

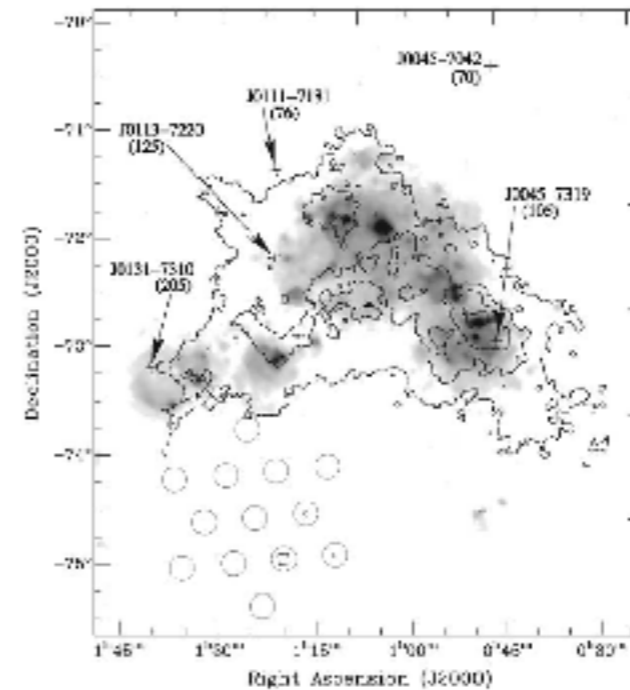
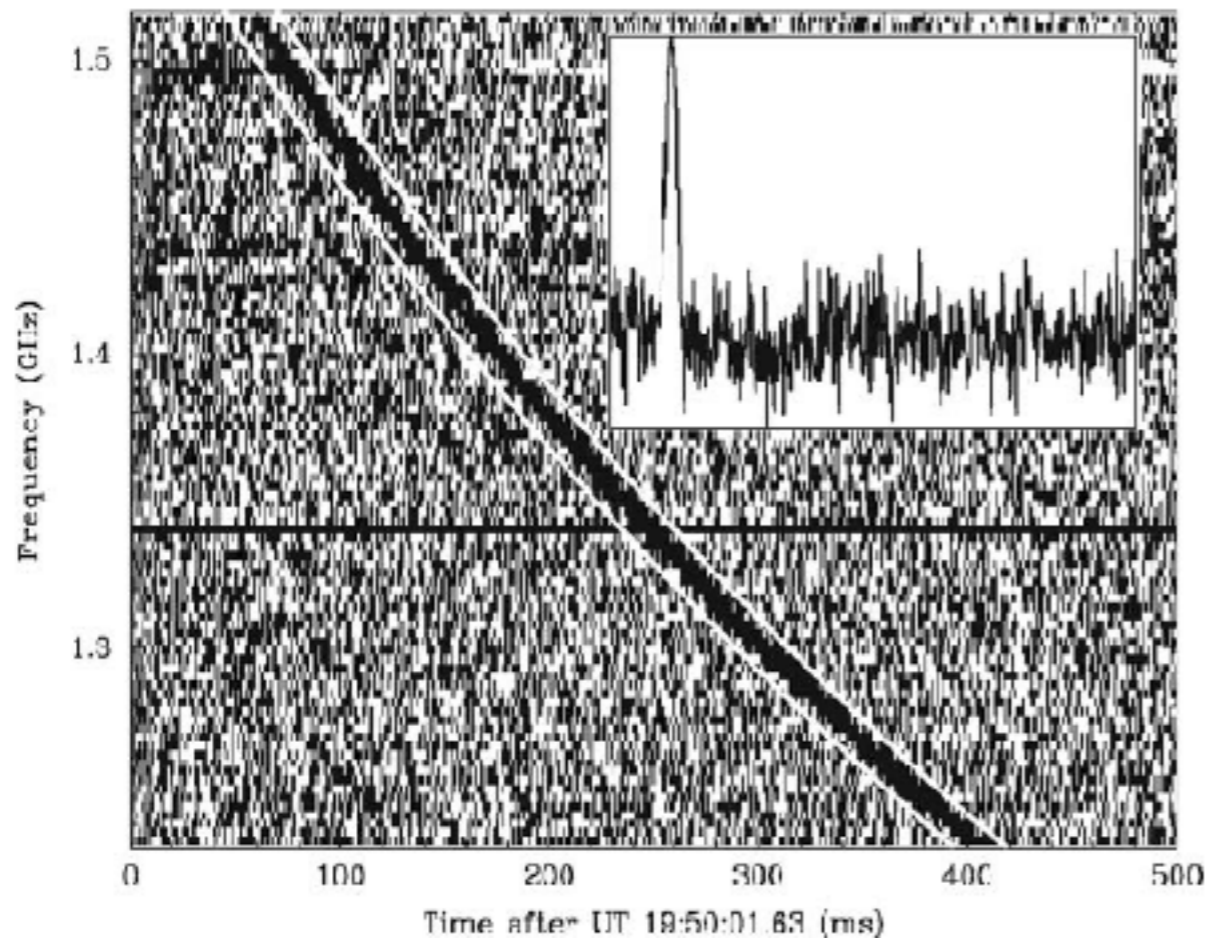
NenuFAR Early Science beamformed-TF data

ES05 : Fast Radio Bursts

Valentin Decoene, Philippe Zarka, et al.

1st Fast Radio Burst (FRB)

- Parkes archival data 1.4 GHz, DM=375, ~5 msec, 30 Jy, 3° from SMC



Lorimer et al. 2007

- Today a few hundred single pulses, a dozen repeaters (Parkes, Arecibo, CHIME...)
- GHz, down to 400 MHz
- 0.1 - 30 Jy + MJy Galactic magnetar
- Very numerous theories, vibrant activity
- <https://www.frbcatalog.org>, <https://www.wis-tns.org>

Early tentative detection at LF

Detection of Fast Radio Bursts at the LPA LPI Radio Telescope

A.E. Rodin, V.A. Fedorova, V.A. Samodourov, and S.V. Logvinenko

Pushchino Radio Astronomy Observatory

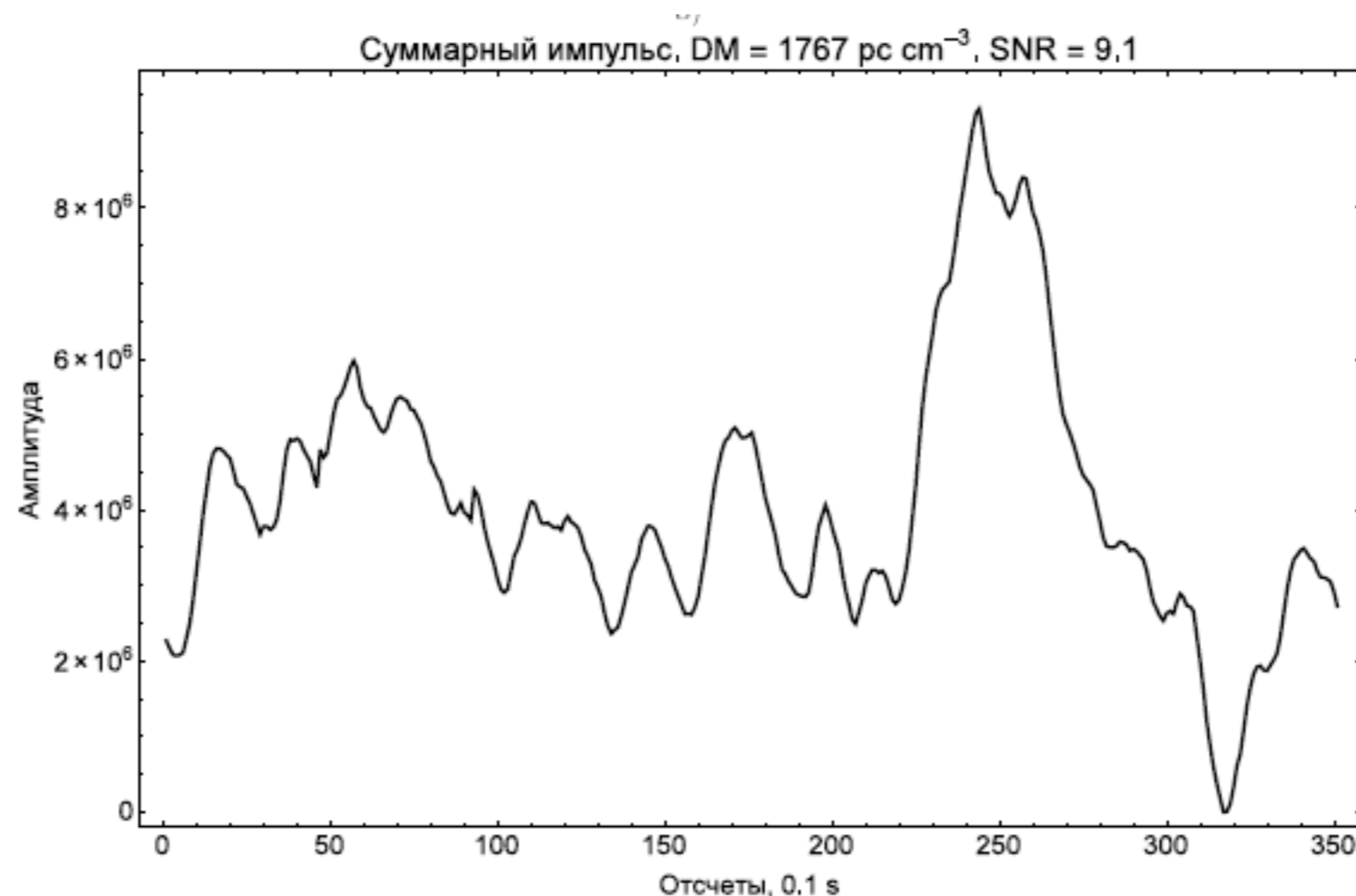
Astrospace Centre, P.N. Lebedev Physical Institute, Russian Academy of Sciences

Pushchino, Moscow Region, 142290 Russia

E-mail: rodin@prao.ru

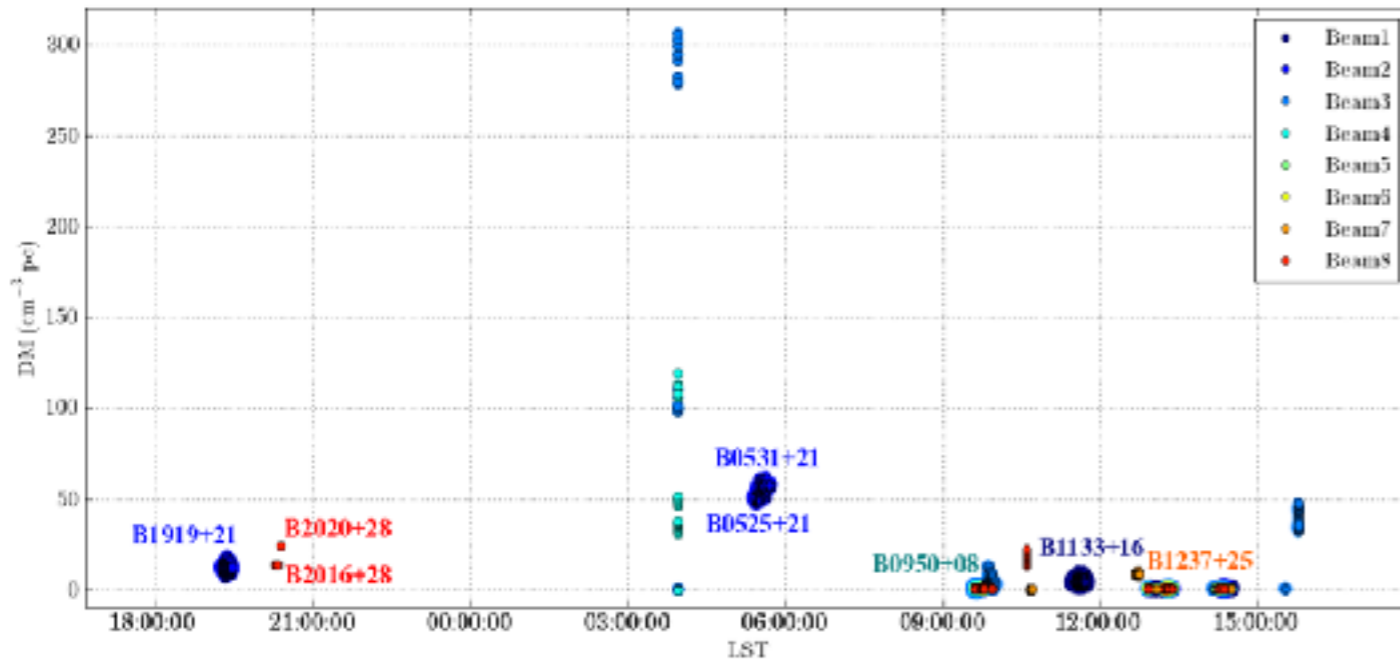
Received May 23, 2018

Abstract. We present results of searching for single pulse signals at the LPA LPI radio telescope at a frequency of 111 MHz in 2012–2018. Areas around FRB 121102 ($\alpha = 05^{\text{h}}32^{\text{m}}$, $\delta = 33^{\circ}05'$) and $\alpha = 05^{\text{h}}32^{\text{m}}$, $\delta = 41^{\circ}40'$ were analysed. We detected three radio bursts with $DM = 247, 570, \text{ and } 1767 \text{ pc cm}^{-3}$.



LOFAR : first attempts

Unsuccessful attempts of blind FRB detection

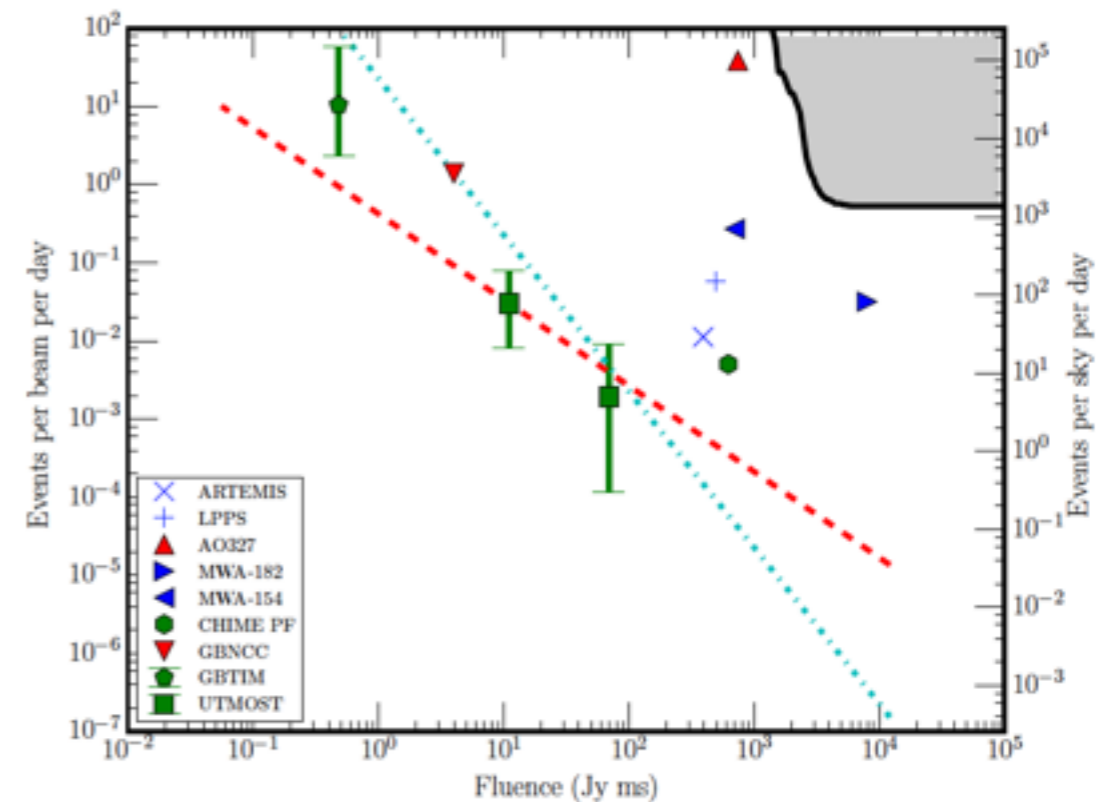


incoherent beam + TBB, 119-185 MHz

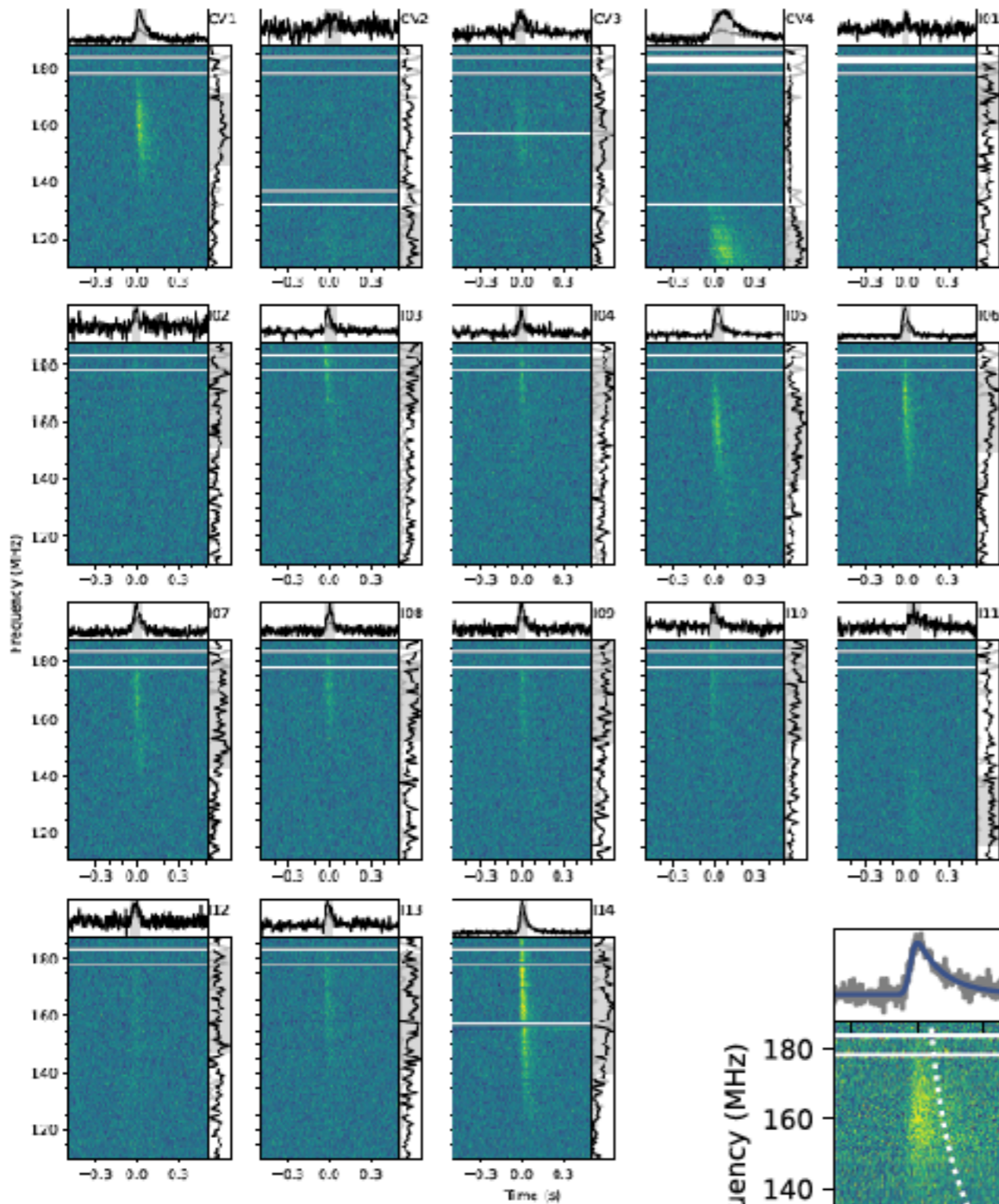
[ter Veen et al., A&A, 2019]

ARTEMIS, UK & Fr LOFAR stations
coherent dedispersion

[Karastegiou et al., MNRAS, 2015]

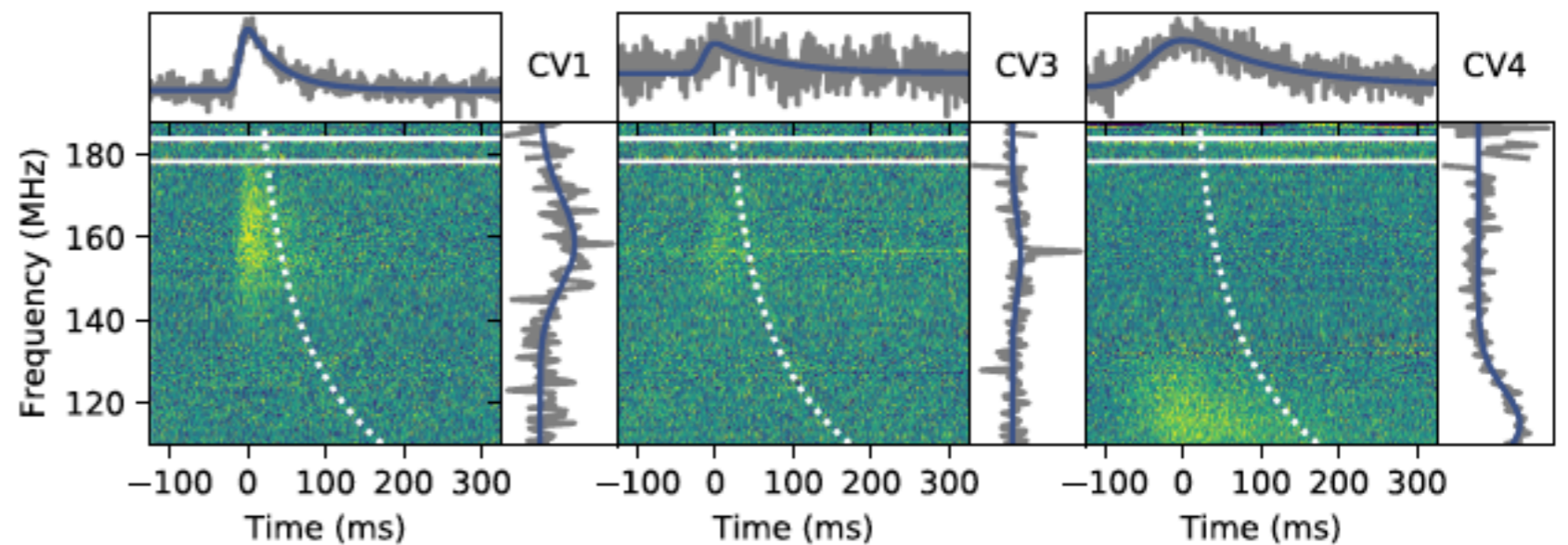


LOFAR : first detection

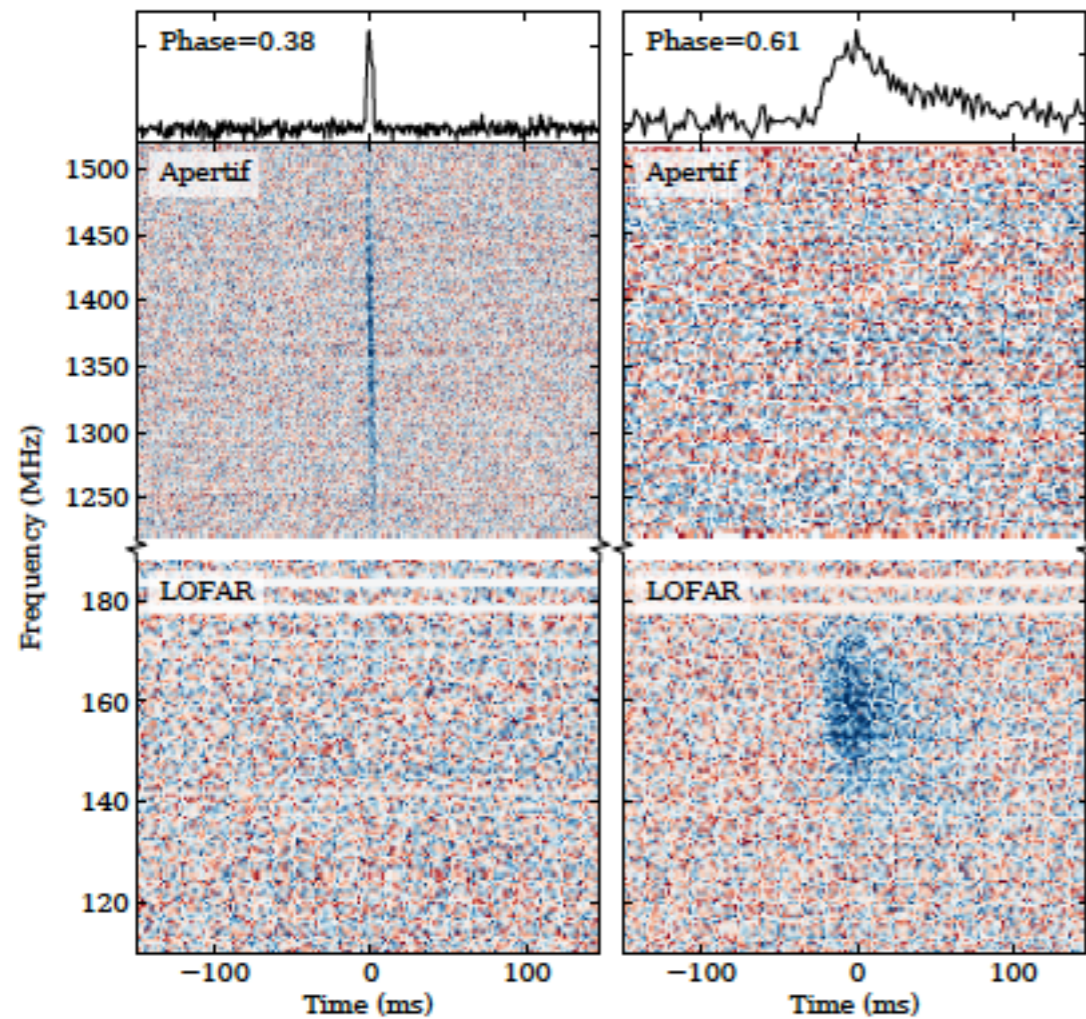


→ FRB repeaters (FRB 20180916)
start being detected down to 110 MHz

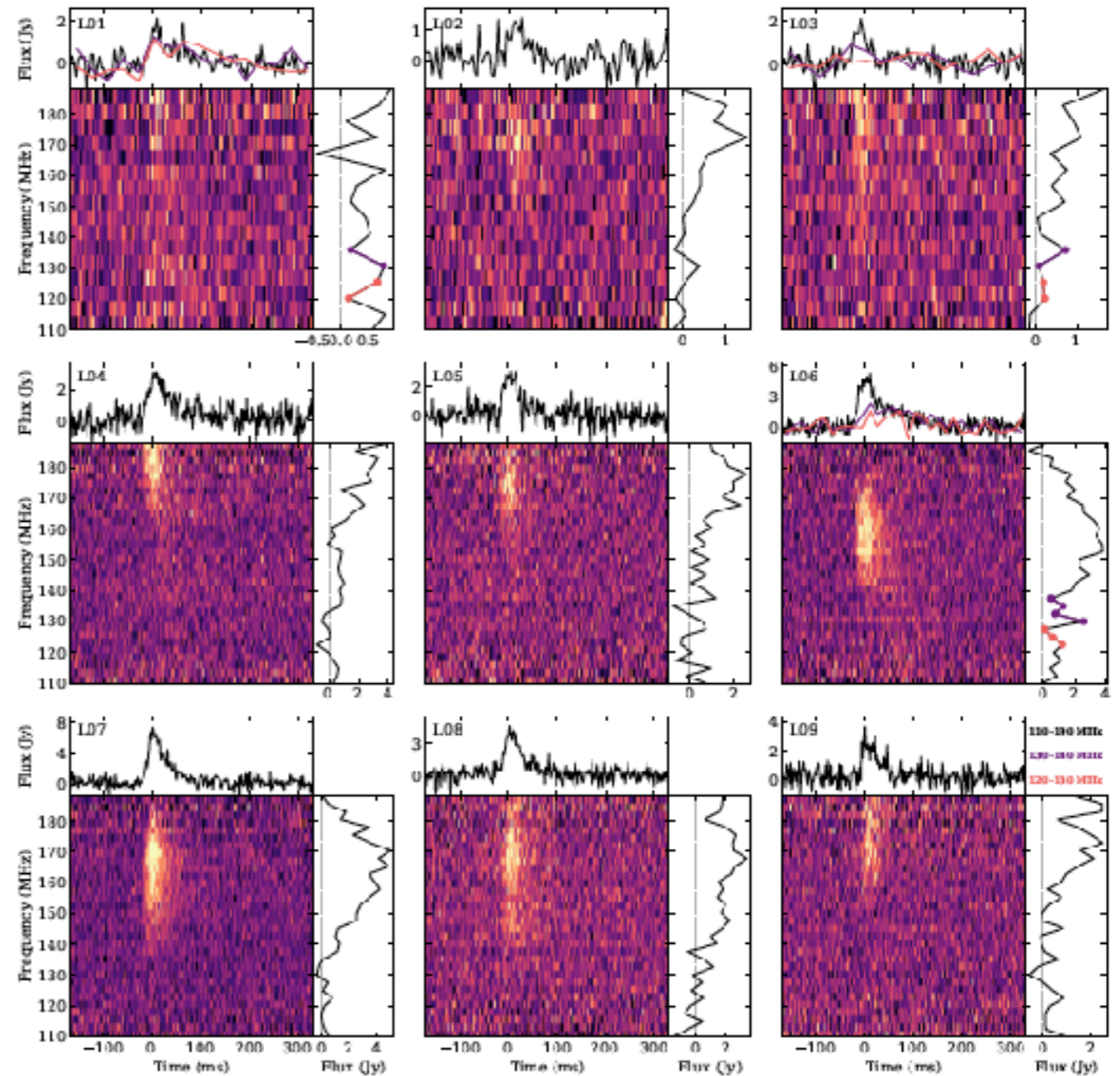
[Pleunis et al., ApJL, 2021]



LOFAR + Westerbork/Apertif



[Pastor-Marazuela et al., arxiv, 2021]



Interests : Physical constraints (« sad trombone effect », blobs, multiple, phase shift...), emission mechanism

NenuFAR

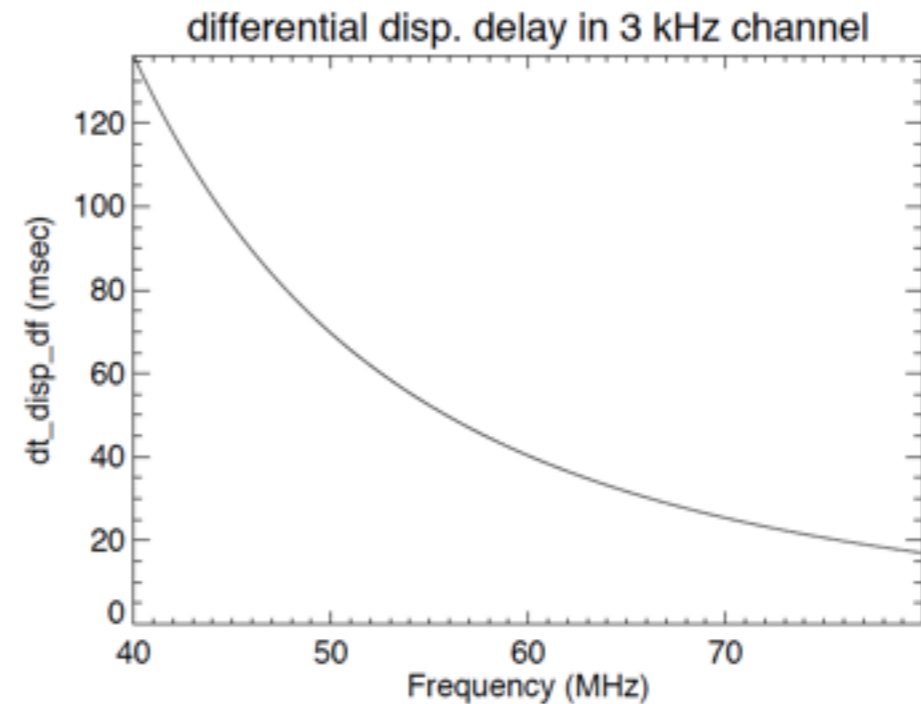
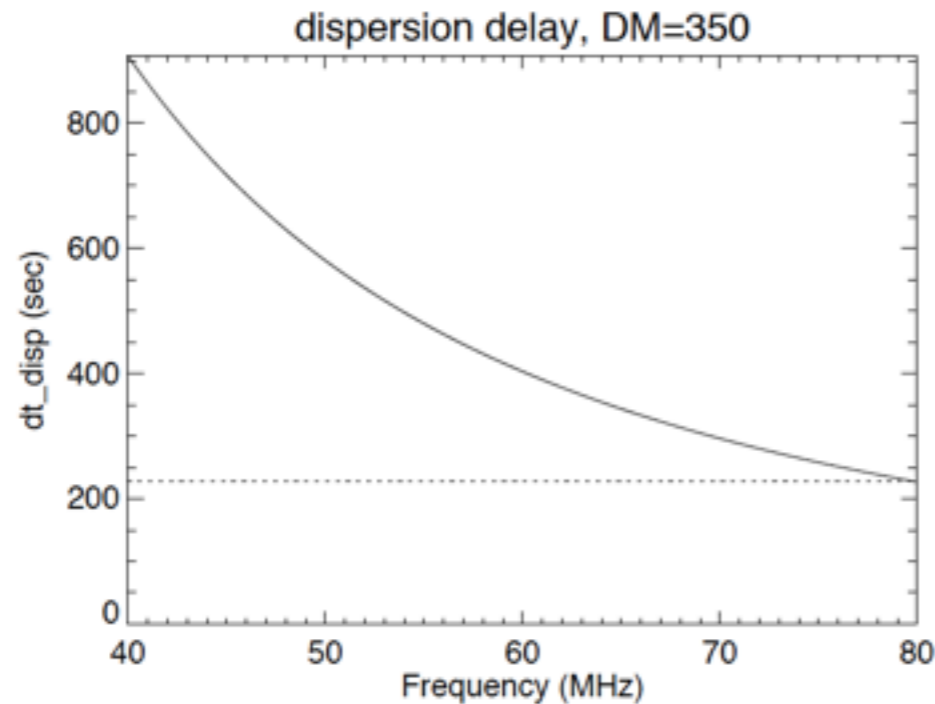


10-85 MHz, beamformed observations, steerable, FoV 8° - 60° FWHM

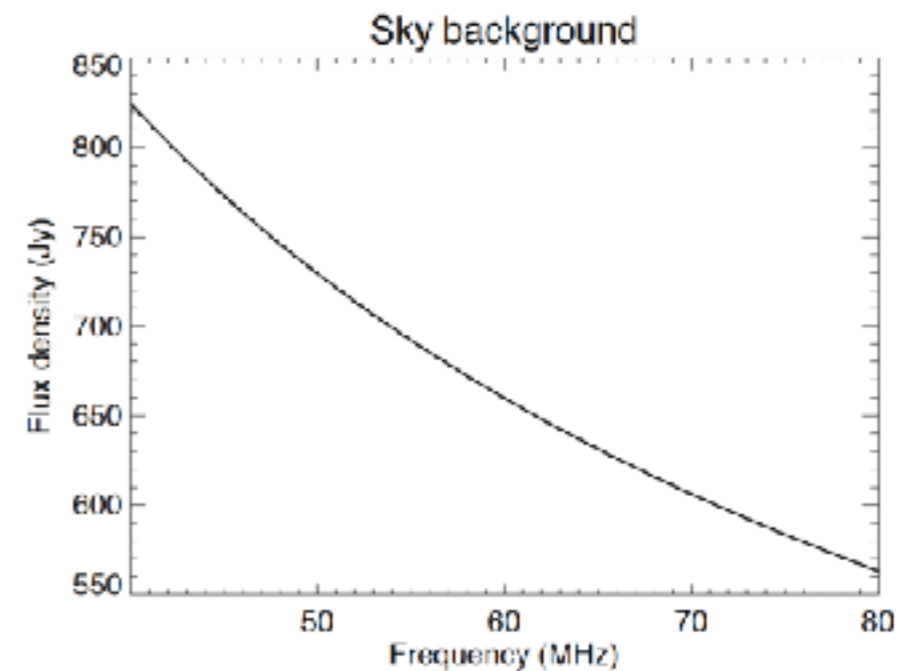
Low frequencies

Very long dispersive delays

ex: DM=500 : 4863 s (81 min.) in 20-80 MHz, 972 s (16 min.) in 40-80 MHz



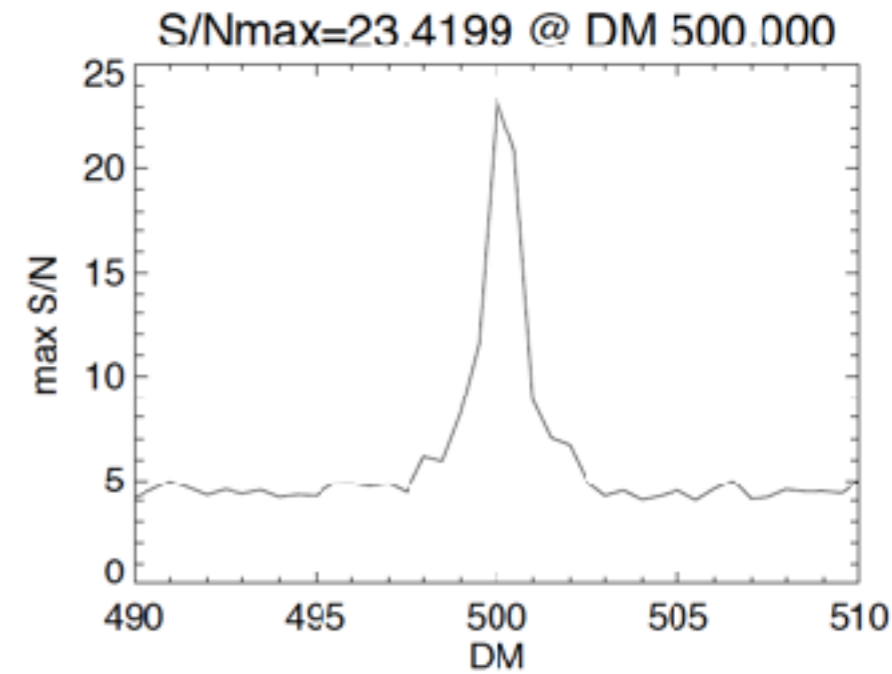
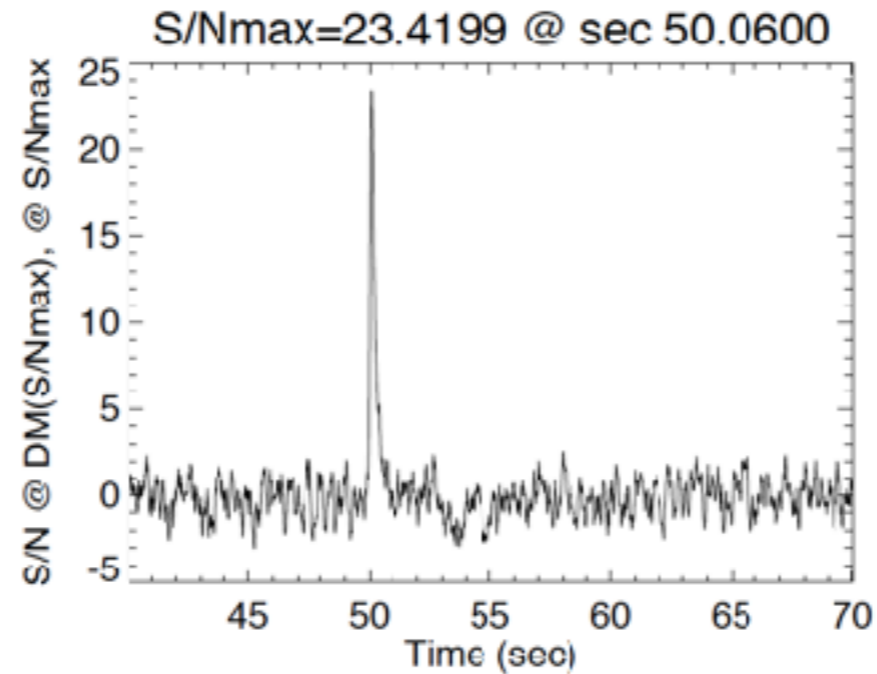
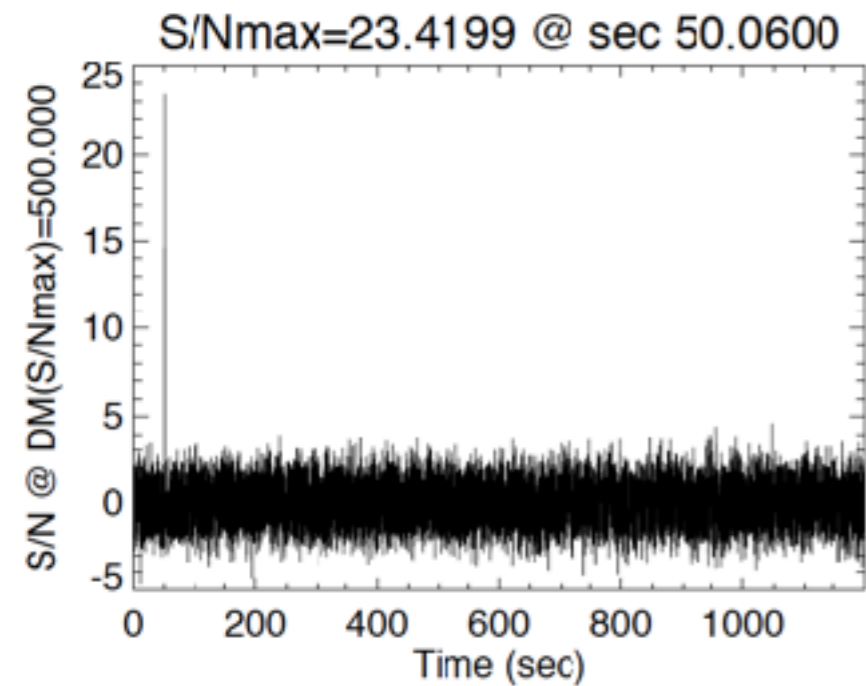
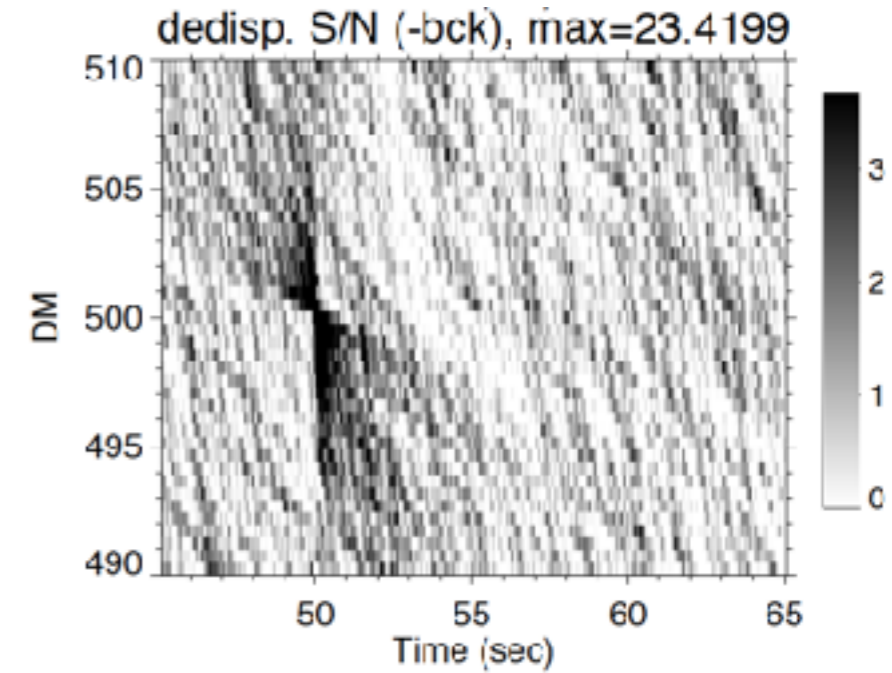
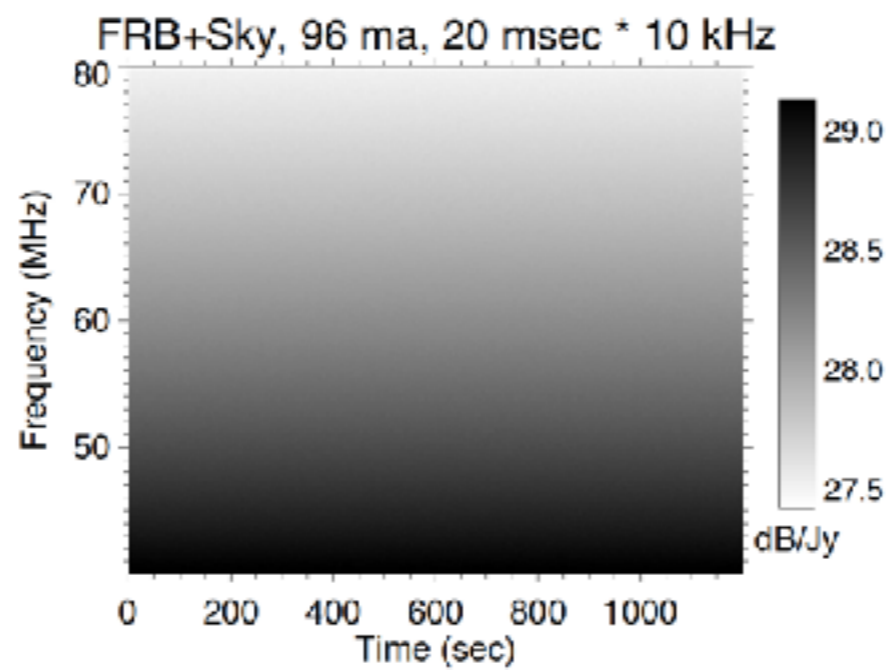
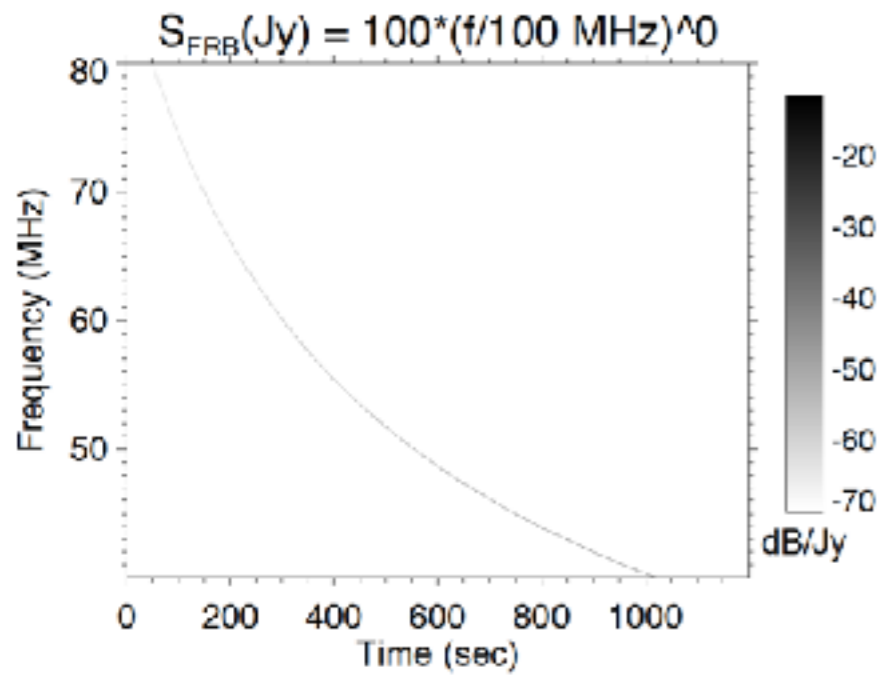
Very bright sky background, A-team sources



- Observations, in 40-80 MHz, at 21 msec x 3 kHz resolutions
- start with repeaters, moderate DM

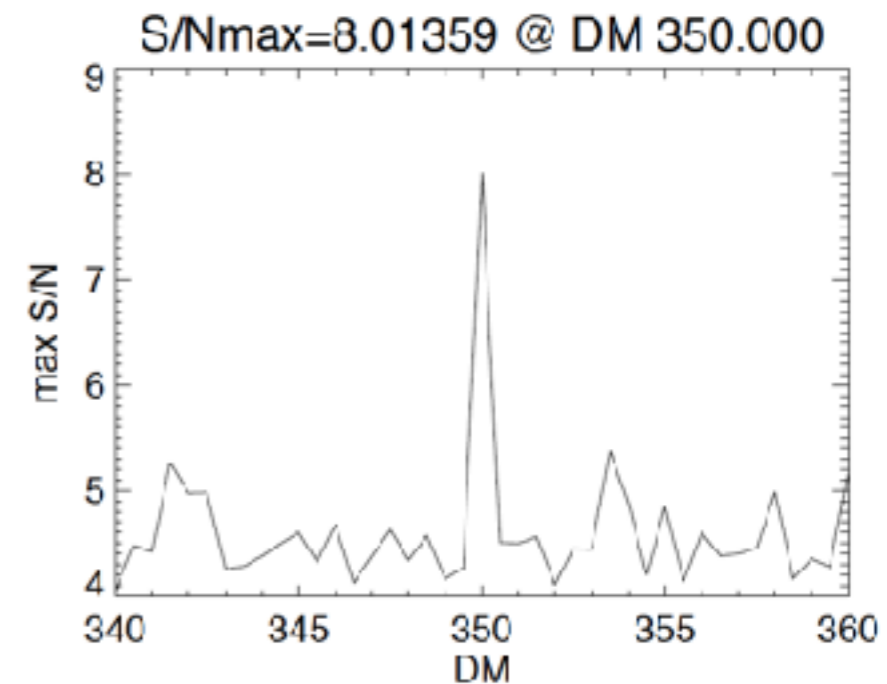
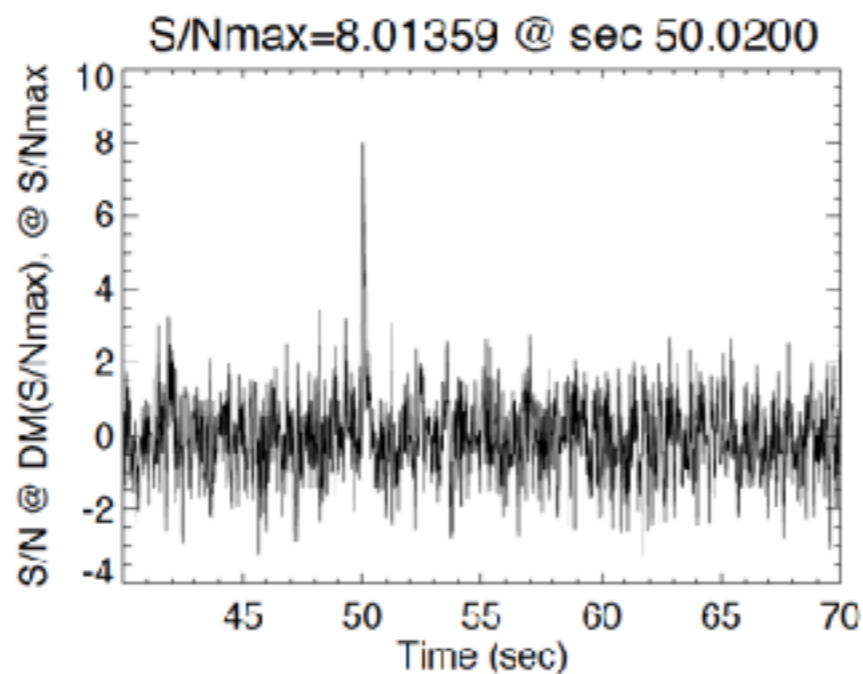
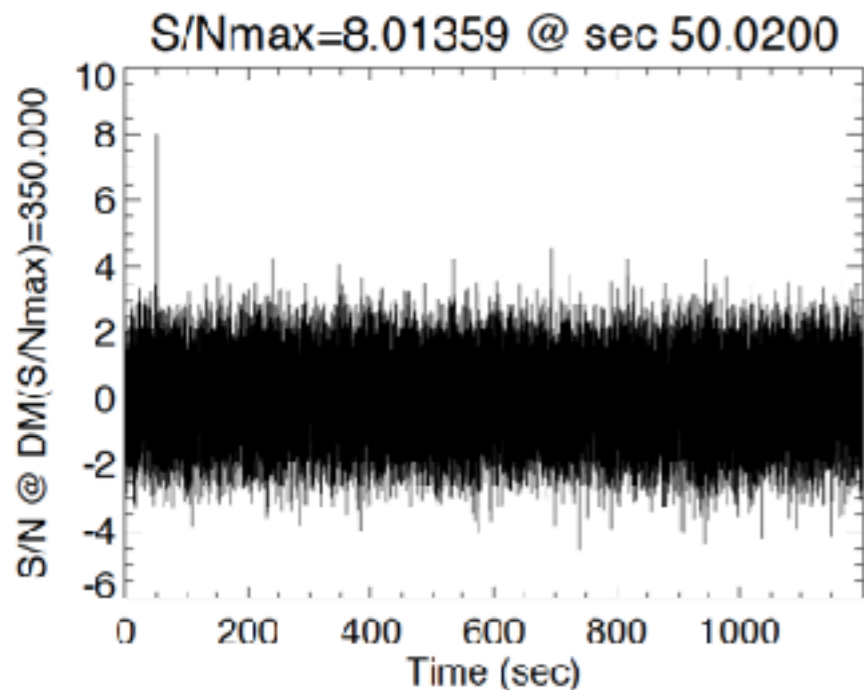
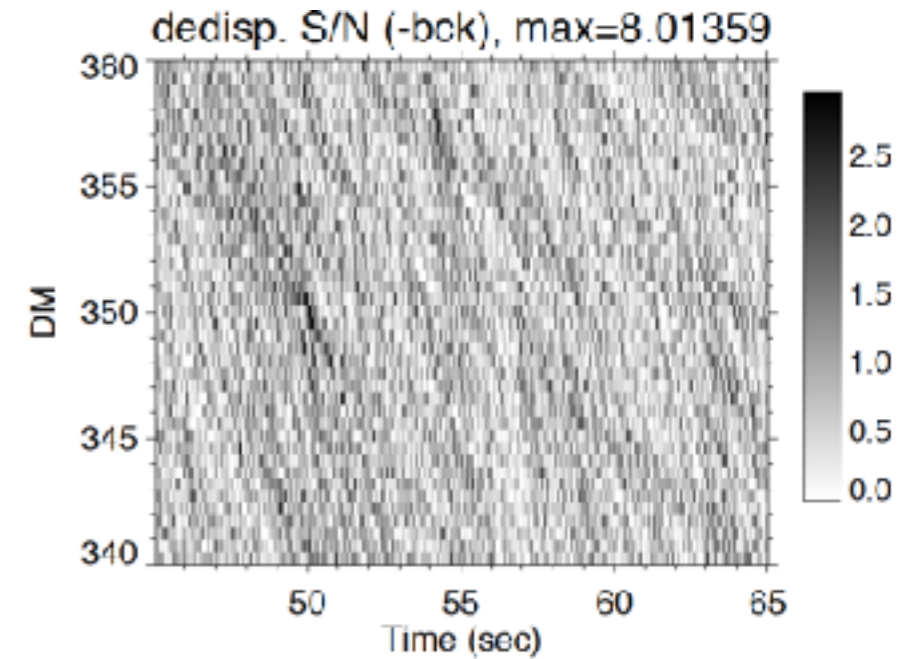
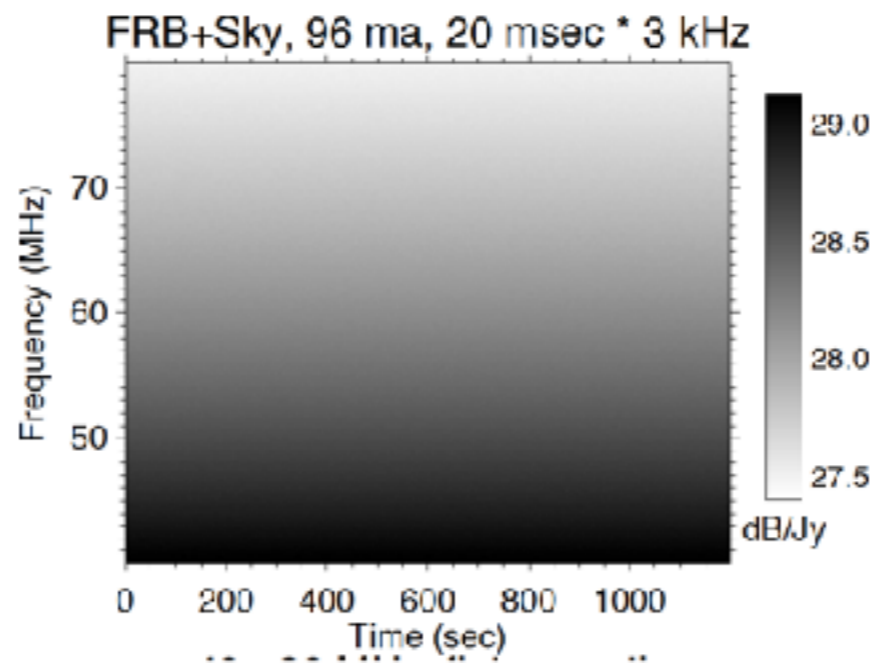
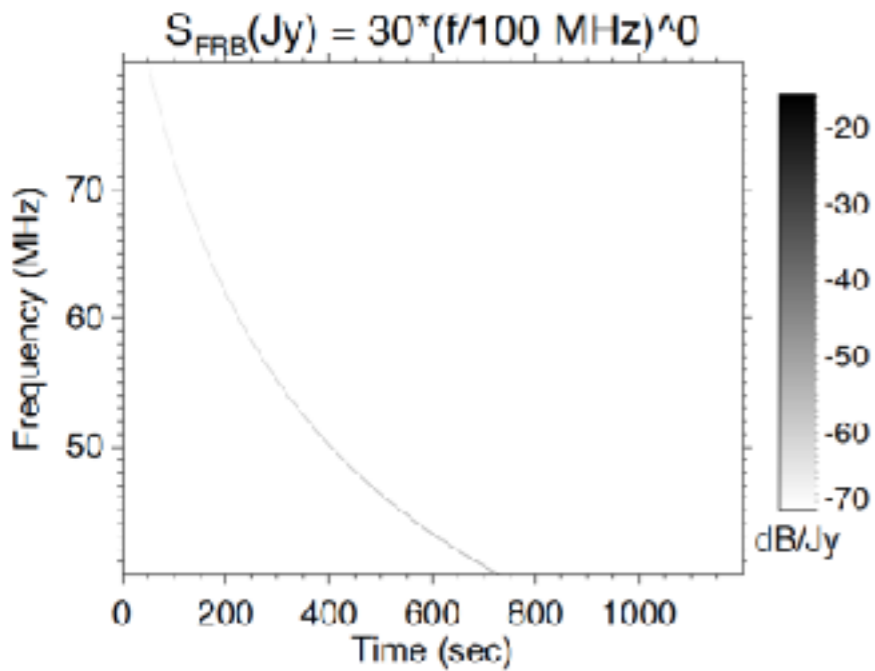
Simulations

100 Jy FRB at DM = 500 pc.cm⁻³



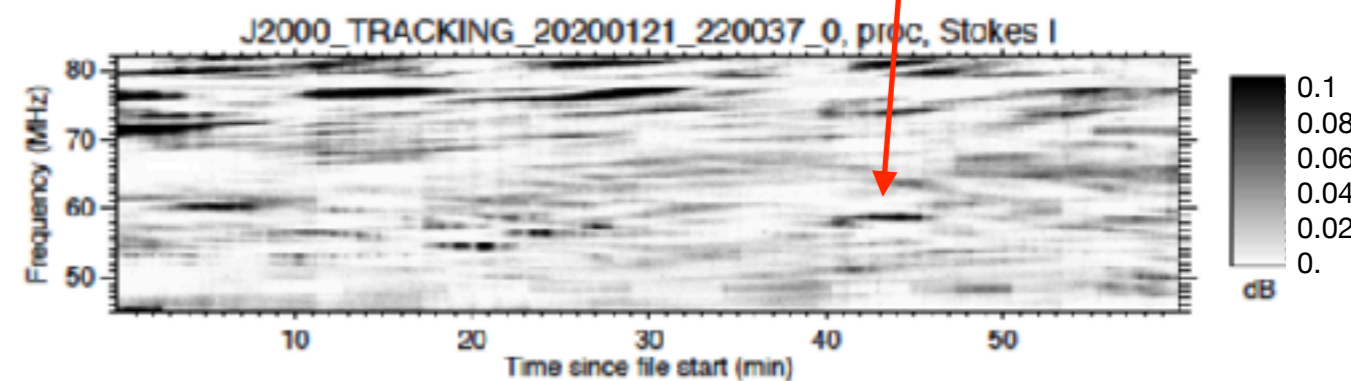
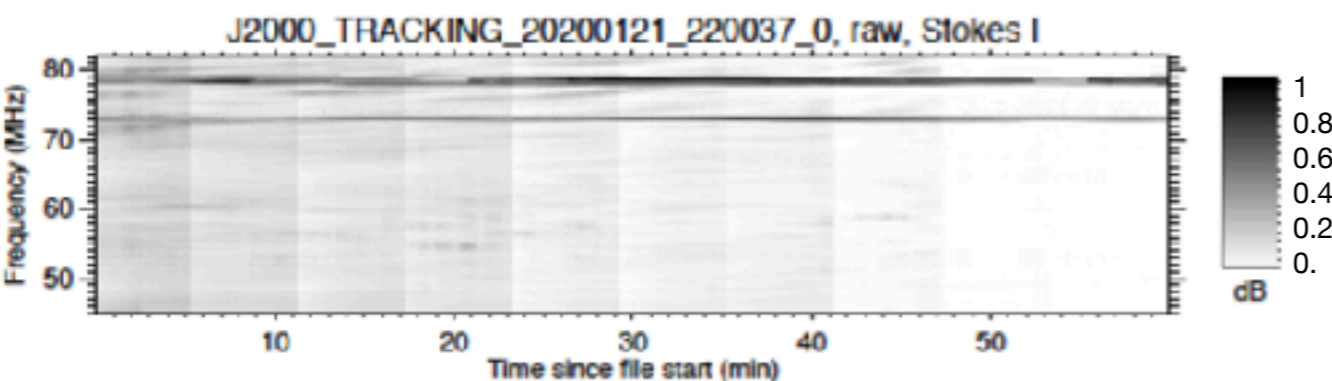
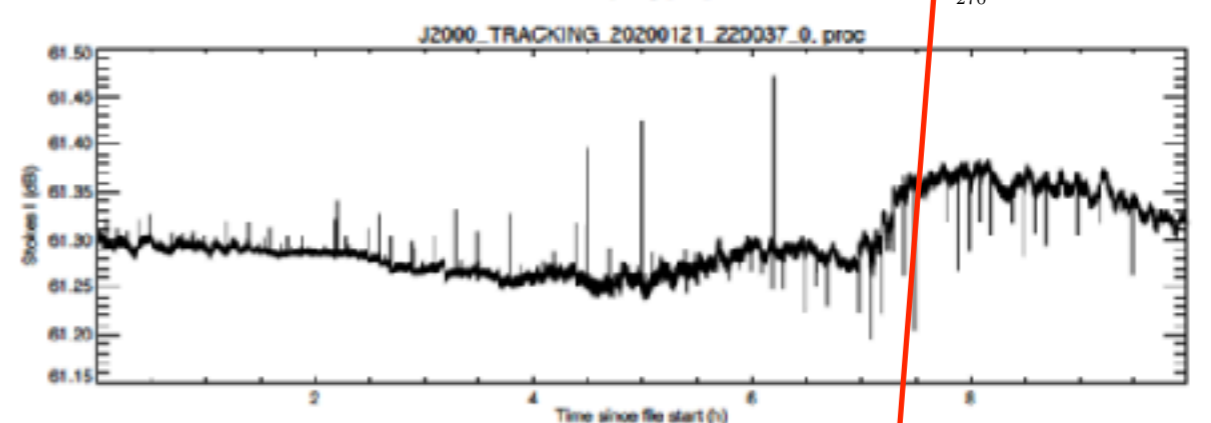
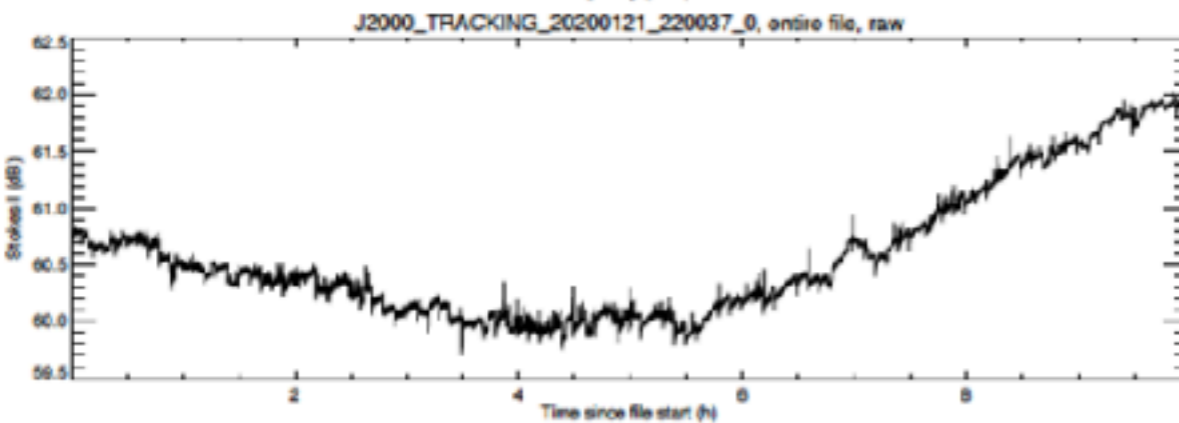
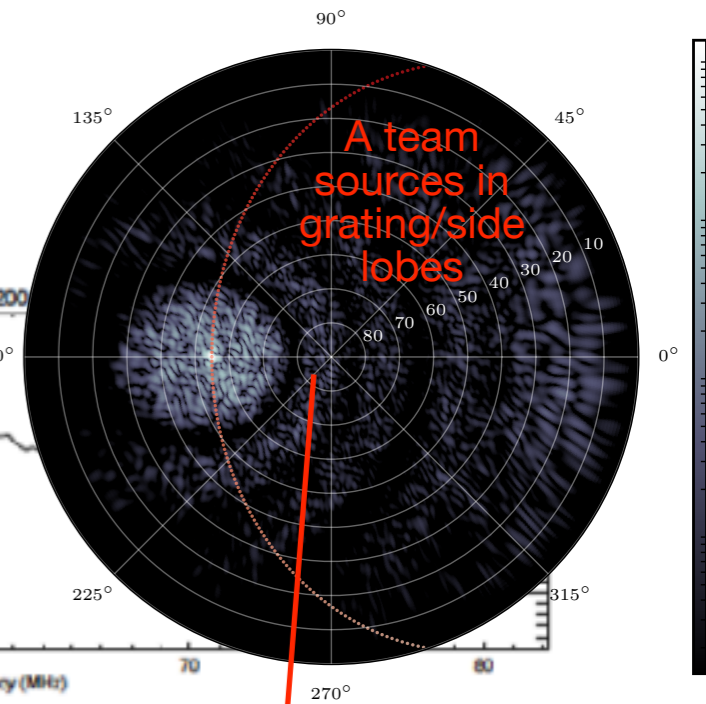
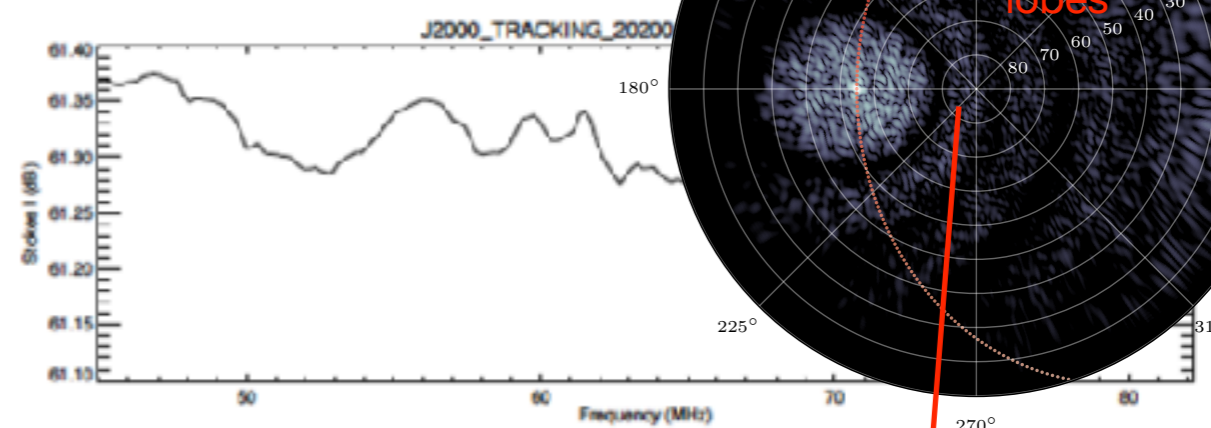
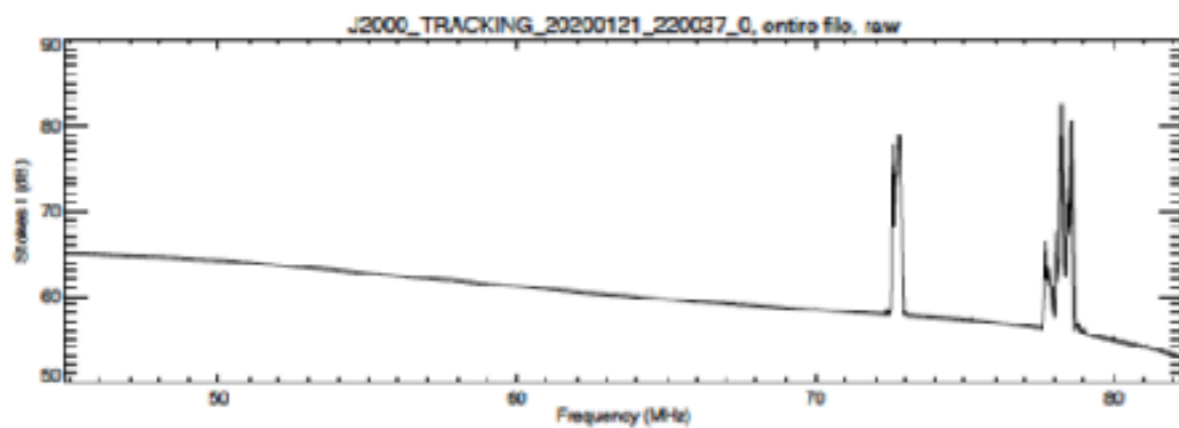
Simulations

30 Jy FRB at DM = 350 pc.cm⁻³



Observations & pre-processing

- IDL (& Python) pipeline(s) : RFI flagging, bandpass correction, gain(t) correction, intra-channel de-dispersion, integration / t,f, computation of Stokes parameters
- Flexible, parameterized, documented
- L0 → L1, volume reduction ~ x60 ; SNR preserved or improved



- L0 :
 - $df=3.05$ kHz $dt=21.0$ msec, 1 or 2 beams (On only), 12-49 MHz & 49-86 MHz
 - Undisputed-pulsar mode for repeater FRB180916

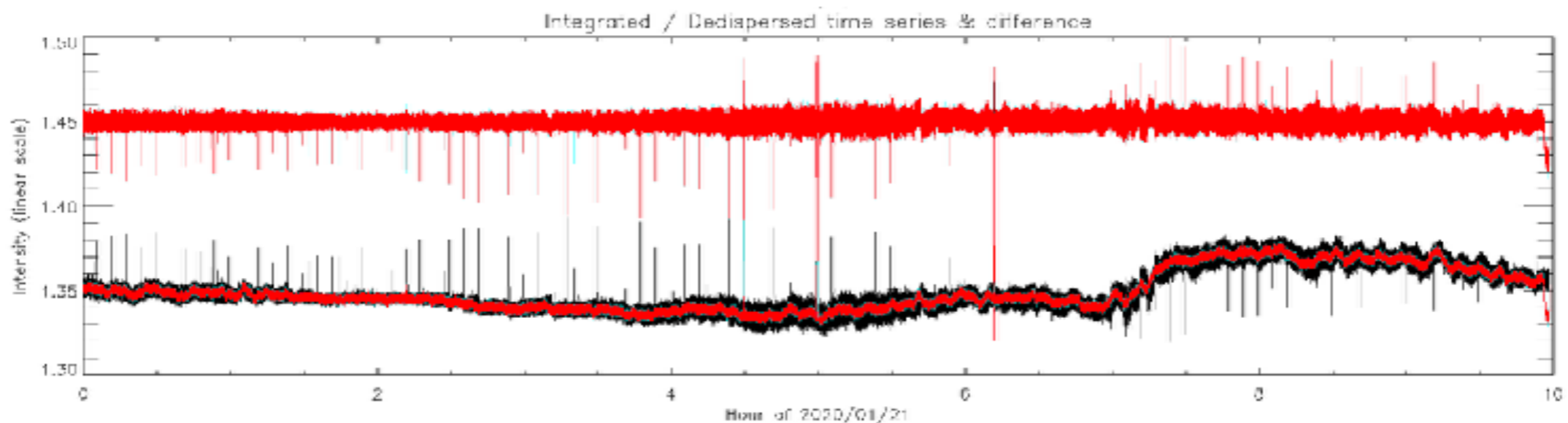
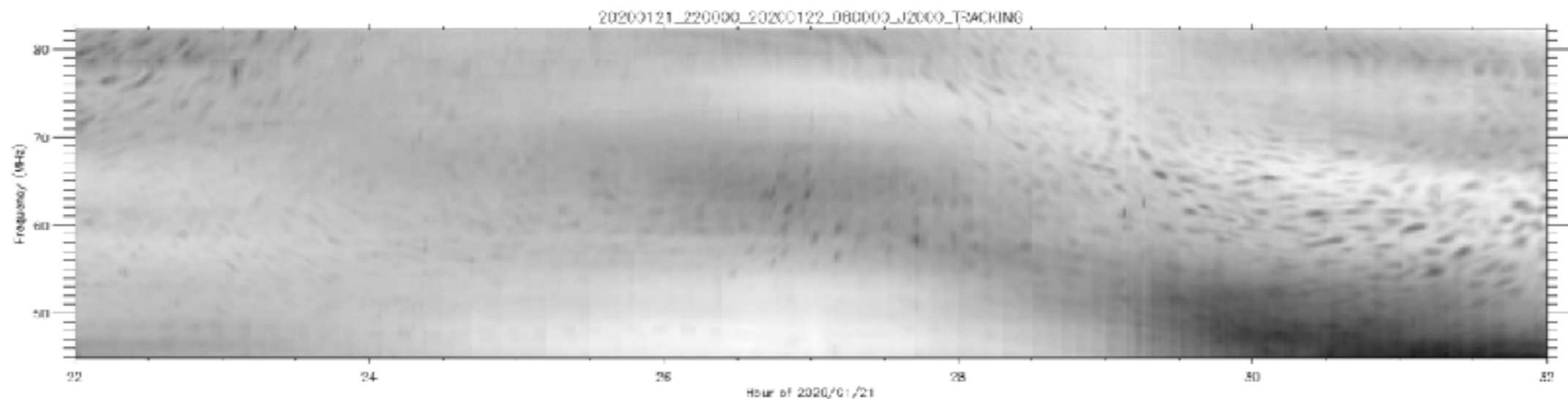
- L1 :
 - 195 kHz x 21 msec, Stokes IVL, RFI mitigation, gain correction (6-min.) in 2 passes, in-band dedispersion at expected DM (repeaters), spectral whitening
 - Volume reduced by $\sim x64$

- Targets : 9 repeating FRB, Galactic magnetar, Zenith pointings (blind search)
- Calibration / test : PSRB0329+54 & PSRB2217+47 observed before/after observations

FRB151125	50.00 h
FRB180814	289.00 h
FRB180908	19.00 h
FRB181017	20.00 h
FRB190303	66.33 h
FRB190907	18.00 h
FRB20200120	37.50 h
FRB180916	40.00 h
FRB180916_TF_PULSAR	315.73 h
FRB181030	125.60 h
FRB181030_TF_PULSAR	79.00 h
SGR1935+2154	44.00 h
PSRB0329+54	58.29 h
PSRB2217+47	7.93 h
ZENITH	117.50 h
Total	1330 h

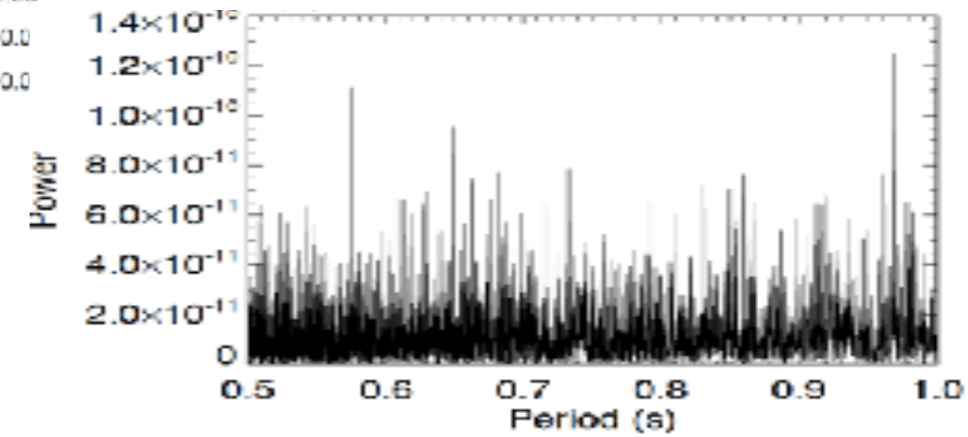
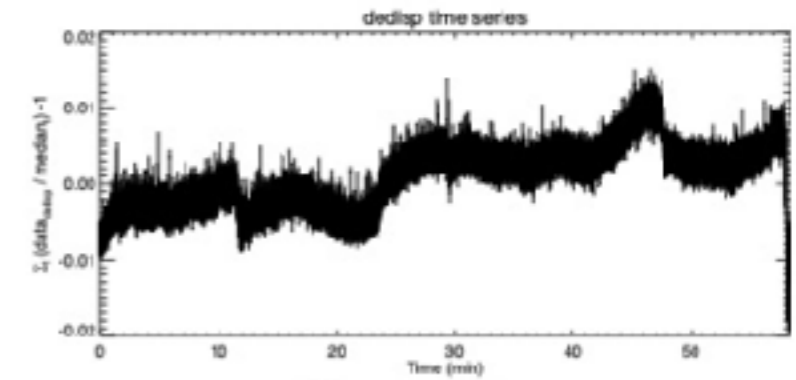
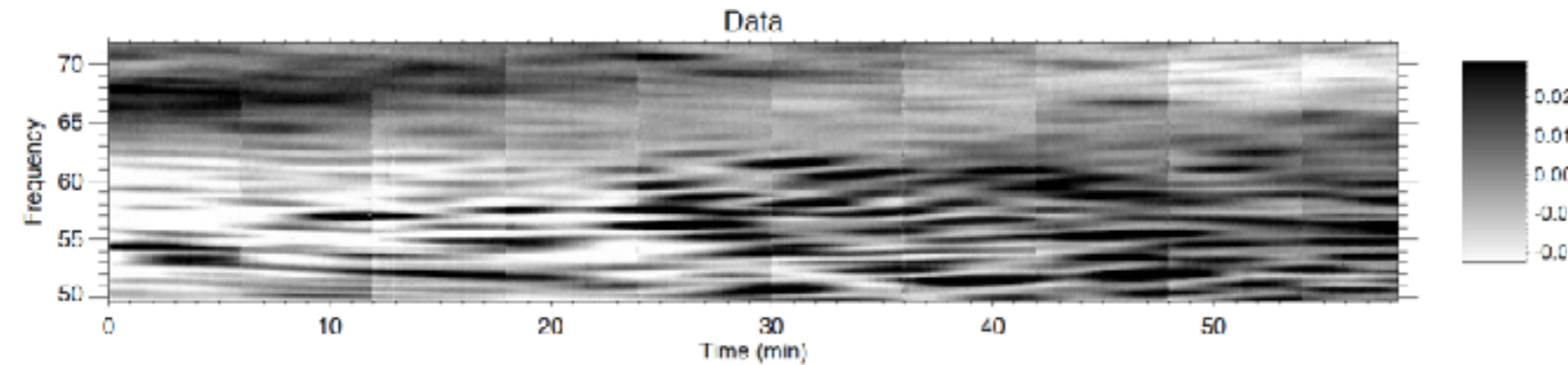
Post-processing

- Spectral whitening, + RFI mitigation, time smoothing, filtering of sources in side lobes
- Search in Stokes I (no Off beam)
- Repeaters : Parametric de-dispersion around expected DM + search for spikes
- 20121102 repeater : simultaneous NRT observations 31/9-6/9/2019 (DM ~ 560)
- Non-repeaters : Parametric de-dispersion in broad DM range + search for spikes
- Use of simulations
 - Study of occurrence (periodicities ?), polarization ...

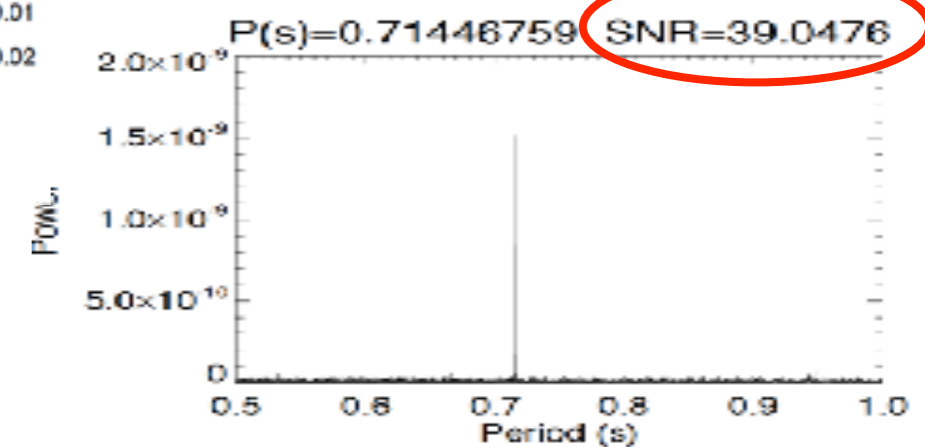
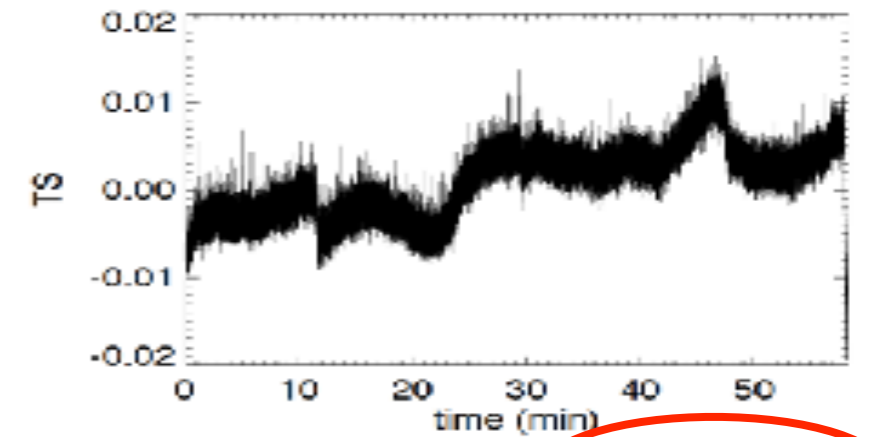
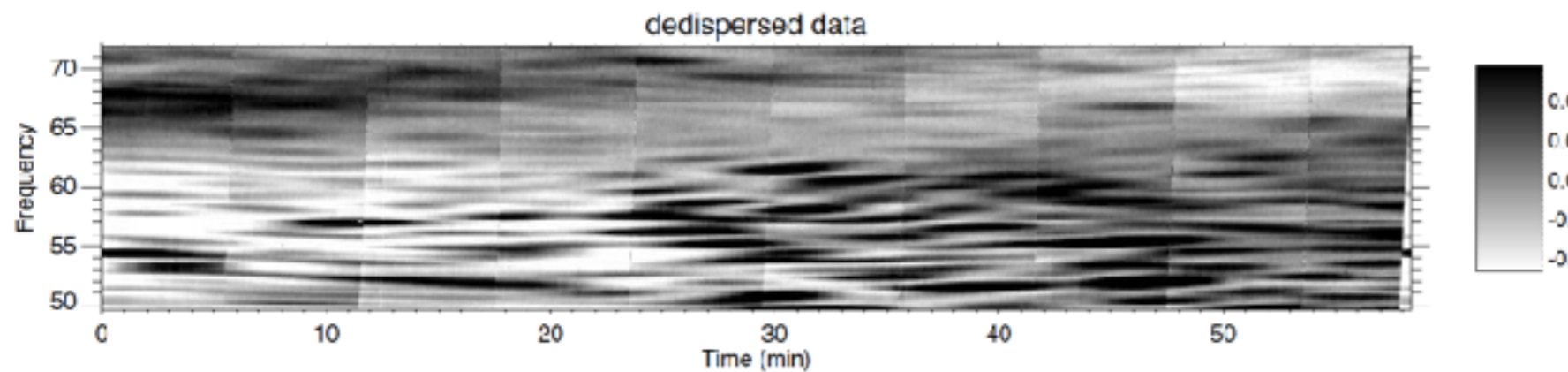


Benchmarking on PSR0329+54

L1 data

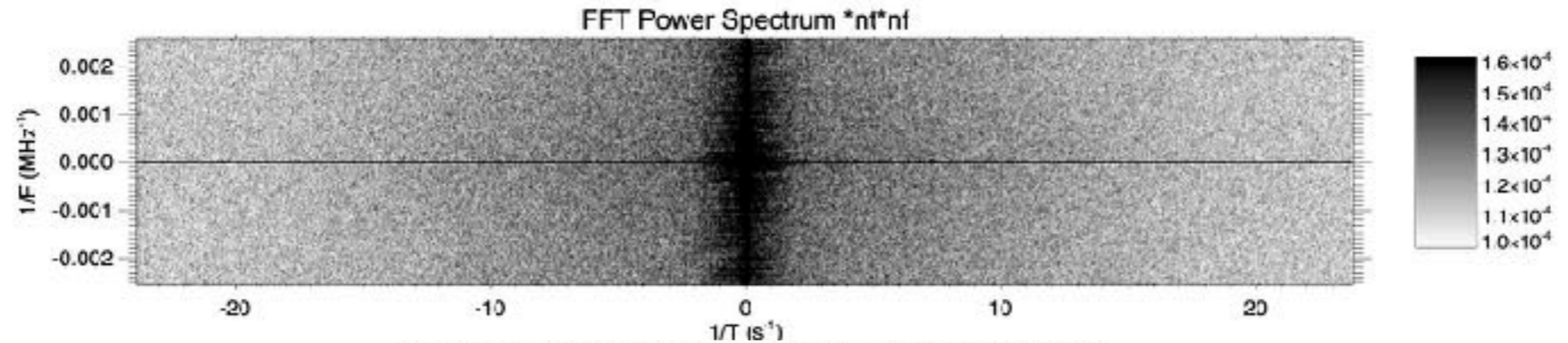


L1 data dedispersed

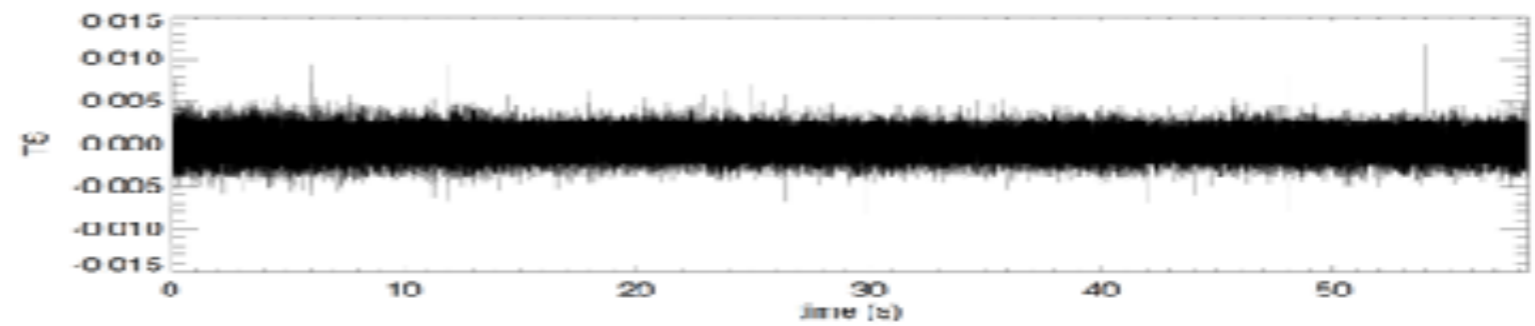
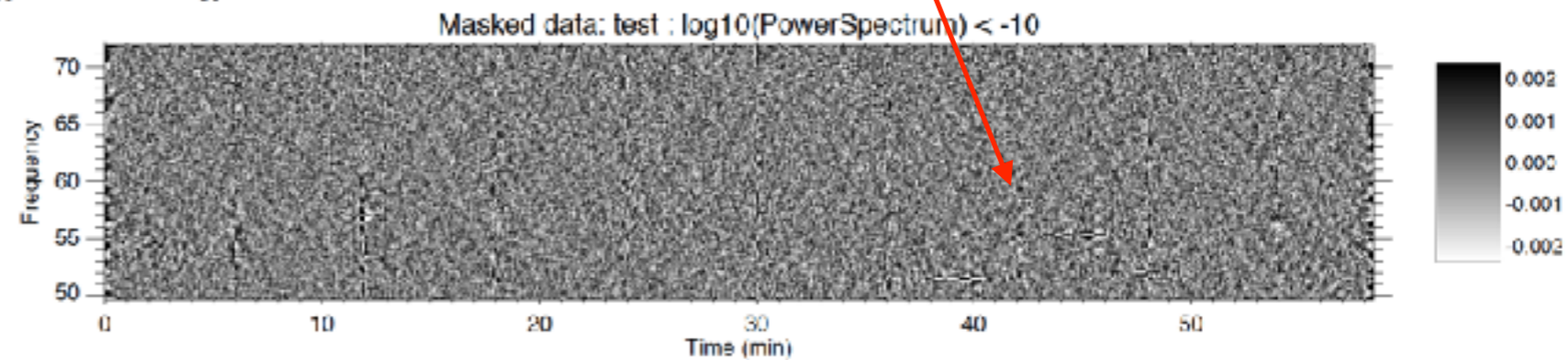
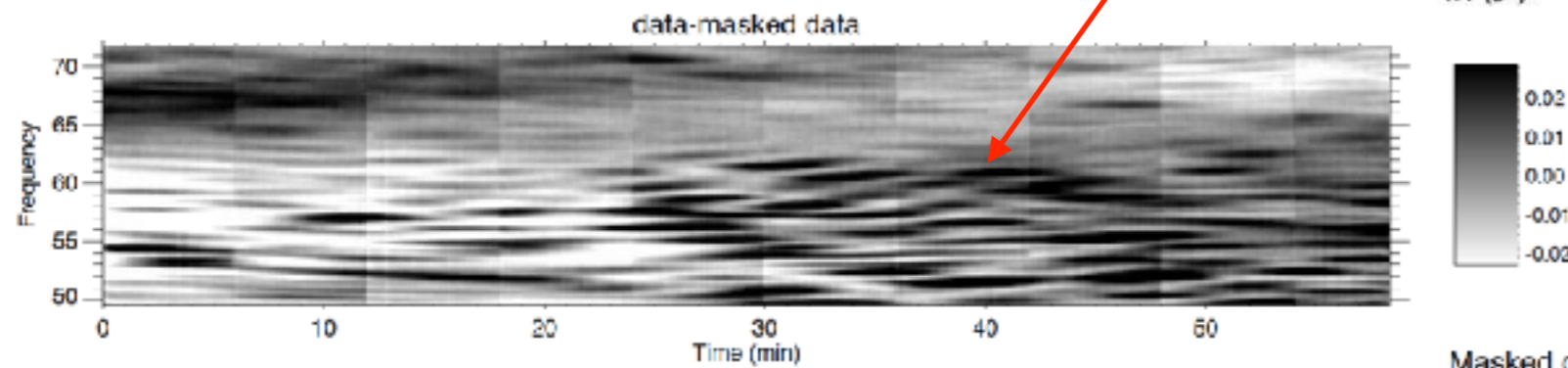
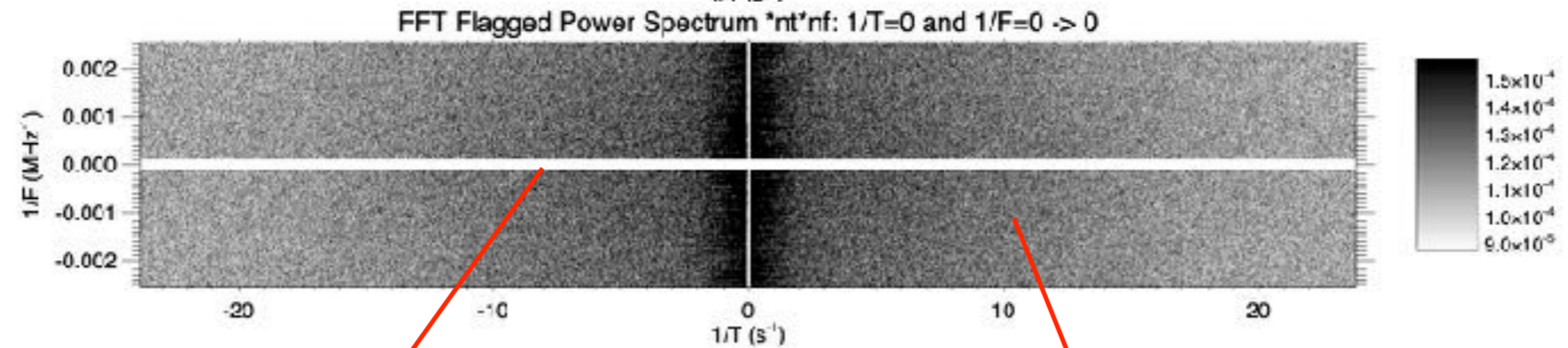


Benchmarking on PSR0329+54 : FFT filtering

2D FFT

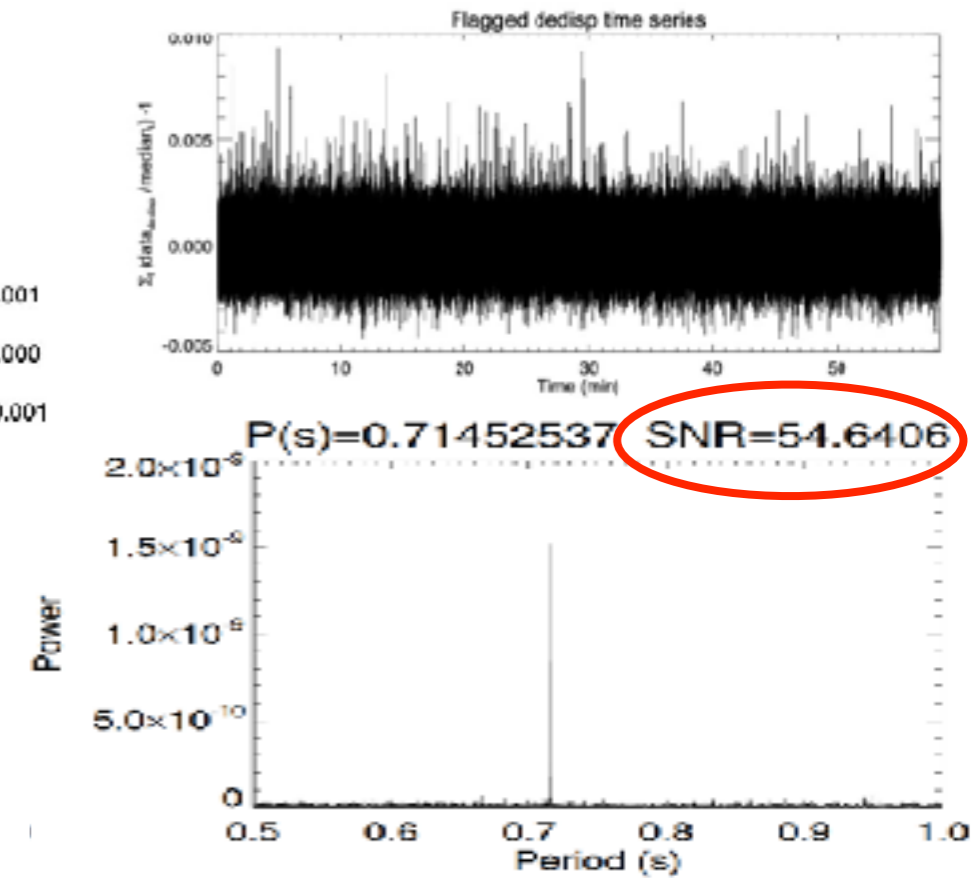
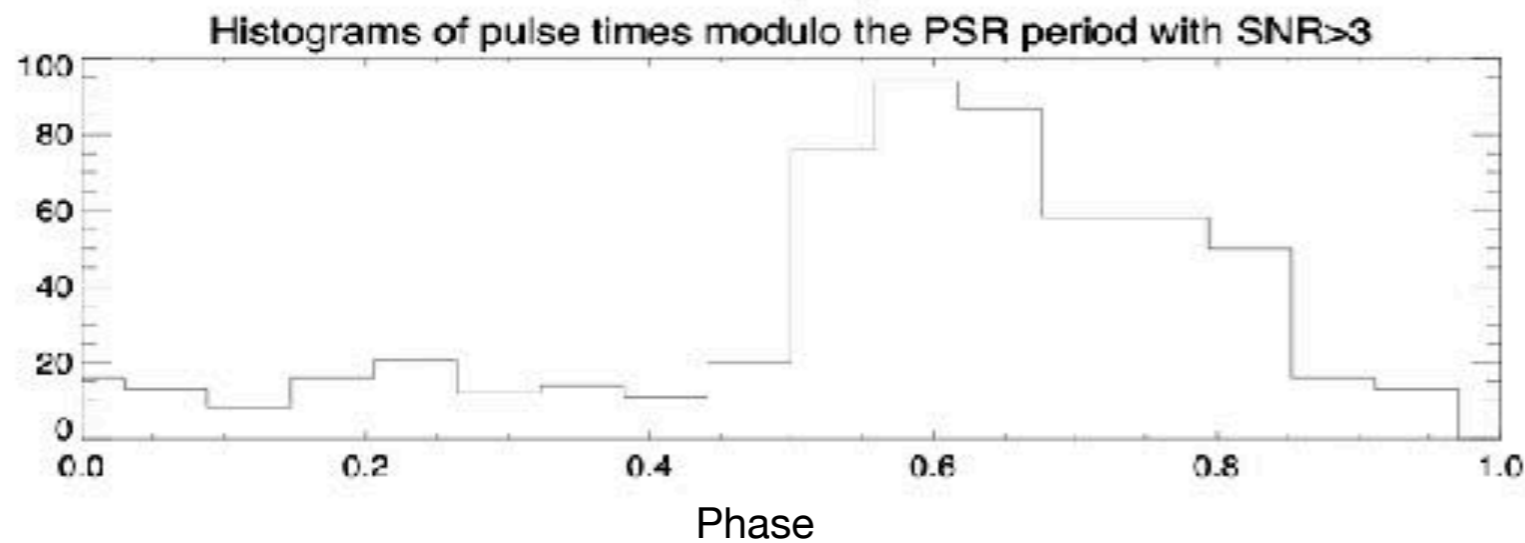
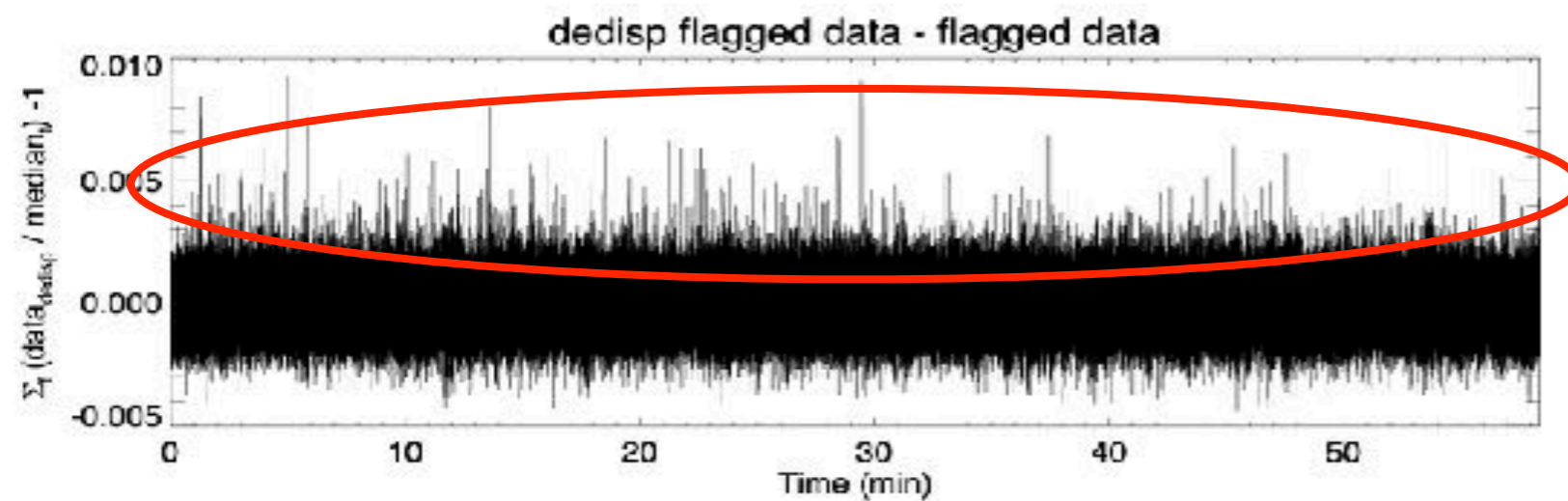
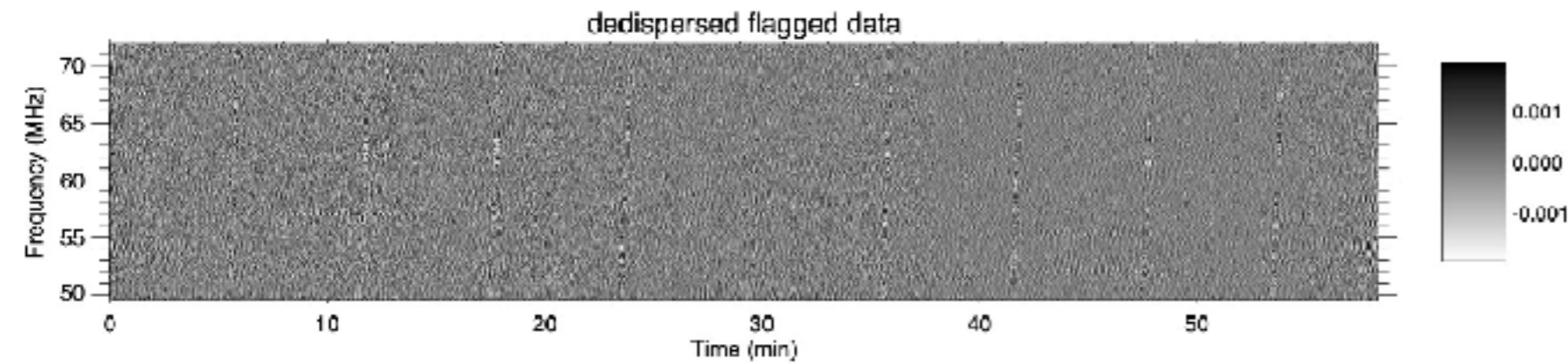


+ filtering

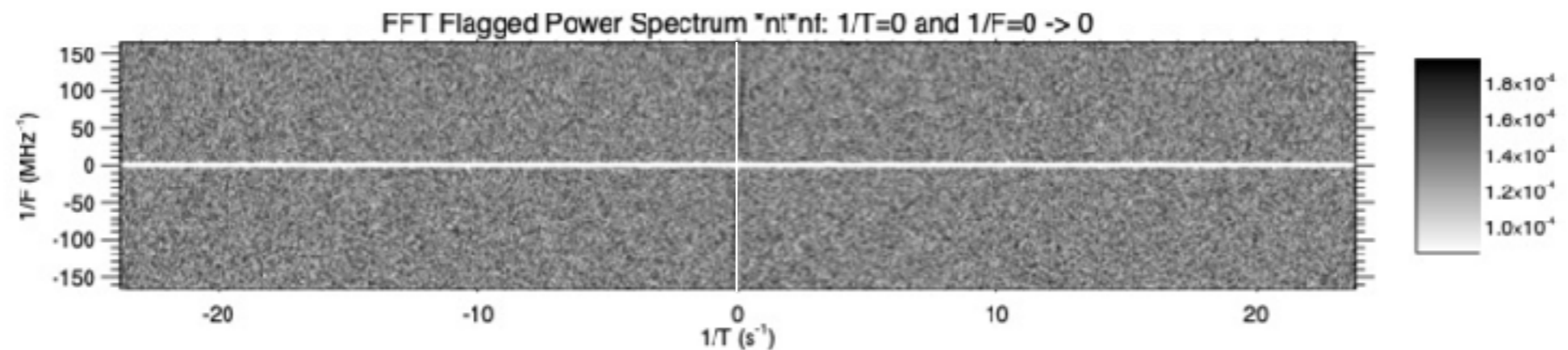
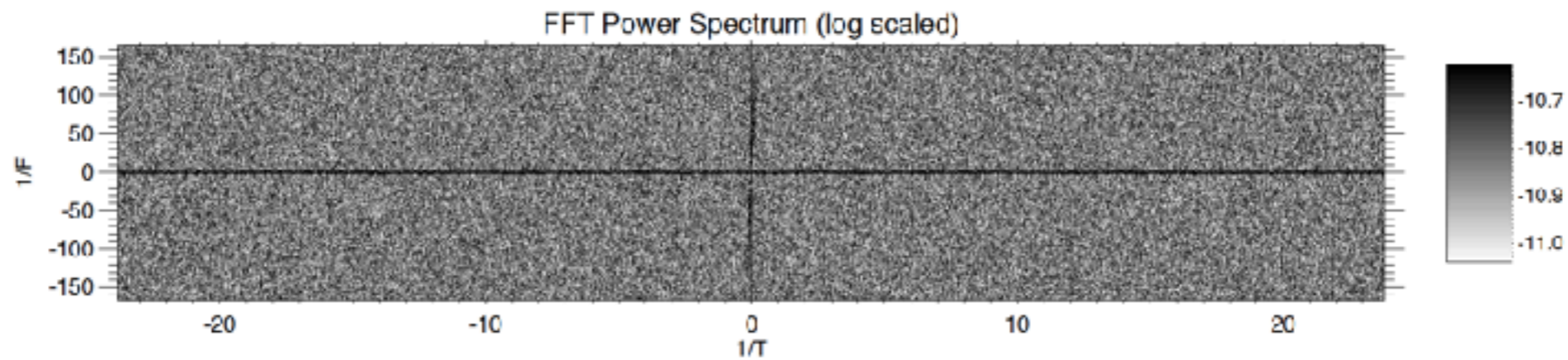
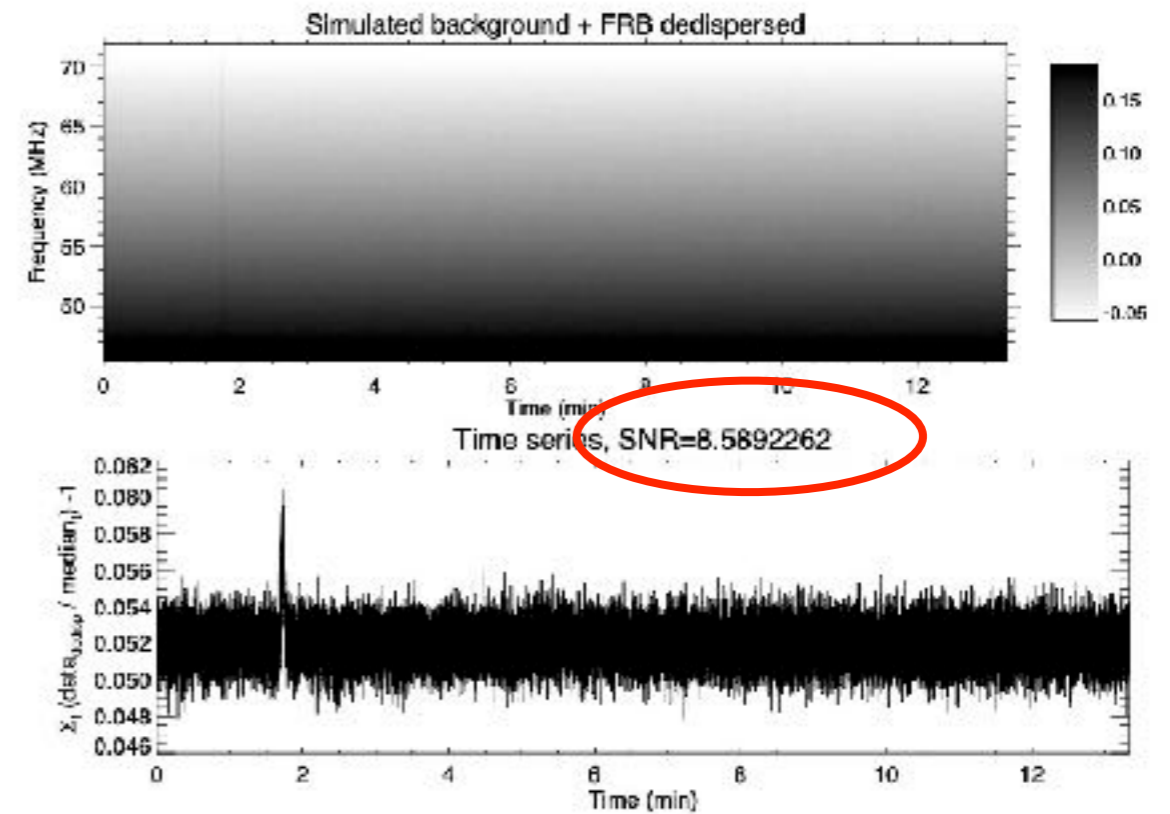
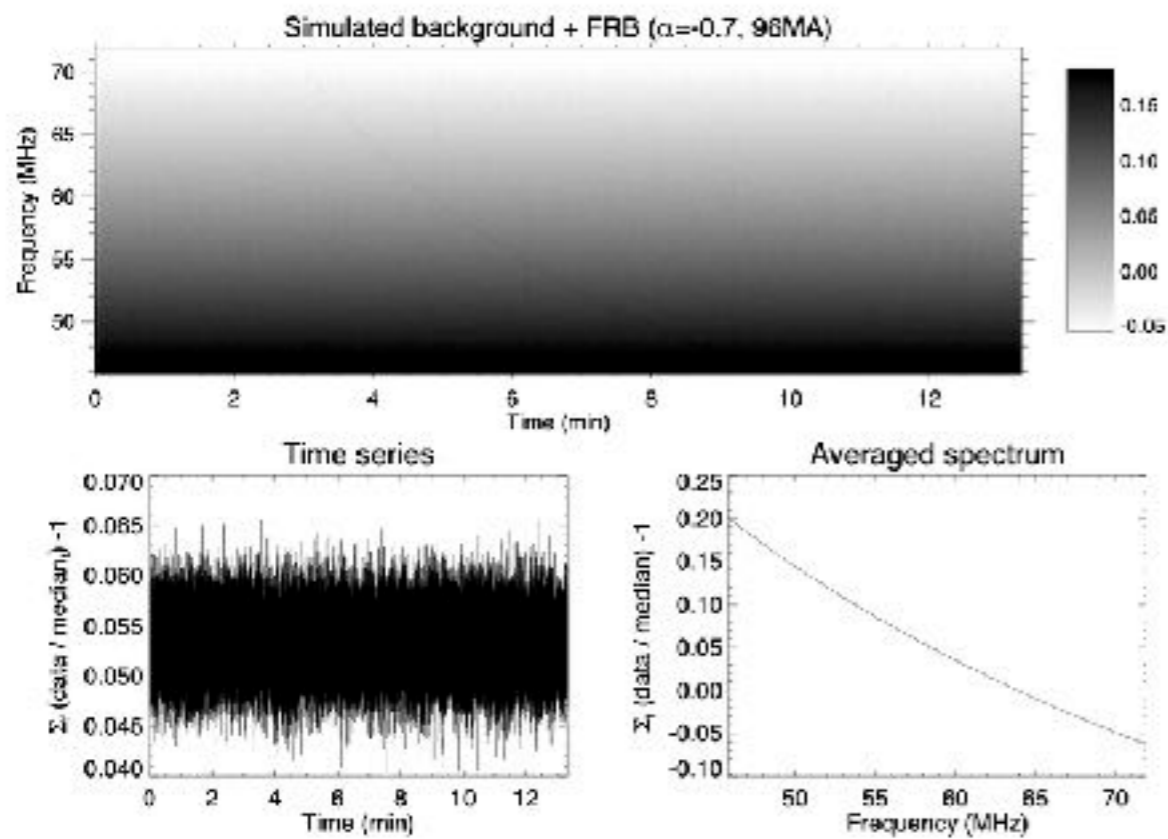


Benchmarking on PSR0329+54 : FFT filtering

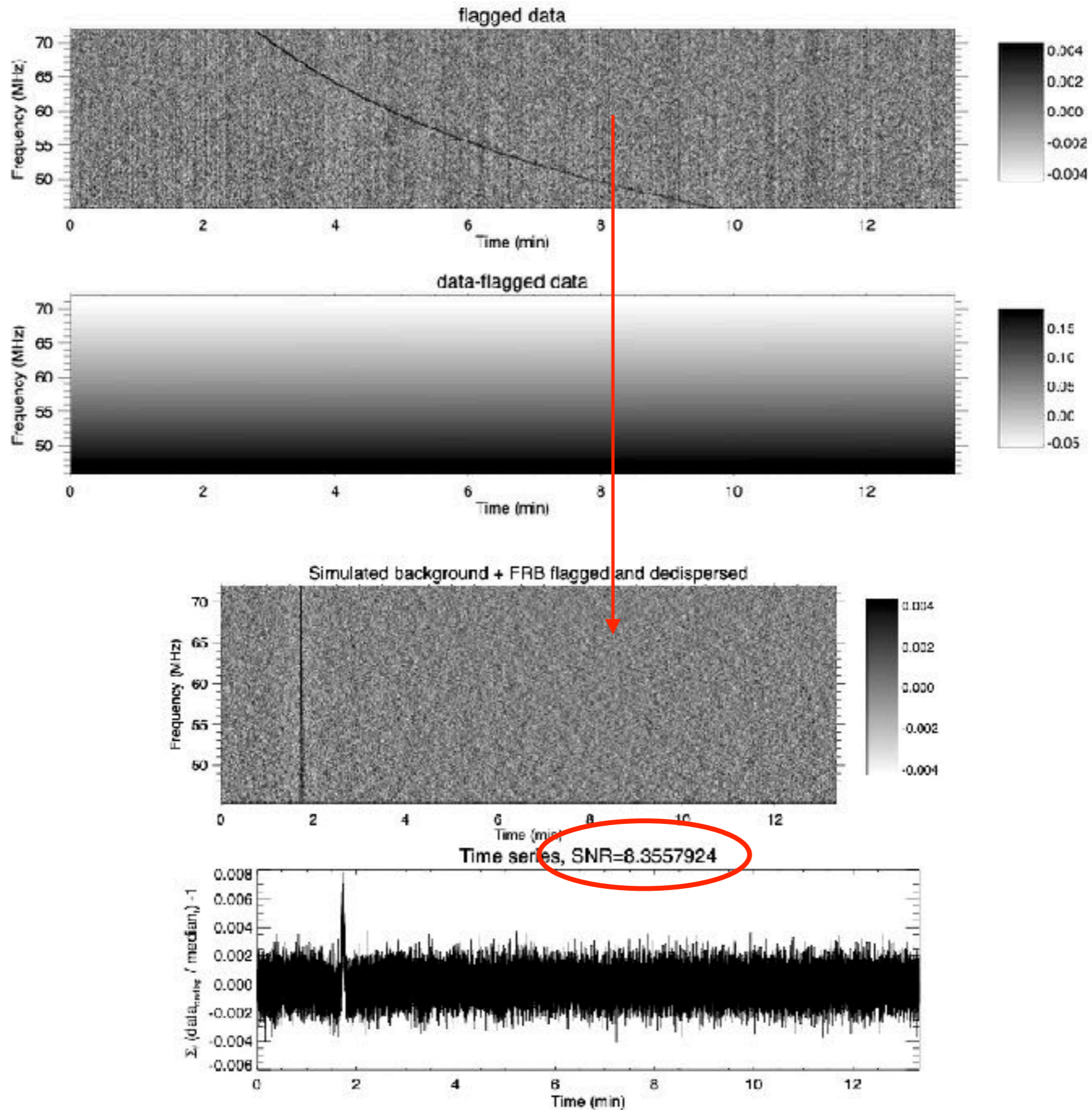
Filtered data dedispersed



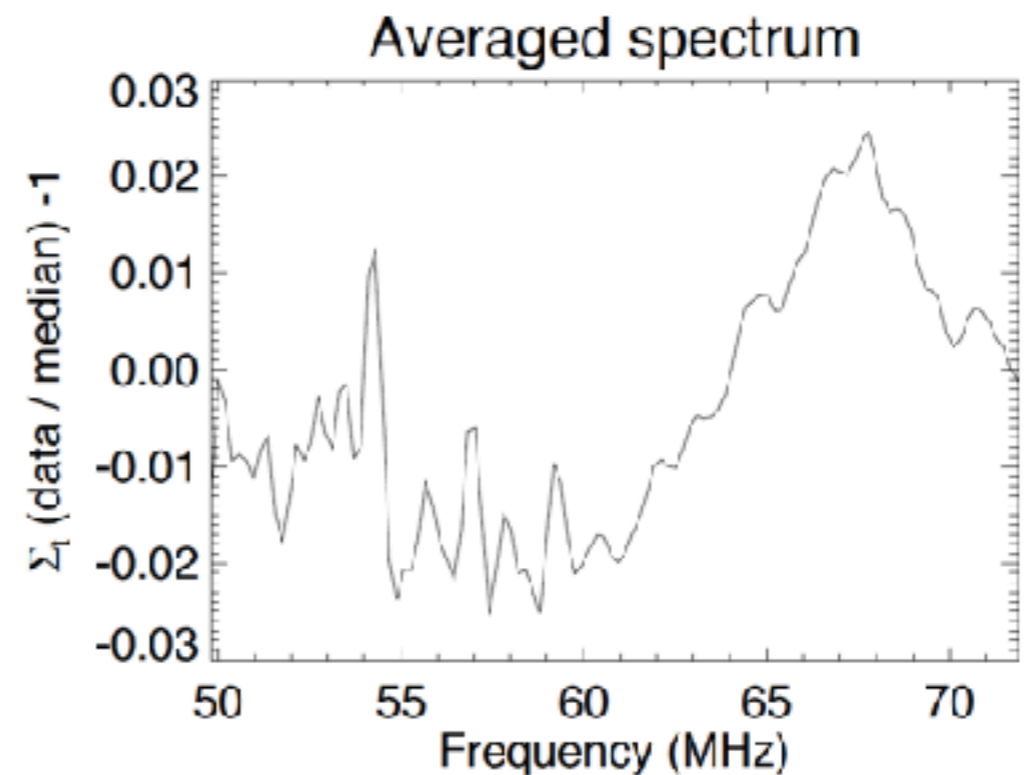
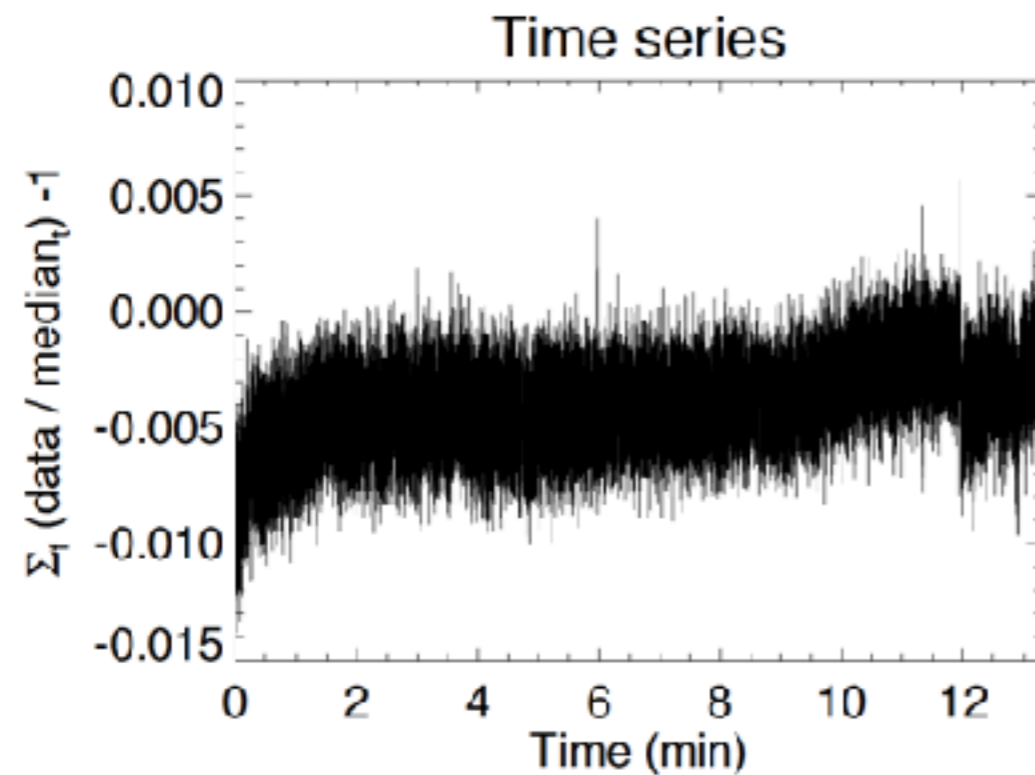
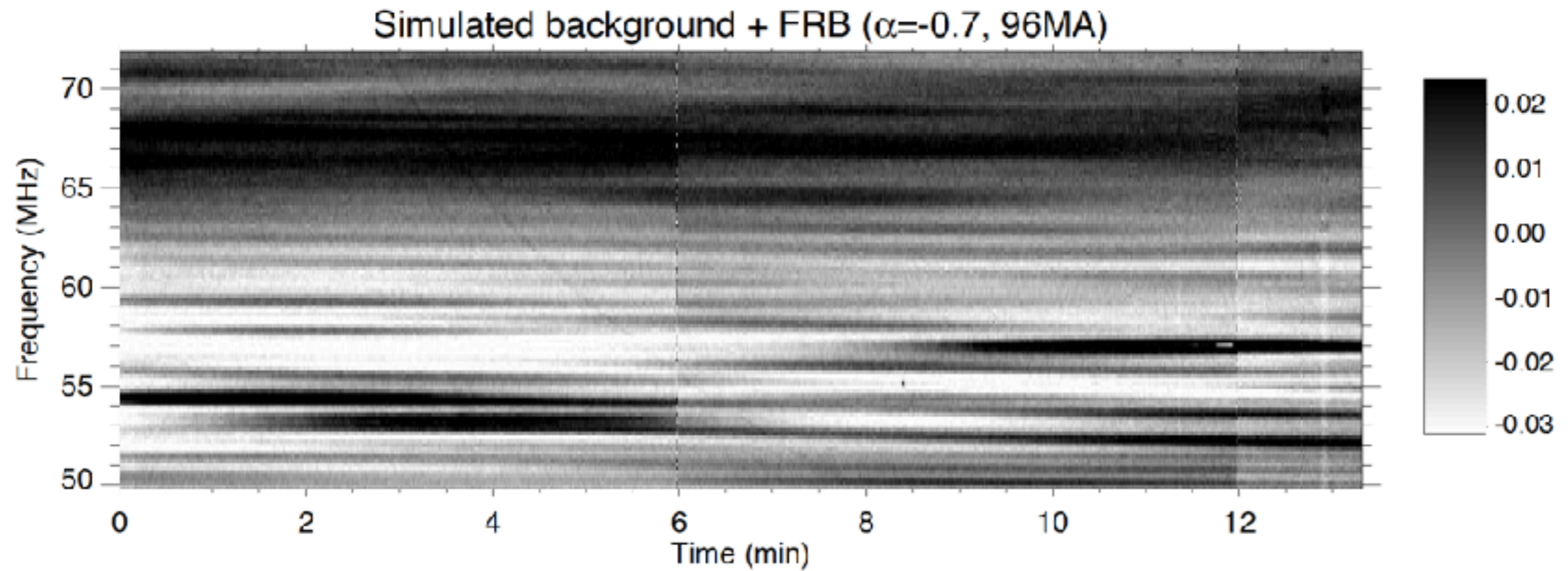
Application to FRB : simulations



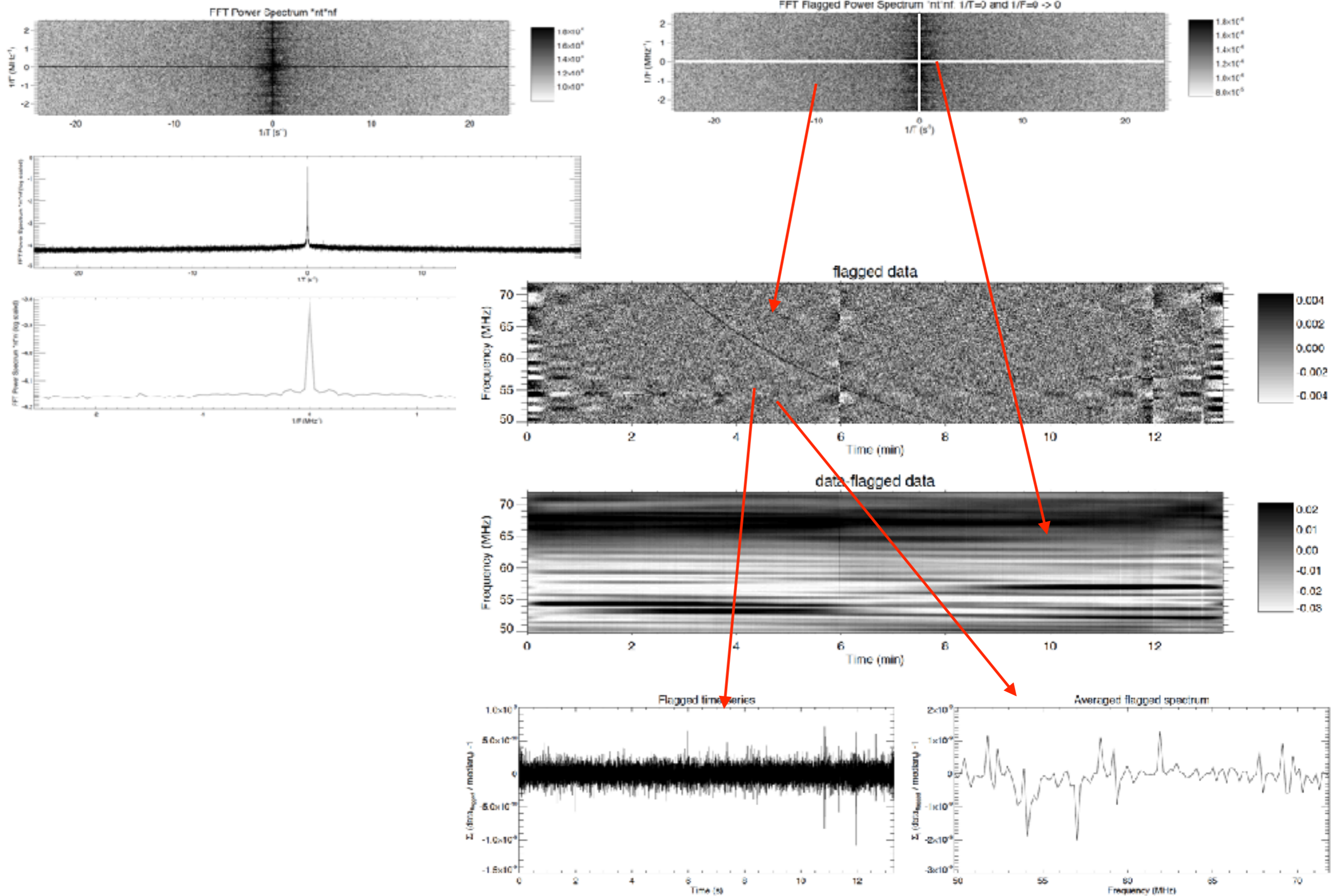
Application to FRB : simulations



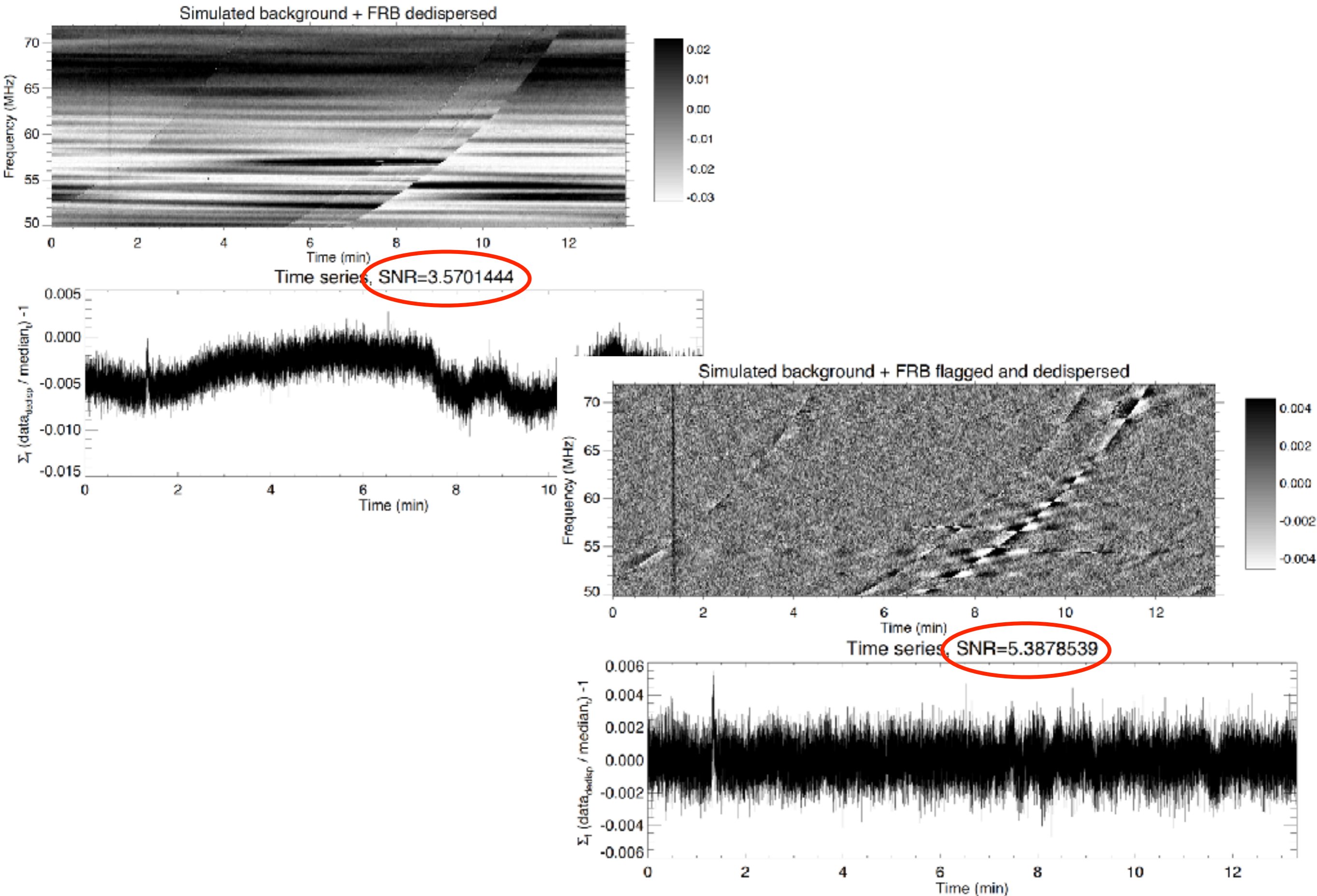
Application to FRB : observations + simulated FRB



Application to FRB : observations + simulated FRB



Application to FRB : observations + simulated FRB



NenuFAR observations : ongoing (Early Science phase)

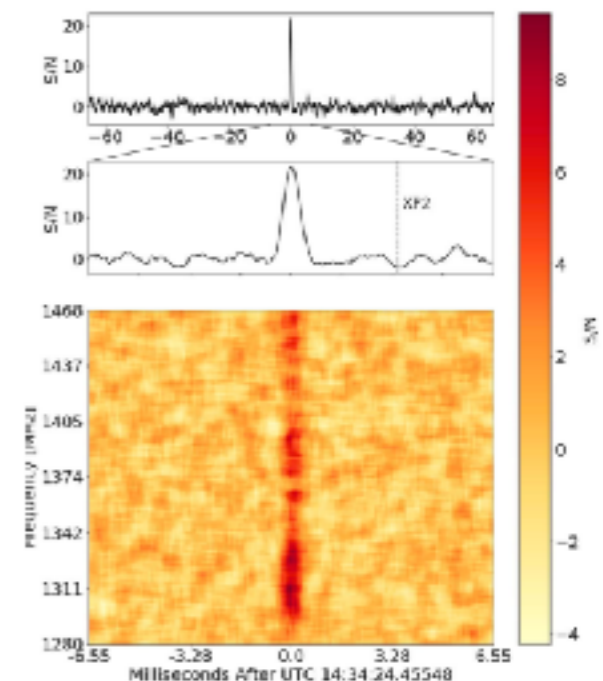
Targets	position	DM (pc.cm ⁻³)	Fluence (Jy.ms)	Peak flux (Jy)
FRB180814	R.A= 04h22m22s $\delta = +73^{\circ}4'$	190	10 – 60	1
FRB181030	R.A= 10h54m07s $\delta = +73^{\circ}44' \pm 26''$	103.5	7 – 30	3.2
FRB121102	R.A= 5h32m09s $\delta = +33^{\circ}05'13''$	560	0.11	0.03
FRB190303	R.A= 13h53m00s $\delta = +48^{\circ}15'00''$	222	2 – 3	0.5
FRB180916	R.A= 01h58m00s $\delta = +65^{\circ}44'00''$	350	2 – 30	0.5 – 4
FRB151125	R.A= 01h31m00s $\delta = +30^{\circ}58'48''$	273	2450	0.54 (> 1600ms)
Zenith pointing	local zenith	blind search	-	-
SGR1935+2154	R.A= 19h34m55.68s $\delta = +21^{\circ}53'48.2''$	332.7	480k	110k
FRB190907	R.A= 08h09m00s $\delta = +46^{\circ}16'00''$	311	1.7	0.3
FRB181017	R.A= 22h06m00s $\delta = +08^{\circ}50'34''$	240	31	89
FRB180908	R.A= 12h32m00s $\delta = +74^{\circ}12'00''$	196	2.7	0.6
FRB20200120	R.A= 09h57m56.7s $\delta = +68^{\circ}49'32''$	87.2	2	1.8

→ we are sensitive to a few 10s Jy

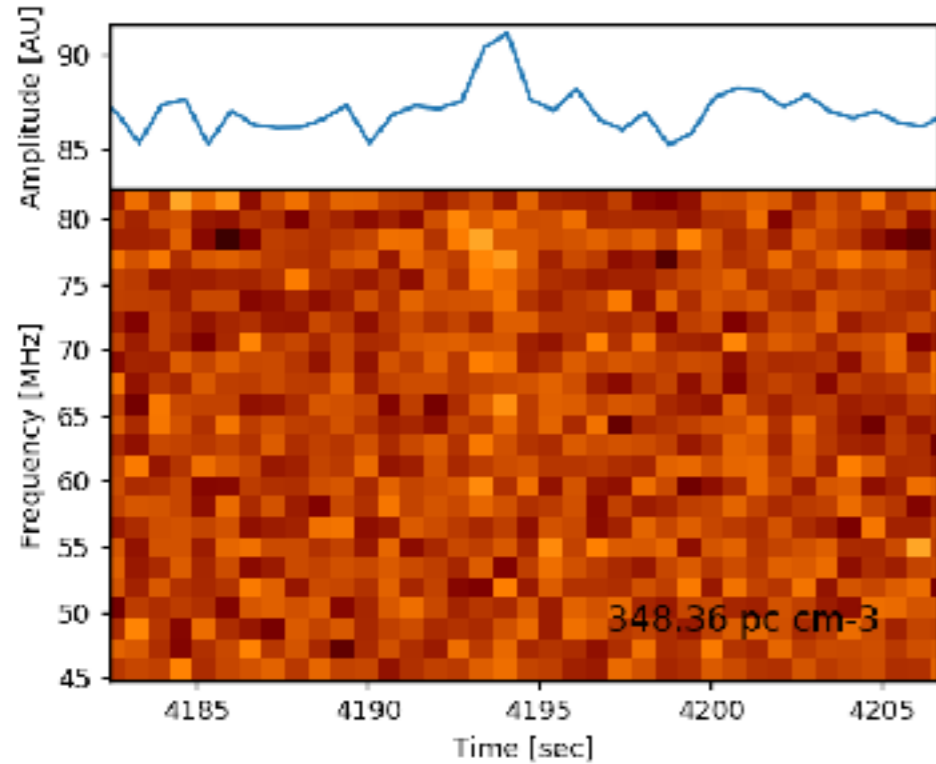
and there should be plenty

SGR 1935+2154 GF (=FRB 20200428),
542 Jy, Galactic magnetar

[Bochenek et al., Nature, 2020]



False alert: 20210322

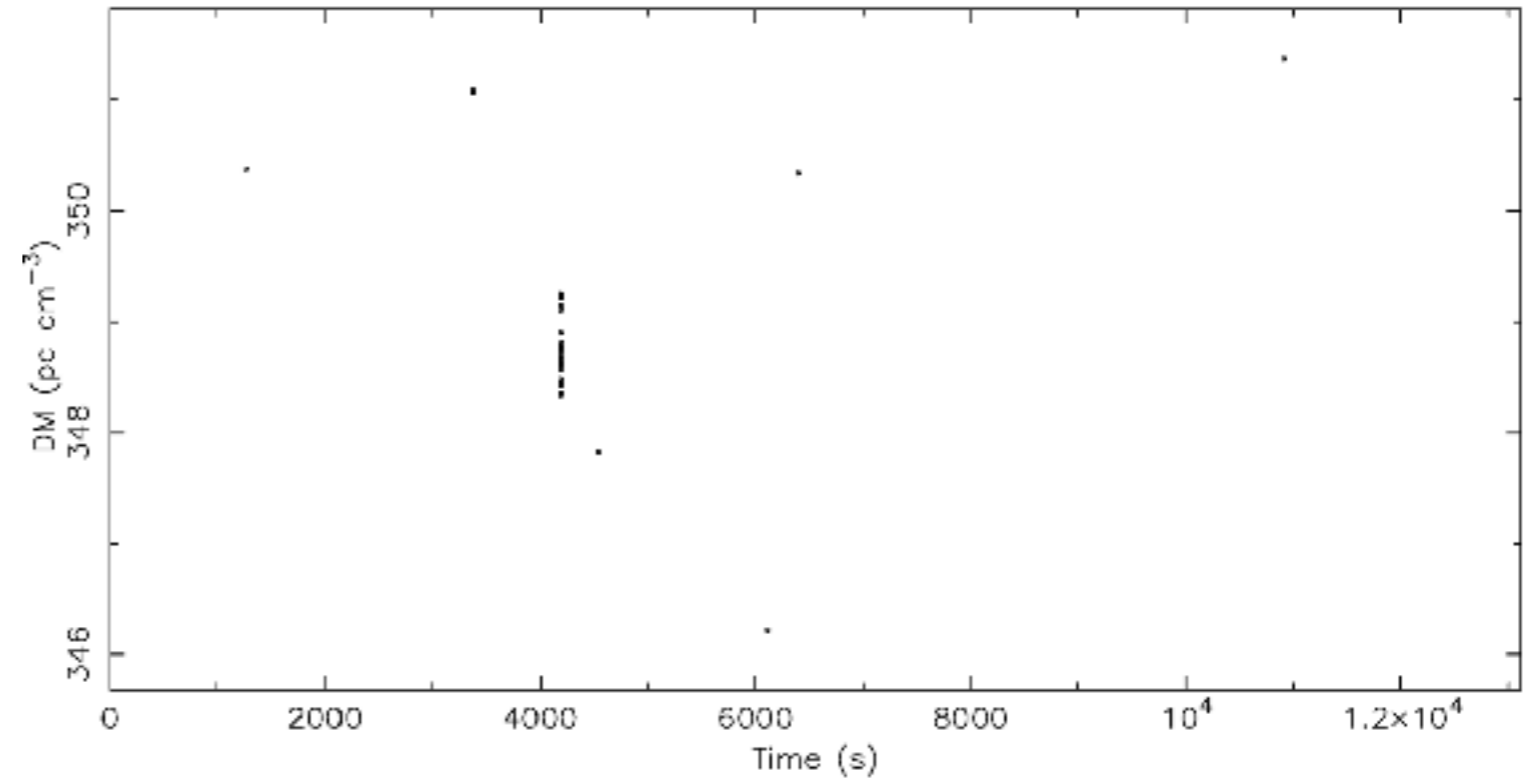
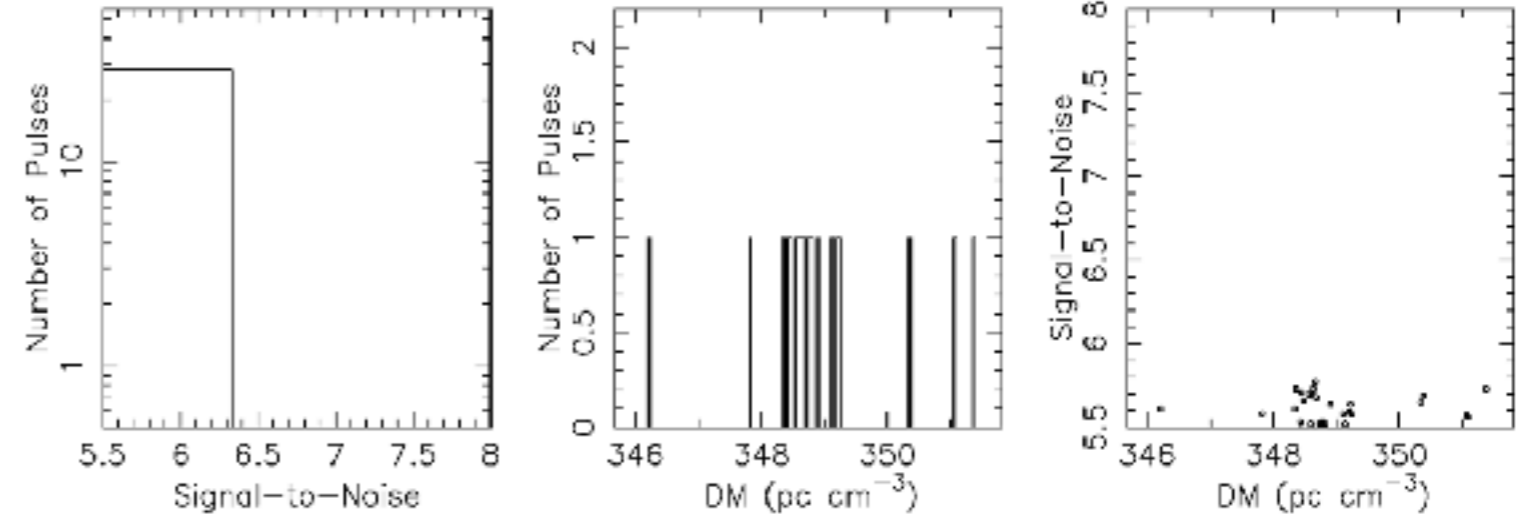


Single pulse results for 'search'

Source: FRB180916
Telescope: nenufar
Instrument: LUPP

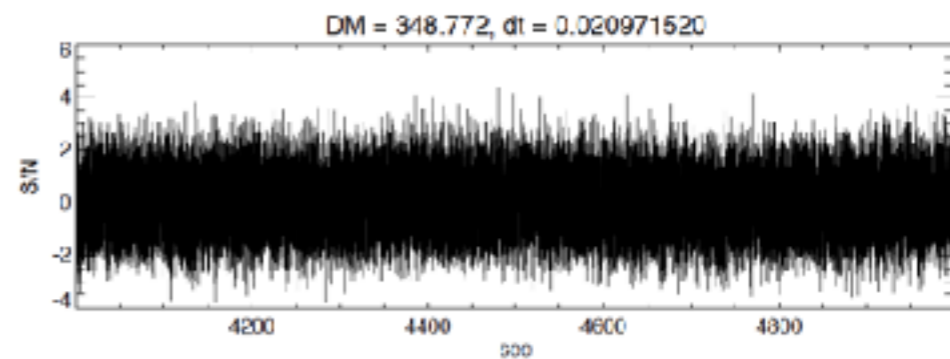
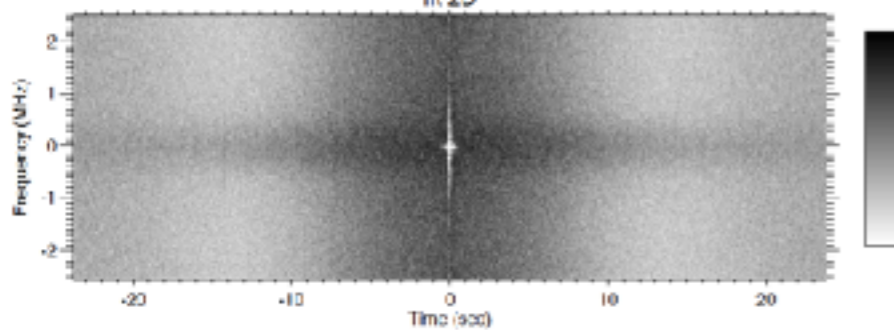
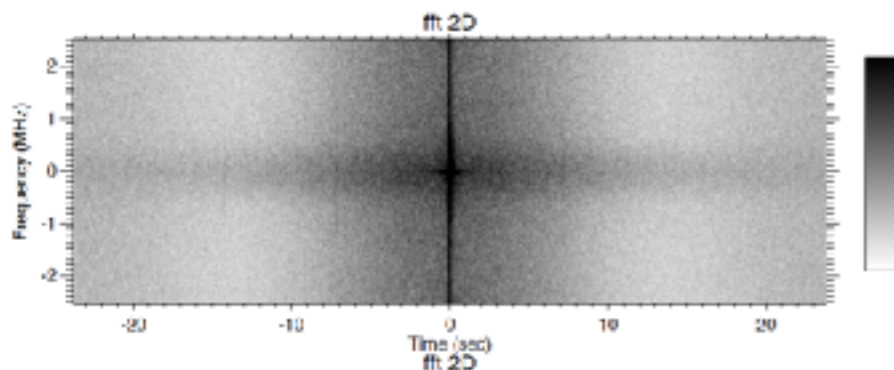
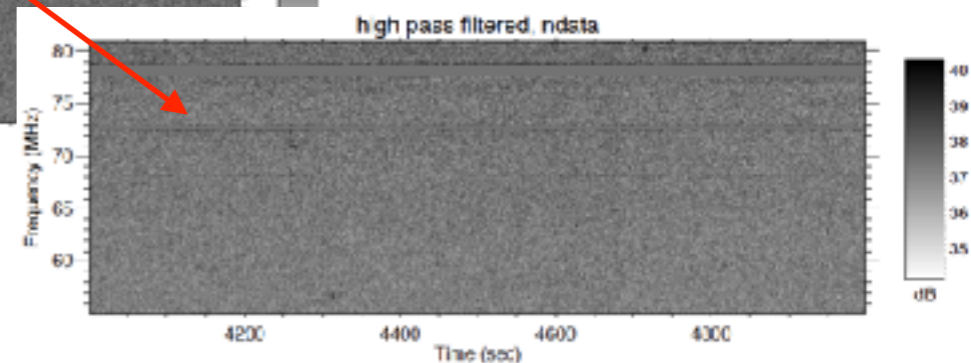
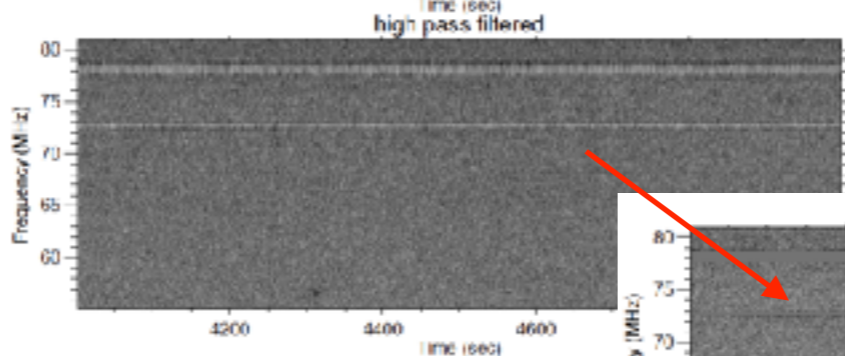
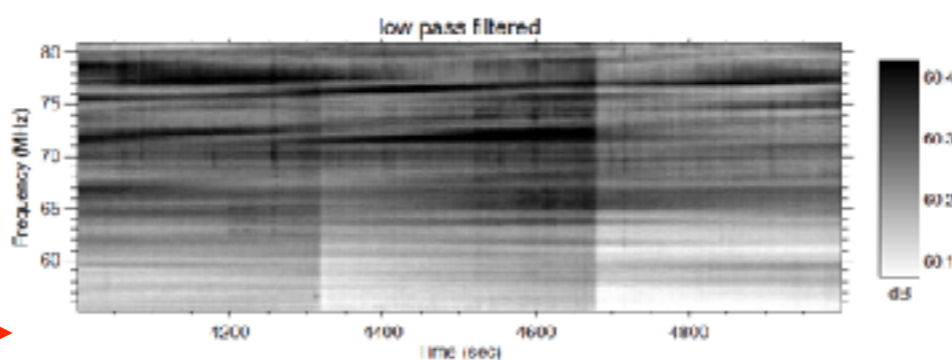
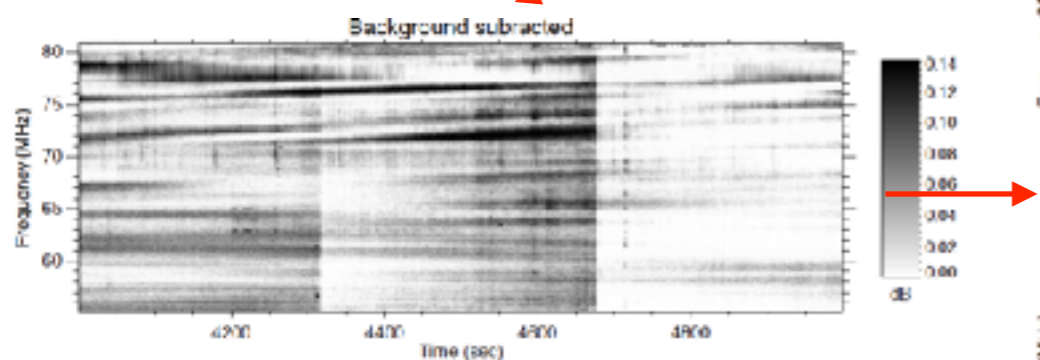
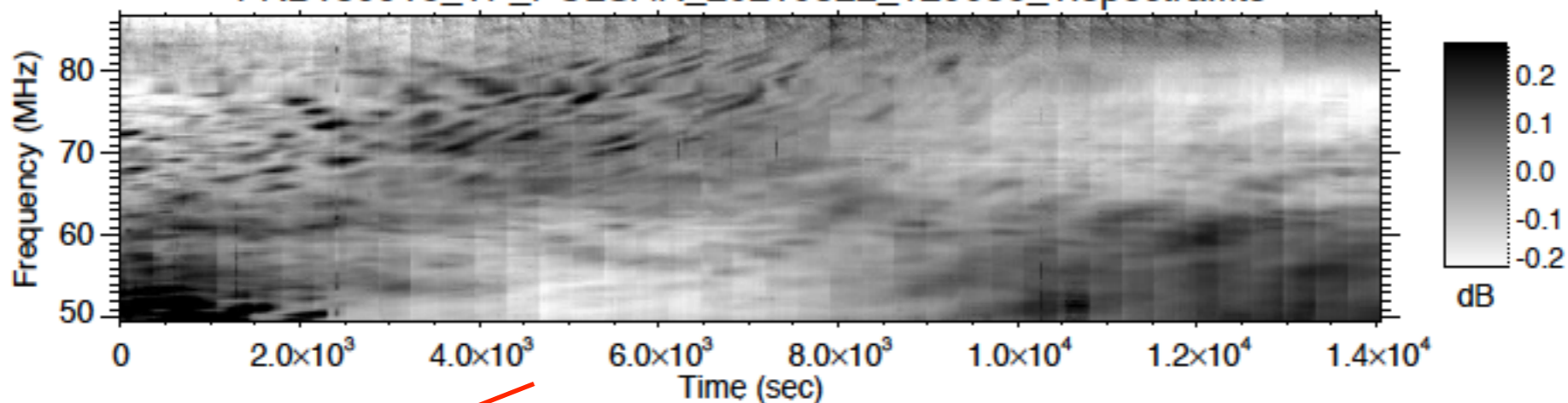
RA (J2000): 01:57:60.0000
DEC (J2000): 65:43:59.9988
MJD_{topo}: 59295.501504629690

N samples: 156416
Sampling time: 83886.00 μ s
Freq_{ctr}: 63.6 MHz

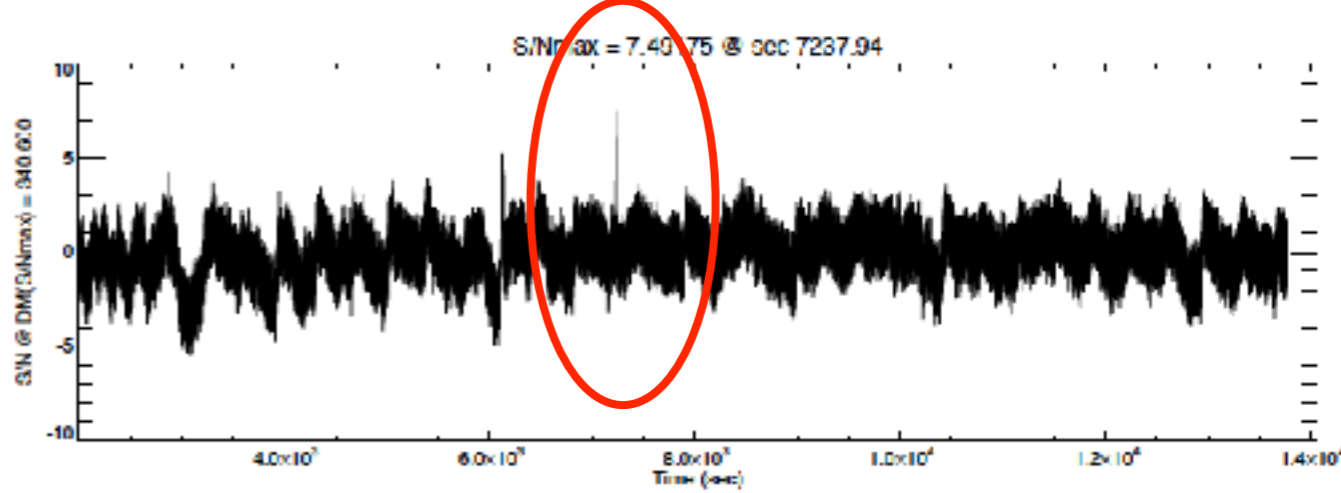
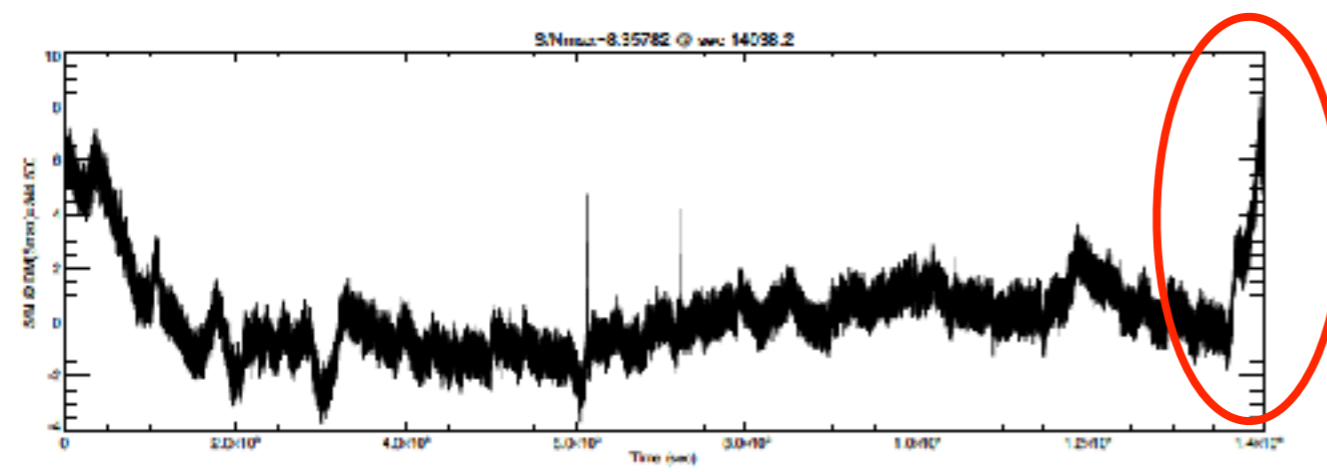
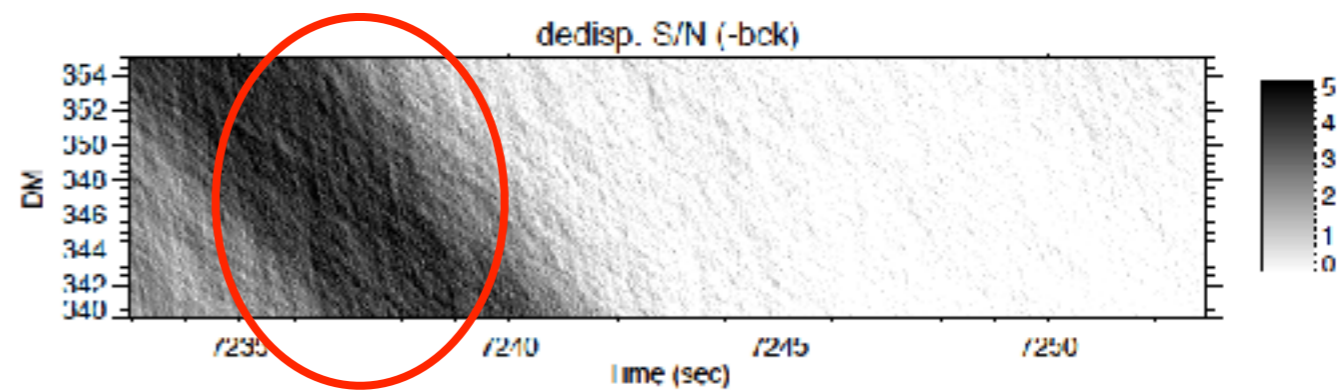
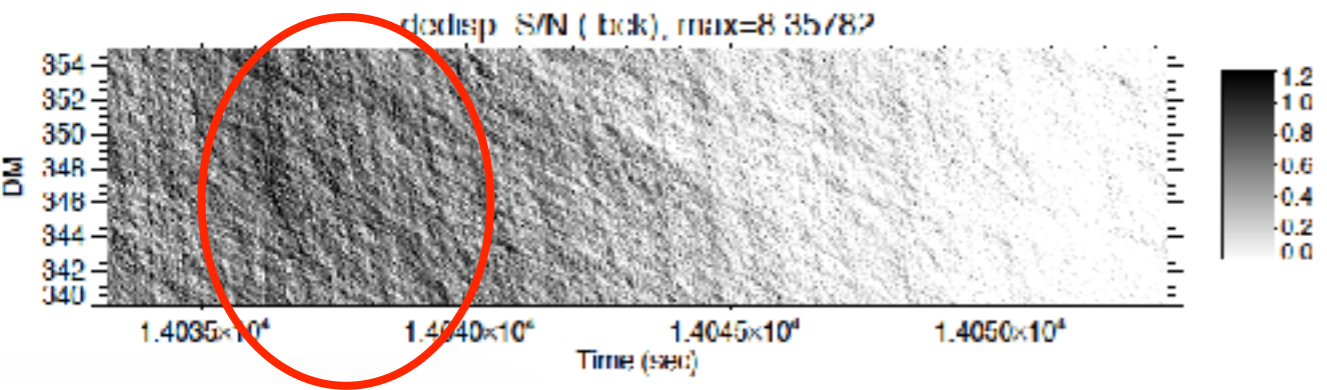
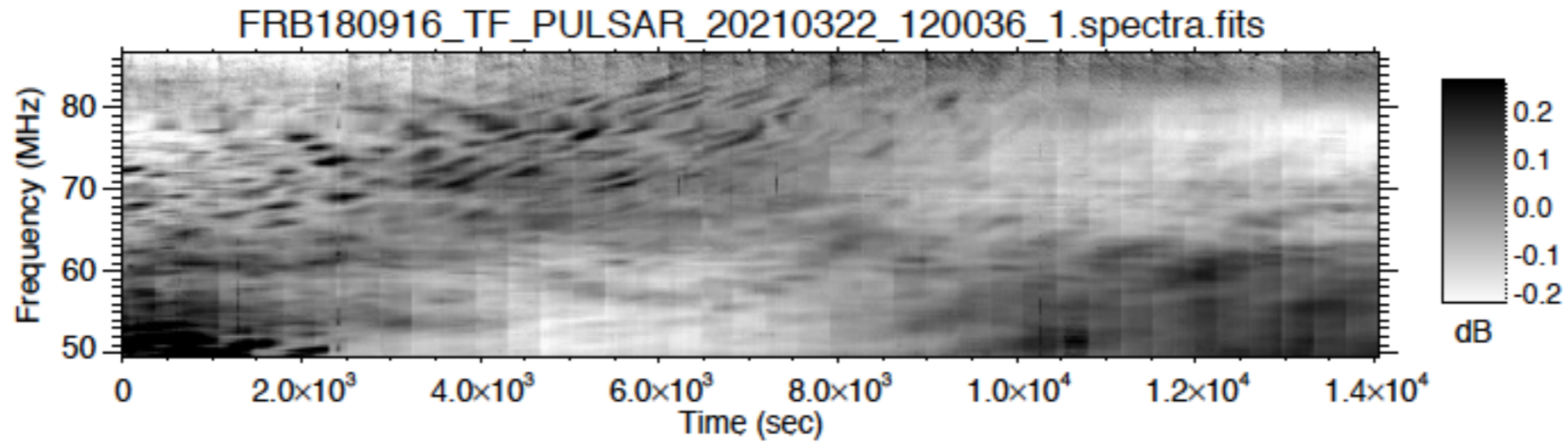


False alert: 20210322

FRB180916_TF_PULSAR_20210322_120036_1.spectra.fits



False alert: 20210322



Systematic analysis to be done.

Expanding the team:

- Valentin Decoene
- Philippe Zarka
- Jean-Mathias Griebmeier
- Fabrice Mottez
- Kumiko Kotera
- Olivier Martineau

+

- Cherry Ng
- Guillaume Voisin

(+ coll. L. Bondonneau, M. Brionne)

To be continued...