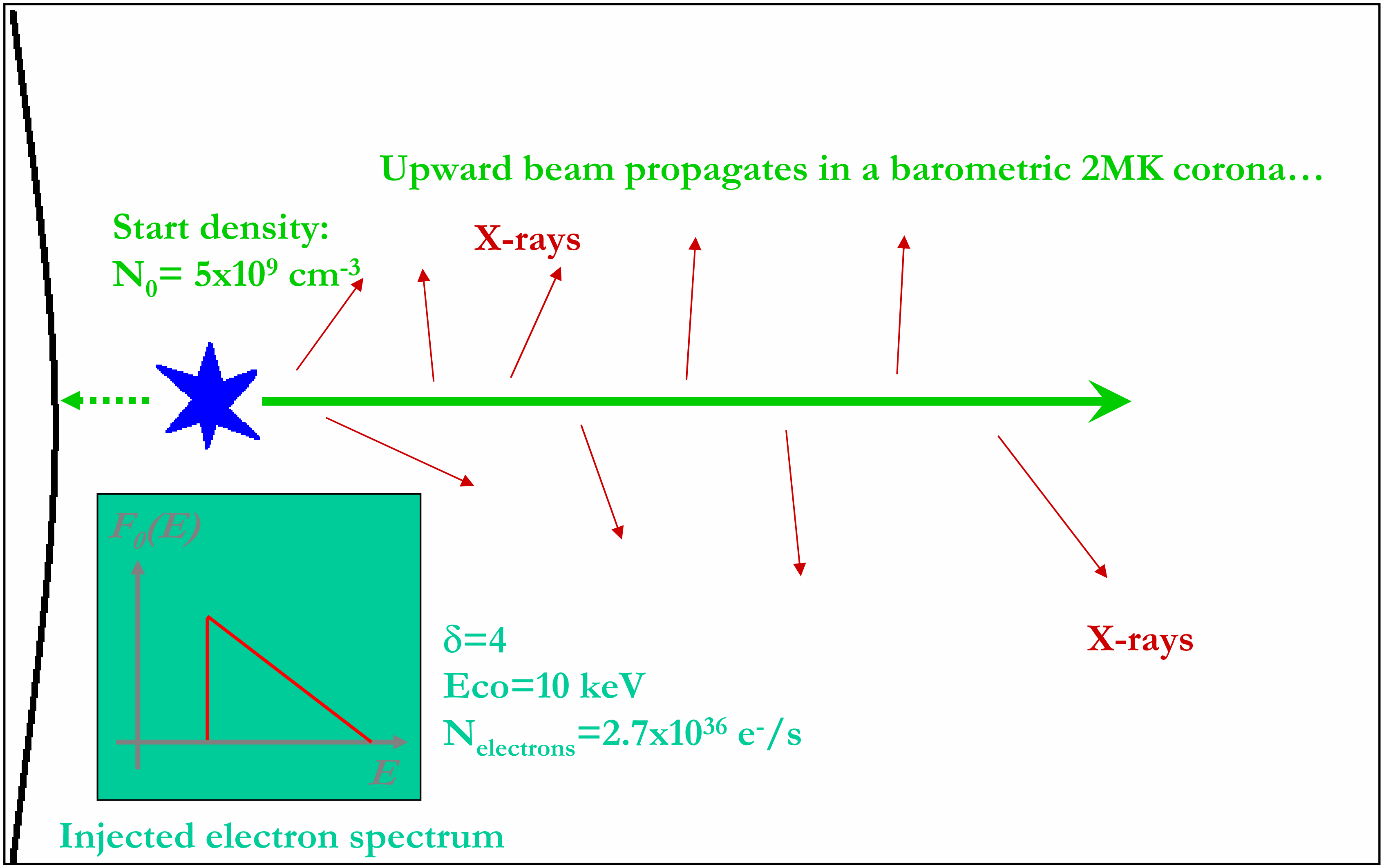
Type III

X-rays ???

Reconnection,
Particle acceleration

Observed photon spectrum

Model:



Upward beam propagates in a barometric 2MK corona…

Start density:
$N_0 = 5 \times 10^{9}$ cm^{-3}

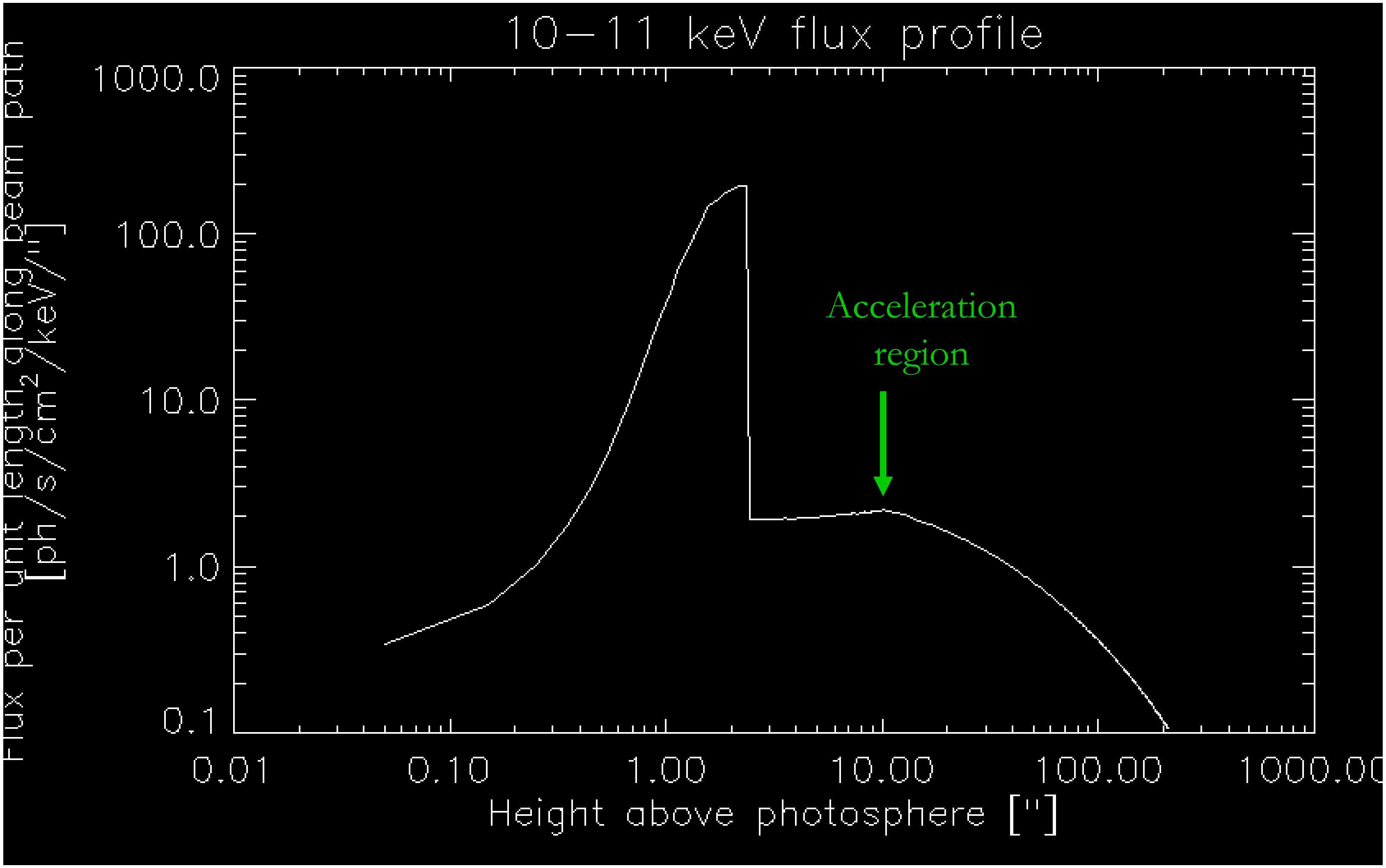
X-rays

$\delta=4$
Eco=10 keV
$N_{electrons} = 2.7 \times 10^{36}$ e^{-}/s

X-rays

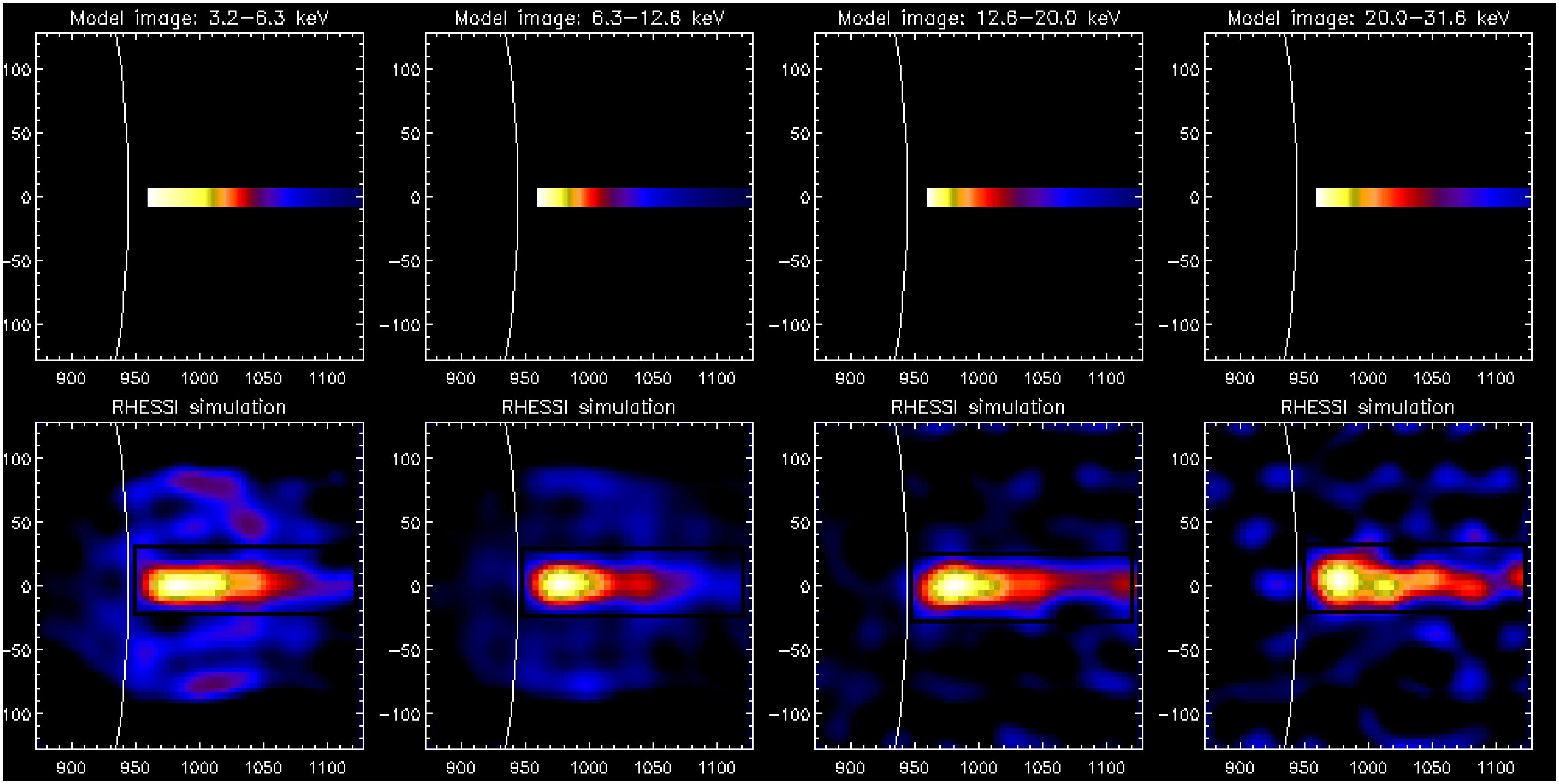
Injected electron spectrum

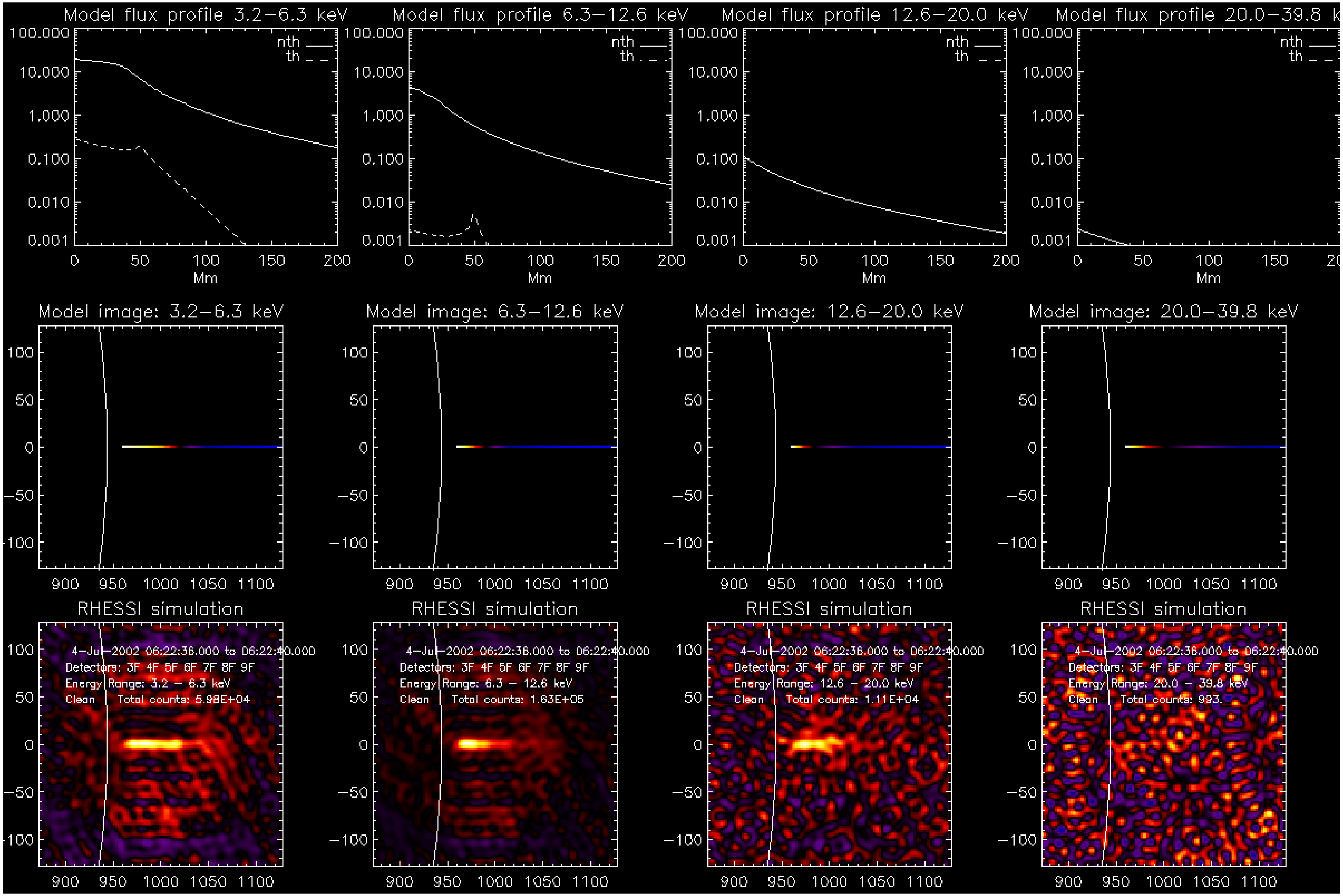
Combined, symmetric downward and upward beam:



→ Need flares with occulted footpoints!

N_0=5x10^9 cm^{-3}, δ=4, Eco=10 keV, N_{beam}=2.7x10^{36} electrons/s, dt=4s





δ=7 (→ elongated structure less obvious)

Summary 1: Modeling

- Flare-like “upwards-going” coronal electron beams should be observable
- Coronal beam heating due to beam only observable when local densities are high (10^{11} cm^{-3})
- Best candidates are occulted flares (→ limb)
- At limb, elongated structures are expected (best: small δ)

Observations:

- Start point: list of decimetric radio bursts from Phoenix-2 spectrometer (ETH Zurich)
- → 867 type III bursts between RHESSI launch and June 2005.
- 326 were also observed by RHESSI, with attenuator state 0.
- Take the ones that have X-ray sources above the solar limb

→ 29 candidates

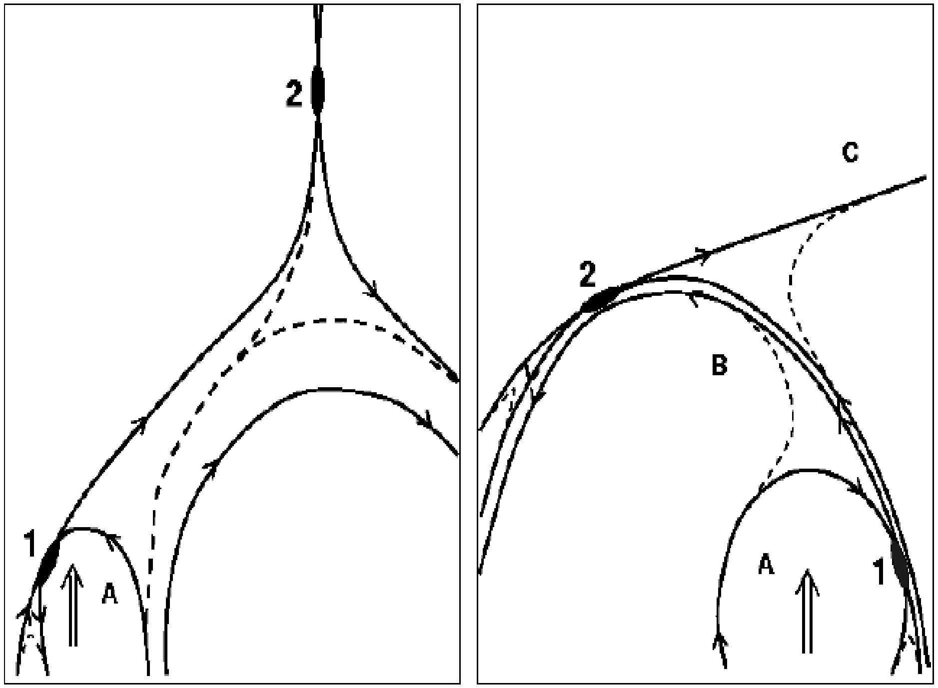
Conclusion so far…

- No clear Type IIIs associated with limbic electron beams propagating outwards (using X-rays as proxy) have been found so far. Statistically, a few were expected. Will use NRH 900ms data…
- RHESSI imaging requires ~10^{35} electrons/s
- For detection, about 5×10^{33} electrons/s [above 10 keV] are needed. Just the fact that Type IIIs and HXR lightcurves are *rarely* time-correlated means we rarely have that many electrons in the Type III-producing beam…
- In agreement with previous estimations: interplanetary Type III-emitting electron beams contain only ~10^{31} electrons/s (Lin, 1973) : product of a (secondary) reconnection process higher up in the corona?

Two (simultaneous) reconnection sites?

2: Secondary reconnection site:
~10^{31} electrons/s

1: Main energy release site
(main driver):
$10^{35\text{-}36}$ electrons/s



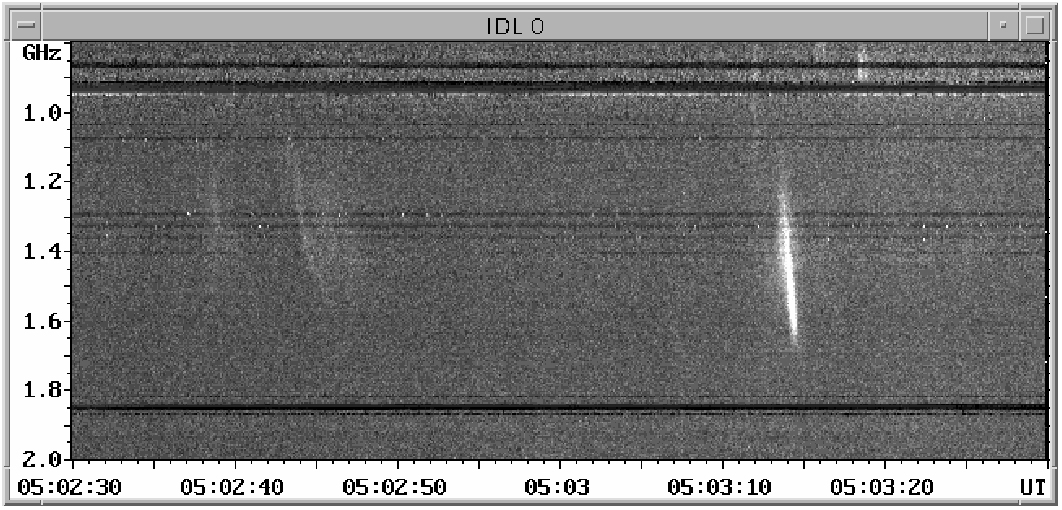
Benz et al., 2005

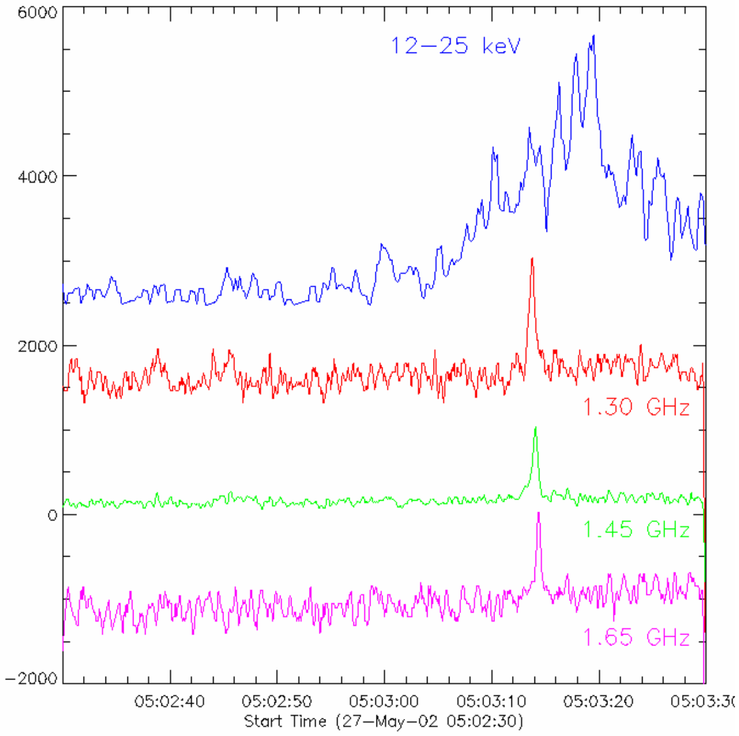
Reverse Drift Bursts in the 0.8-4.5 GHz Band and their Relation to X-Rays

František Fárník and Marian Karlický

Astronomical Institute
Academy of Sciences
251 65 Ondřejov
Czech Republic
ffarnik@asu.cas.cz karlicky@asu.cas.cz

First exampl 27 May 02



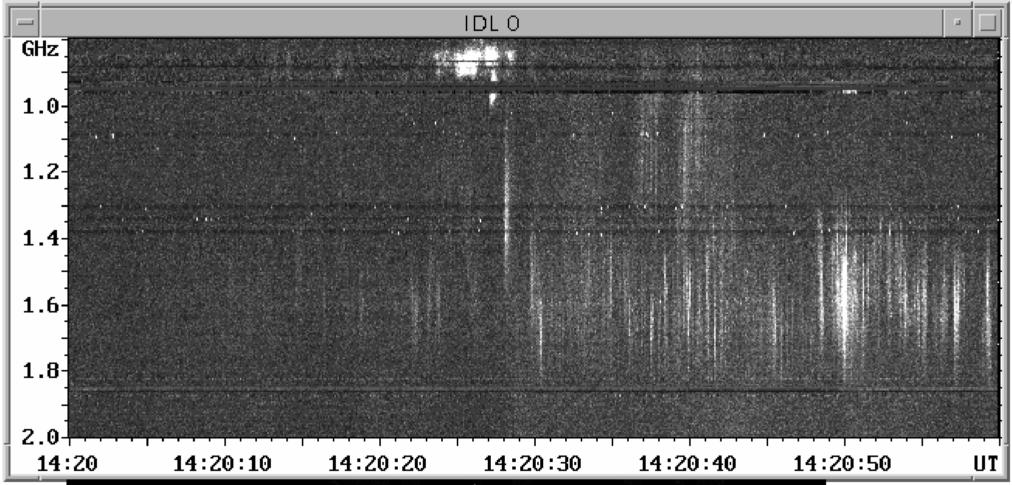


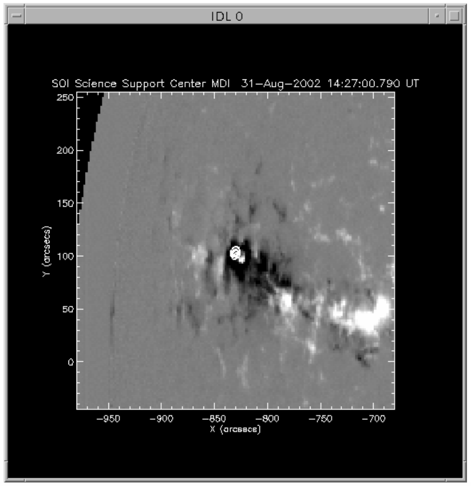
Typical features of many events in our data set:

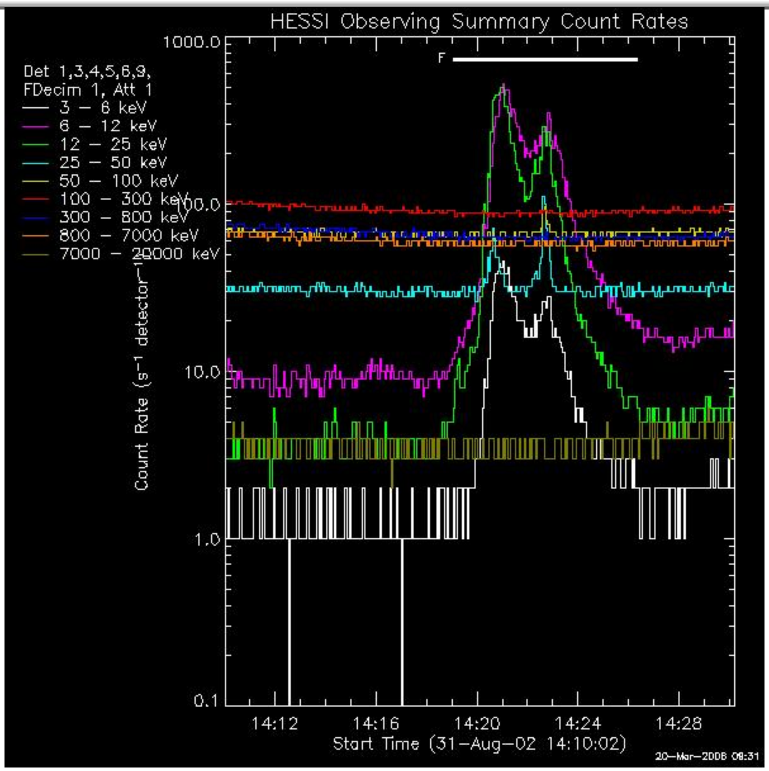
*** very weak hard X-ray emission, short and nearly symmetrical profile**
*** compact hard X-ray source**
*** soft X-ray importance C**
*** high frequency drift**
*** RDBs during the rise phase in RHESSI flux**
*** RDBs are nearly always observed during the hard X-ray burst but it seems to be impossible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

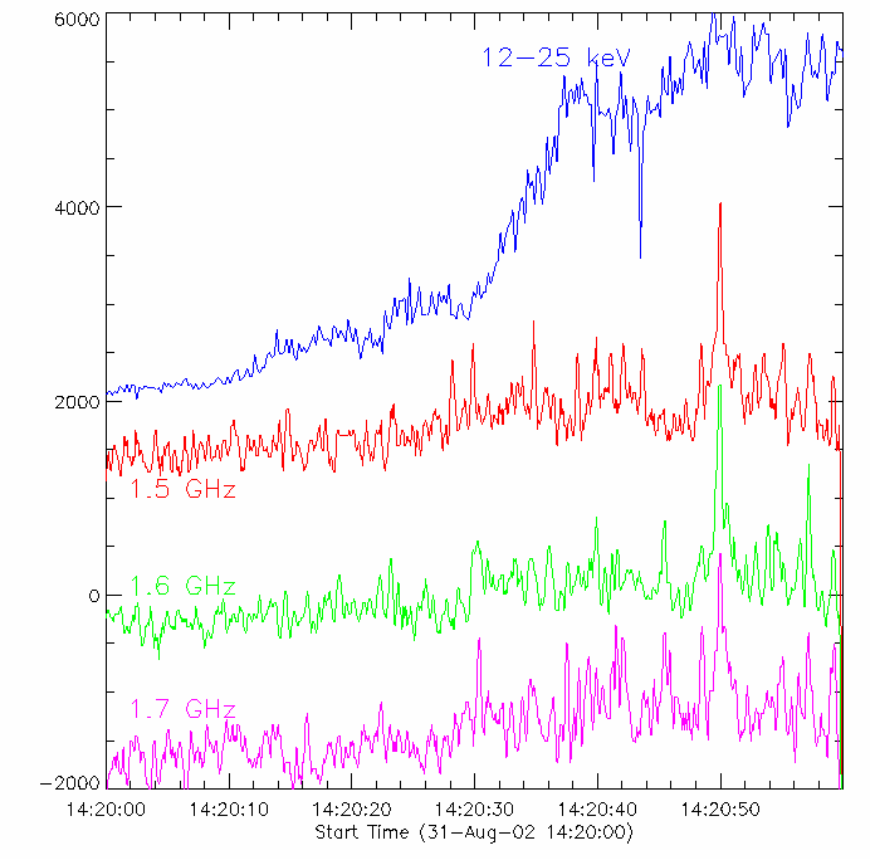
A few other examples:

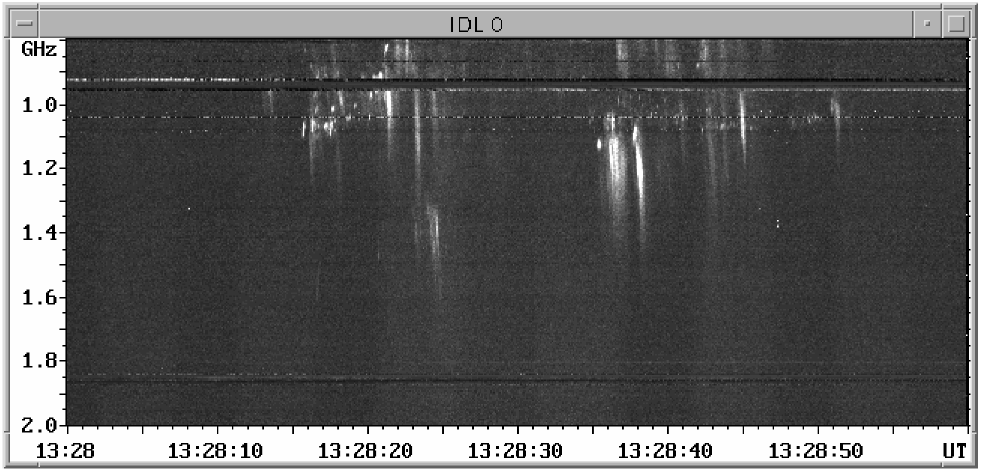
31 AUGUST 2002

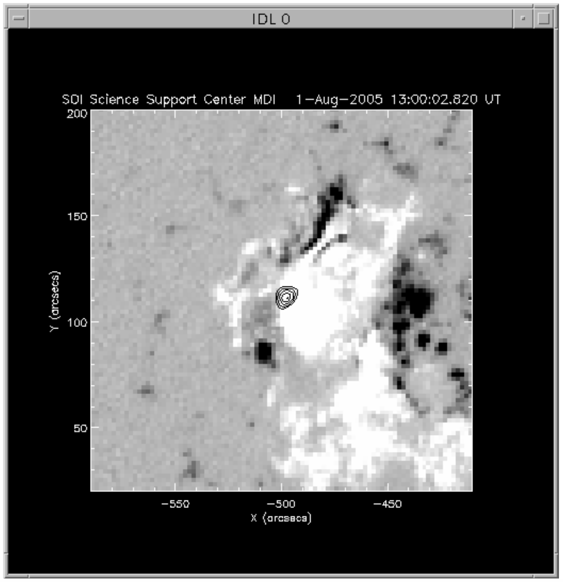


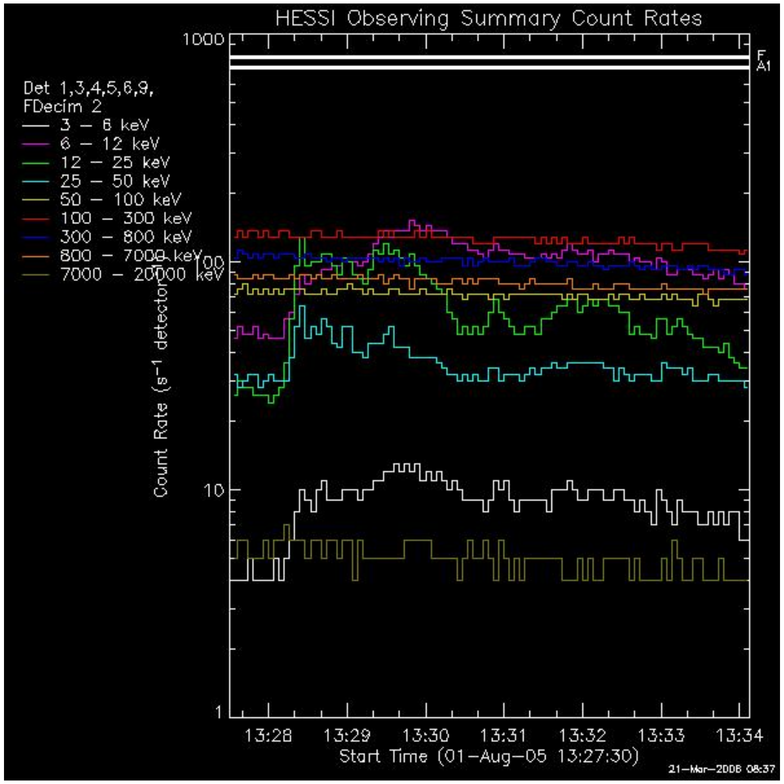


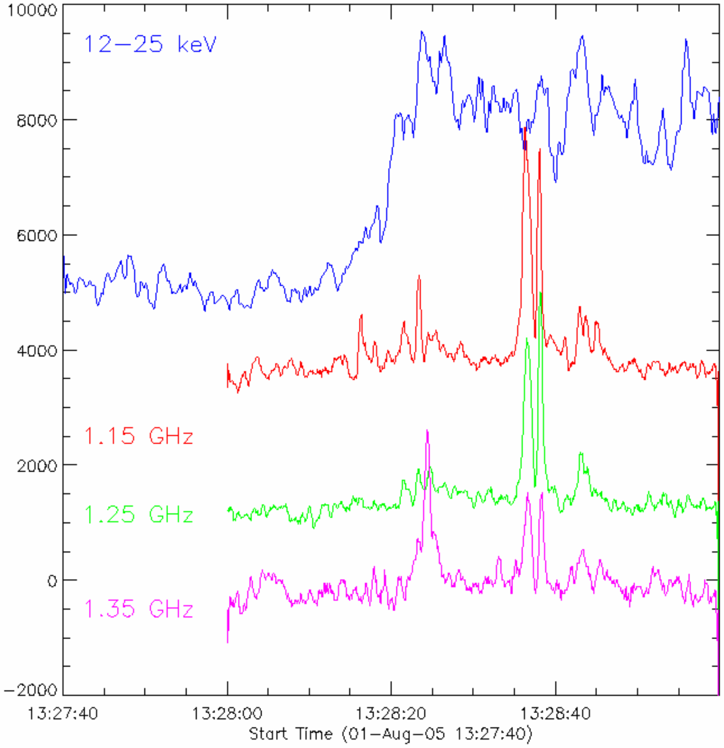





IDL 0
GHz
1.0
1.2
1.4
1.6
1.8
2.0
13:28
13:28:10
13:28:20
13:28:30
13:28:40
13:28:50
UT


IDL 0
SOI Science Support Center MDI 1-Aug-2005 13:00:02.820 UT
200
150
100
50
Y (arcsecs)
-550
-500
-450
X (arcsecs)


HESSI Observing Summary Count Rates
Det 1,3,4,5,6,9,
FDecim 2
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
1000
100
10
1
Count Rate (s^{-1} detector^{-1})
F
A1
13:28
13:29
13:30
13:31
13:32
13:33
13:34
Start Time (01-Aug-05 13:27:30)
21-Mar-2006 08:37


10000
8000
6000
4000
2000
0
-2000
12-25 keV
1.15 GHz
1.25 GHz
1.35 GHz
13:27:40
13:28:00
13:28:20
13:28:40
Start Time (01-Aug-05 13:27:40)

CONCLUSIONS

- Reverse Drift Bursts are mostly observed during the rise (flash) phase of hard X-ray emission.

- 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.

Fin