Identification of Saturn lightning registered by UTR-2 radio telescope and spacecraft Cassini

C. Milostnaya[1], V. Zakharenko[1], A. Konovalenko[1], P. Zarka[4], G. Fischer[2], J.–M. Grießmeier[3], G. Litvinenko[1], B. Ryabov[1], D. Vavriv[1], V. Ryabov[5], H.Rucker[2], P. Ravier[6], M. Sidorchuk[1], B. Cecconi[4], A. Coffre[7], L. Denis[7], C. Fabrice[7], R. Kozhyn[1], D.Mukha[1], L. Pallier[4], J. Schneider[8], V. Shevchenko[1], V. Vinogradov[1], R. Weber[6], V. Nikolaenko[1]

(1) Institute of Radio Astronomy, Kharkov, Ukraine;
(2) Space Research Institute, Graz, Austria;
(3) ASTRON, Netherlands Institute for Radio Astronomy, Postbus 2, 7990 AA, Dwingeloo, The Netherlands;
(4) LESIA, Observatoire de Paris, CNRS, UPMC, Universitre Paris Diderot; 5 Place Jules Janssen, 92190 Meudon,France;
(5) Complex Systems Department, Future University, Hakodate, Hokkaido, Japan;
(6) LESI, University d'Orleans, France;
(7) Station de Radioastronomie de Nançay, Observatoire de Paris, 18 Nançay, France;
(8) LUTH, Observatoire de Paris; 5 Place Jules Janssen, 92190 Meudon, France;

Saturn Electrostatic Discharges – SED

- Spacecrafts: Voyagers, Cassini > 25 years

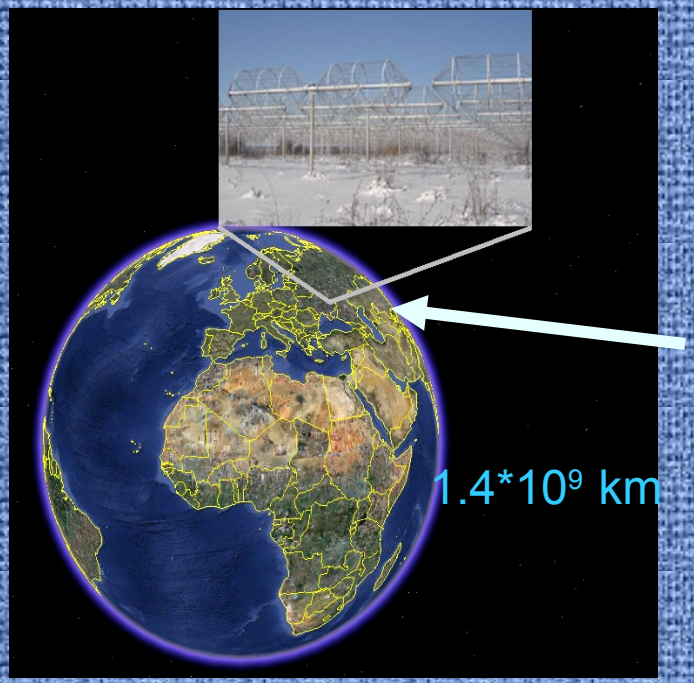
9 storms (V1,V2,0,A-F)

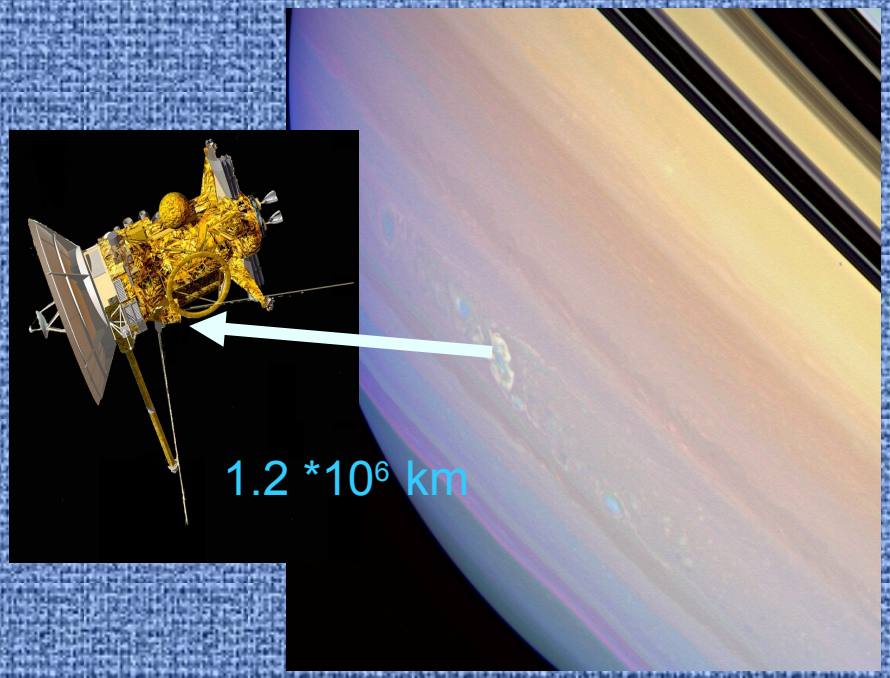
- UTR-2,

storm E (Jan-Feb 2006),

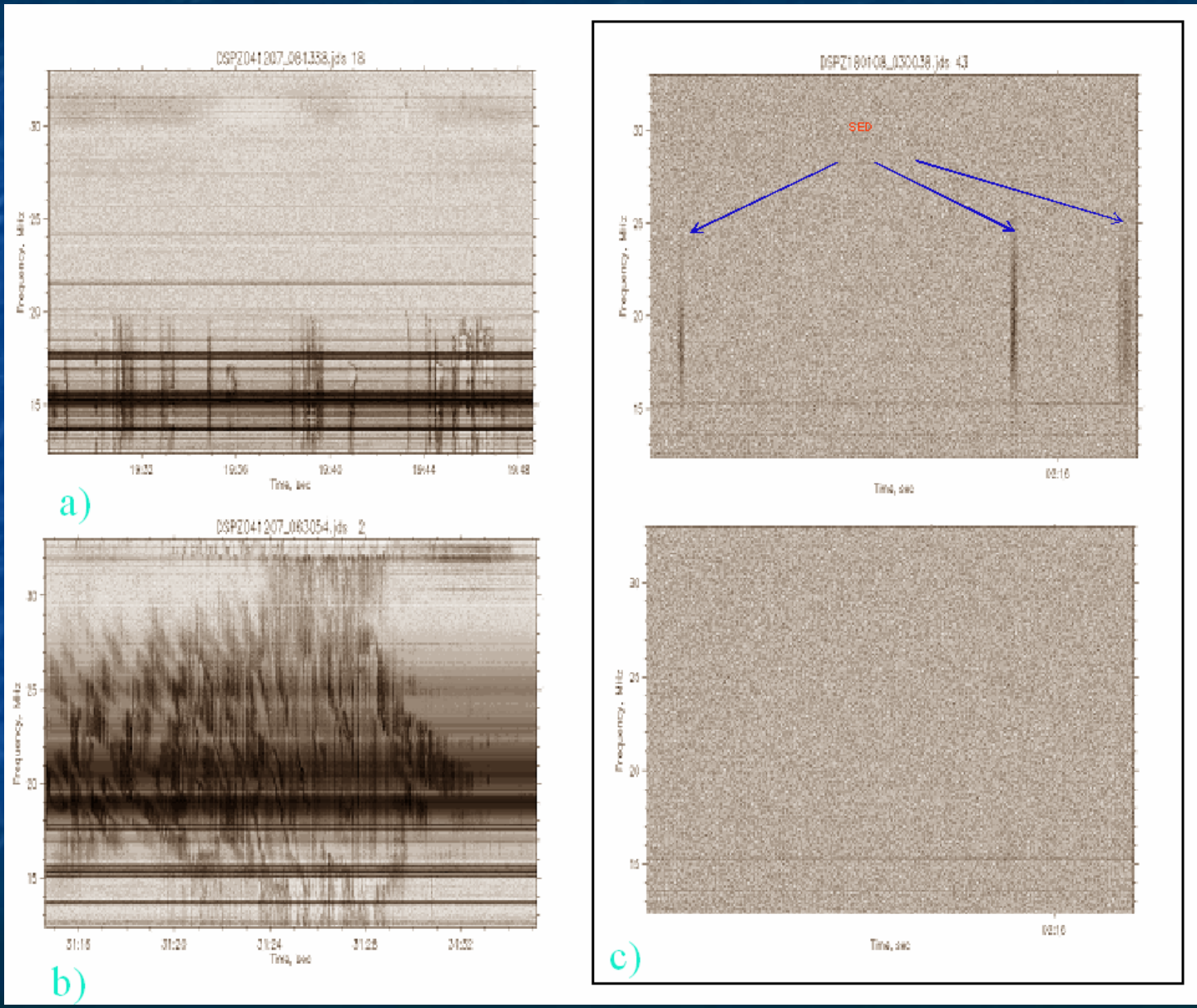
F(Nov 2007 - Aug 2008)

Difficulties 1.
Cassini / UTR-2 flux ratio





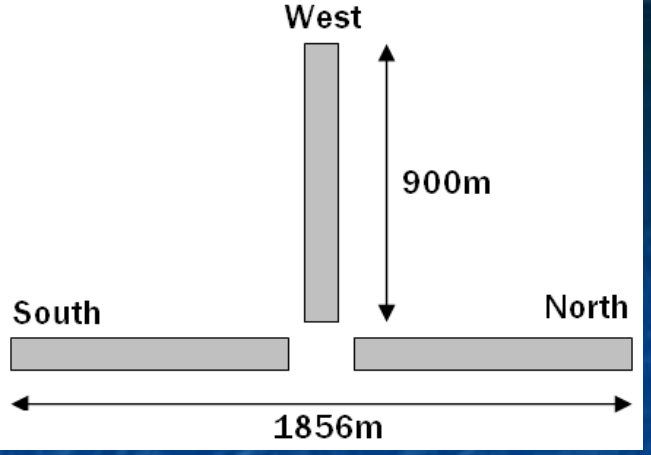
Difficulties 2. Interference (left, top), relay switching (left, bottom), SED (right) ON (top), OFF (bottom)

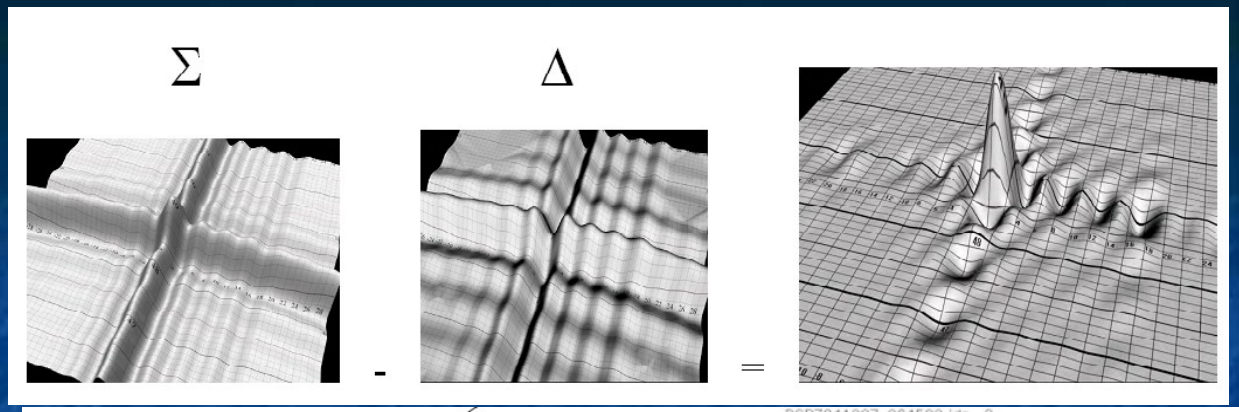


Ground-based identification of SEDs, new algorithm

- UTR-2, 5 beam operating mode
- "ON-OFF" mode, a sum-difference mode of a two-channel receiver

- Multichannel algorithm:
  - data limit in each narrow-band channel at 3σ
  - sub-bands (12-33 MHz → 20 sub-bands)
  - signal exceeding 4σ in two sub-bands
  - Visual inspection (for remove wide-band noise in the range 27 ... 33 MHz saturated by large number of weak but relatively broadband sources).



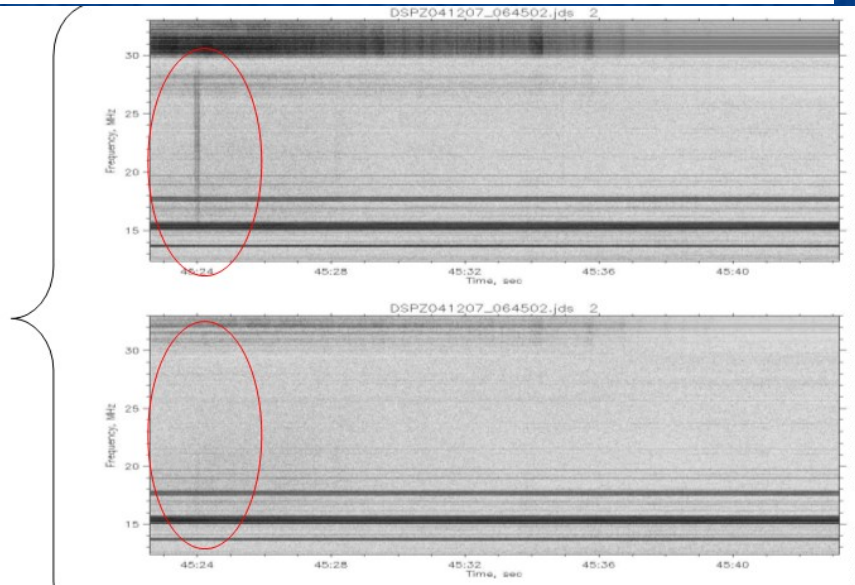


ON-OFF 3rd – 5th beams

3rd beam "ON"

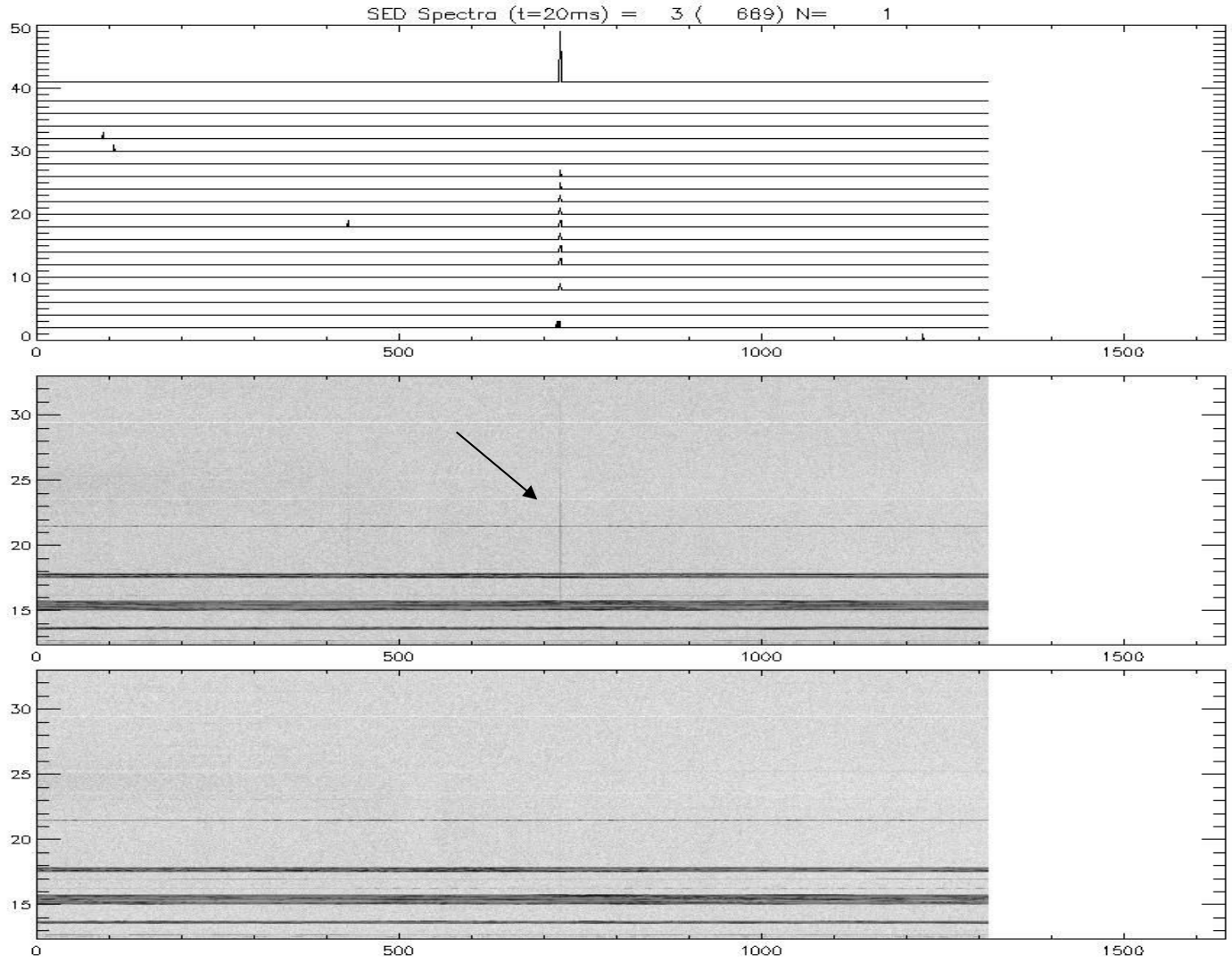
Σ

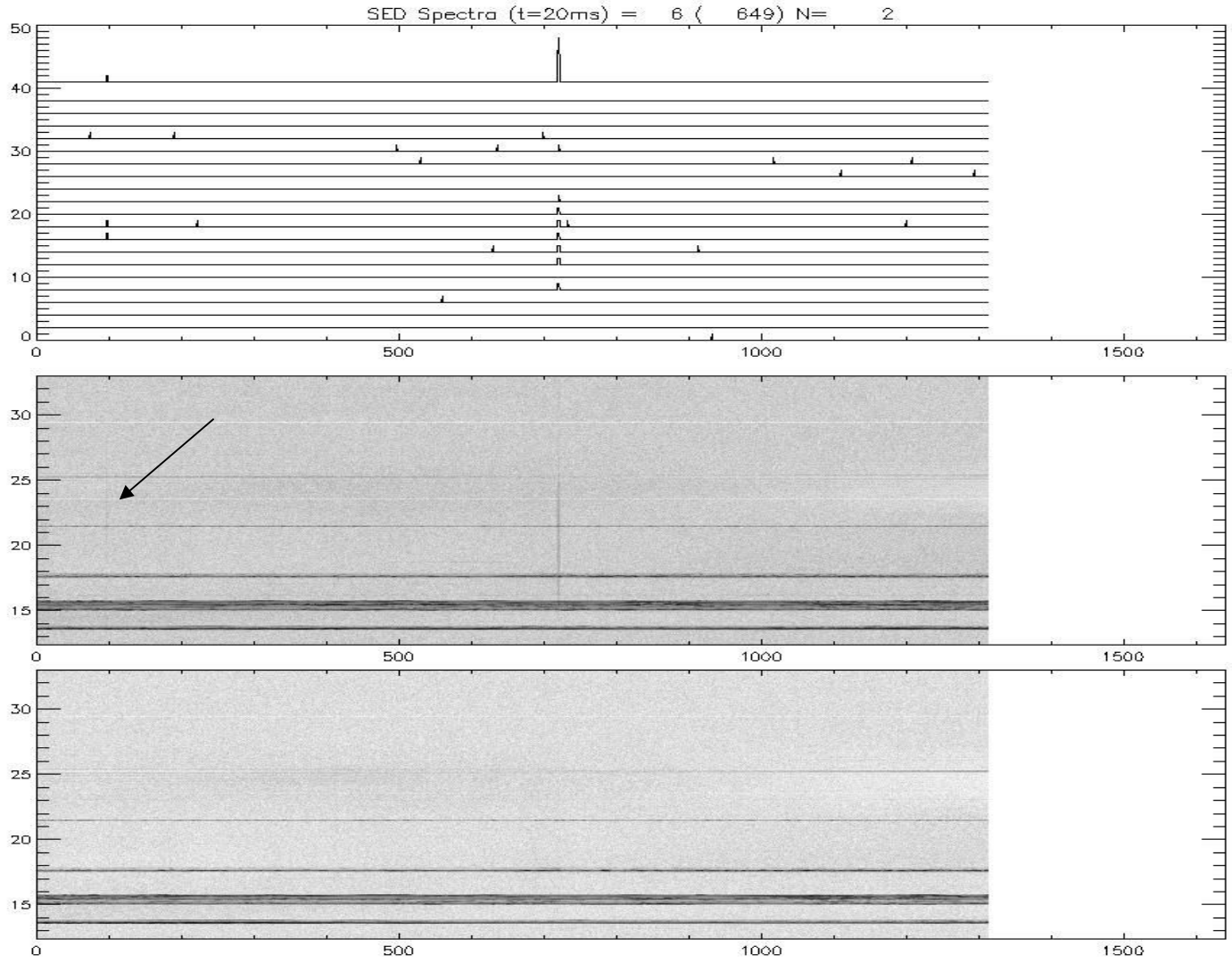
Δ

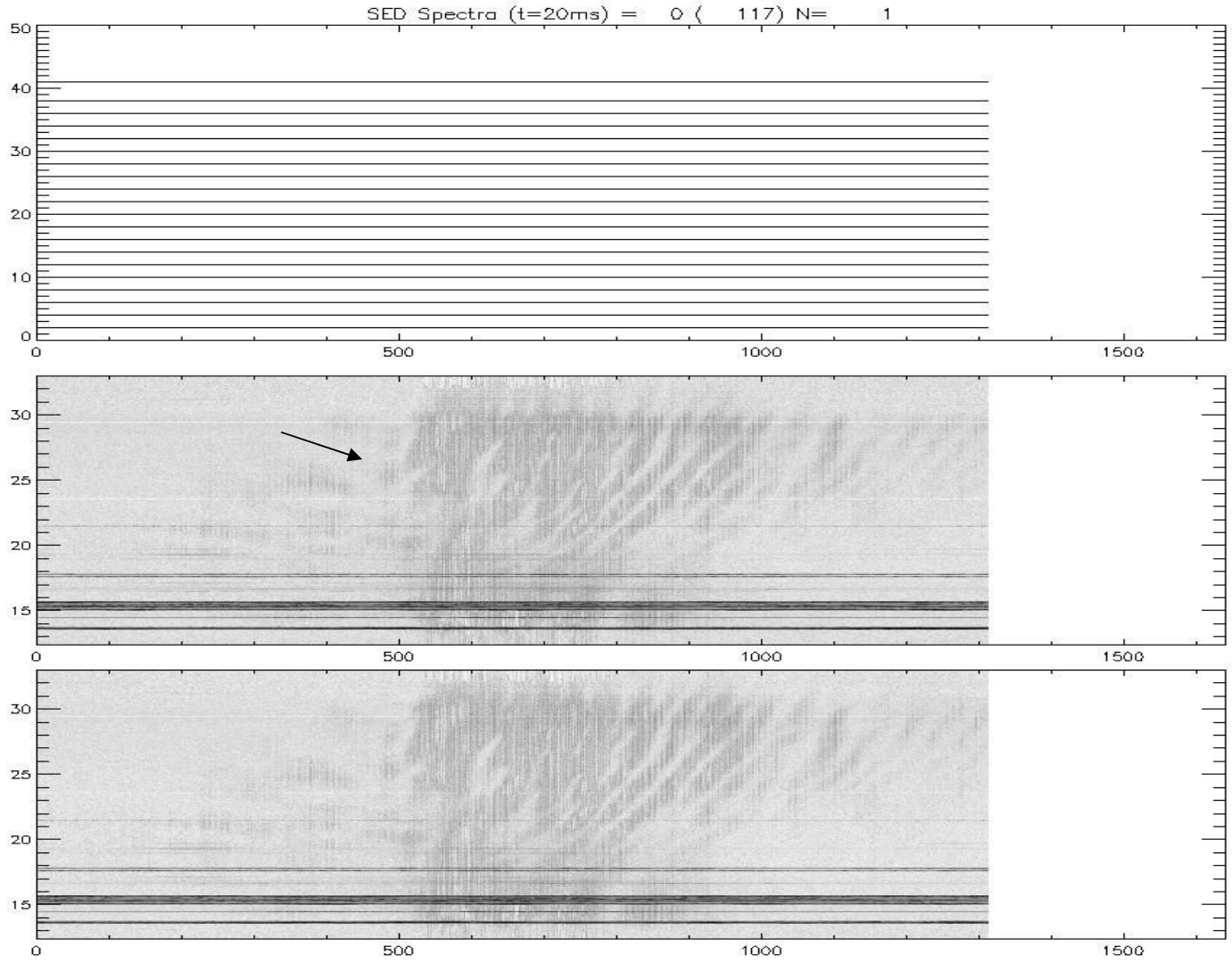


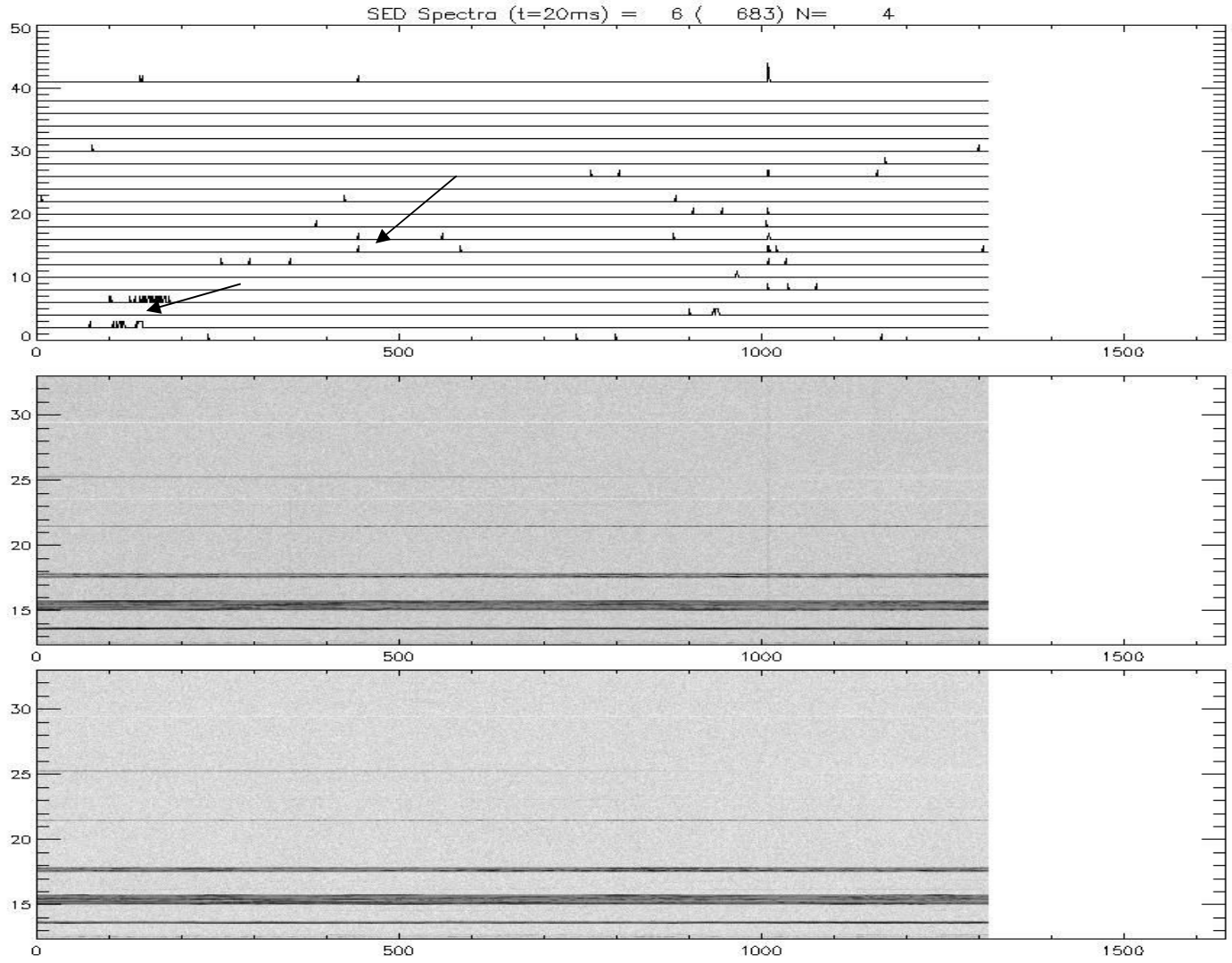
5th beam "OFF"

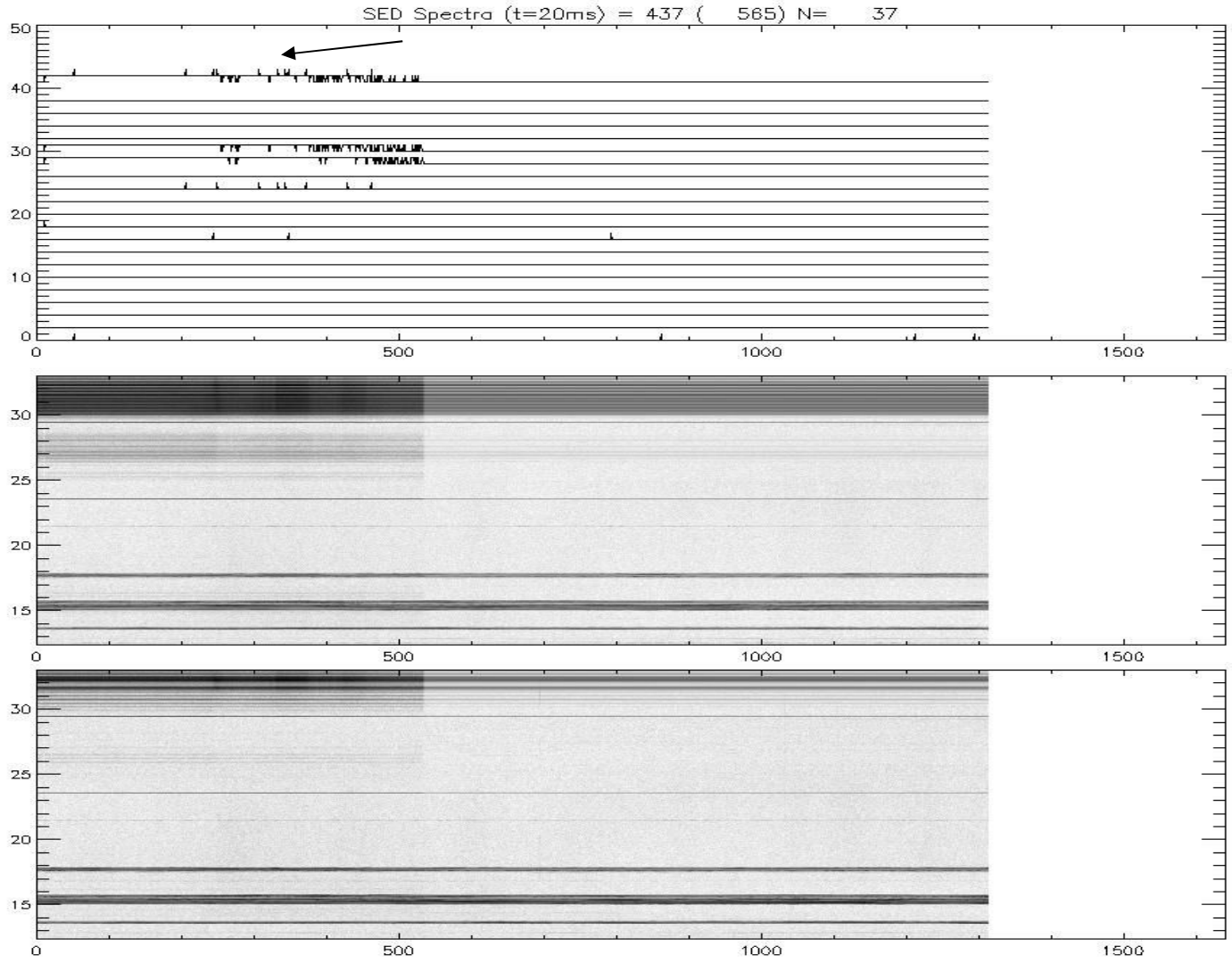
Σ

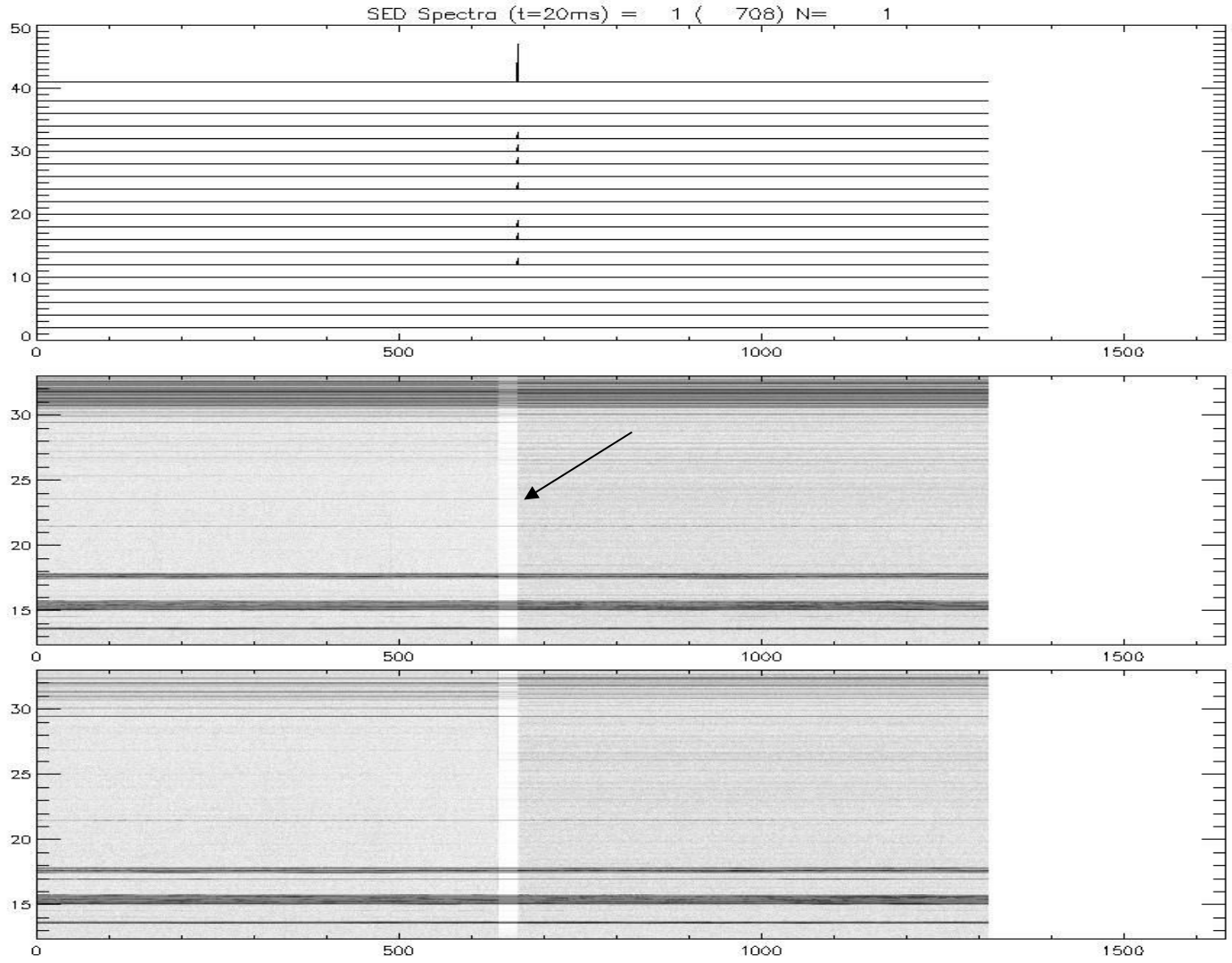

SED Spectra (t=20ms) = 3 (669) N= 1
50
40
30
20
10
0
0
500
1000
1500
30
25
20
15
0
500
1000
1500
30
25
20
15
0
500
1000
1500


SED Spectra (t=20ms) = 6 (649) N= 2
50
40
30
20
10
0
0
500
1000
1500
30
25
20
15
0
500
1000
1500
30
25
20
15
0
500
1000
1500


SED Spectra (t=20ms) = 0 (117) N= 1
50
40
30
20
10
0
0
500
1000
1500
30
25
20
15
0
500
1000
1500
30
25
20
15
0
500
1000
1500


SED Spectra (t=20ms) = 6 (683) N= 4
50
40
30
20
10
0
0
500
1000
1500
30
25
20
15
0
500
1000
1500
30
25
20
15
0
500
1000
1500

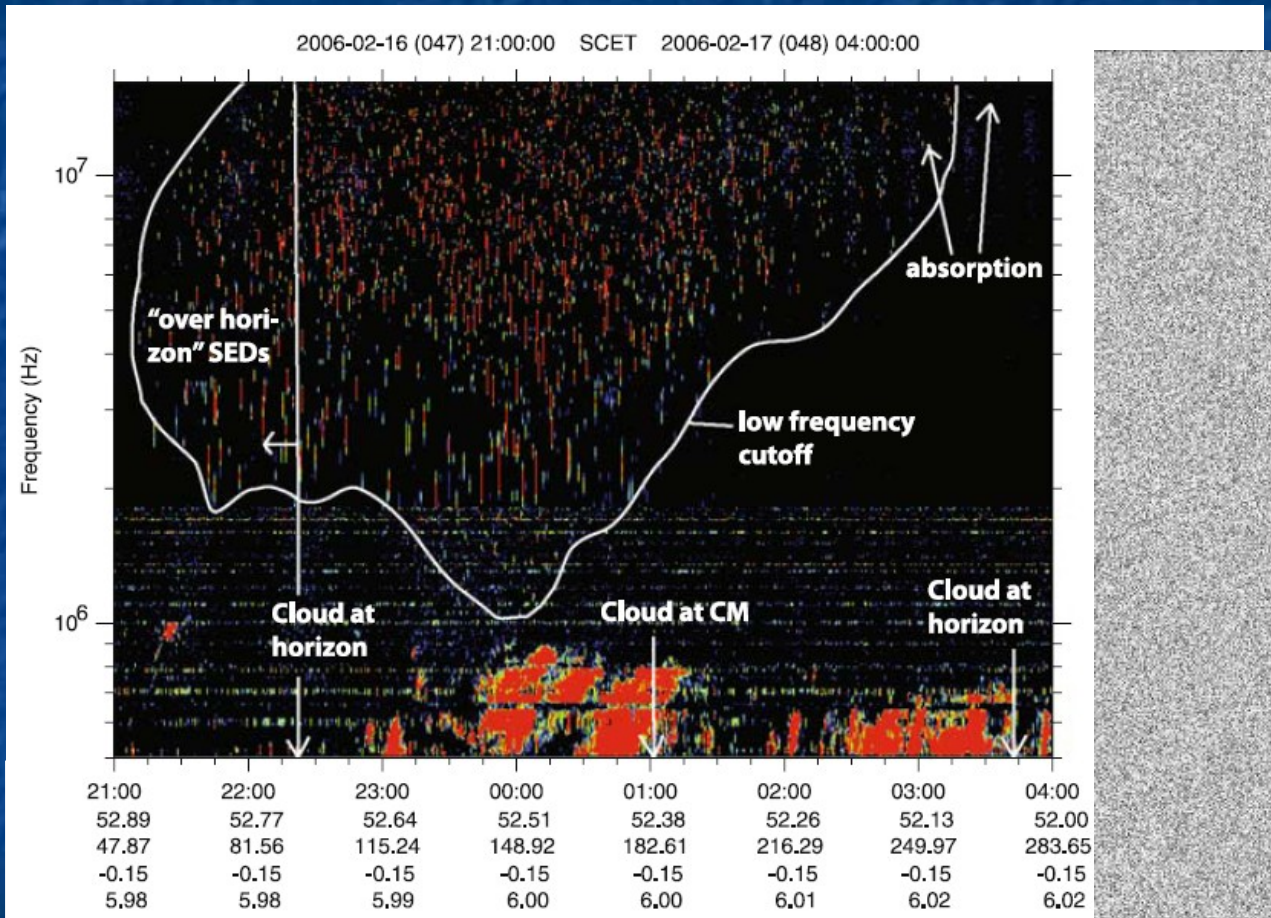

SED Spectra (t=20ms) = 437 (565) N= 37
50
40
30
20
10
0
0
500
1000
1500
30
25
20
15
0
500
1000
1500
30
25
20
15
0
500
1000
1500


SED Spectra (t=20ms) = 1 (708) N= 1
50
40
30
20
10
0
0
500
1000
1500
30
25
20
15
0
500
1000
1500
30
25
20
15
0
500
1000
1500

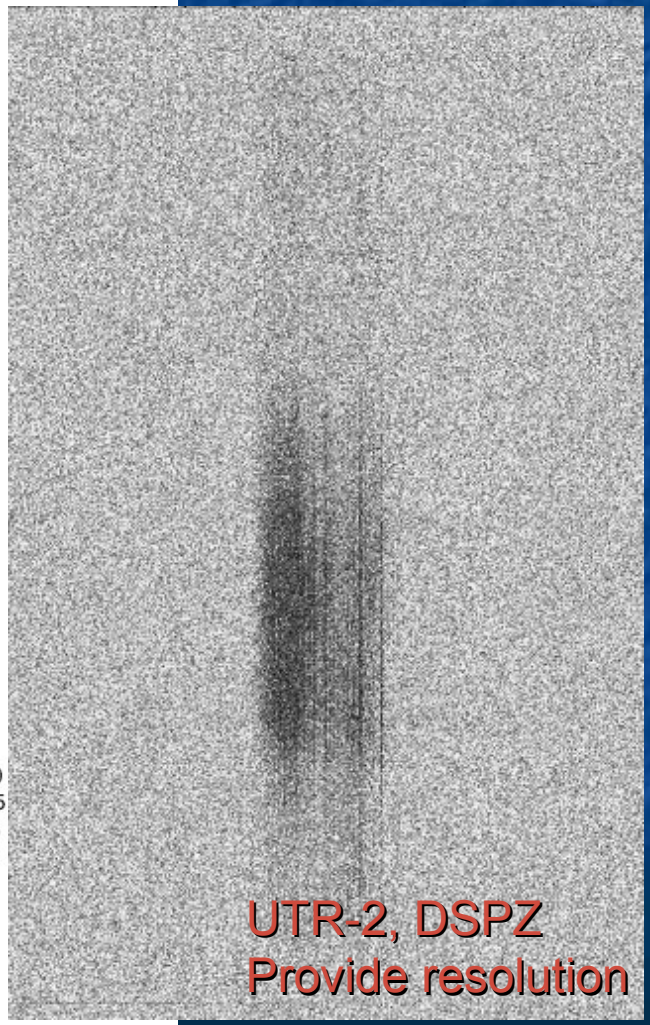
Date, time and some SED characteristics

Day	Date	Start	End	SED flashes	SED rate	τ, ms
A1	01/12/2007 F9	01:30:52	07:20:08	303	0.0171	29.8
A2	01/12/2007 F11	23:43:40	04:39:39	269	0.0129	19.4
A3	02/12/2007 F13	23:40:51	02:28:03	71	0.0071	21.1
A4	04/12/2007 F15	04:16:47	07:18:00	226	0.0207	29.9
A5	05/12/2007 F17	02:00:52	07:28:08	49	0.0025	22.9
A8	12/12/2007 F33	04:27:24	07:13:42	35	0.0035	16.5

Comparison UTR-2 data and SC data

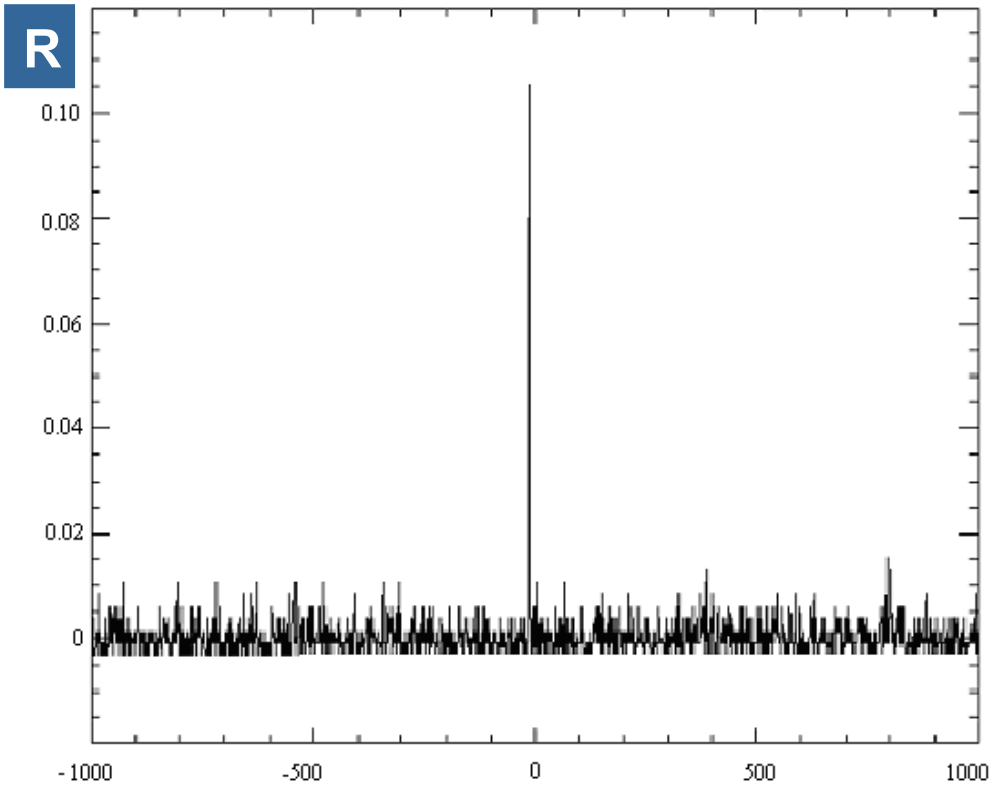


SC, RPWS



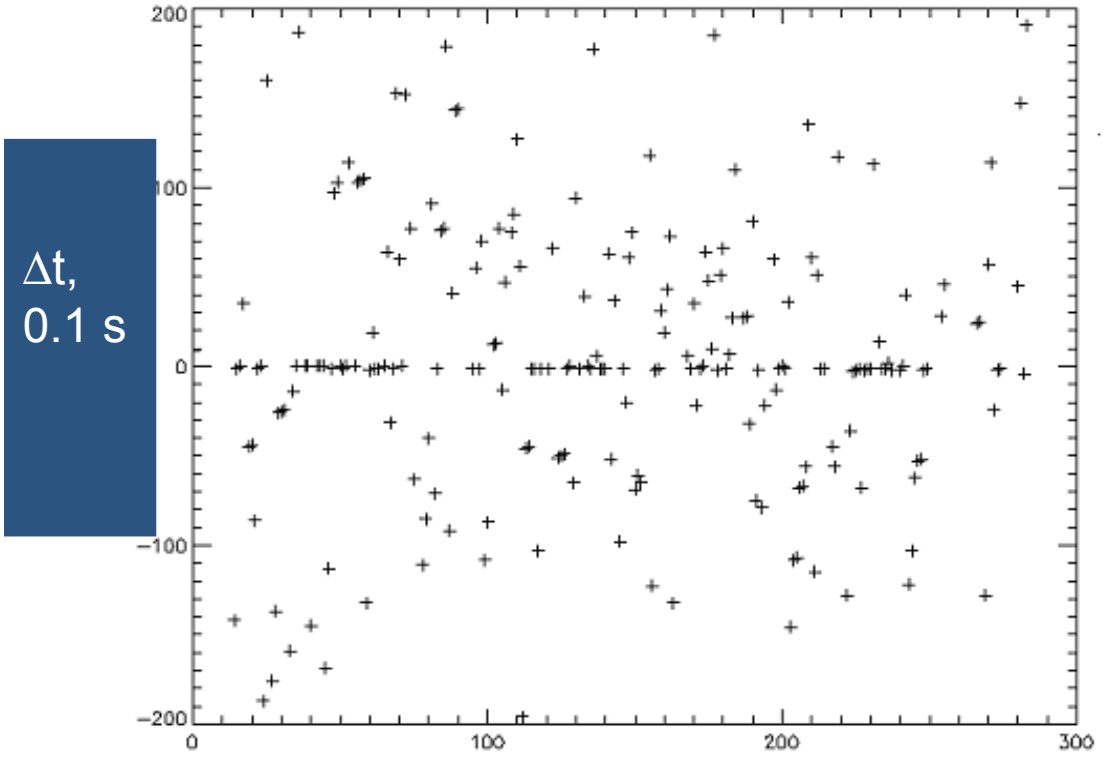
UTR-2, DSPZ
Provide resolution

Cross-correlation function A2 after time correction



Δt, 0.1 s

Time difference function A2



Duty cycle of RPWS and number of coincident events

64 from 285; 110 ms (22.5%)

96 from 393; 20 ms (24.4%)

UTR-2: ≅ 400

SC “Cassini“ ≅ 910/0.22 ≅ 4140

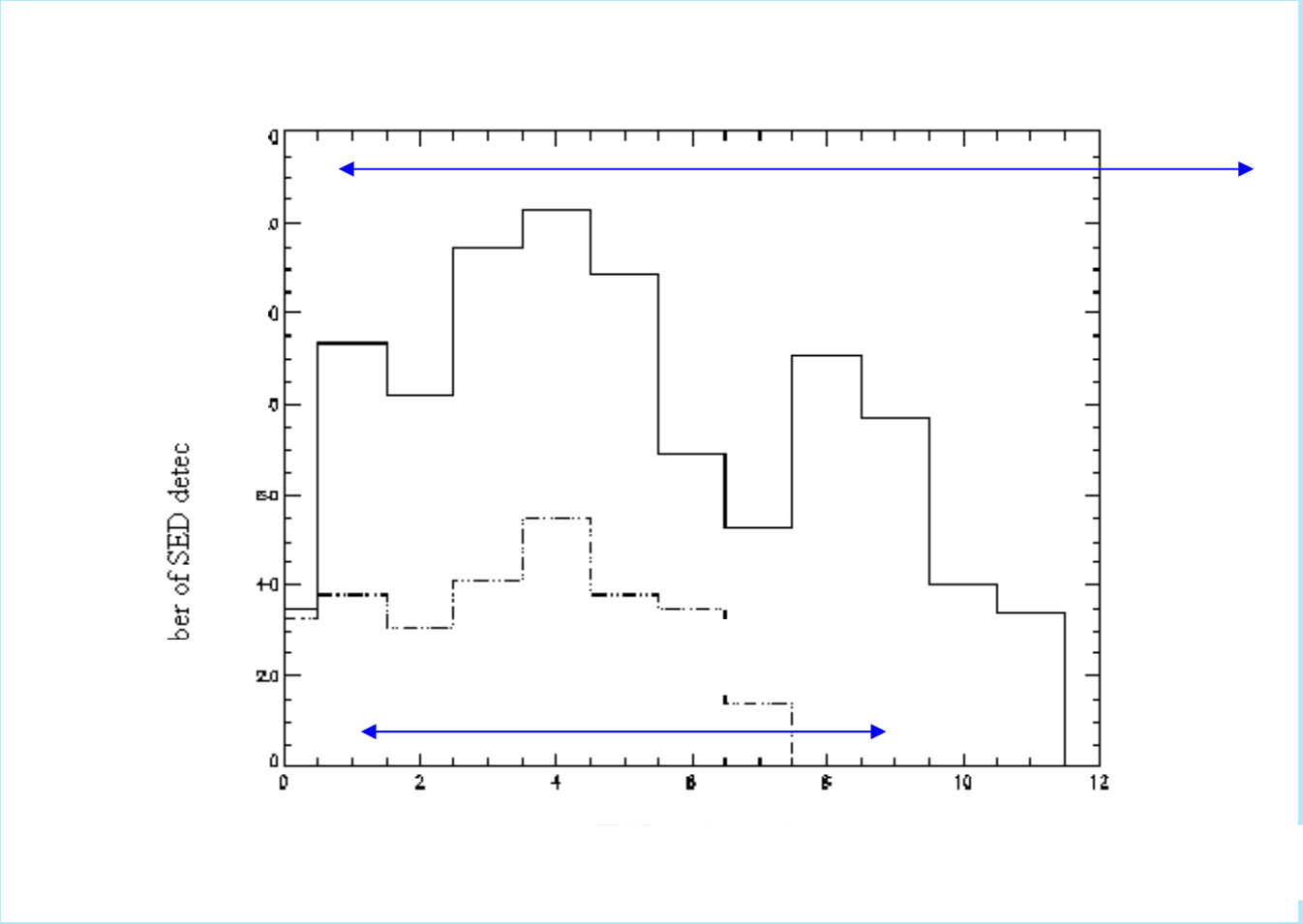
sensitivity:

≅ 1/10 with multichannel algorithm

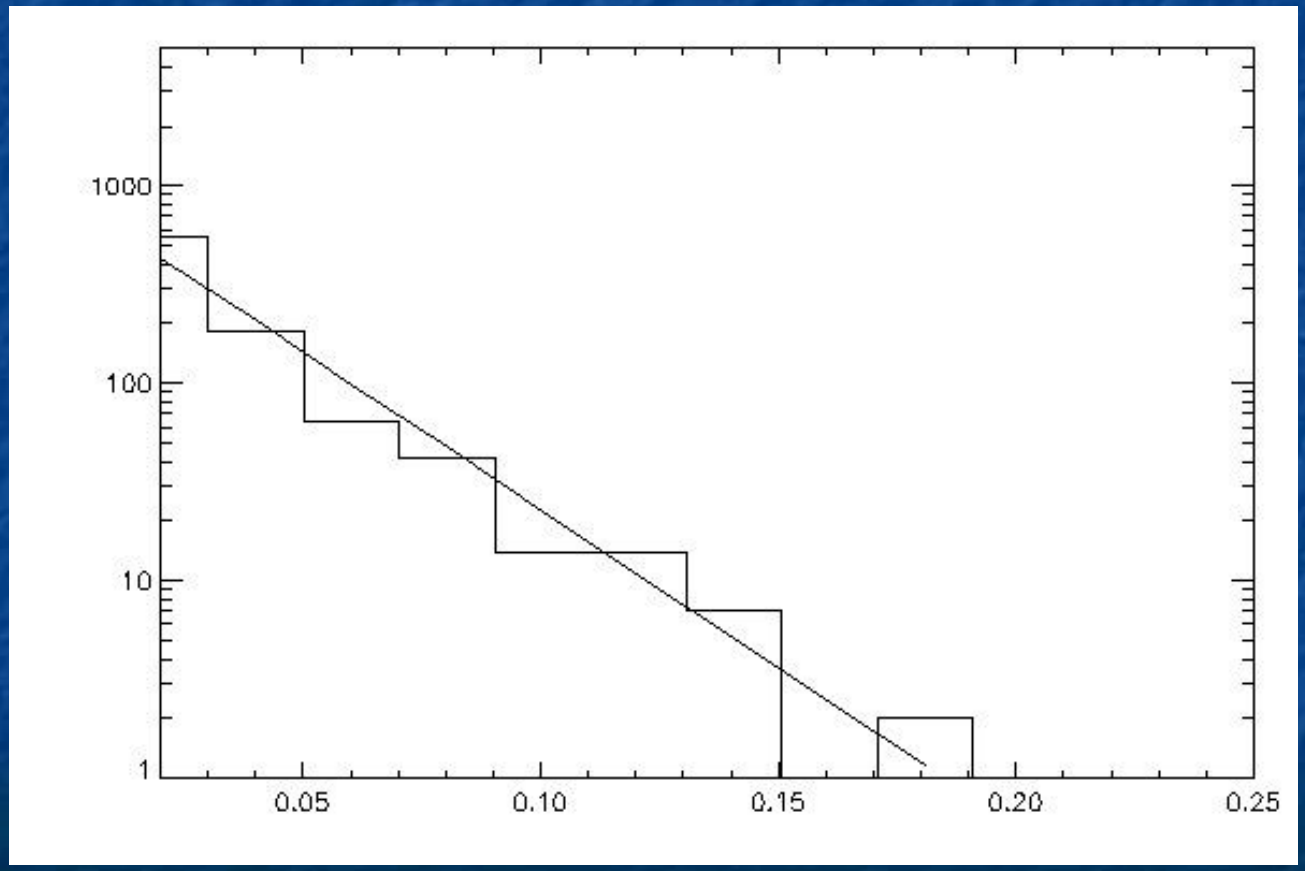
duty cycle RPWS in survey mode
3.56 s from 16 s ≅ 22%
(> 6 MHz)

severe limitation established by multichannel algorithm, direction for reliability

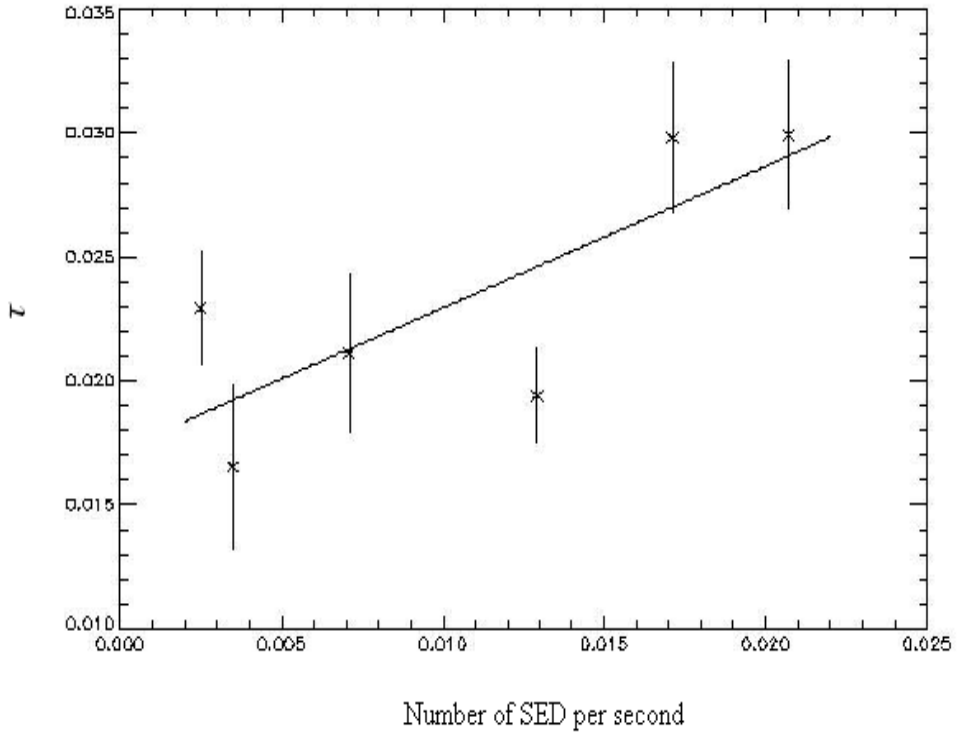
SED activity (A2)

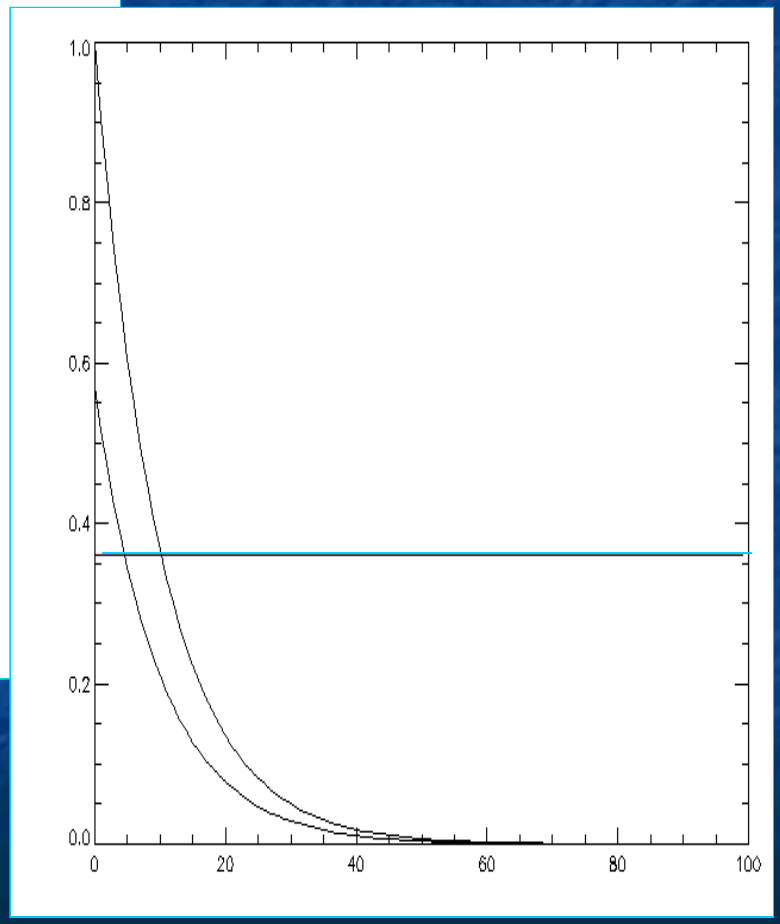


SED duration histogram for A1-A5 & A8 (total 953)
τ = 27,2 ms



τ vs storm activity (left panel). Model (right panel).





Conclusions

- Multichannel algorithm let us to detect SED with high level of reliability
- CCF, time differences and integral activity function show a high degree of coincidence with the Cassini data
- We can talk about the application of this method to detect lightning on other planets, which have not the artificial satellites.

Thank you
for attention

UTR-2: This is the world largest radio-telescope in the decameter frequency range (operated from about 8–32 MHz) located in Kharkov, Ukraine. It consists of 2040 dipoles and has an effective area of 150,000 m2 (Konovalenko et al. 2001). Its sensitivity of a few Jansky (Jy) enables it to detect lightning from Saturn that is expected to produce a flux of the order of 100 Jy at Earth (Zarka et al. 2004).