In Situ Observation of a Type II Solar Radio Burst Source Region

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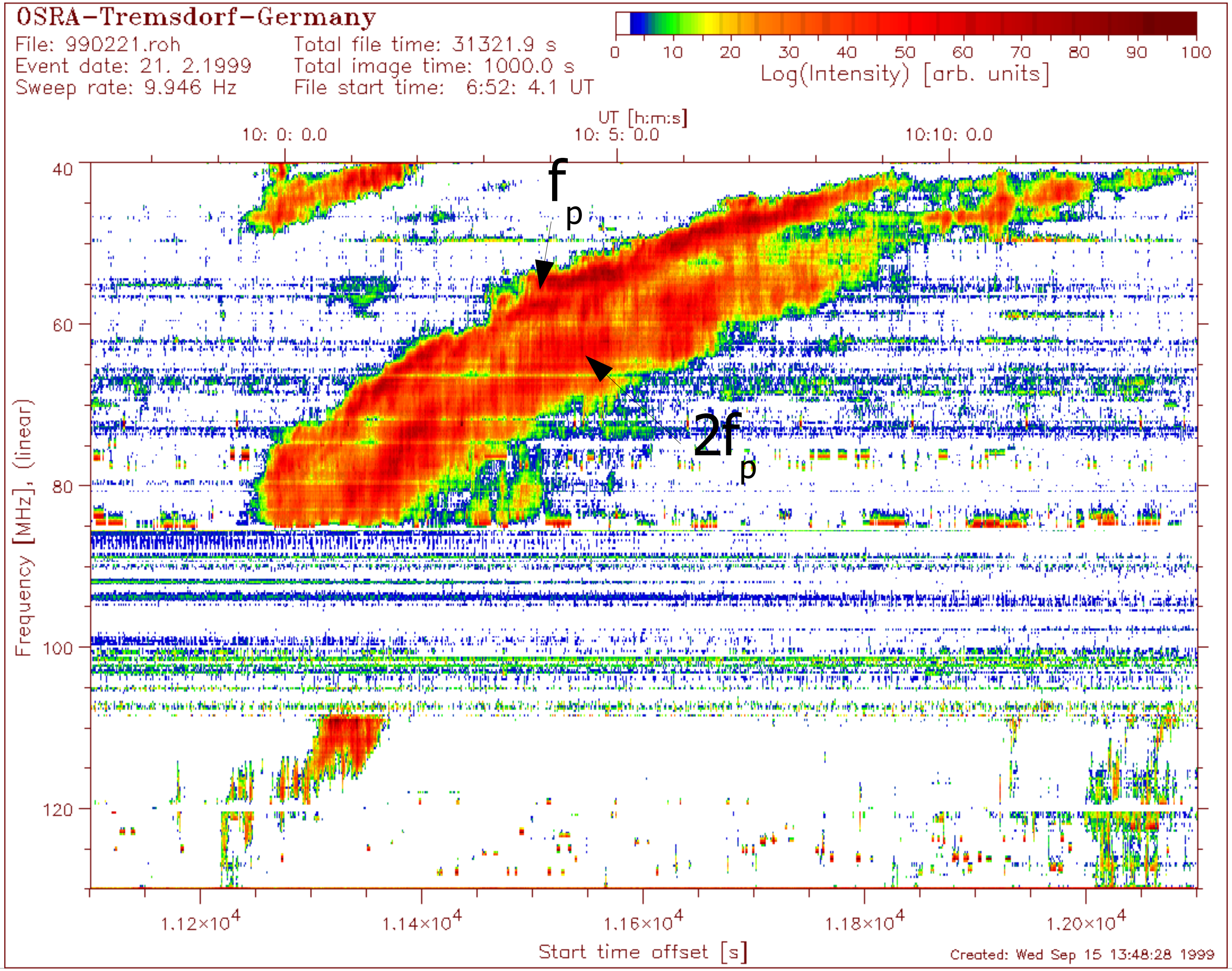
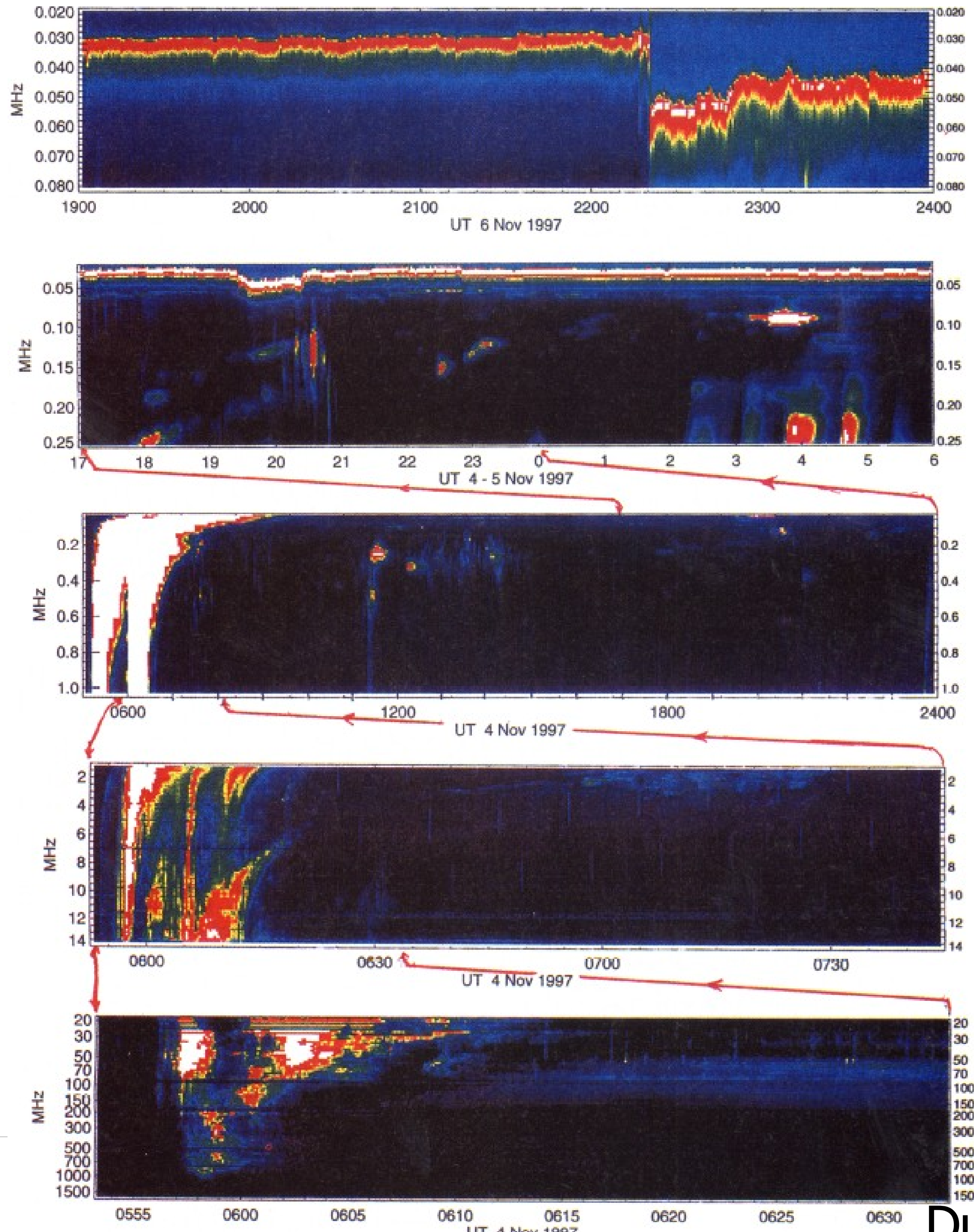
Outline

- Introduction to type-II solar radio bursts
- Cluster-WIND observation of a CME driven fast interplanetary shock

Type-II Radio burst



IRF



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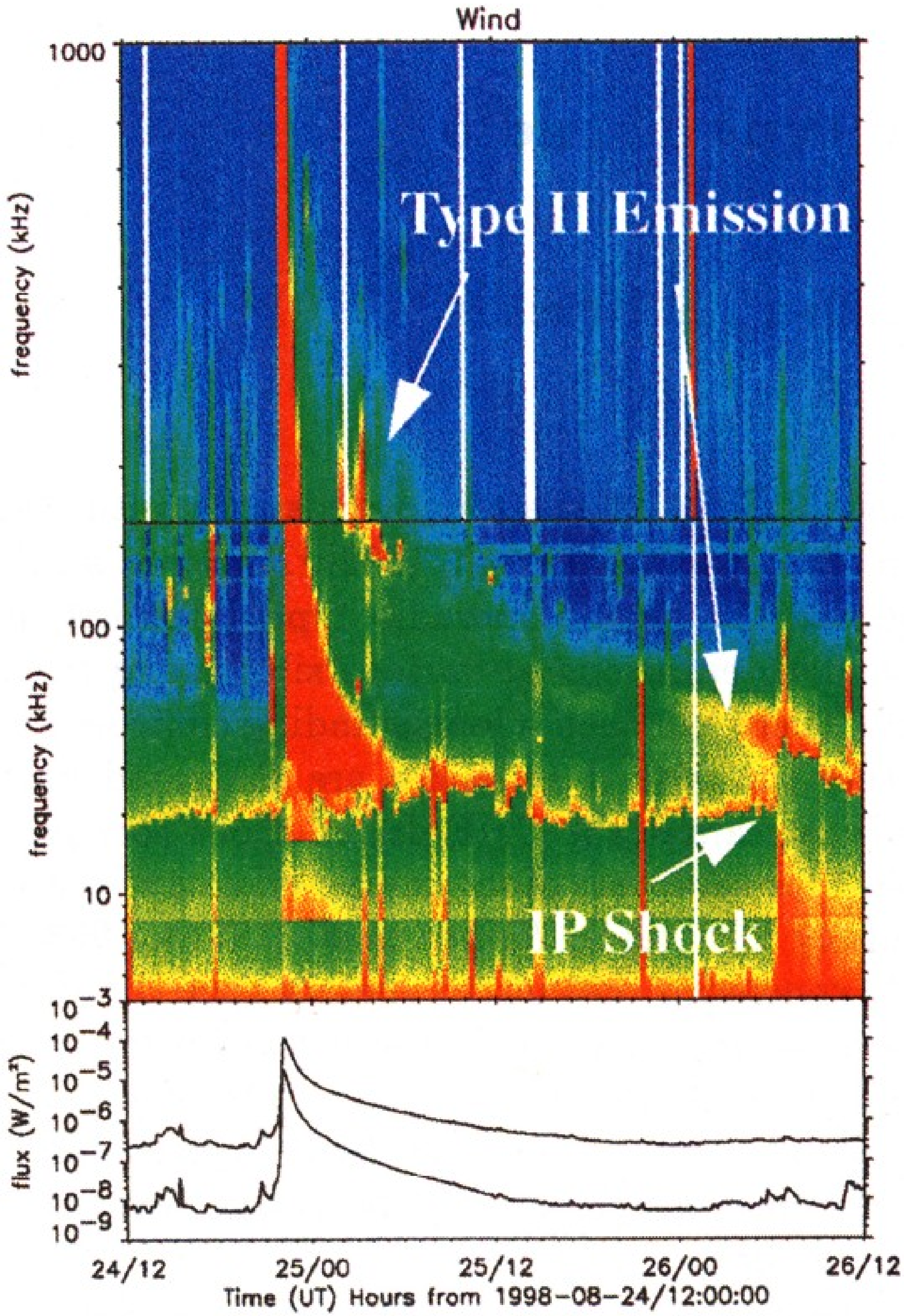
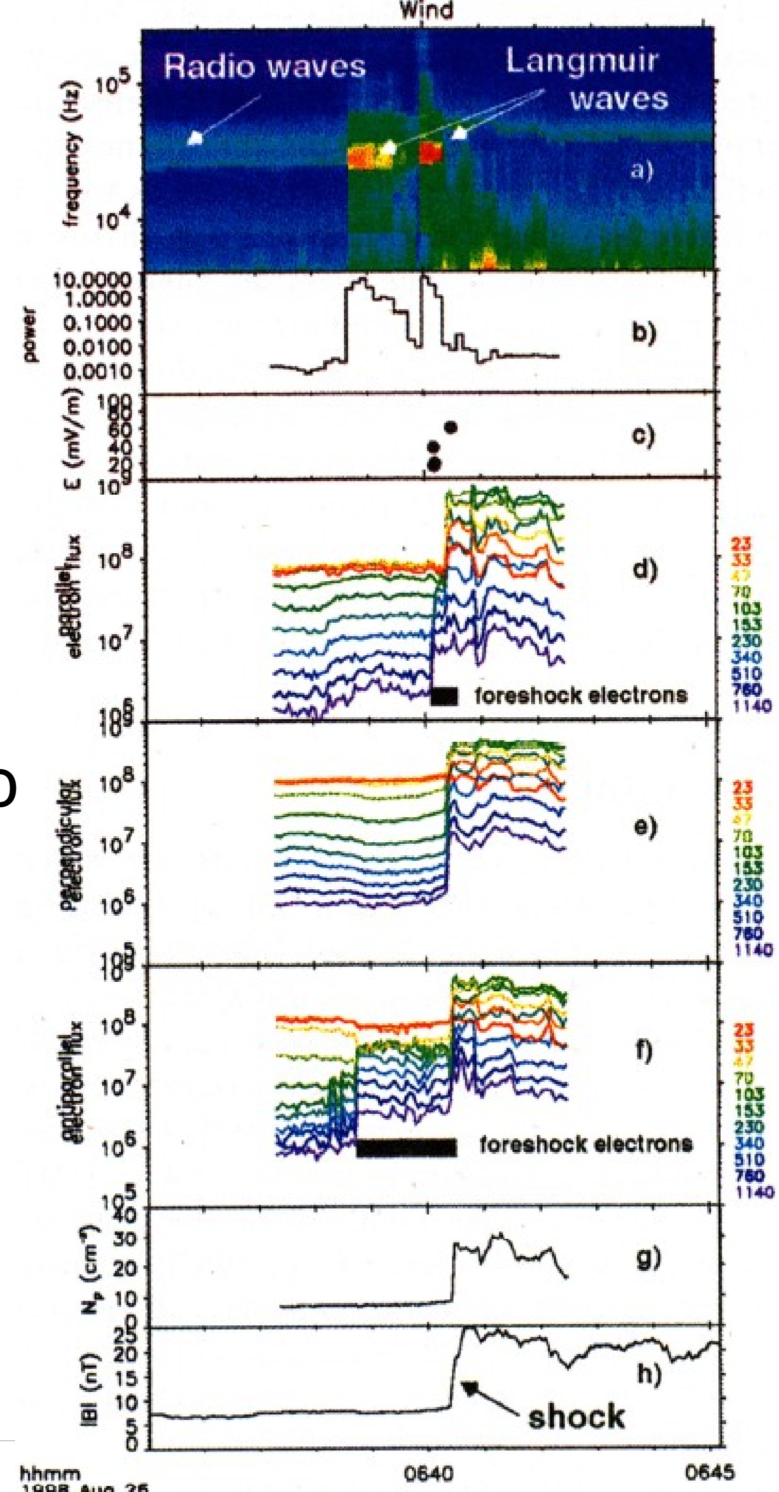
Dulk et. al. (1999)



Bale et. al. (1999)

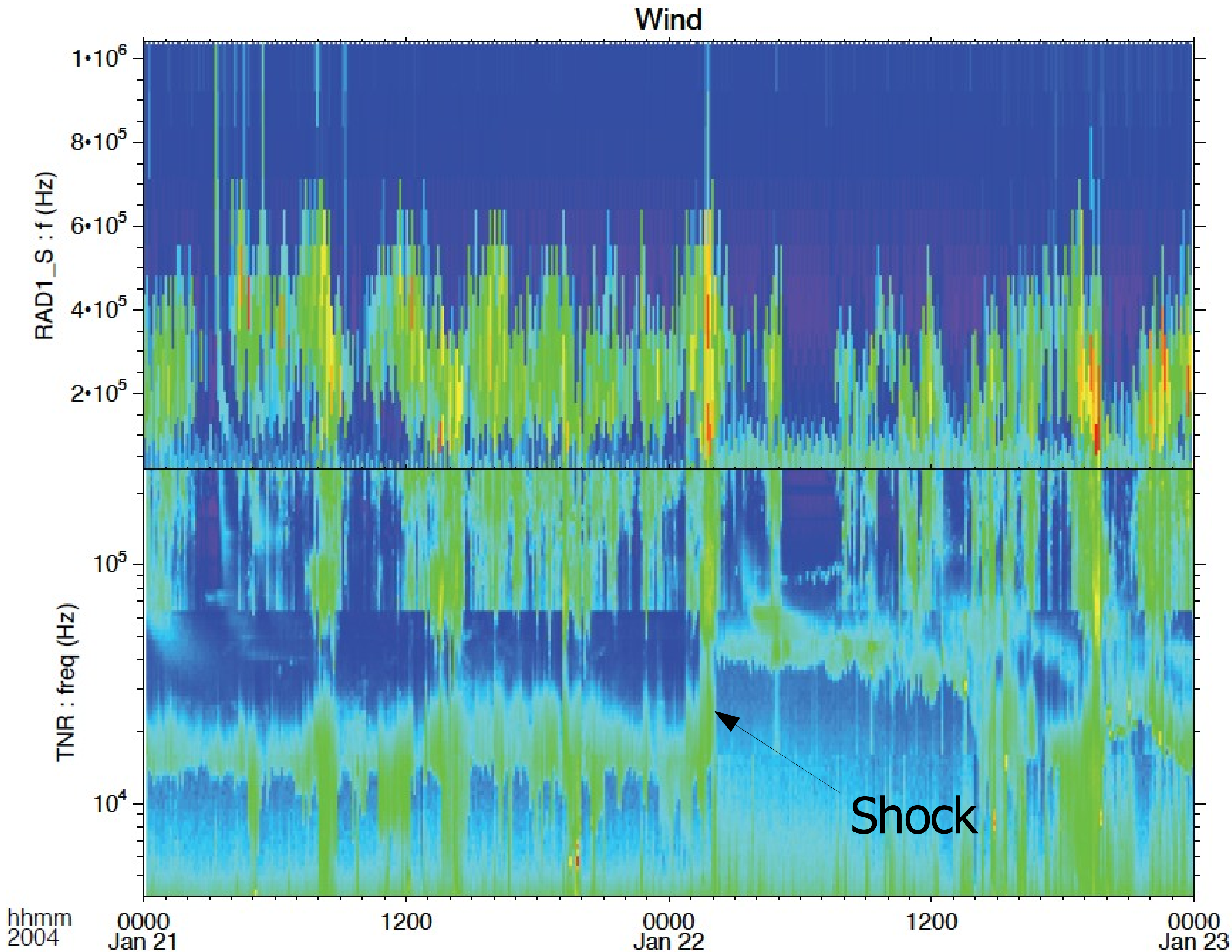
Generation mechanism

- Foreshock electrons generate Langmuir waves
- Langmuir waves convert into radio waves via:
  - $l+l=t$ (radiation at $2f_p$)
  - $l+s=t$ (radiation at $\sim f_p$)

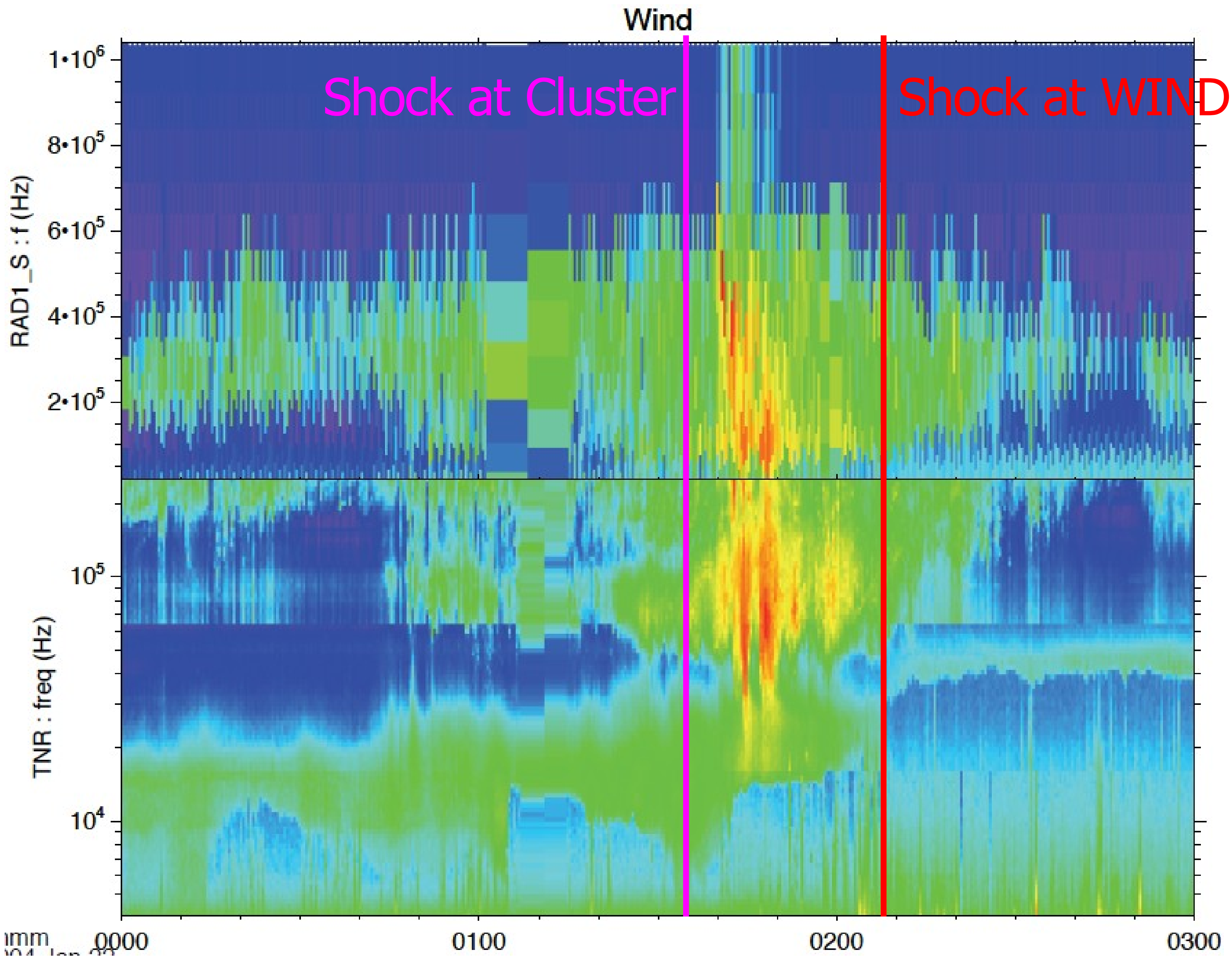


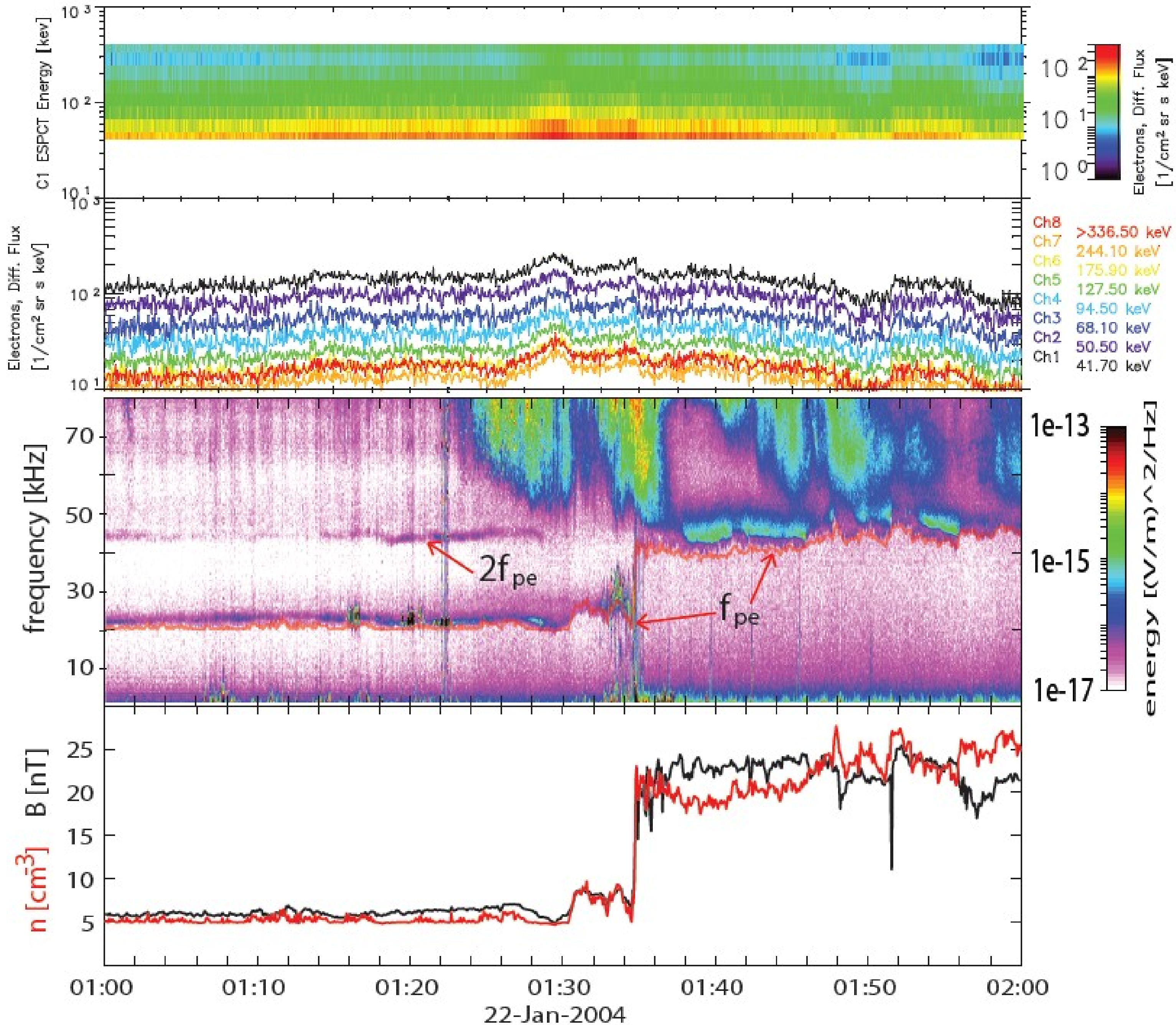
Bale et. al. (1999)

Cluster-WIND observation of a CME driven interplanetary shock



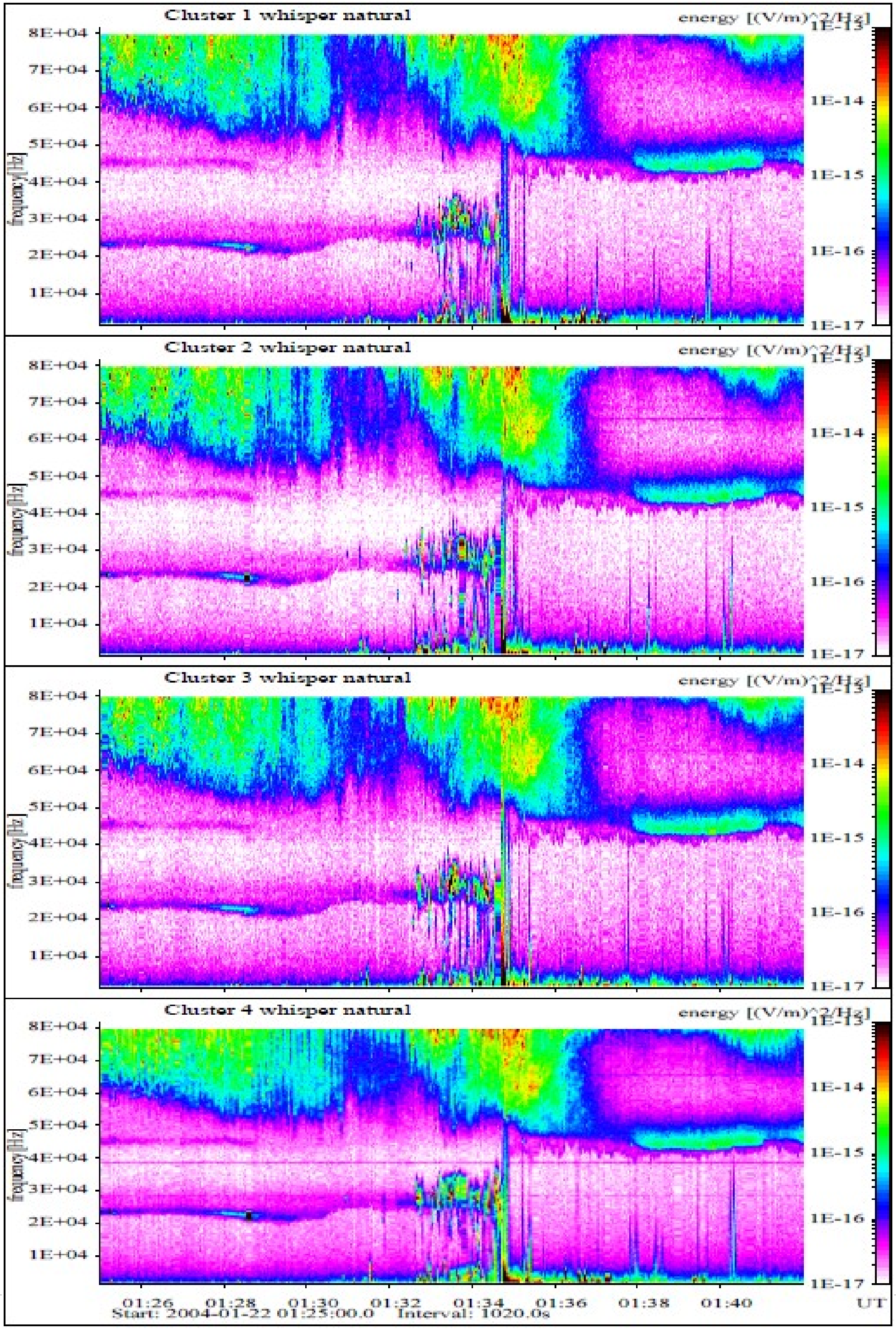
Wind
1•10^6
8•10^5
6•10^5
4•10^5
2•10^5
RAD1_S : f (Hz)
10^5
10^4
TNR : freq (Hz)
Shock
hhmm
2004
0000
Jan 21
1200
0000
Jan 22
1200
0000
Jan 23

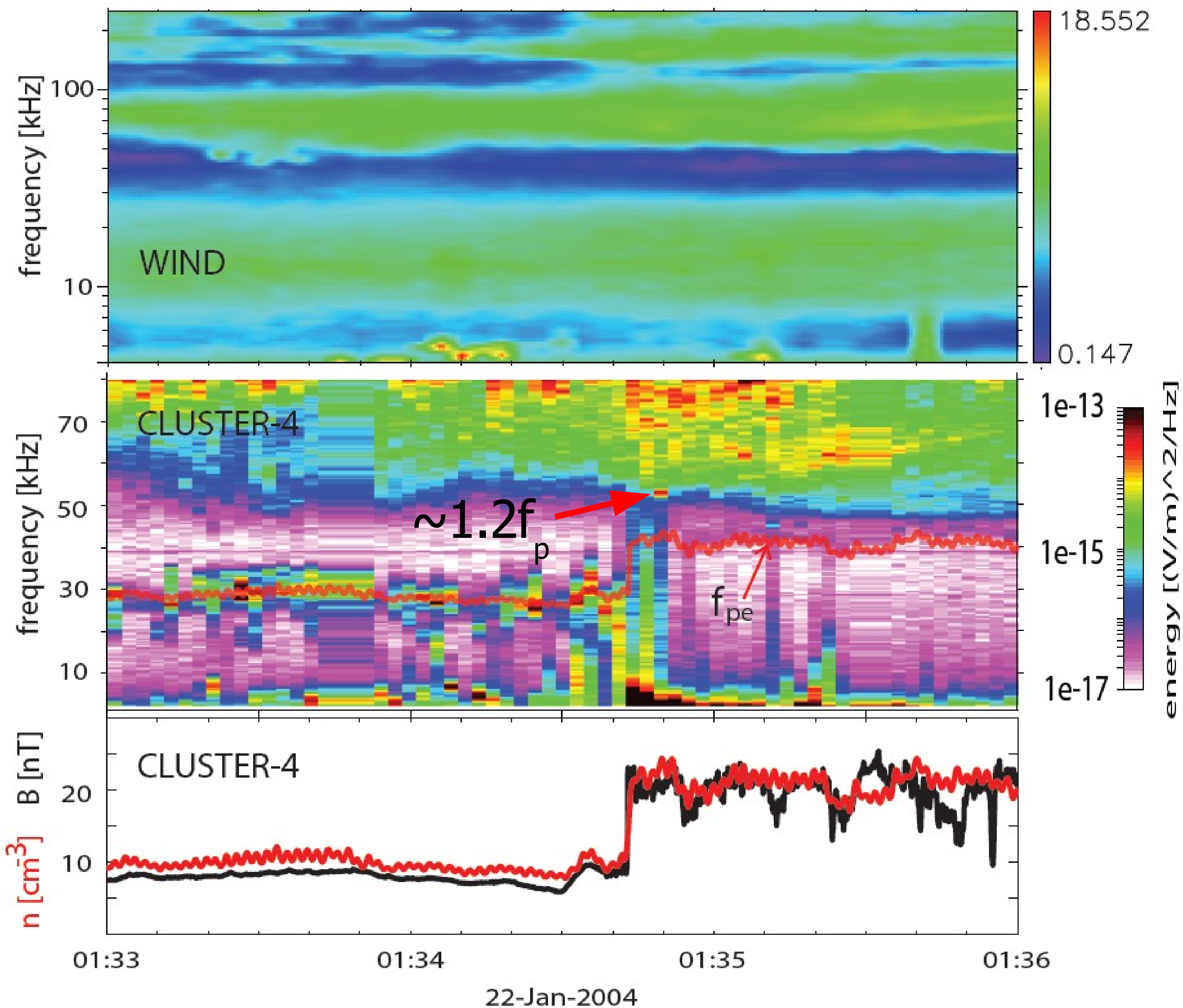

Wind
Shock at Cluster
Shock at WIND
RAD1_S : f (Hz)
1•10^6
8•10^5
6•10^5
4•10^5
2•10^5
TNR : freq (Hz)
10^5
10^4
0000
0100
0200
0300


C1 ESPCT Energy [kev]
Electrons, Diff. Flux [1/cm² sr s keV]
Ch8 >336.50 keV
Ch7 244.10 keV
Ch6 175.90 keV
Ch5 127.50 keV
Ch4 94.50 keV
Ch3 68.10 keV
Ch2 50.50 keV
Ch1 41.70 keV
frequency [kHz]
2fpe
fpe
energy [(V/m)^2/Hz]
n [cm-3] B [nT]
01:00
01:10
01:20
01:30
01:40
01:50
02:00
22-Jan-2004

Shock characteristics

- V_n = 740 *[0.9 -0.3 0.3] km/s GSE
- quasi-perpendicular θ_{BN}=80 degrees and
- supercritical, Alfvén Mach number 5.6
- $B_{down}/B_{up} \approx n_{down}/n_{up} \approx 3.8$
- The shock ramp scale is ~0.2 sec, ~150 km

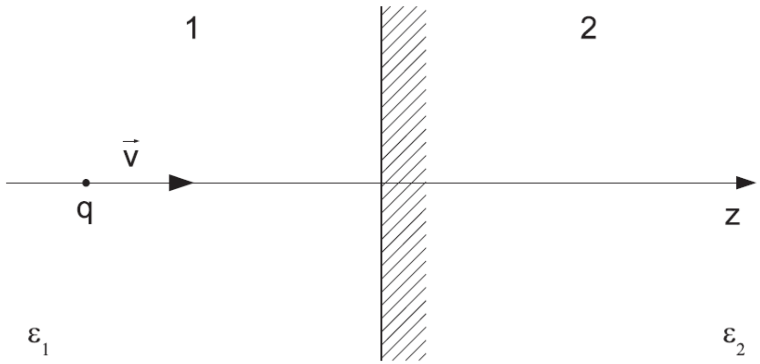

Cluster 1 whisper natural
Cluster 2 whisper natural
Cluster 3 whisper natural
Cluster 4 whisper natural
energy [(V/m)^2/Hz]
frequency [Hz]
8E+04
7E+04
6E+04
5E+04
4E+04
3E+04
2E+04
1E+04
1E-13
1E-14
1E-15
1E-16
1E-17
01:26 01:28 01:30 01:32 01:34 01:36 01:38 01:40 UT
Start: 2004-01-22 01:25:00.0 Interval: 1020.0s



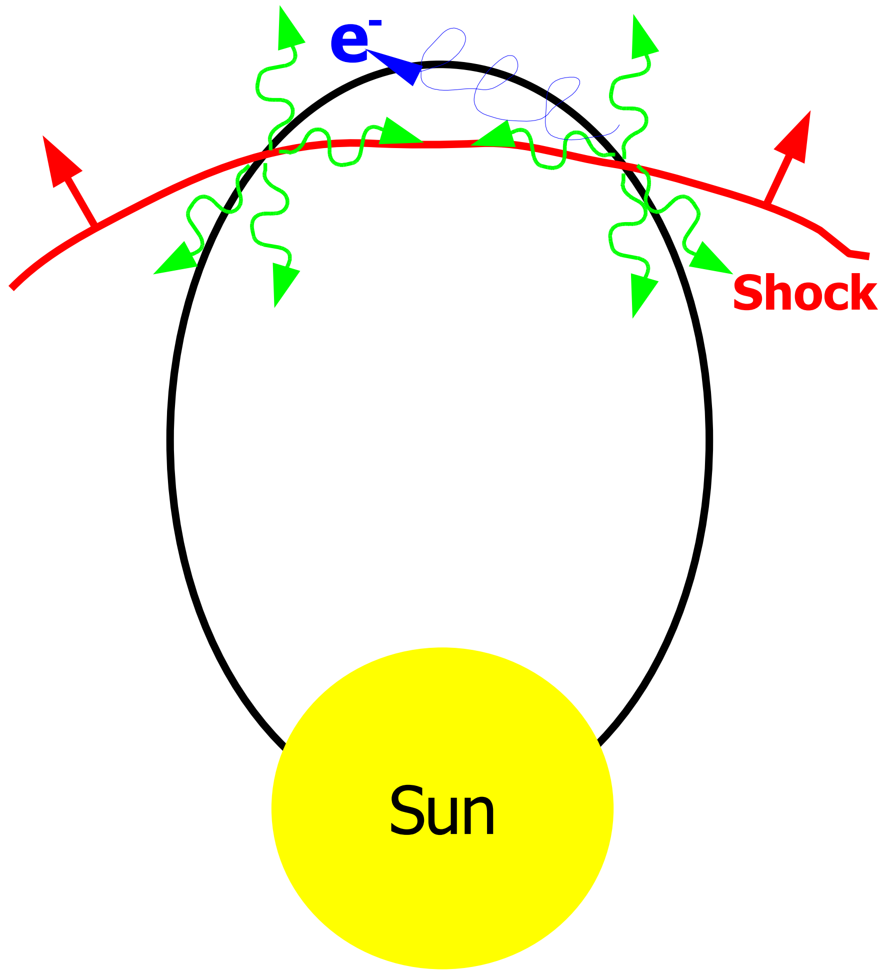
WIND
frequency [kHz]
100
10
18.552
0.147
CLUSTER-4
frequency [kHz]
70
50
30
10
~1.2f p
f pe
1e-13
1e-15
1e-17
energy [(V/m)^2/Hz]
CLUSTER-4
B [nT]
n [cm-3]
20
10
01:33
01:34
01:35
01:36
22-Jan-2004

Transition radiation

- Energetic electrons cross density irregularities and generate radio waves
- $f \sim 1.2\text{-}1.3\, f_p$ for 500 keV electrons
- Radiation mechanism require small scale (~tens of km) density irregularities



Schematic



Conclusions

- We observe type-II source region located in the at the ramp of a fast interplanetary shock
- Observations cannot be explained by the conventional model
- The transition radiation can be an important physical mechanism for generation of radio waves at shock fronts and it must be considered in addition to other mechanisms
- More detailed theory needs to be developed