ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
Εθνικόν και Καποδιστριακόν
Πανεπιστήμιον Αθηνών

Ηλιακή Φυσική

Ενότητα 3: Ατμόσφαιρα του ήλιου

Ξενοφών Δ. Μουσάς

Σχολή Θετικών Επιστημών

Τμήμα Φυσικής

ARTEMIS IV

ο ηλιακός ραδιοφασματογράφος που παρατηρεί τον Ήλιο σε συχνότητες από 20 μέχρι 650 MHz 365 ημέρες το έτος από το πρωί βρέξει χιονίσει

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J.-L.Bougeret 4, M. Maksimovic 4, R. Romagnan 4, A. Bouteille 4, G. Dumas 4, M. Pick 4 and K.L. Klein 4

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Ευχαριστίες

Ιδιαίτερες Ευχαριστίες οφείλονται στη NASA, ESA, ESO, NOAO/NSO/Kitt Peak FTS/AURA/NSF

στους Ερευνητές και λοιπούς συντελεστές των επιγείων τηλεσκοπίων και διαστημικών πειραμάτων, στην κυρία Παν. Πρέκα Παπαδήμα, στους κυρίους Αλ. Χείλαρη, Αθ. Κοντογεώργο, Παν. Τσιτσιπή, Πάνο Παπασπύρου για τις ενδιαφέρουσες συζητήσεις, σε αυτούς που μας έδωσαν μετρήσεις ή συμβουλές, στην Wikipedia για πολλές πολύτιμες εικόνες που προσφέρονται χωρίς δικαιώματα χρήσης και συνεπώς είναι πολύτιμες σε κάθε δάσκαλο.

Ηλιακές ραδιοεκπομπές

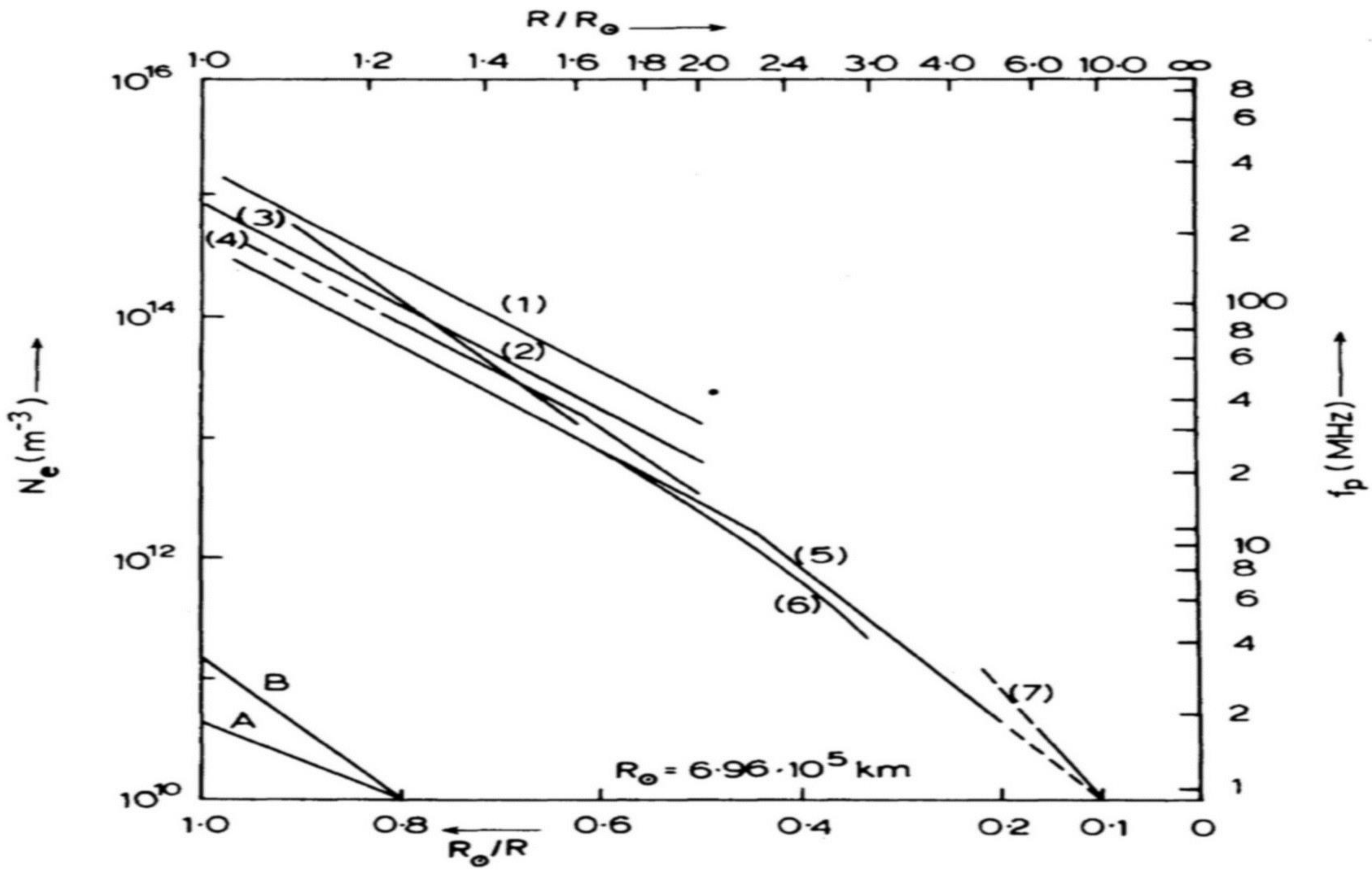
τρεις μηχανισμοί παράγουν Η/Μ ακτινοβολία στο ηλιακό στέμμα

- • Εκπομπή πλάσματος
- • Εκπομπή γυροσύγχροτρον
- • Εκπομπή πέδης

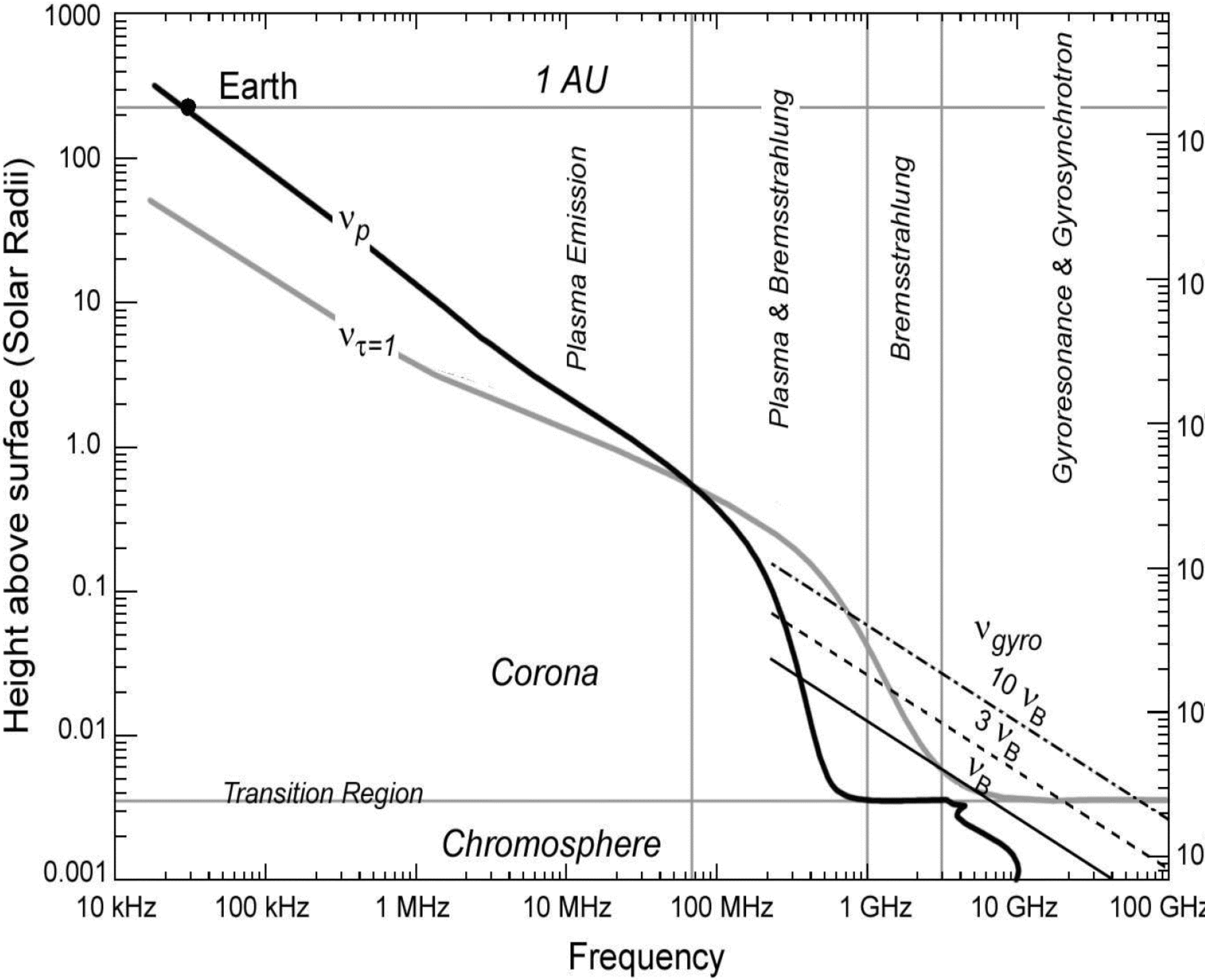
(Krüger 1979).

ARTEMIS IV λειτουργεί στην περιοχή των μετρικών, δεκαμετρικών και δεκατομετρικών ηλεκτρομαγνητικών κυμάτων

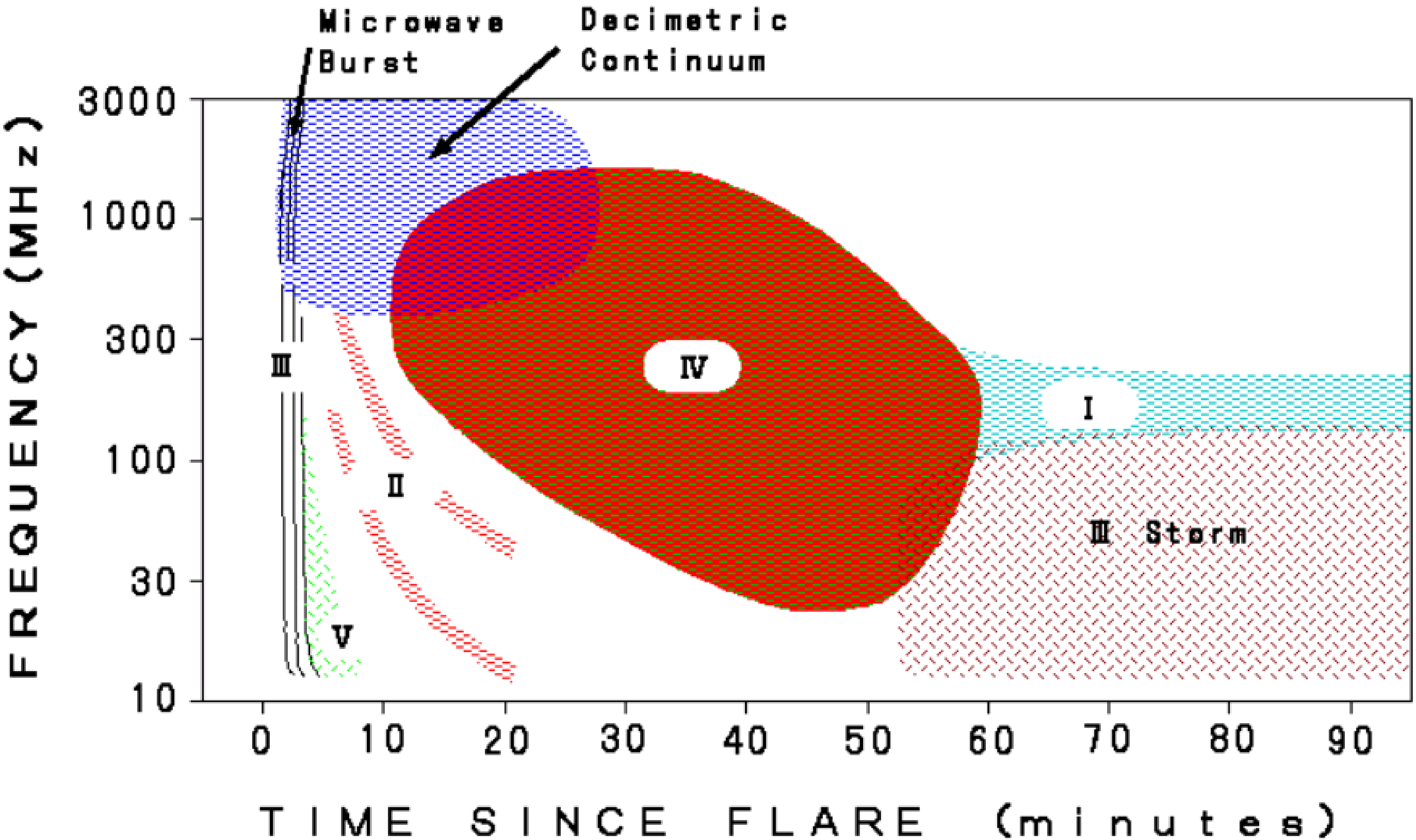
- λειτουργεί ο ηλιακός ραδιοφασματογράφος, επικρατεί Εκπομπή πλάσματος
- και ενίοτε γυροσύγχροτρον
- Εκπομπή πέδης επικρατεί στην εκπομπή του ήρεμου ήλιου.



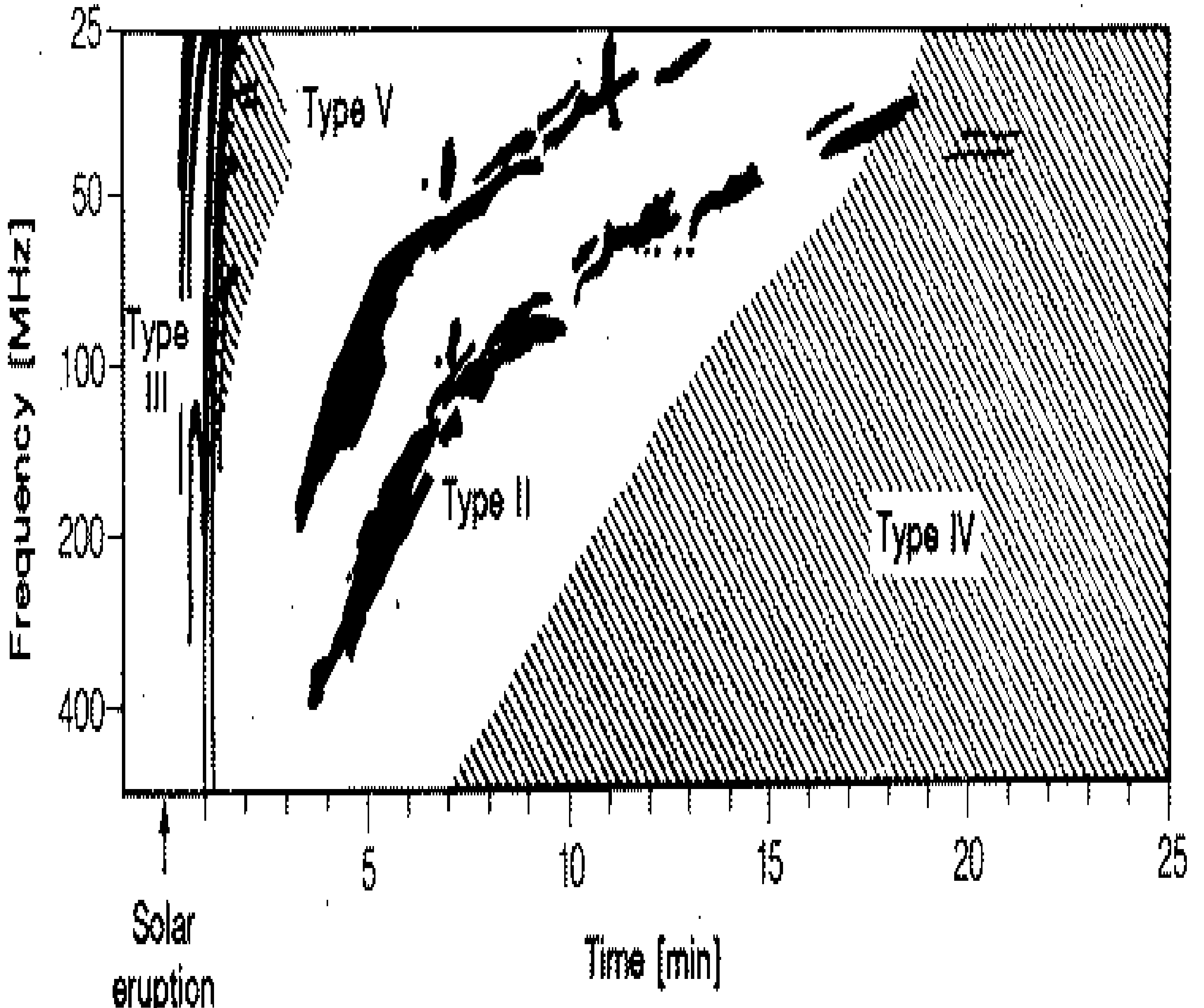
(1) και (2) Newkirk, (3) von Kluber, (4) Ney, (5) van de Hulst, (6) Allen, (7) Blackwell (McLean 1981).



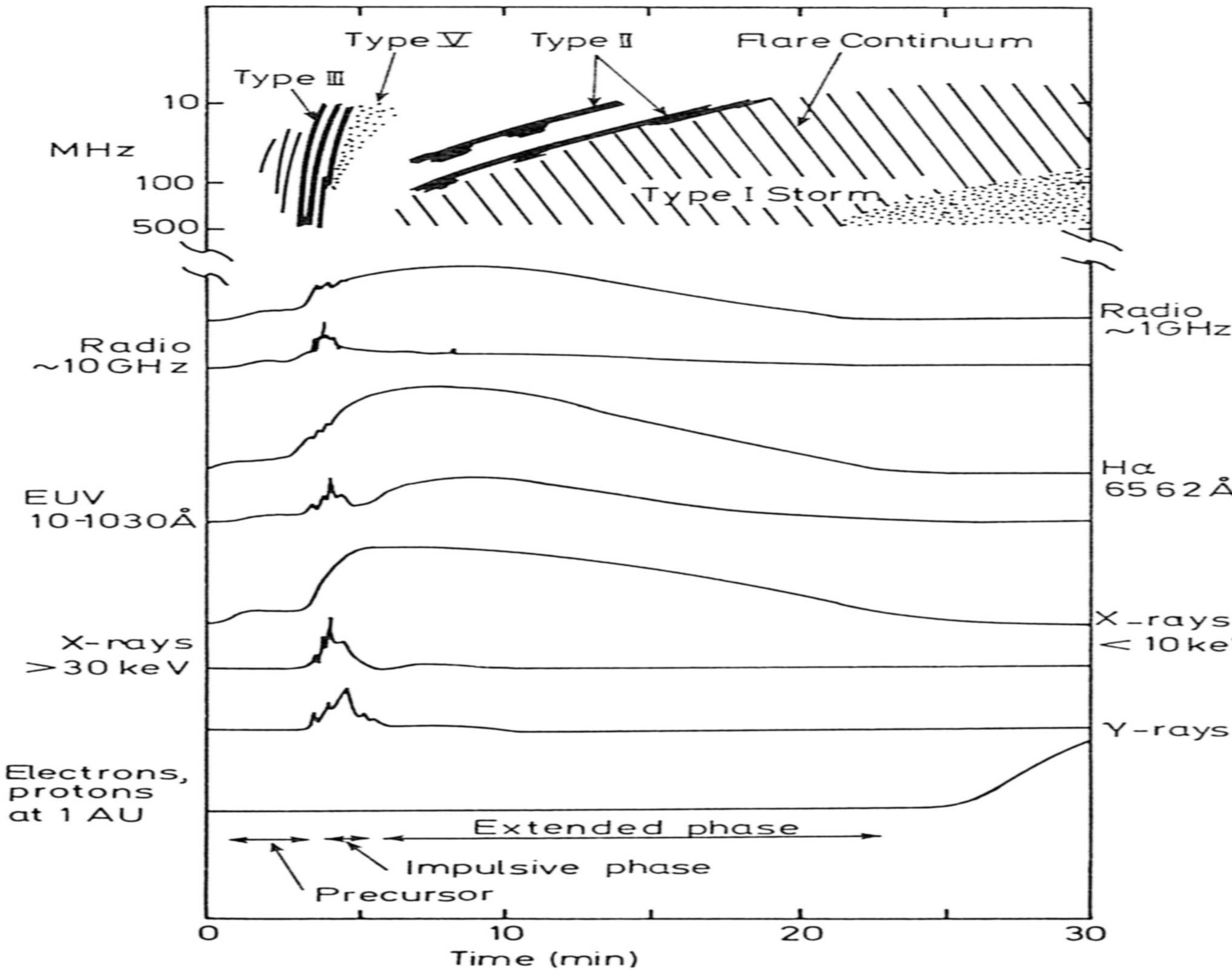
1000
100
10
1.0
0.1
0.01
0.001
Height above surface (Solar Radii)
Earth
1 AU
ν_p
$\nu_{\tau=1}$
Plasma Emission
Plasma & Bremsstrahlung
Bremsstrahlung
Gyroresonance & Gyrosynchrotron
ν_{gyro}
$10\ \nu_B$
$3\ \nu_B$
ν_B
Corona
Transition Region
Chromosphere
10^8
10^7
10^6
10^5
10^4
10^3
Height above surface (km)
10 kHz
100 kHz
1 MHz
10 MHz
100 MHz
1 GHz
10 GHz
100 GHz
Frequency

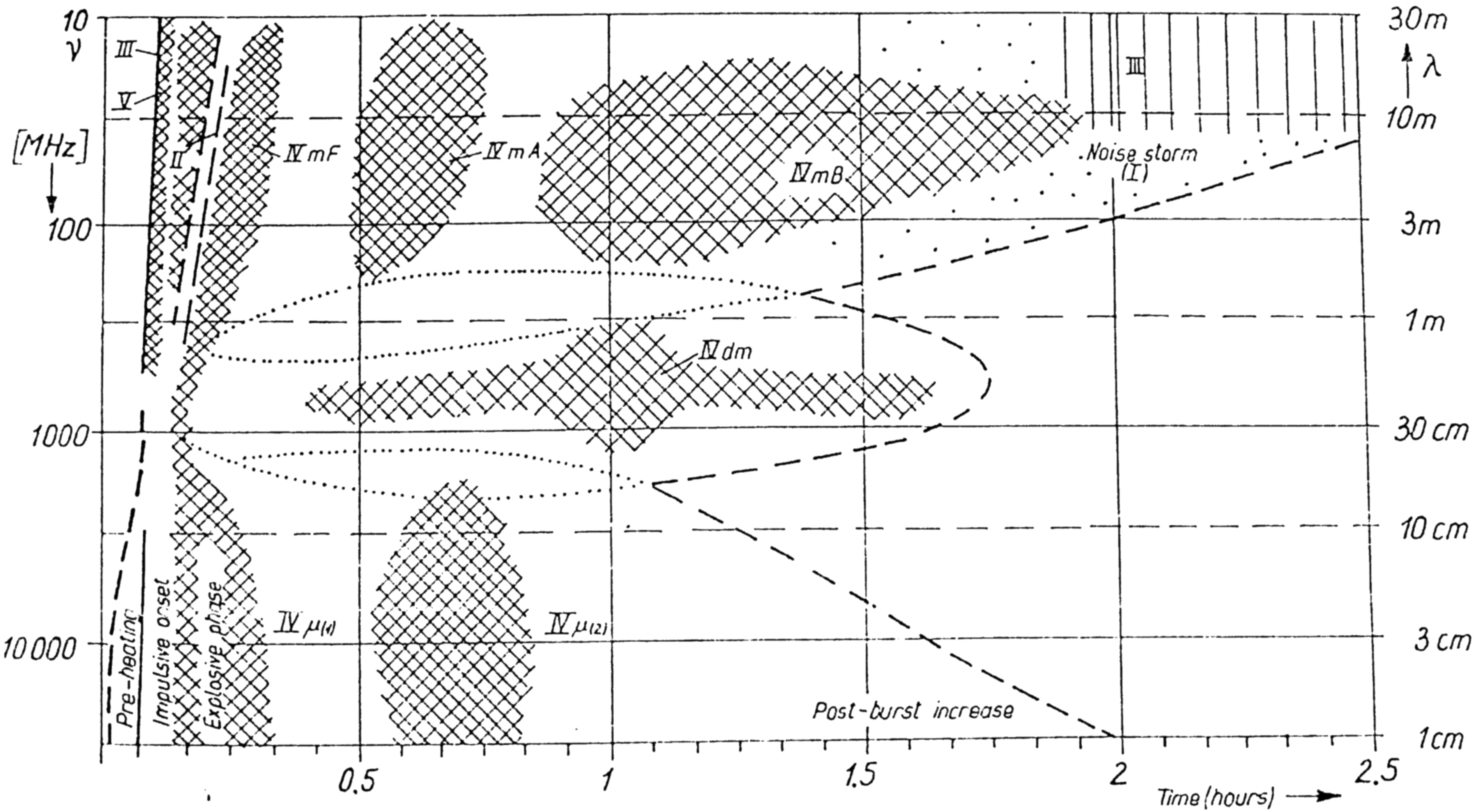


Microwave
Burst
Decimetric
Continuum
3000
1000
300
100
30
10
FREQUENCY (MHz)
III
II
V
IV
I
III Storm
0
10
20
30
40
50
60
70
80
90
TIME SINCE FLARE (minutes)

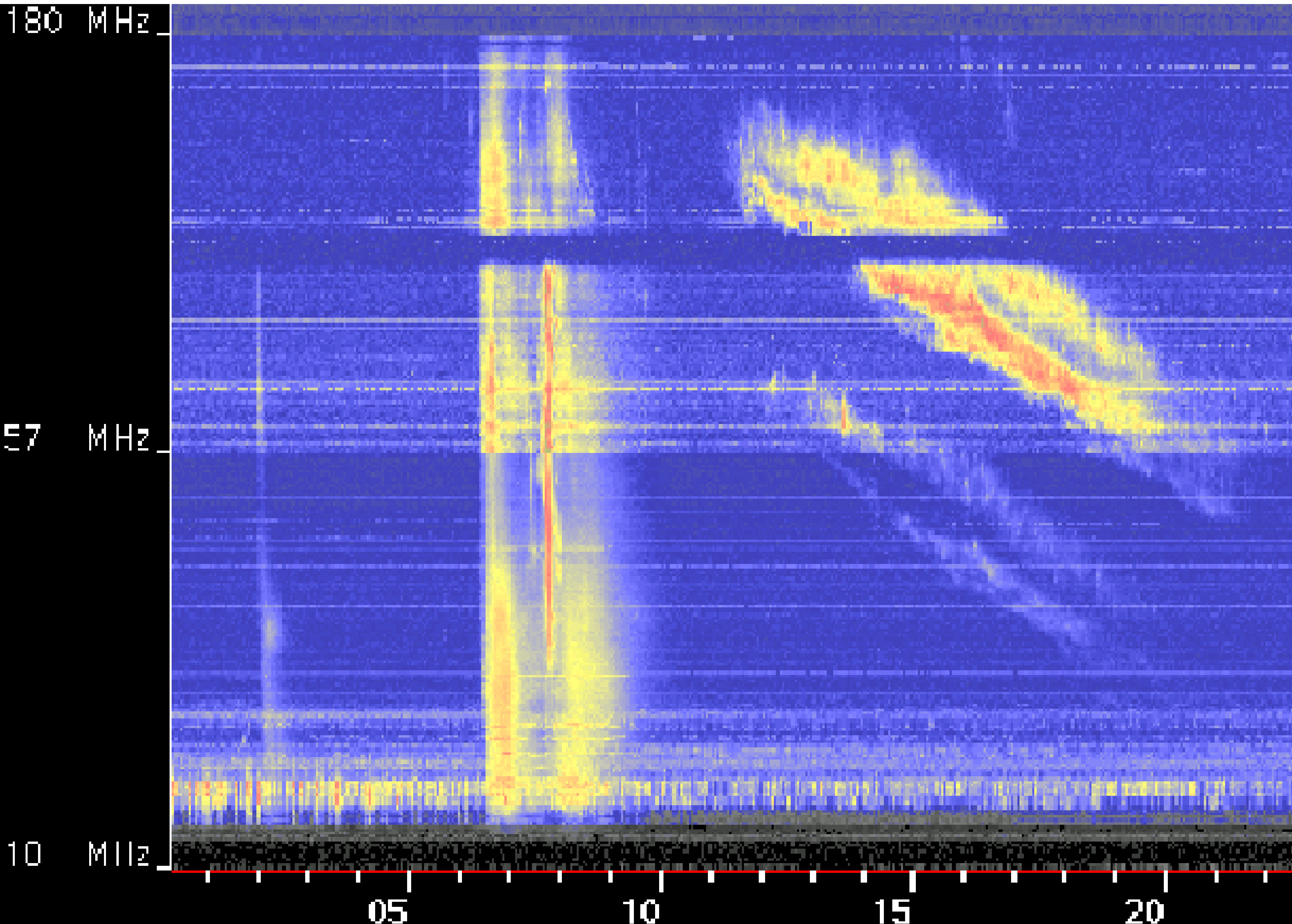


Frequency [MHz]
25
50
100
200
400
Type III
Type V
Type II
Type IV
5
10
15
20
25
Solar eruption
Time [min]

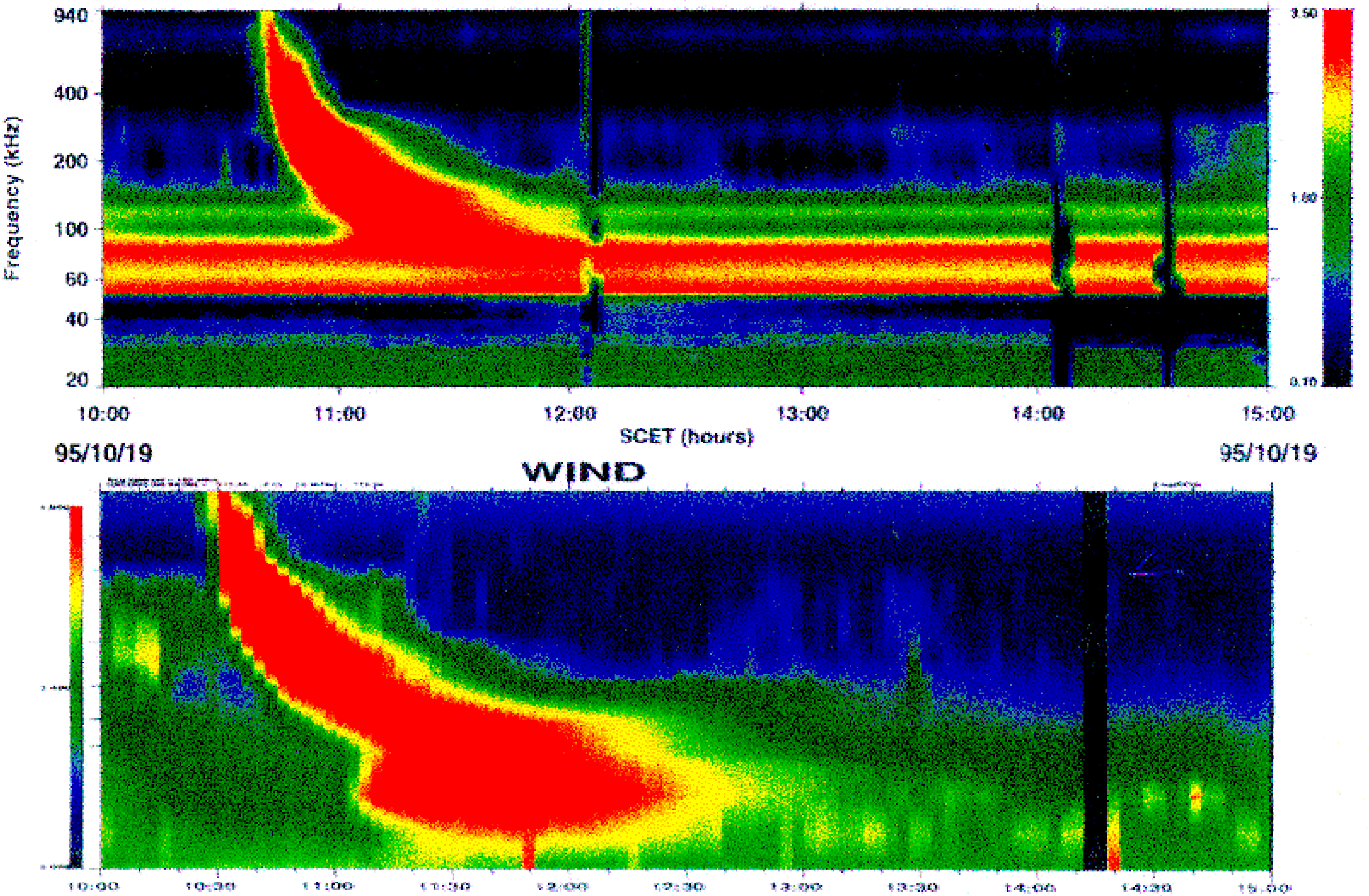

Type V
Type II
Flare Continuum
Type III
10
MHz
100
500
Type I Storm
Radio
~1GHz
Radio
~10GHz
Hα
6562Å
EUV
10-1030Å
X-rays
<10keV
X-rays
>30keV
γ-rays
Electrons,
protons
at 1 AU
Extended phase
Impulsive phase
Precursor
0
10
20
30
Time (min)

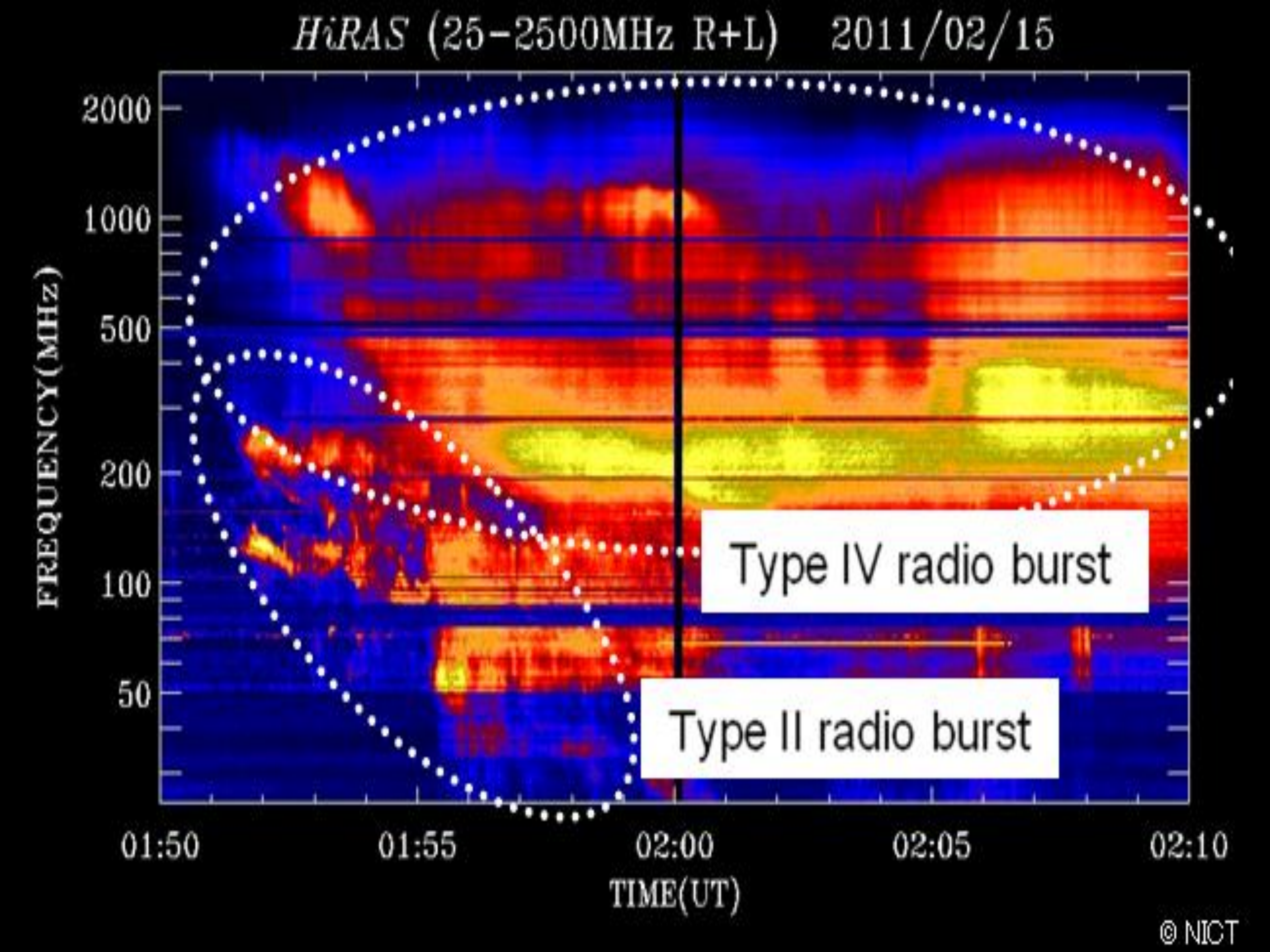


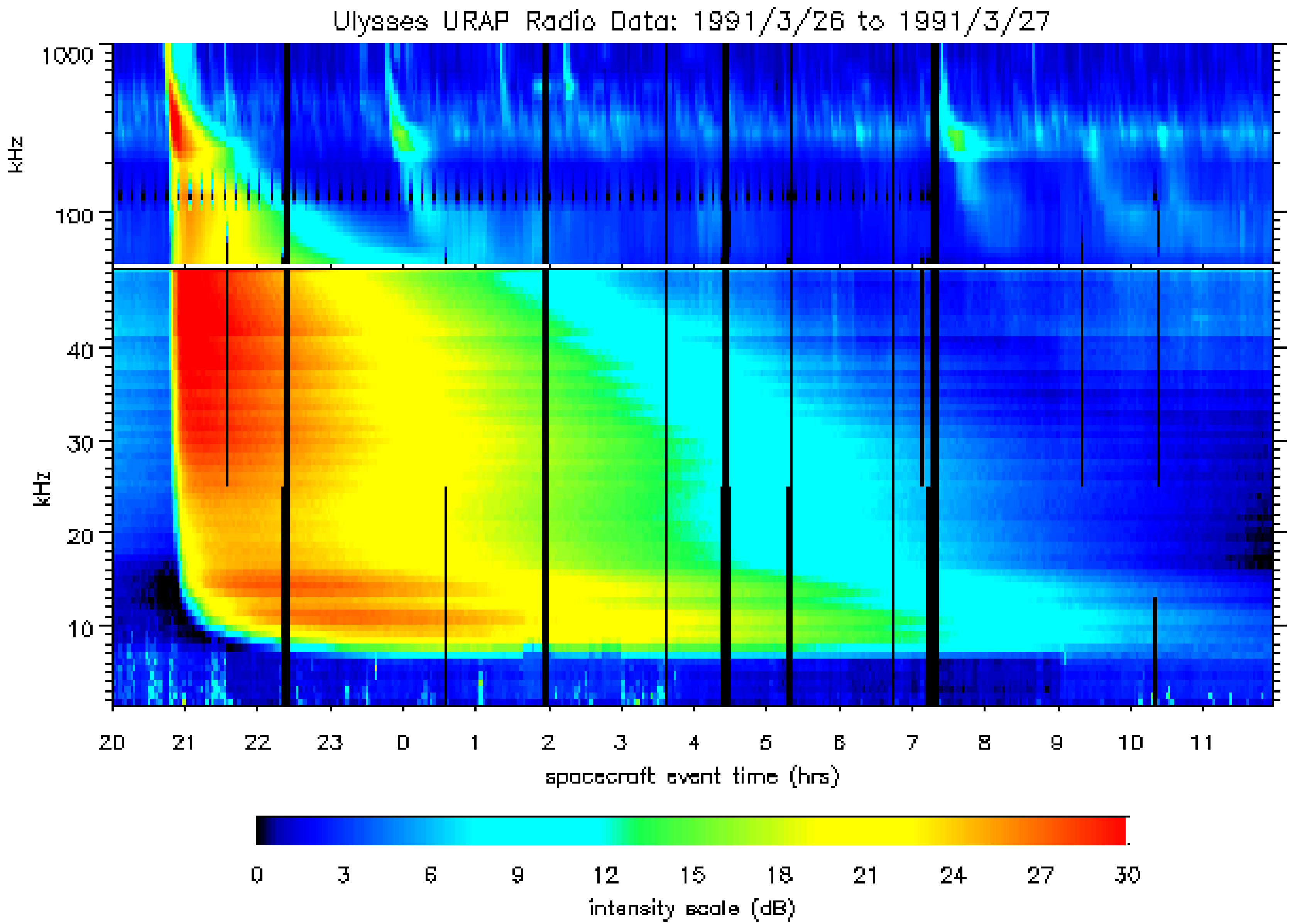
Χρονική και συχνοτική αλληλουχία των διαφόρων τύπων ραδιοεξάρσεων τύπου IV που μπορεί να καταγραφούν κατά τη διάρκεια μιας ηλιακής έκλαμψης (Krüger 1979).


180 MHz
57 MHz
10 MHz
05
10
15
20

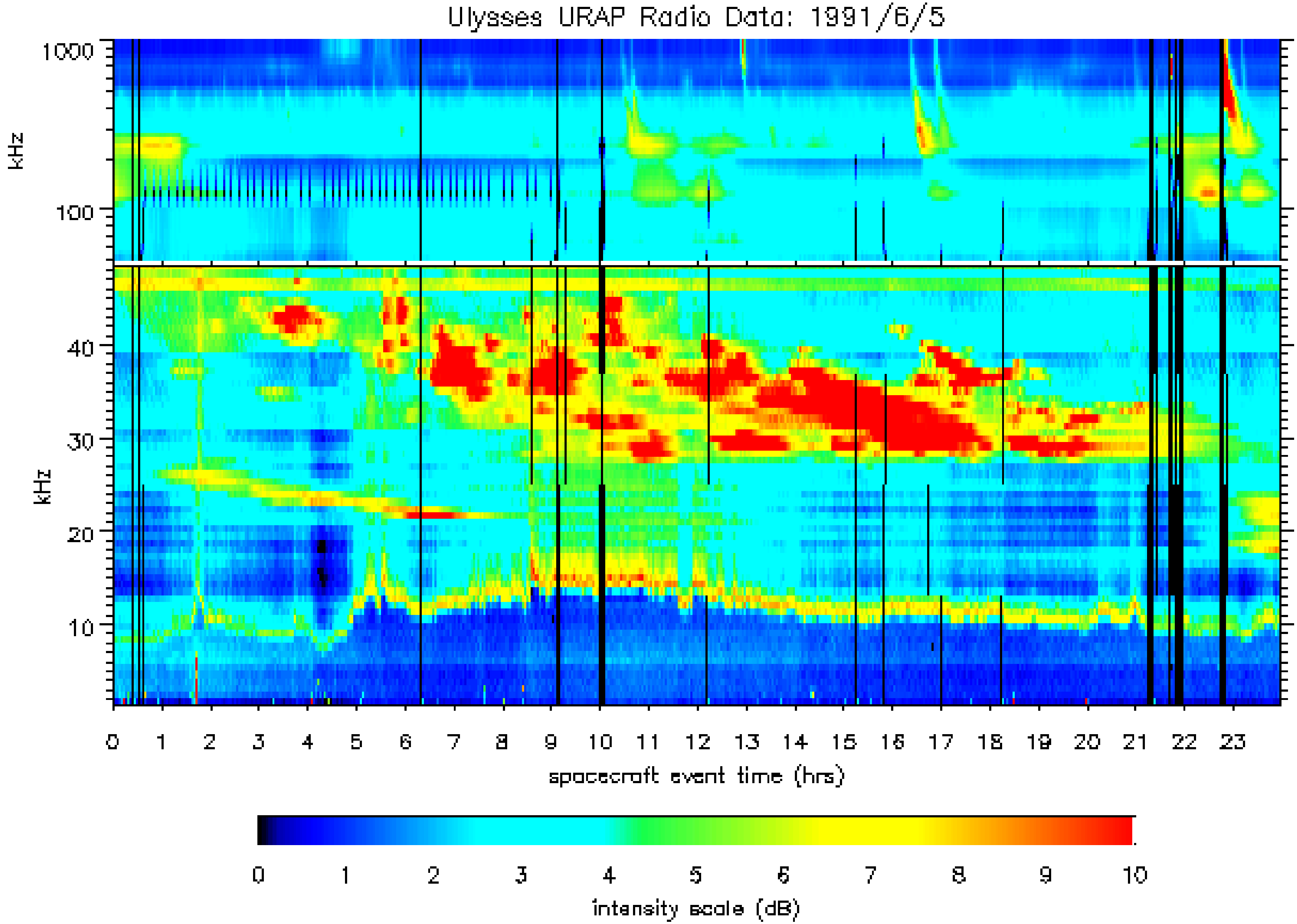
Ulysses 72°N Latitude




HiRAS (25-2500MHz R+L) 2011/02/15
FREQUENCY(MHz)
2000
1000
500
200
100
50
01:50
01:55
02:00
02:05
02:10
TIME(UT)
Type IV radio burst
Type II radio burst
© NICT

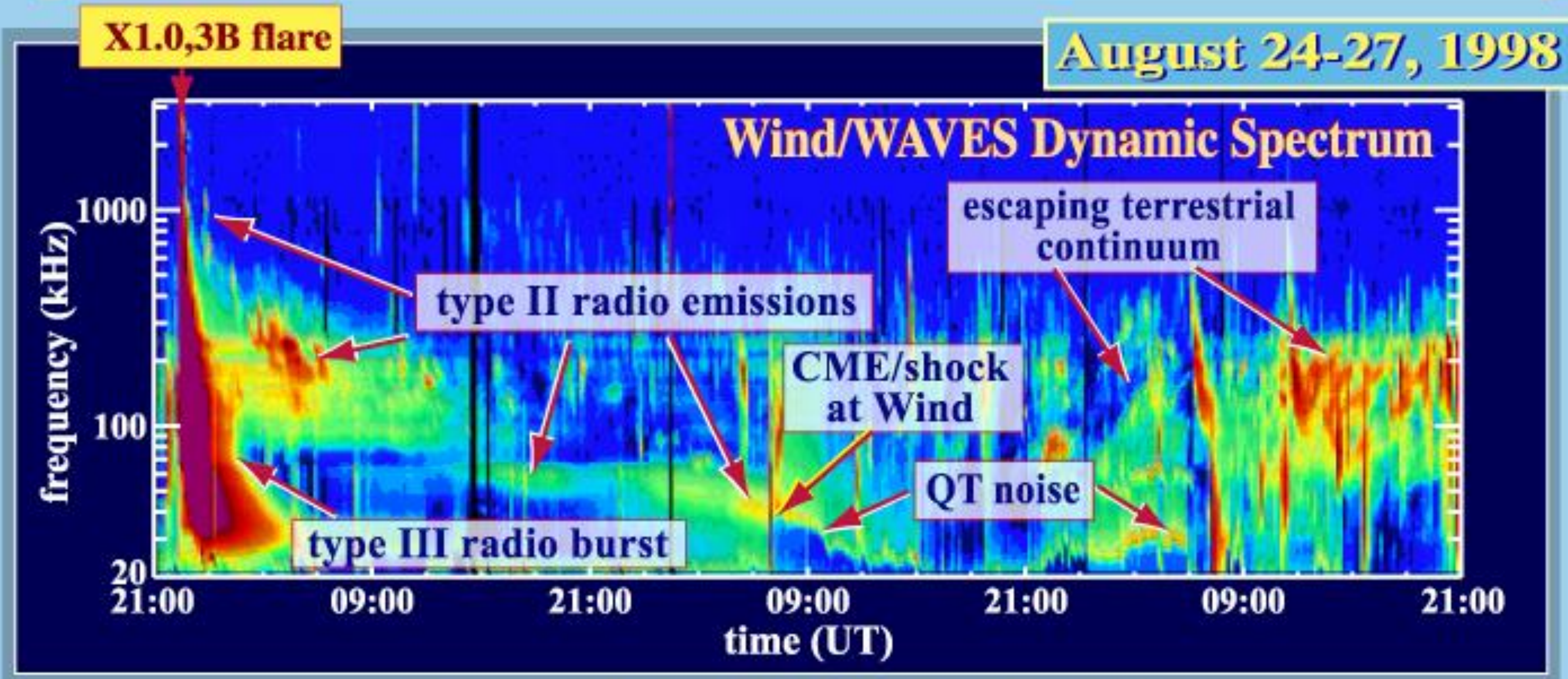


Ulysses URAP Radio Data: 1991/3/26 to 1991/3/27
kHz
1000
100
kHz
40
30
20
10
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10
11
spacecraft event time (hrs)
0
3
6
9
12
15
18
21
24
27
30
intensity scale (dB)



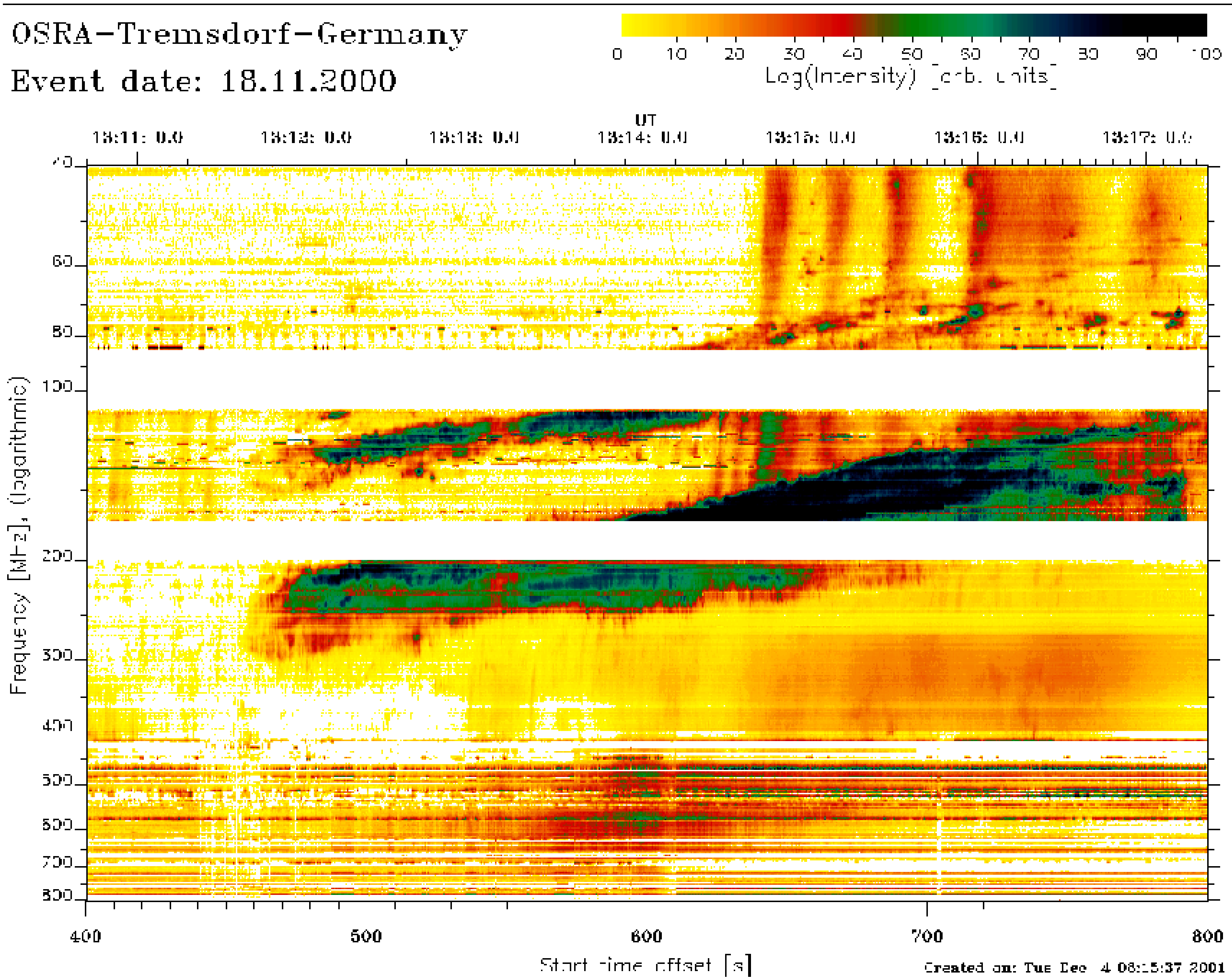
Ulysses URAP Radio Data: 1991/6/5
kHz
1000
100
kHz
40
30
20
10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
spacecraft event time (hrs)
0 1 2 3 4 5 6 7 8 9 10
intensity scale (dB)

Radio Signatures of a Solar-Terrestrial Event

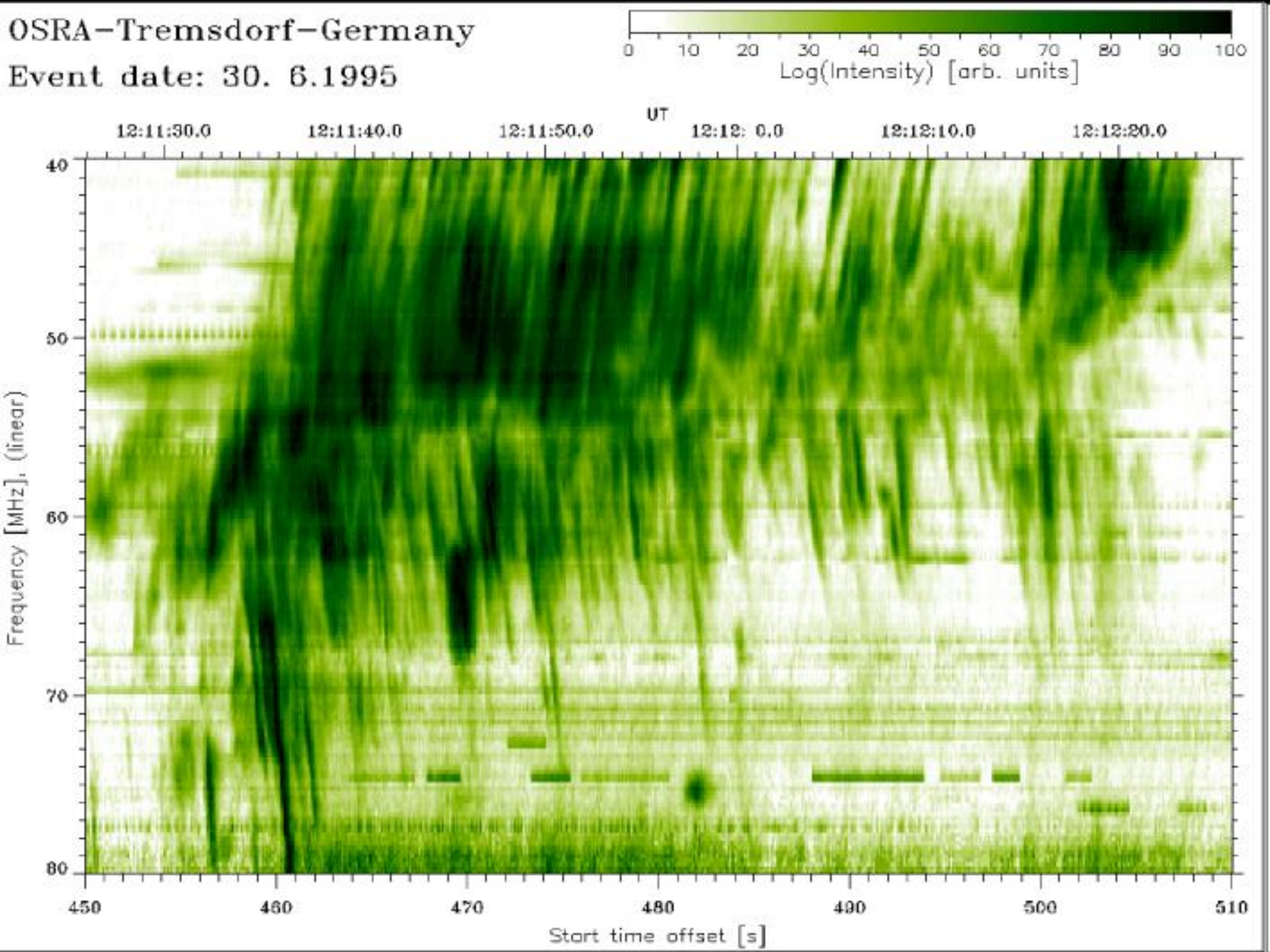


Solar - Terrestrial Radio Paradigm

Physical Process:	Flare/ CME →	Coronal shock (CME, Flare) →	Interplanetary shock (CME) →	Shock arrival at Earth (1AU) →	Magnetospheric response
	↓	↓	↓	↓	↓
Radio Signature:	Complex type III	Coronal type II	Interplanetary type II	Quasi-Thermal (QT) noise	Escaping continuum, AKR



OSRA-Tremsdorf-Germany
Event date: 18.11.2000
Log(Intensity) [arb. units]
UT
13:11: 0.0
13:12: 0.0
13:13: 0.0
13:14: 0.0
13:15: 0.0
13:16: 0.0
13:17: 0.0
Frequency [MHz], (logarithmic)
Start time offset [s]
Created on: Tue Dec 4 08:15:37 2001


OSRA-Tremsdorf-Germany
Event date: 30. 6.1995
0 10 20 30 40 50 60 70 80 90 100
Log(Intensity) [arb. units]
UT
12:11:30.0
12:11:40.0
12:11:50.0
12:12: 0.0
12:12:10.0
12:12:20.0
40
50
60
70
80
Frequency [MHz], (linear)
450
460
470
480
490
500
510
Start time offset [s]

A Holistic View to Study Explosive Solar Phenomena and Space Weather

A COMPREHNSIVE (MULTI INSTRUMENT--MULTI FREQUENCY) STUDY OF EXPLOSIVE SOLAR PHENOMENA AND SPACE WEATHER

1. **optical**
2. **UV**
3. **X-rays**
4. **gamma rays**
5. **radio bursts (type III, type II and type IV) ARTEMIS**
6. **energetic particles, electron and spectra, anisotropies etc**
7. **cosmic rays**
8. **solar wind plasma (velocity, density, temperature, magnetic field)**
9. **LOFAR**
10. **many observing points (spacecrafts, on the Moon etc)**

ARTEMIS IV is the Franco-Hellenic <u>solar radiospectrograph</u> operated by the University of Athens at Thermopylae

frequency range of 20 to 650 MHz

two receivers operating in parallel.
the Global Spectral Analyser (ASG),
a sweep frequency receiver and
the Acousto-Optic Spectrograph
(SAO), a multichannel acousto-optical receiver.

The sweep frequency analyser (ASG) covers
the full frequency band with a time resolution of 10 spectra/s.

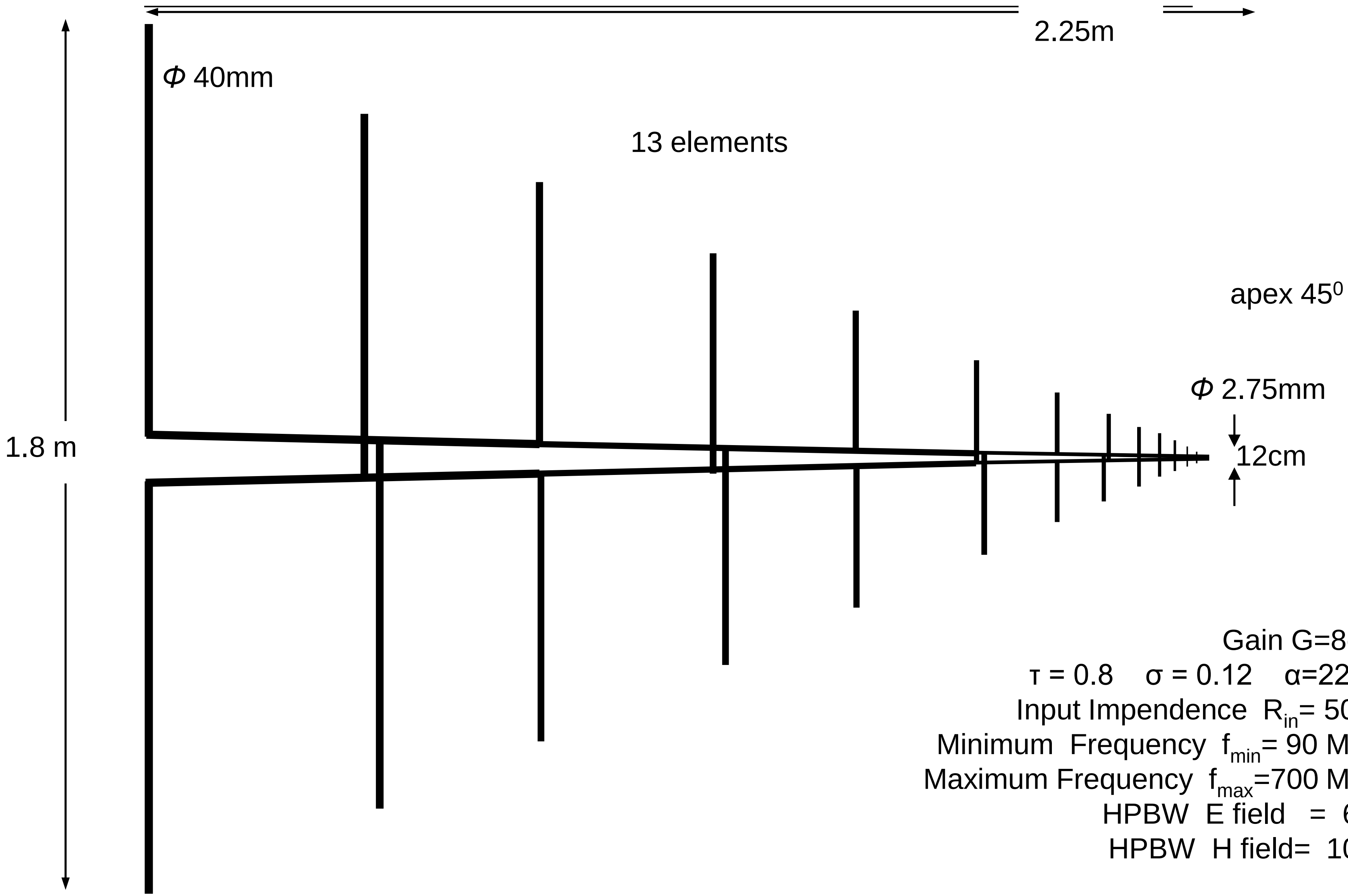
The high sensitivity multi-channel acousto-optical analyser covers
the 265-450 MHz range, with high frequency and time resolution (100 spectra/s);
its recordings are used, mostly, for the study of fine structures

we keep **1.2 to 1.6 GB/day (out of 10GB/day)**

improved solar radio spectrograph

- of the University of Athens operating at the Thermopylae Satellite Telecommunication Station. Observations now cover the frequency range from 20 to 650 MHz. The spectrograph has a 7-meter moving parabola fed by a log-periodic antenna for 100mhZ 650 MHz and a stationary inverted V fat dipole antenna for the 20â€“100 MHz range. Two receivers are operating in parallel, one swept frequency for the whole range (10 spectrums/sec, 630 channels/spectrum) and one acousto-optical receiver for the range 270 to 450 MHz (100 spectrums/sec, 128 channels/spectrum).
- The data acquisition system consists of two PCs (equipped with 12 bit, 225 ksamples/sec ADC, one for each receiver).
- Sensitivity is about 3 SFU and 30 SFU in the 20â€“100 MHz and 100â€“650 MHz range respectively.
- The daily operation is fully automated: receiving universal time from a GPS, pointing the antenna to the sun, system calibration, starting and stopping the observations at preset times, data acquisition, and archiving on DVD. We can also control the whole system through modem or Internet.
- The instrument can be used either by itself or in conjunction with other instruments to study the onset and evolution of solar radio bursts and associated interplanetary phenomena.

Log – Period Antenna



Gain G=8dbi

$\tau = 0.8$ $\sigma = 0.12$ $\alpha=22.5^0$

Input Impendence $R_{in}= 50\ \Omega$

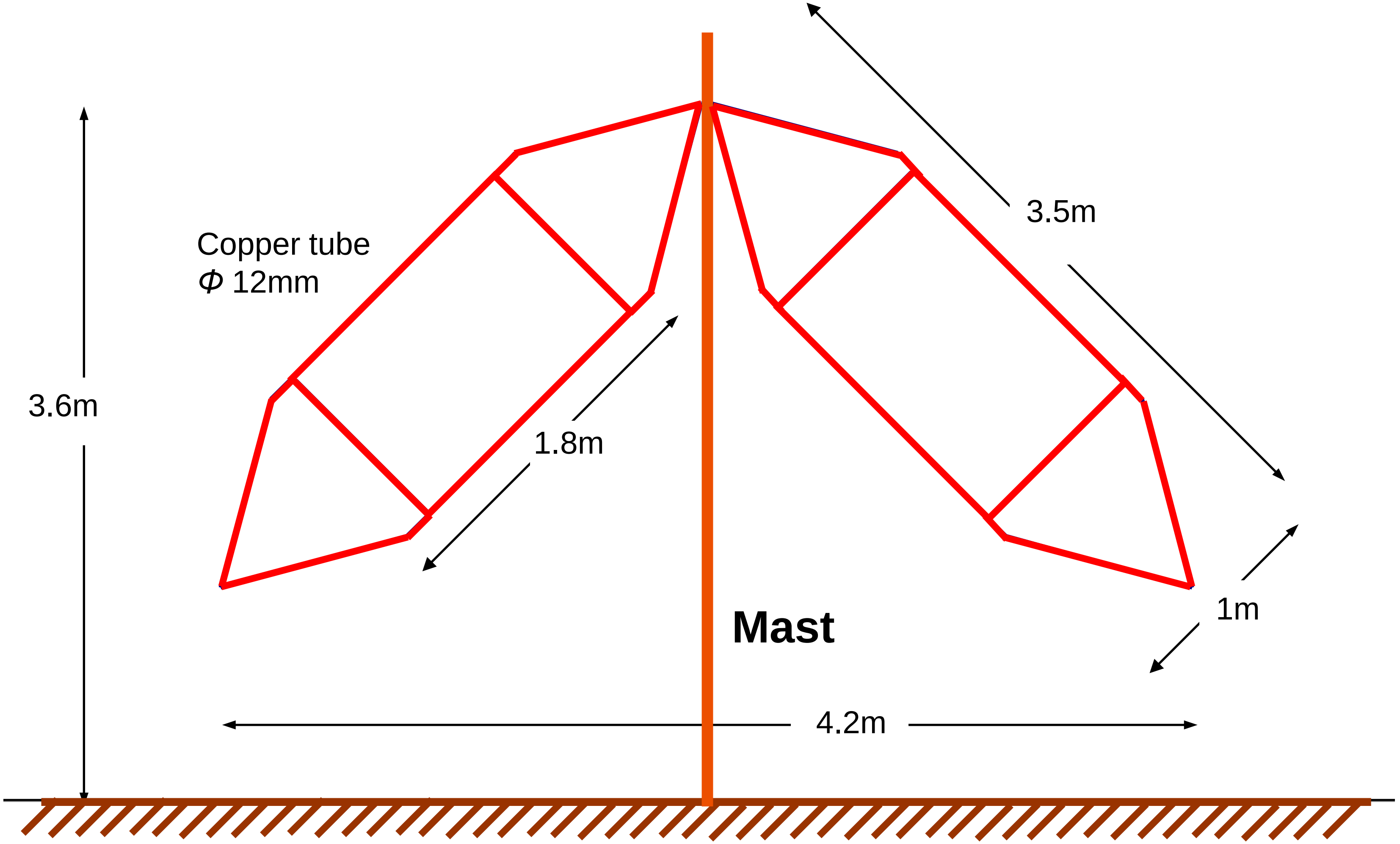
Minimum Frequency $f_{min}= 90$ MHz

Maximum Frequency $f_{max}=700$ MHz

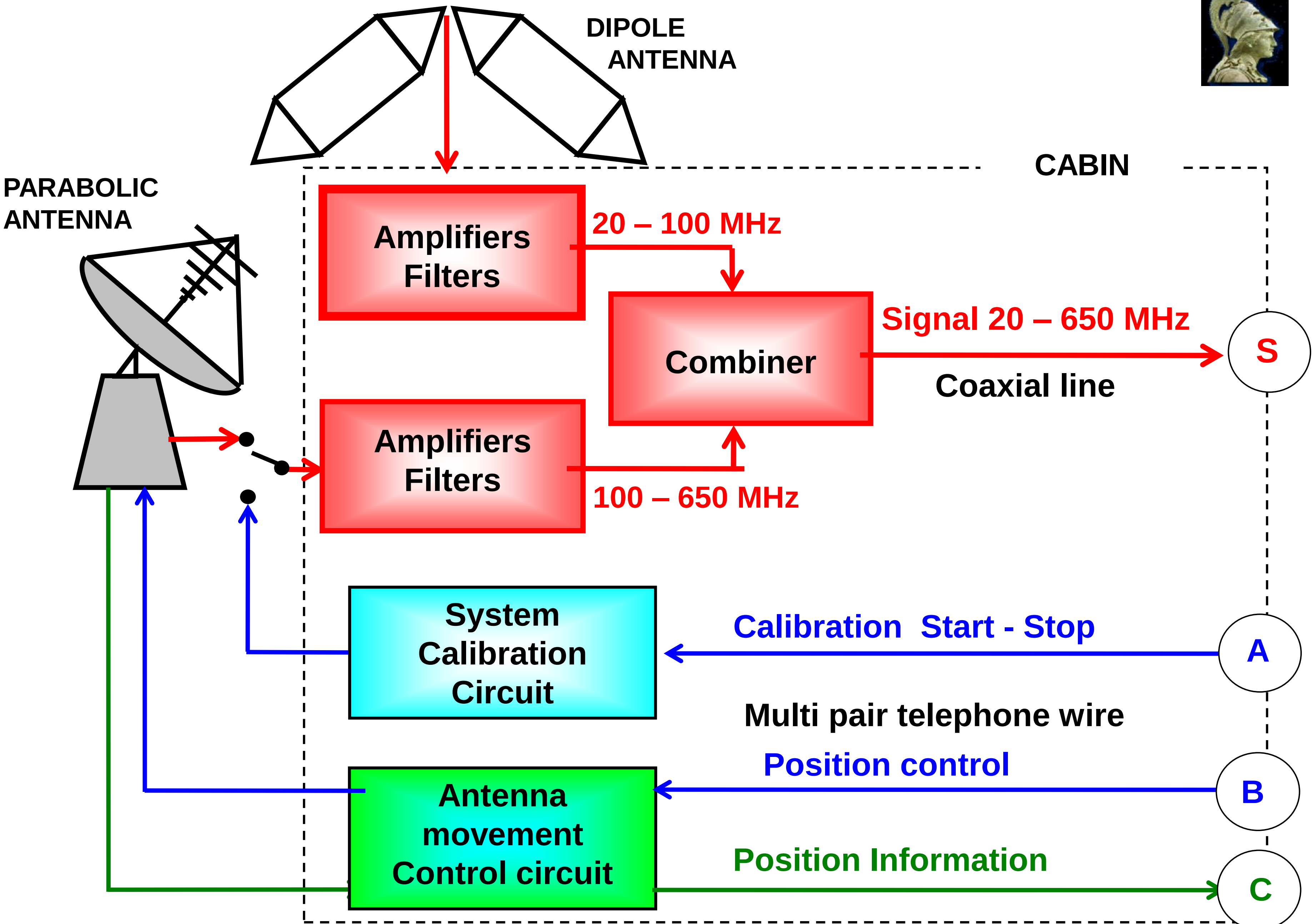
HPBW E field = 65^0

HPBW H field= 105^0

Inverted V Dipole Antenna for 20 - 100MHz range



Antennas and cabin



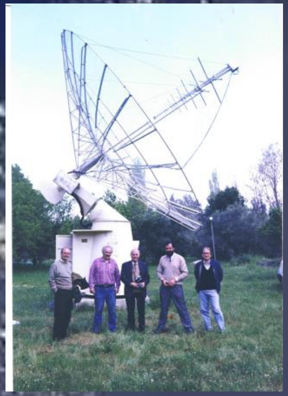
ARTEMIS IV

solar radiospectrograph
operated by the University of Athens at Thermopylae

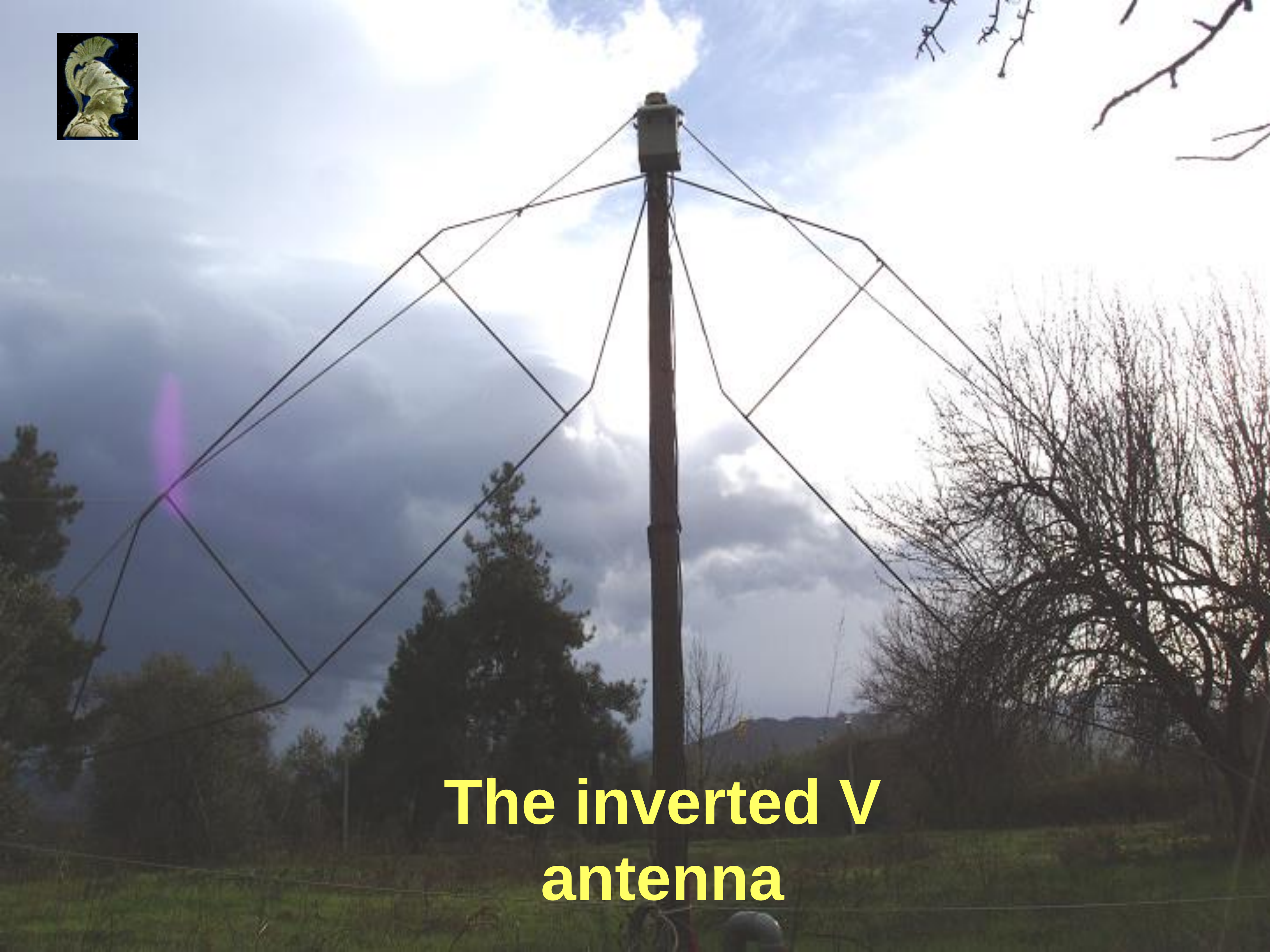
Latitude 38 49' N,
Longitude 22 41' E

The observations last nearly **9 hours and 40 minutes** daily, which is 4 hours and 50 minutes before and after local noon**,**

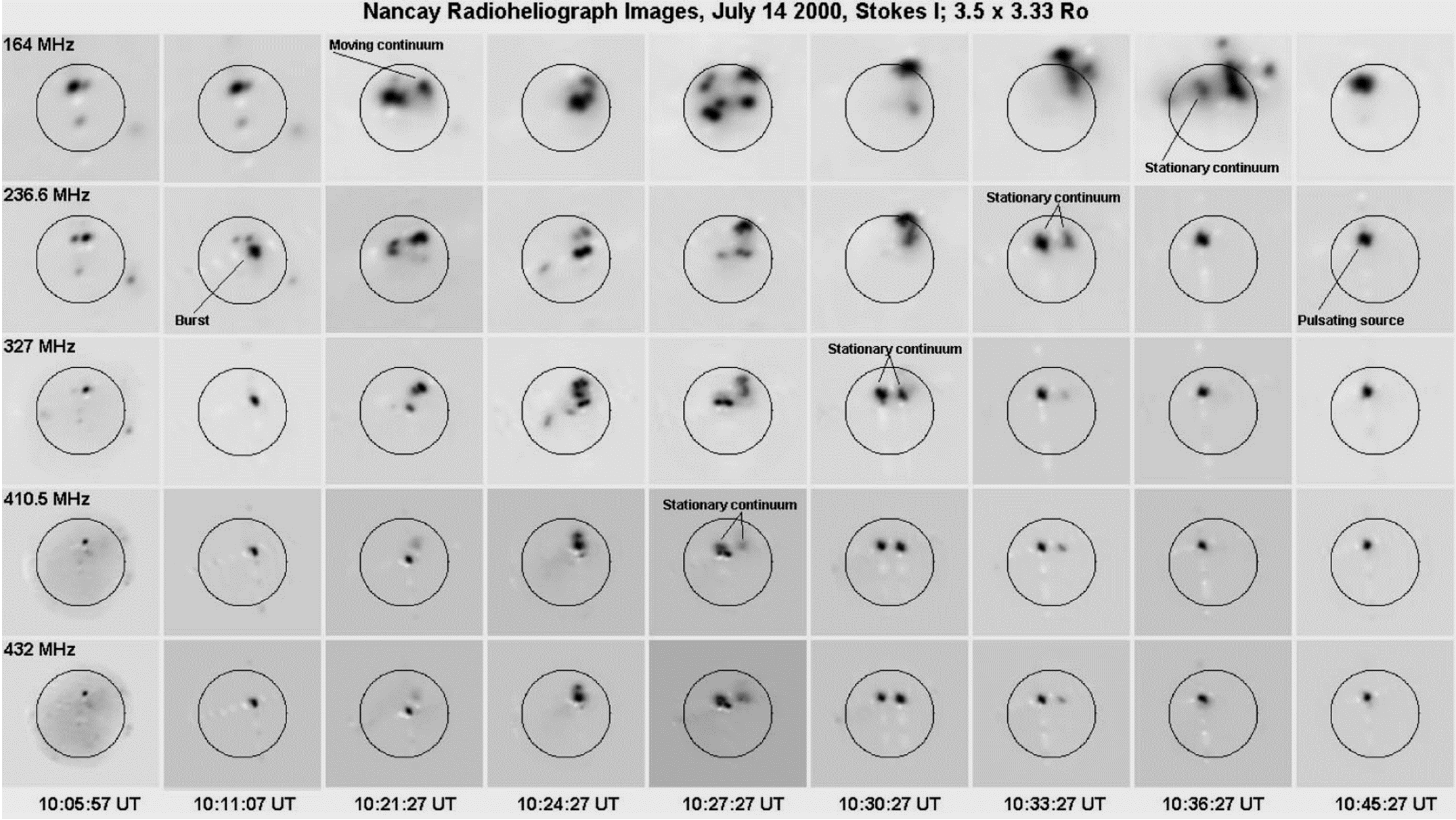
365 days/year



ASG 20-680 MHz, 10 spectra/sec
at 630 frequencies
SOA 250-450MHz, 100 spectra/sec
at 128 frequencies 1.4GB/day, 365 days/year for 15 years



The inverted V antenna



Nancay Radioheliographe images

web site for radio monitoring

M. Pick, M. Maksimovic, J. L. Bougeret, A. Lecacheux,
R. Romagnan, A. Bouteille, K. Suedile
LESIA, Observatoire de Paris
C. Alissandrakis, X. Moussas (Greece)

Why a web site for radio monitoring ?

Main objectives

-Radio associated with CMEs, onset, development

-Electron beams from the low corona to the interplanetary medium

Goal: one radio spectrum in combining data from different spectrographs (large freq. Range)

-Nançay Radioheliograph

- SECCHI CME summary (R. Howard, A. Vourlidas)

-Link with S-Waves pages

- Home
- **DATA PRODUCTS**
  - User guide
  - **Plots-Movies**
  - NRH Real Time
- **DATA SOURCES**
  - Instruments
  - Coronal Mass Ejections
- **DOWNLOAD DATA**
  - Artemis
  - NRH
- Gallery
- Links
- Team
- News

Contacts :
A. Bouteille
M. Pick
R. Romagnan

Welcome

Latest News

10 Nov 2011 : New link to RHESSI data

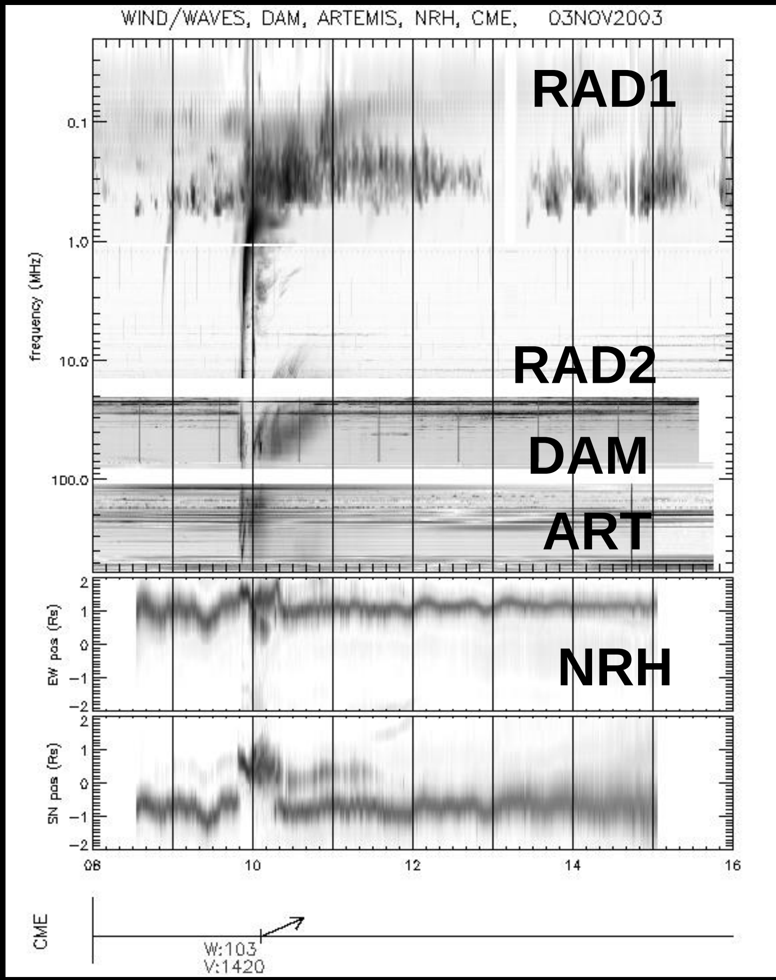
This radio survey project is a joint effort of the Paris Observatory, the University of Athens, the University of Ioannina and the Solar Physics Branch of the Naval Research Laboratory. The present web site is brought to you by the LESIA , UMR 8109, Observatoire de Paris-Meudon and is made possible thanks to a grant from the french Space Agency CNES.

The primary goal of the project is to support multi-wavelength data analysis and space missions dedicated to research on solar activity and on solar-terrestrial relationships, more particulary the SOHO and STEREO missions.

This site provides daily surveys which include :
- Radio spectra covering a large frequency range obtained by combining data sets from Artemis (Thermopyle, Greece), Decameter array (DAM, Nançay France), and spectrographs from WIND and STEREO missions.
- Processed Radio imaging at two frequencies and access to multi-frequency data from the Nançay Radioheliograph (NRH) providing files readable by Solar Soft.
- Coronal Mass Ejections (CMEs) occurrences observed by SOHO and STEREO.

http://secchirh.obspm.fr

Web Page



- **1D-images (EW and SN) 164 MHz**
- **Composite spectrum 600 MHz-≤ 25 MHz**

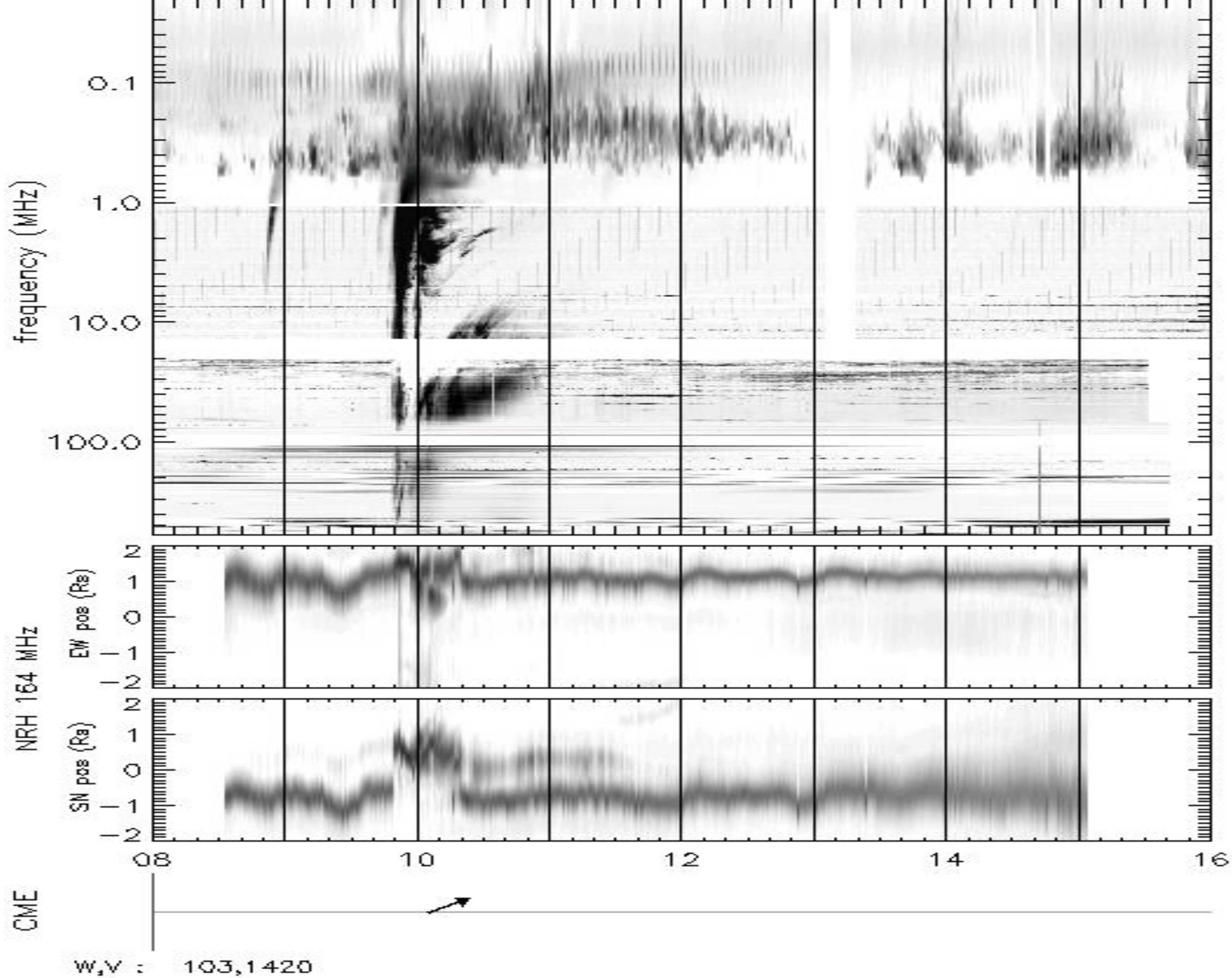
  Artemis
  Nançay DAM spectrographs
  WAVES/WIND

- **2D-movie**

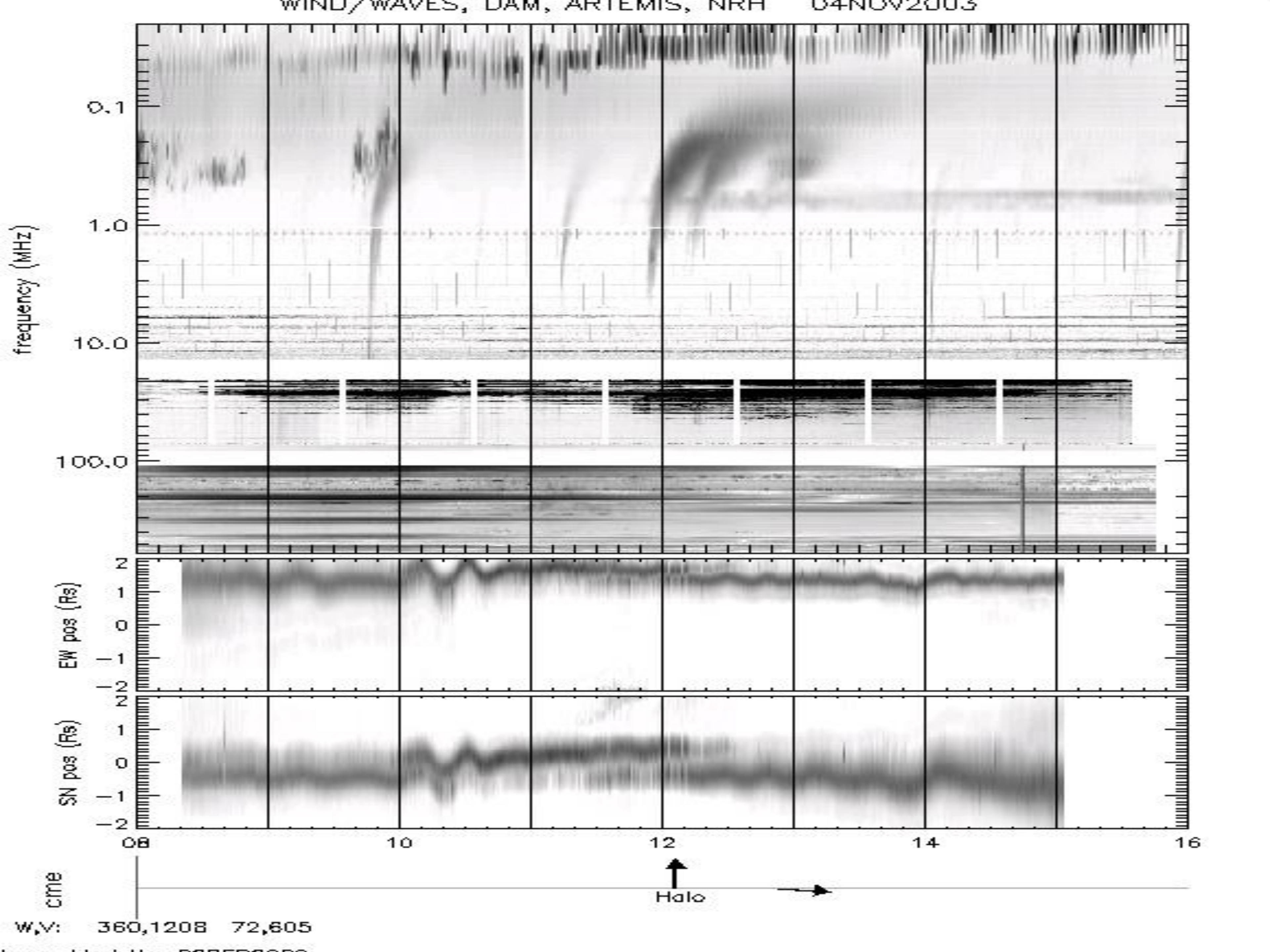
  Cad 120s 6-8 hours
  ZOOM Cad 10s /1hours
  RAD2 16S

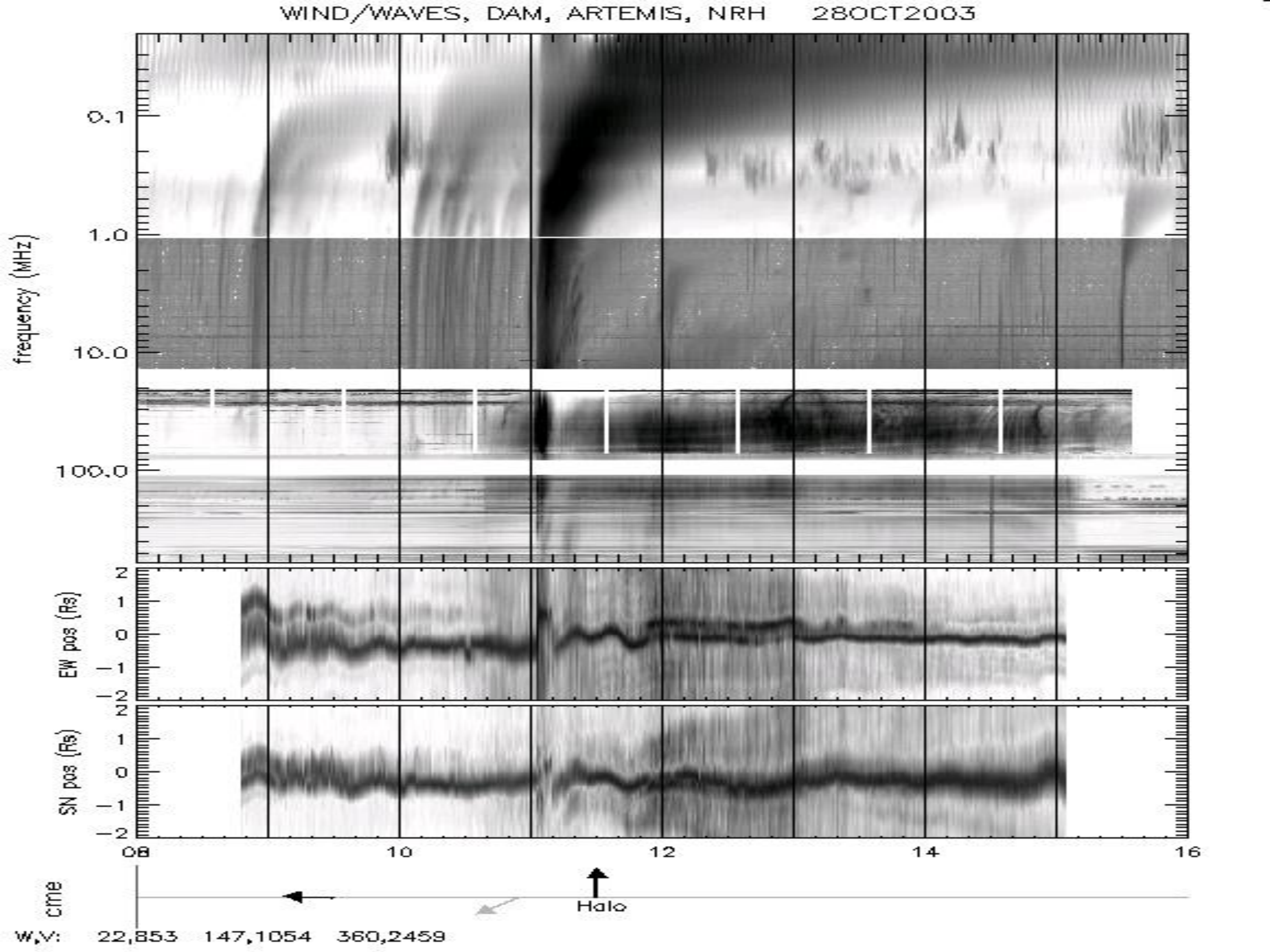
- **Includes CME timing**

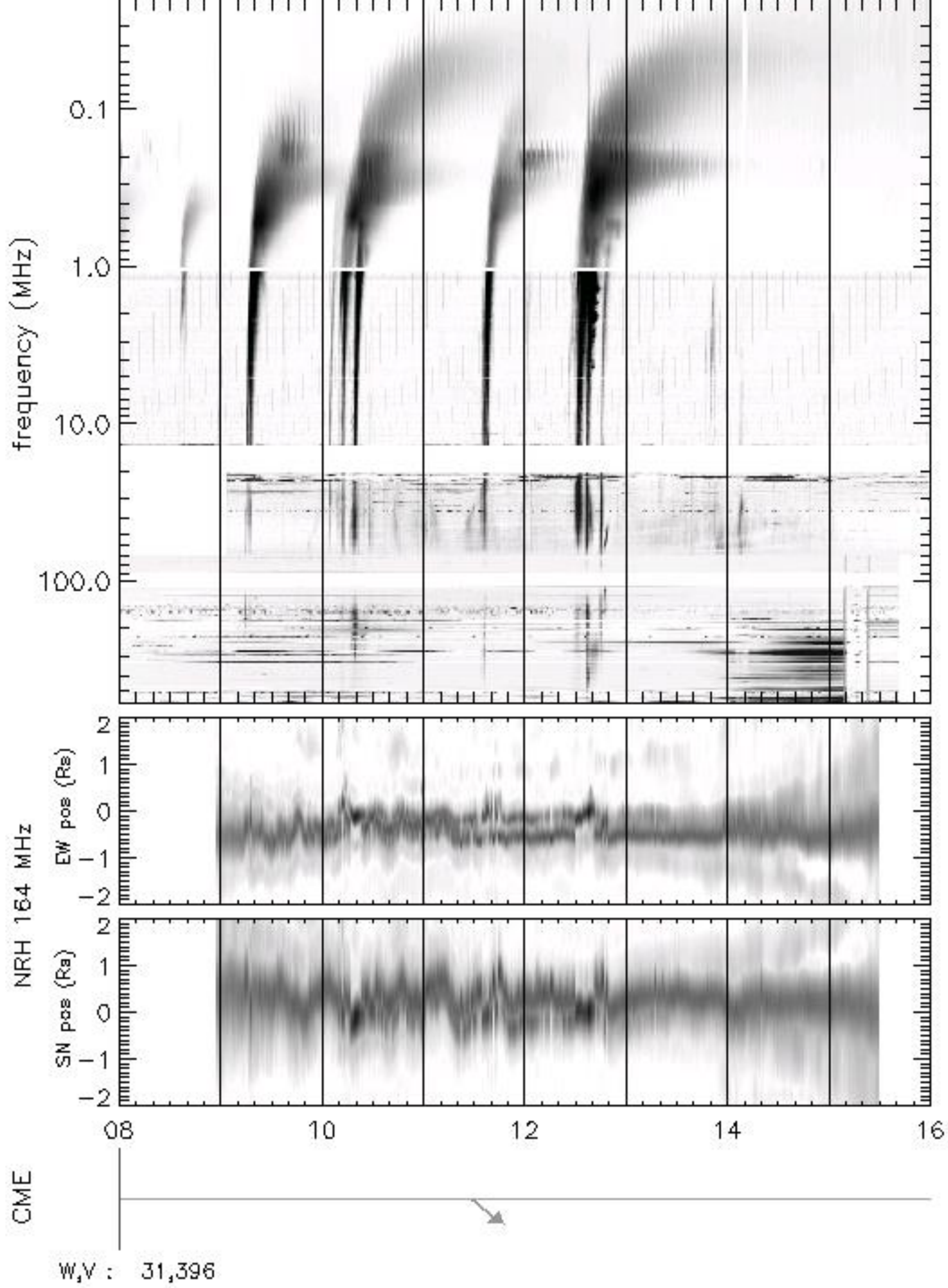
- **Link with S-Waves**
- **Stereo measurements (Nançay) DAM**

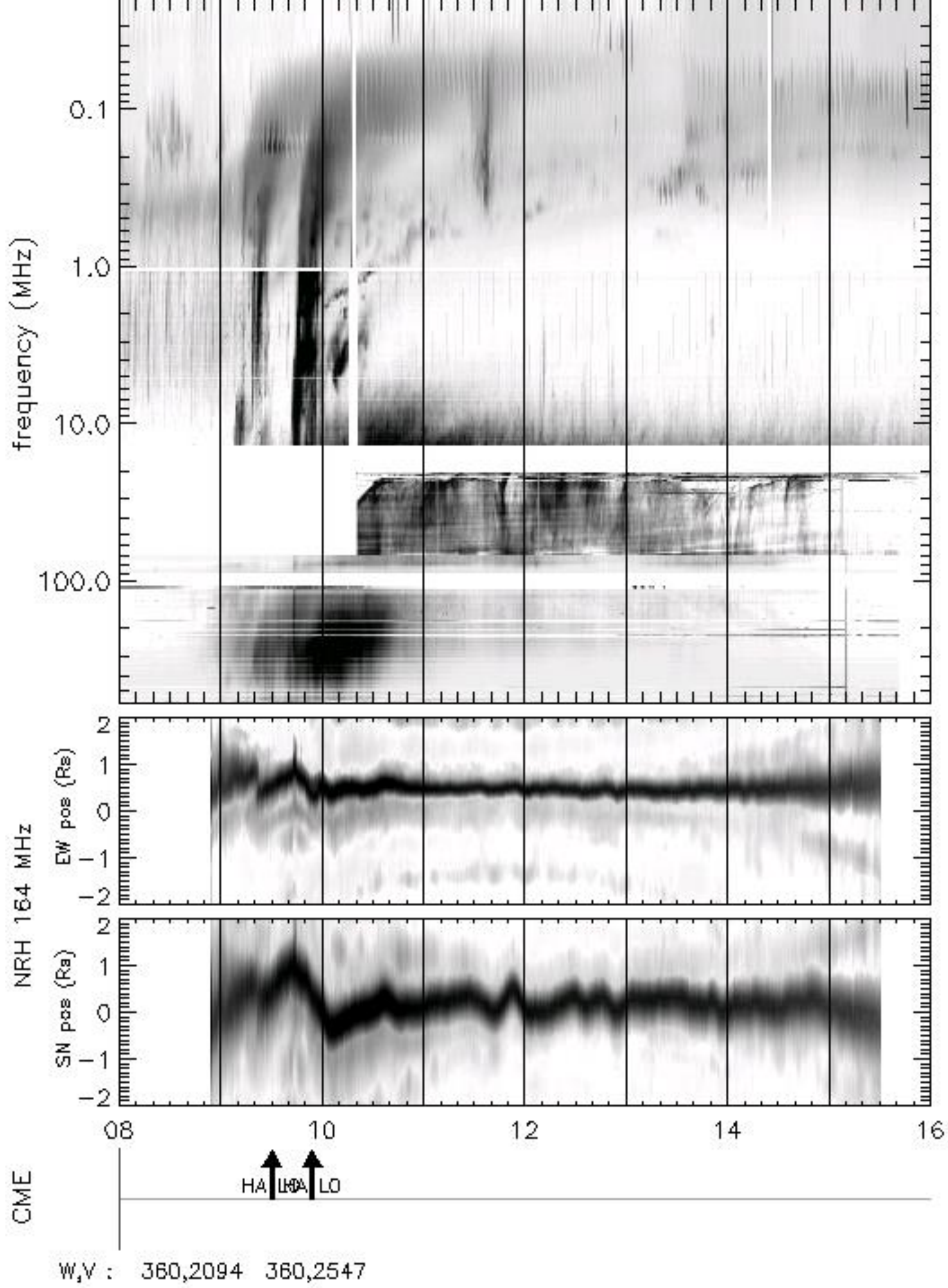


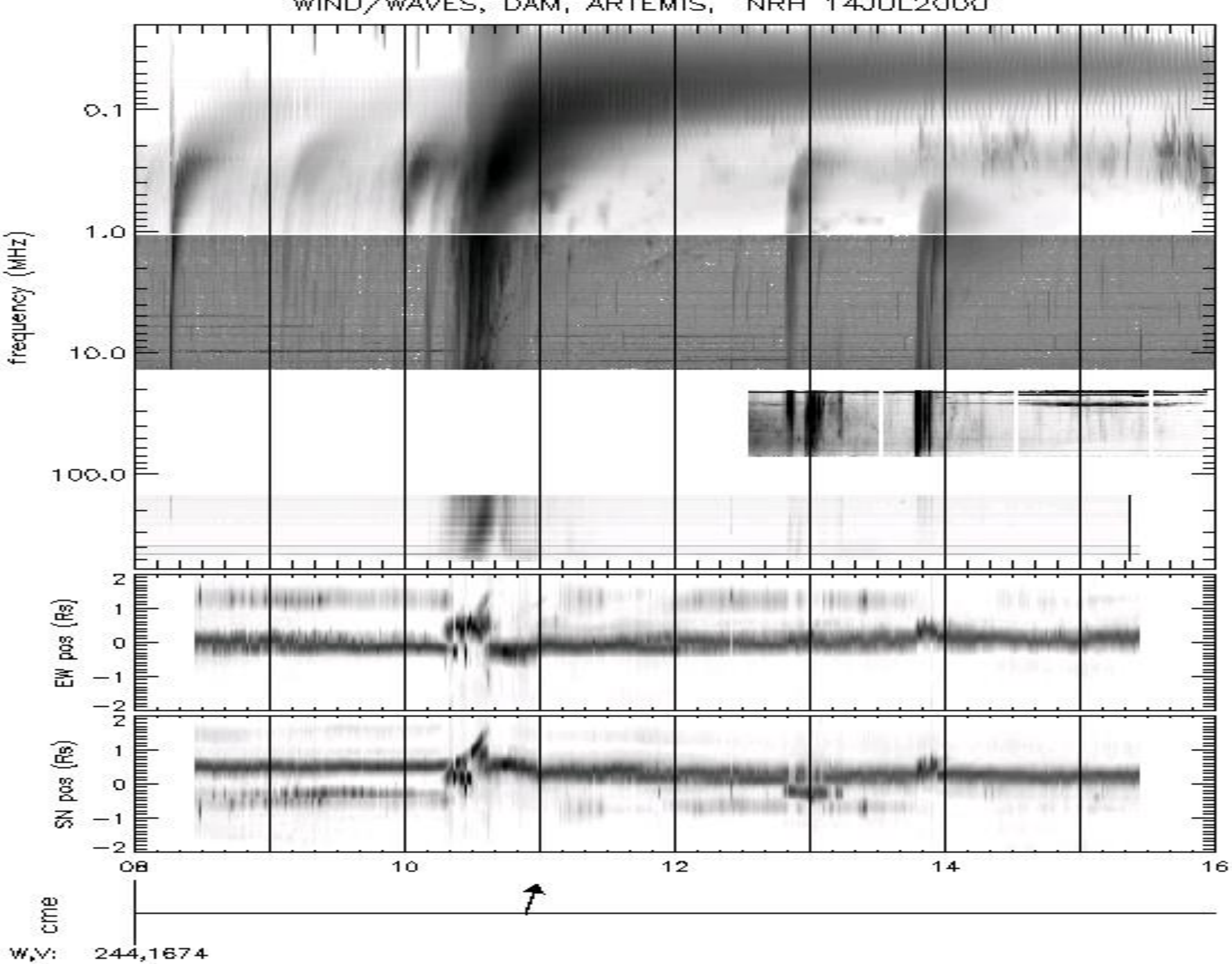
frequency (MHz)
0.1
1.0
10.0
100.0
NRH 164 MHz
EW pos (Rs)
SN pos (Rs)
2
1
0
−1
−2
08
10
12
14
16
CME
W,V : 103,1420


WIND/WAVES, DAM, ARTEMIS, NRH 04NOV2003
frequency (MHz)
0.1
1.0
10.0
100.0
EW pos (Rs)
SN pos (Rs)
2
1
0
−1
−2
08
10
12
14
16
cme
Halo
W,V: 360,1208 72,605

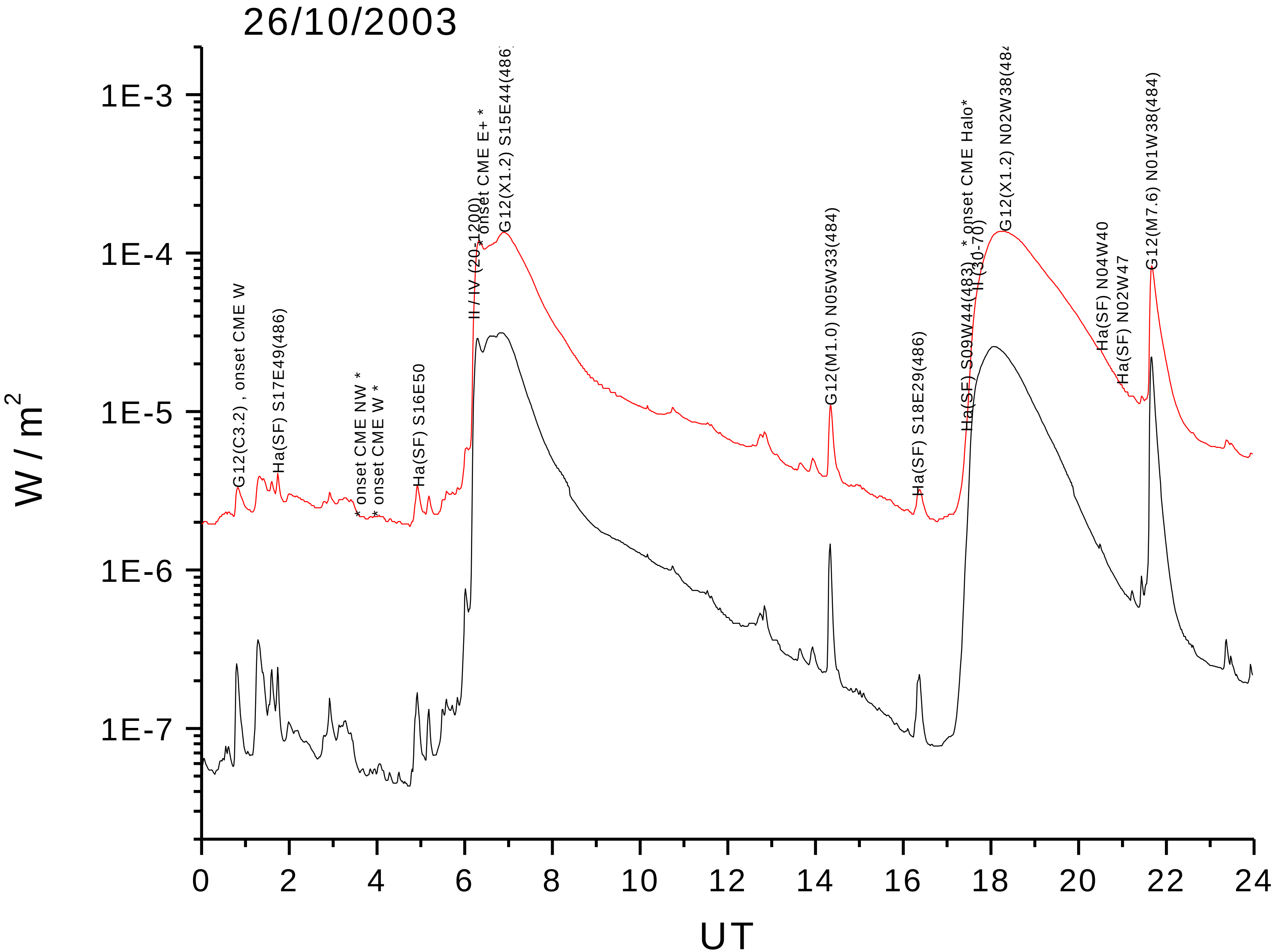

WIND/WAVES, DAM, ARTEMIS, NRH 28OCT2003
frequency (MHz)
0.1
1.0
10.0
100.0
EW pos (Rs)
SN pos (Rs)
2
1
0
−1
−2
08
10
12
14
16
cme
Halo
W,V: 22,853 147,1054 360,2459

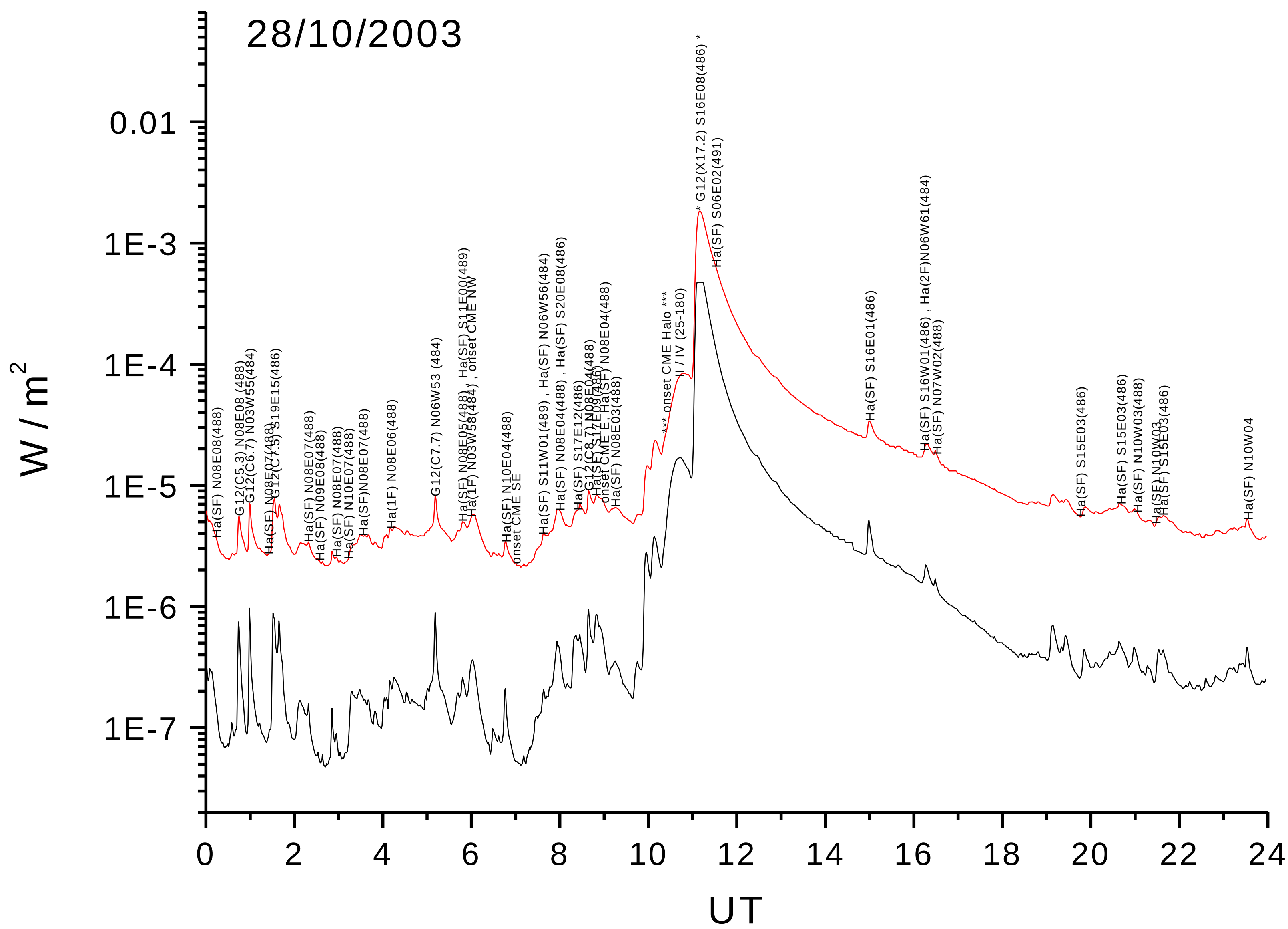

frequency (MHz)
0.1
1.0
10.0
100.0
NRH 164 MHz
EW pos (Rs)
SN pos (Rs)
08
10
12
14
16
CME
W,V : 31,396

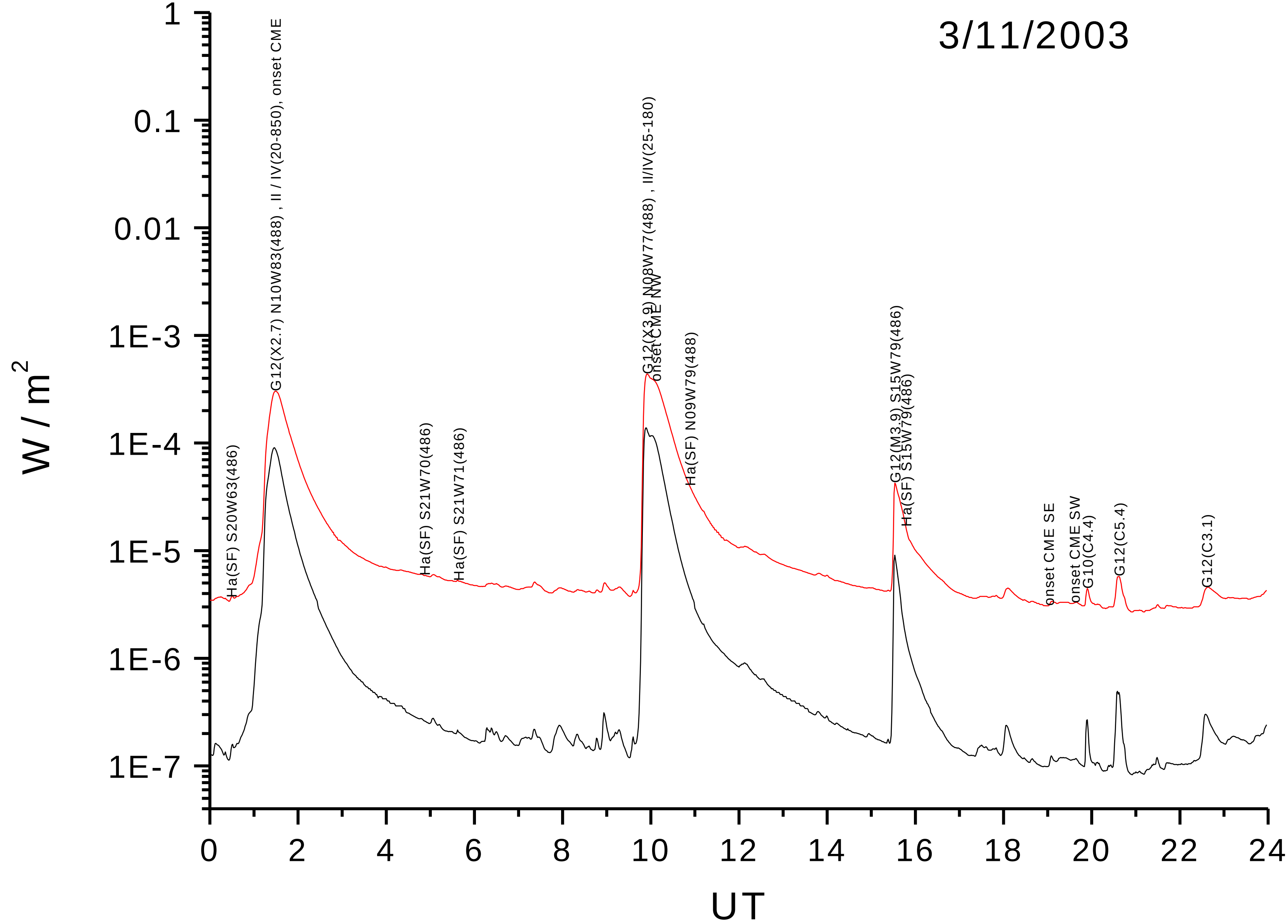

frequency (MHz)
0.1
1.0
10.0
100.0
NRH 164 MHz
EW pos (Rs)
SN pos (Rs)
2
1
0
−1
−2
08
10
12
14
16
CME
HA
LO
W,V : 360,2094 360,2547


WIND/WAVES, DAM, ARTEMIS, NRH 14JUL2000
frequency (MHz)
0.1
1.0
10.0
100.0
EW pos (Rs)
SN pos (Rs)
2
1
0
−1
−2
08
10
12
14
16
cme
W,V: 244,1674

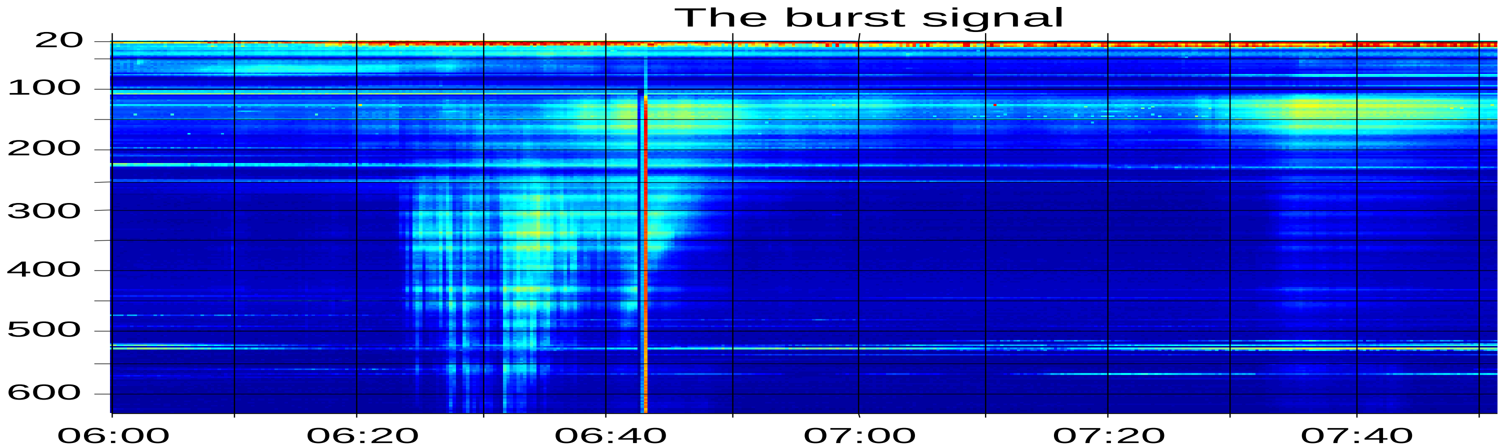
October & November 2003 events


26/10/2003
1E-3
1E-4
1E-5
1E-6
1E-7
W / m2
0
2
4
6
8
10
12
14
16
18
20
22
24
UT
G12(C3.2) , onset CME W
Ha(SF) S17E49(486)
* onset CME NW *
* onset CME W *
Ha(SF) S16E50
II / IV (20-1200)
* onset CME E+ *
G12(X1.2) S15E44(486)
G12(M1.0) N05W33(484)
Ha(SF) S18E29(486)
Ha(SF) S09W44(483)
* onset CME Halo*
II (30-70)
G12(X1.2) N02W38(484)
Ha(SF) N04W40
Ha(SF) N02W47
G12(M7.6) N01W38(484)

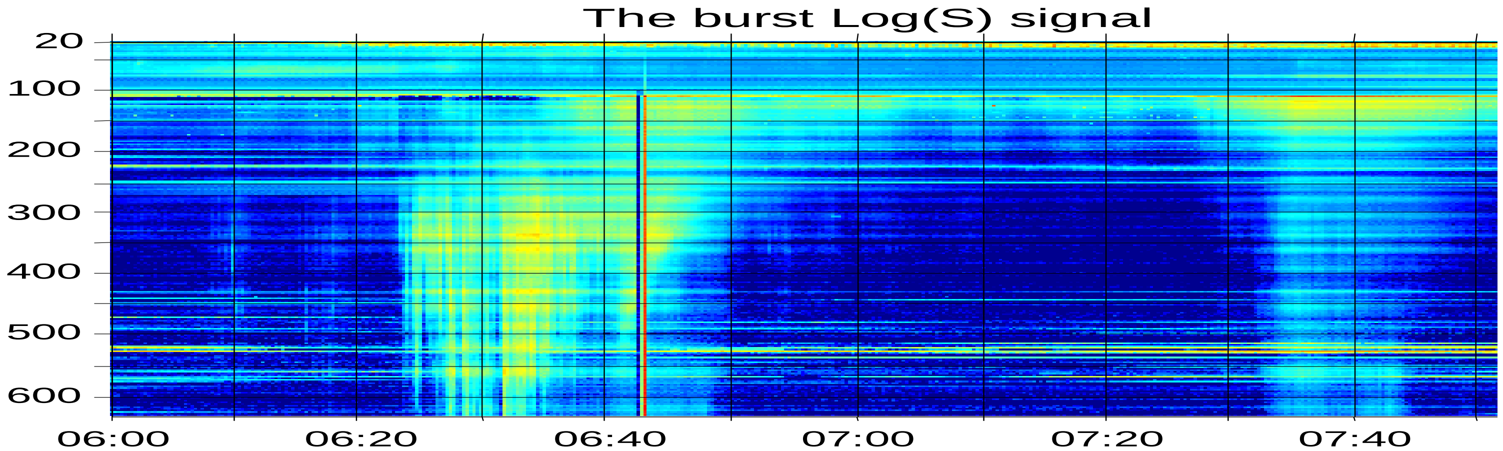

28/10/2003
W / m^2
UT
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
0
2
4
6
8
10
12
14
16
18
20
22
24
* G12(X17.2) S16E08(486) *
Ha(SF) S06E02(491)
*** onset CME Halo ***
II / IV (25-180)
Ha(SF) S16E01(486)
Ha(SF) S16W01(486) , Ha(2F)N06W61(484)
Ha(SF) N07W02(488)
G12(C7.7) N06W53 (484)
Ha(SF) N08E05(488) , Ha(SF) S11E00(489)
Ha(1F) N03W58(484) , onset CME NW
Ha(SF) N10E04(488)
onset CME SE
Ha(SF) S11W01(489) , Ha(SF) N06W56(484)
Ha(SF) N08E04(488) , Ha(SF) S20E08(486)
Ha(SF) N08E08(488)
G12(C5.3) N08E08 (488)
G12(C6.7) N03W55(484)
Ha(SF) N08E07(488)
G12(C7.5) S19E15(486)
Ha(SF) N08E07(488)
Ha(SF) N09E08(488)
Ha(SF) N08E07(488)
Ha(SF) N10E07(488)
Ha(SF)N08E07(488)
Ha(1F) N08E06(488)
Ha(SF) S17E12(486)
Ha(SF) N08E04(488)
Ha(SF) N08E03(488)
Ha(SF) S15E03(486)
Ha(SF) S15E03(486)
Ha(SF) N10W03(488)
Ha(SF) N10W03
Ha(SF) S15E03(486)
Ha(SF) N10W04


3/11/2003
W / m^2
UT
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
0
2
4
6
8
10
12
14
16
18
20
22
24
Ha(SF) S20W63(486)
G12(X2.7) N10W83(488) , II / IV(20-850), onset CME
Ha(SF) S21W70(486)
Ha(SF) S21W71(486)
G12(X3.9) N08W77(488) , II/IV(25-180)
onset CME NW
Ha(SF) N09W79(488)
G12(M3.9) S15W79(486)
Ha(SF) S15W79(486)
onset CME SE
onset CME SW
G10(C4.4)
G12(C5.4)
G12(C3.1)

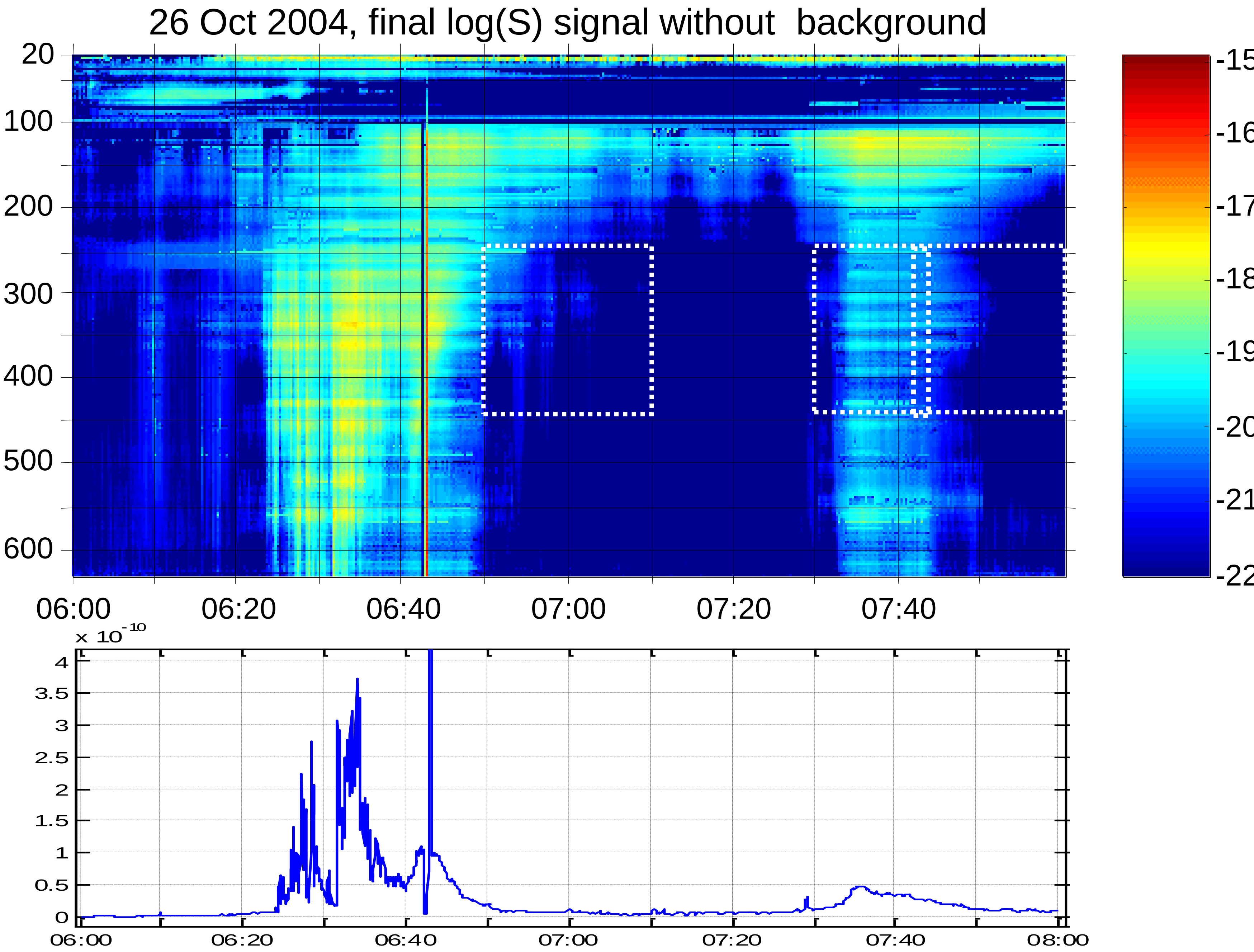
The 26 October 2003
MAJOR SOLAR RADIO BURST FROM 06:00 TO 08:00 UTC



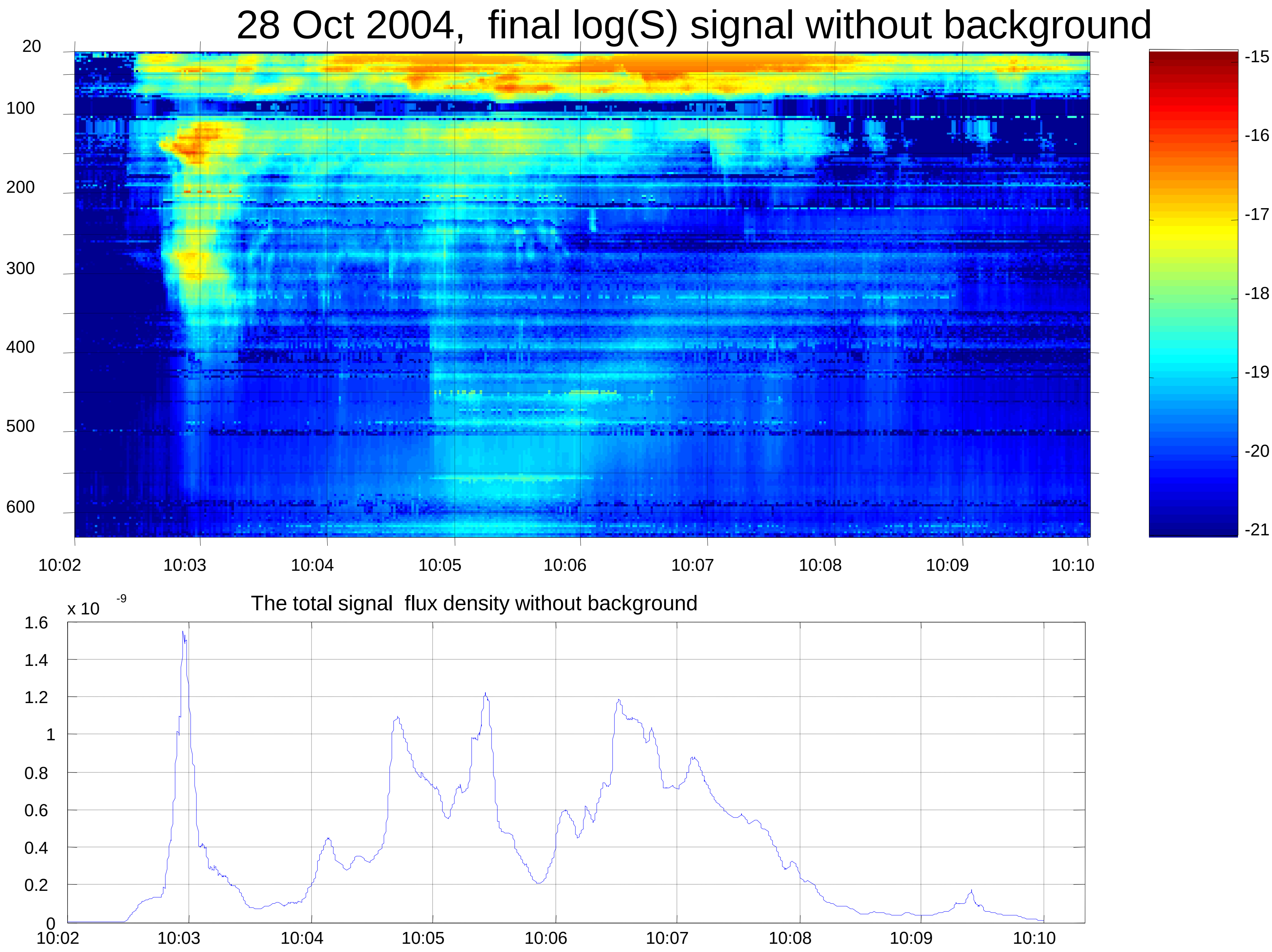
The radio event us it is recorded

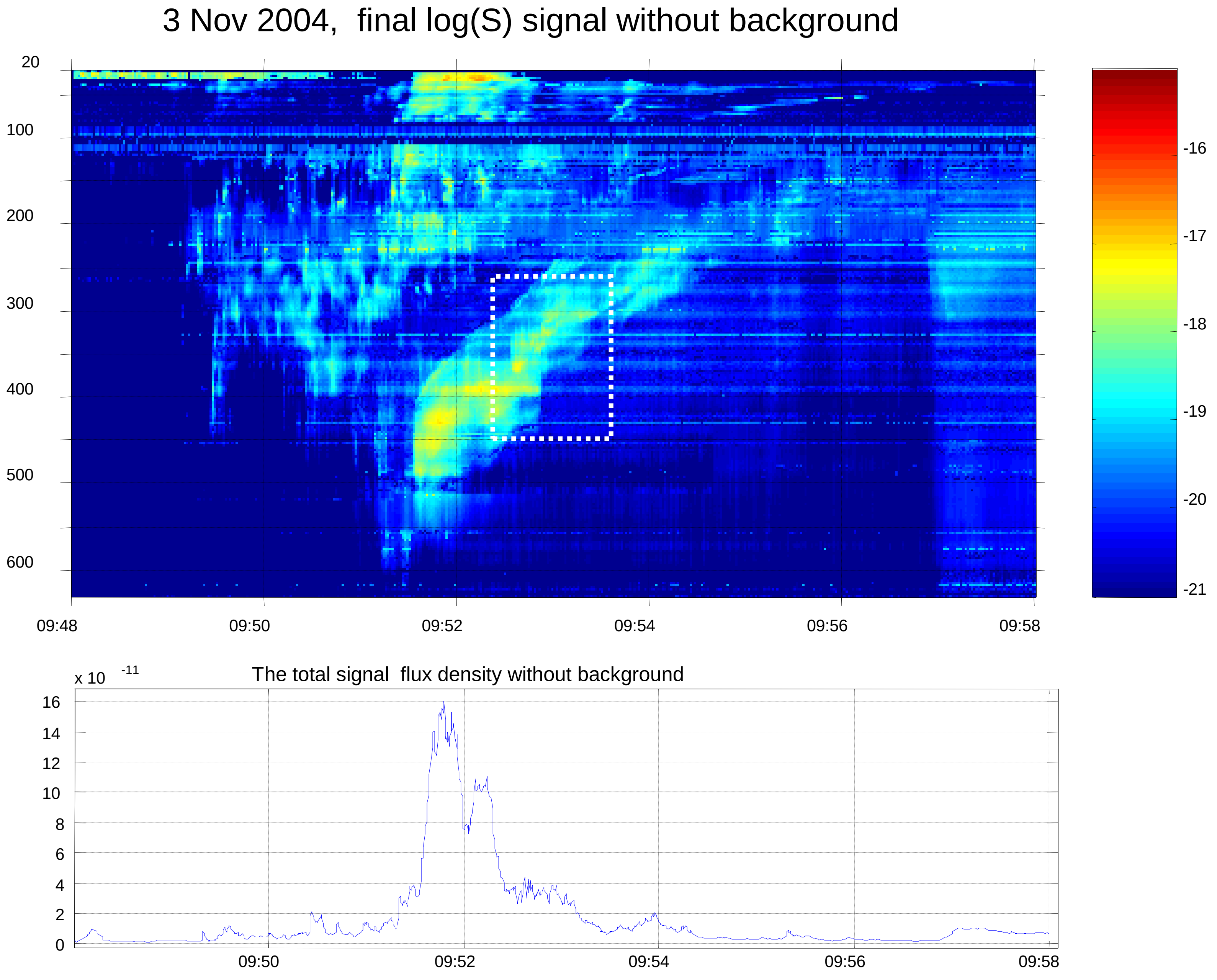


The log(s.f.u.) for the event 1s.f.u.=10^{-22} W m^{-2} Hz^{-1}

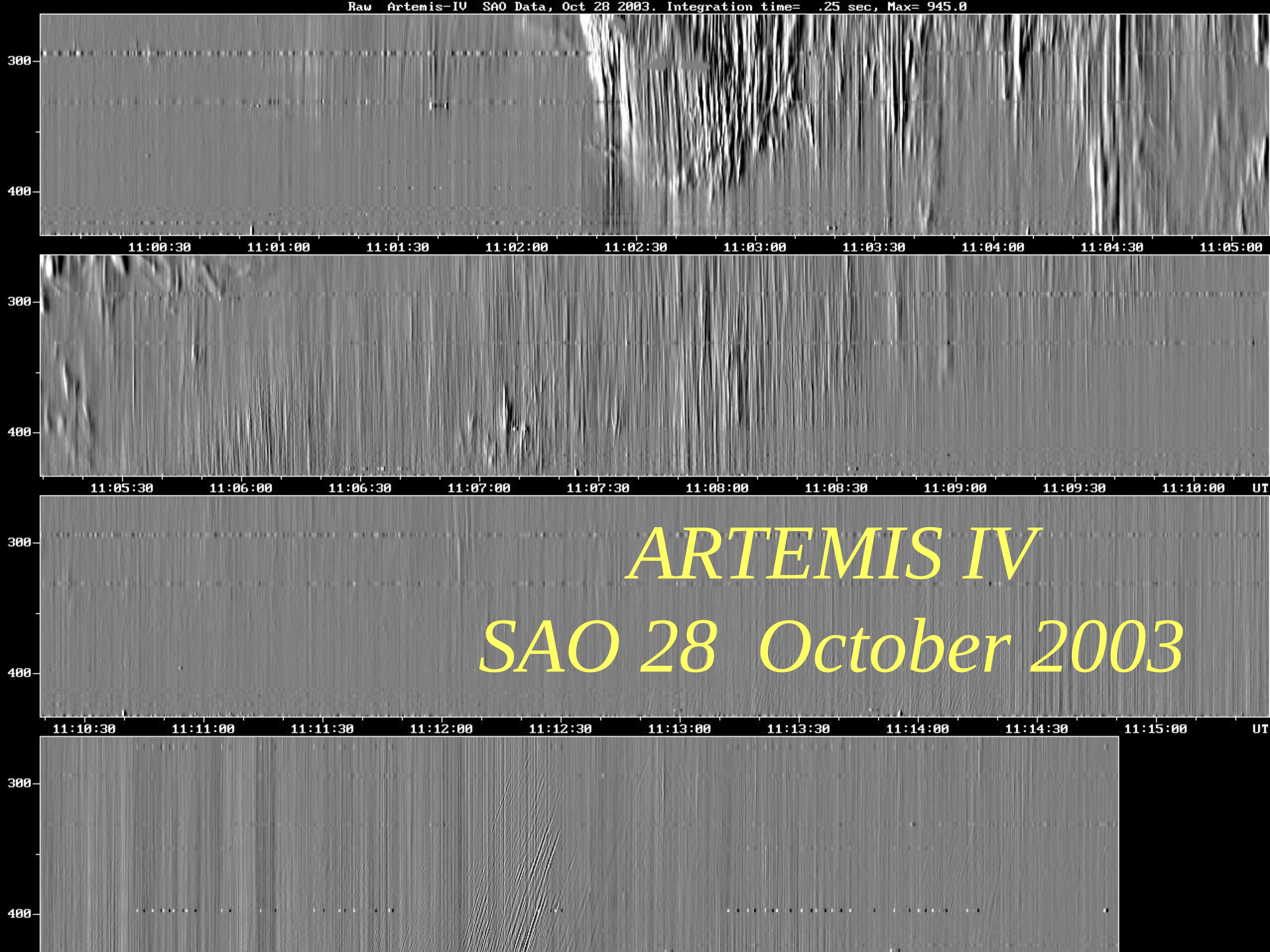


26 Oct 2004, final log(S) signal without background
20
100
200
300
400
500
600
06:00
06:20
06:40
07:00
07:20
07:40
× 10^-10
4
3.5
3
2.5
2
1.5
1
0.5
0
08:00


28 Oct 2004, final log(S) signal without background
20
100
200
300
400
500
600
10:02
10:03
10:04
10:05
10:06
10:07
10:08
10:09
10:10
-15
-16
-17
-18
-19
-20
-21
The total signal flux density without background
x 10 -9
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10:02
10:03
10:04
10:05
10:06
10:07
10:08
10:09
10:10



3 Nov 2004, integration time 0.5sec

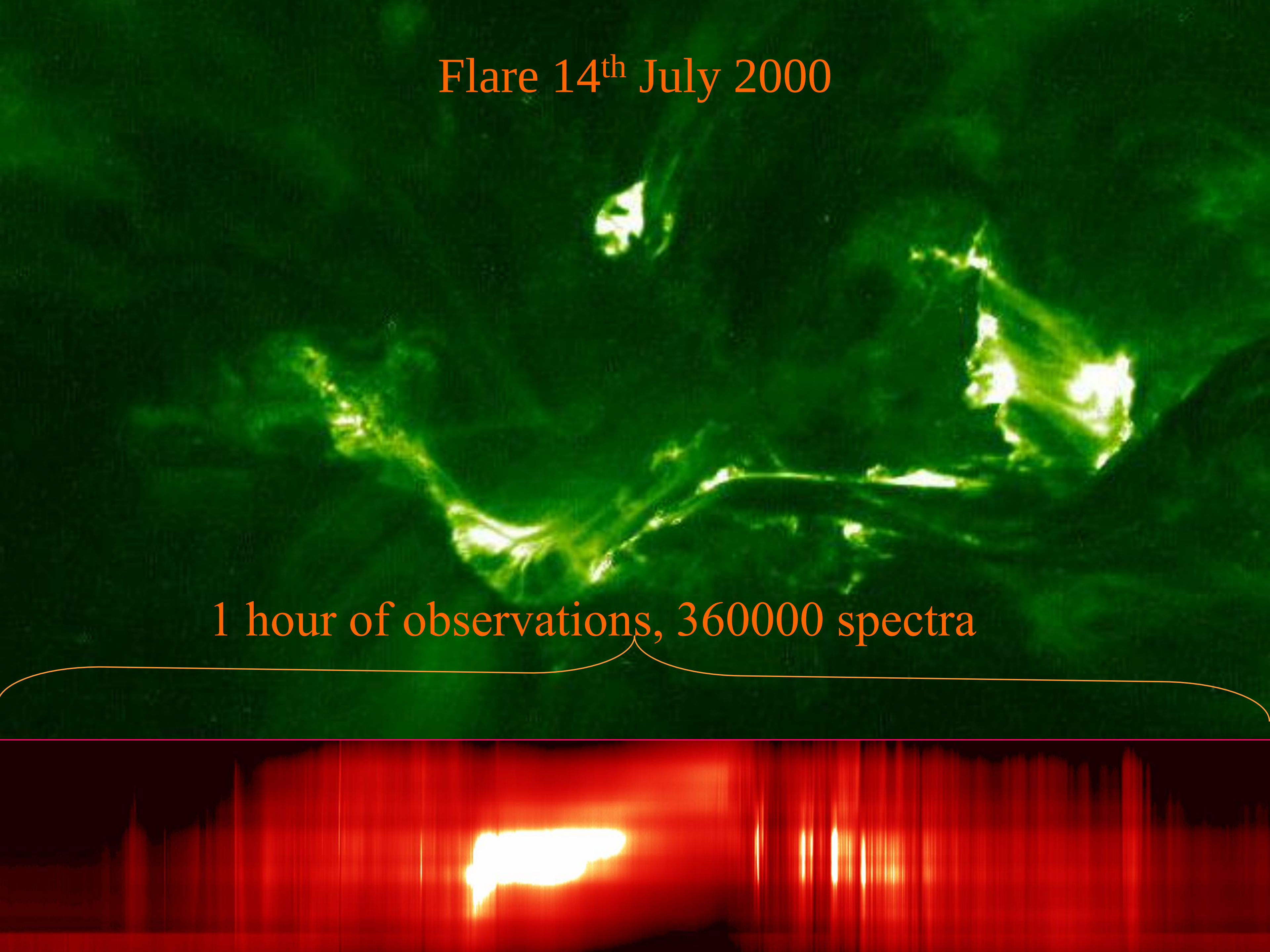

Raw Artemis-IV SAO Data, Oct 28 2003. Integration time= .25 sec, Max= 945.0
300
400
11:00:30
11:01:00
11:01:30
11:02:00
11:02:30
11:03:00
11:03:30
11:04:00
11:04:30
11:05:00
11:05:30
11:06:00
11:06:30
11:07:00
11:07:30
11:08:00
11:08:30
11:09:00
11:09:30
11:10:00
UT
11:10:30
11:11:00
11:11:30
11:12:00
11:12:30
11:13:00
11:13:30
11:14:00
11:14:30
11:15:00
UT
ARTEMIS IV
SAO 28 October 2003

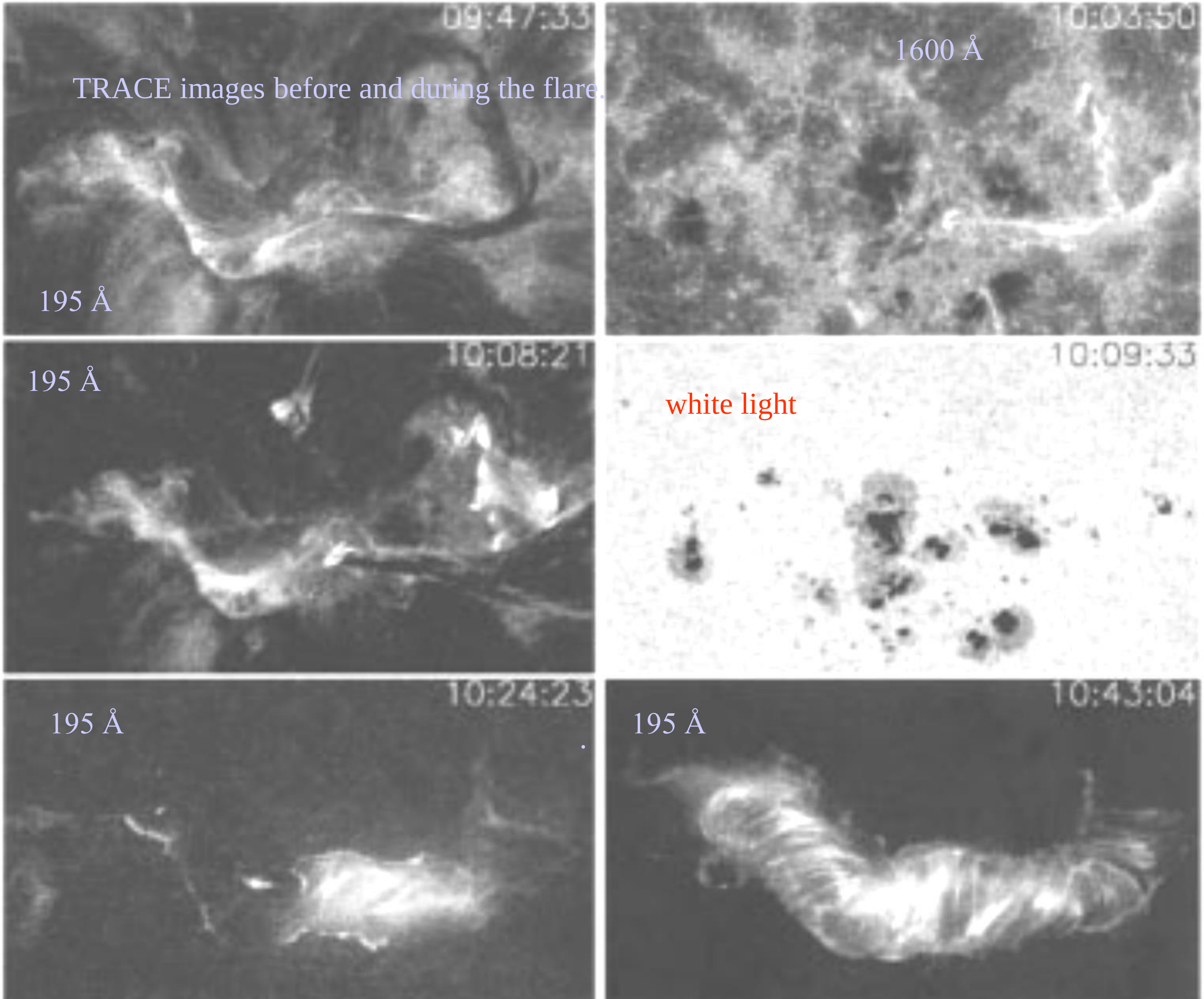
RADIO SIGNATURES OF MAGNETIC RESTRUCTURING DURING THE

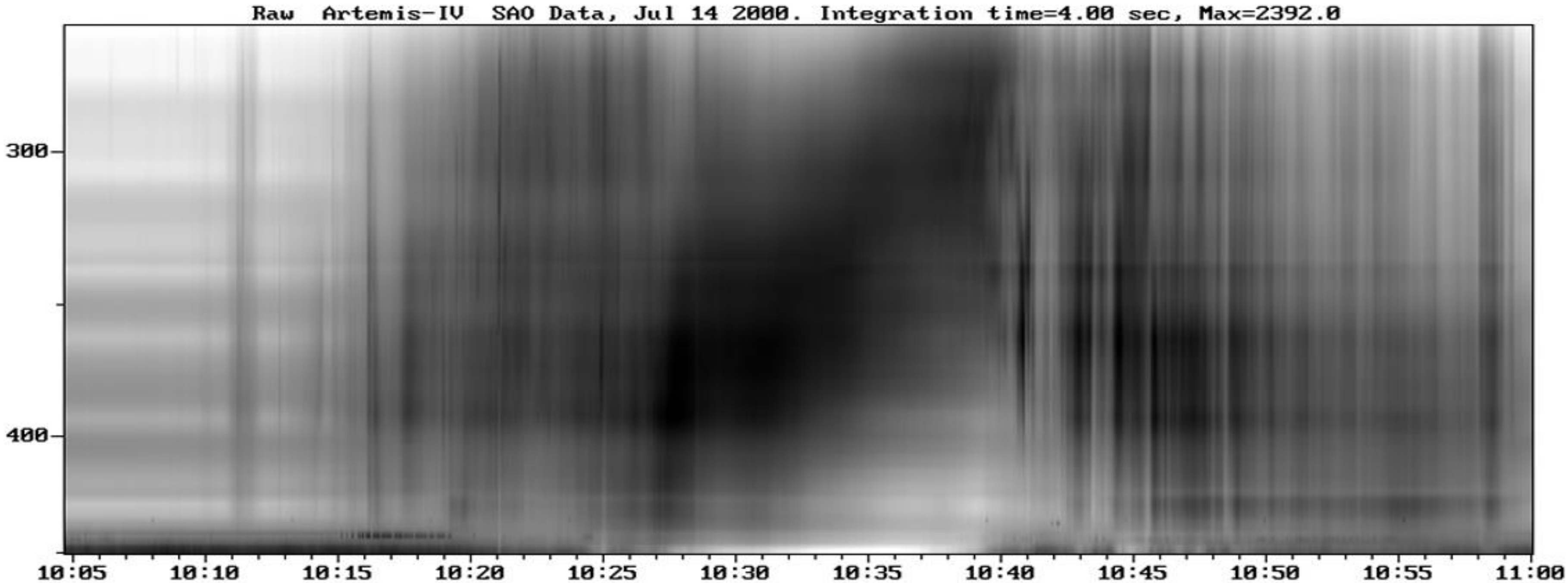
2000 JULY 14

MAJOR SOLAR EVENT

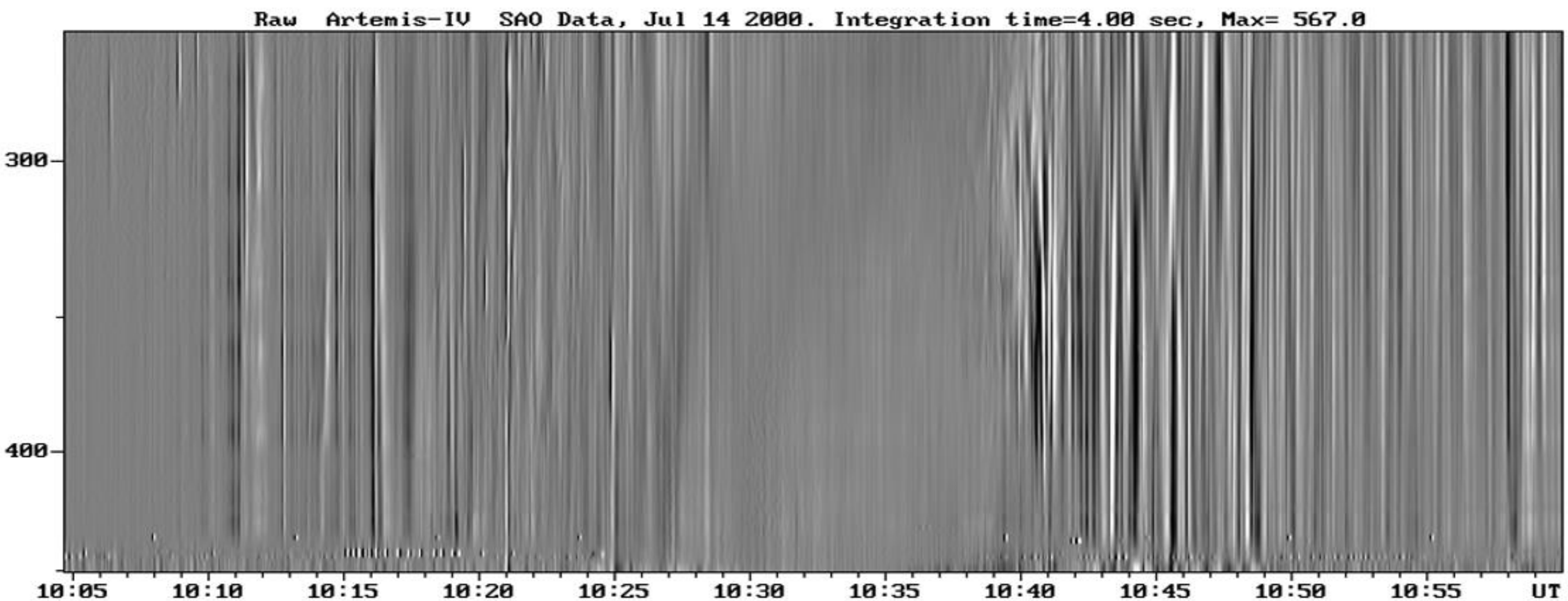
- **C. Caroubalos(1), P. Tsitsipis(4), A. Kontogeorgos(4), X. Moussas(2), C. E. Alissandrakis(3), A. Hillaris(2), P. Preka-Papadema(2), J. Polygiannakis(2), J.-L. Bougeret(5), G. Dumas(5), V. Kurt(6), C. Vassiliou(2), C. Perche(5), K. Gazeas (2), G. Kolovos(2)**


Flare 14th July 2000
1 hour of observations, 360000 spectra

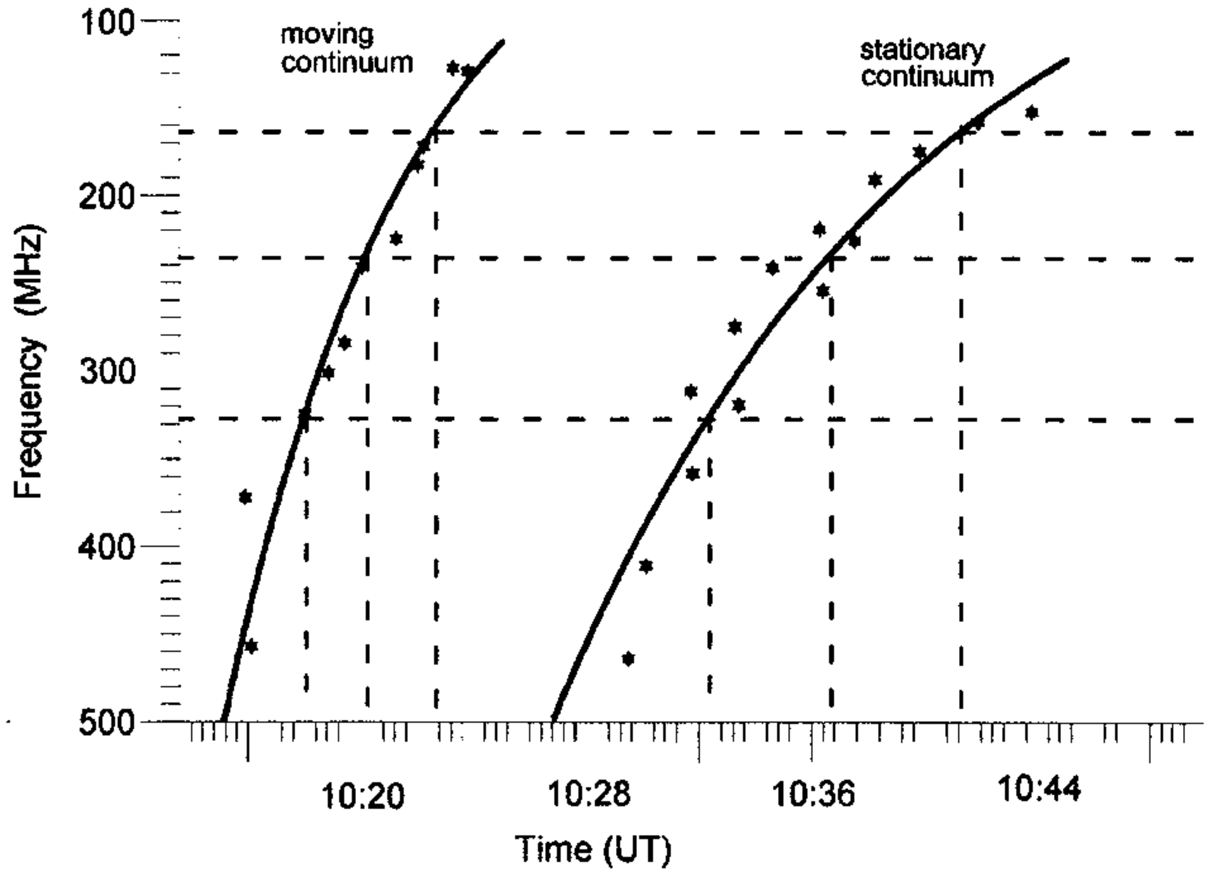

09:47:33
TRACE images before and during the flare.
195 Å
10:03:50
1600 Å
10:08:21
195 Å
10:09:33
white light
10:24:23
195 Å
10:43:04
195 Å



Raw Artemis-IV SAO Data, Jul 14 2000. Integration time=4.00 sec, Max=2392.0
300
400
10:05
10:10
10:15
10:20
10:25
10:30
10:35
10:40
10:45
10:50
10:55
11:00



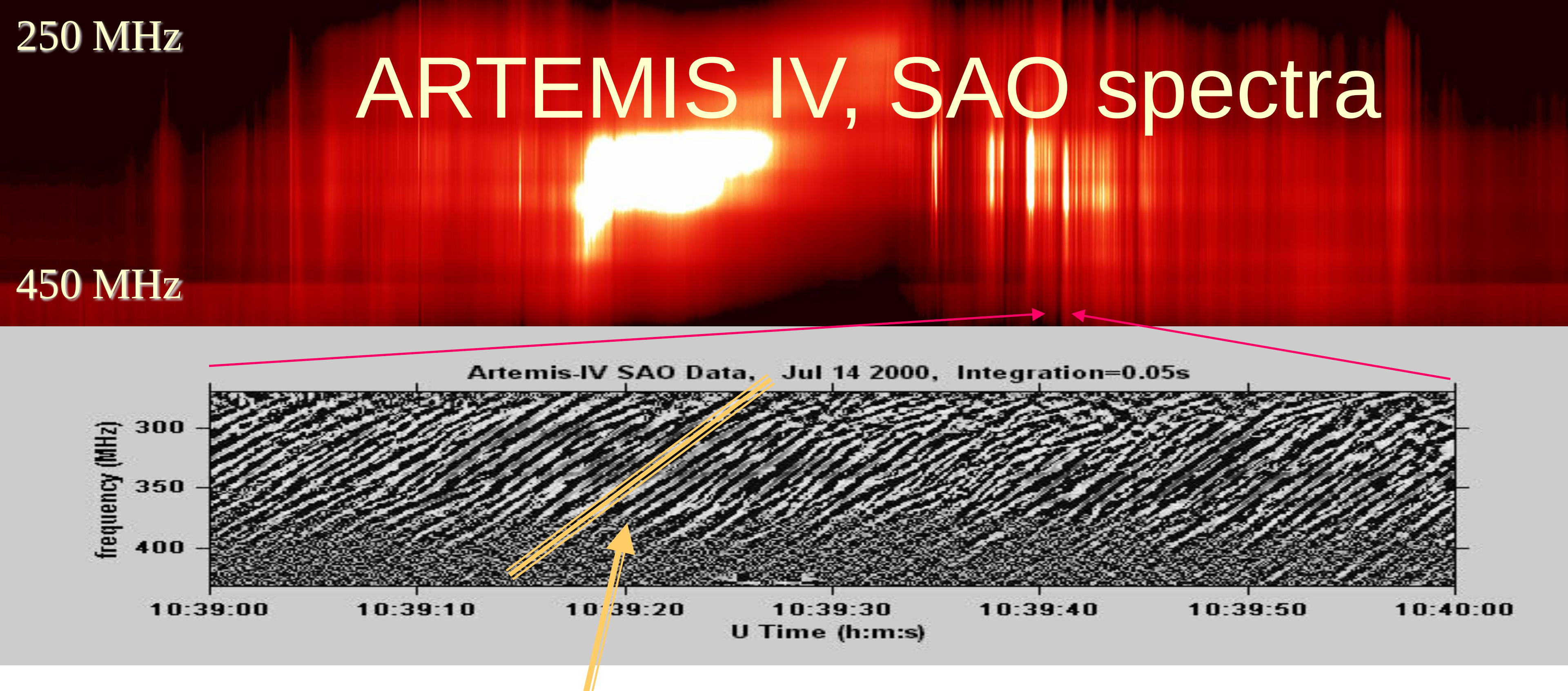
Raw Artemis-IV SAO Data, Jul 14 2000. Integration time=4.00 sec, Max= 567.0
300
400
10:05
10:10
10:15
10:20
10:25
10:30
10:35
10:40
10:45
10:50
10:55
UT



Position of maxima of the type II and type IV as a function of frequency (linear scale) and time.

Both are fitted with exponential curves (*solid lines*).

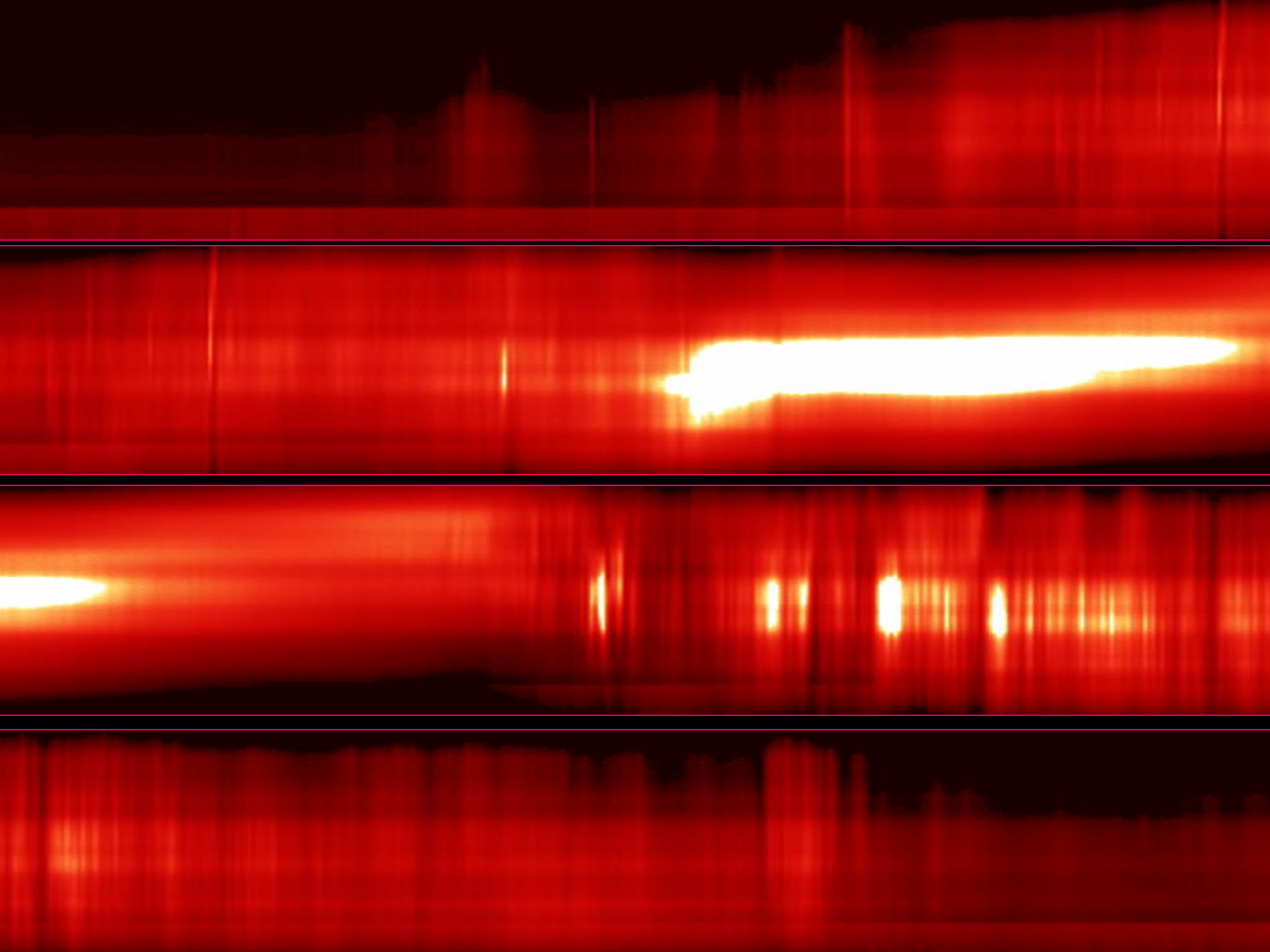
ARTEMIS IV, SAO spectra

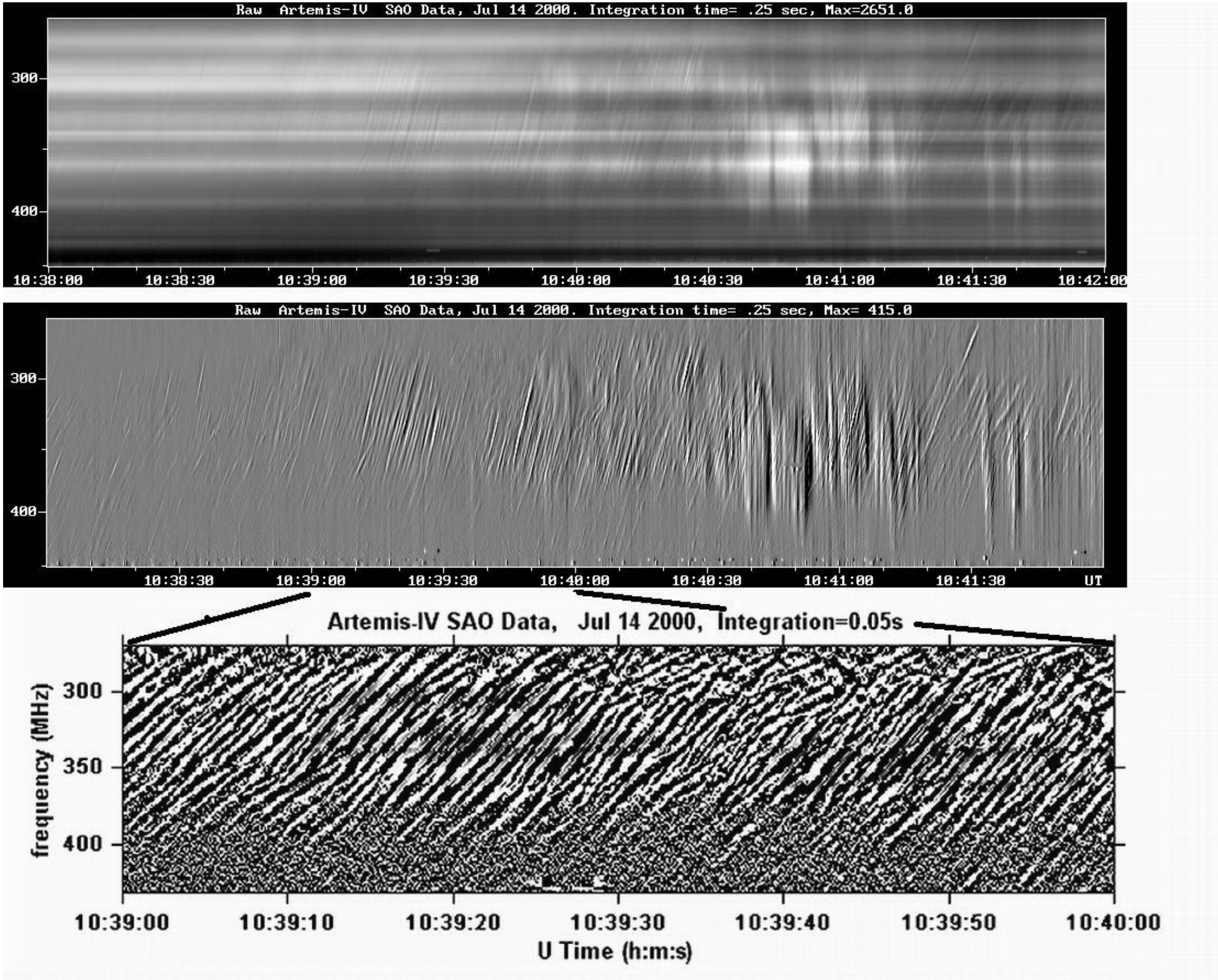


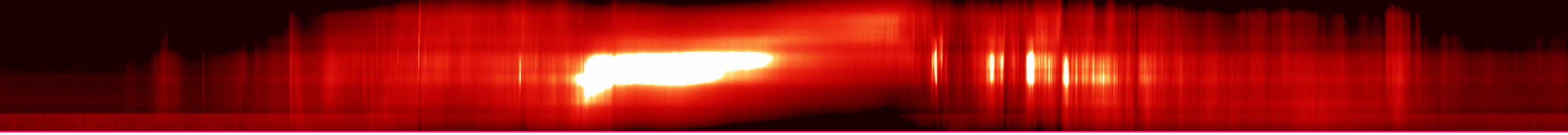
We measure the slope (df/dt) of every burst and we caclulate the speed of the electron beam which creates this ***fiber burst*** (based on a model for the solar corona density).

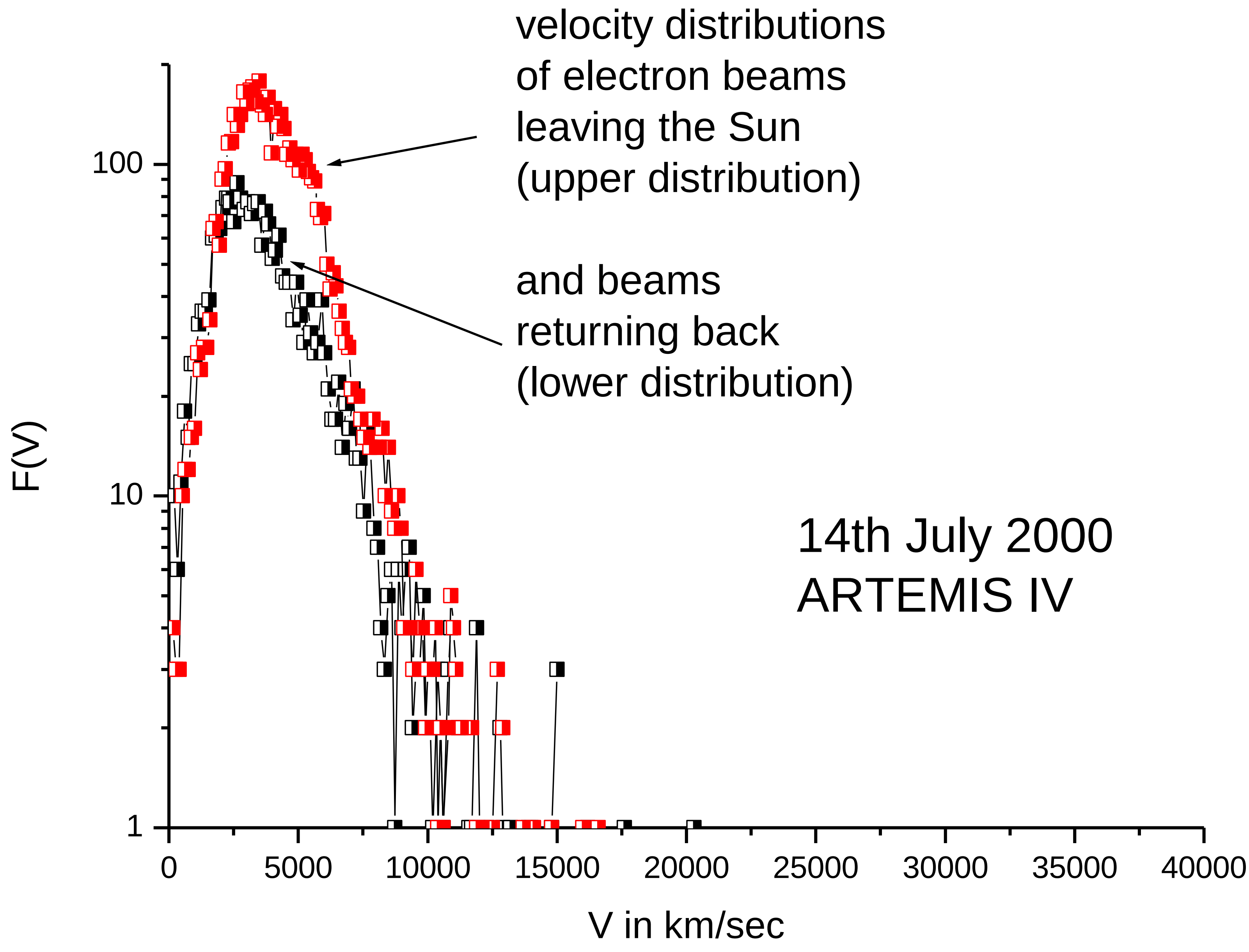
We calculate the production rate of beams per minute, both for beams leaving the Sun and returning back to the Sun

14th July 2000 flare and CME

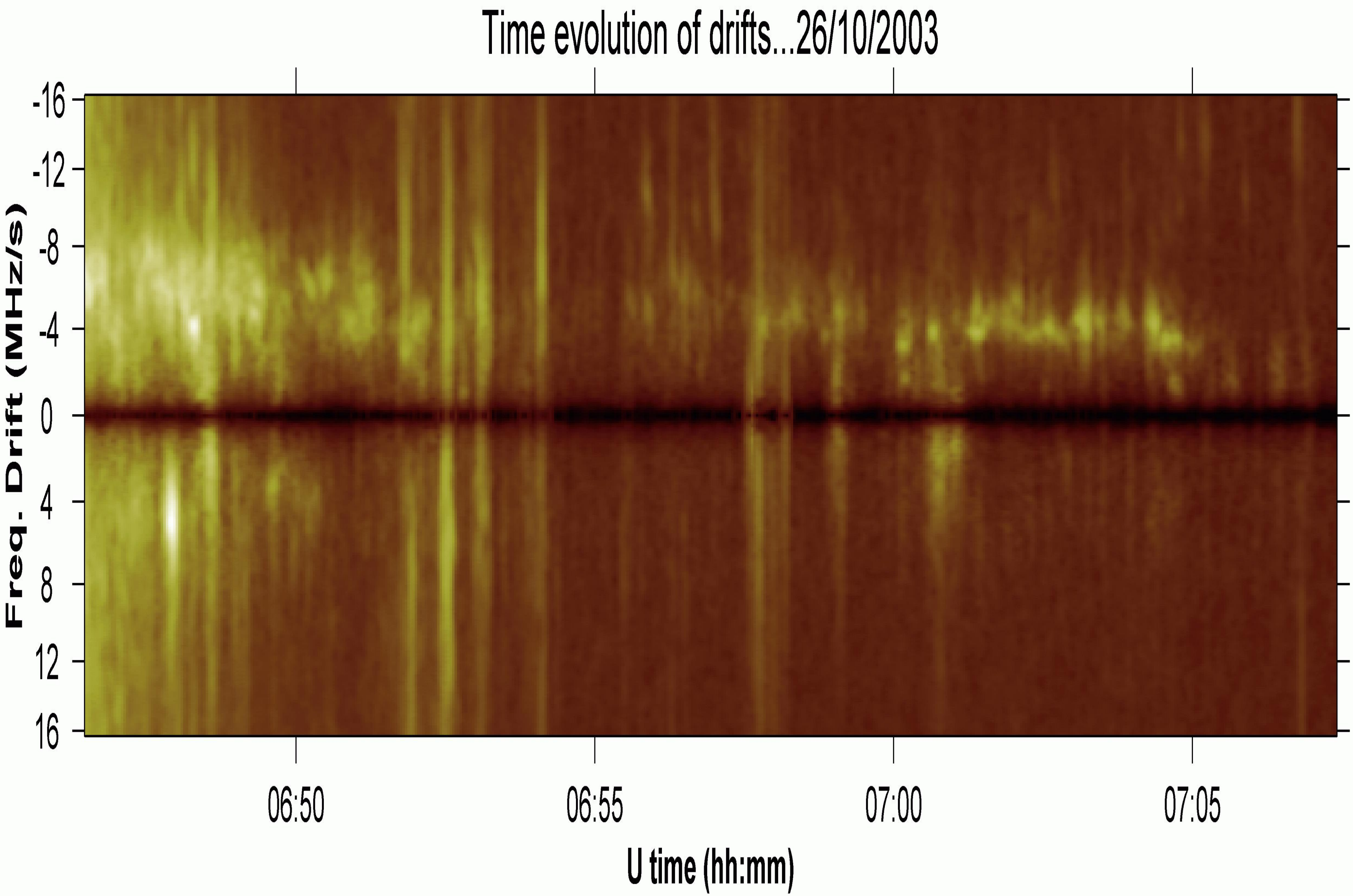



Raw Artemis-IV SAO Data, Jul 14 2000. Integration time= .25 sec, Max=2651.0
300
400
10:38:00
10:38:30
10:39:00
10:39:30
10:40:00
10:40:30
10:41:00
10:41:30
10:42:00
Raw Artemis-IV SAO Data, Jul 14 2000. Integration time= .25 sec, Max= 415.0
300
400
10:38:30
10:39:00
10:39:30
10:40:00
10:40:30
10:41:00
10:41:30
UT
Artemis-IV SAO Data, Jul 14 2000, Integration=0.05s
frequency (MHz)
300
350
400
10:39:00
10:39:10
10:39:20
10:39:30
10:39:40
10:39:50
10:40:00
U Time (h:m:s)

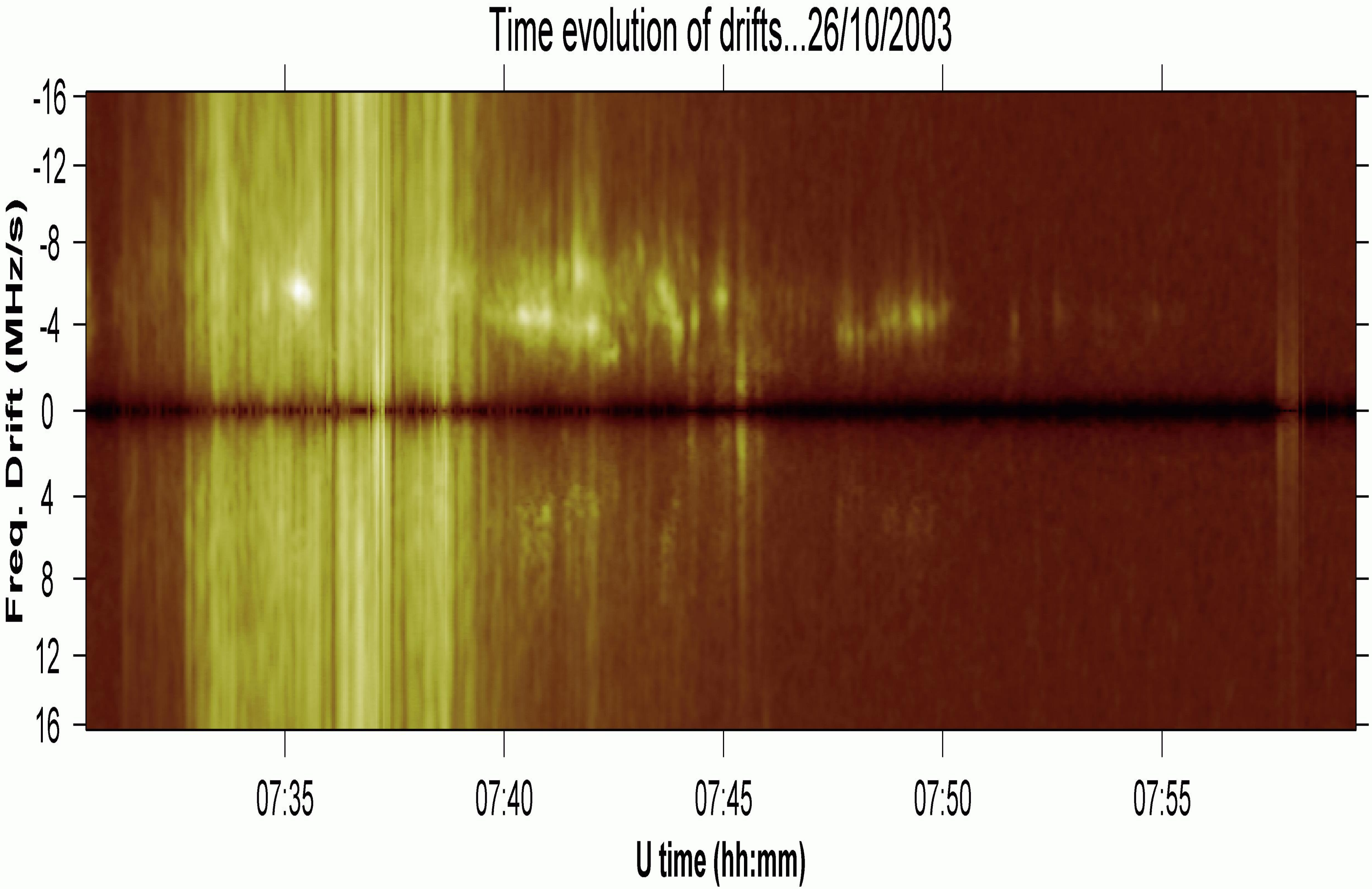


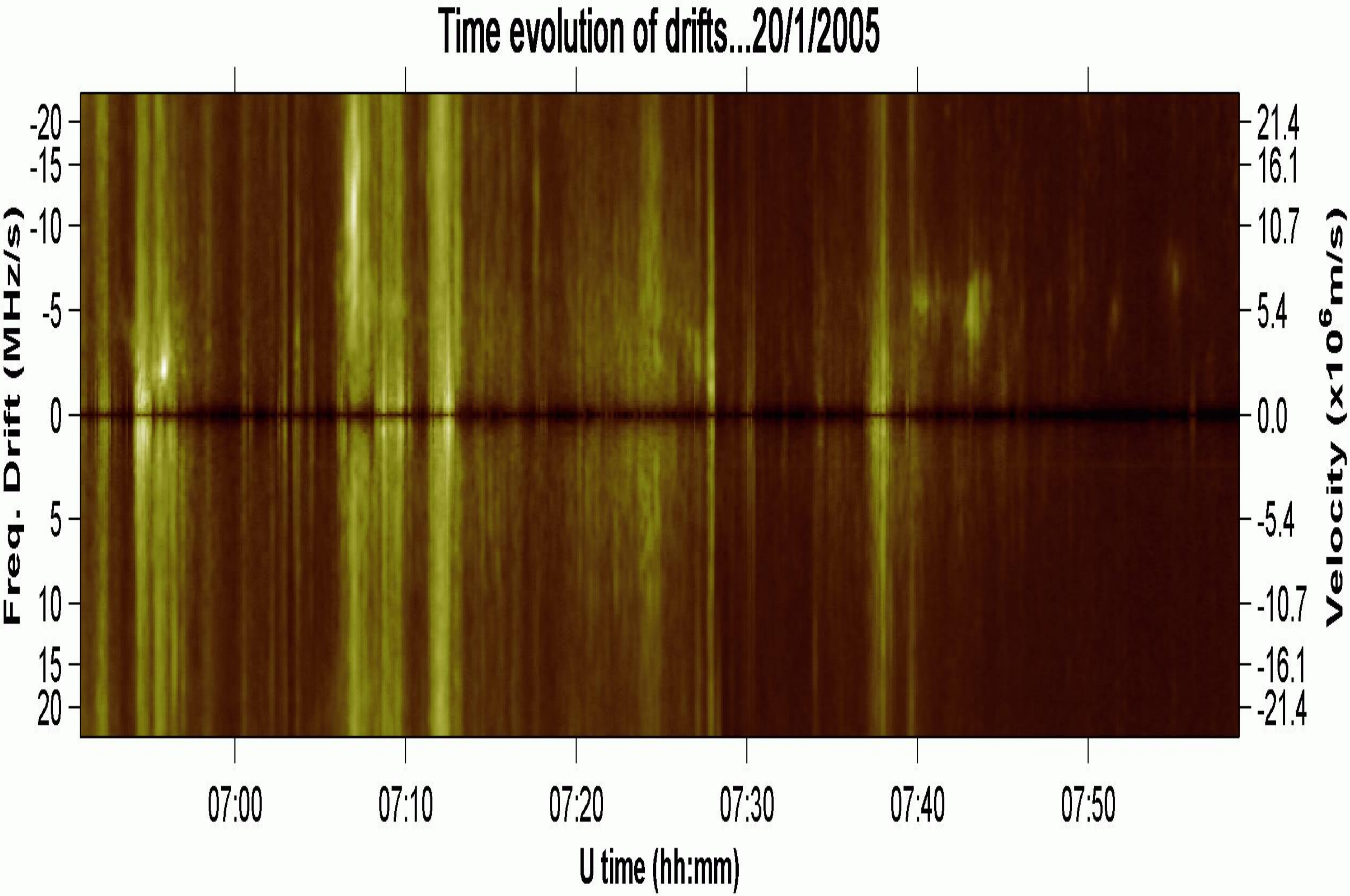


velocity distributions
of electron beams
leaving the Sun
(upper distribution)
and beams
returning back
(lower distribution)
14th July 2000
ARTEMIS IV
F(V)
100
10
1
0
5000
10000
15000
20000
25000
30000
35000
40000
V in km/sec

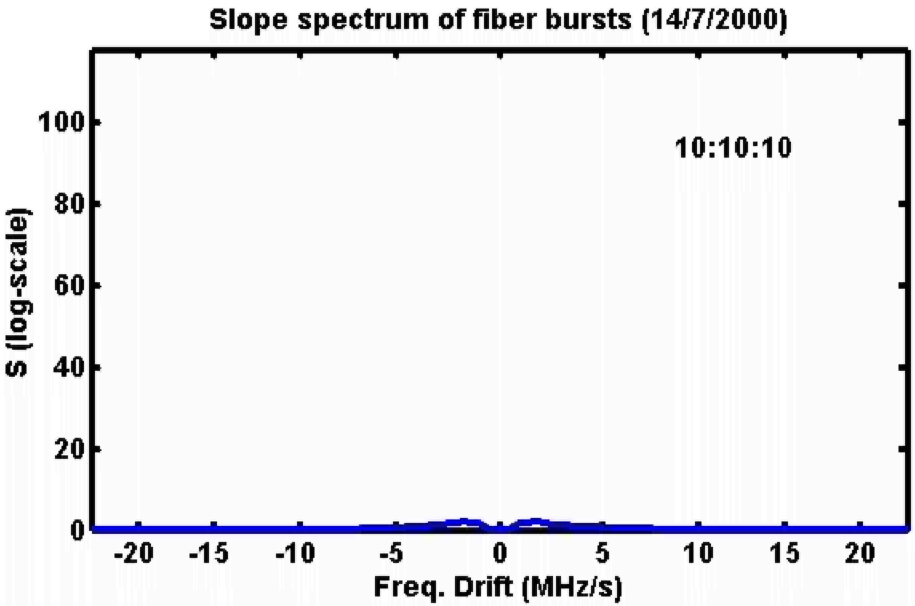


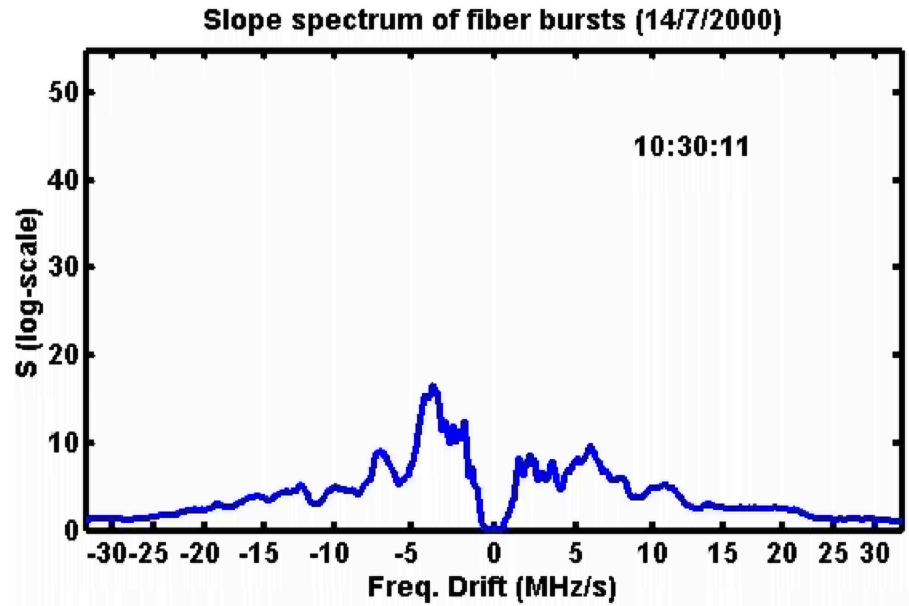
Time evolution of drifts...26/10/2003
Freq. Drift (MHz/s)
-16
-12
-8
-4
0
4
8
12
16
06:50
06:55
07:00
07:05
U time (hh:mm)

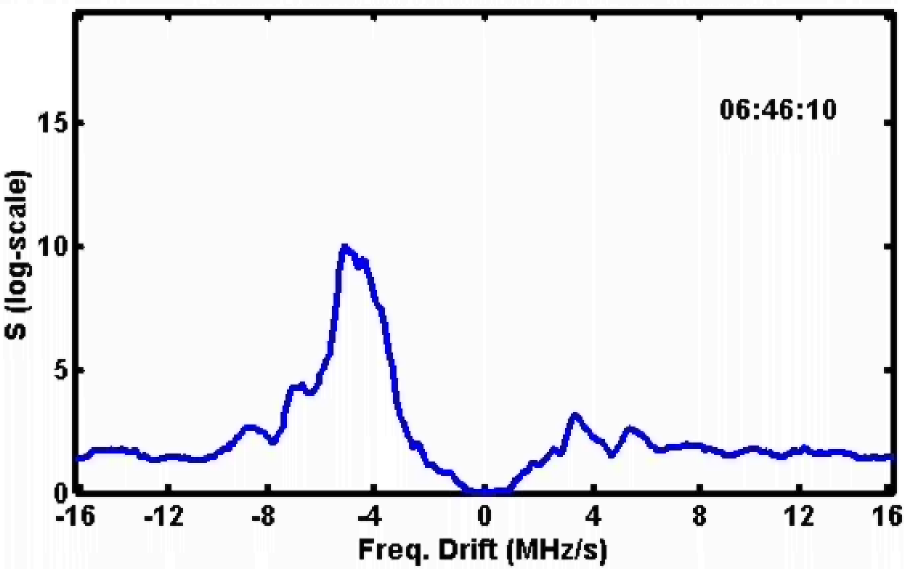

Time evolution of drifts...26/10/2003
Freq. Drift (MHz/s)
-16
-12
-8
-4
0
4
8
12
16
07:35
07:40
07:45
07:50
07:55
U time (hh:mm)

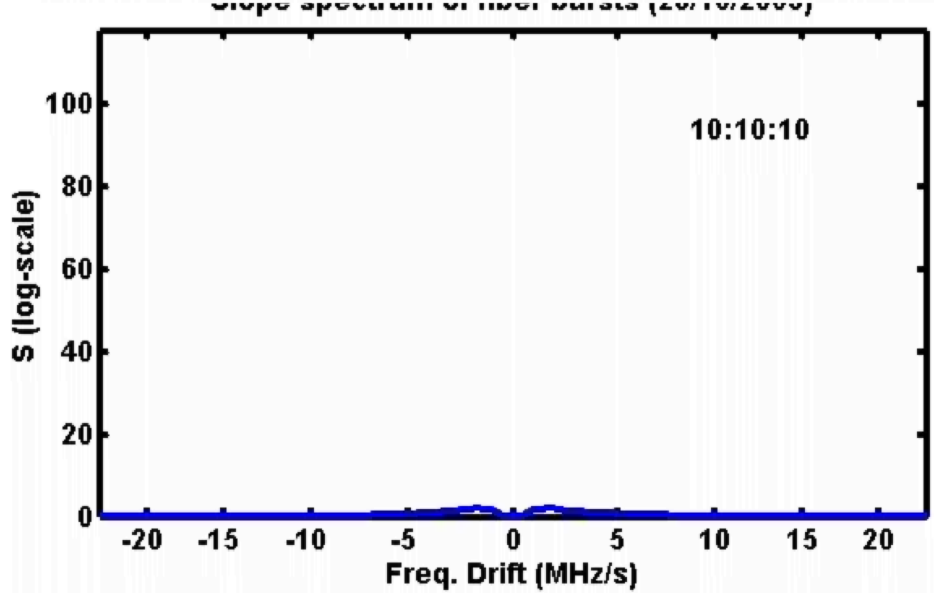

Time evolution of drifts...20/1/2005
Freq. Drift (MHz/s)
-20
-15
-10
-5
0
5
10
15
20
Velocity (x10^{6}m/s)
21.4
16.1
10.7
5.4
0.0
-5.4
-10.7
-16.1
-21.4
07:00
07:10
07:20
07:30
07:40
07:50
U time (hh:mm)

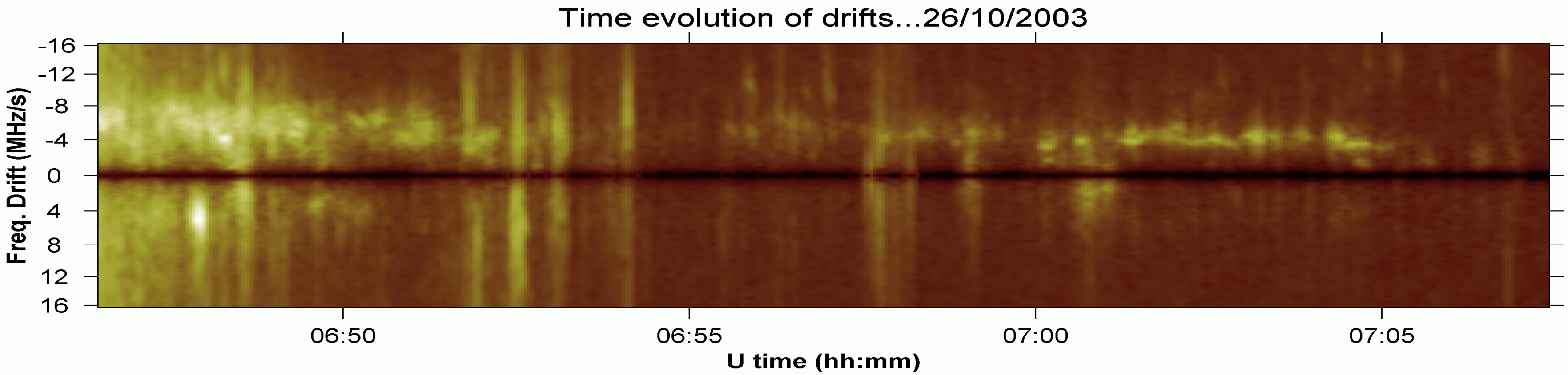
Fine structure with ARTEMIS SAO

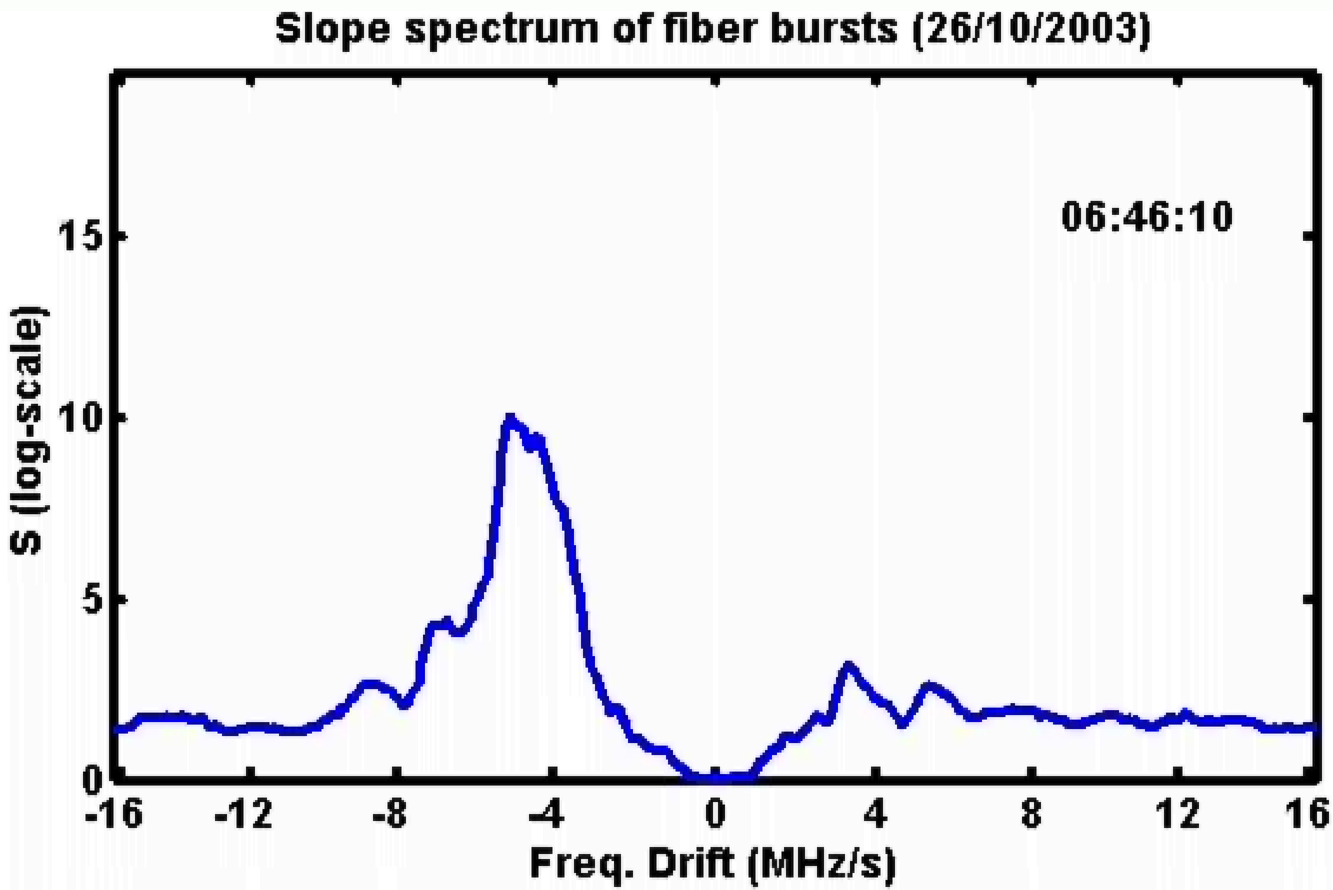


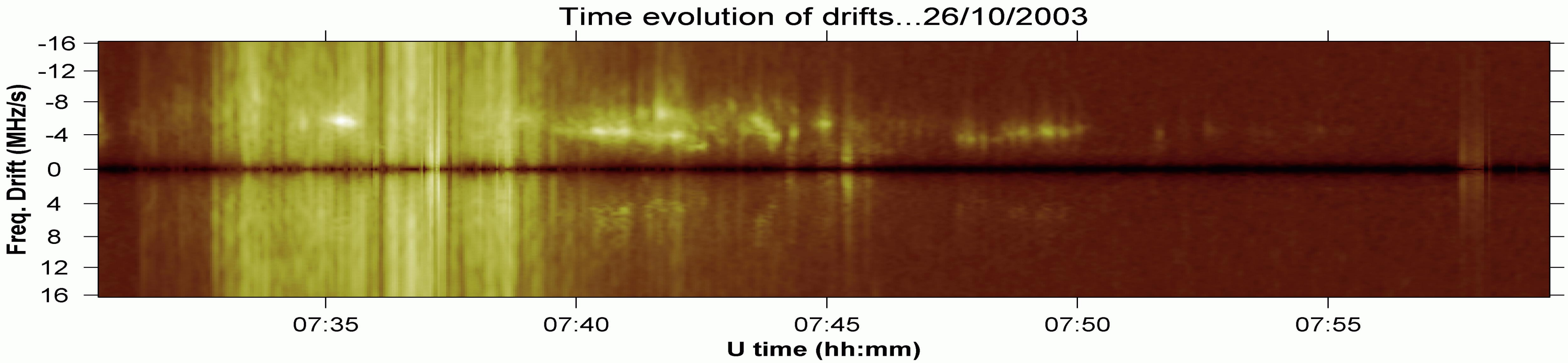


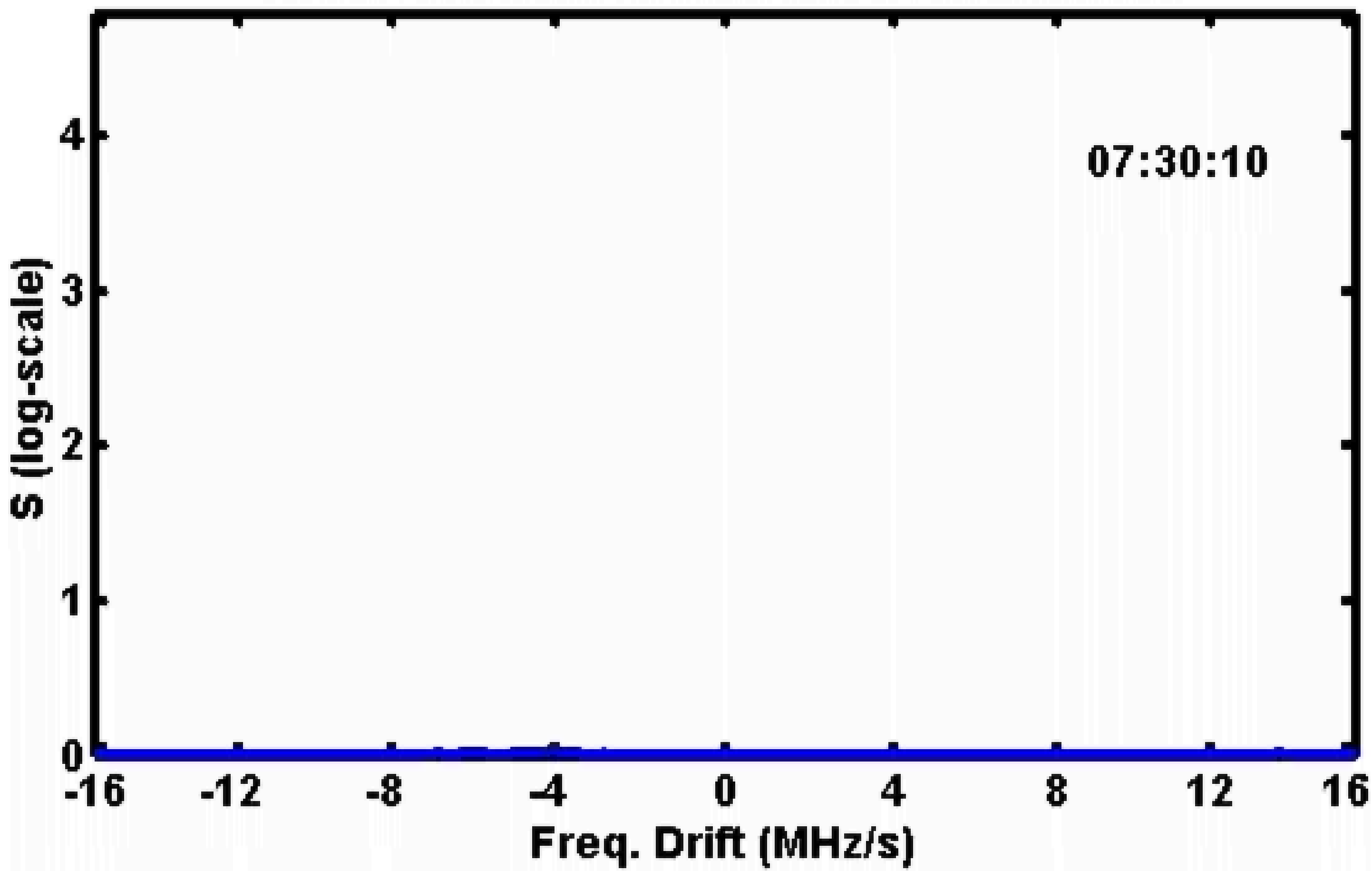


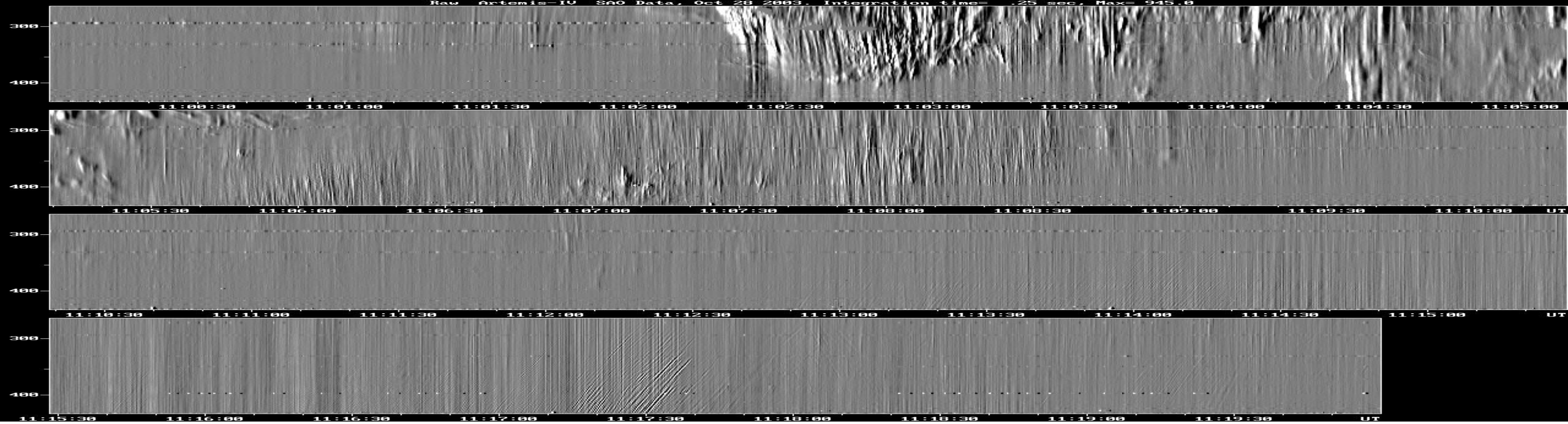



Time evolution of drifts...26/10/2003
Freq. Drift (MHz/s)
-16
-12
-8
-4
0
4
8
12
16
06:50
06:55
07:00
07:05
U time (hh:mm)

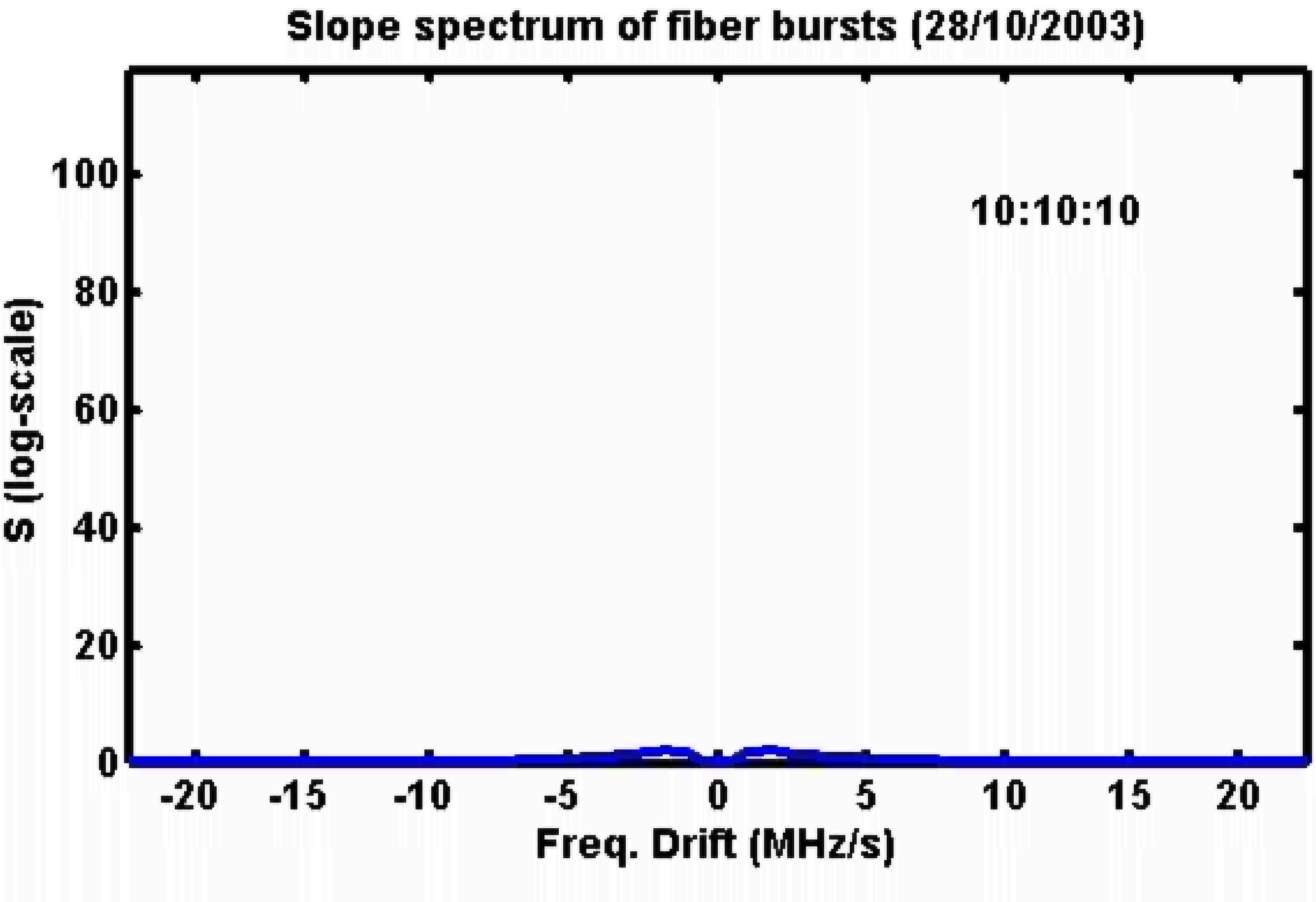

Slope spectrum of fiber bursts (26/10/2003)
06:46:10
S (log-scale)
0
5
10
15
-16
-12
-8
-4
0
4
8
12
16
Freq. Drift (MHz/s)


Time evolution of drifts...26/10/2003
Freq. Drift (MHz/s)
-16
-12
-8
-4
0
4
8
12
16
07:35
07:40
07:45
07:50
07:55
U time (hh:mm)

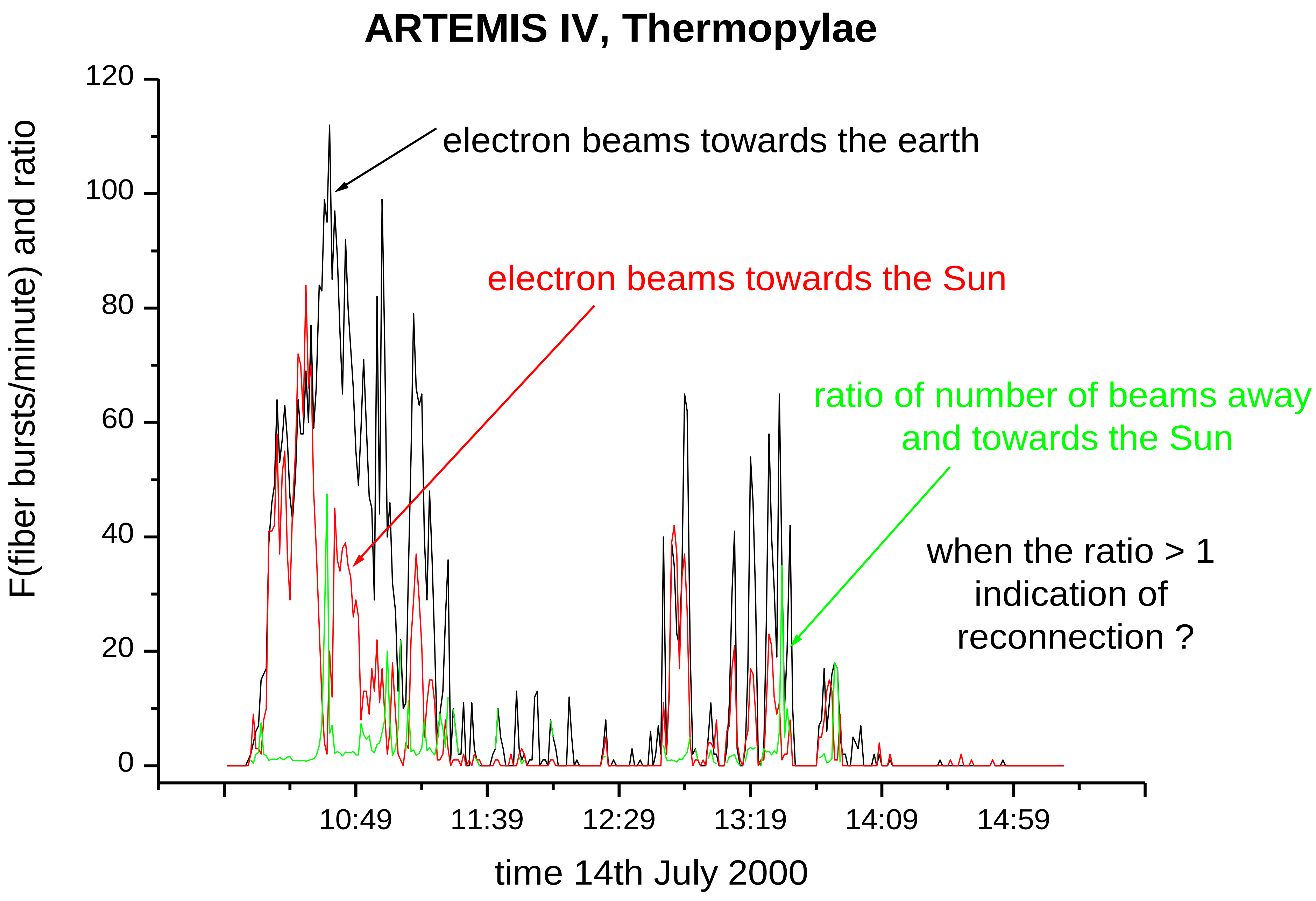

07:30:10
S (log-scale)
0
1
2
3
4
-16
-12
-8
-4
0
4
8
12
16
Freq. Drift (MHz/s)

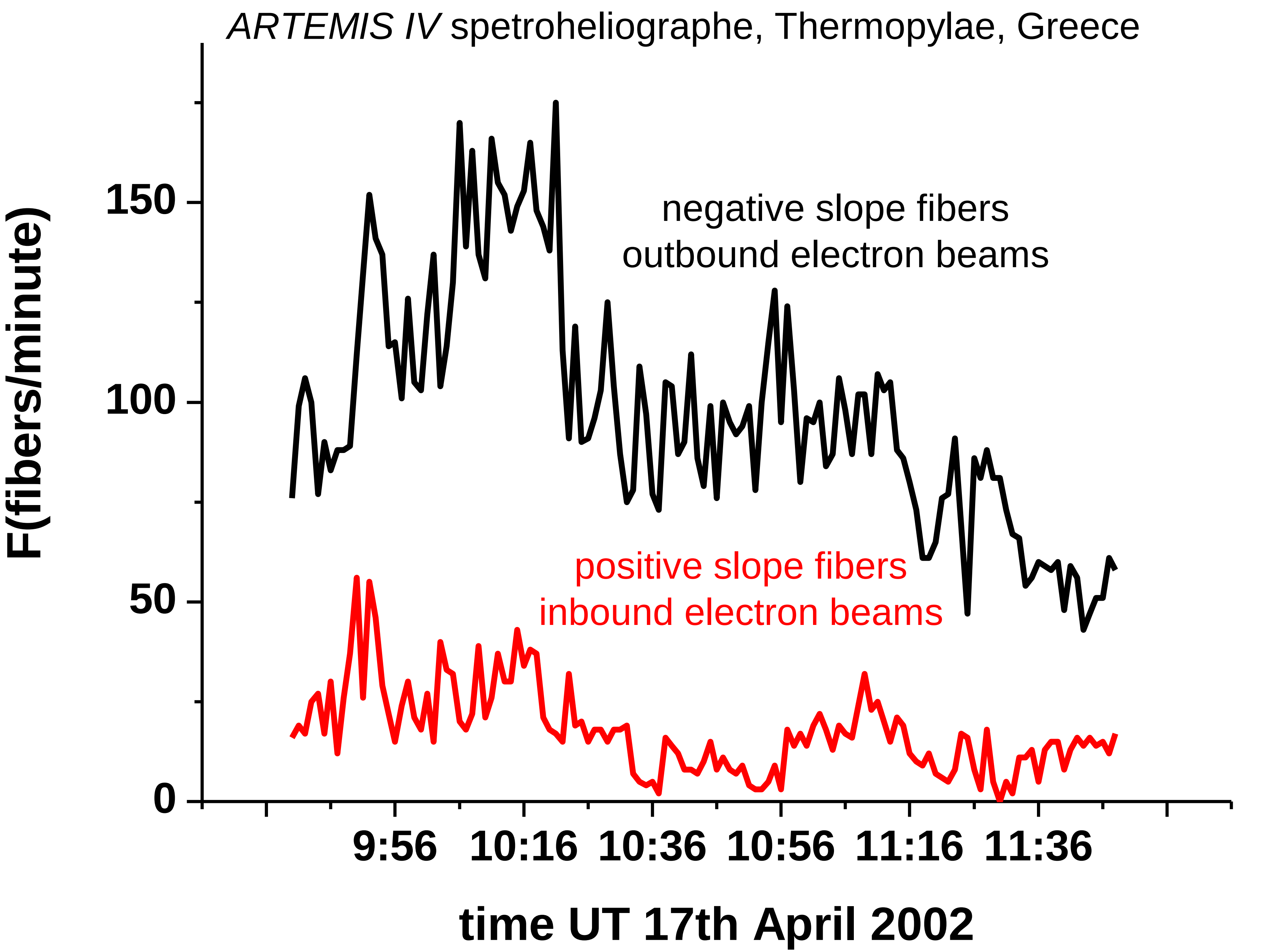


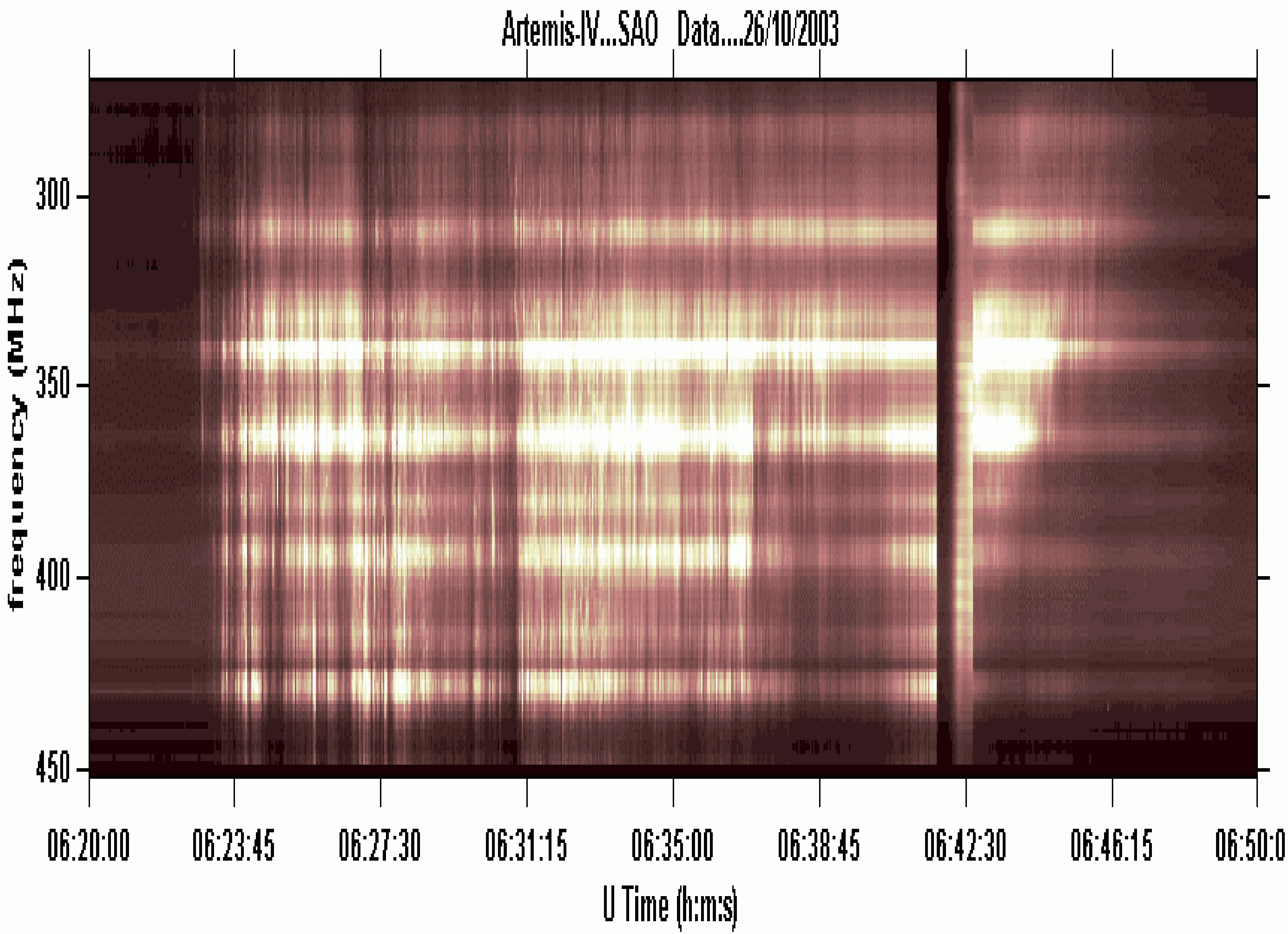
Raw Artemis-IV SAO Data, Oct 28 2003. Integration time= .25 sec, Max= 945.0
300
400
11:00:30
11:01:00
11:01:30
11:02:00
11:02:30
11:03:00
11:03:30
11:04:00
11:04:30
11:05:00
11:05:30
11:06:00
11:06:30
11:07:00
11:07:30
11:08:00
11:08:30
11:09:00
11:09:30
11:10:00
UT
11:10:30
11:11:00
11:11:30
11:12:00
11:12:30
11:13:00
11:13:30
11:14:00
11:14:30
11:15:00
11:15:30
11:16:00
11:16:30
11:17:00
11:17:30
11:18:00
11:18:30
11:19:00
11:19:30



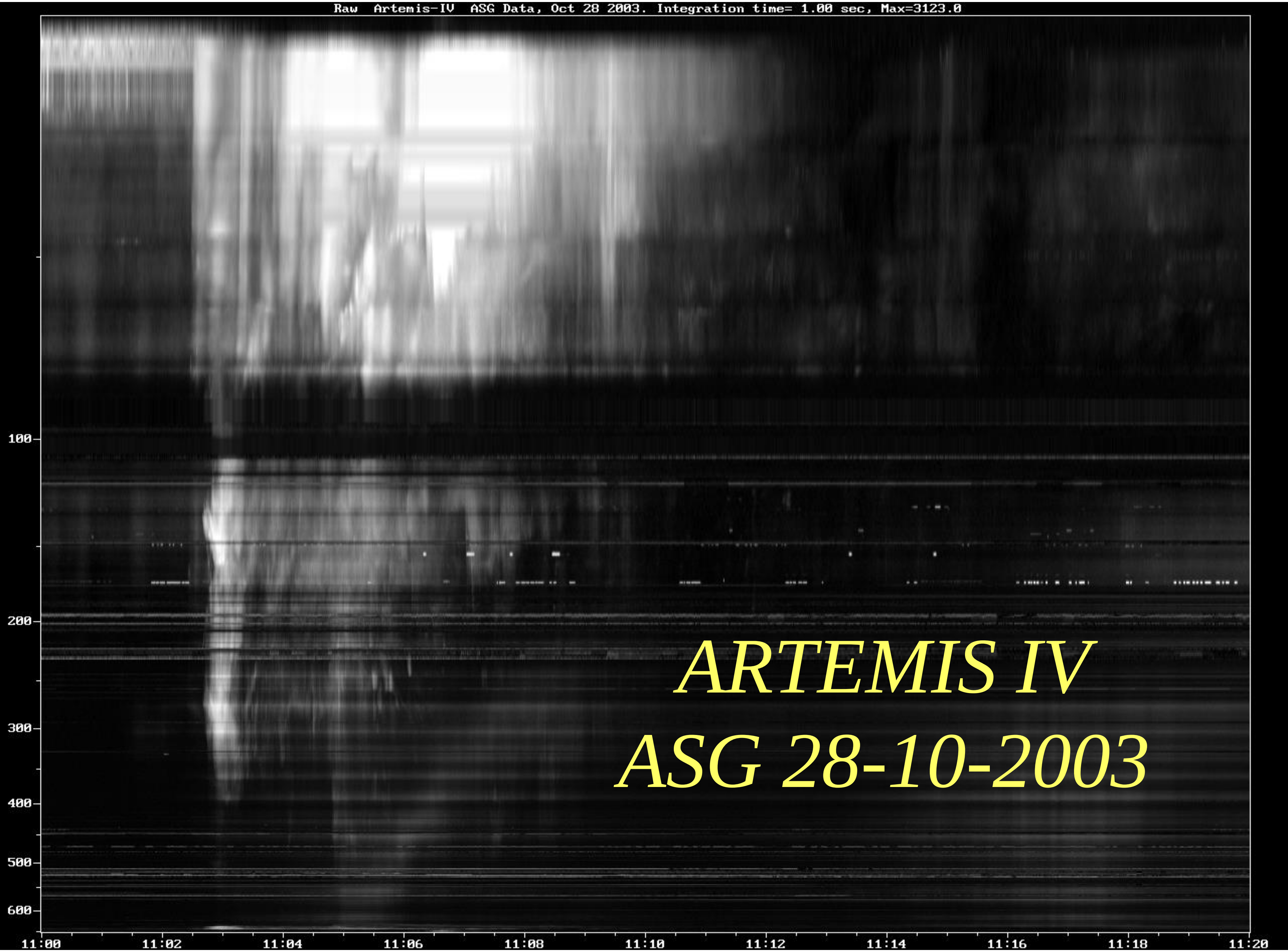
Slope spectrum of fiber bursts (28/10/2003)
10:10:10
S (log-scale)
0
20
40
60
80
100
-20
-15
-10
-5
0
5
10
15
20
Freq. Drift (MHz/s)

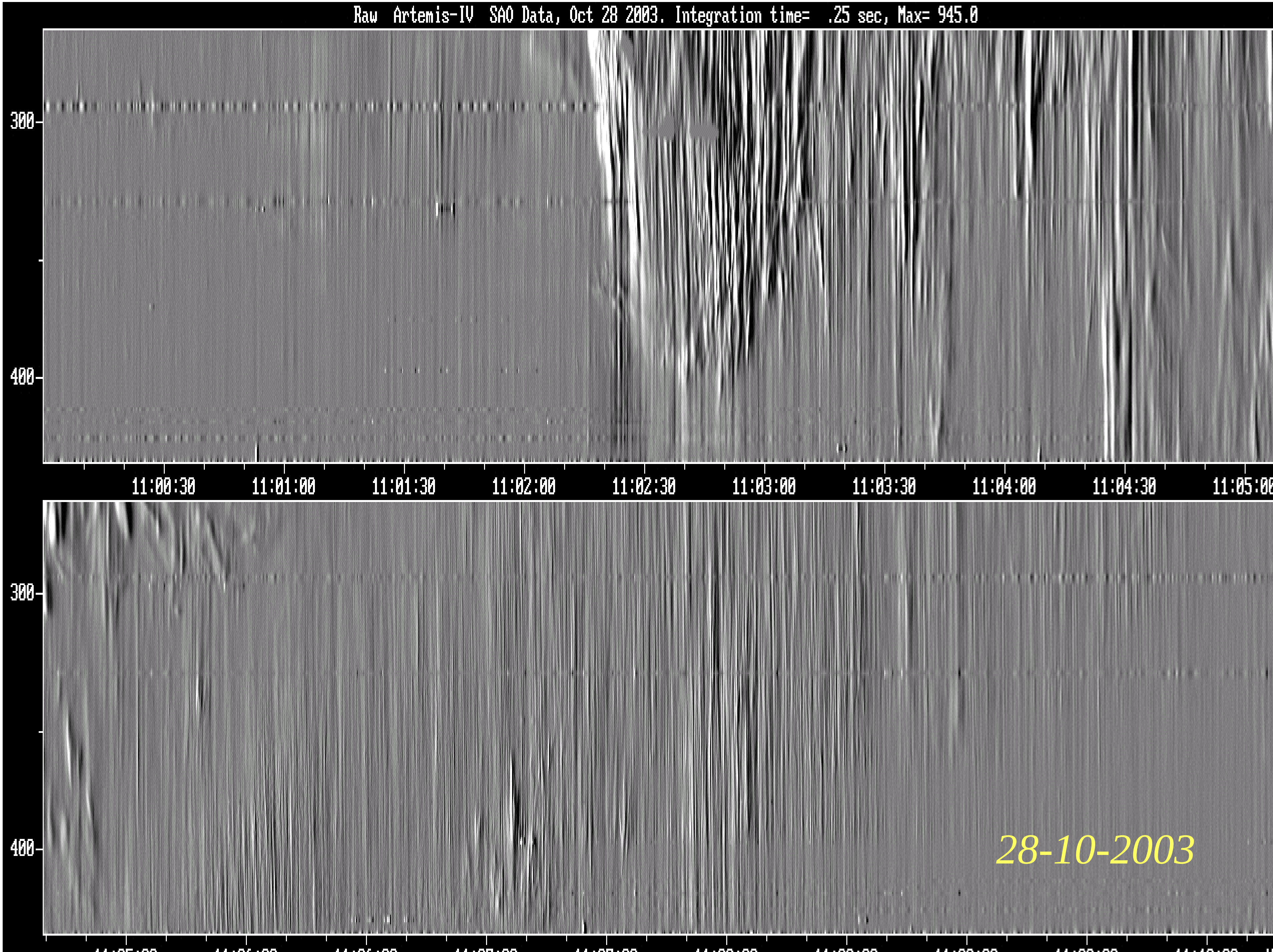

ARTEMIS IV, Thermopylae
F(fiber bursts/minute) and ratio
120
100
80
60
40
20
0
electron beams towards the earth
electron beams towards the Sun
ratio of number of beams away
and towards the Sun
when the ratio > 1
indication of
reconnection ?
10:49
11:39
12:29
13:19
14:09
14:59
time 14th July 2000

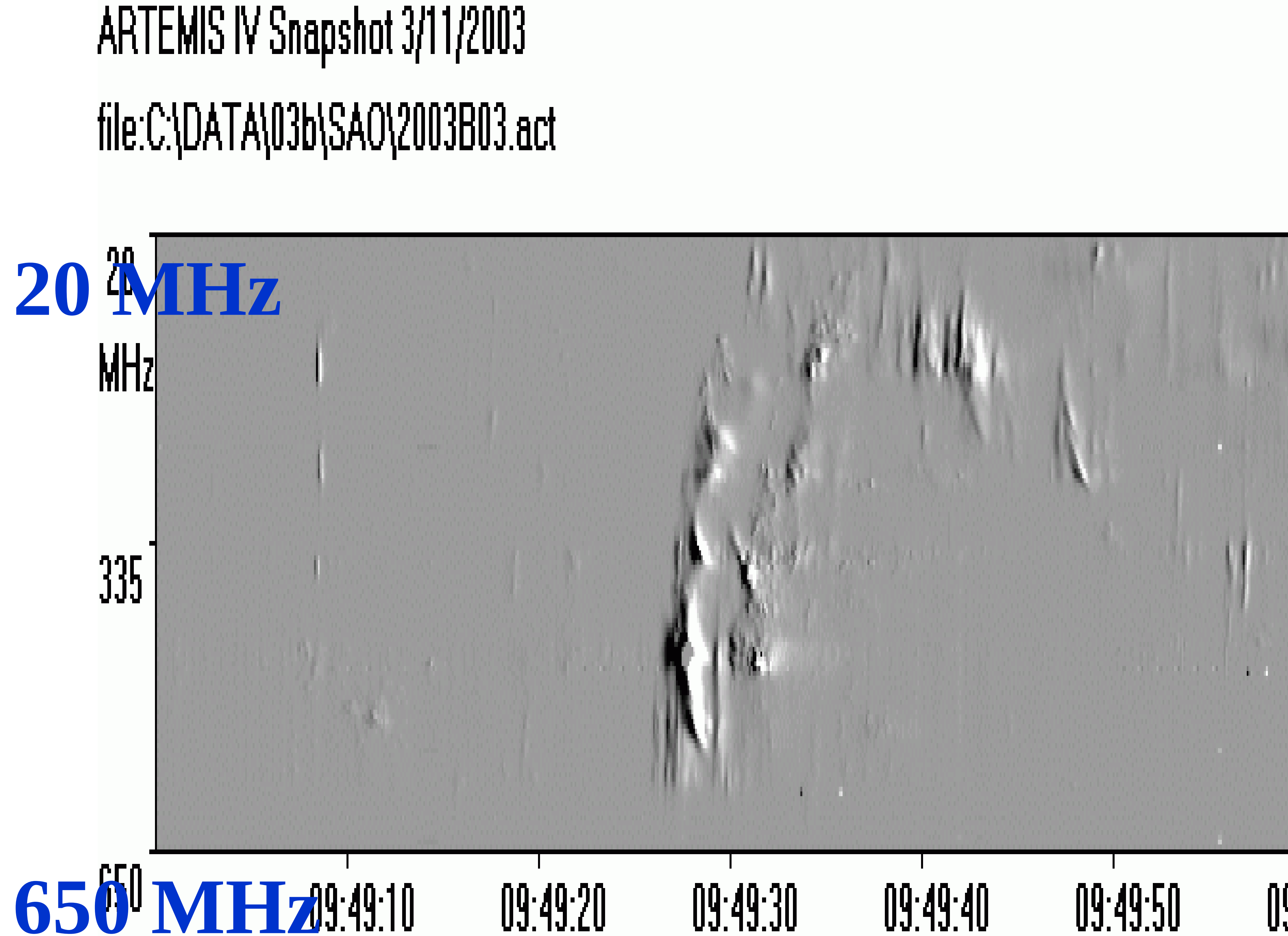

ARTEMIS IV spetroheliographe, Thermopylae, Greece
negative slope fibers
outbound electron beams
positive slope fibers
inbound electron beams
F(fibers/minute)
150
100
50
0
9:56
10:16
10:36
10:56
11:16
11:36
time UT 17th April 2002



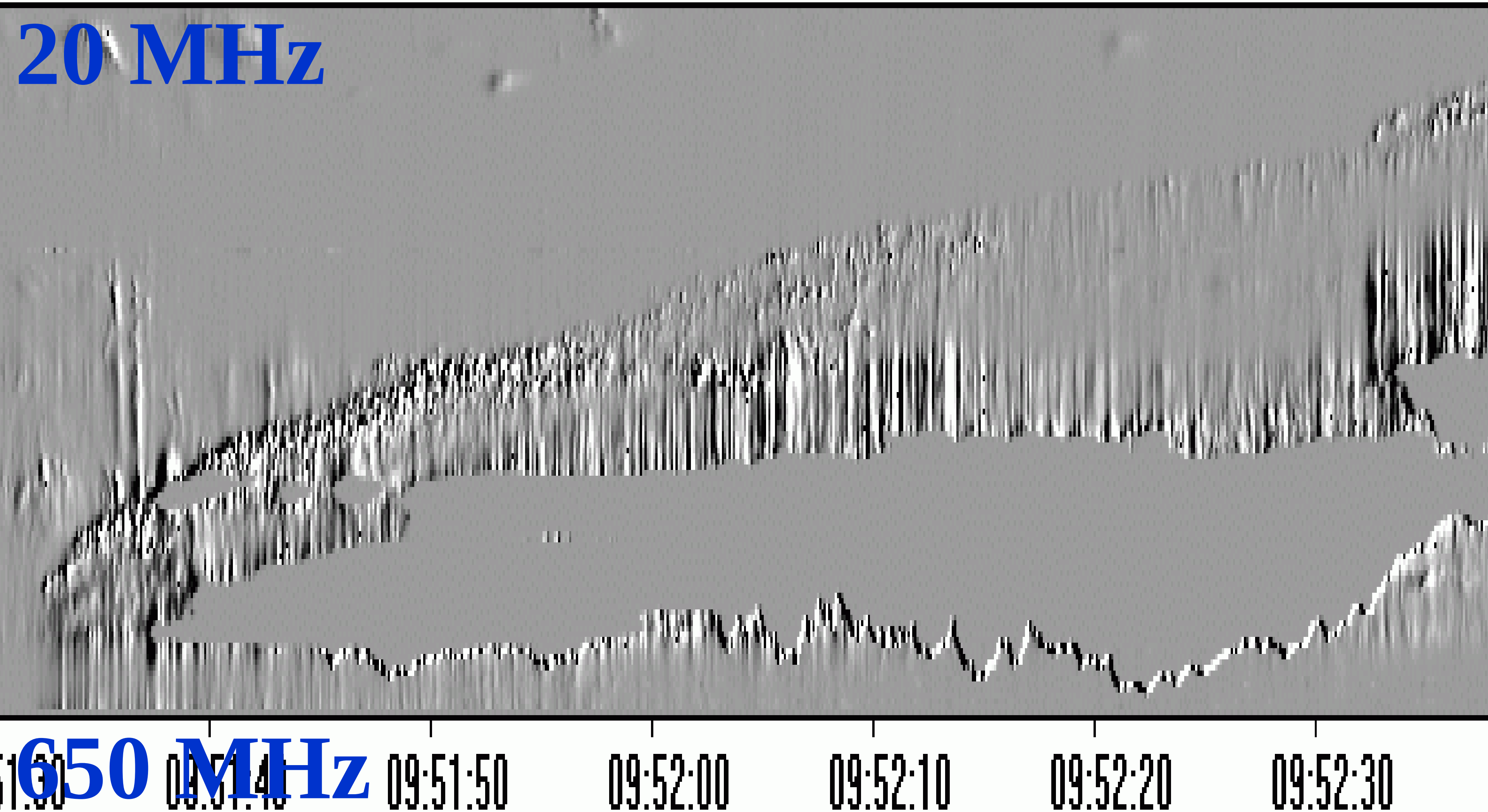
Artemis-IV...SAO Data....26/10/2003
frequency (MHz)
300
350
400
450
06:20:00
06:23:45
06:27:30
06:31:15
06:35:00
06:38:45
06:42:30
06:46:15
06:50:0
U Time (h:m:s)

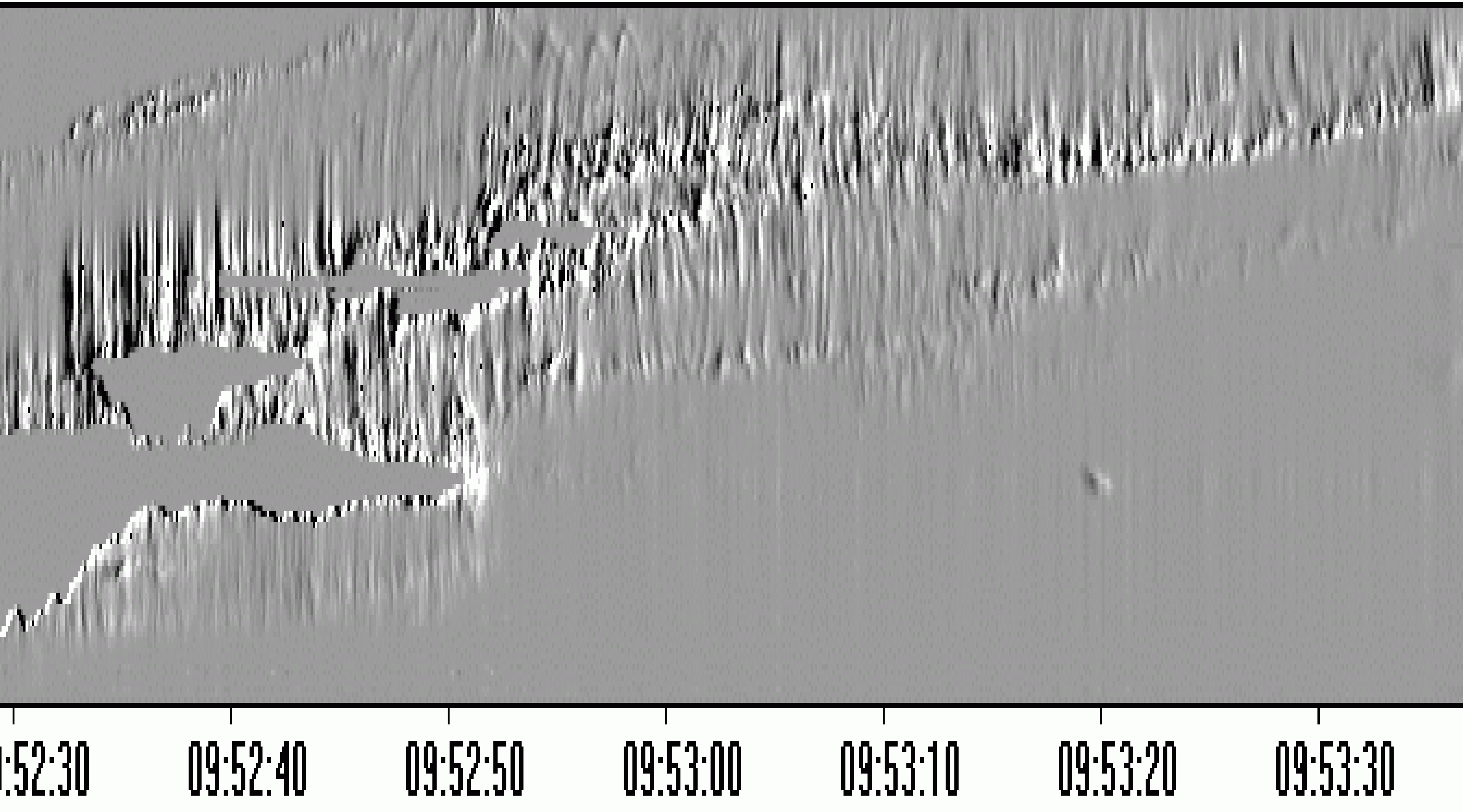

Raw Artemis-IV ASG Data, Oct 28 2003. Integration time= 1.00 sec, Max=3123.0
100
200
300
400
500
600
11:00
11:02
11:04
11:06
11:08
11:10
11:12
11:14
11:16
11:18
11:20
ARTEMIS IV
ASG 28-10-2003


Raw Artemis-IV SAO Data, Oct 28 2003. Integration time= .25 sec, Max= 945.0
300
400
11:00:30
11:01:00
11:01:30
11:02:00
11:02:30
11:03:00
11:03:30
11:04:00
11:04:30
28-10-2003

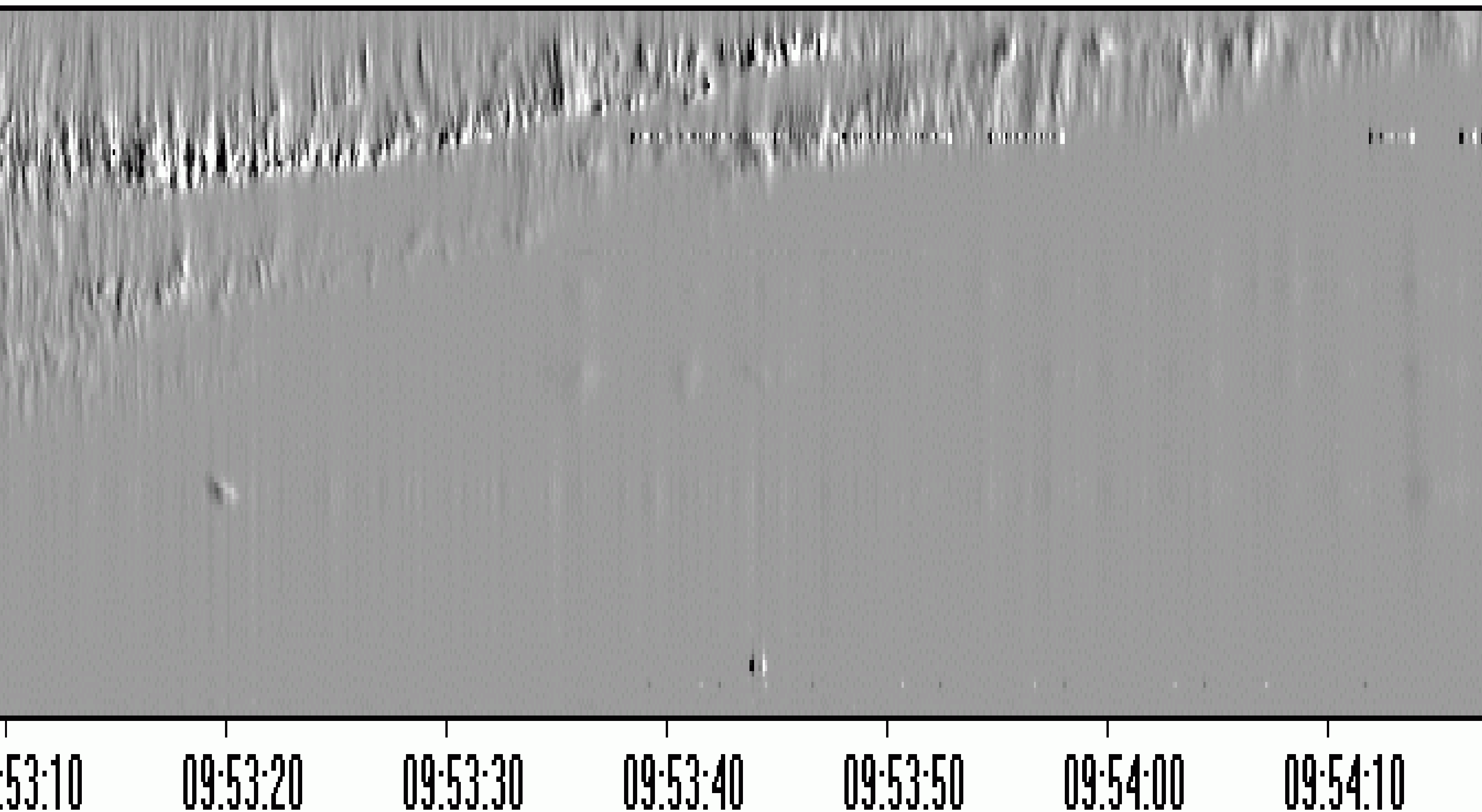


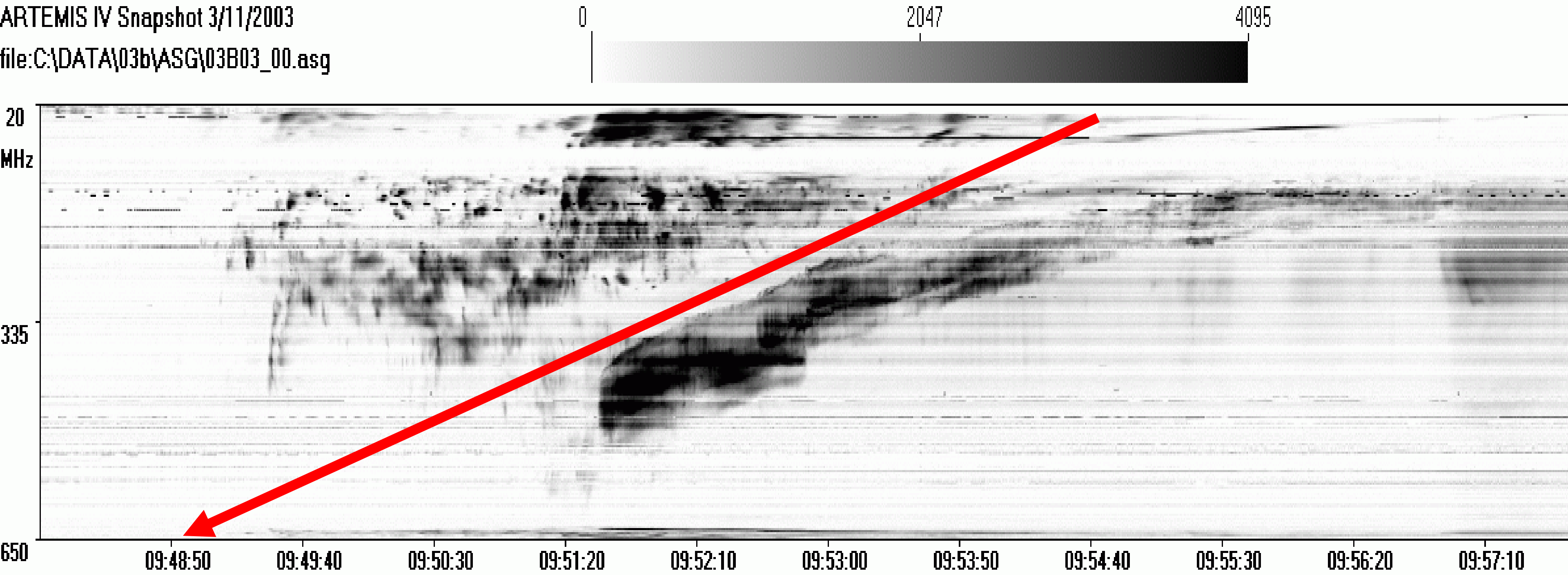
ARTEMIS IV Snapshot 3/11/2003
file:C:\DATA\03b\SAO\2003B03.act
20 MHz
20
MHz
335
650
650 MHz
09:49:10
09:49:20
09:49:30
09:49:40
09:49:50

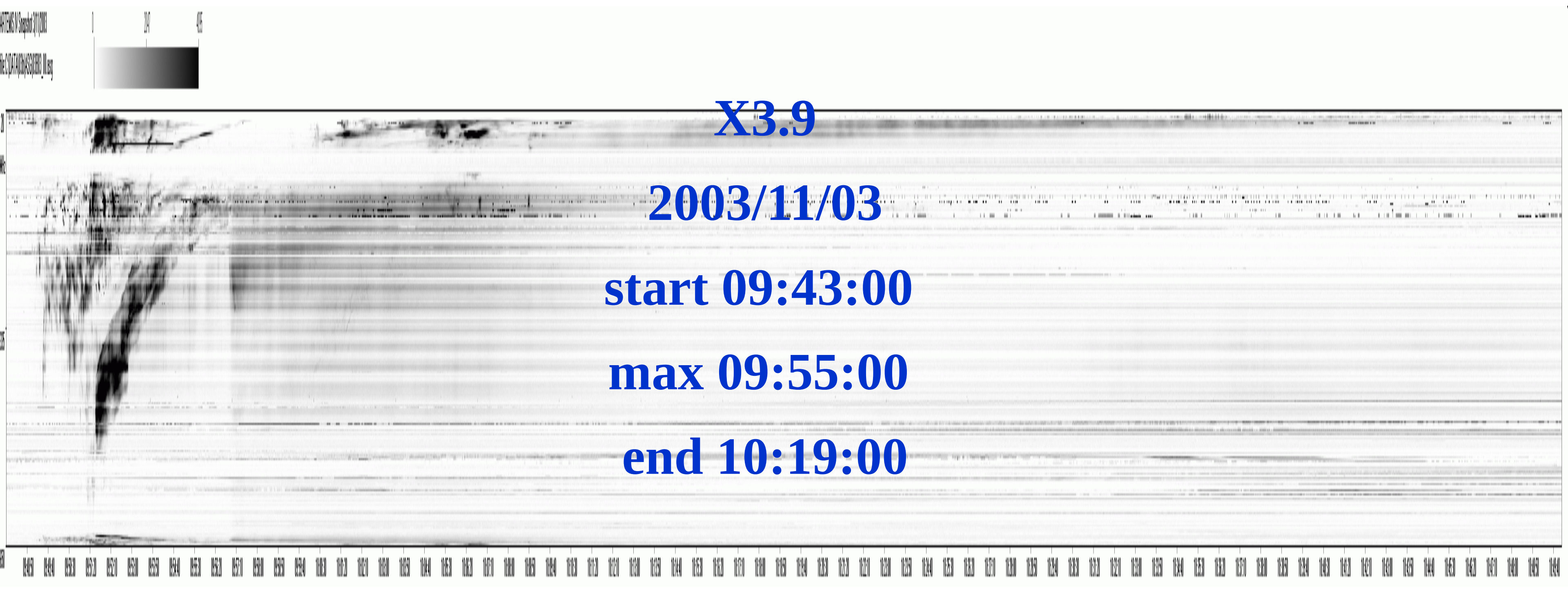

20 MHz
650 MHz
09:51:50
09:52:00
09:52:10
09:52:20
09:52:30

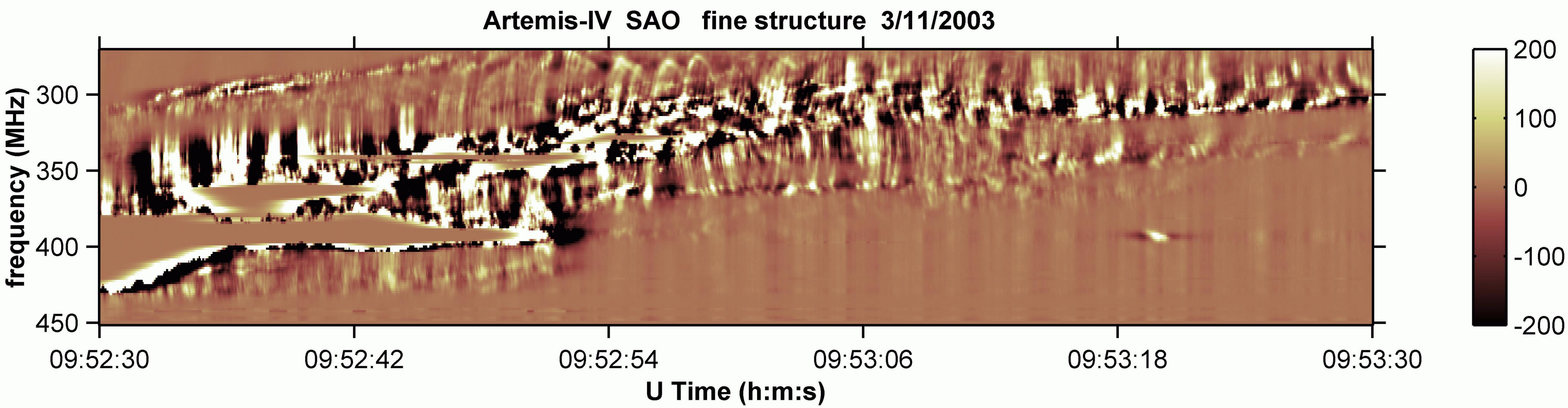


09:52:40
09:52:50
09:53:00
09:53:10
09:53:20
09:53:30

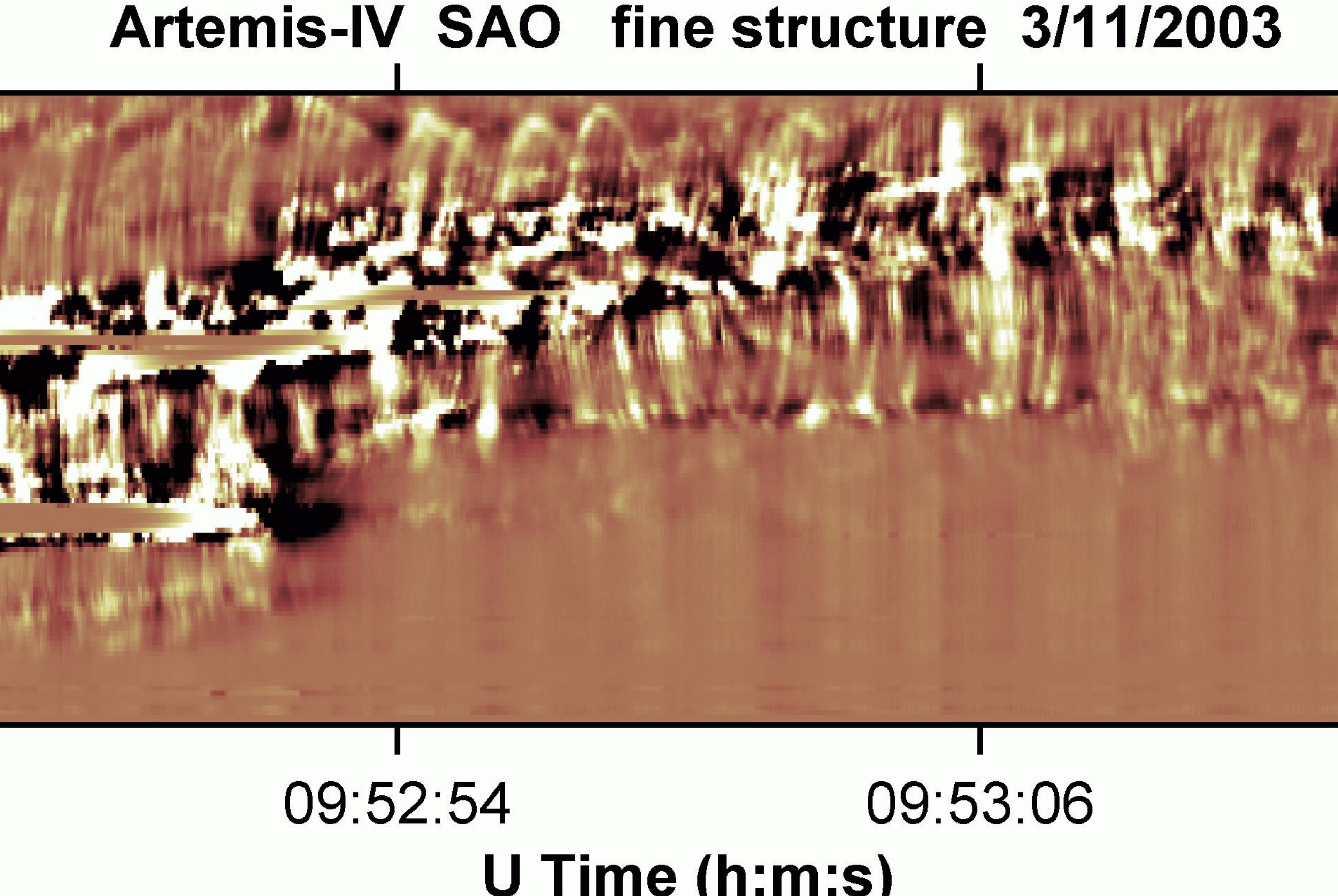

09:53:20
09:53:30
09:53:40
09:53:50
09:54:00
09:54:10


ARTEMIS IV Snapshot 3/11/2003
file:C:\DATA\03b\ASG\03B03_00.asg
0
2047
4095
20
MHz
335
650
09:48:50
09:49:40
09:50:30
09:51:20
09:52:10
09:53:00
09:53:50
09:54:40
09:55:30
09:56:20
09:57:10

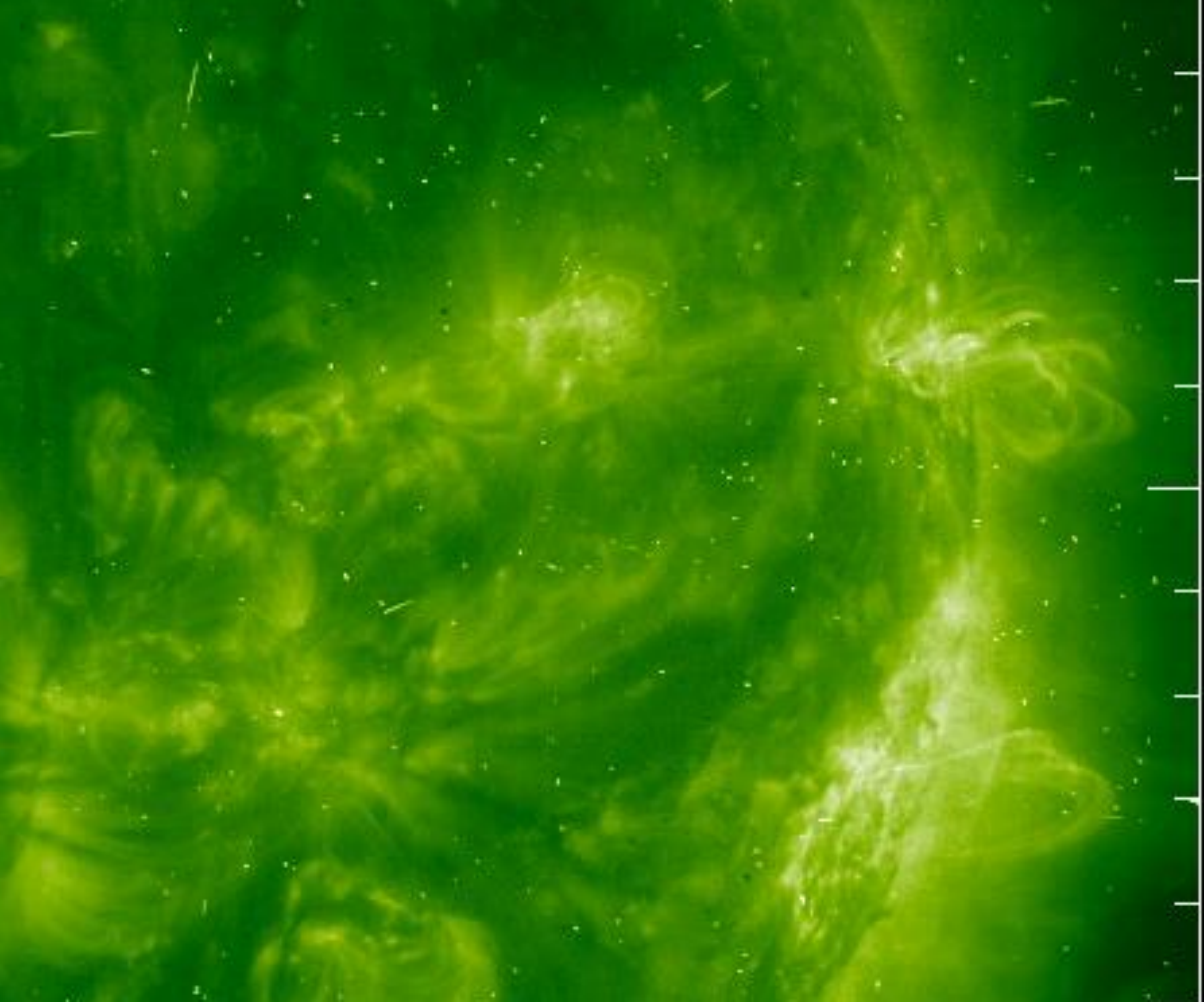

X3.9
2003/11/03
start 09:43:00
max 09:55:00
end 10:19:00

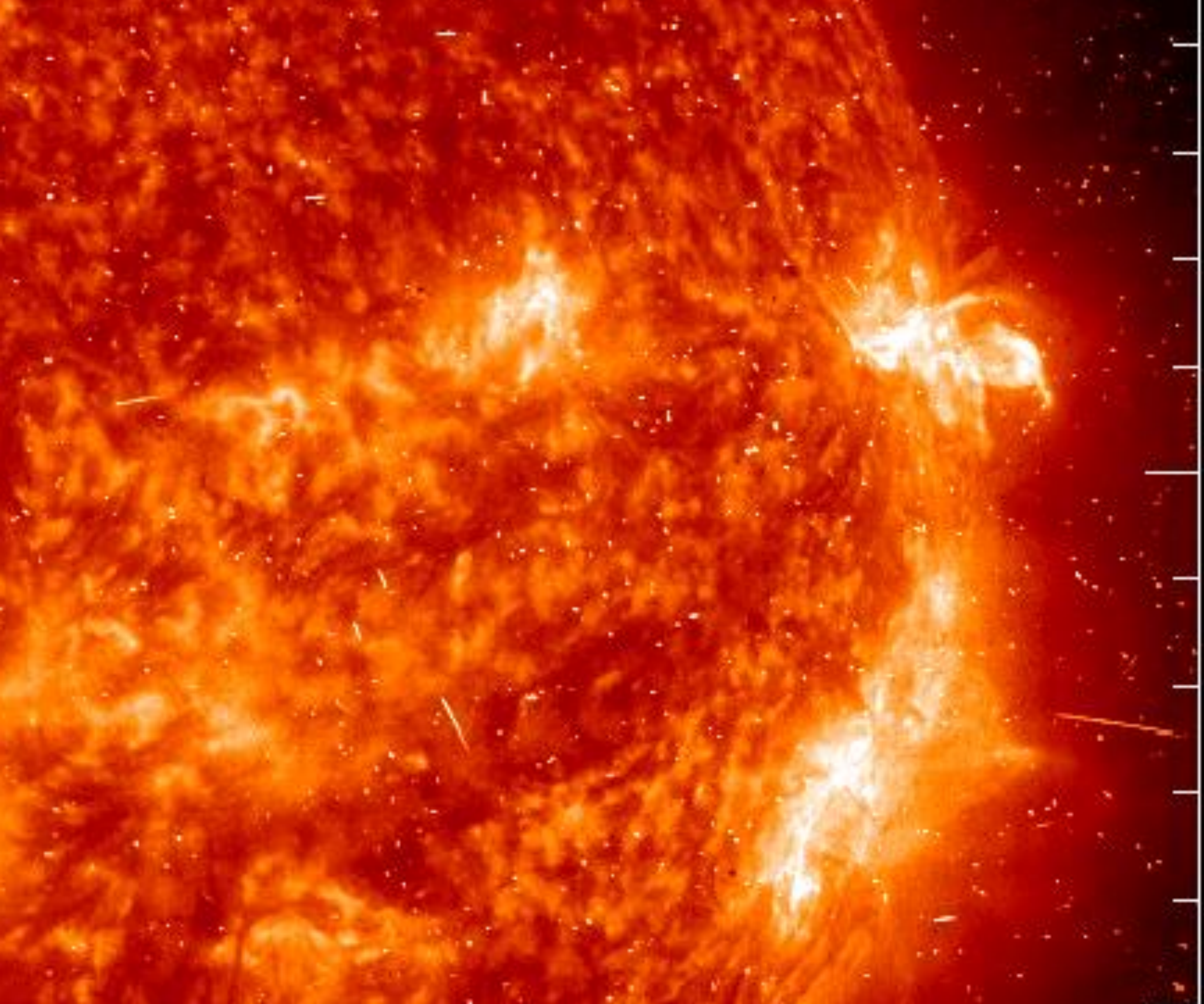


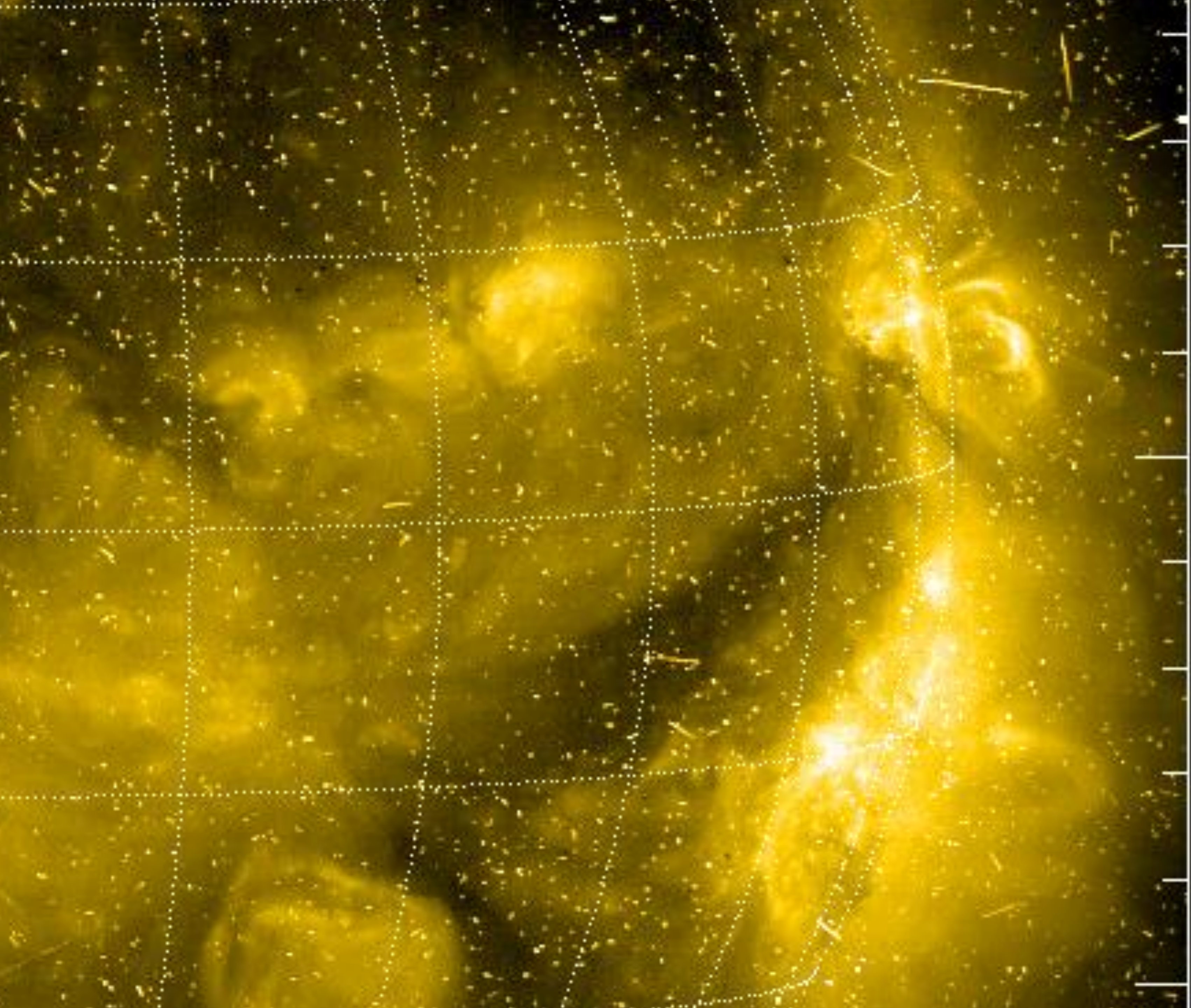
Artemis-IV SAO fine structure 3/11/2003
frequency (MHz)
300
350
400
450
09:52:30
09:52:42
09:52:54
09:53:06
09:53:18
09:53:30
U Time (h:m:s)
200
100
0
-100
-200

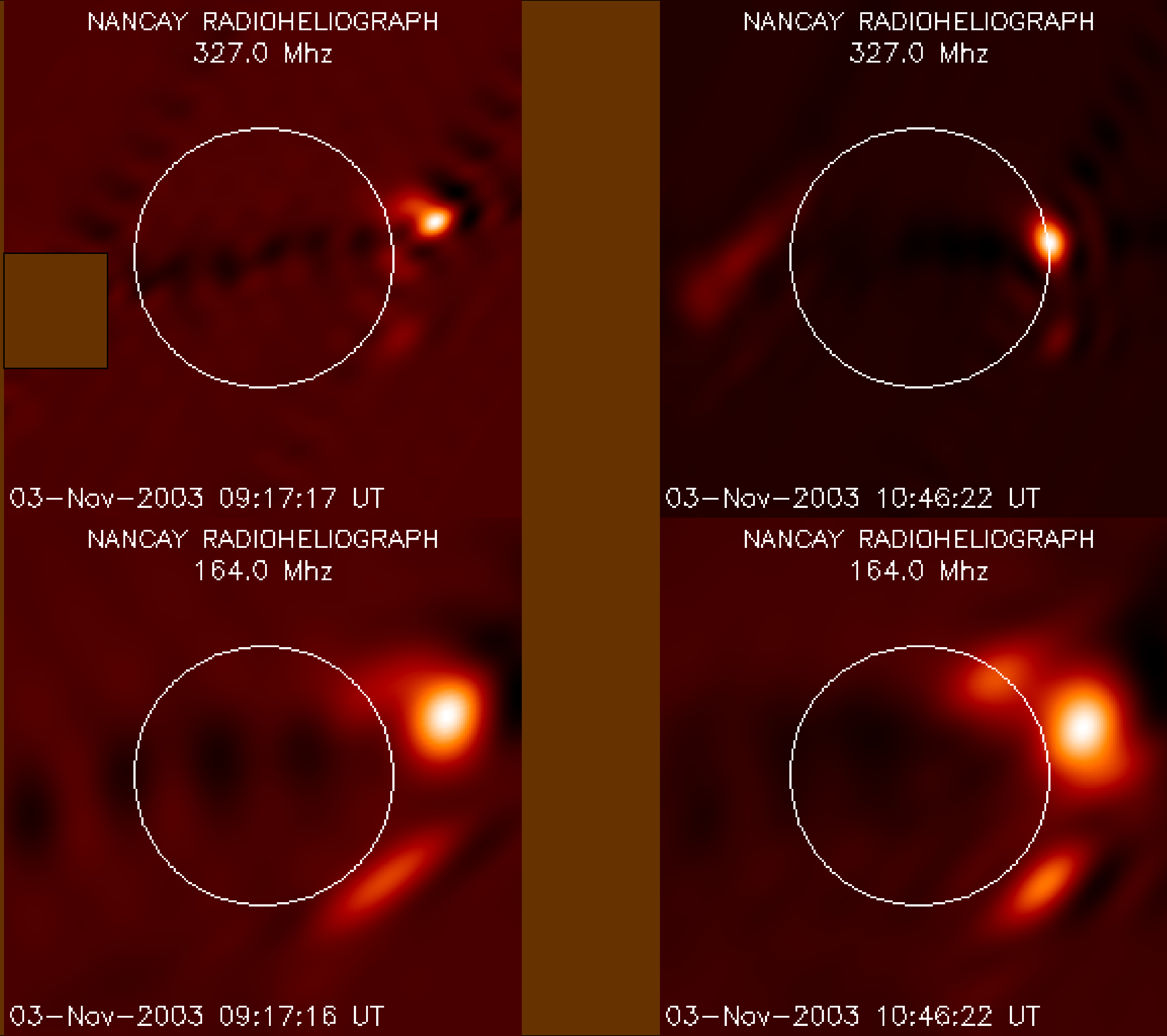


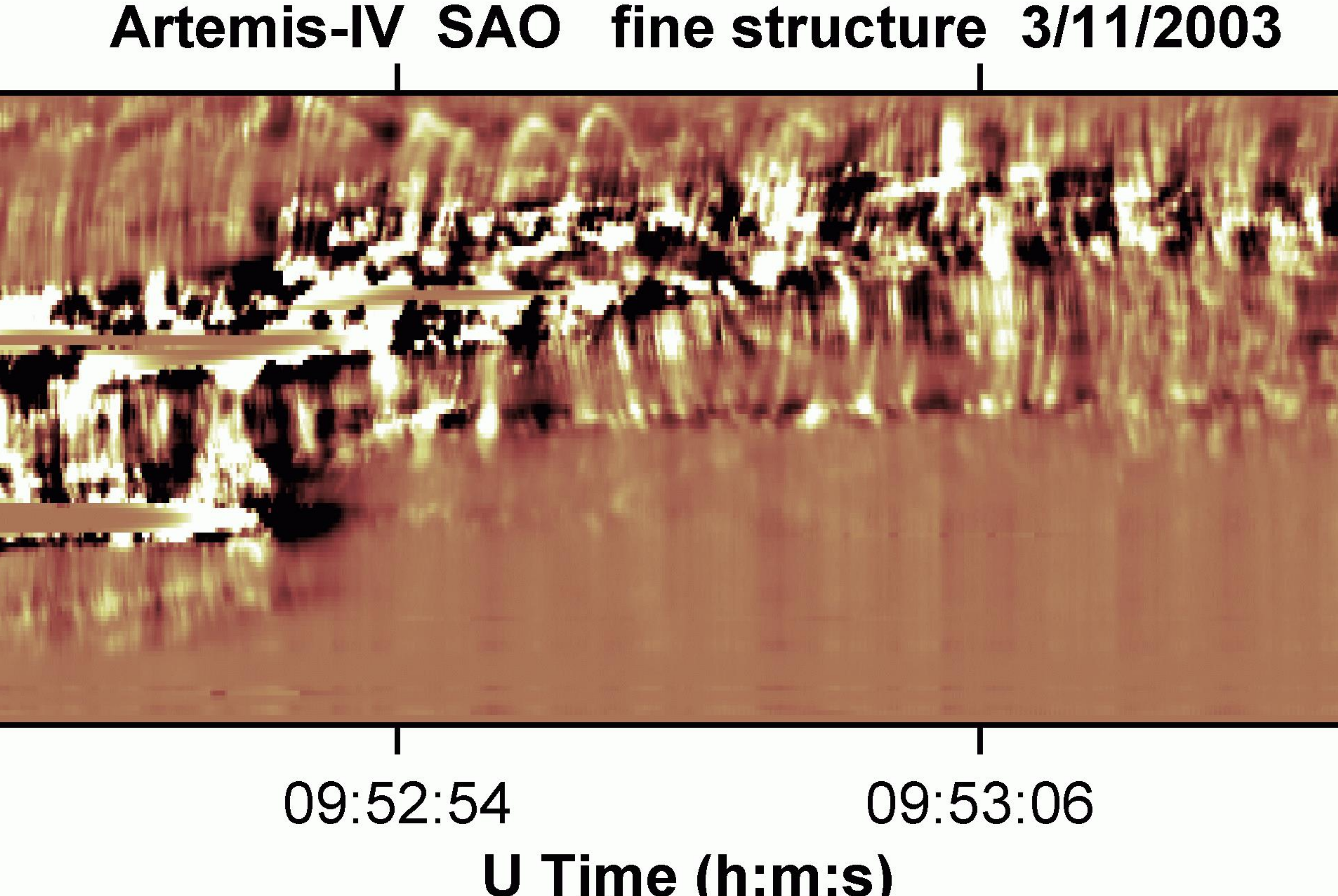
Artemis-IV SAO fine structure 3/11/2003
09:52:54
09:53:06
U Time (h:m:s)








NANCAY RADIOHELIOGRAPH
327.0 Mhz
03-Nov-2003 09:17:17 UT
NANCAY RADIOHELIOGRAPH
327.0 Mhz
03-Nov-2003 10:46:22 UT
NANCAY RADIOHELIOGRAPH
164.0 Mhz
03-Nov-2003 09:17:16 UT
NANCAY RADIOHELIOGRAPH
164.0 Mhz
03-Nov-2003 10:46:22 UT

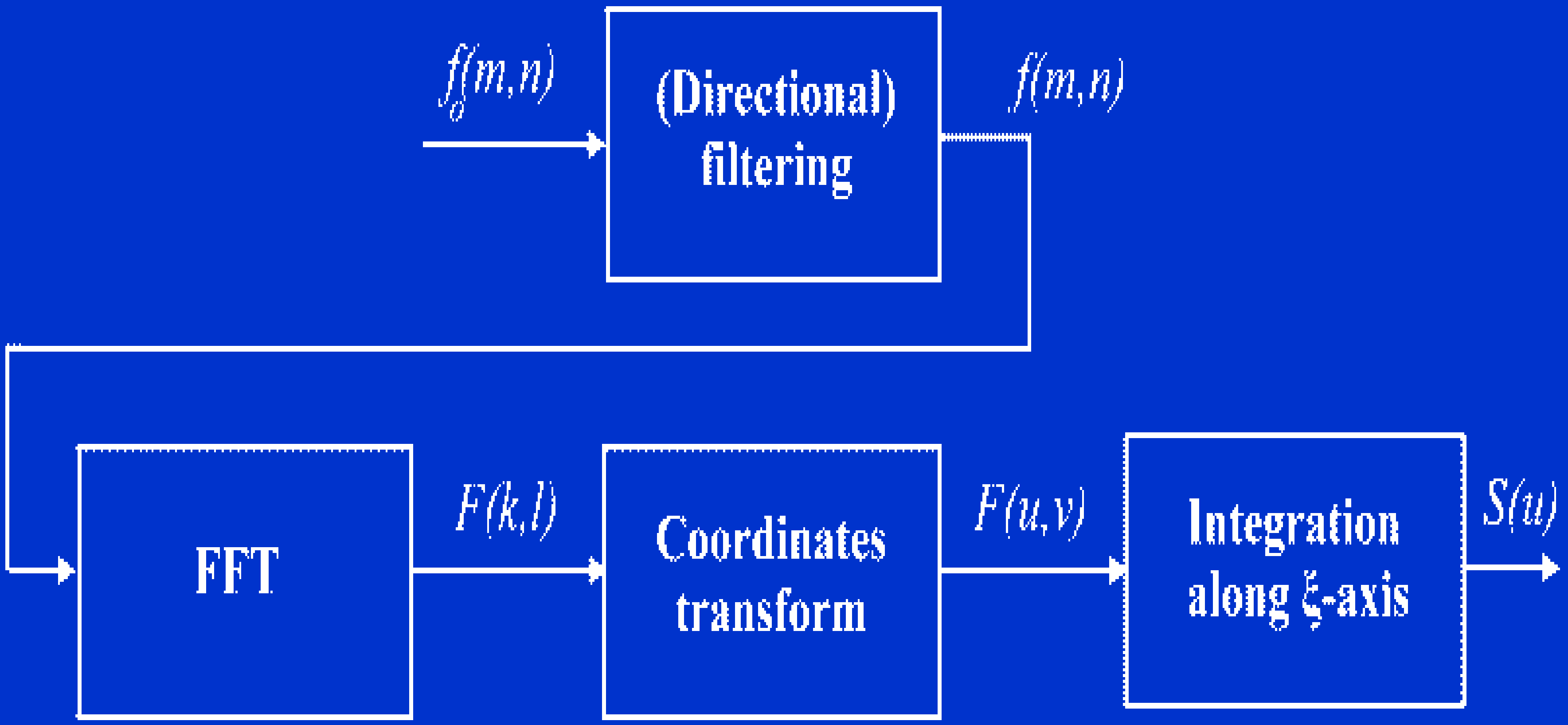

Artemis-IV SAO fine structure 3/11/2003
09:52:54
09:53:06
U Time (h:m:s)

Thank you!

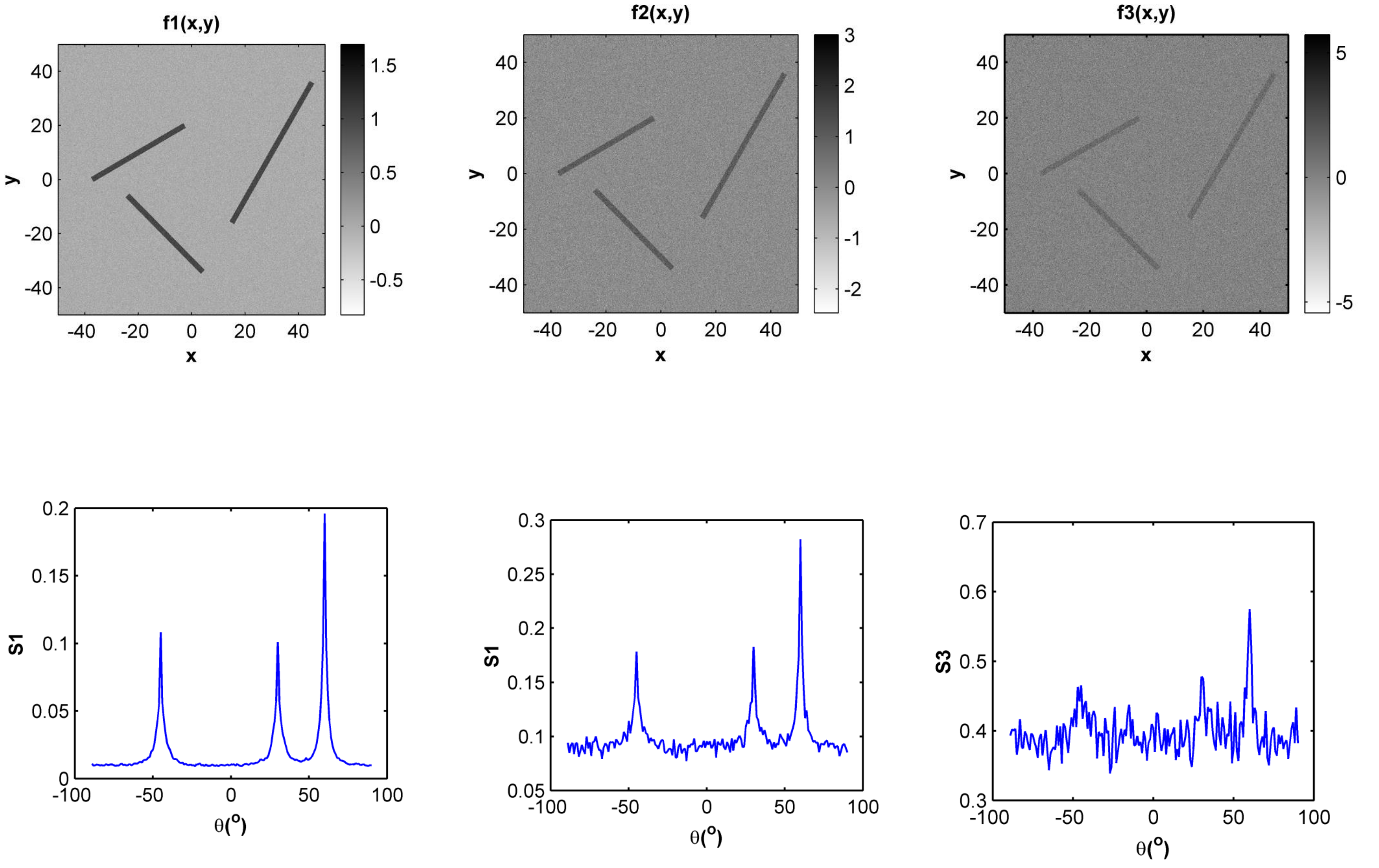
- Appendix with the method

Method to find linear or quasilinear and other structures

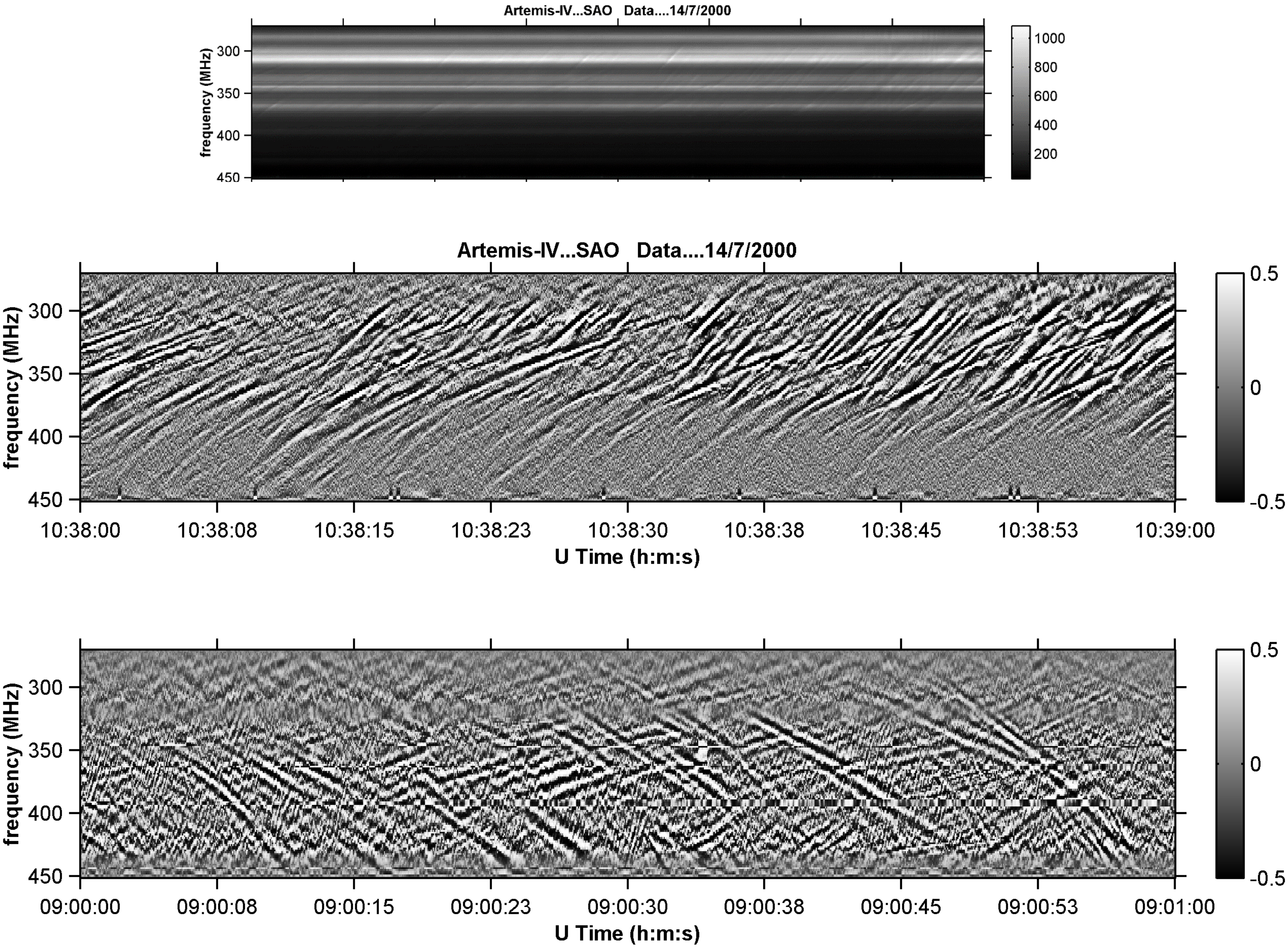
Fast Estimation of slopes
The Algorithm



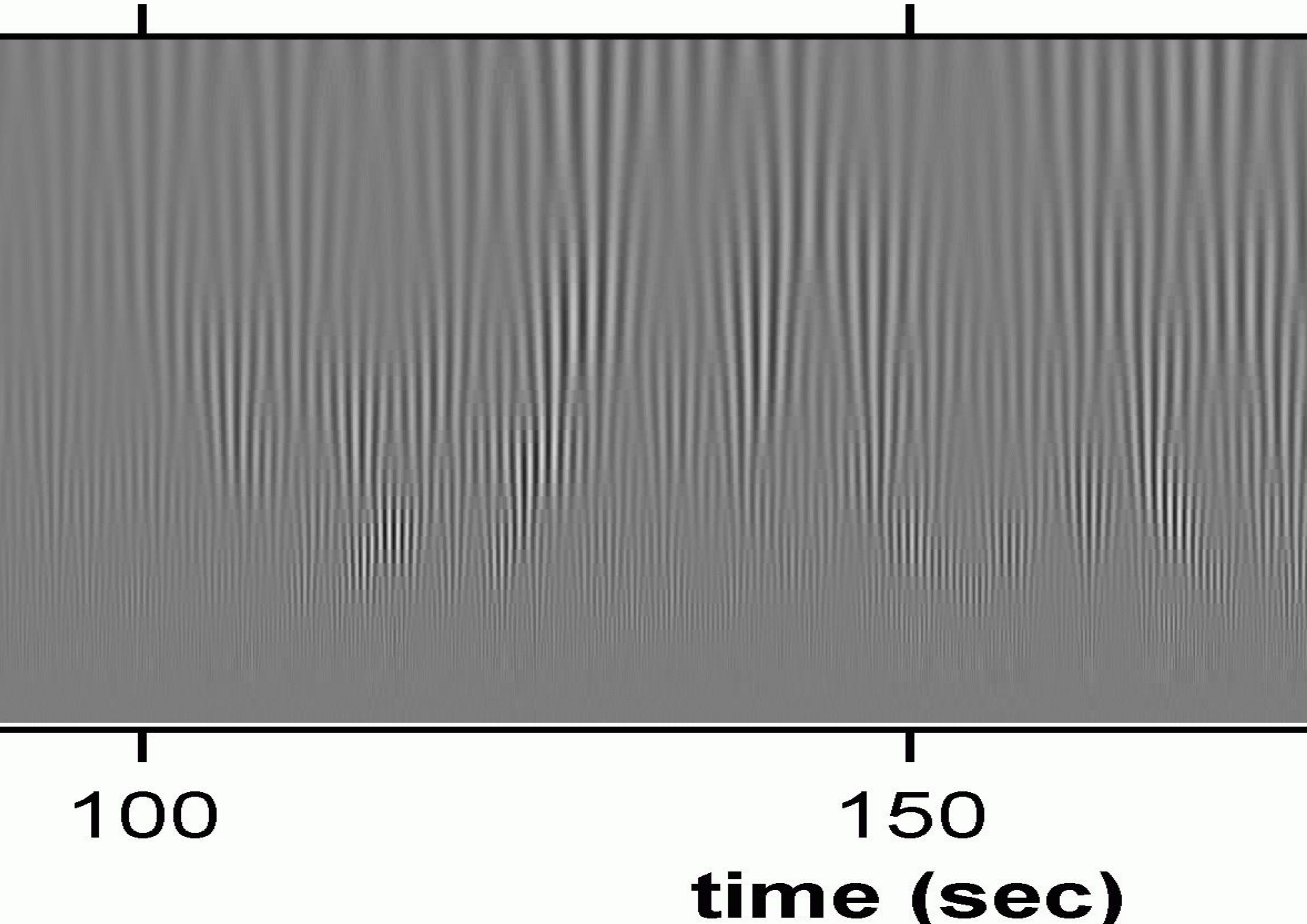
•Applied to dynamic solar radio spectra obtained by ARTEMIS



f1(x,y)
f2(x,y)
f3(x,y)
y
x
40
20
0
-20
-40
-40 -20 0 20 40
1.5
1
0.5
0
-0.5
3
2
1
0
-1
-2
5
0
-5
S1
S1
S3
0.2
0.15
0.1
0.05
0
0.3
0.25
0.2
0.15
0.1
0.05
0.7
0.6
0.5
0.4
0.3
-100 -50 0 50 100
θ(°)



Artemis-IV...SAO Data....14/7/2000
frequency (MHz)
300
350
400
450
1000
800
600
400
200
Artemis-IV...SAO Data....14/7/2000
frequency (MHz)
300
350
400
450
0.5
0
-0.5
10:38:00
10:38:08
10:38:15
10:38:23
10:38:30
10:38:38
10:38:45
10:38:53
10:39:00
U Time (h:m:s)
frequency (MHz)
300
350
400
450
0.5
0
-0.5
09:00:00
09:00:08
09:00:15
09:00:23
09:00:30
09:00:38
09:00:45
09:00:53
09:01:00
U Time (h:m:s)


100
150
time (sec)

Properties of very short-duration solar radio bursts

Jasmina Magdalenic[1], B. Vrsnak[1], P. Zlobec[2], G. Mann[3], H. Aurass[3], A. Hillaris[4]

servatory, Zagreb, Croatia; [2]INAF-Trieste Astronomical Observatory, Italy [3]Astrophysical Institute Potsdam, Germany [4]University of At

DATA

For the analysis we use high time resolution single frequency data (1ms) recorded by the *Solar multichannel radiopolarimetric system of the INAF-Trieste Astronomical Observatory* (L-hand and R-hand circular polarization, further on LCP and RCP). Spectral characteristics are inspected utilizing the dynamic spectra recorded by the *solar radiospectrograph ARTHEMIS IV (University Of Athens)* and the *Tremsdorf spectrograph* of the *Astrophysical Institute Potsdam* (AIP). One-to one identification of bursts in both types of data assured us that the bursts are of the solar origin.

In selecting SSSs we applied two criteria:

1) the duration of a burst has to be significantly shorter than the duration of spikes at the given frequency;
2) the bursts profile has to be smooth and simple.

Spectral features in the studied frequency range (450 - 270 MHz) are consider as narrow-band bursts if their bandwidth amounts up to 20 MHz ($\Delta f/f \approx$ 4 - 7%).

We divided SSSs into the following categories:

BROAD-BAND: a) broad-band SSS pulses, b) broad-band drifting SSSs

NARROW-BAND: a) narrow-band spike-like SSSs, b) narrow-band drifting SSSs,

COMPLEX SSSs: "Rain-drops"

(consisting of a narrow-band emission "head" and a broad-band absorption "tail")

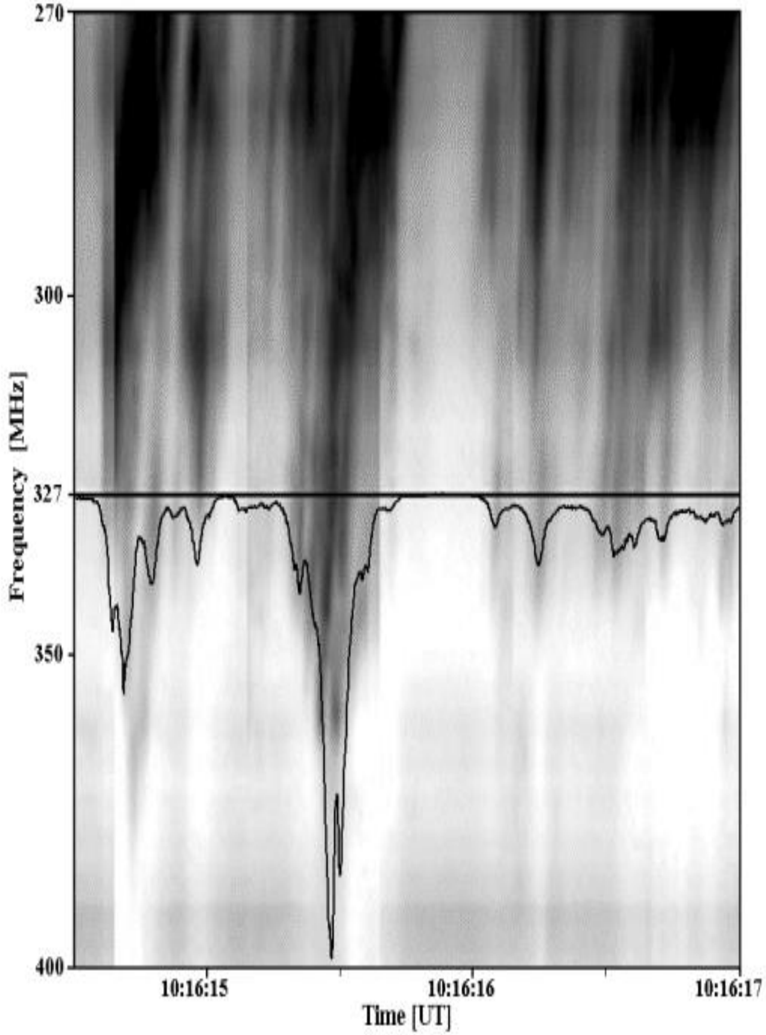


Fig.3 One-to-one correspondence of the bursts recorded in single frequency measurements at 327 MHz (intensity amplitude is increasing downwards), and the dynamic spectrum (ARTHEMIS IV).

b) broad-band drifting SSS

Drifting broad-band SSSs appear in rather dense groups and generally the bursts are overlapping, so it is difficult to isolate time profiles of individual bursts. When analyzed with a lower time/frequency resolution they could apparently look like broad-band pulsations of a longer duration.

Characteristics:

- average duration at half power is about $d_{1/2}$ = 20-40 ms
- average drift rate amounts to $\Delta f / \Delta t = -650$ MHz/s,

(comparable to the upper limit of type III bursts drift rates in the same frequency range, but an order of magnitude larger than the drift rate of other fine structures, e.g., fiber bursts or tadpoles (Slottje, 1972).

- frequency range of appearance 250 - 450 MHz

<u>**Rain drops: emission head, absorbtion tail towards low frequencies**</u>

frequency drift of heads –6+-13 MHz

frequency drift of tails –1000+-400 MHz

bandwidth of heads 5+-2 MHz

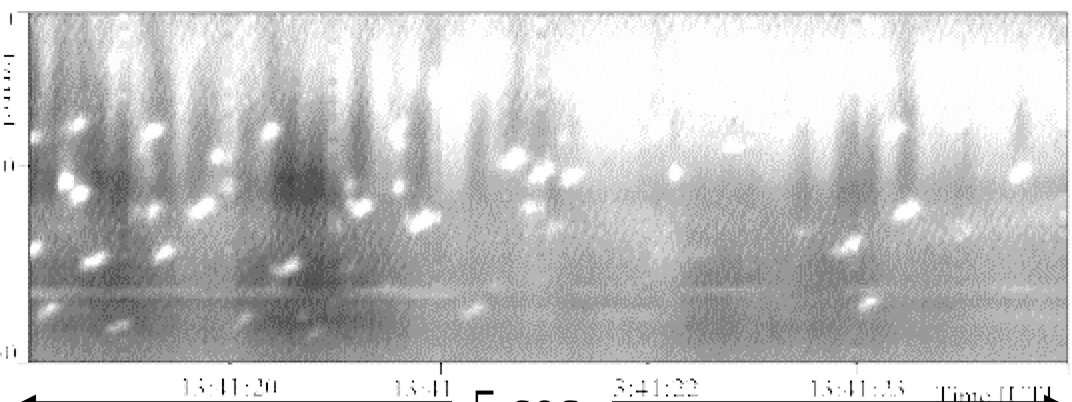
bandwidth of tails 28+-7 MHz

duration 50, ms 20 ms

270 MHz

300 MHz

400 MHz



5 sec

BROAD-BAND:

a) broad-band SSS pulses,

b) broad-band drifting SSSs

NARROW-BAND:

a) narrow-band spike-like SSSs,

b) narrow-band drifting SSSs,

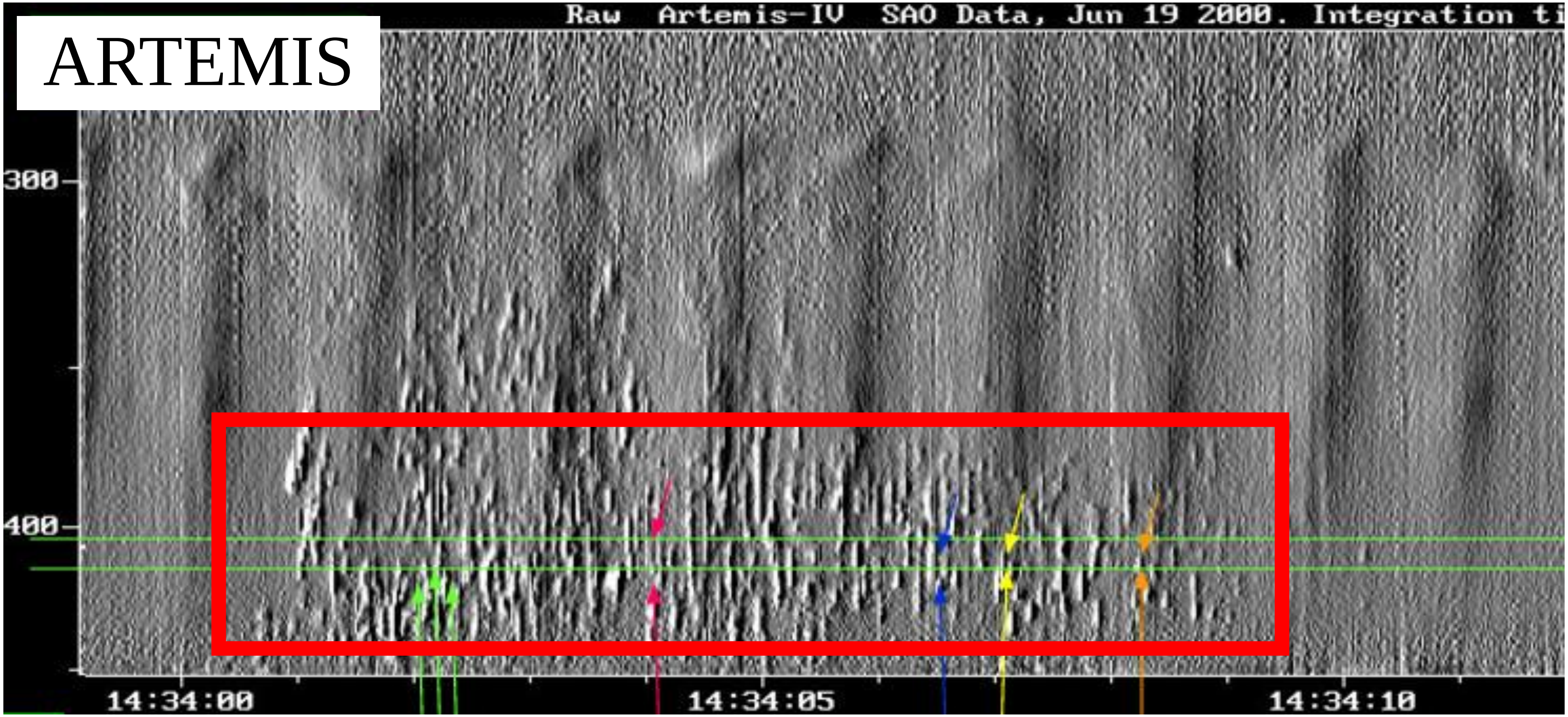
COMPLEX SSSs:

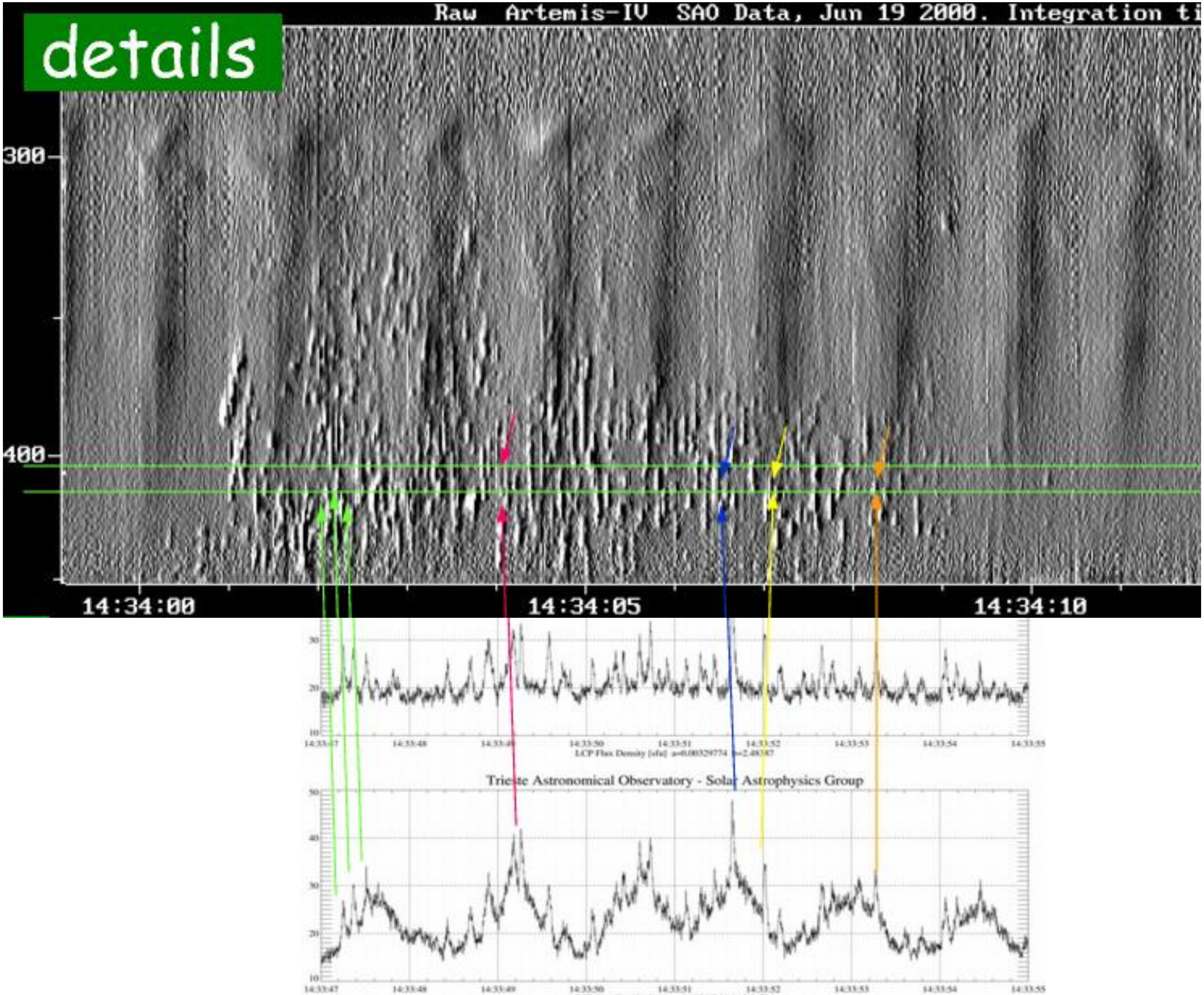
"Rain-drops"

SUPER SHORT STRUCTURES IN SOLAR RADIO BURSTS

from Magdalenić Jasmina1, Paolo Zlobec2, Bojan Vršnak1, AlexanderHillaris3, MauroMesserotti2, Hvar Observatory, Faculty of Geodesy, Croatia, INAF -Trieste Astronomical Observatory, Italy, University of Athens, Greece

SPIKES: shortest radio structures (in red rectangle)




details
Raw Artemis-IV SAO Data, Jun 19 2000. Integration ti
300
400
14:34:00
14:34:05
14:34:10
Trieste Astronomical Observatory - Solar Astrophysics Group

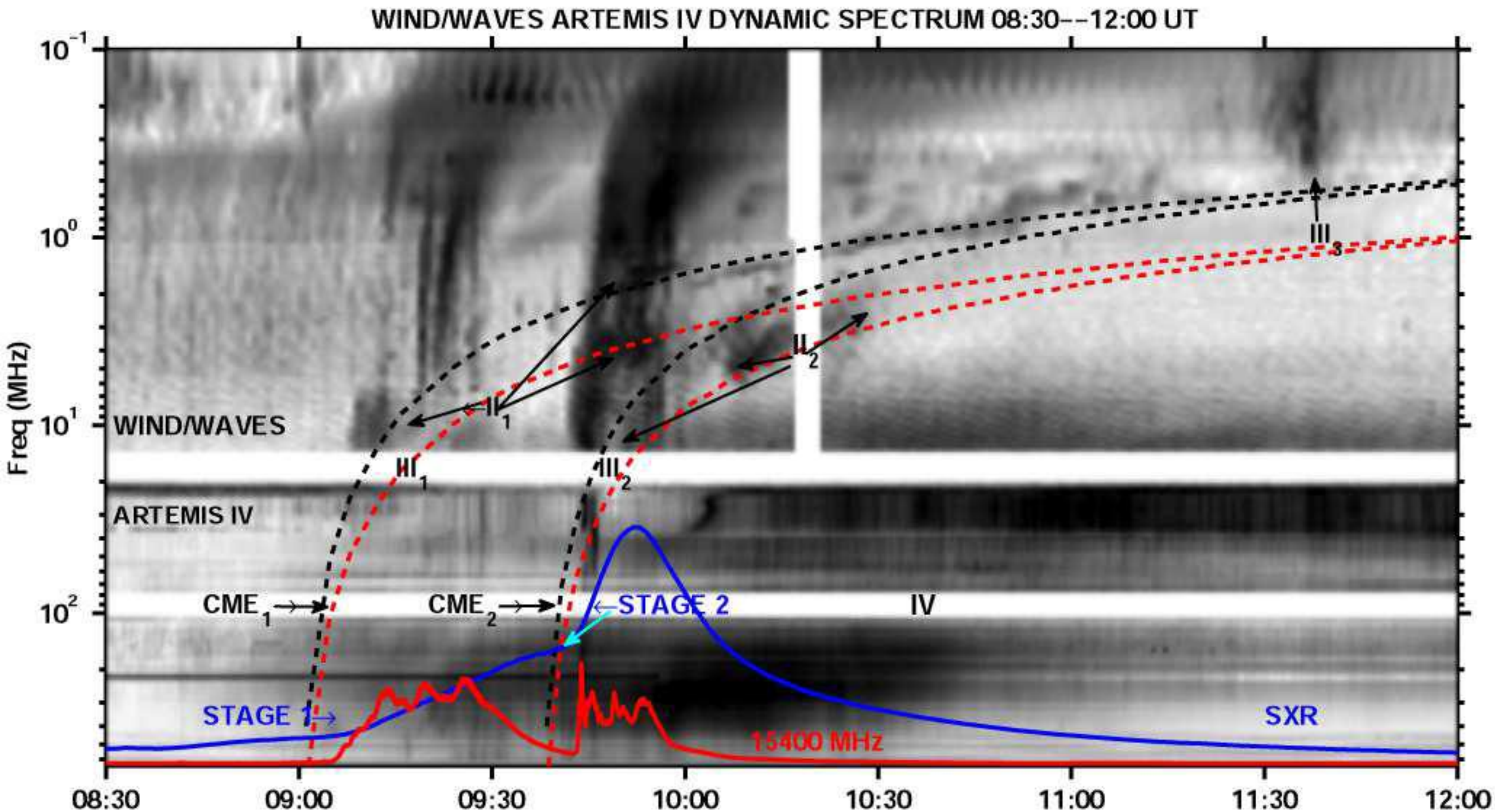
improved solar radio spectrograph

- of the University of Athens operating at the Thermopylae Satellite Telecommunication Station. Observations now cover the frequency range from 20 to 650 MHz. The spectrograph has a 7-meter moving parabola fed by a log-periodic antenna for 100â€“650 MHz and a stationary inverted V fat dipole antenna for the 20â€“100 MHz range. Two receivers are operating in parallel, one swept frequency for the whole range (10 spectrums/sec, 630 channels/spectrum) and one acousto-optical receiver for the range 270 to 450 MHz (100 spectrums/sec, 128 channels/spectrum).
- The data acquisition system consists of two PCs (equipped with 12 bit, 225 ksamples/sec ADC, one for each receiver).
- Sensitivity is about 3 SFU and 30 SFU in the 20â€“100 MHz and 100â€“650 MHz range respectively.
- The daily operation is fully automated: receiving universal time from a GPS, pointing the antenna to the sun, system calibration, starting and stopping the observations at preset times, data acquisition, and archiving on DVD. We can also control the whole system through modem or Internet.
- The instrument can be used either by itself or in conjunction with other instruments to study the onset and evolution of solar radio bursts and associated interplanetary phenomena.

The 17 January 2005 Complex Solar Radio Event Associated with Interacting Fast Coronal Mass Ejections

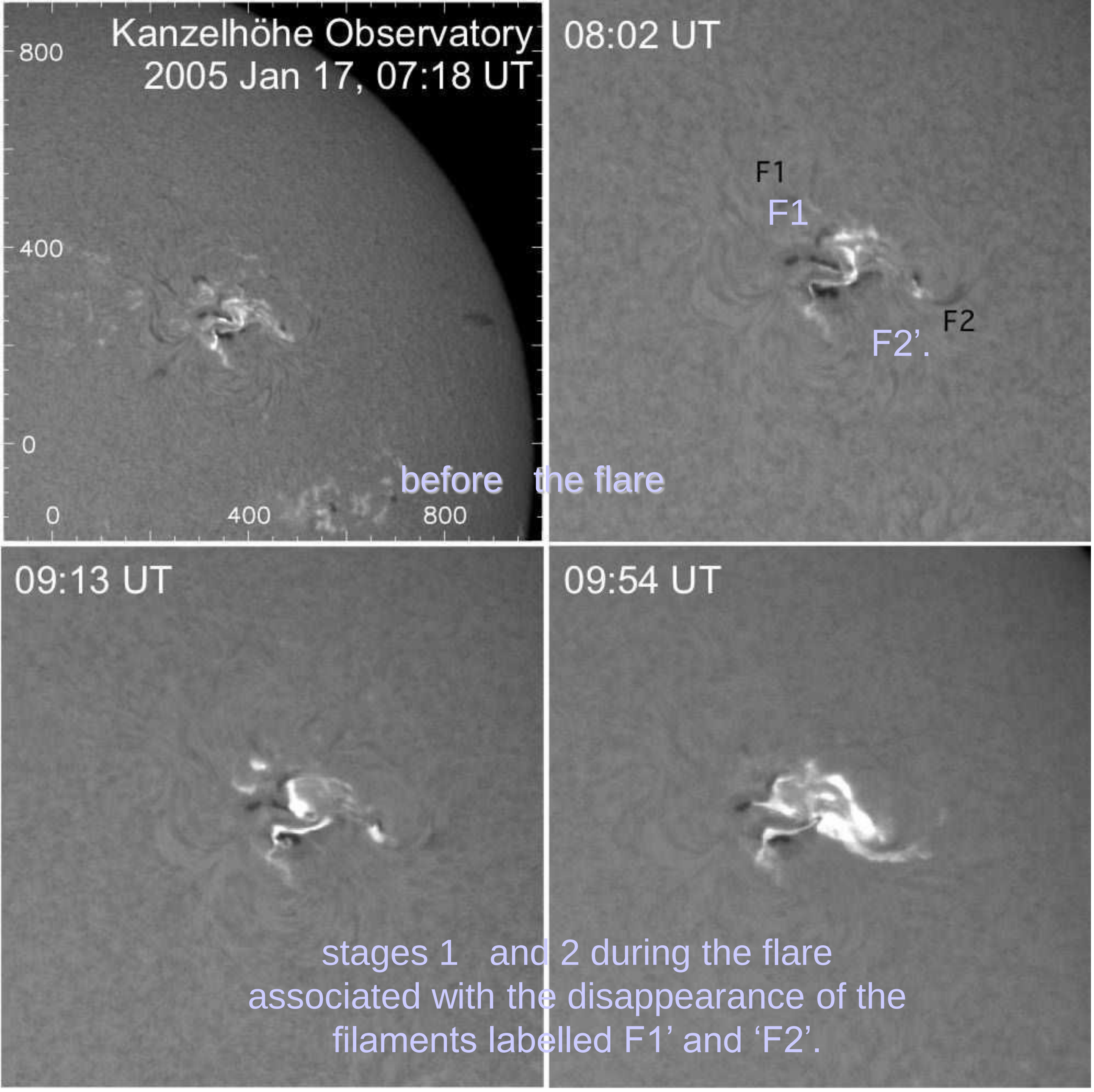
A. Hillaris[1], O. Malandraki[2], K.-L Klein[3], P. Preka-Papadema[1], X. Moussas[1], C. Bouratzis[1], E. Mitsakou[1], P. Tsitsipis[4], A. Kontogeorgos[4]

ARTEMIS-IV/*Wind*/WAVES dynamic spectrum.
Overlays: The profiles of GOES SXR flux (dark blue) and RSTN flux density at 15400 MHz (red) and the frequency-time plots derived from the linear fits to the front trajectories of CME1 and CME2 and an empirical density model for fundamental (black dashed curve) and harmonic (red dashed curve)plasma emission.
The type IV continuum, the type II (II1 and II2) and type III GG bursts (III1 and III2), the stages 1 and 2 of the SXR flux rise, and the type III burst (III3) around the convergence of the fronts of CME1 and CME2 are annotated on the plot



• 17 January 2005

- 2 fast coronal mass ejections
- in <u>close succession</u> during two distinct episodes of a 3B/X3.8 flare.
- Both were accompanied by metre-to-kilometre type-III groups tracing energetic electrons that escape into the interplanetary space and
- by decametre-to-hectometre type-II bursts attributed to CME-driven shock waves.
- A peculiar type-III burst group was observed below 600 kHz 1.5 hours after the second type III group.
- It occurred without any simultaneous activity at higher frequencies, around the time <u>**when the two CMEs were expected to interact**</u>.
- We associate this emission with the interaction of the CMEs at heliocentric distances of about 25 Ro.
- Near-relativistic electrons observed by the EPAM experiment onboard ACE near 1 AU revealed <u>**successive particle releases**</u> that can be <u>**associated with the two flare/CME events**</u> and the low-frequency type-III burst at the time of CME interaction.
- We study shock acceleration and acceleration in the course of magnetic reconnection for the escaping electron beams revealed by the type III bursts and for the electrons measured *in situ*.



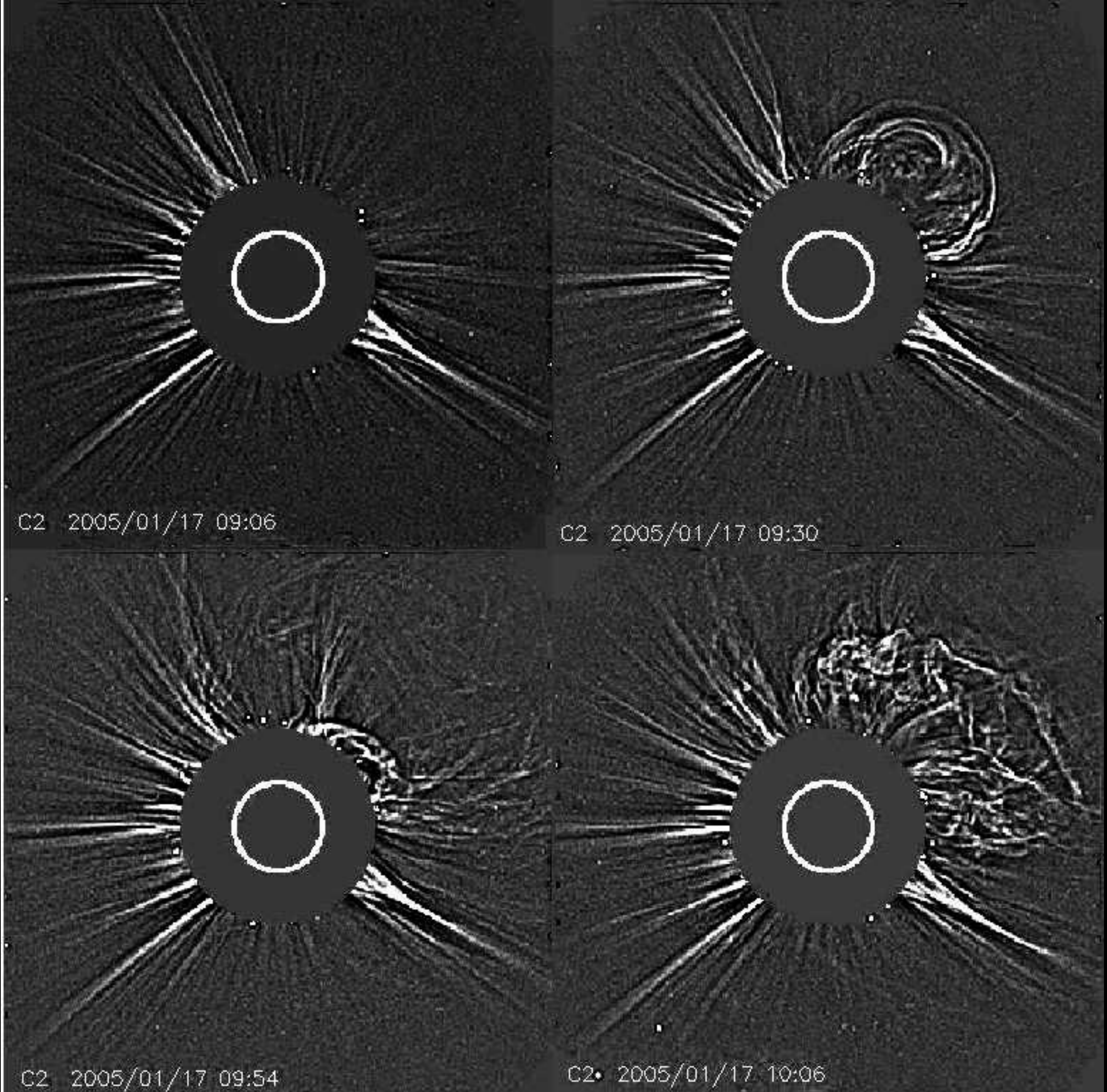
Active region 10720

17 January 2005

in H line centre (top left)

and in the wing,

observed at Kanzelhohe Observatory (courtesy M. Temmer).


C2 2005/01/17 09:06
C2 2005/01/17 09:30
C2 2005/01/17 09:54
C2 2005/01/17 10:06

Radio Observations of the 20 January 2005 X-class Flare

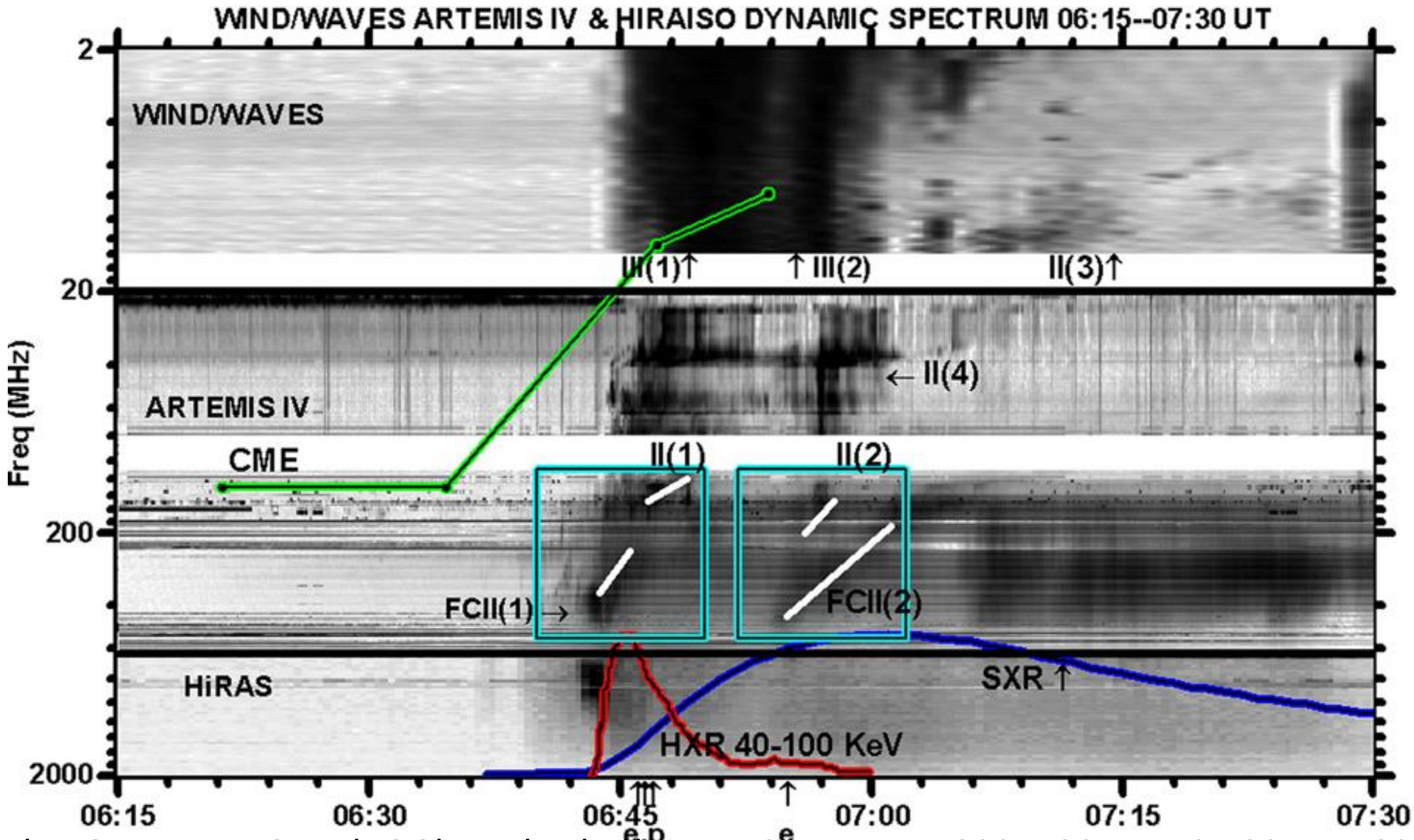
C. Bouratzis · P. Preka-Papadema · A. Hillaris ·P. Tsitsipis · A. Kontogeorgos · V.G. Kurt · X. Moussas

Dynamic spectra of ARTEMIS-IV – *Wind/Waves* – HiRAS, 2000 MHz– 20 kHz, + SXR, HXR, γ -ray data.

Standard Flare –CME model and the *reconnection outflow termination shock* model.

A proper combination of these mechanisms provides an adequate model for the interpretation of the observational data.

Solar Phys. (2010) 267: 343–359



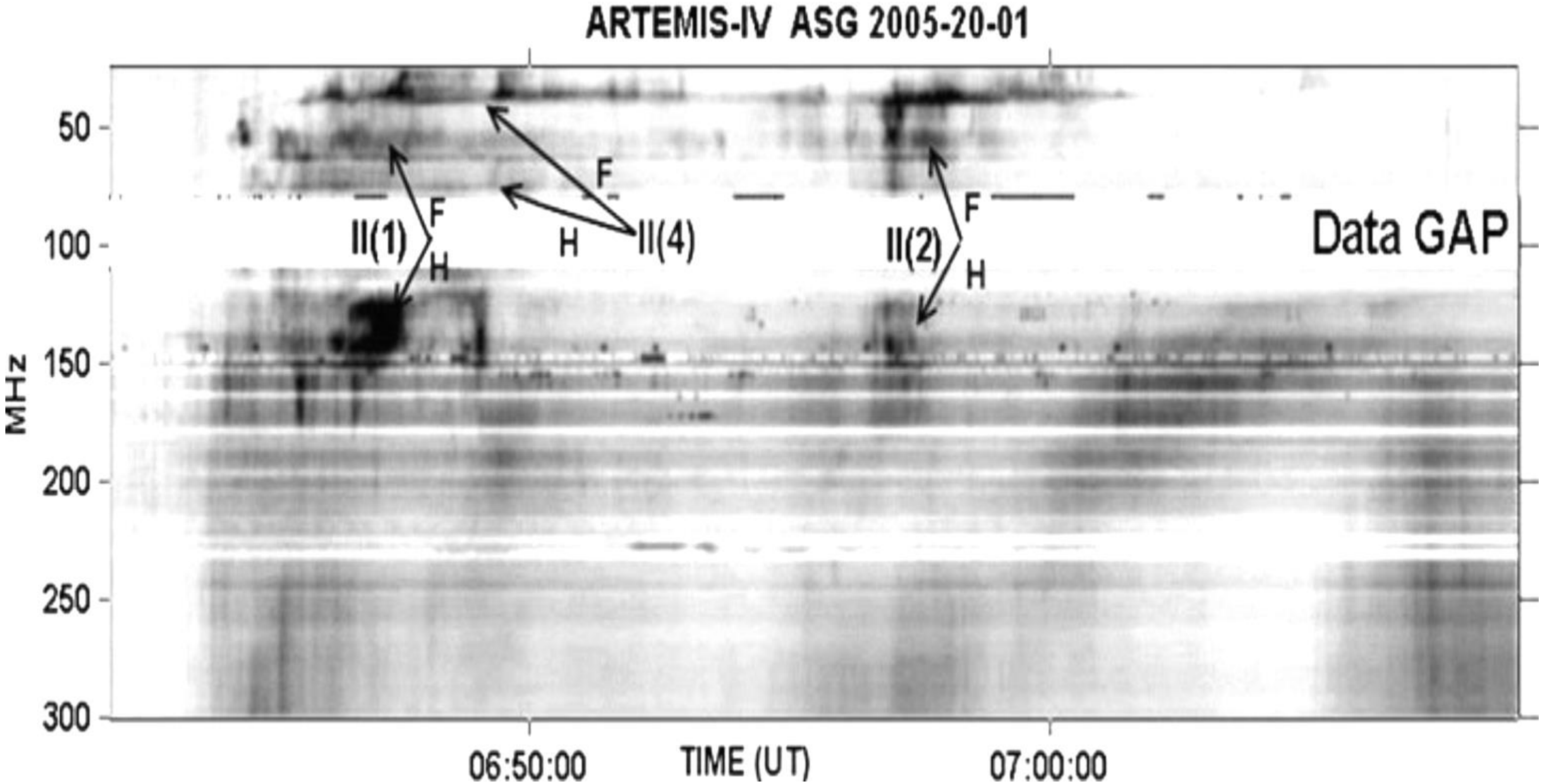
HiRAS, ARTEMIS-IV (ASG), and *Wind/Waves* 20 January 2005, 06:15 – 07:30 UT , 2000 – 2 MHz;

CME trajectory using the **Newkirk model** for the height to frequency conversion (green);

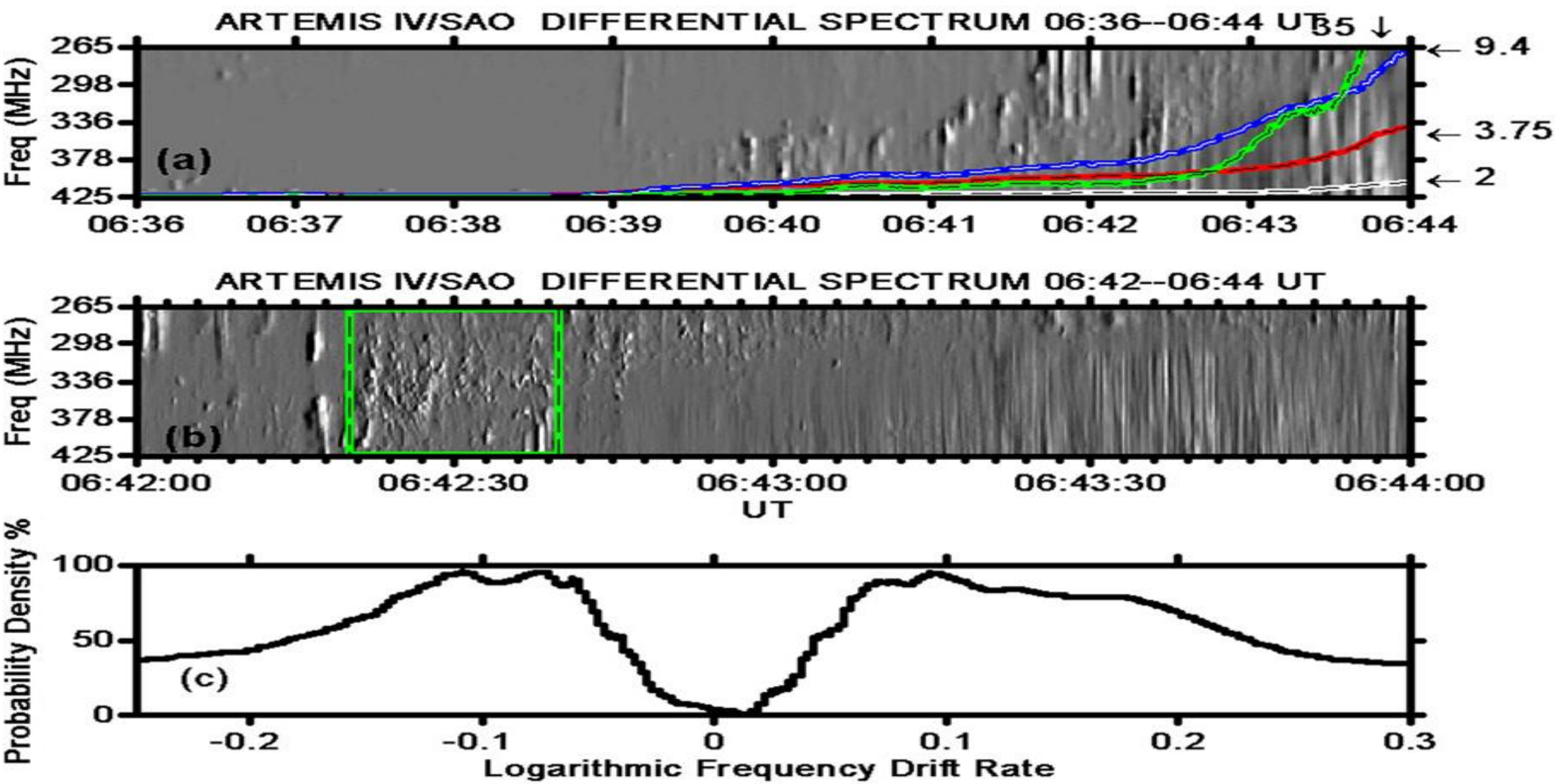
GOES SXR flux (blue); the SONG 40 – 100 KeV Channel (red);

the two Type II/FCII combinations (II(1)/FCII(1) and II(2)/FCII(2)) are in cyan frames;

The electron and proton release times as reported by Grechnev *et al.* (2008), Simnett (2007), and Saiz (2005) are annotated with arrows under the plot.



ARTEMIS-IV/ASG dynamic spectrum (linear frequency scale 300 – 40 MHz) of fundamental-harmonic bands of the two metric (II(1) and II(2)) and the decametric (II(4)) shocks.



Narrow-band Type III and spikes at high resolution (30 ms) dynamic spectrum;

ARTEMIS-IV/SAO and the corresponding microwave enhancement

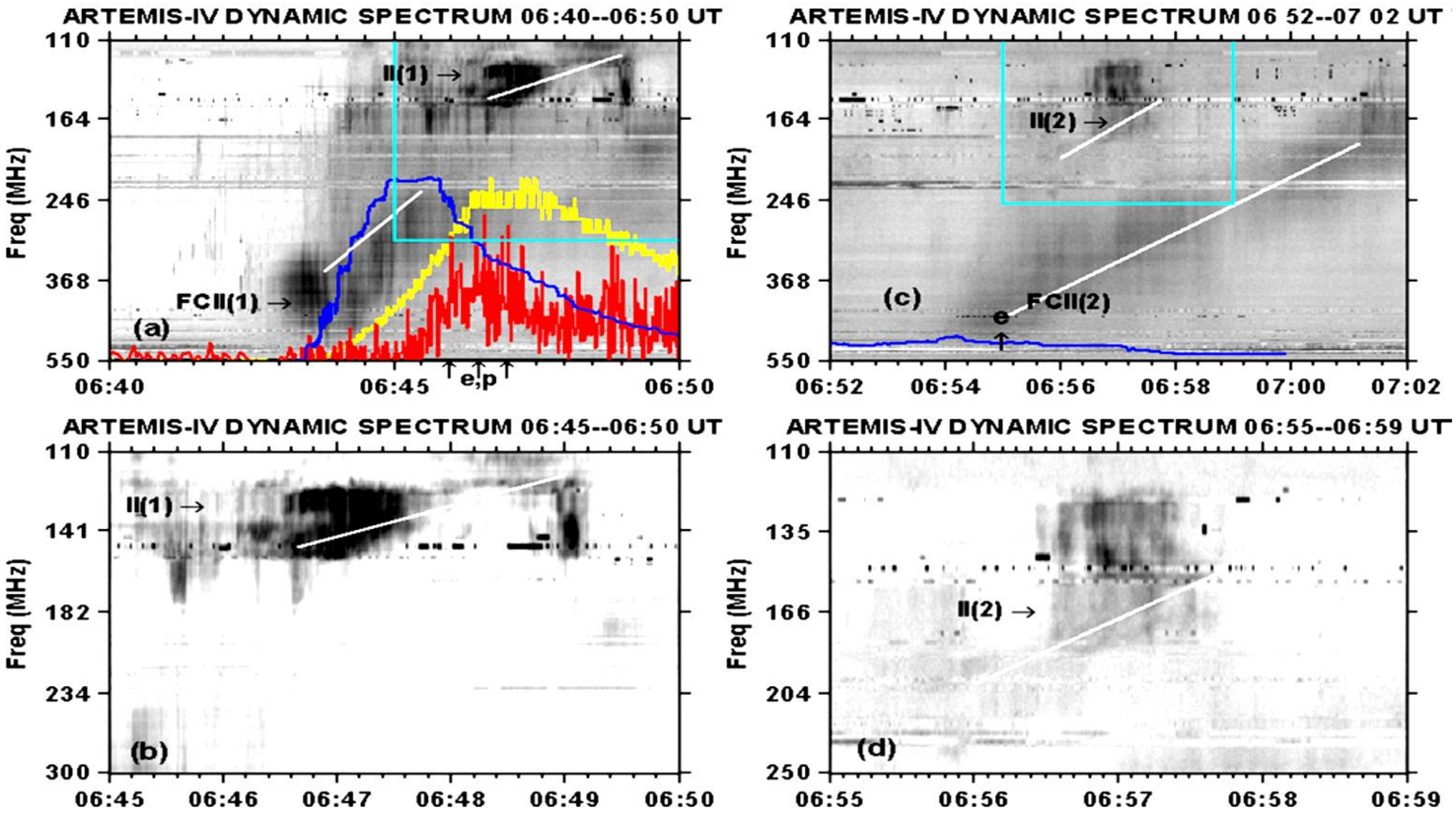
(frequencies 35.0 (green), 9.4 (blue), 3.75 (red) and 2.2 (white) GHz).

06:36 – 06:44 UT onset of the 20 January 2005 event.

ARTEMIS-IV differential spectrum (SAO) in the 06:42 – 06:44 UT interval with 10 msec resolution. On the left, a group of spikes at 06:42:20 UT, marked by the frame, on the right details of the pulsating *patch*.

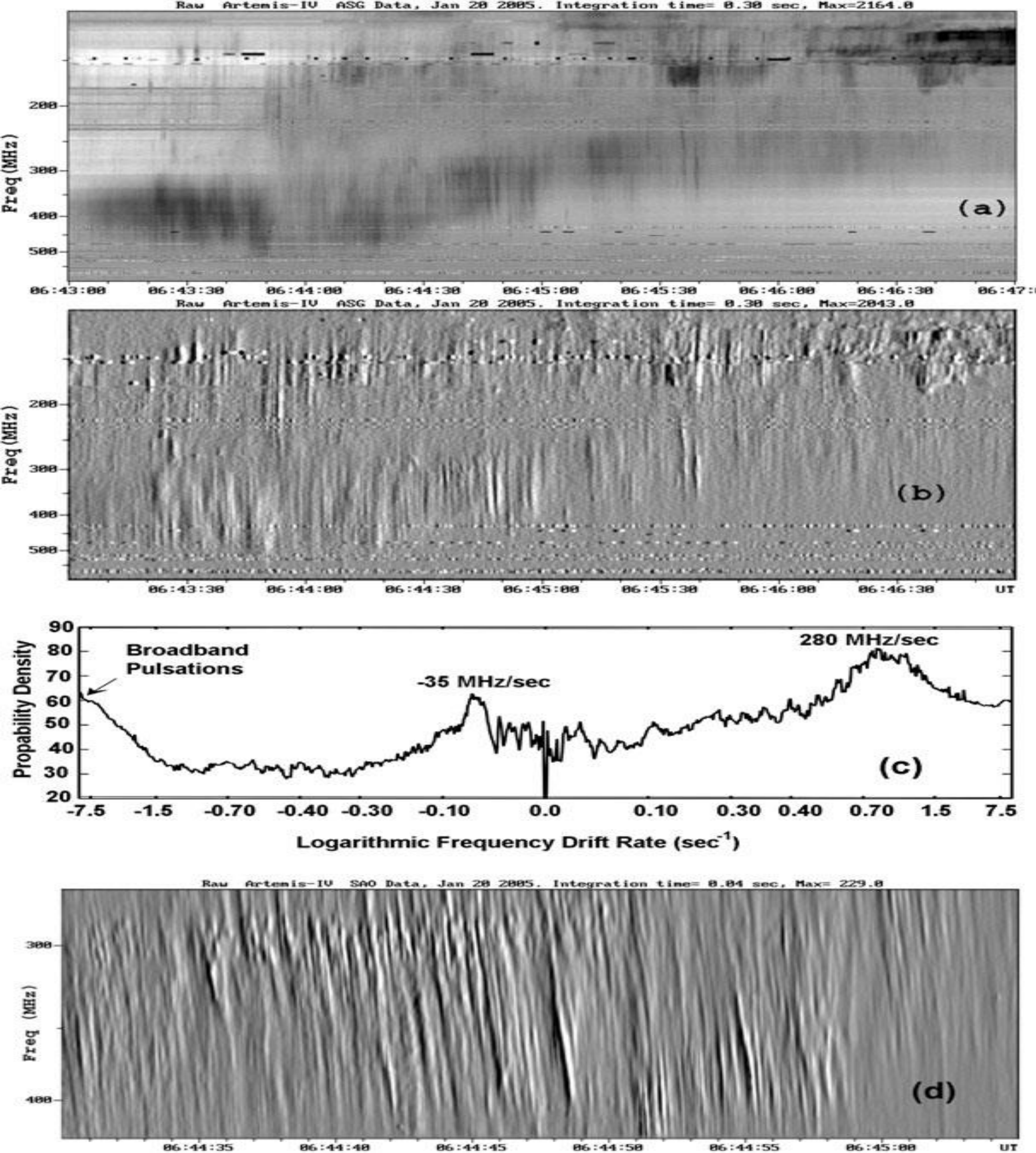
Evolution of average (logarithmic) frequency drift rate (d*f*/*f* d*t*) of the marked spike cluster in the period 06:42:20 – 06:42:40 UT; peaks appear at 0.10, ̅70.06, −0.11 sec−1

(Tsitsipis *et al.*, 2006, 2007)



ARTEMIS-IV (ASG) dynamic spectra of the Type II/FCII bursts (cyan frames on prev. Figure); (a) II(1)/FCII(1) 06:40 – 06:50 UT. The electron and proton release times (06:46 – 06:47 UT, marked with arrows under the plot. We have also included SONG/CORONAS-F normalized flux at 40 – 100 KeV (blue), 0.775 – 2.0 MeV (yellow) and 60 – 100 MeV (red). (b) Details of the Type II(1) shock in the 110 – 300 MHz range and the 06:45 – 06:50 UT time interval; it is enclosed by the box in (a). (c) II(2)/FCII(2) 06:52 – 07:02 UT. The electron release time (06:55 UT) is marked with an arrow.

We have also included SONG/CORONAS-F normalized flux at 40 – 100 Kev (blue). (d) Details of the Type II(2) shock in the 110 – 250 MHz range and the 06:55 – 06:59 UT time interval; it is enclosed by the box in (c).



ARTEMIS-IV Spectra of II(1)/FCII(1),

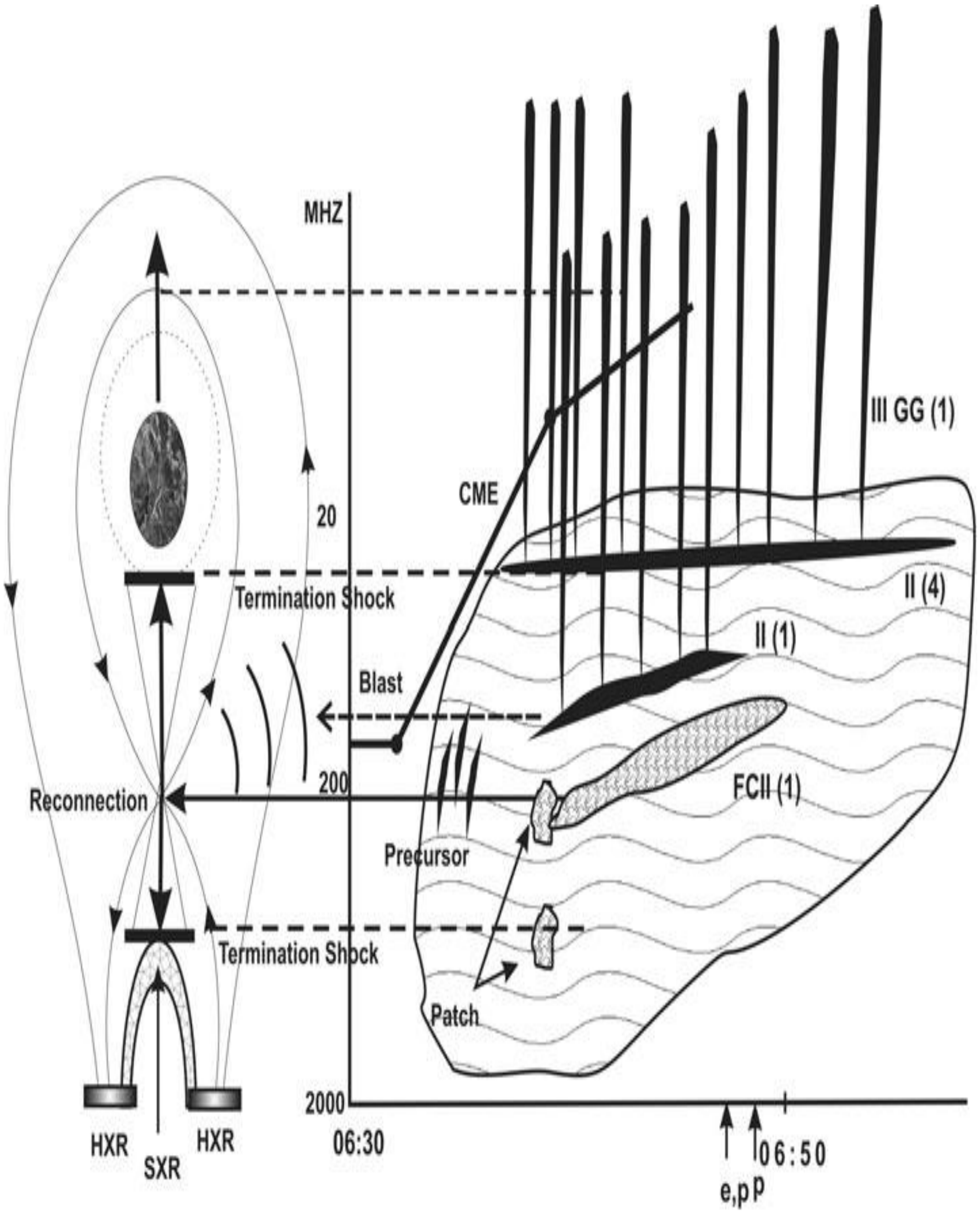
***bidirectional* Type III**

and reverse-drift Type III-like bursts;

(a) ASG dynamic spectrum (06:43 – 06:47 UT) (b) ASG differential spectrum, (c) evolution of average (logarithmic) frequency drift rate (d*f*/*f* d*t*) of the lowerpart of the differential spectrum (06:44 – 06:46 UT and 450 – 300 MHz) with peaks at -0.10 sec^{-1} (20 Mm sec^{-1} outbound) and 0.83 sec^{-1} (≈120 Mmsec^{-1} reverse drift);

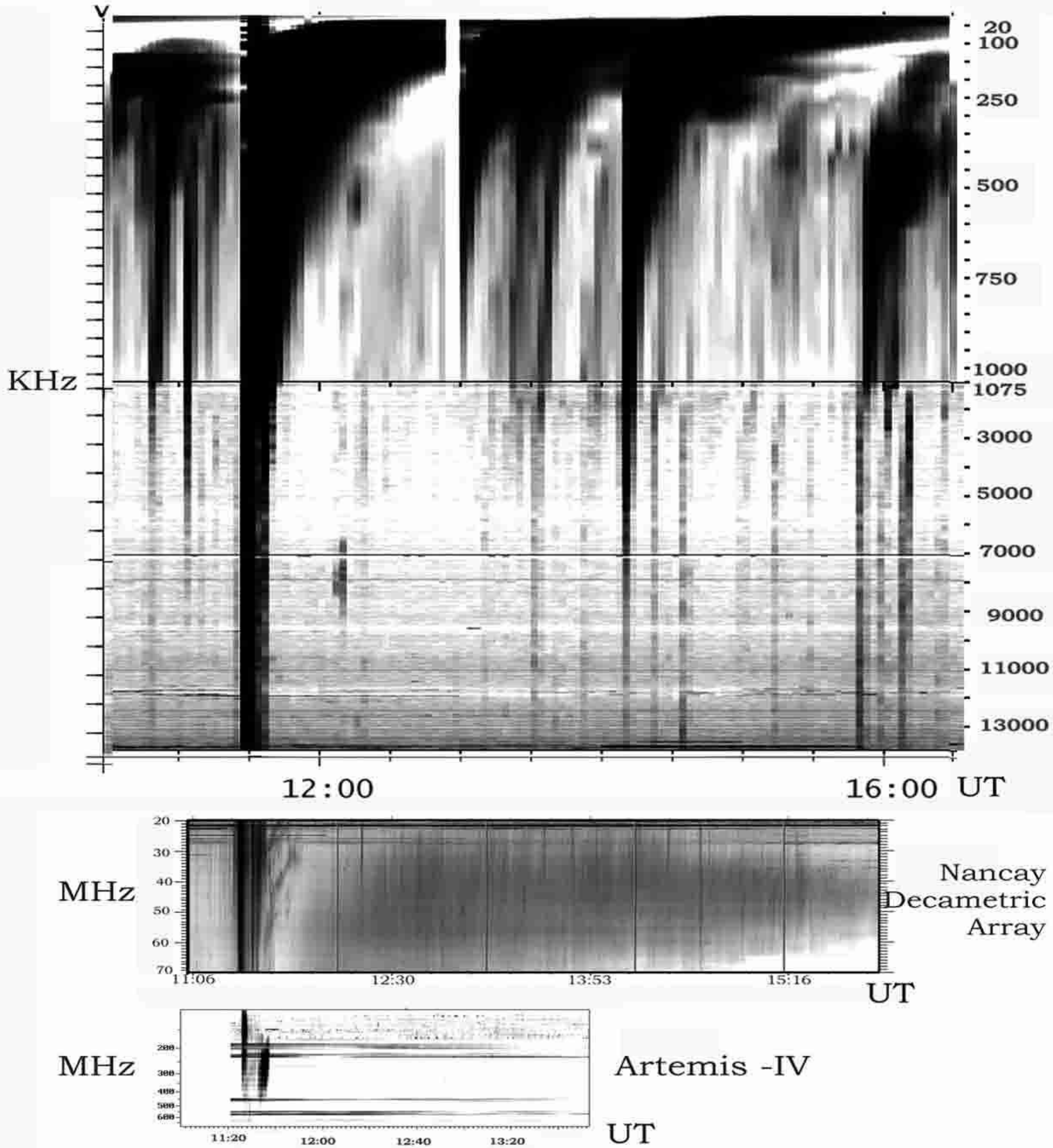
we have **assumed radial propagation** and a **twofold Newkirk density – height coronal model**.

(d) SAO differential spectrum 06:44:30 – 06:45:05 UT.

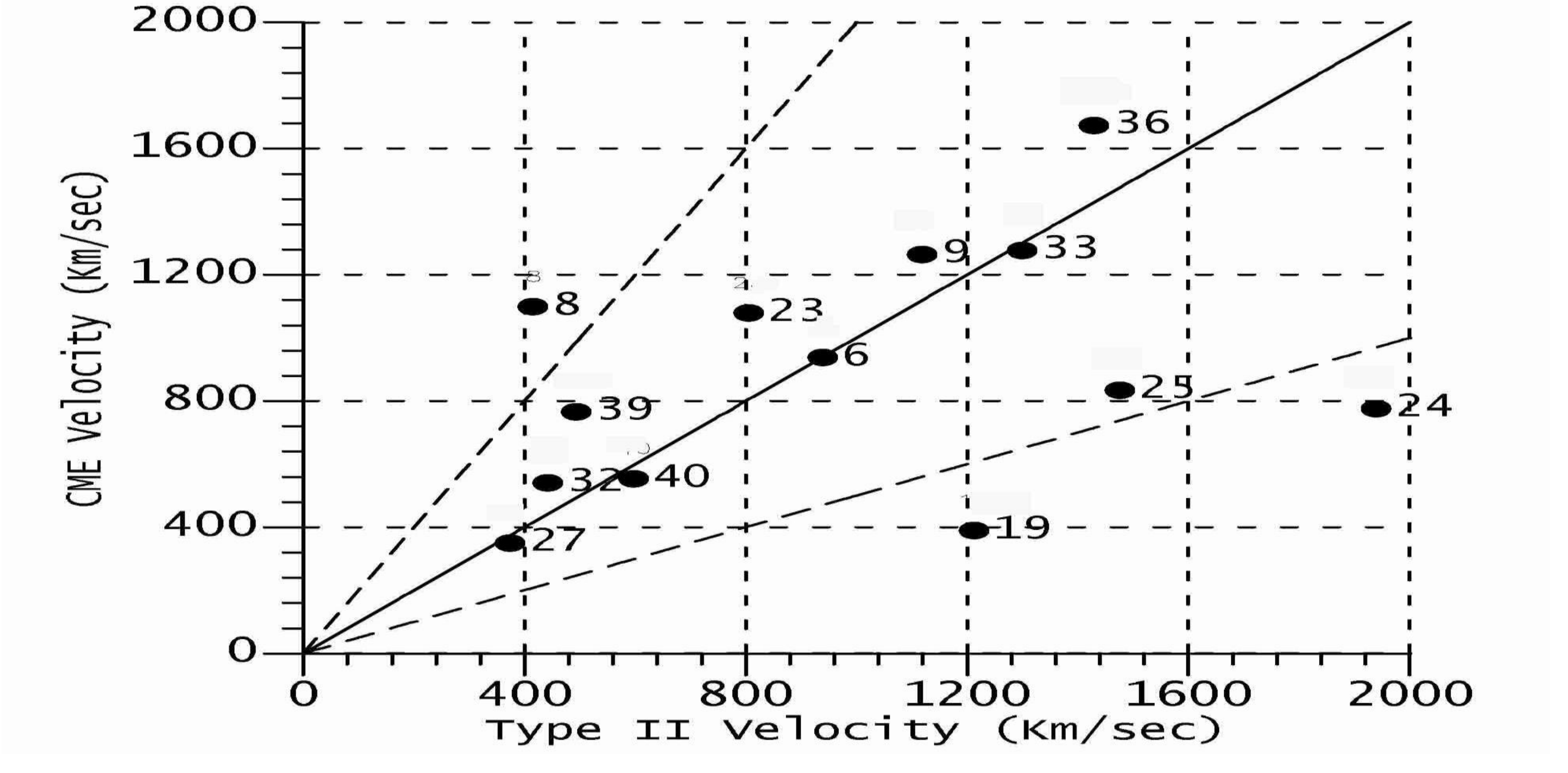


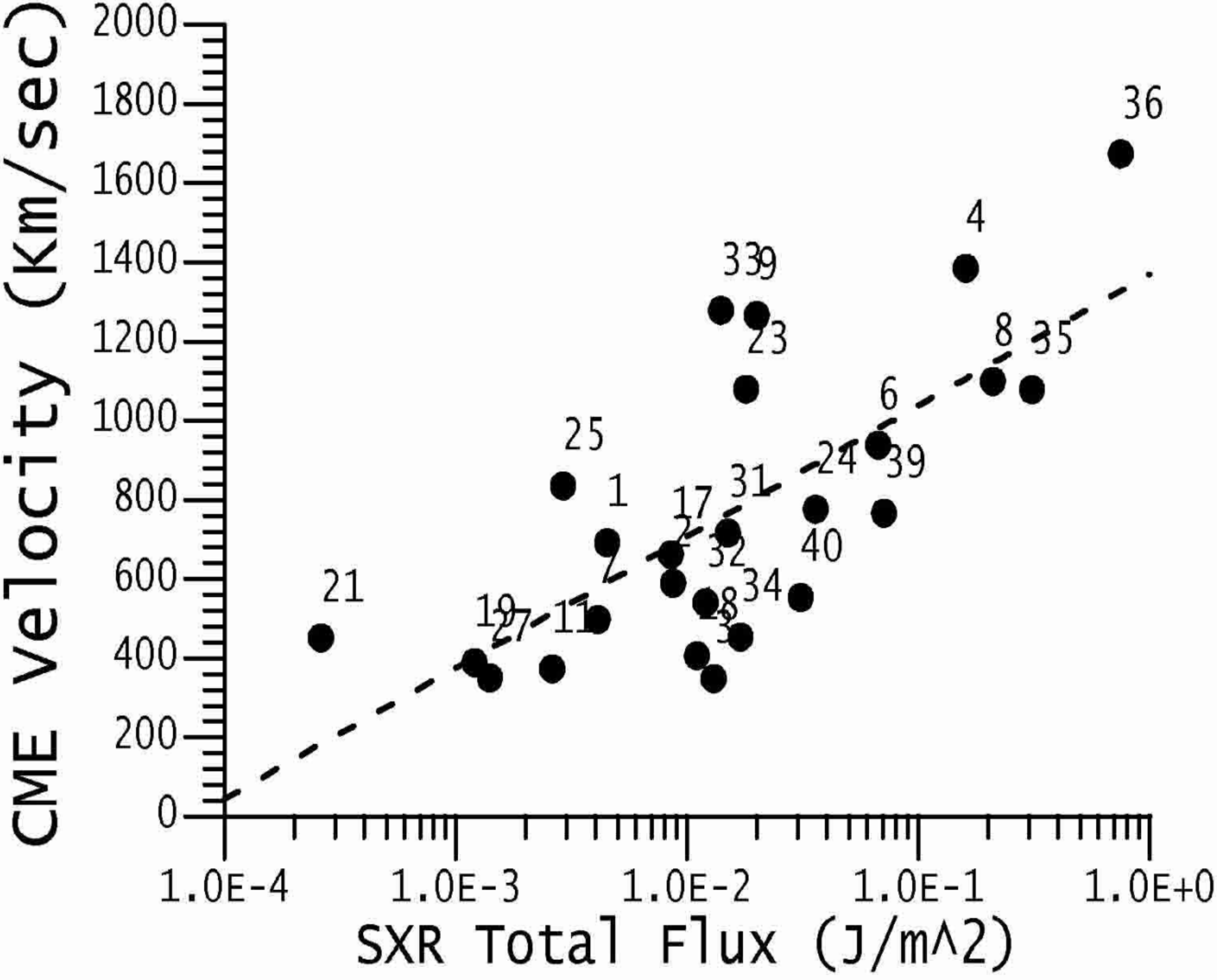
- Comparison of the **standard CME– flare model** with the combined HiRAS, ARTEMIS-IV (ASG)
- and *Wind/Waves* dynamic spectrum.
- On the left we present the CME-induced reconnection (**Forbes**, 2003) supplemented with the reconnection outflow jets and the corresponding termination shocks (Aurass, Vršnak, and Mann, 2002) where the upward shock appears after the CME.
- An additional Type II event originating from the flare-loop expansion moves sideways. On the right we present the dynamic spectrum resulting from this process.

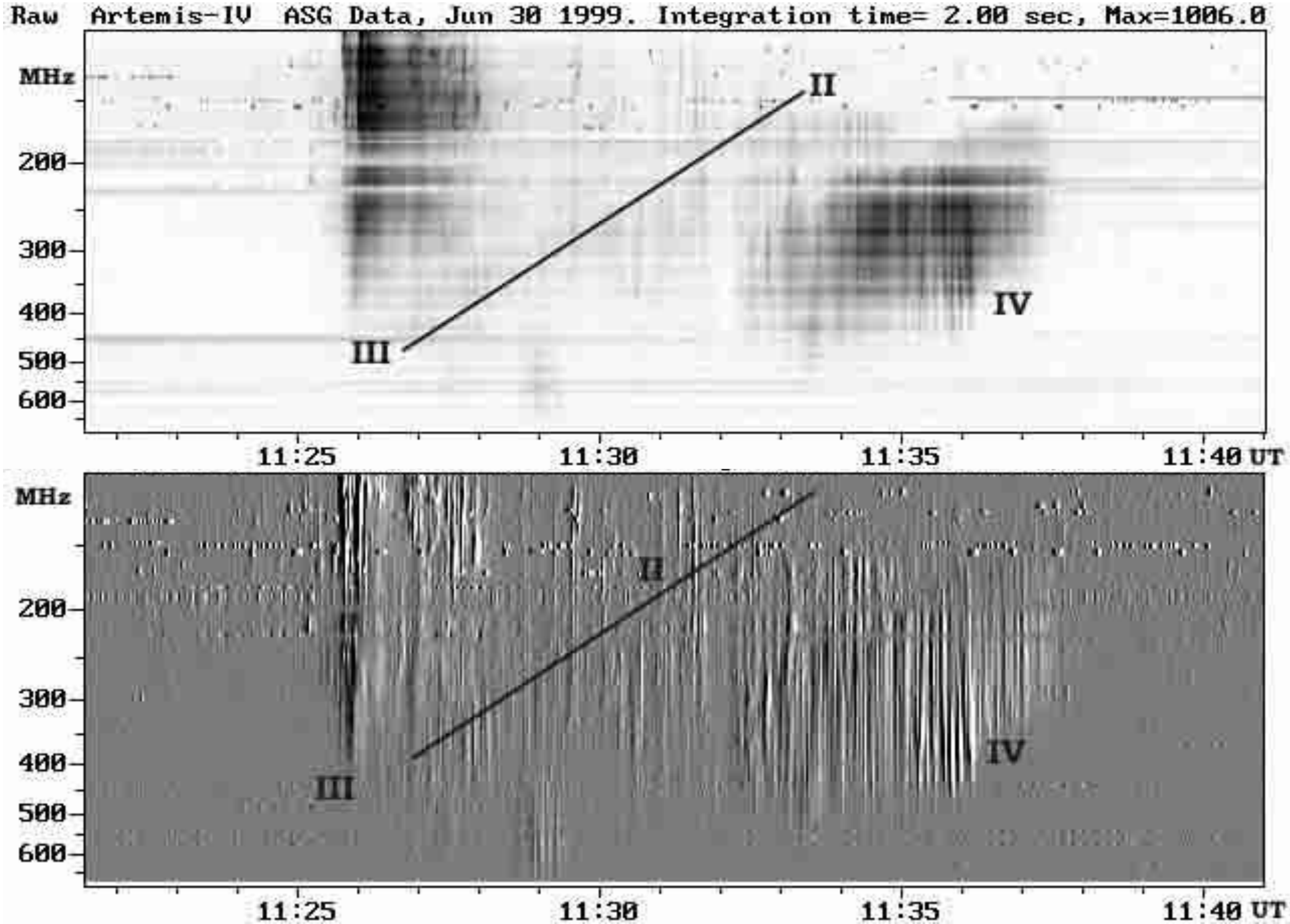
WIND/WAVES Summary Plot 30-JUN-1999



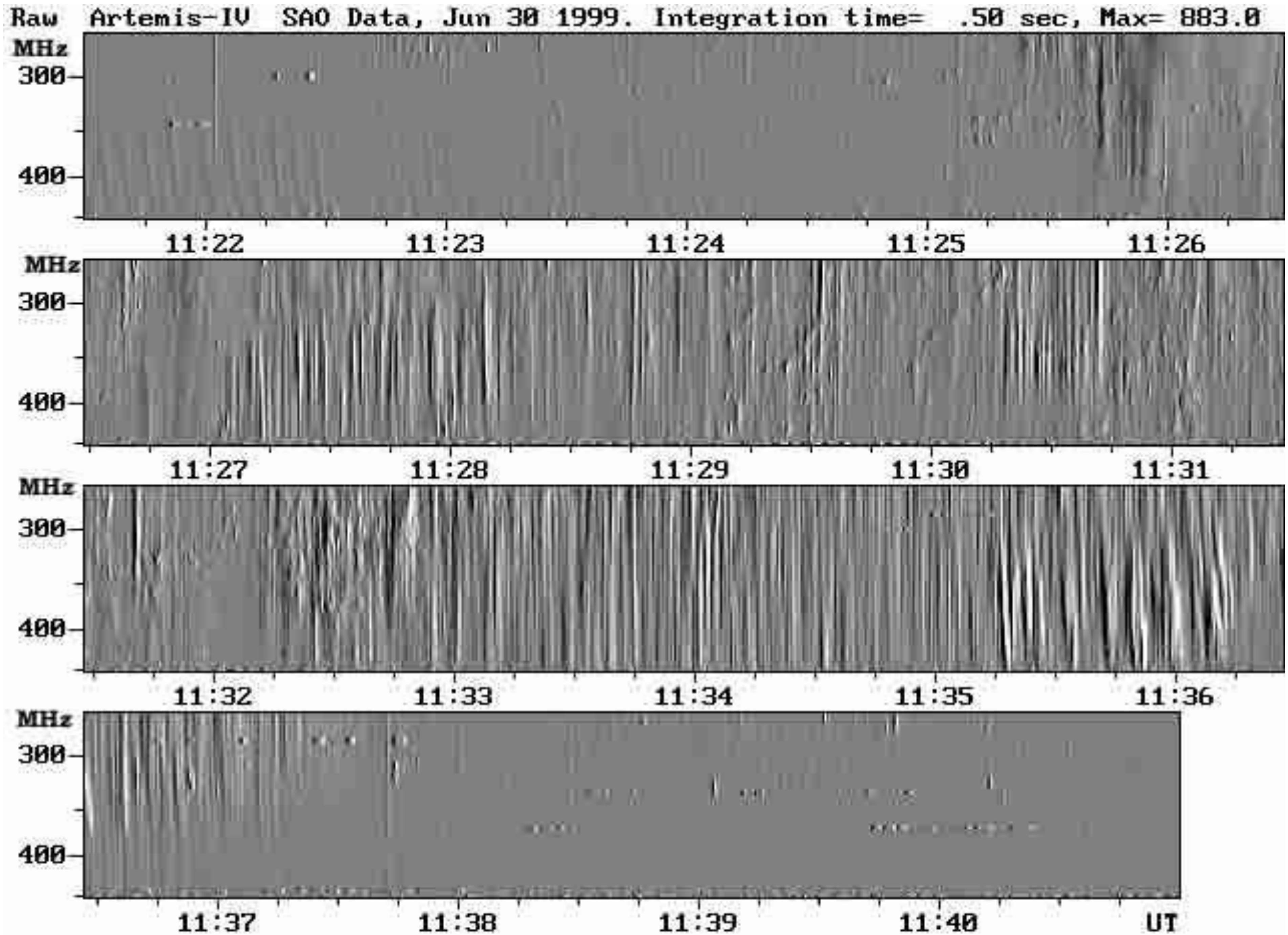
Comparing velocities: CME vs type II




CME Velocity (Km/sec)
SXR Total Flux (J/m^2)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
1.0E-4
1.0E-3
1.0E-2
1.0E-1
1.0E+0
36
4
8
35
6
24
39
40
34
33
9
23
31
17
32
25
1
21
19
27
11



Raw Artemis-IV ASG Data, Jun 30 1999. Integration time= 2.00 sec, Max=1006.0
MHz
200
300
400
500
600
II
III
IV
11:25
11:30
11:35
11:40 UT



Raw Artemis-IV SAO Data, Jun 30 1999. Integration time= .50 sec, Max= 883.0
MHz
300
400
11:22
11:23
11:24
11:25
11:26
11:27
11:28
11:29
11:30
11:31
11:32
11:33
11:34
11:35
11:36
11:37
11:38
11:39
11:40
UT

Τέλος Ενότητας

Χρηματοδότηση

- Το παρόν εκπαιδευτικό υλικό έχει αναπτυχθεί στο πλαίσιο του εκπαιδευτικού έργου του διδάσκοντα.
- Το έργο «**Ανοικτά Ακαδημαϊκά Μαθήματα στο Πανεπιστήμιο Αθηνών**» έχει χρηματοδοτήσει μόνο την αναδιαμόρφωση του εκπαιδευτικού υλικού.
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Ο δικαιούχος μπορεί να παρέχει στον αδειοδόχο ξεχωριστή άδεια να χρησιμοποιεί το έργο για εμπορική χρήση, εφόσον αυτό του ζητηθεί.

Διατήρηση Σημειωμάτων

Οποιαδήποτε αναπαραγωγή ή διασκευή του υλικού θα πρέπει να συμπεριλαμβάνει:

- το Σημείωμα Αναφοράς
- το Σημείωμα Αδειοδότησης
- τη δήλωση Διατήρησης Σημειωμάτων
- το Σημείωμα Χρήσης Έργων Τρίτων (εφόσον υπάρχει)

μαζί με τους συνοδευόμενους υπερσυνδέσμους.