Pulsars and Fast Transients with the MWA

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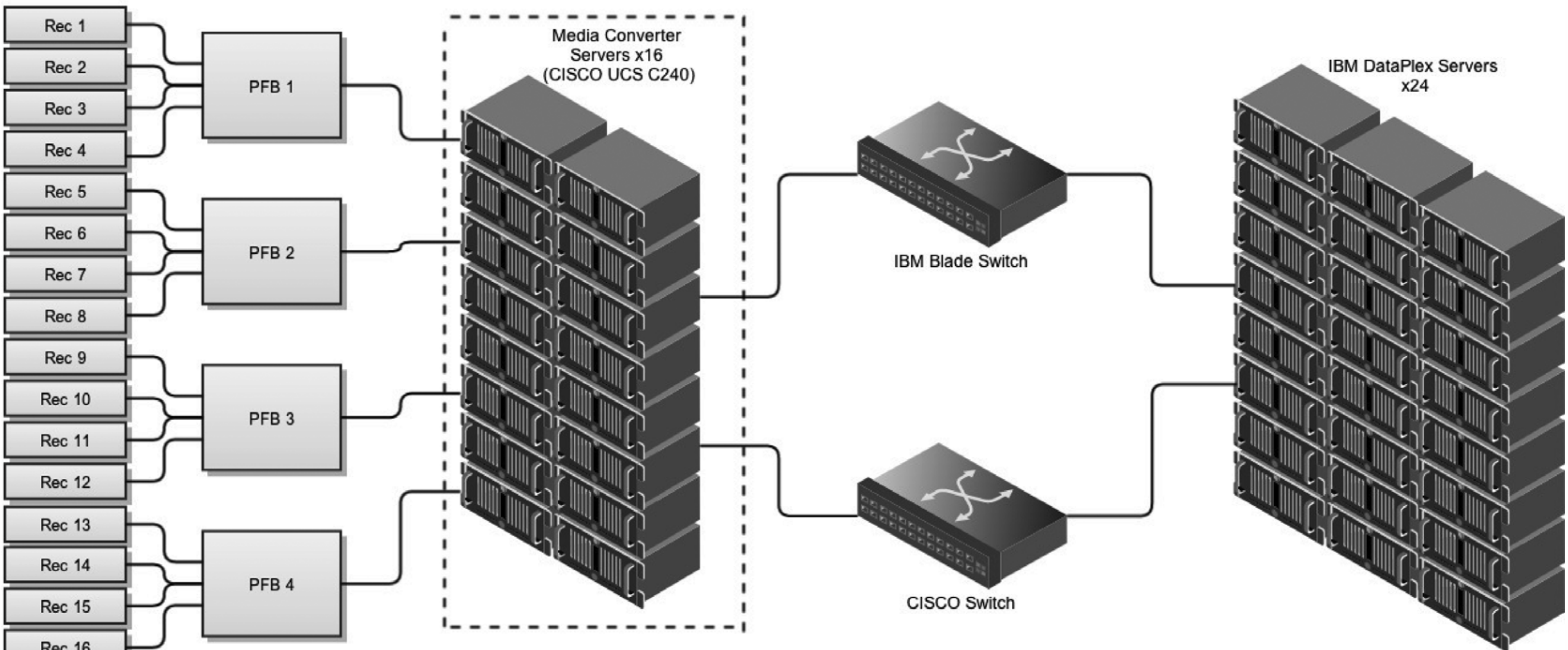
CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

MWA
MURCHISON WIDEFIELD ARRAY

Curtin University

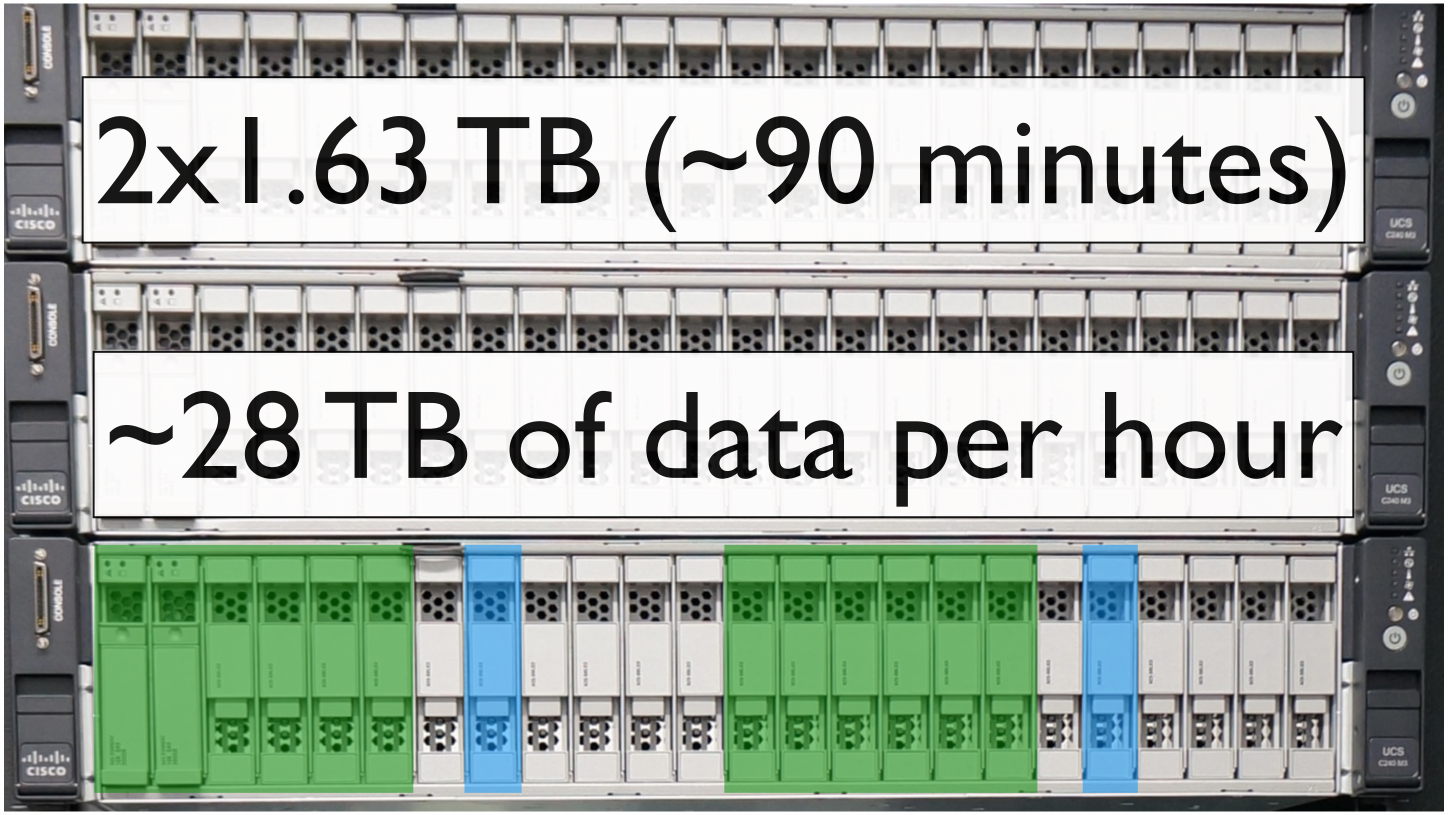
MWA Voltage Capture (VCS)

MWA Voltage Capture



Tremblay et al. 2015

MWA Voltage Capture



Data Capture RAIDs (2x6x300 GB)

Data Product Drives (2x1 TB)

MWA VCS Science

CAASTRO ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

Publications from the VCS commissioning:

Millisecond pulsar PSR J0437-4715 (Bhat et al. 2014, ApJ, 791, L32)
VCS system description + pulsar detections (Tremblay et al. 2015, PASA, 32, 5)
Crab giants from MWA+Parkes observations (Oronsaye et al. 2015, ApJ, 809, 51)

Currently active programs (2015):

MSP observations
Targeted searches (pulsars and RRATs of interest)
FRB searches

Longer-term programs (2016+)

Routine observations of PTA MSPs
Continued searches for FRBs
A low-frequency census southern pulsars
Polarimetric studies of pulsars
Pulsar emission mechanism studies
…
Profit

VCS Recording + reprocessing = multiple science projects using the same data

MWA Single Pulses

MWA-VCS and FRBs

Prospects for the Detection of Fast Radio Bursts with the Murchison Widefield Array

Cathryn M. Trott[1,2], Steven J. Tingay[1,2] and Randall B. Wayth[1]

International Centre for Radio Astronomy Research, Curtin University, Bentley WA 6845, Australia

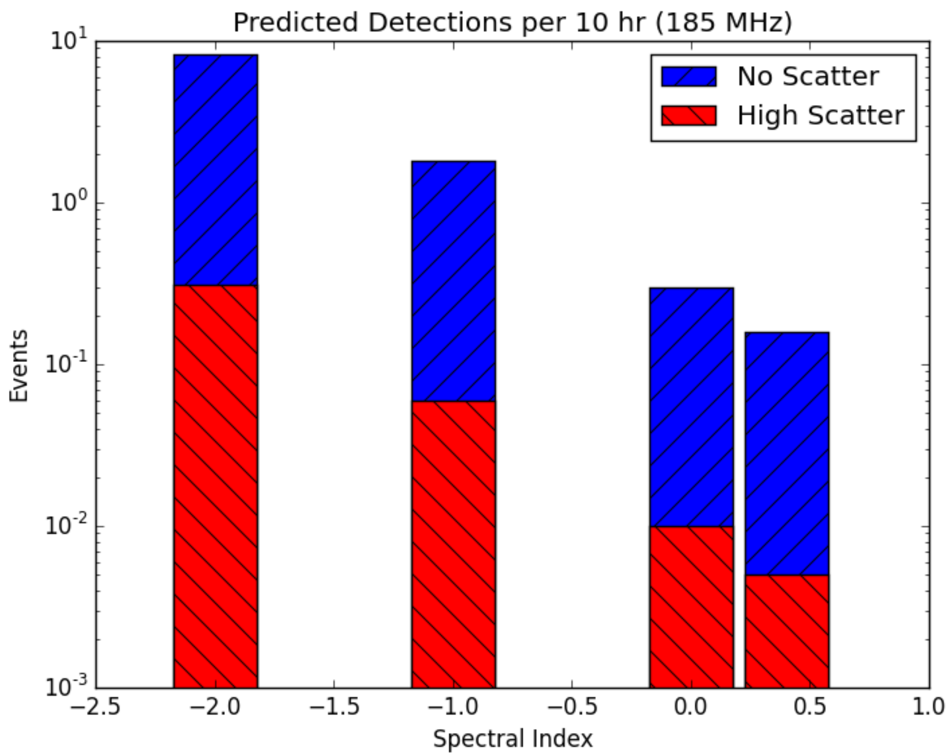
Fast Radio Burst
nals, presumed to be
discovery of six hig
scope suggests that
Widefield Array (M

α	Scatter	Coherent	Incoherent	Imaging
-2	Zero	88 ± 19	16 ± 8	38 ± 12
-1	Zero	23 ± 9	$3.5^{+3.0}_{-3.5}$	$8.5^{+5.0}_{-6.0}$
0	Zero	$5.6^{+4.4}_{-5.6}$	$0.7^{+1.5}_{-0.7}$	$1.7^{+1.8}_{-1.7}$
-2	High	$8.3^{+4.9}_{-5.9}$	$1.7^{+1.8}_{-1.7}$	$3.3^{+3.0}_{-3.3}$
-1	High	$2.5^{+3.0}_{-2.5}$	$0.4^{+1.0}_{-0.4}$	$0.8^{+1.5}_{-0.8}$
0	High	$0.6^{+1.4}_{-0.6}$	$0.1^{+0.2}_{-0.1}$	$0.2^{+0.5}_{-0.2}$
N_{noise} ($> 7\sigma$)		2×10^5	0.5	300
N_{noise} ($> 8\sigma$)		80	2×10^{-4}	0.2

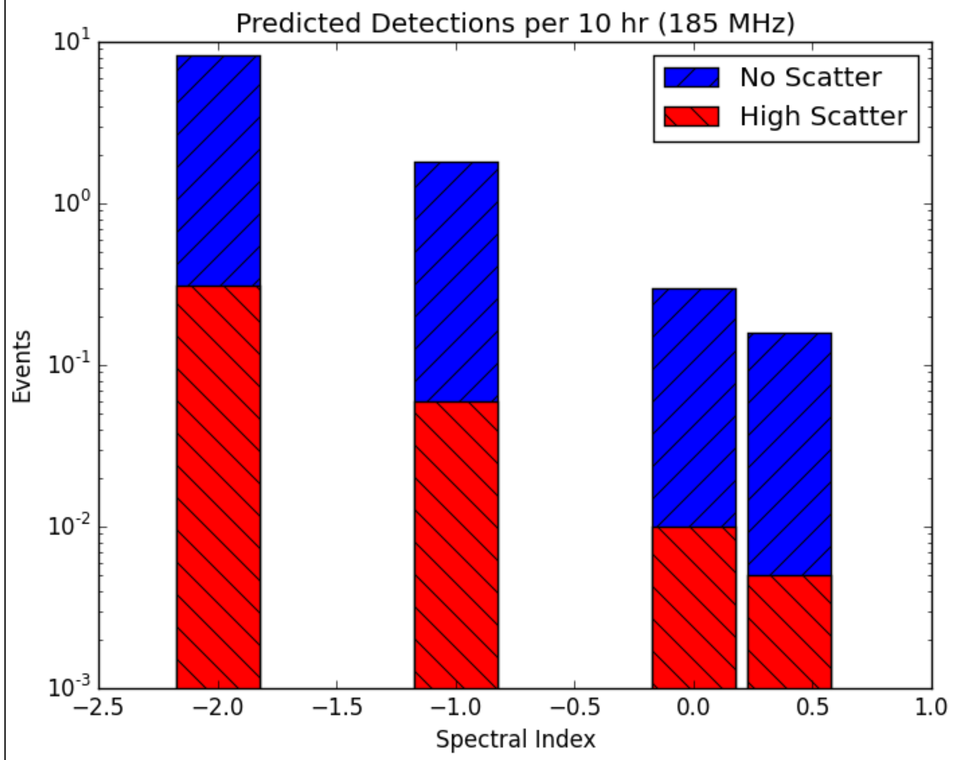
Table 2: Expected number of fast transient detections per 10-hour day with S/N ≥ 7 for each observing mode of the MWA, for zero-scatter and high-scatter scenarios, assuming ten hours per night of zenith observing. Uncertainties describe the 68% confidence intervals for a single night of observing. Also listed are the expected number of detections due to noise, N_{noise}. For the coherent case, a higher threshold of 8σ is more feasible.

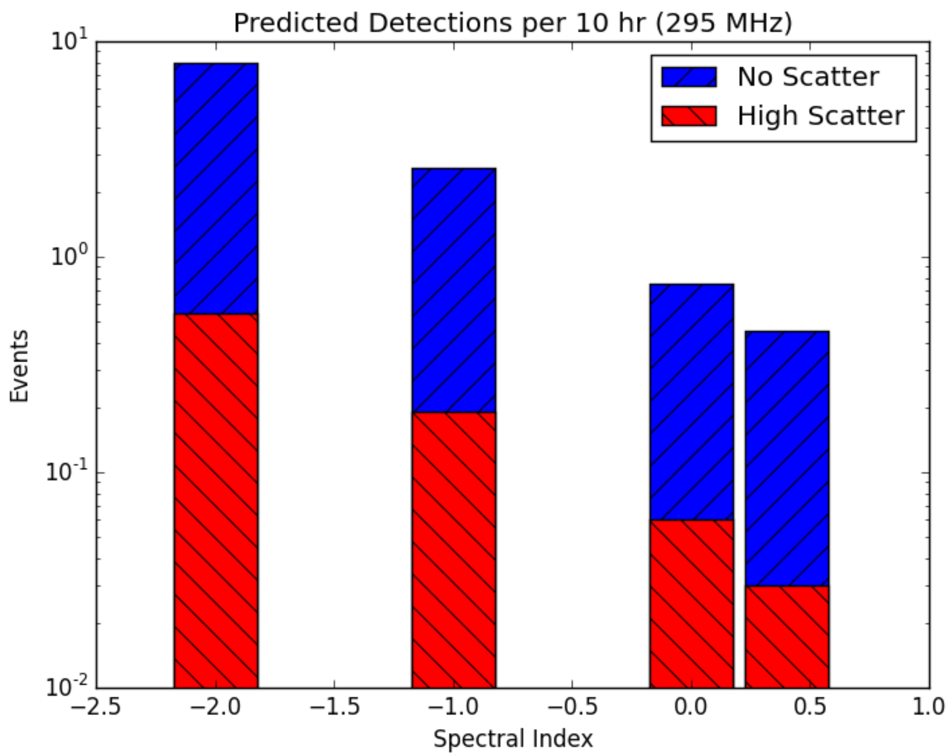
Trott, Tingay & Wayth 2013

MWA-VCS and FRBs

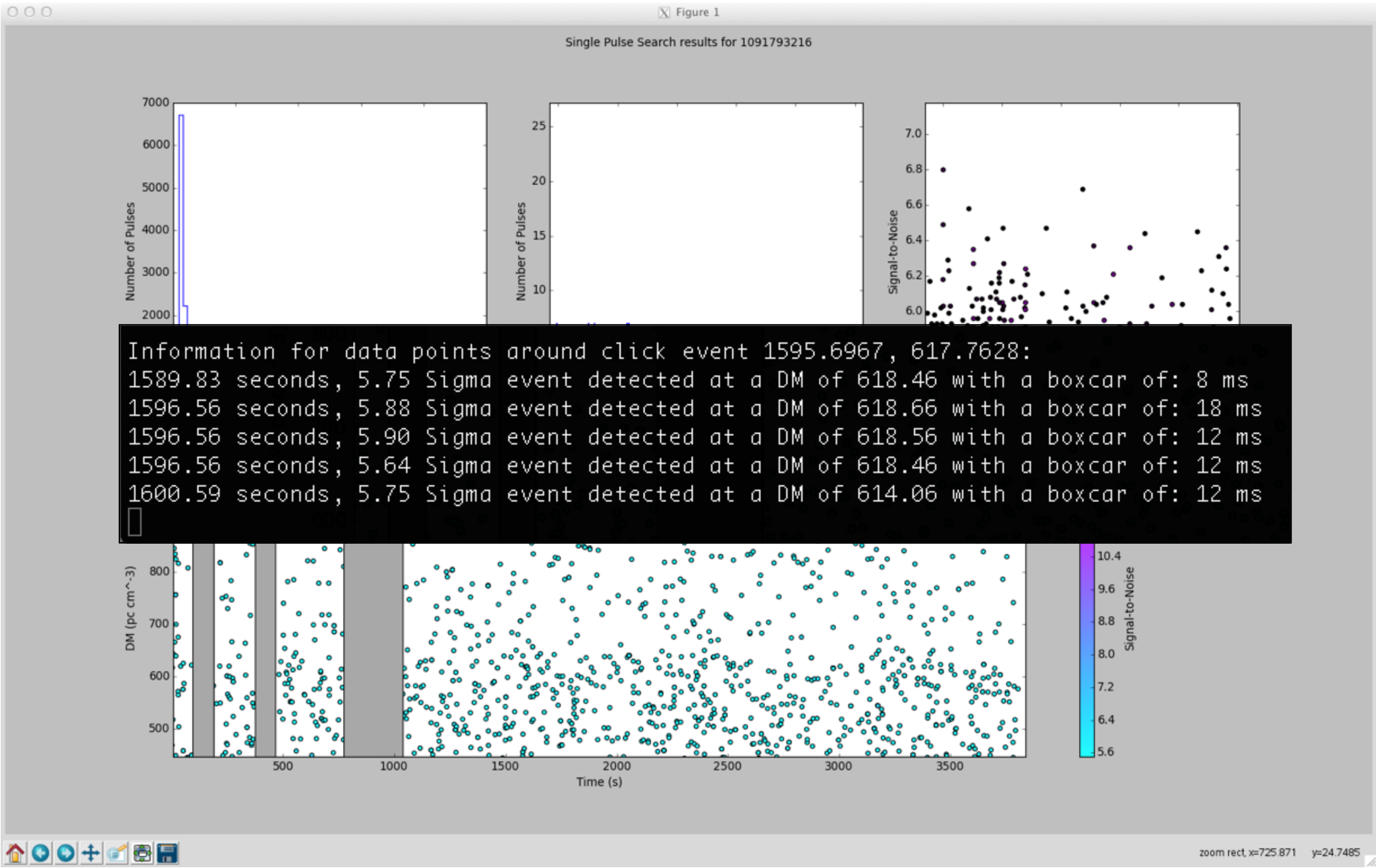


MWA-VCS and FRBs

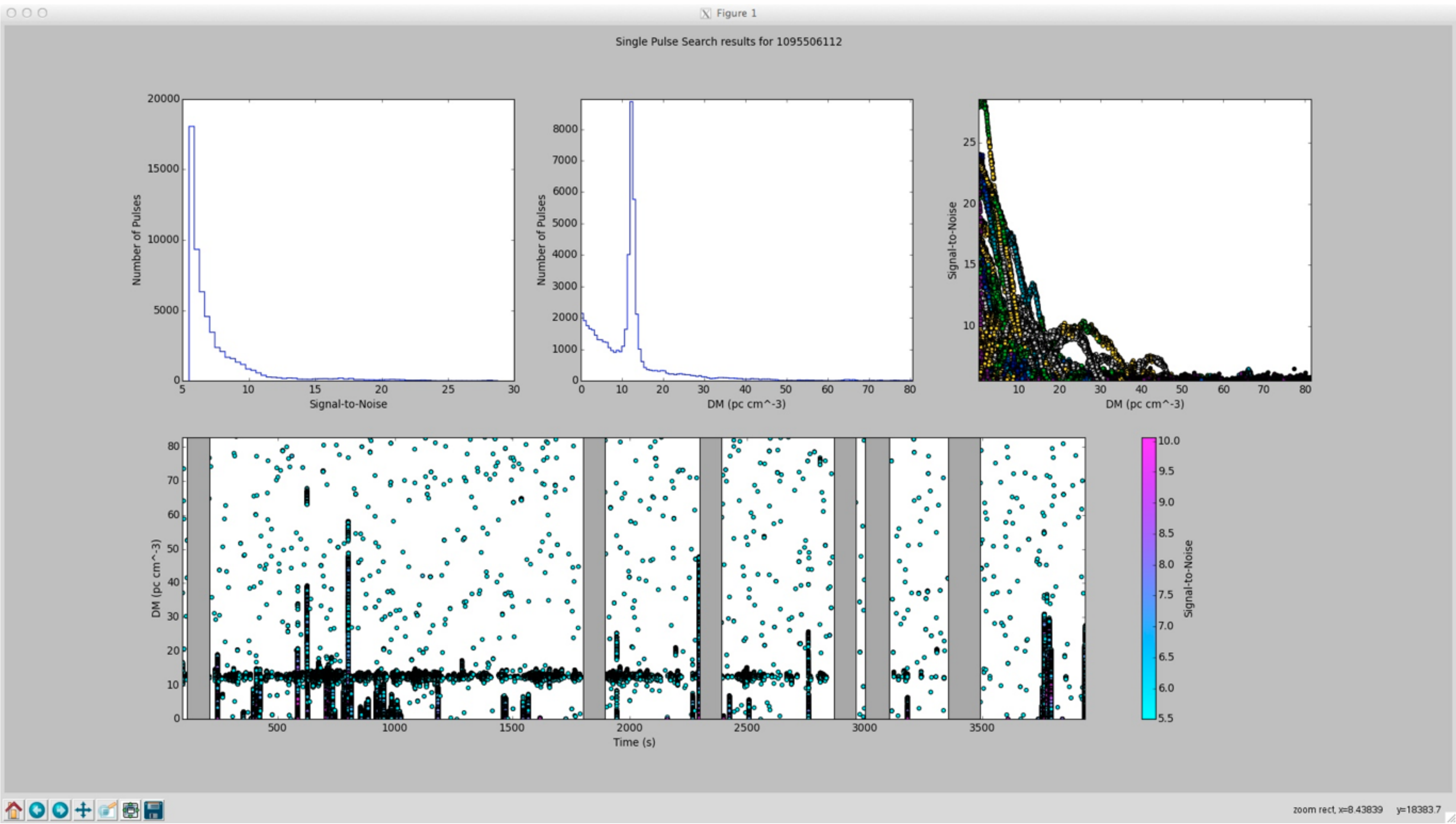




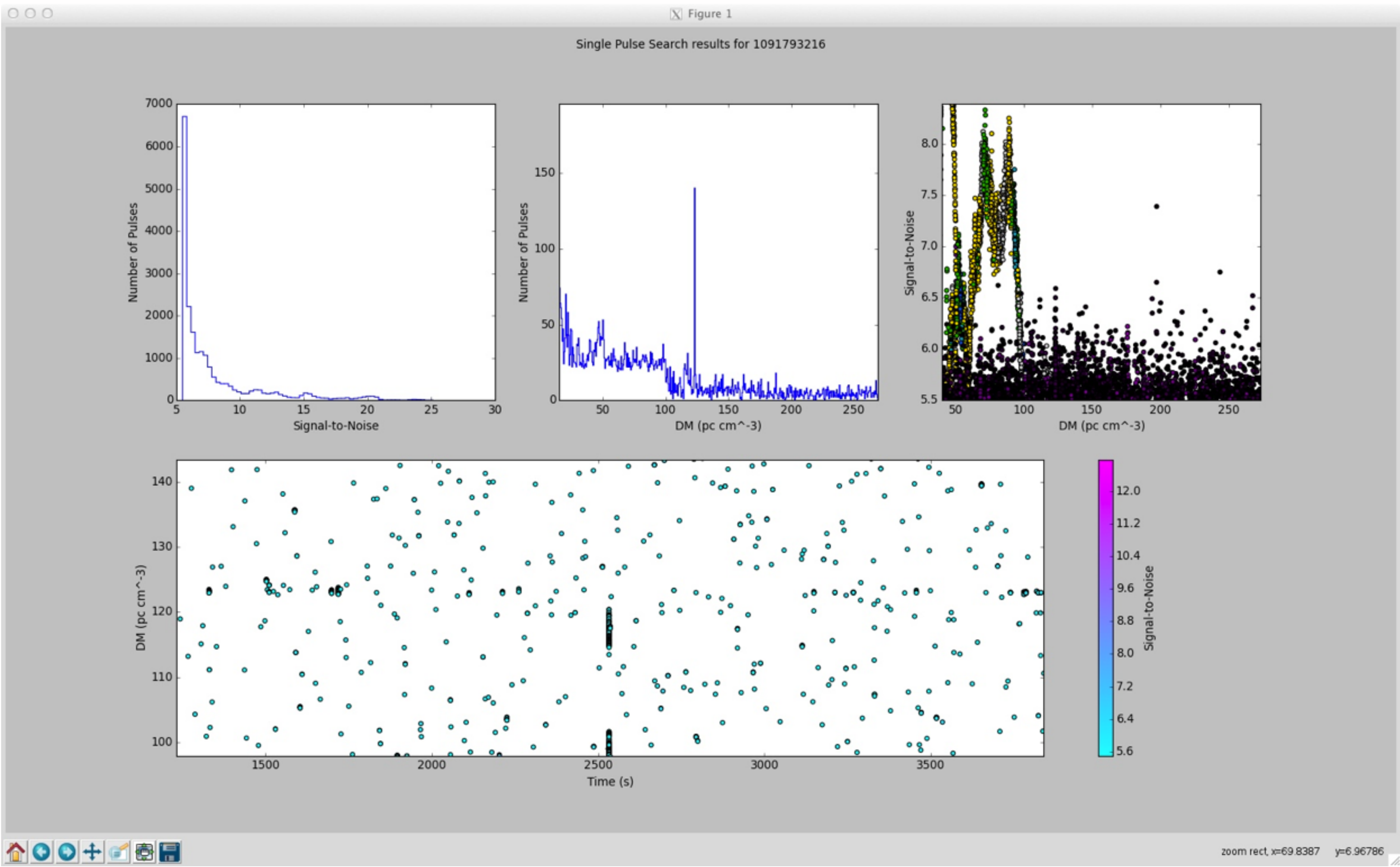
MWA Single Pulses



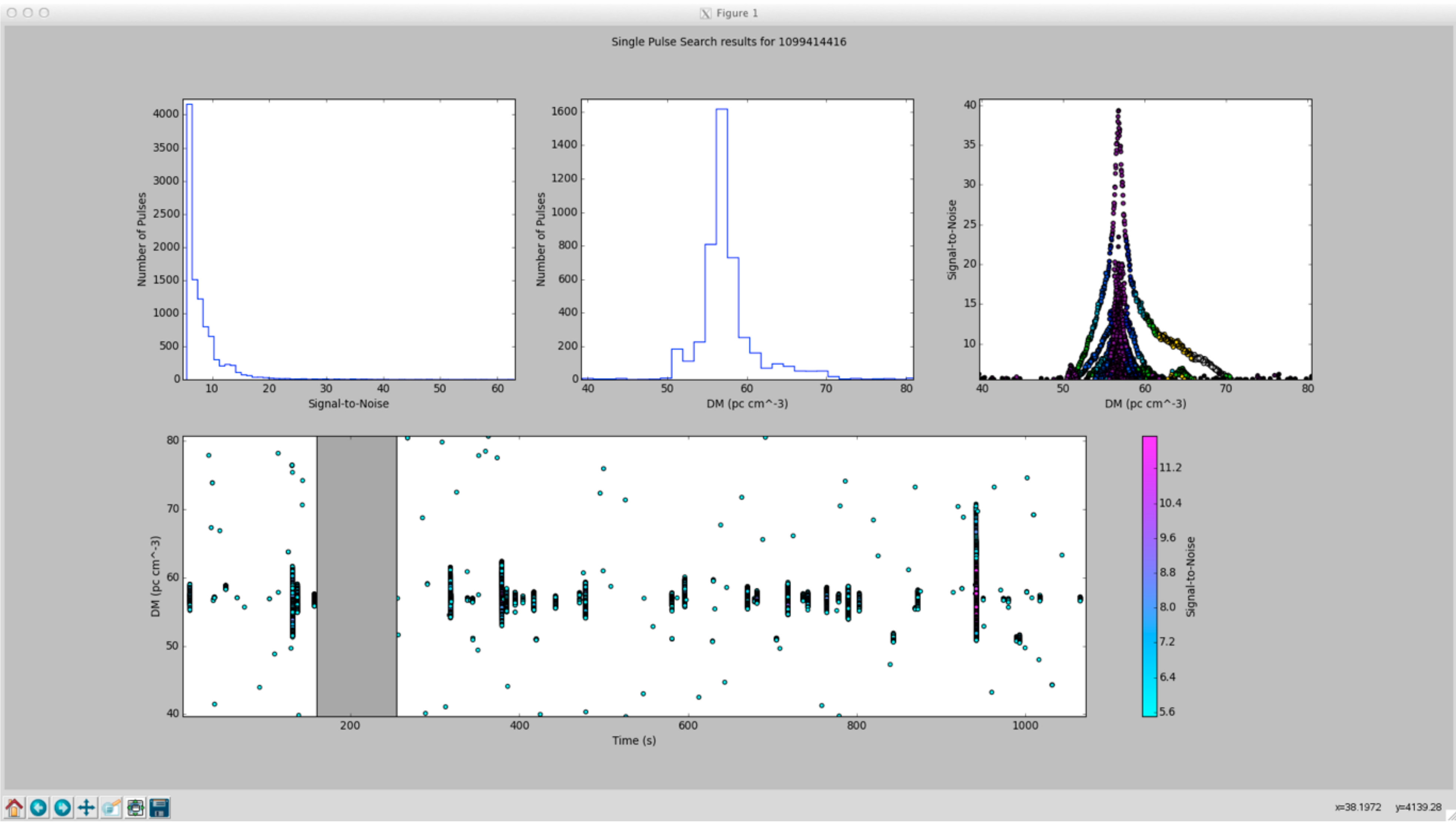
PSR J1921+2153



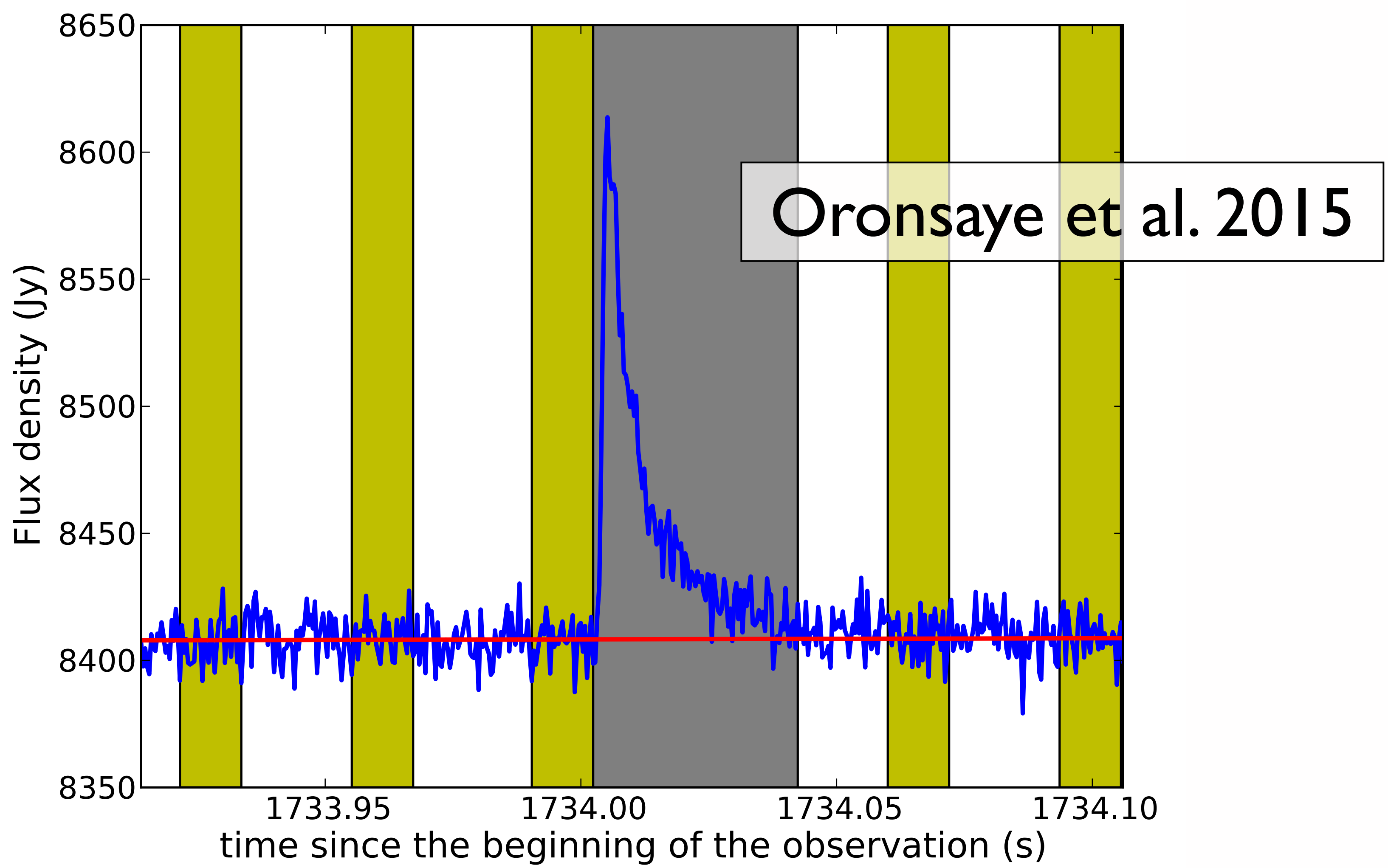
PSR J1731-4744



PSR J0534+2200



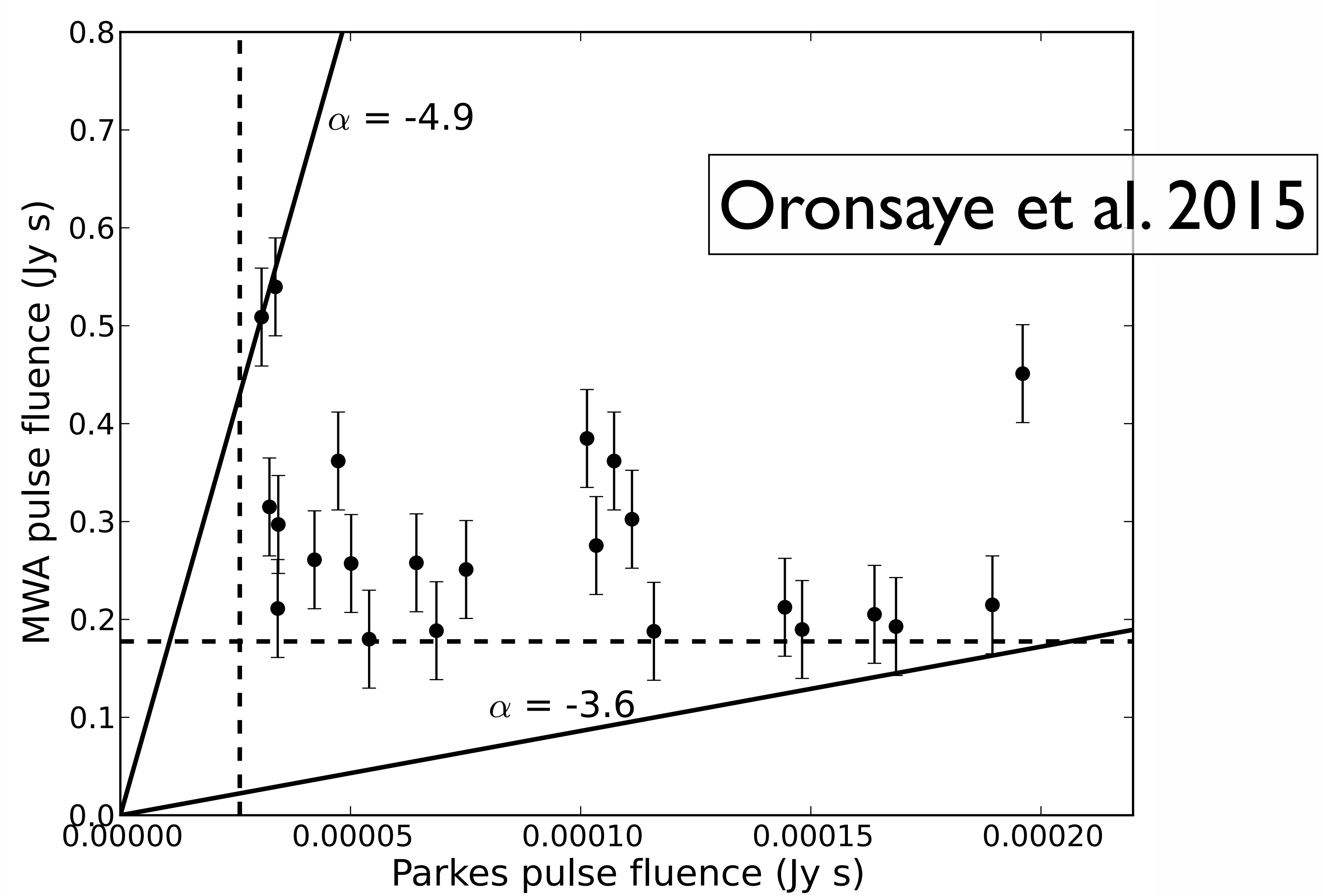
MWA and Crab Giant Pulses



MWA and Crab Giant Pulses

- ~45 minutes of MWA & Parkes observations of Crab
- 2075 Pulses detected at Parkes
- 55 Pulses detected at the MWA
- 23 Coincident Pulses (~51% from MWA P.o.V.)
- Spectral index range
- Measure of variable scattering

MWA and Crab Giant Pulses

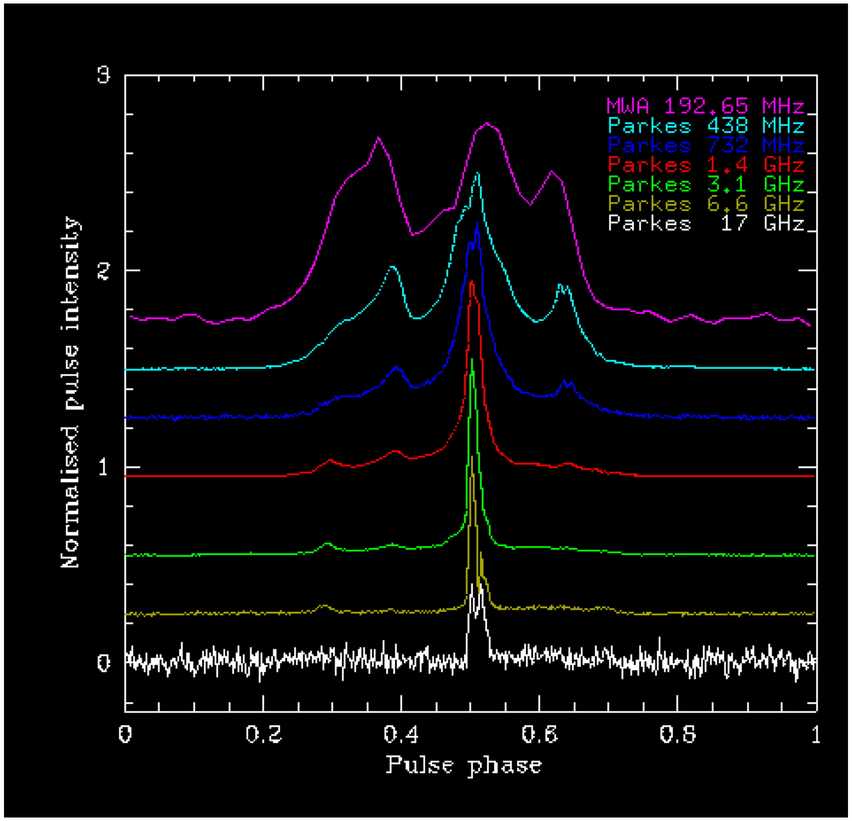


MWA and Periodic Emission

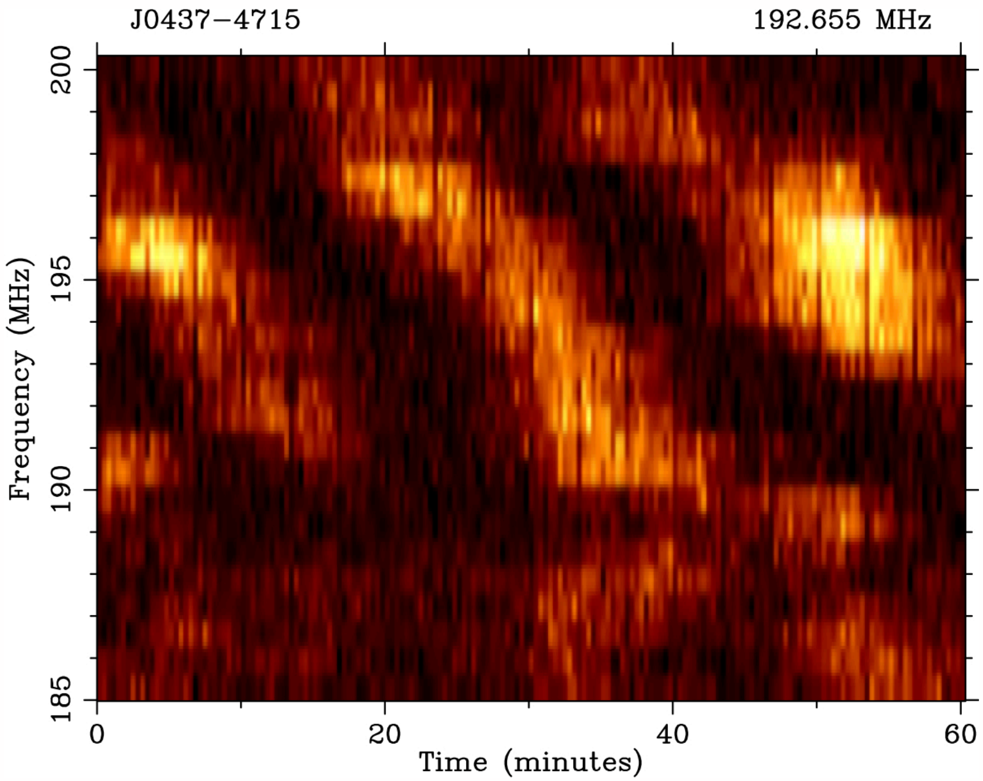
PSR J0437-4715

Bhat et al. 2014

$D_{screen} \sim 120$ pc



Profile evolution

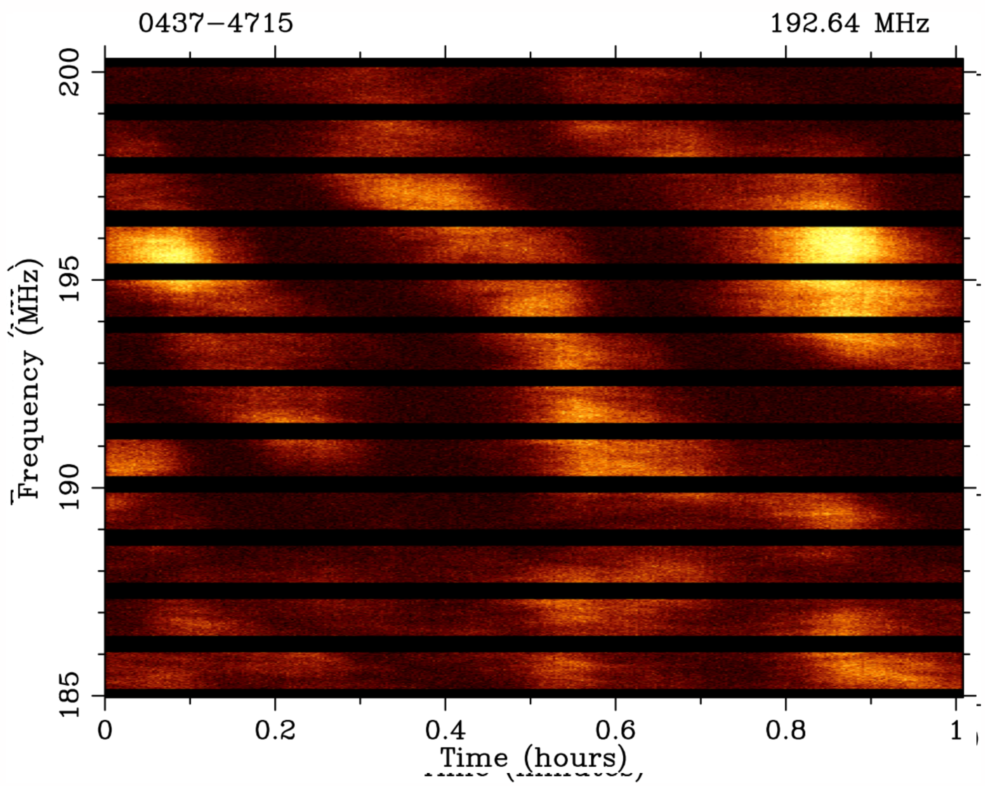


Scintillation

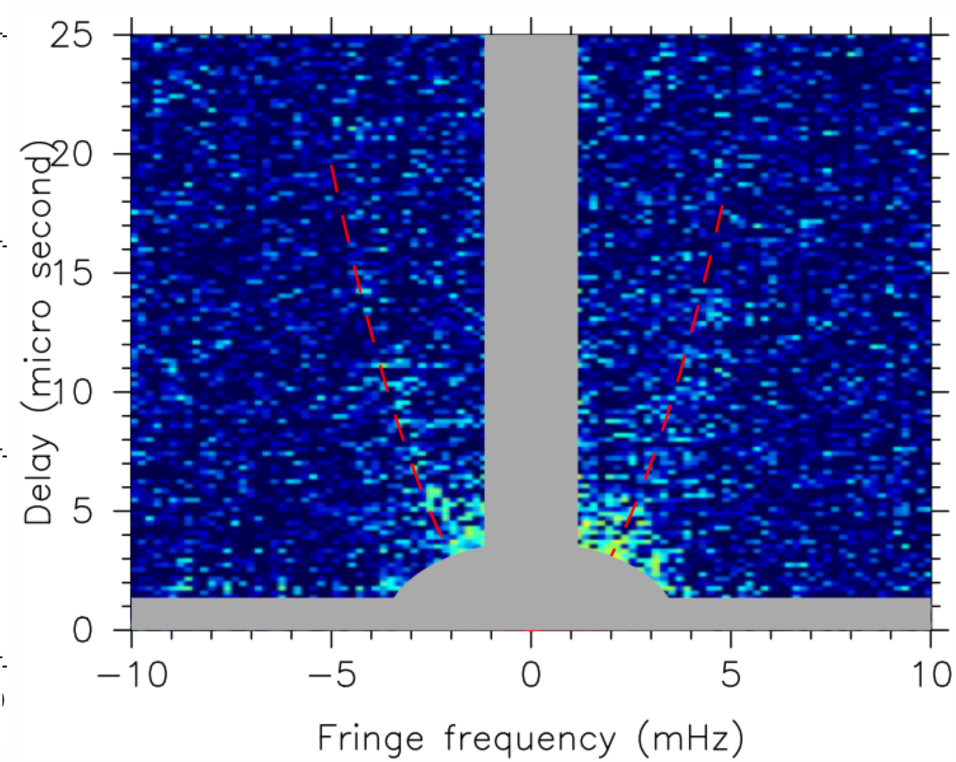
PSR J0437-4715

Bhat et al. submitted
Bhat et al. 2014

D_{screen} = 121±3 pc

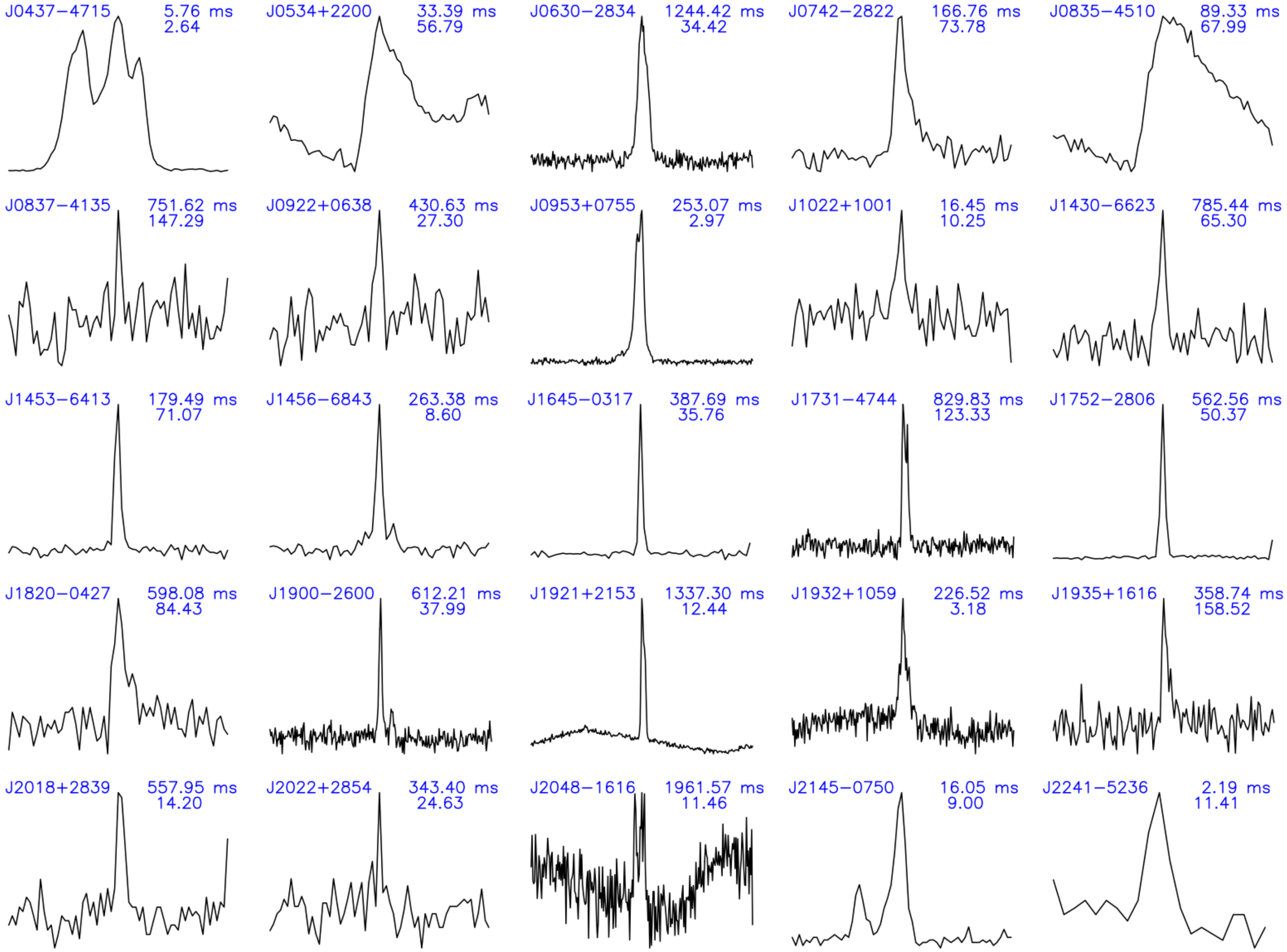


Scintillation



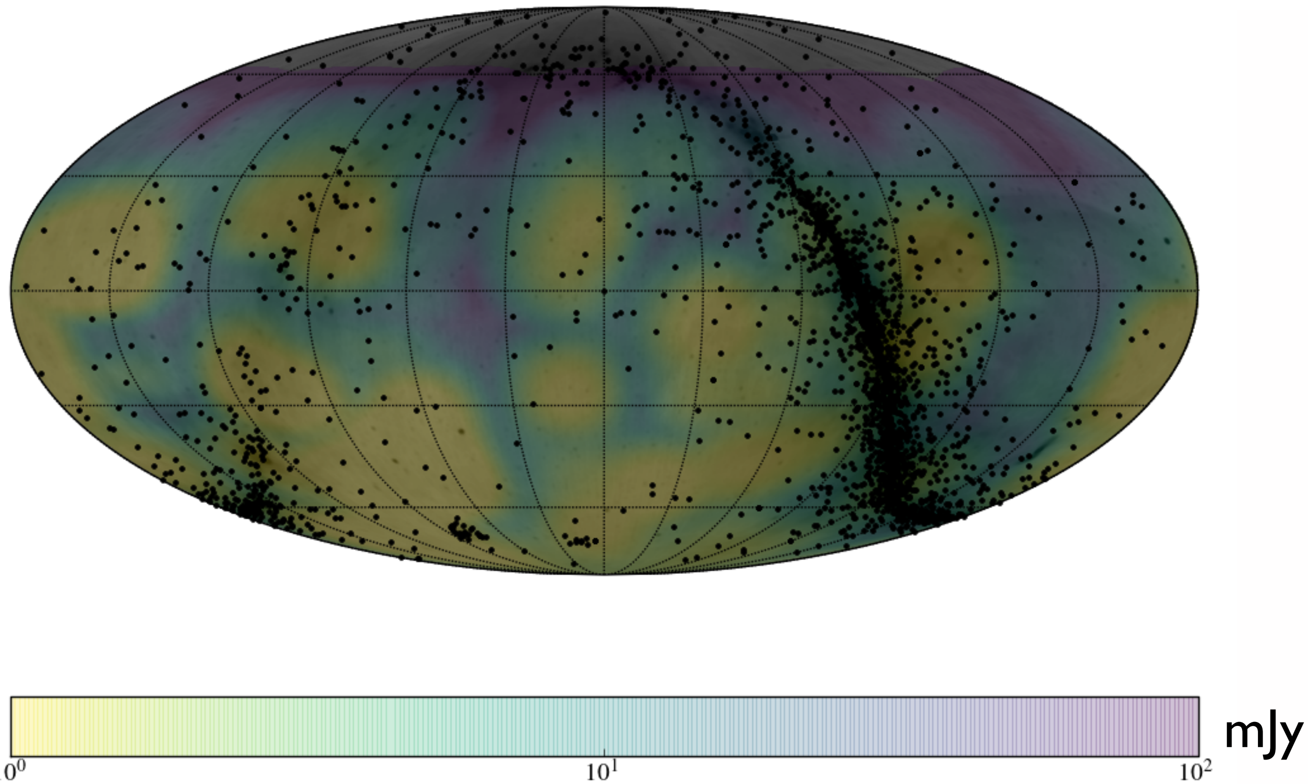
Parabolic Arc

MWA Pulsars



J0437−4715 5.76 ms 2.64
J0534+2200 33.39 ms 56.79
J0630−2834 1244.42 ms 34.42
J0742−2822 166.76 ms 73.78
J0835−4510 89.33 ms 67.99
J0837−4135 751.62 ms 147.29
J0922+0638 430.63 ms 27.30
J0953+0755 253.07 ms 2.97
J1022+1001 16.45 ms 10.25
J1430−6623 785.44 ms 65.30
J1453−6413 179.49 ms 71.07
J1456−6843 263.38 ms 8.60
J1645−0317 387.69 ms 35.76
J1731−4744 829.83 ms 123.33
J1752−2806 562.56 ms 50.37
J1820−0427 598.08 ms 84.43
J1900−2600 612.21 ms 37.99
J1921+2153 1337.30 ms 12.44
J1932+1059 226.52 ms 3.18
J1935+1616 358.74 ms 158.52
J2018+2839 557.95 ms 14.20
J2022+2854 343.40 ms 24.63
J2048−1616 1961.57 ms 11.46
J2145−0750 16.05 ms 9.00
J2241−5236 2.19 ms 11.41

Archived MWA Voltages



Integrated rms of archived VCS data (Oct. 9 2015)

What's next?

Longer-term programs (2016+)

Routine observations of PTA MSPs†

Continued searches for FRBs†

A low-frequency census southern pulsars

Polarimetric studies of pulsars

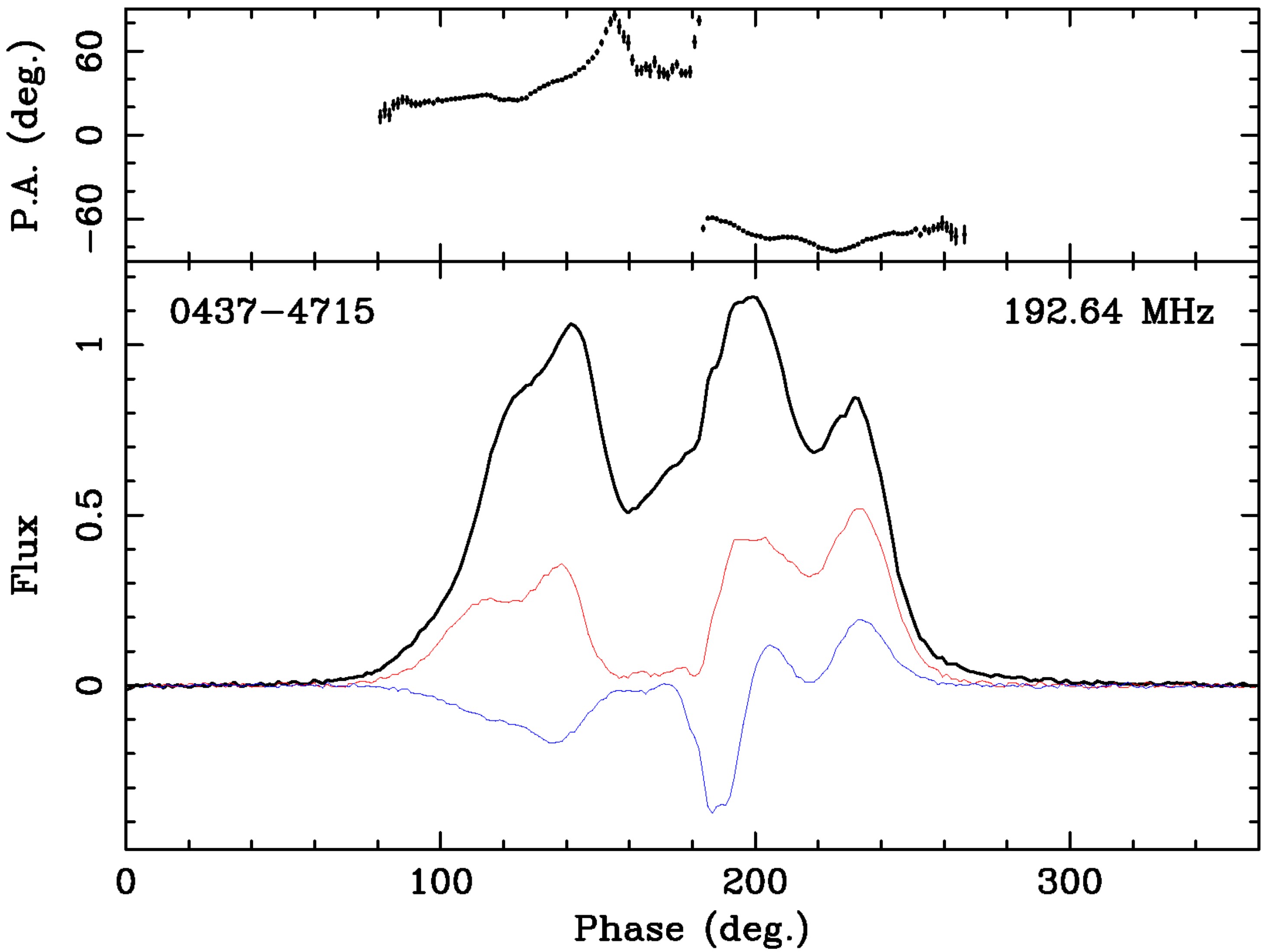
Pulsar emission mechanism studies†

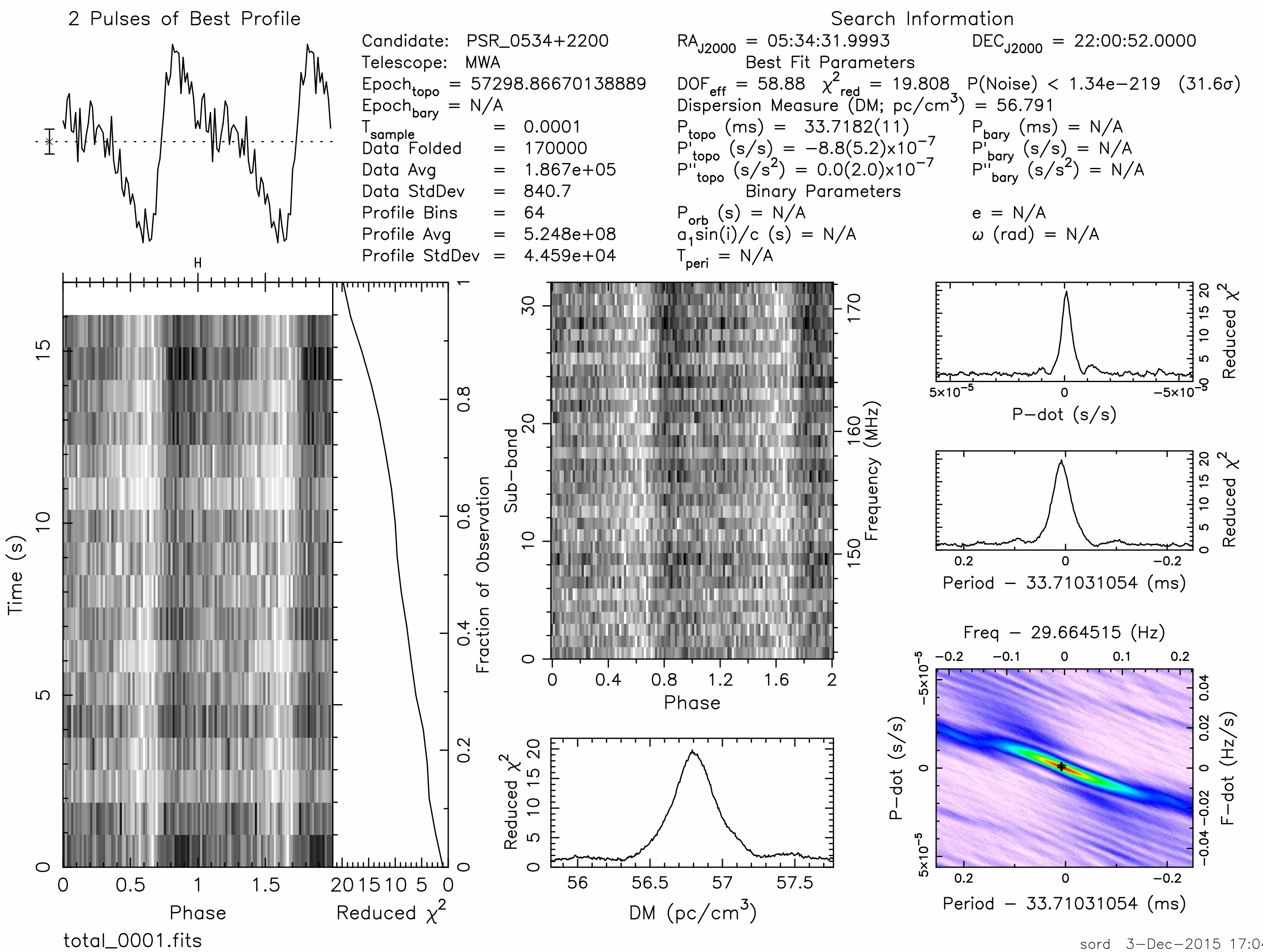
VLBI with GMRT

Non-standard correlator 'modes'

† MWA TAC dependant

Thank you


P.A. (deg.)
60
0
−60
0437−4715
192.64 MHz
Flux
1
0.5
0
0
100
200
300
Phase (deg.)


2 Pulses of Best Profile
Search Information
Candidate: PSR_0534+2200
Telescope: MWA
Epoch_topo = 57298.86670138889
Epoch_bary = N/A
T_sample = 0.0001
Data Folded = 170000
Data Avg = 1.867e+05
Data StdDev = 840.7
Profile Bins = 64
Profile Avg = 5.248e+08
Profile StdDev = 4.459e+04
RA_J2000 = 05:34:31.9993
DEC_J2000 = 22:00:52.0000
Best Fit Parameters
DOF_eff = 58.88 χ²_red = 19.808 P(Noise) < 1.34e−219 (31.6σ)
Dispersion Measure (DM; pc/cm³) = 56.791
P_topo (ms) = 33.7182(11)
P'_topo (s/s) = −8.8(5.2)x10⁻⁷
P''_topo (s/s²) = 0.0(2.0)x10⁻⁷
P_bary (ms) = N/A
P'_bary (s/s) = N/A
P''_bary (s/s²) = N/A
Binary Parameters
P_orb (s) = N/A
a₁sin(i)/c (s) = N/A
T_peri = N/A
e = N/A
ω (rad) = N/A
Time (s)
Phase
Reduced χ²
Fraction of Observation
total_0001.fits
Sub−band
Frequency (MHz)
DM (pc/cm³)
P−dot (s/s)
Period − 33.71031054 (ms)
Freq − 29.664515 (Hz)
F−dot (Hz/s)
sord 3−Dec−2015 17:04

Why parabolic arcs?

f_ν = "delay"
f_t = "fringe frequency"

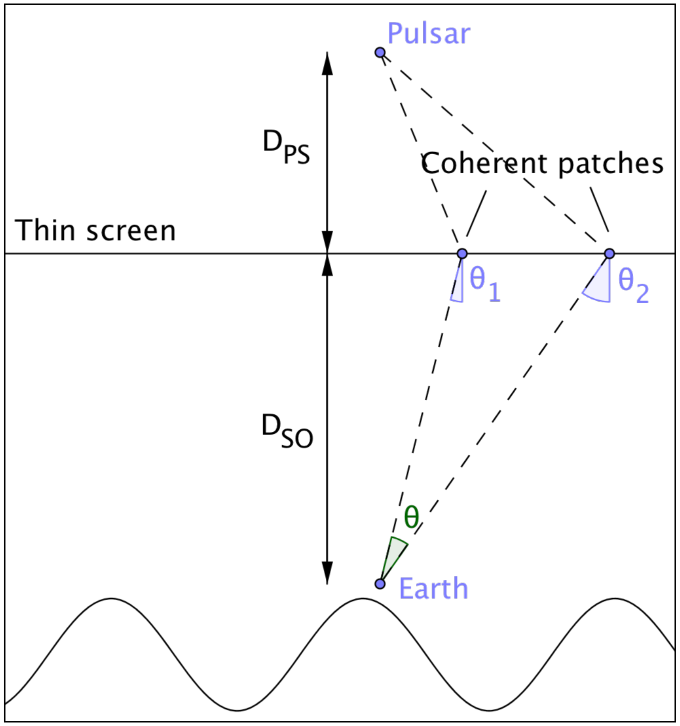
- Consider two coherent patches on thin screen
- Relation of f_ν to f_t:

$$\boxed{f_\nu = \eta f_t^2}$$

- η is curvature of parabola

$$\eta = \frac{D_s}{2c}\frac{\lambda^2}{V_{\mathrm{eff}}^2 \cos^2\alpha}$$
$$D_s = D\,s\,(1-s)$$

- **Measurement of η yields distance s**



MWA-VCS and FRBs

185 MHz (Incoherent Search)		
α	No Scatter	High Scatter
-2	8	0
-1	2	0
0	0	0
+0.4	0	0

295 MHz (Incoherent Search)		
α	No Scatter	High Scatter
-2	8	1
-1	3	0
0	1	0
+0.4	0	0