Radboud Universiteit Nijmegen

Identifying Real Fast Radio Transients using TBBs

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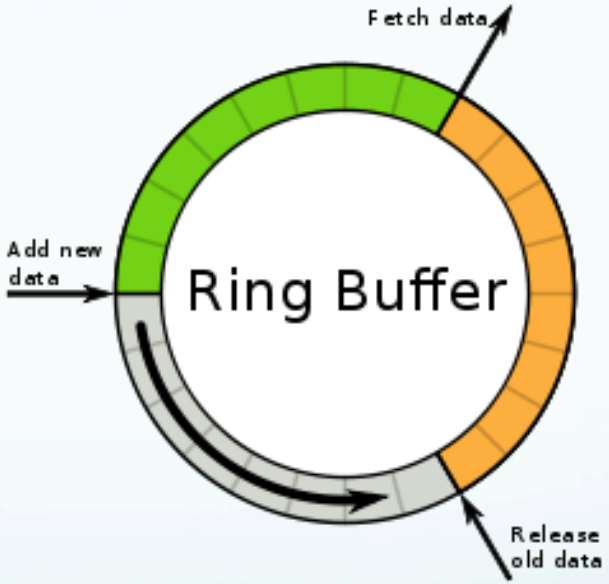
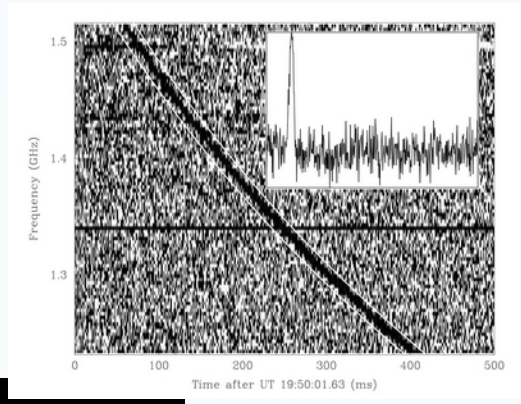
Transient KSP, CR KSP

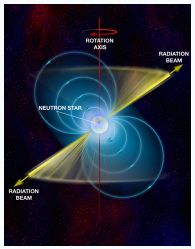
- Transient Buffer Boards (TBBs)
  - Parallel System in LOFAR
  - Ring buffer of raw data from each antenna
  - Look back in time (5sec)
  - Offline processing

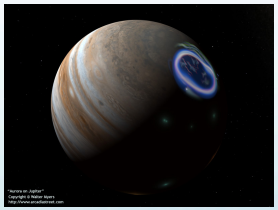


FRATs : Fast Radio Transients

- Millisecond radio pulses possibly originating from:
  - Lorimer Bursts (FRBs)
    - one time extragalactic burst
  - Pulsars and RRATS
  - Flaring stars
  - Lightning from Saturn
  - Jupiter aurora radio emission
  - Exoplanets?
  - ETI ??







FRATs: main idea

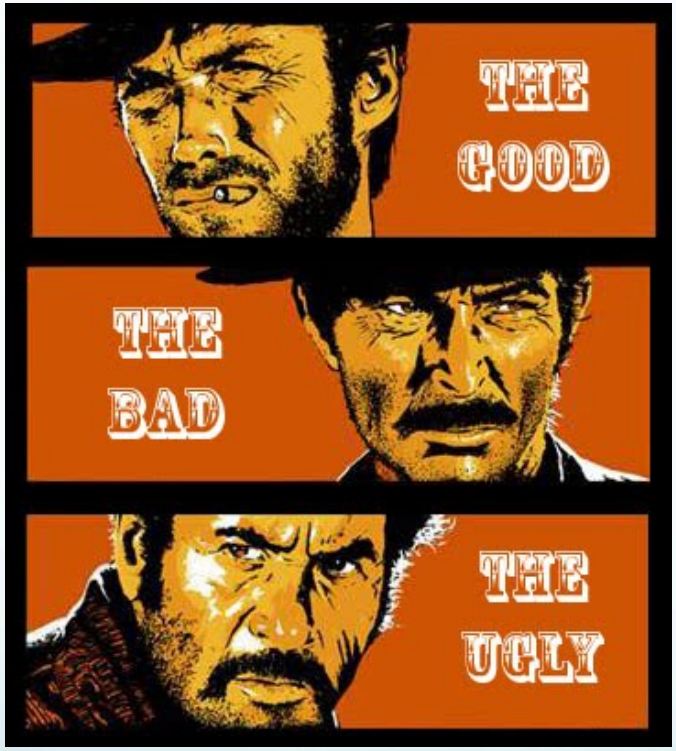
- In parallel to other LOFAR observations
- Use incoherent beam for large sky coverage
- Search it for millisecond pulses
- Use the TBB data to confirm the astrophysical origin

FRATs : Fast Radio Transients

- Past and present:
  - FRATs Trigger Code by parallel observations during LOTAAS (Cycle 0 & 1), MSSS (tests before Cycle 0), and RSM (cycle 1).
  - During Cycle 1 (LC1_053) we are expanding to other regular observations (beamform and imaging)
  - Maximize the observing time to increase

- Future?:
  - LOFAR related : ARTEMIS, AARTFAAC,
  - Multiwavelength: SWIFT/BAT, Fermi, Gaia, Effelsberg, Arecibo, Apertif/ARTS, ...

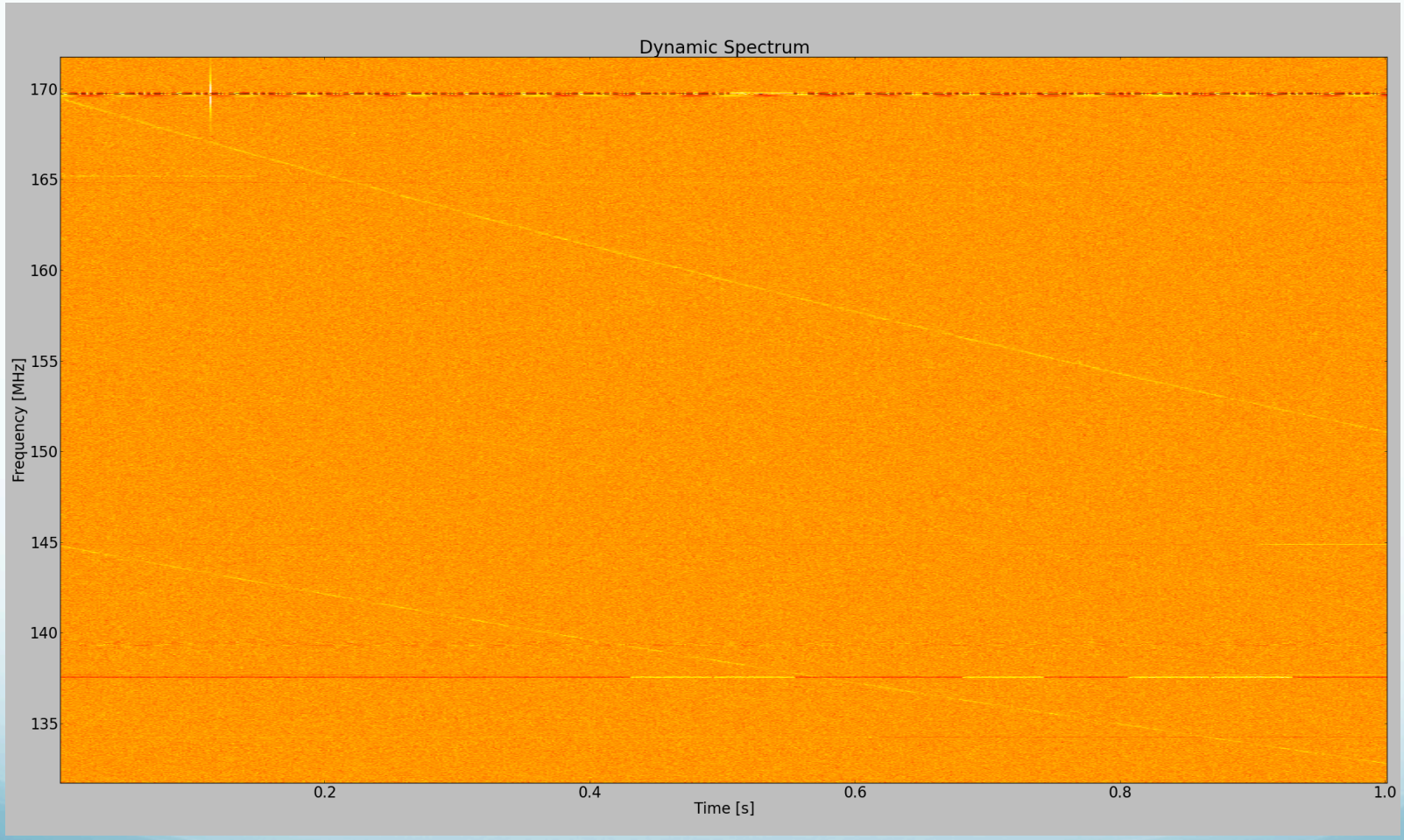
Initial Classification



- Good FRATS
  - Astrophysical source easy to identify
- Bad FRATS
  - Not an astrophysical source or impossible to identify
- Ugly FRATS
  - Astrophysical source but harder to identify

Good FRATS

easy to identify



Dispersion Measure (DM)

- Dispersive nature of interstellar plasma: radio wave interaction with free electrons makes for slower group velocities for lower frequencies.
- Time delay is calculated by:

$$\Delta t = k_{\rm DM} \times {\rm DM} \times \left(\frac{1}{\nu_{\rm lo}^2} - \frac{1}{\nu_{\rm hi}^2} \right)$$

$$k_{\rm DM} = \frac{e^2}{2\pi m_e c} \simeq 4.149 {\rm GHz}^2 {\rm pc}^{-1} {\rm cm}^3 {\rm ms}$$

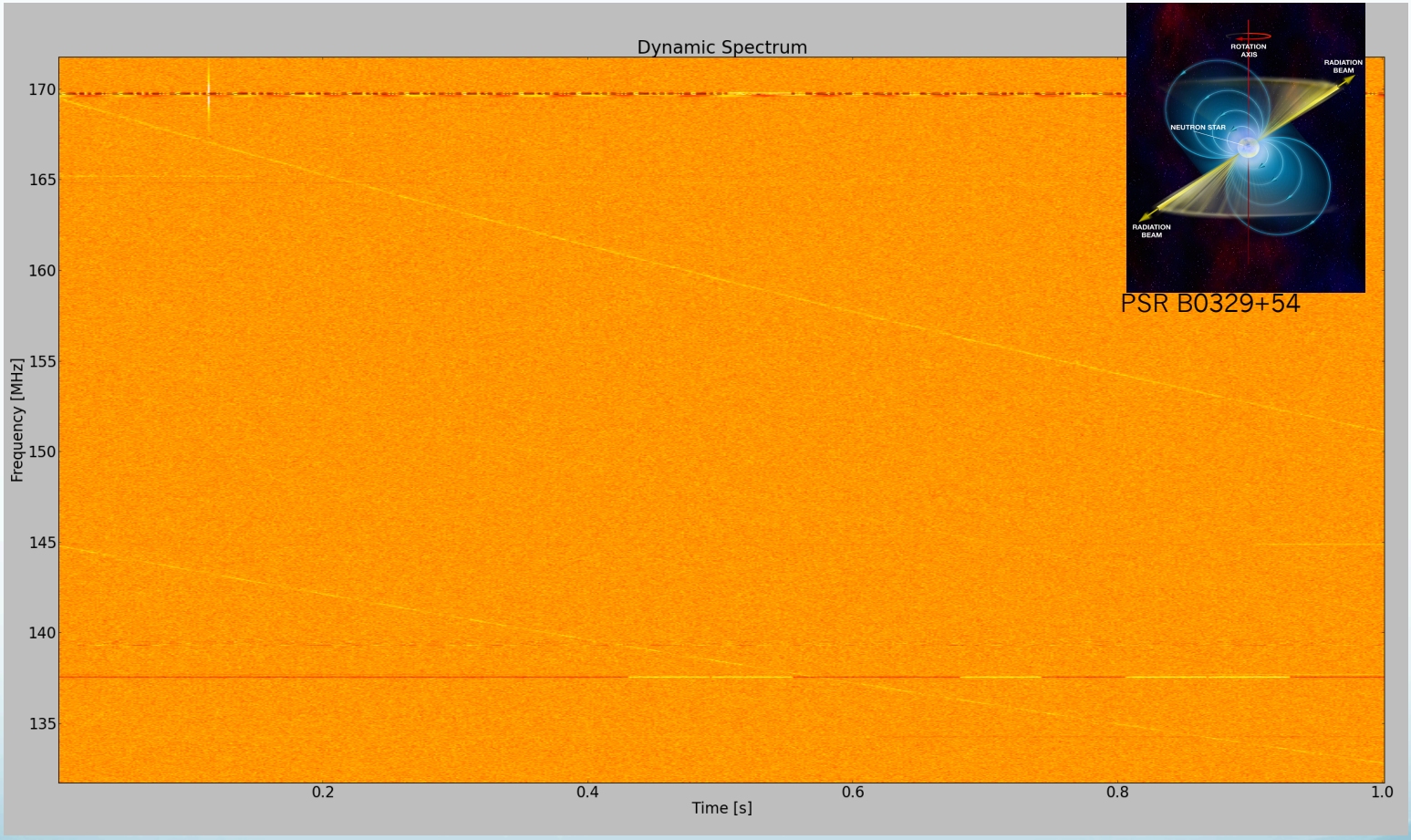
- DM Total column density of free electrons,

$$\mathrm{DM} = \int_0^D n_e(s) ds,$$

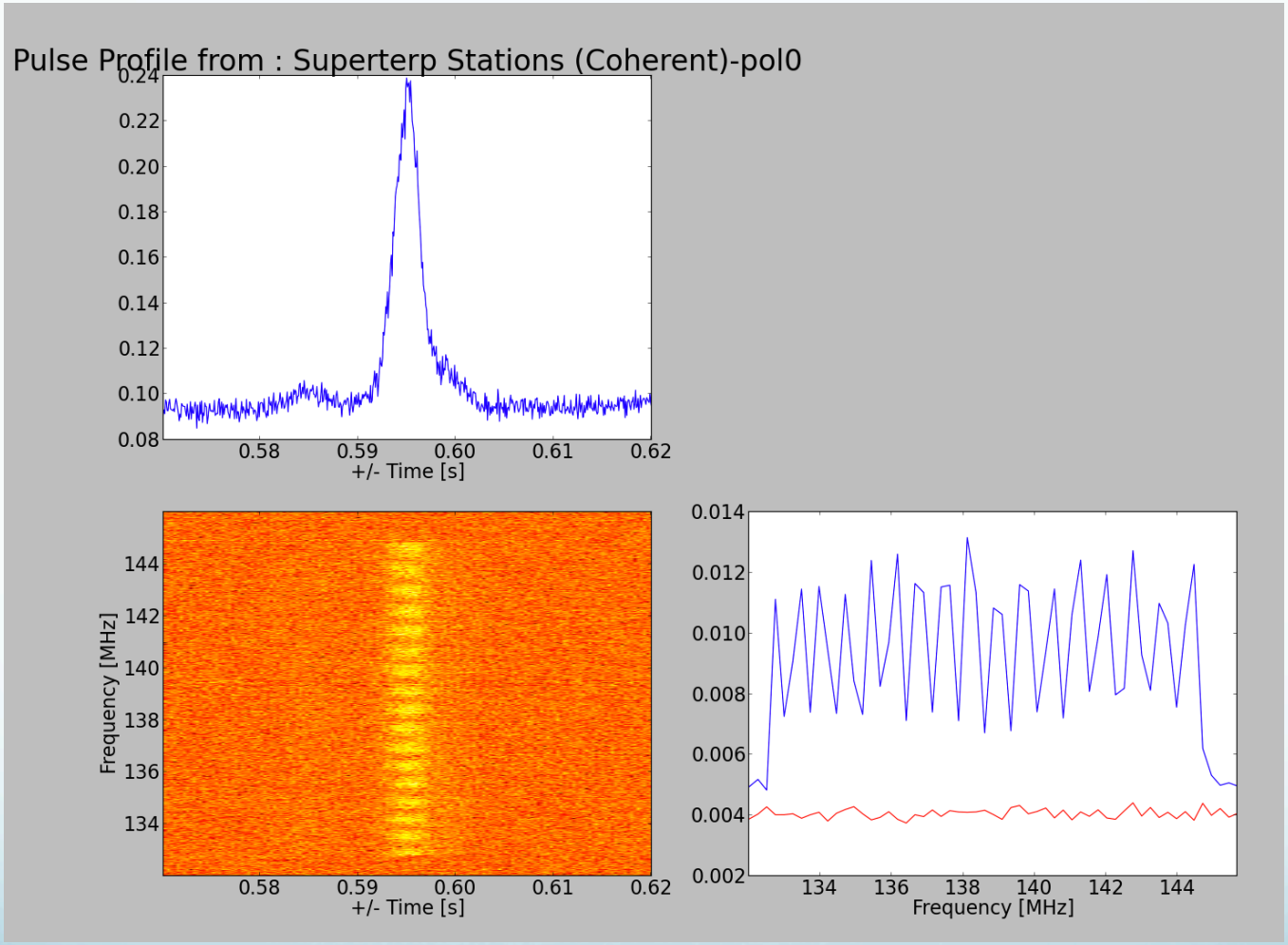
or a distance estimate with n_e models of the ISM.

Good FRATS

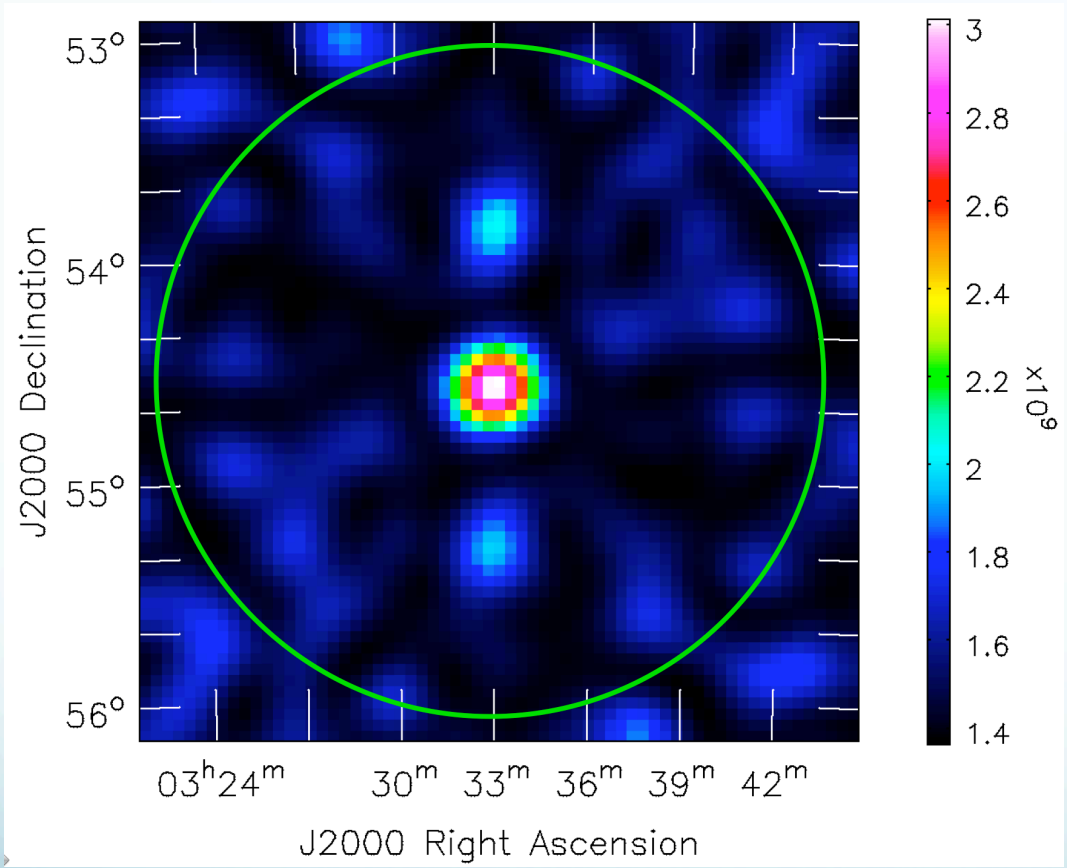

THE
GOOD


Dynamic Spectrum
Frequency [MHz]
170
165
160
155
150
145
140
135
0.2
0.4
0.6
0.8
1.0
Time [s]
ROTATION AXIS
RADIATION BEAM
NEUTRON STAR
RADIATION BEAM
PSR B0329+54

Profile characterization



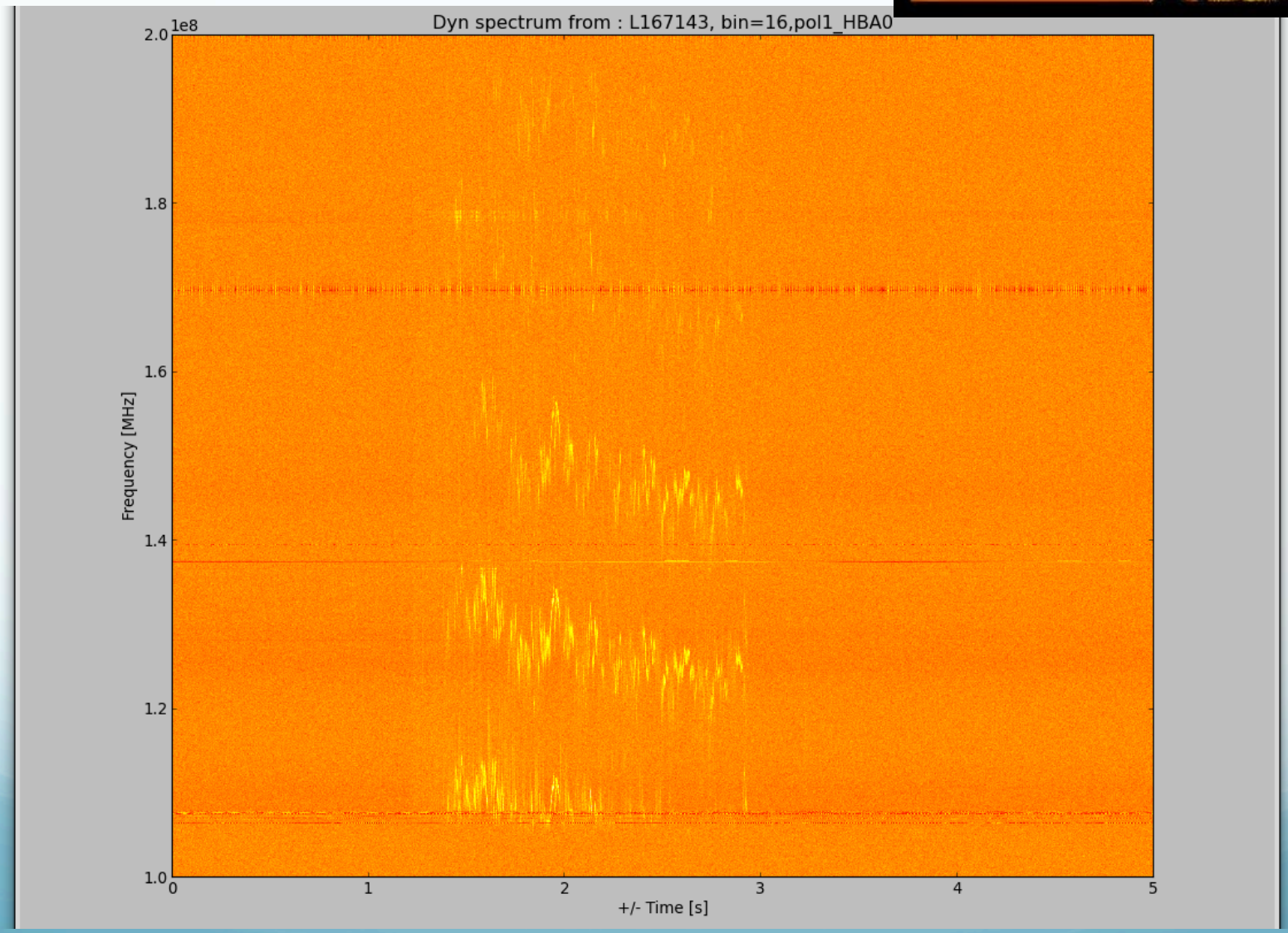
Imaging



- Multi-station beamform imager
- Better angular resolution
- Dedispersed
- Frequency or time integration

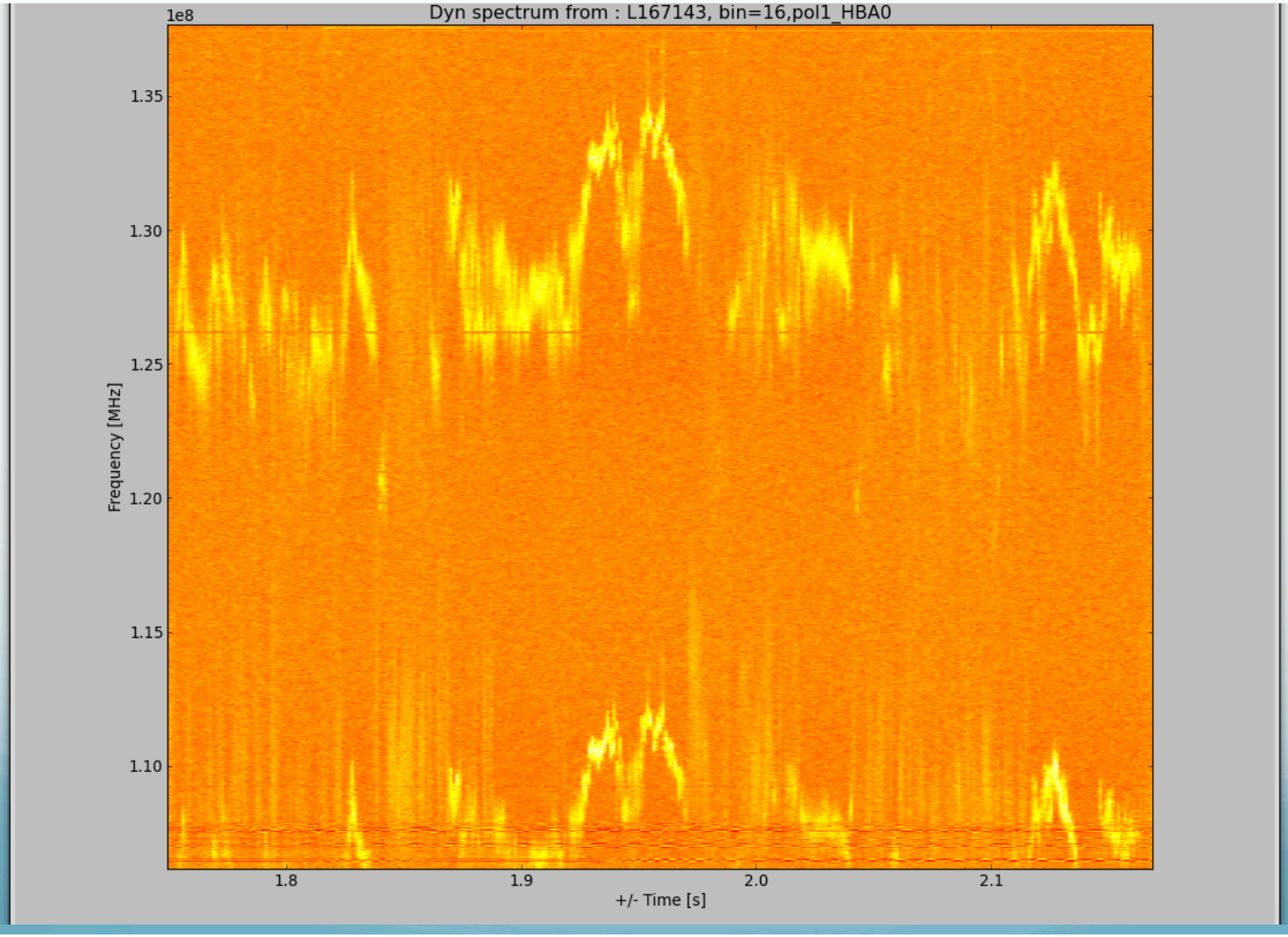
Bad FRATS


THE
BAD


Dyn spectrum from : L167143, bin=16,pol1_HBA0
1e8
2.0
1.8
1.6
1.4
1.2
1.0
Frequency [MHz]
0
1
2
3
4
5
+/- Time [s]

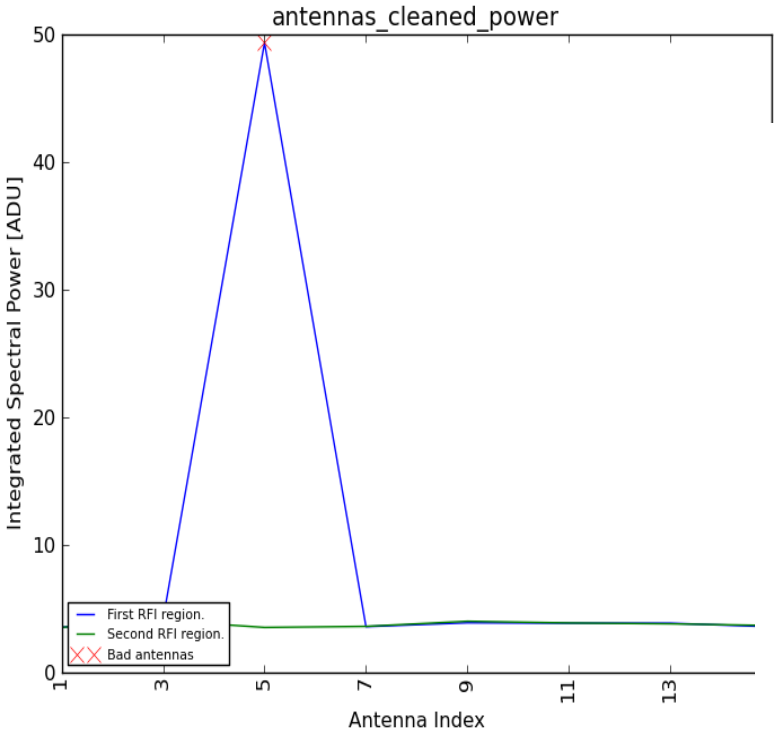
Bad FRATS

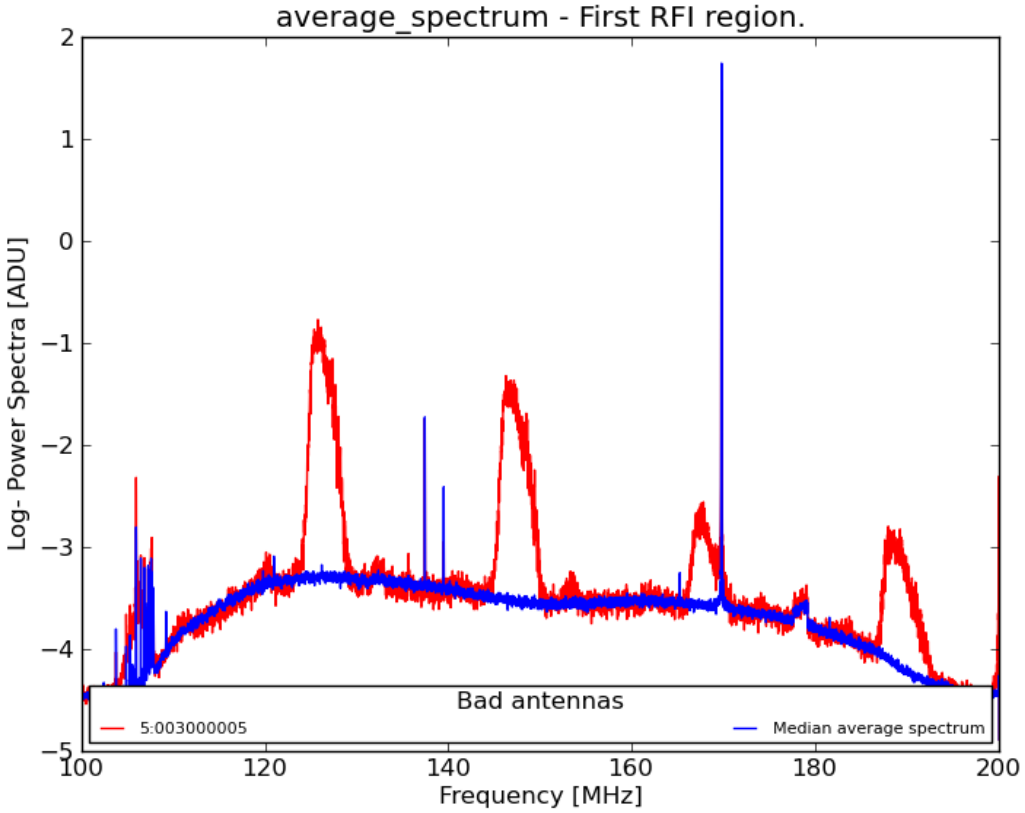

THE
BAD


Dyn spectrum from : L167143, bin=16,pol1_HBA0
1e8
1.35
1.30
1.25
1.20
1.15
1.10
Frequency [MHz]
1.8
1.9
2.0
2.1
+/- Time [s]

Bad FRATS

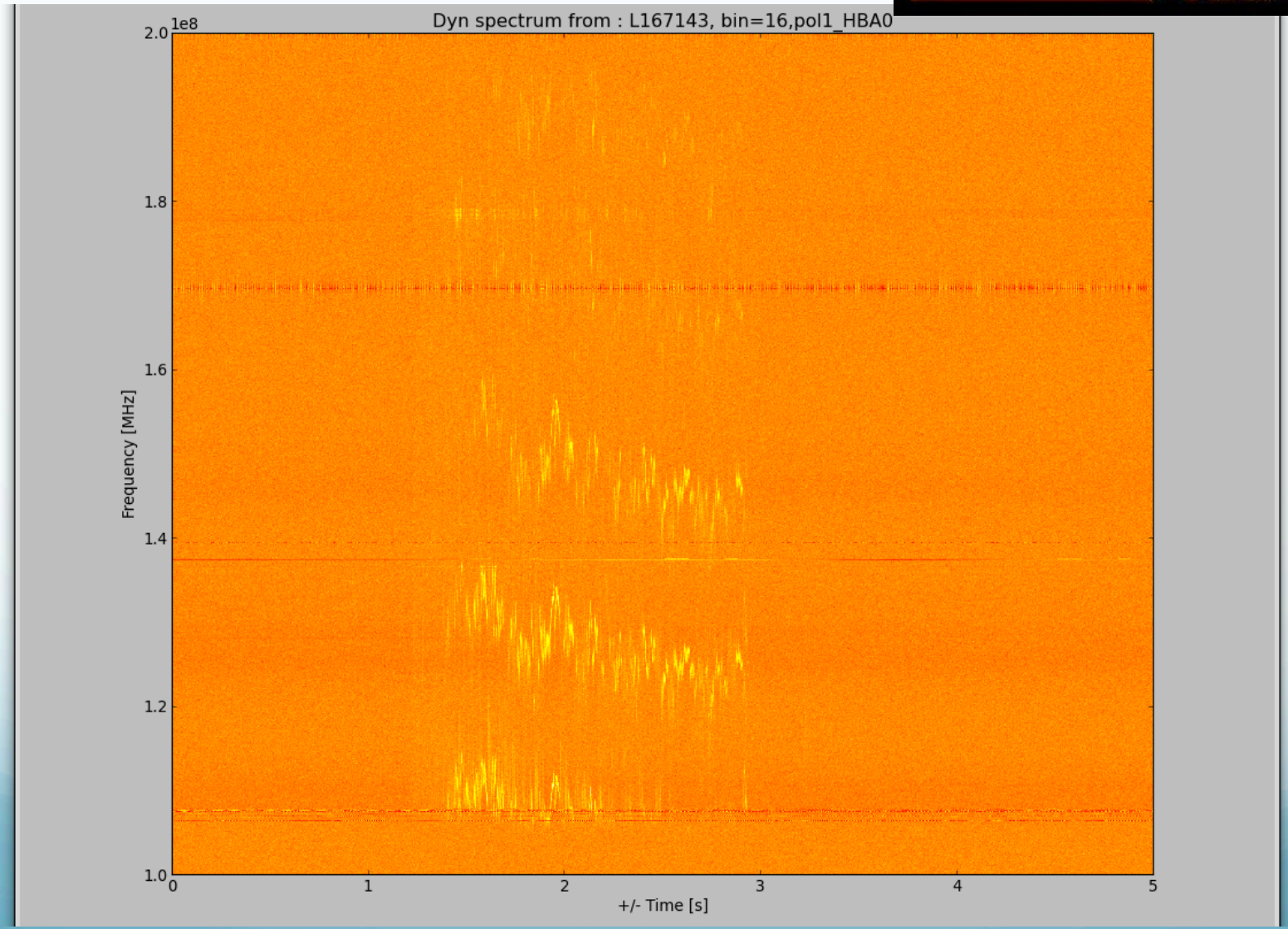

THE
BAD


antennas_cleaned_power
Integrated Spectral Power [ADU]
Antenna Index
First RFI region.
Second RFI region.
Bad antennas


average_spectrum - First RFI region.
Log- Power Spectra [ADU]
Frequency [MHz]
Bad antennas
5:003000005
Median average spectrum

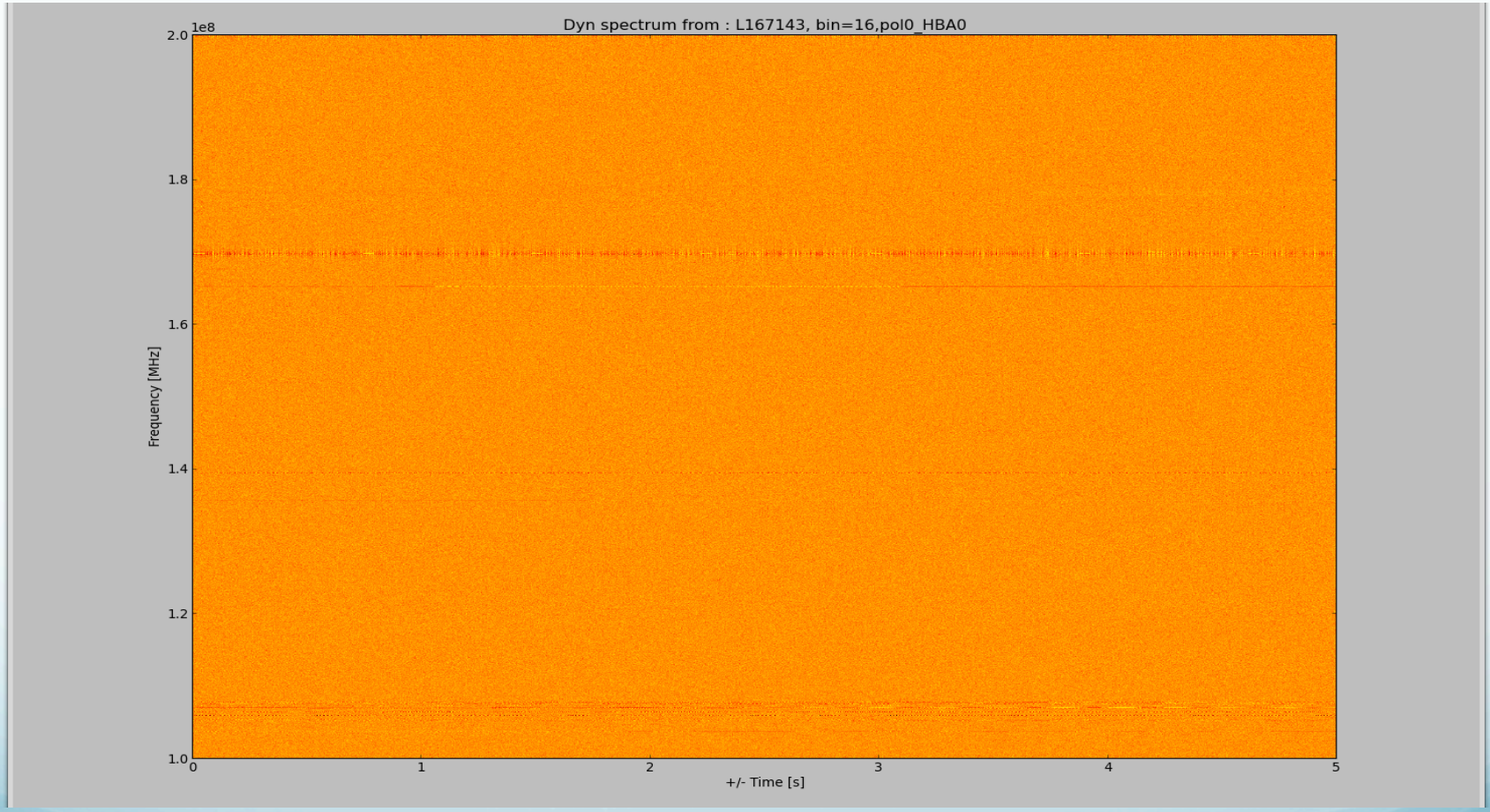
Bad FRATS


THE
BAD

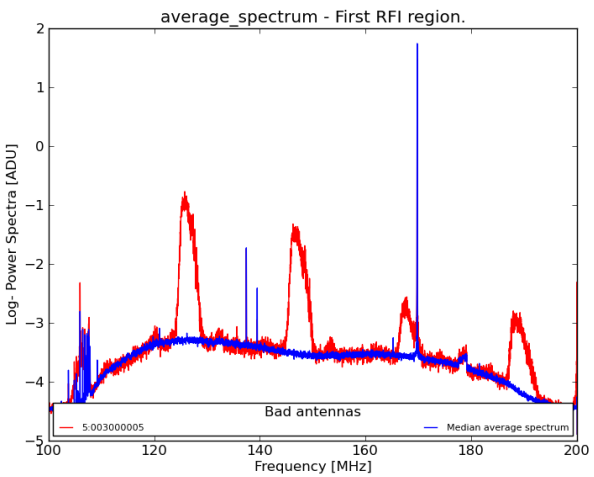

Dyn spectrum from : L167143, bin=16,pol1_HBA0
1e8
2.0
1.8
1.6
1.4
1.2
1.0
Frequency [MHz]
0
1
2
3
4
5
+/- Time [s]

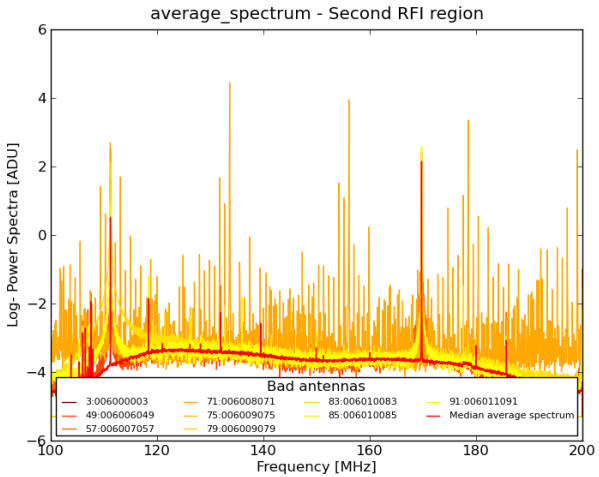
Bad FRATS

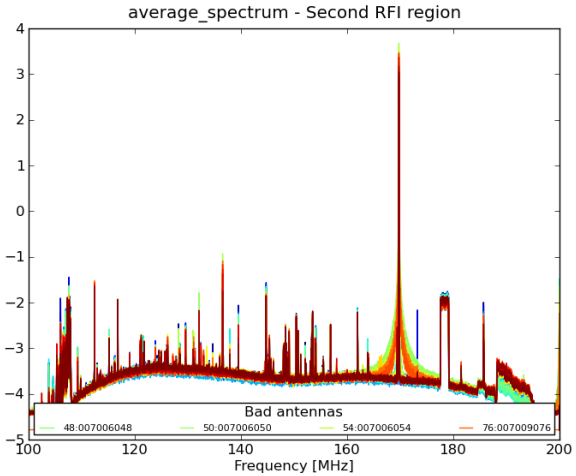

THE
BAD


Dyn spectrum from : L167143, bin=16,pol0_HBA0
1e8
2.0
1.8
1.6
1.4
1.2
1.0
Frequency [MHz]
0
1
2
3
4
5
+/- Time [s]

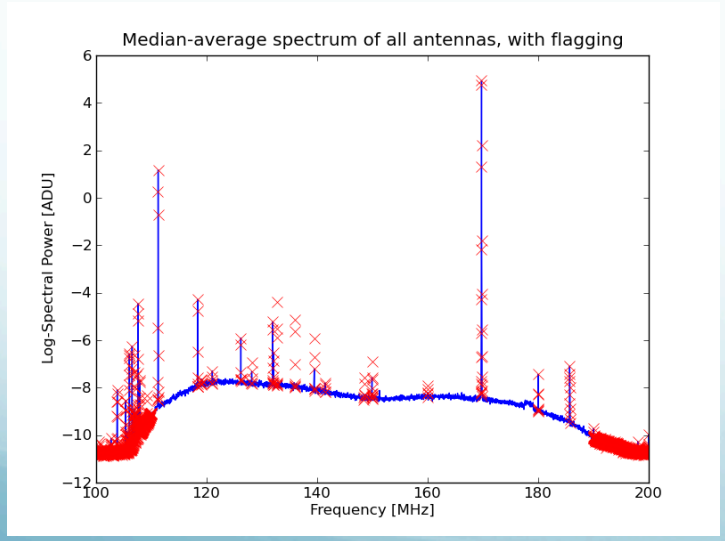
Bad antenna identification

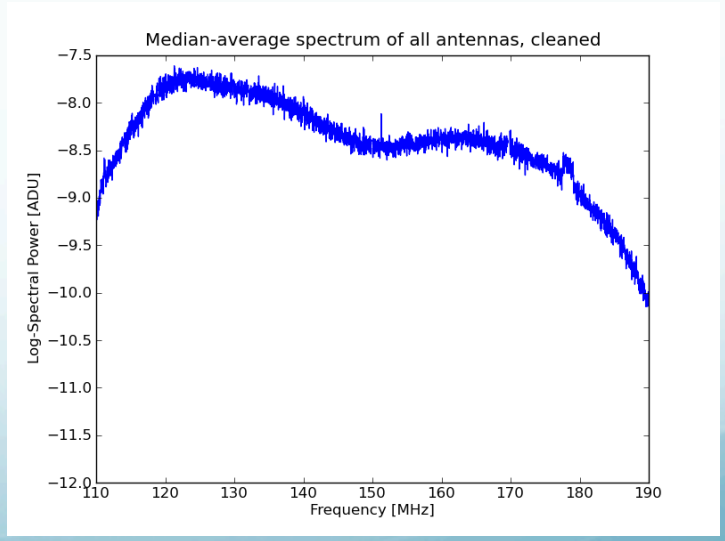




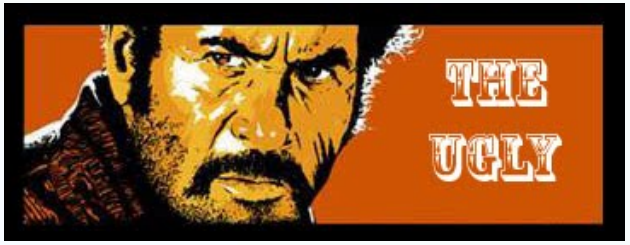


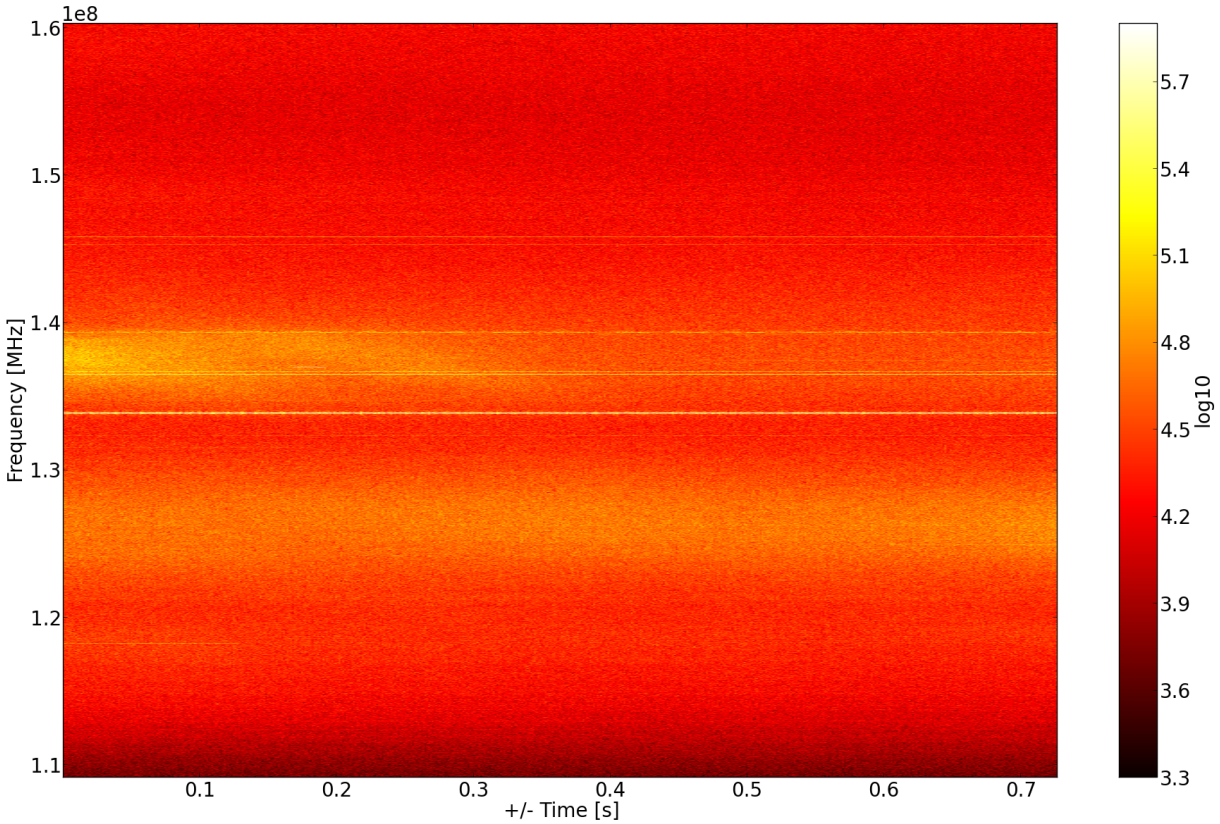
RFI excision



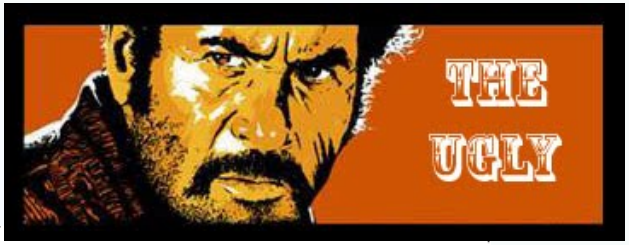


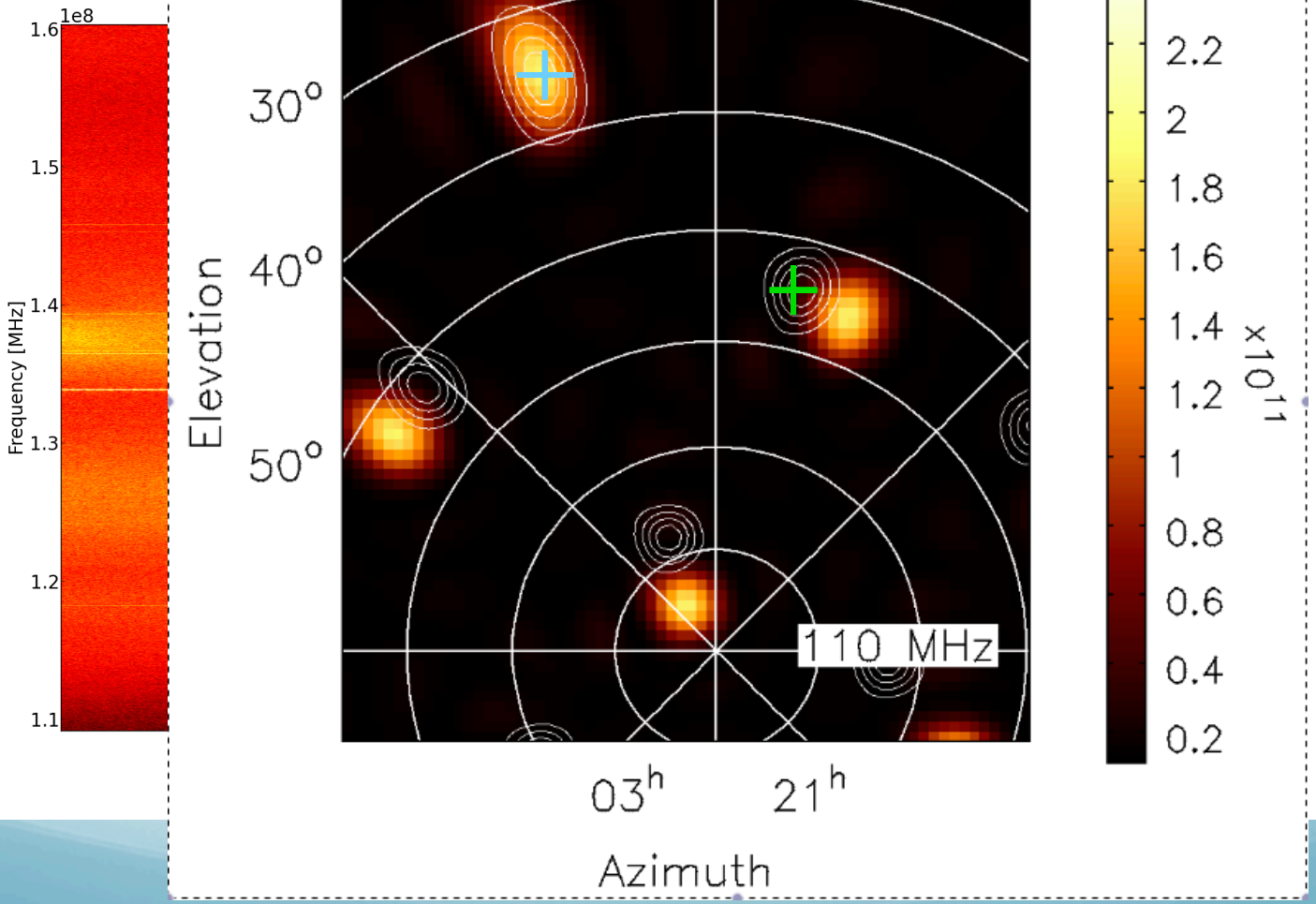
Ugly FRATS


THE
UGLY

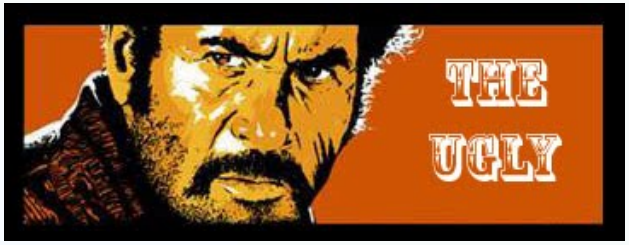

1e8
1.6
1.5
1.4
1.3
1.2
1.1
Frequency [MHz]
0.1
0.2
0.3
0.4
0.5
0.6
0.7
+/- Time [s]
5.7
5.4
5.1
4.8
4.5
4.2
3.9
3.6
3.3
log10

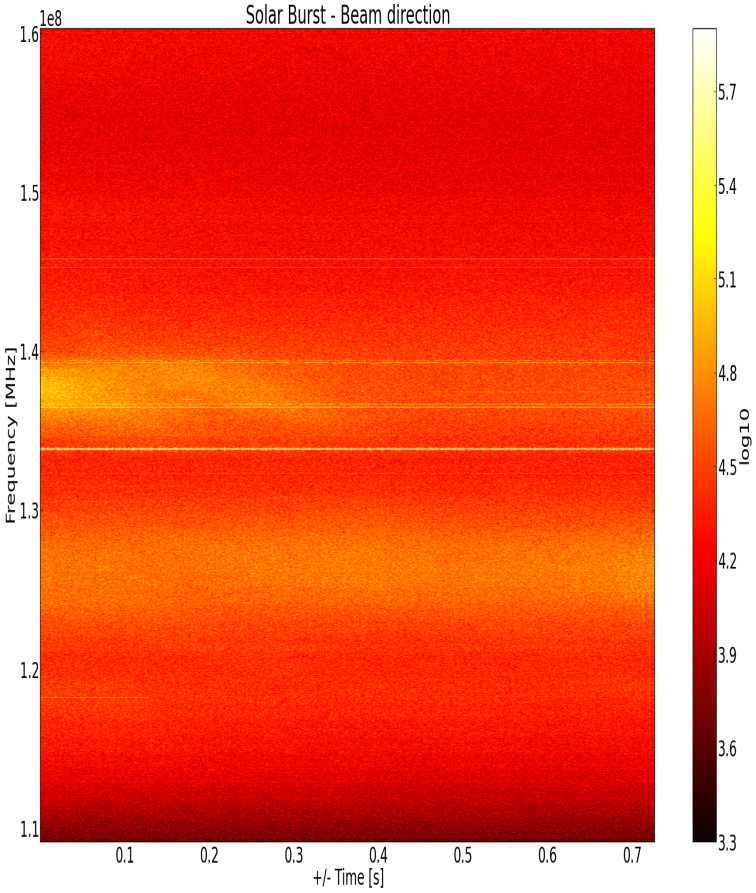
Ugly FRATS

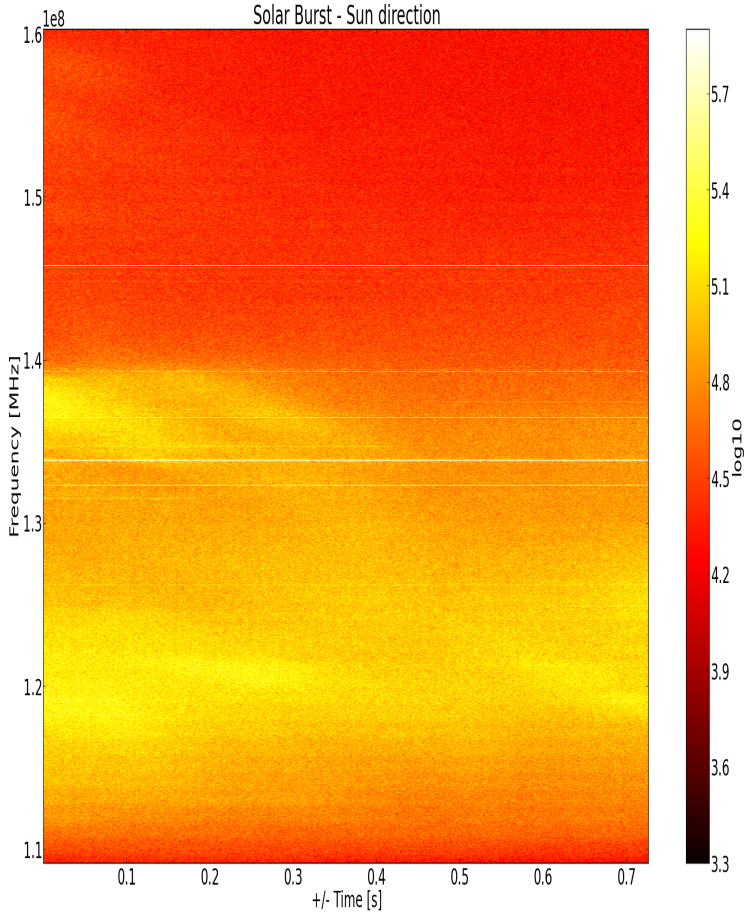

THE
UGLY


1e8
1.6
1.5
1.4
1.3
1.2
1.1
Frequency [MHz]
30°
40°
50°
Elevation
110 MHz
03h
21h
Azimuth
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
×10^11

Ugly FRATS


THE
UGLY


Solar Burst - Beam direction
1e8
1.6
1.5
1.4
1.3
1.2
1.1
Frequency [MHz]
0.1
0.2
0.3
0.4
0.5
0.6
0.7
+/- Time [s]
5.7
5.4
5.1
4.8
4.5
4.2
3.9
3.6
3.3
log10


Solar Burst - Sun direction
1e8
1.6
1.5
1.4
1.3
1.2
1.1
Frequency [MHz]
0.1
0.2
0.3
0.4
0.5
0.6
0.7
+/- Time [s]
5.7
5.4
5.1
4.8
4.5
4.2
3.9
3.6
3.3
log10

Summary

- We have triggered on
  - Pulsars
  - Solar Flares
  - Bad antennas
- With the use of TBBs to identify false positives.
  - We can verify good FRATS candidates
  - We can quickly identify bad candidates
  - We can flag misbehaving antennas
- We can also:
  - Localize triggers with better angular precision than the incoherent beam.
  - Can study the pulses with higher SNR than the incoherent stokes since can add raw data coherently.
  - Determine if the FRBs are astrophysical.

Current status

- Testing FRATS/TBB pipeline
  - Automatic bad antenna identifying / RFI flagging
  - Station phasing for coherent stokes and imaging
    - More consistent (fainter sources)
    - Longer baselines
- **Need to maximize the observing time**