

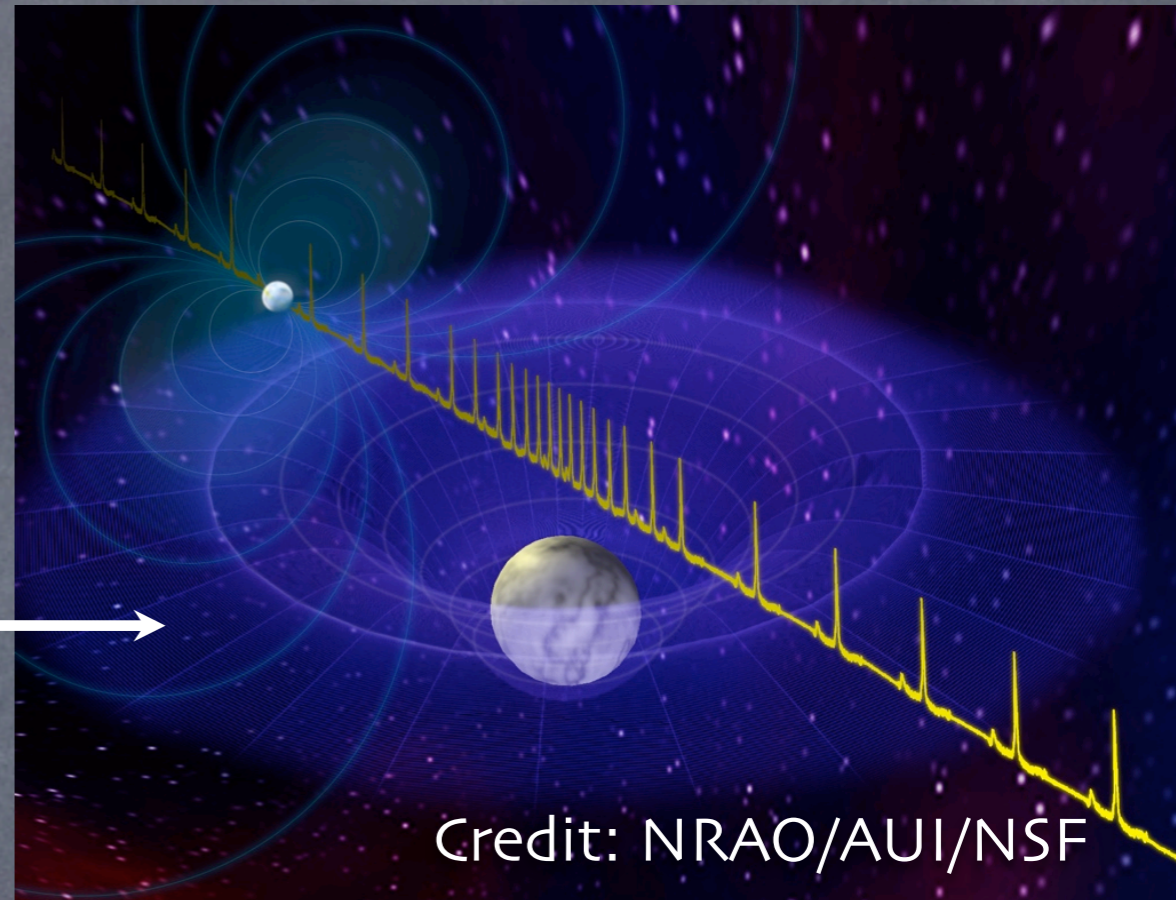
LOFAR Pilot Surveys for Pulsars and Fast Transients



Thijs Coenen (Universiteit van Amsterdam)
and the LOFAR Pulsar Working Group

Why survey for pulsars?

- With pulsars one can study:
 - Pulsars emission processes (cf. Vlad and Tom's talks).
 - Constrain dense matter Equation of State (e.g. Demorest et al 2010).
 - Look for gravitational radiation (indirect detection already with pulsar + NS system).
 - Inter stellar medium, earth's ionosphere, galactic magnetic fields etc.



Why with LOFAR?

- Efficient, multiple beams, large field of view.
- Low-frequency radio relatively under-explored part of parameter space.
- Sensitivity, large collecting area, large bandwidth coverage.

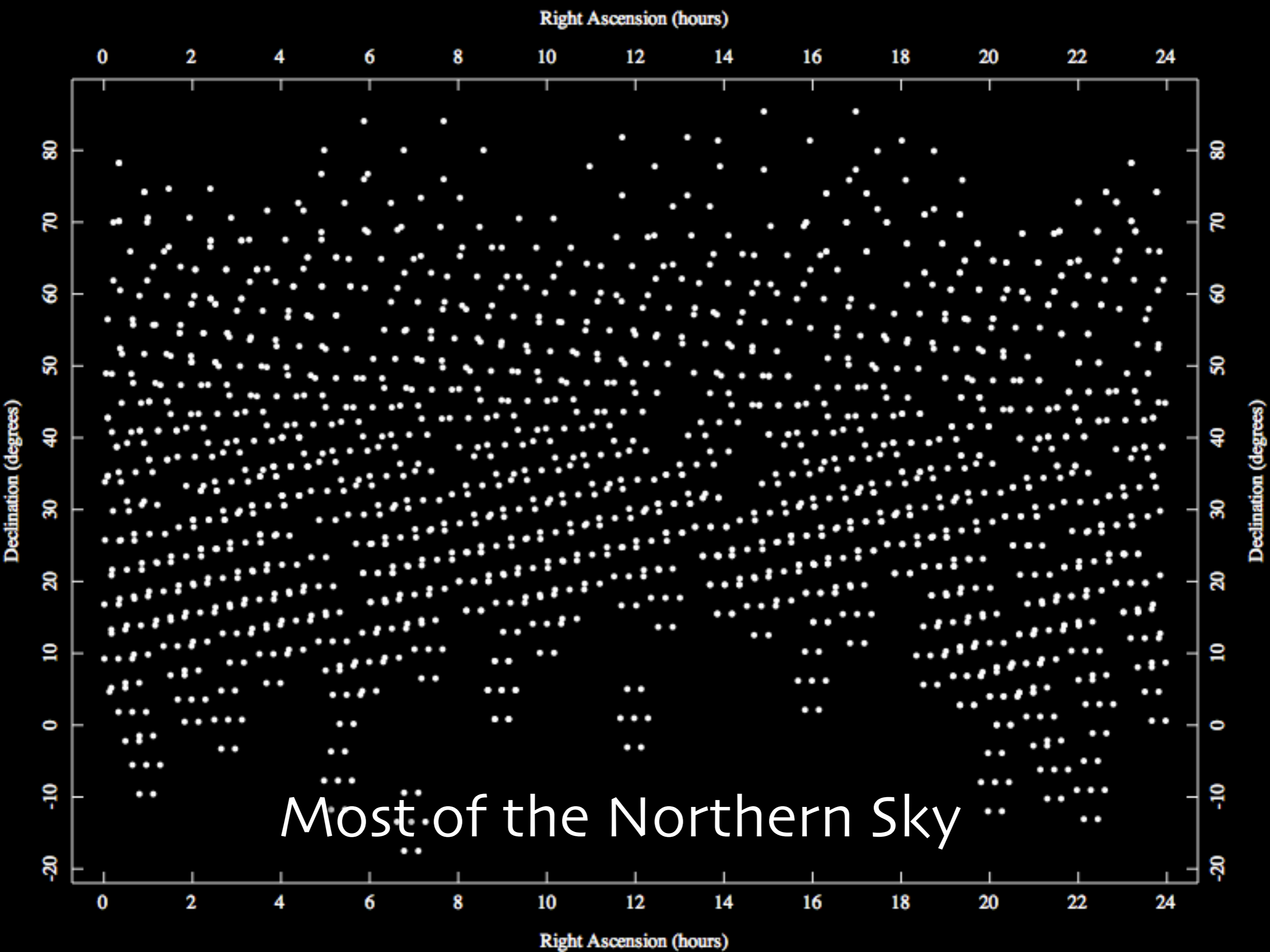


Pulsar Surveys

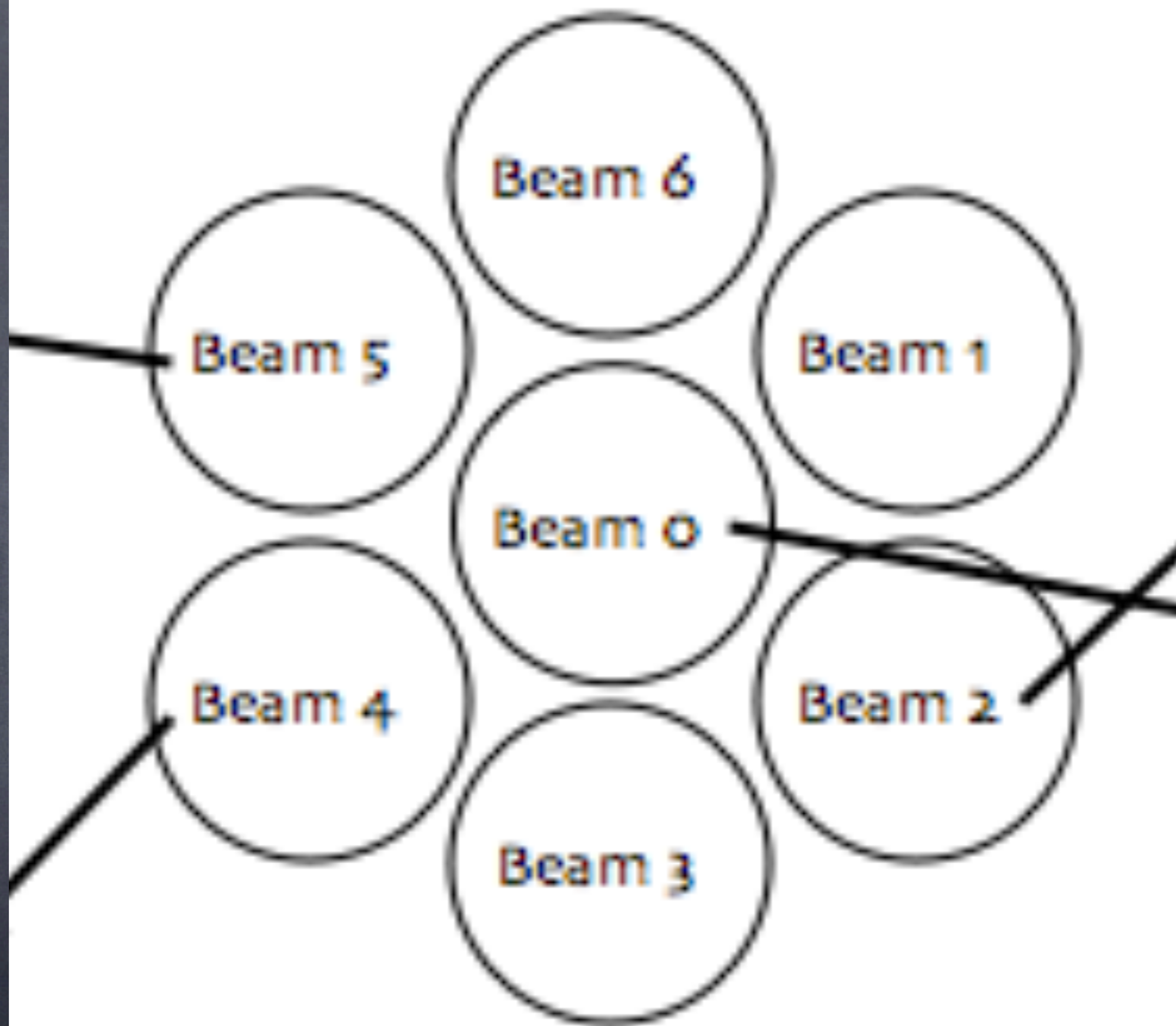
- Different types of surveys test different observing modes and probe different parts of parameter space.
- HBA
 - incoherent : LPPS
 - coherent : LOTAS
- LBA
 - incoherent : LoMASS

LOFAR Pilot Pulsar Survey (LPPS)

- Incoherent addition (about 20 stations).
- 7 beams, 7 MHz bandwidth per beam, 0.65 ms sampling time
- 57 minutes integrations
- 167 square degrees of sky
- Almost 250 observations taken around christmas 2010.

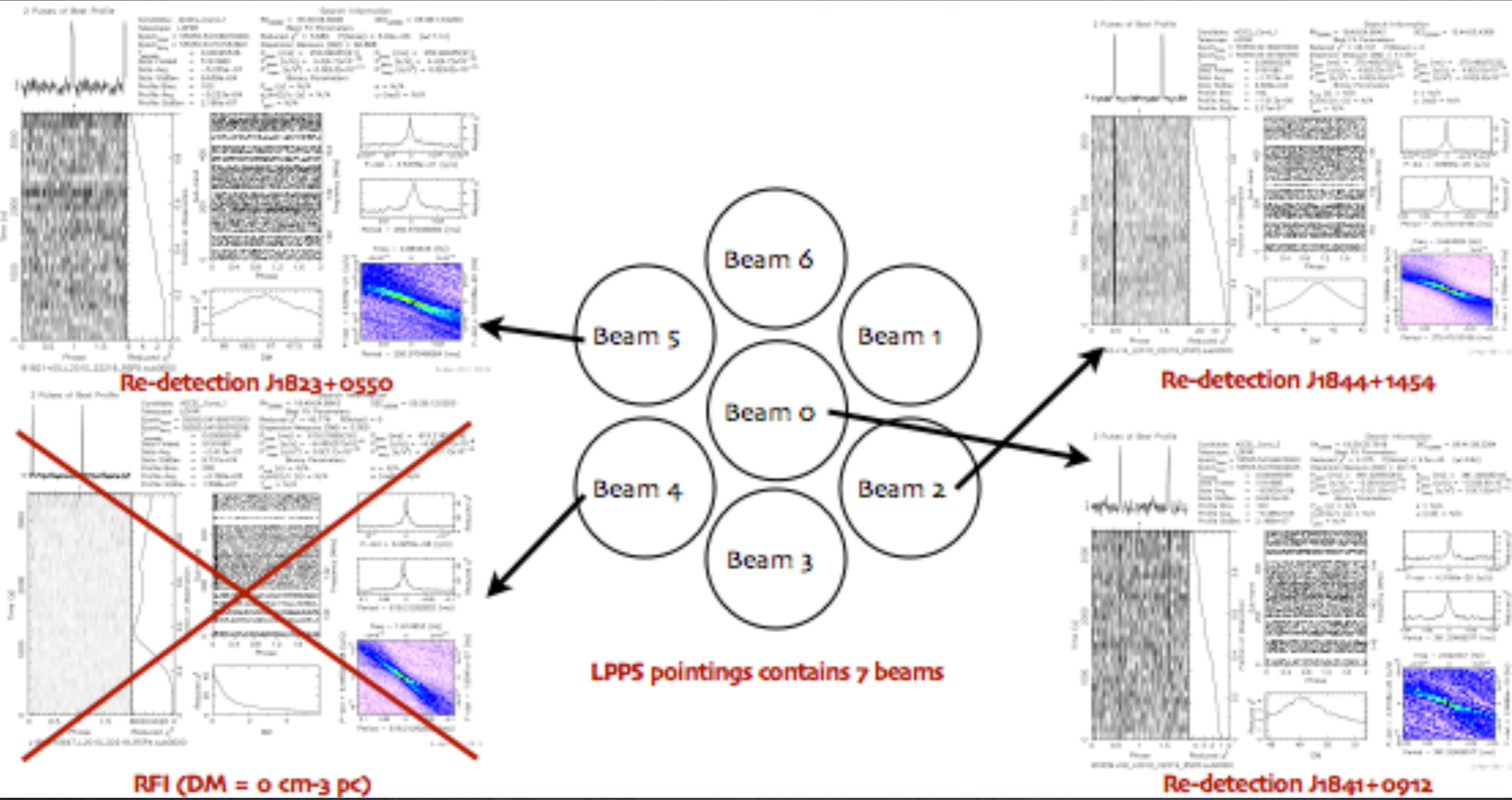


Most of the Northern Sky



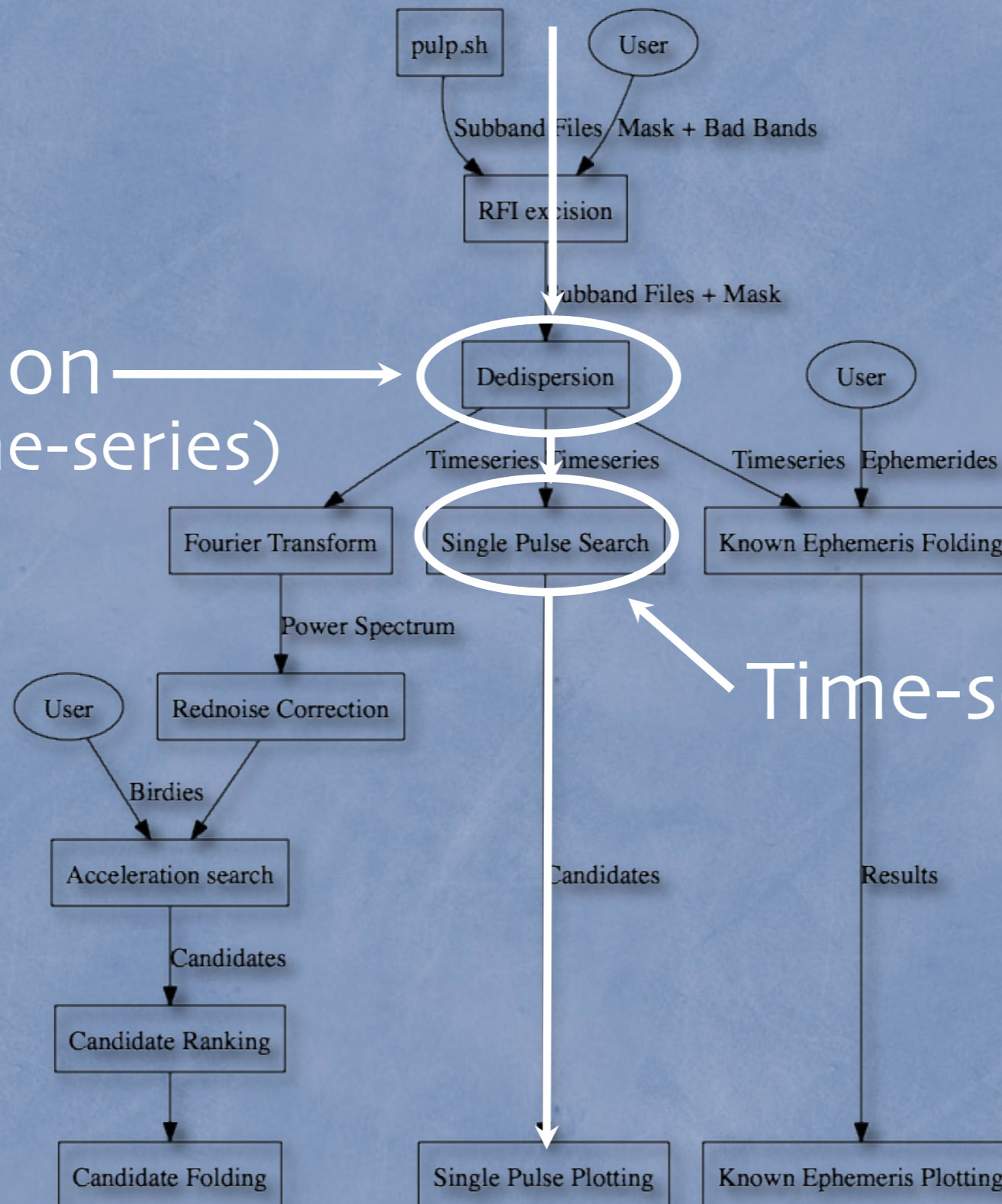
LPP5 pointings contains 7 beams

Blind re-detections in LPPS



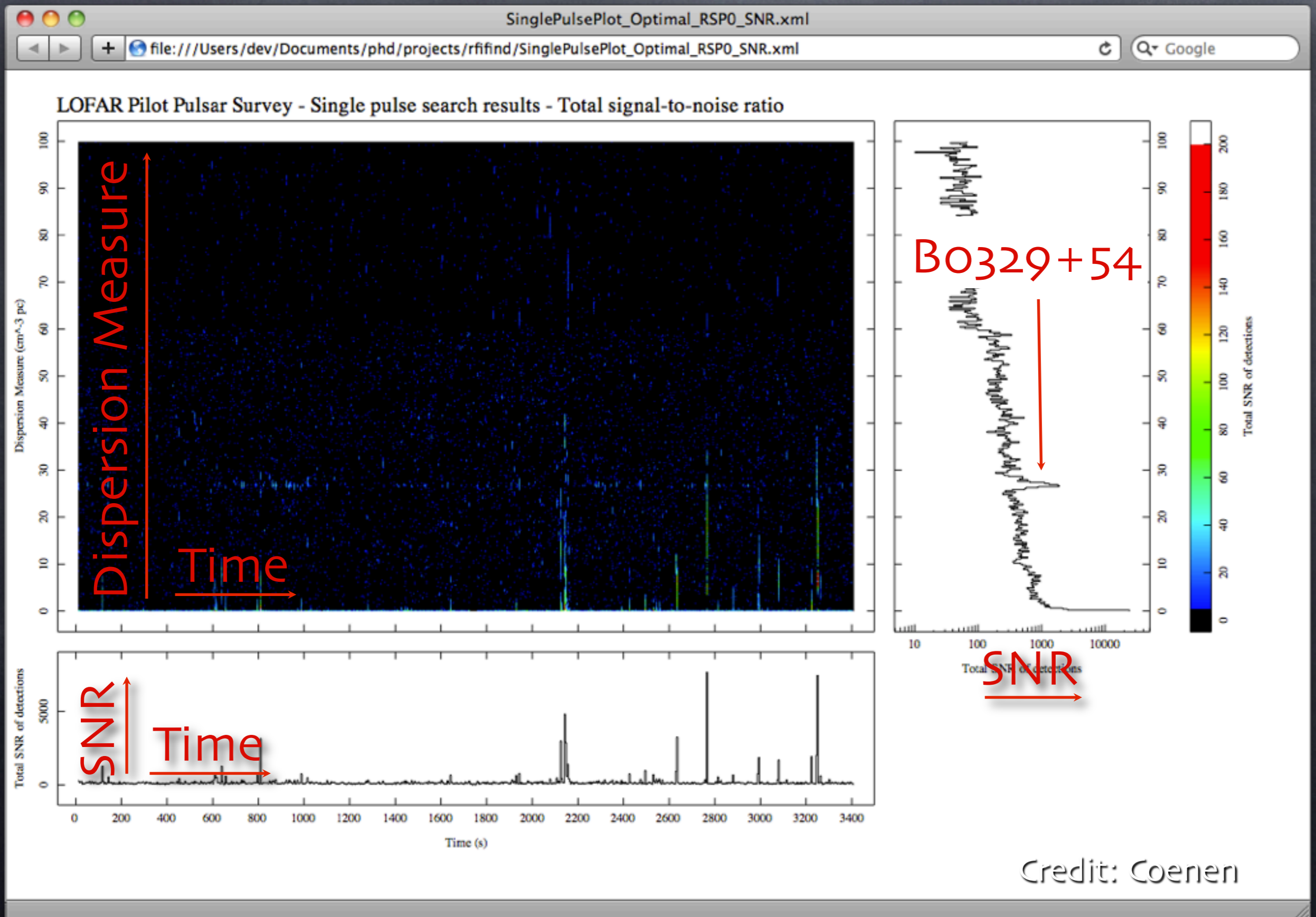
Fast Transients Search

Dedispersion
(creates time-series)



Time-series search

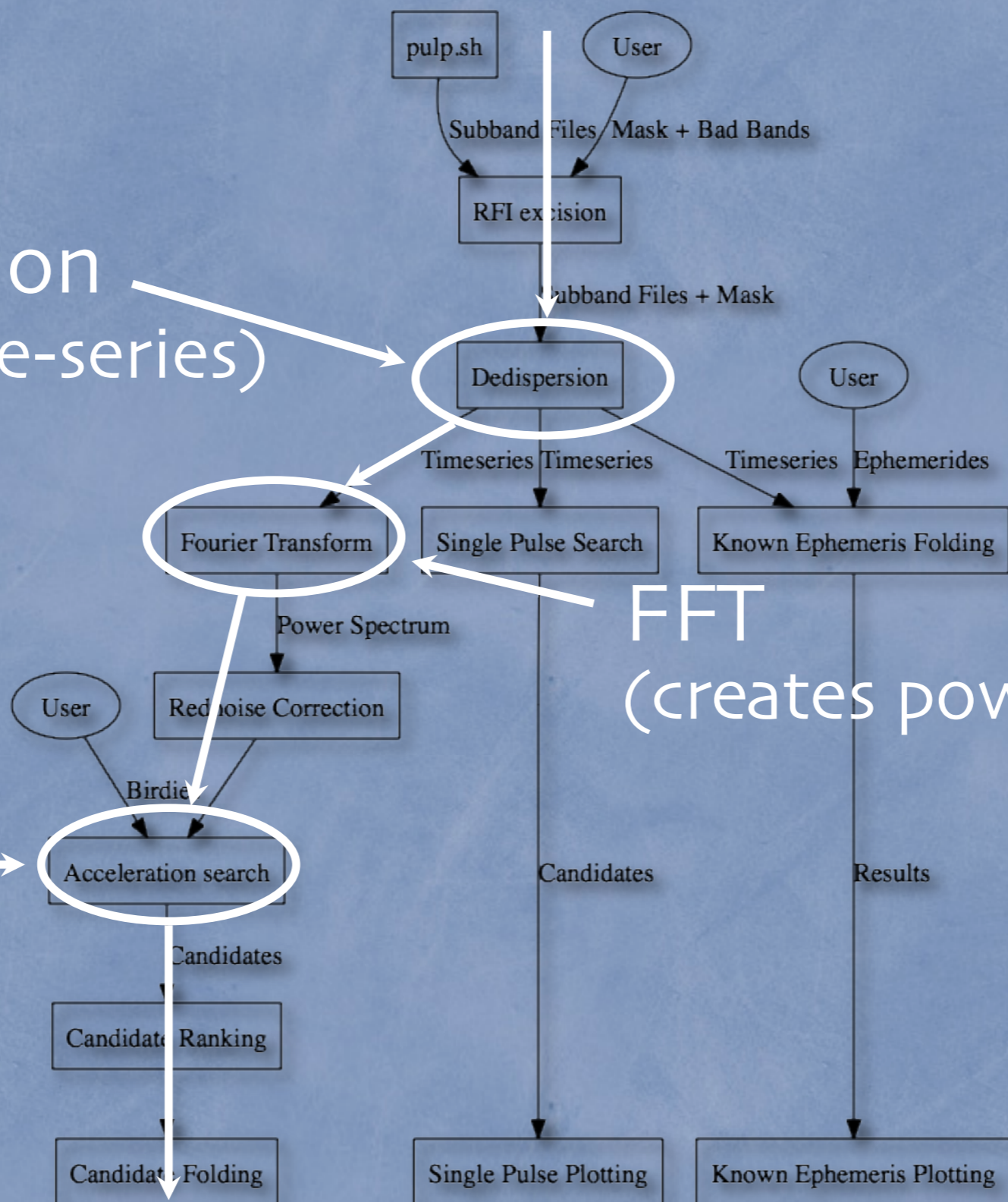
Fast Transients Search



Periodicity search

Dedispersion
(creates time-series)

Search



FFT
(creates power spectrum)

Result: many pulsar candidates...



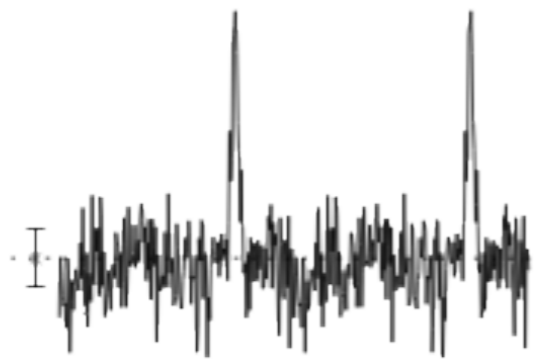
Credit: Coenen

Neural Nets to the rescue!

- Neural nets are machine learning algorithms.
- A new neural net was trained on LPPS data by Jenny Green (Manchester).
- Automatically finds about 100 known pulsars in LPPS data.
- Cuts back on inspection of candidate plots by 2 orders of magnitude!

Re-detection of PSR J0240+63

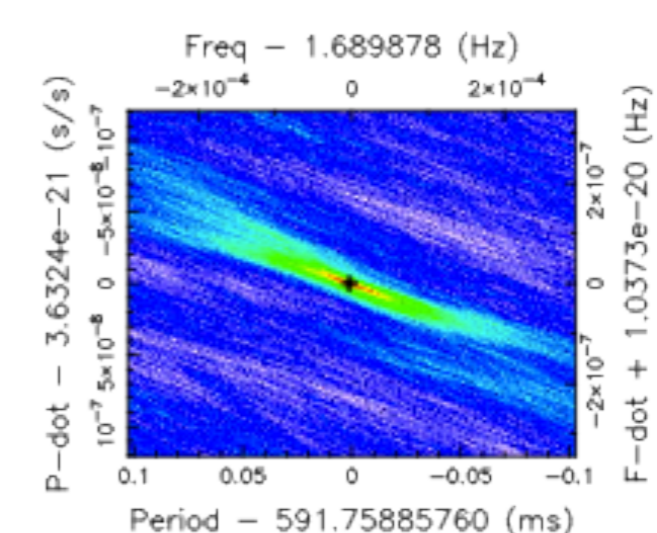
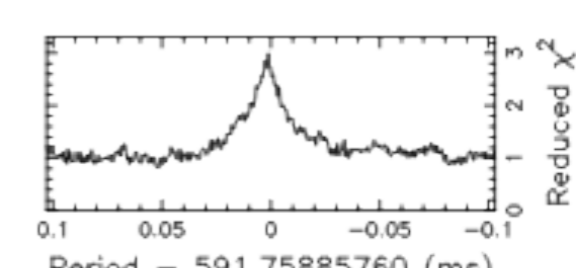
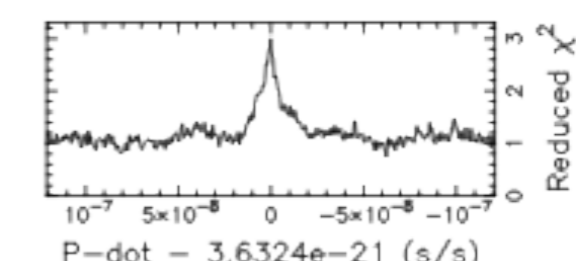
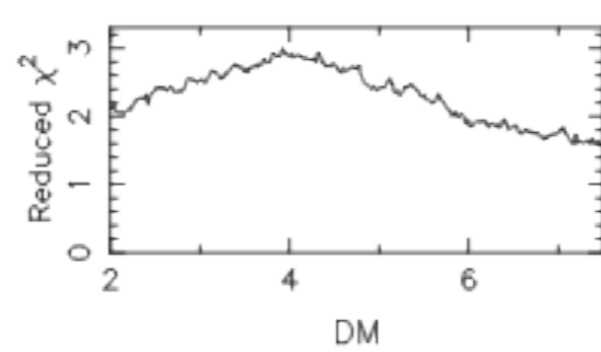
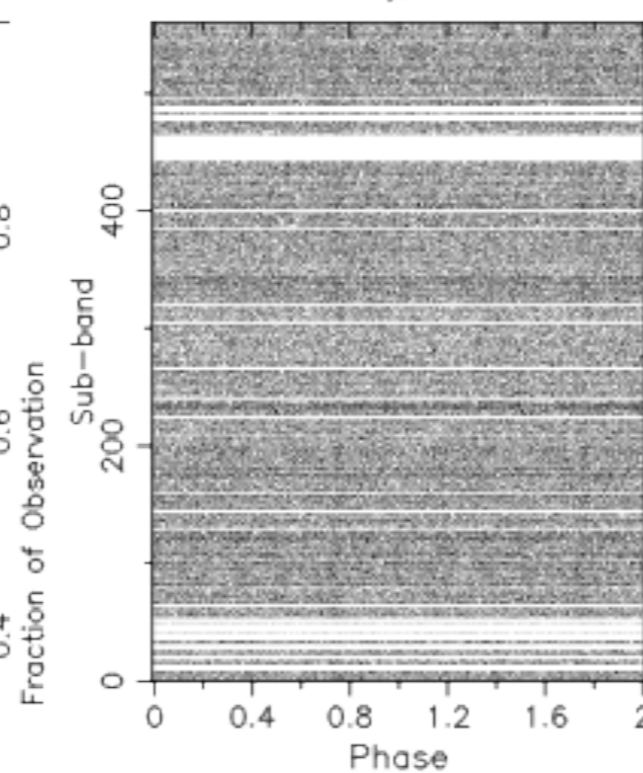
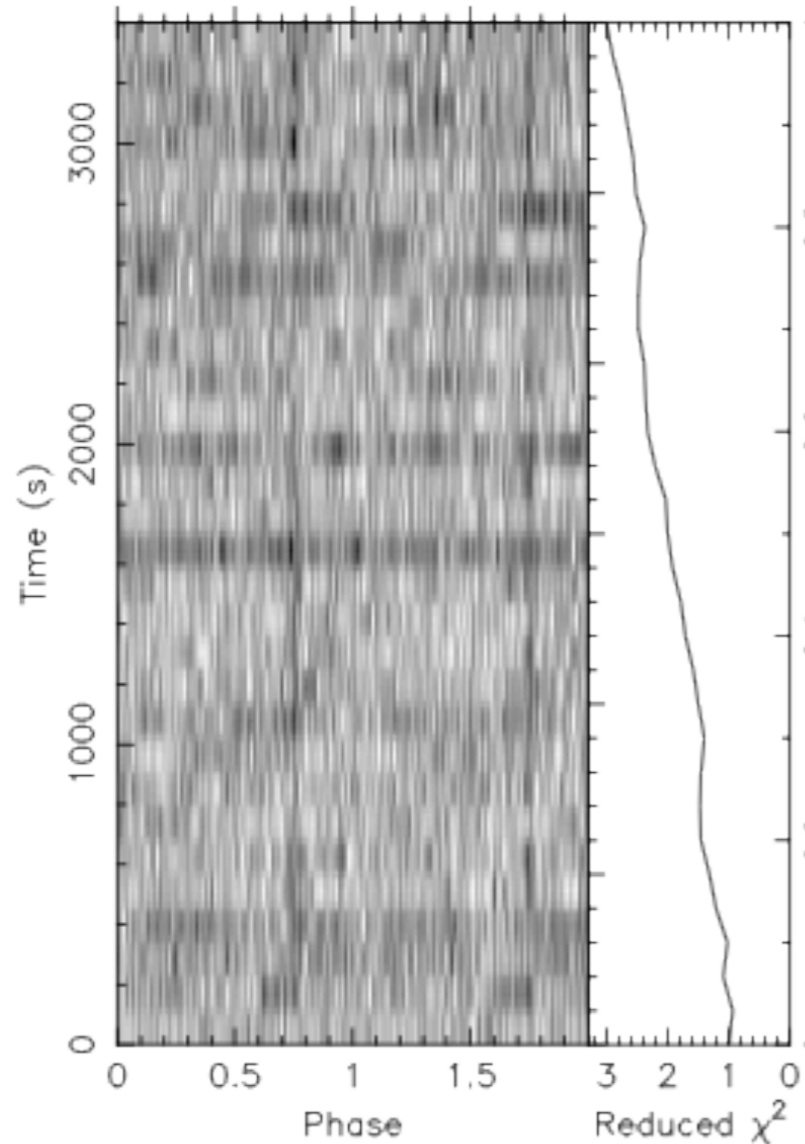
2 Pulses of Best Profile



Candidate: ACCEL_Cand_4
 Telescope: LOFAR
 Epoch_{topo} = 55554.83333330000
 Epoch_{bary} = 55554.83332256713
 T_{sample} = 0.00065536
 Data Folded = 5191680
 Data Avg = 1.557e-07
 Data StdDev = 9.979e+04
 Profile Bins = 200
 Profile Avg = -3.388e+04
 Profile StdDev = 1.608e+07

Search Information

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 T_{peri} = N/A

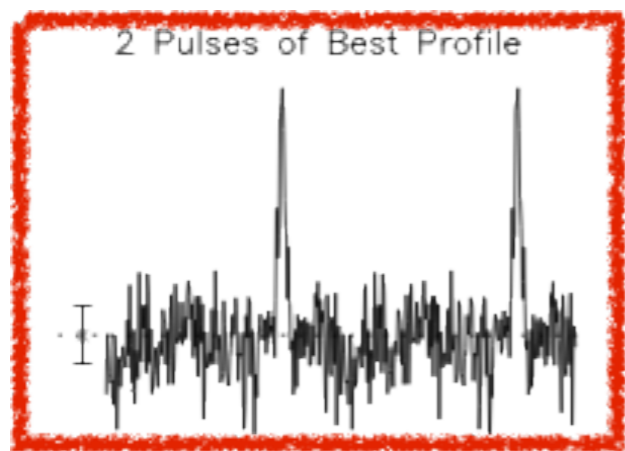


NONE_L2010_22161_RSP0.sub0000

Credit: Stappers & Hassall

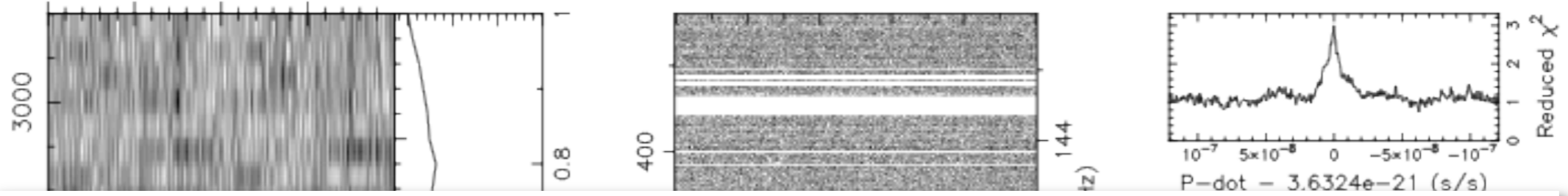
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Re-detection of PSR J0240+63

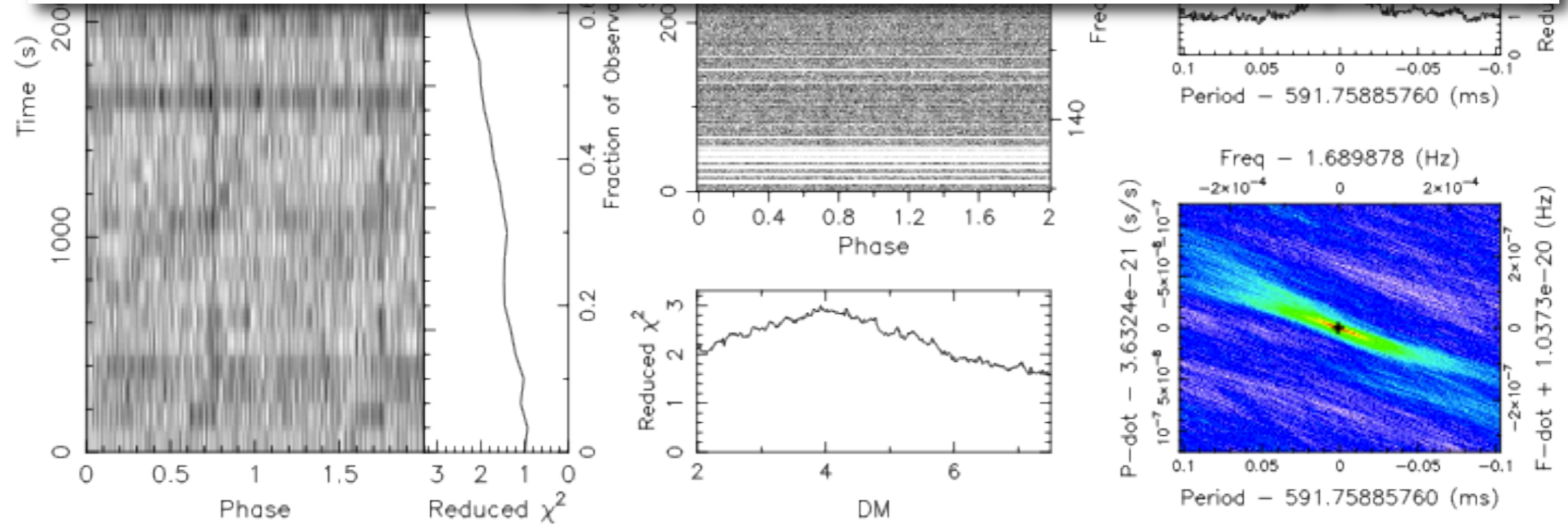


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Pulse-profile (signal versus rotational phase)



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Credit: Stappers & Hassall

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Re-detection of PSR J0240+63

2 Pulses of Best Profile



Signal versus time

Candidate: ACCEL_Cand_4
 Telescope: LOFAR
 Epoch_{topo} = 55554.83333330000
 Epoch = 55554.83332256713

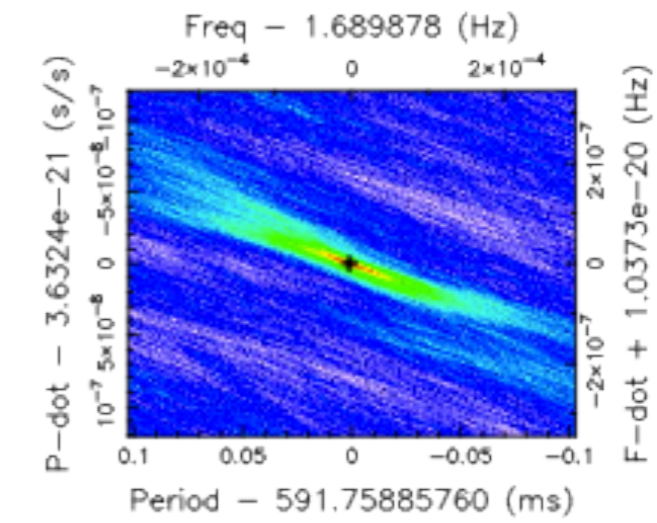
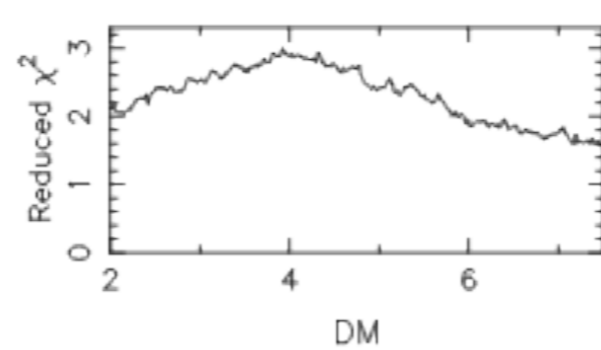
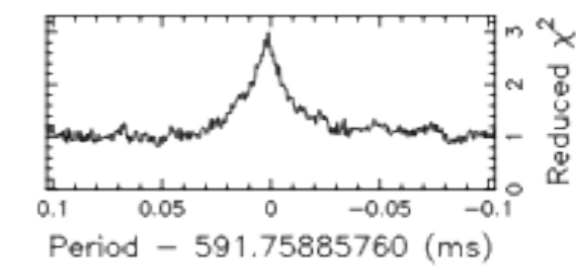
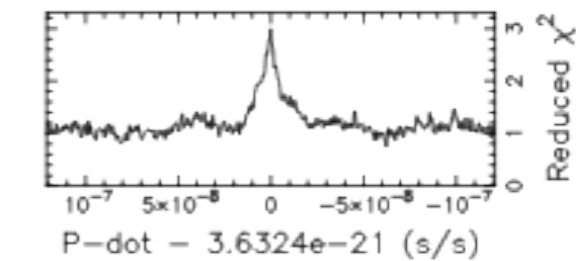
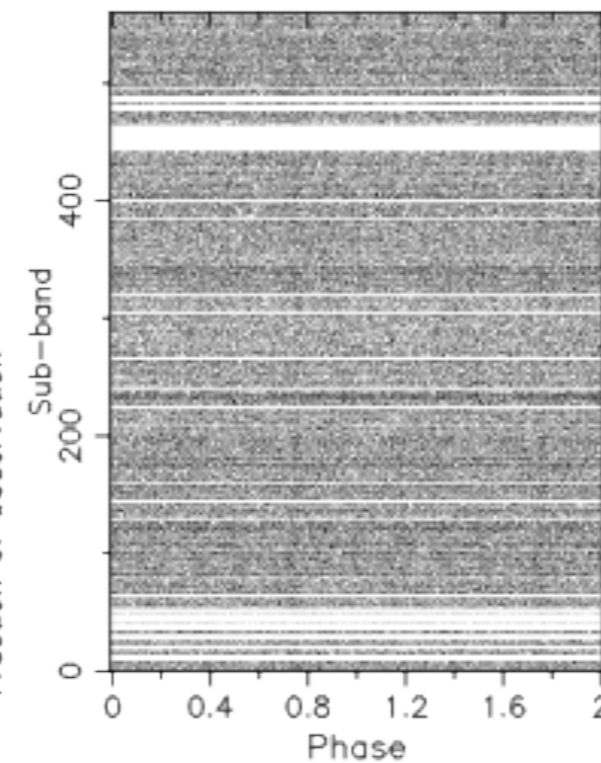
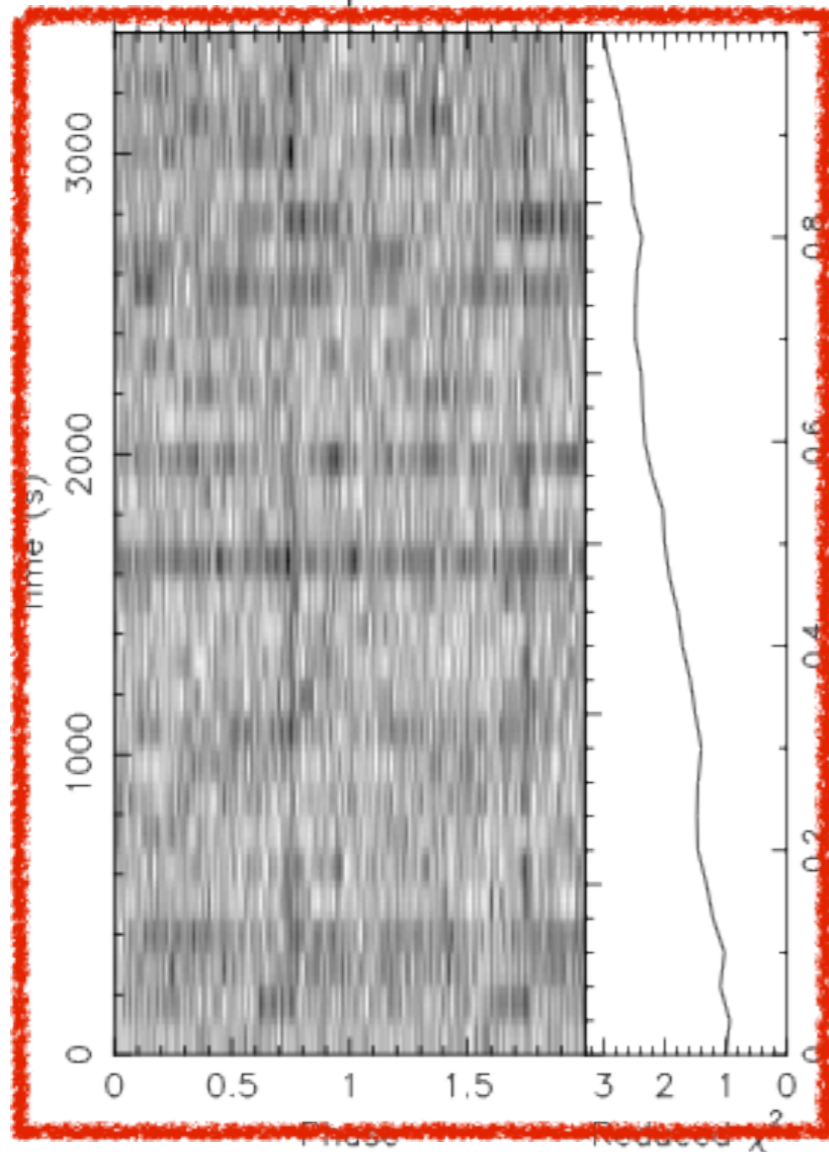
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Profile Bins = 200 P_{orb} (s) = N/A
 Profile Avg = -3.388e+04 $a_1 \sin(i)/c$ (s) = N/A
 Profile StdDev = 1.608e+07 T_{peri} = N/A

e = N/A
 ω (rad) = N/A



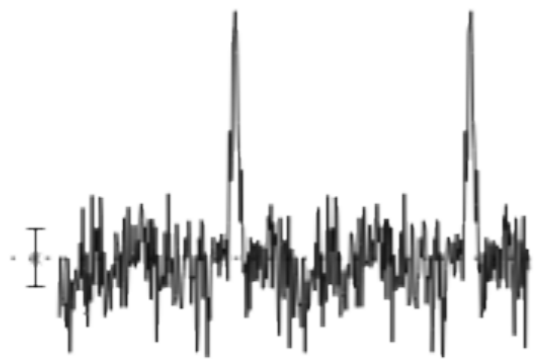
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Credit: Stappers & Hassall

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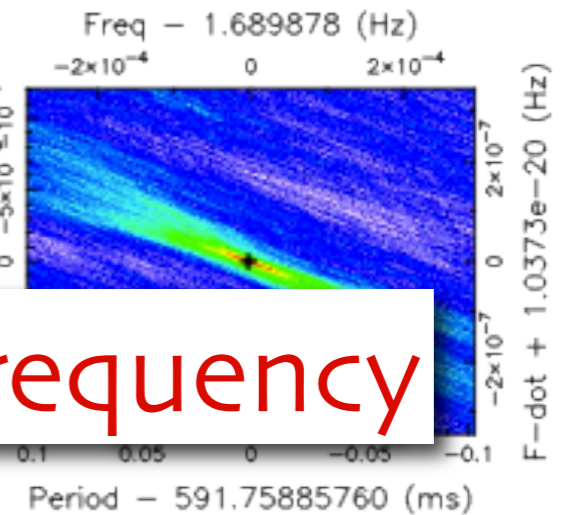
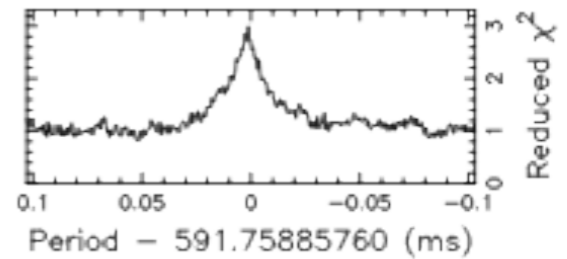
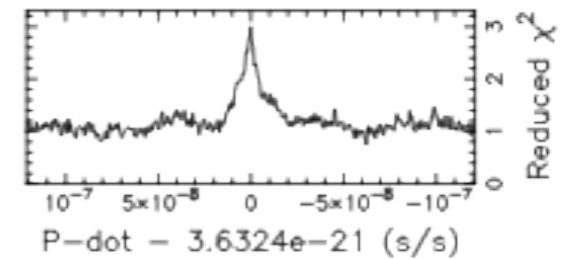
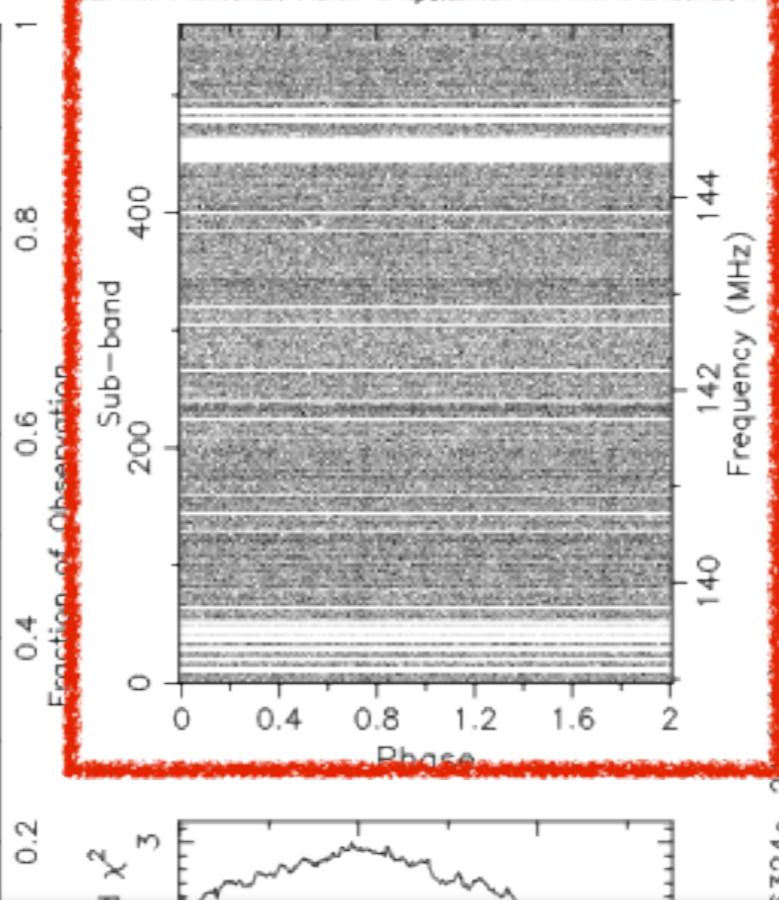
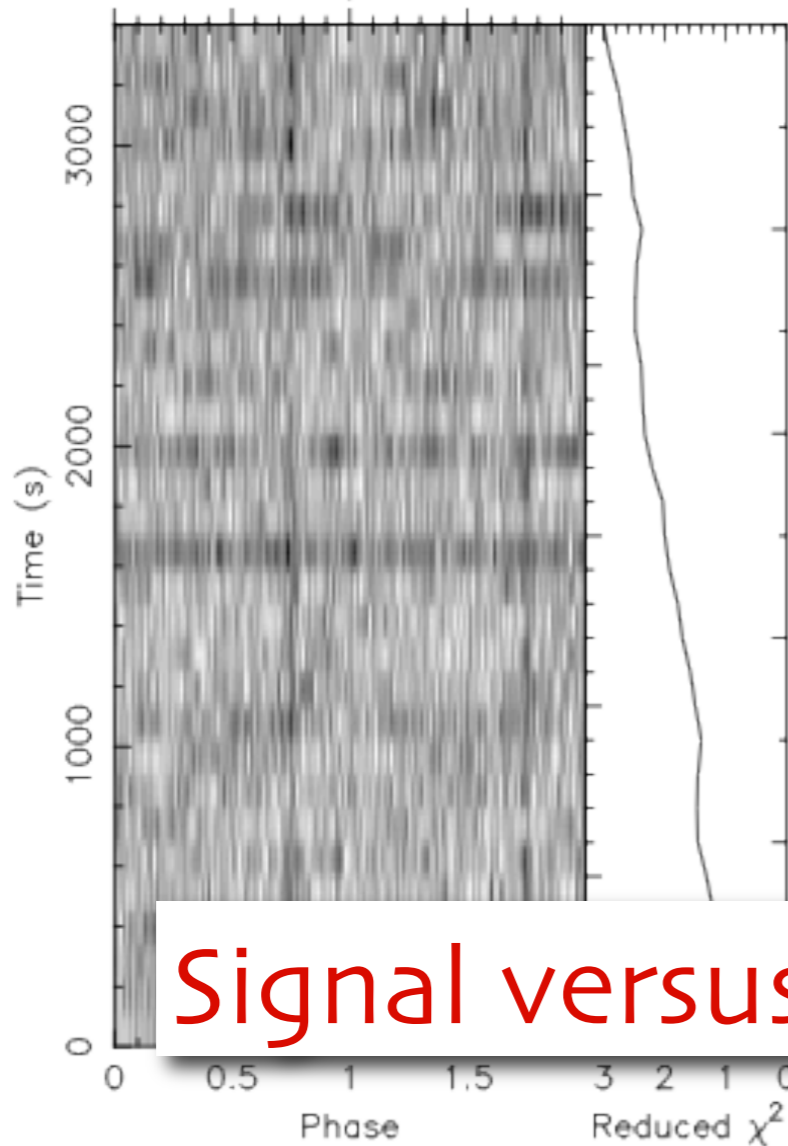
Re-detection of PSR J0240+63

2 Pulses of Best Profile



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 T_{trans} = N/A



Signal versus observational frequency

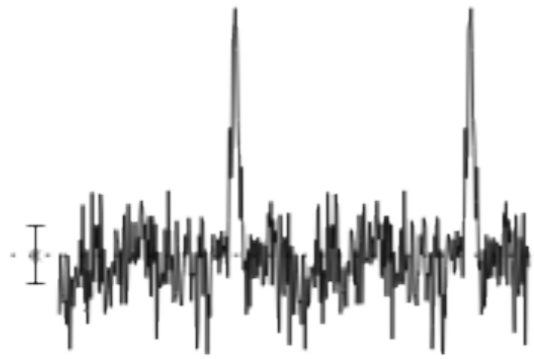
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Credit: Stappers & Hassall

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Re-detection of PSR J0240+63

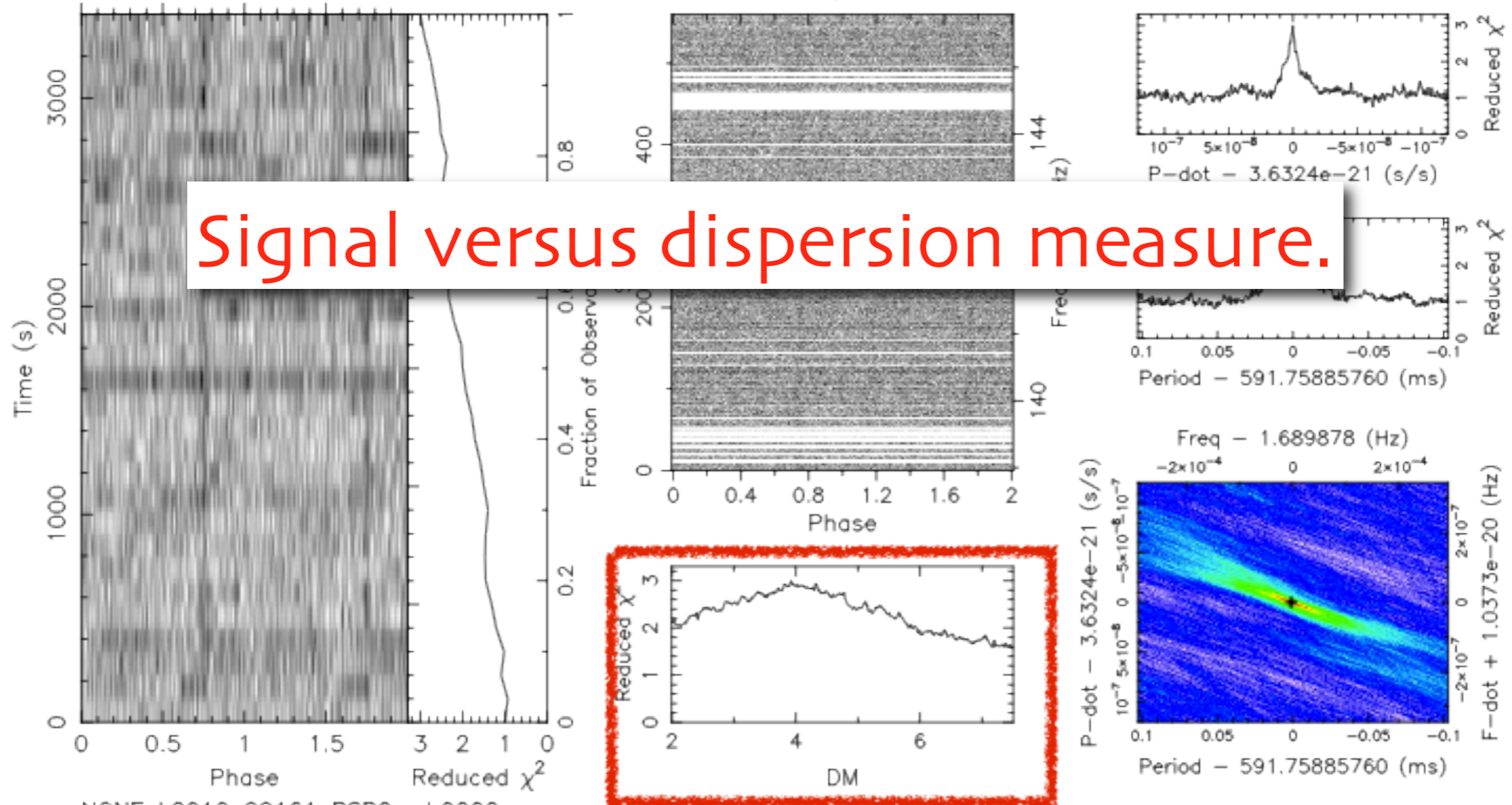
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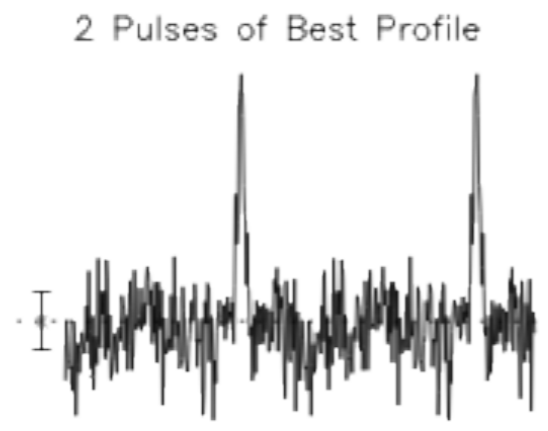
Signal versus dispersion measure.

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Re-detection of PSR J0240+63

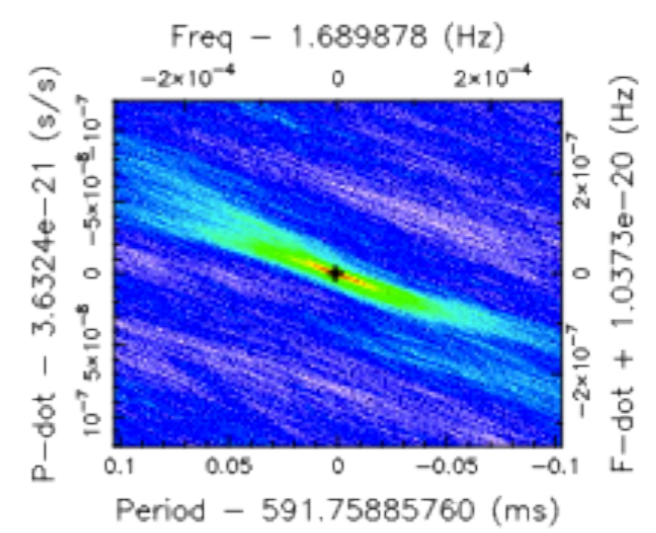
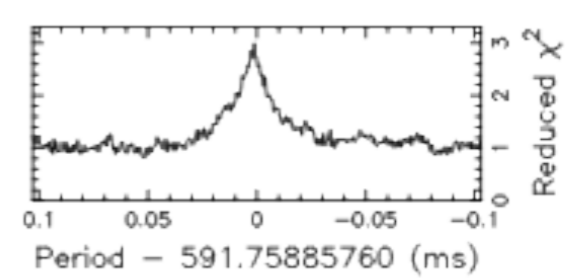
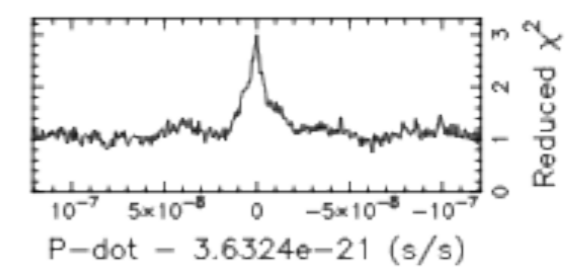
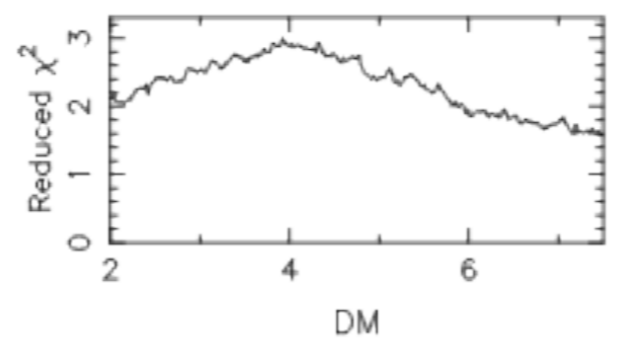
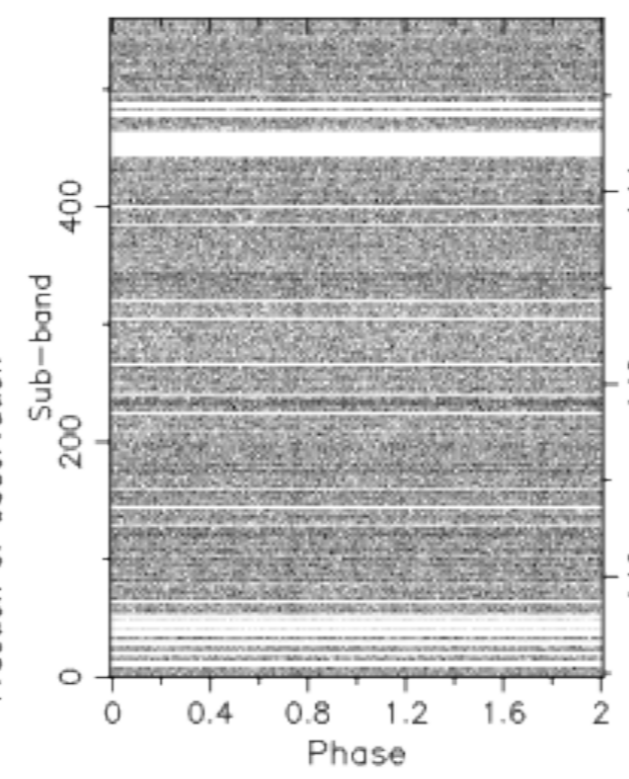
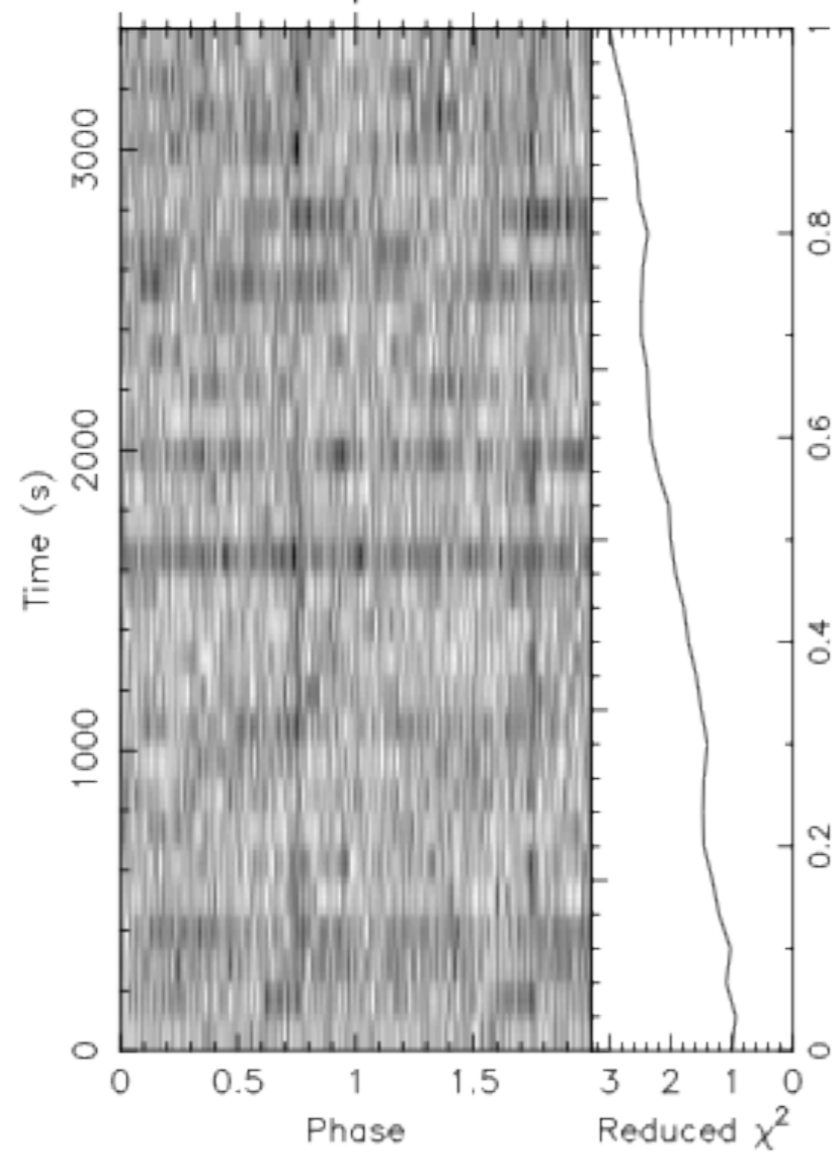


Candidate: ACCEL_Cand_4
 Telescope: LOFAR
 Epoch_{topo} = 55554.83333330000
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 Data Avg = 1.557e-
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$a_1 \sin(i)/c$ (s) = N/A ω (rad) = N/A
 T_{peri} = N/A

And then some ...



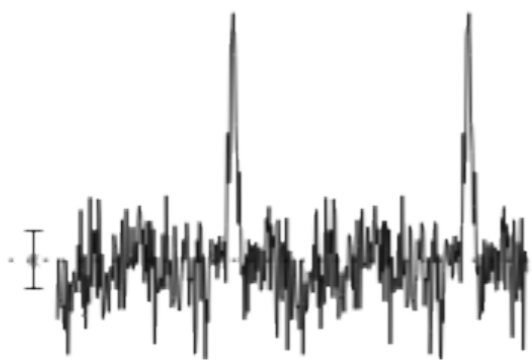
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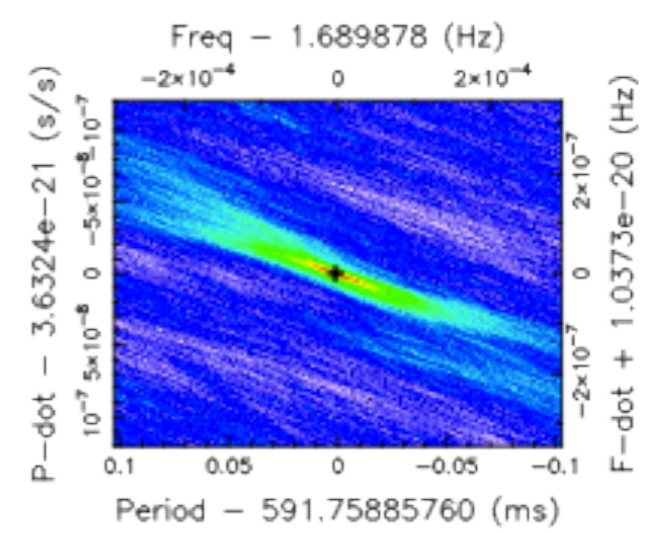
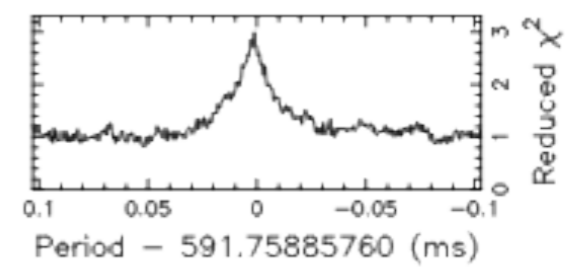
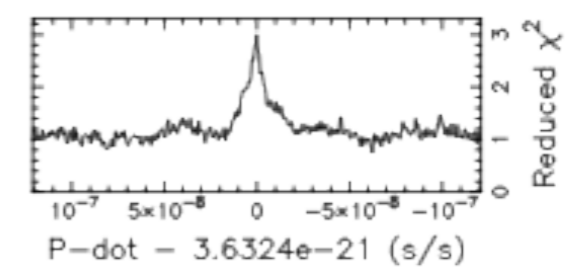
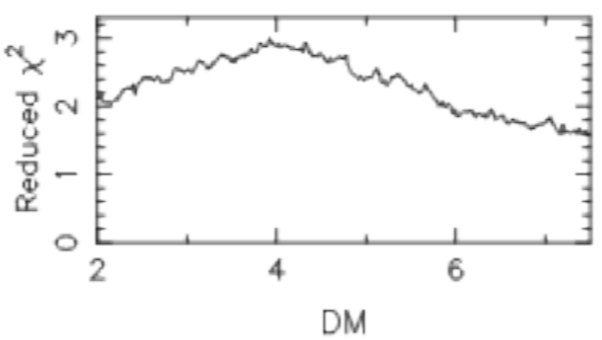
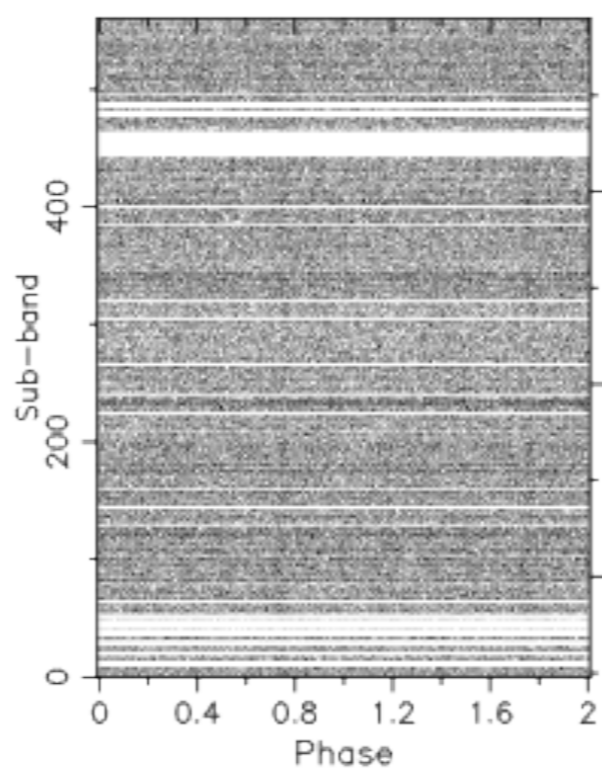
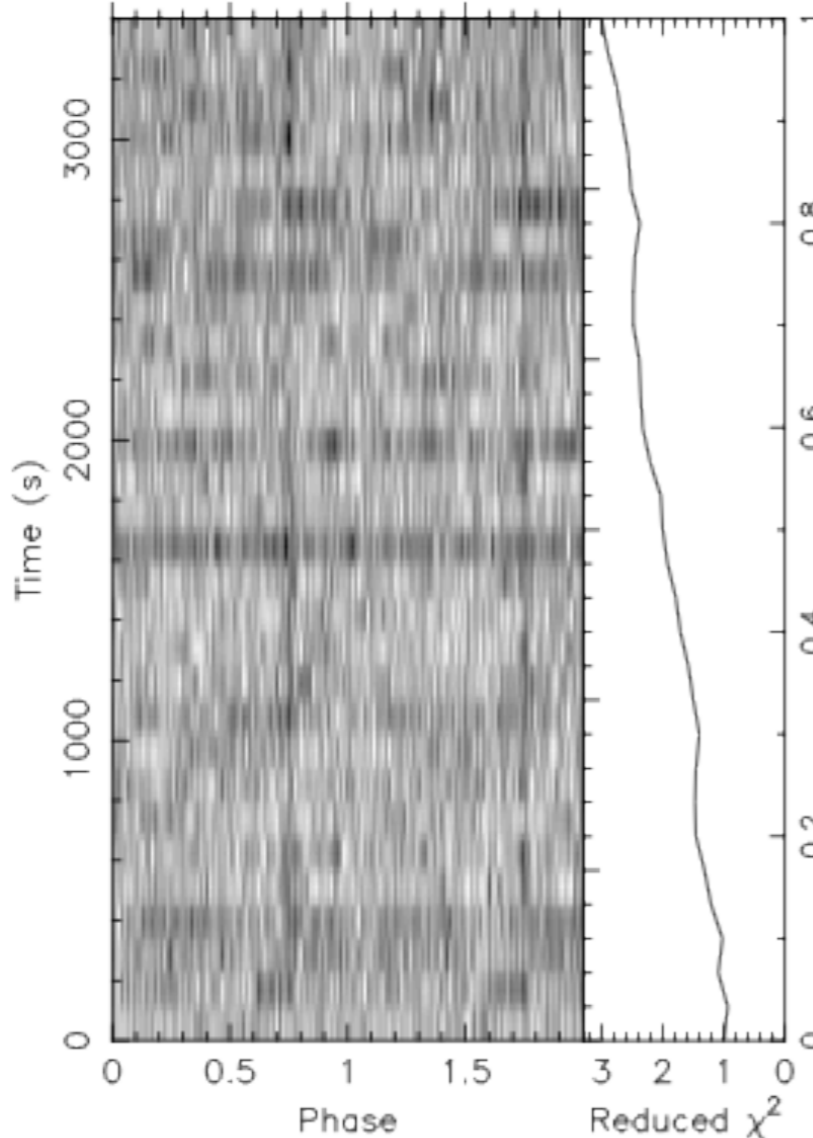
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 a₁sin(i)/c (s) = N/A ω (rad) = N/A
 T_{peri} = N/A



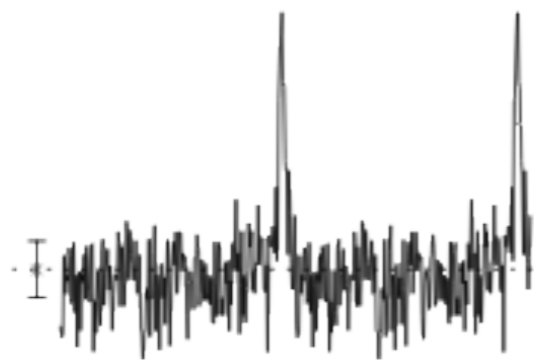
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Credit: Stappers & Hassall

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Independent discovery J2317+68

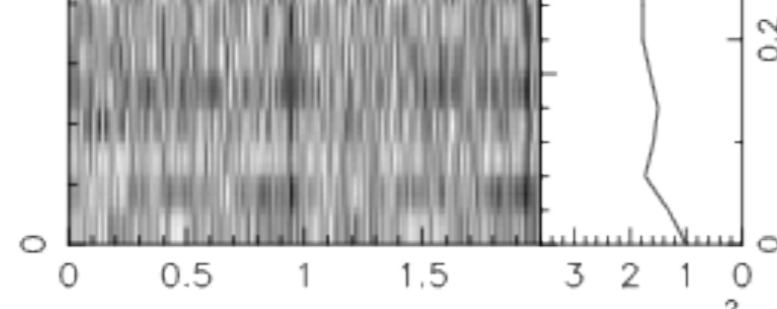
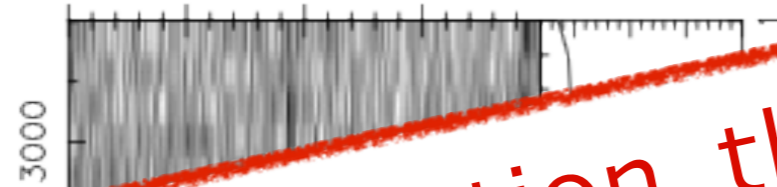
2 Pulses of Best Profile



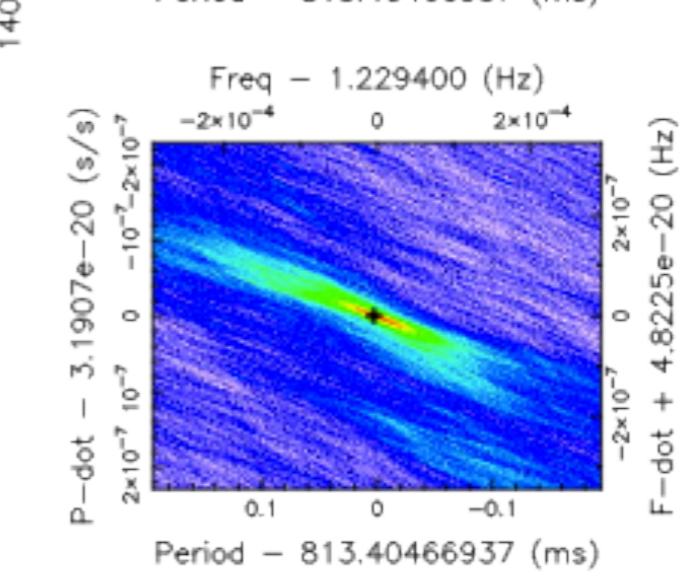
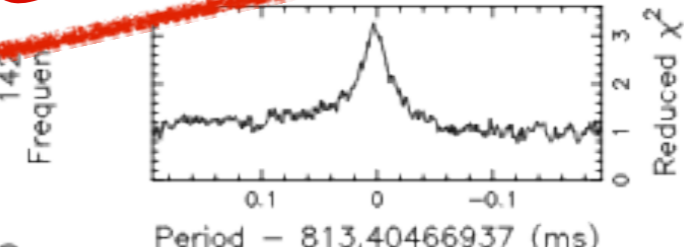
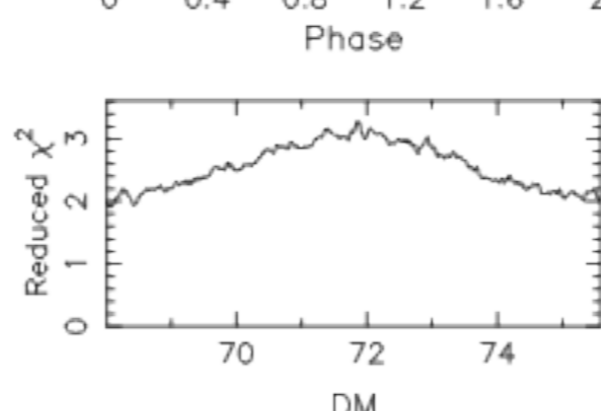
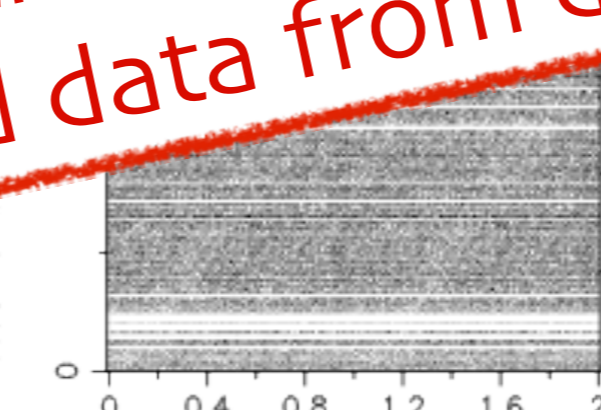
Candidate: ACCEL_Cand_2
 Telescope: LOFAR
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 Epoch_{bary} = 55559.64567106420
 T_{sample} = 0.00065536
 Data Folded = 5191680
 Data Avg = 9.48e-08
 Data StdDev = 9.508e+04
 Profile Bins = 200
 Profile Avg = 1.589e+04
 Profile StdDev = 1.532e+07

Search Information
 RA_{J2000} = 23:17:26.5502 DEC_{J2000} = 68:44:25.4076
 Folding Parameters
 Reduced χ^2 = 3.279 P(Noise) < 1.16e-49 ($\approx 14.8\sigma$)
 Dispersion Measure (DM) = 71.876
 P_{topo} (ms) = 813.4076(11) P_{bary} (ms) = 813.4076(11)
 P'_{topo} (s/s) = 0.0(2.4)x10⁻⁹ P'_{bary} (s/s) = 0.0(2.4)x10⁻⁹
 P''_{topo} (s/s²) = 0.0(4.6)x10⁻¹² P''_{bary} (s/s²) = 0.0(4.6)x10⁻¹²
 Binary Parameters
 P_{orb} (s) = N/A
 a₁ sin(i) (s) = N/A

Better detection than that of the Green Bank Telescope (a.k.a. the largest steerable dish)!
 Using uncalibrated data from december 2010!



NONE_L2010_22293_RSP3.sub0000



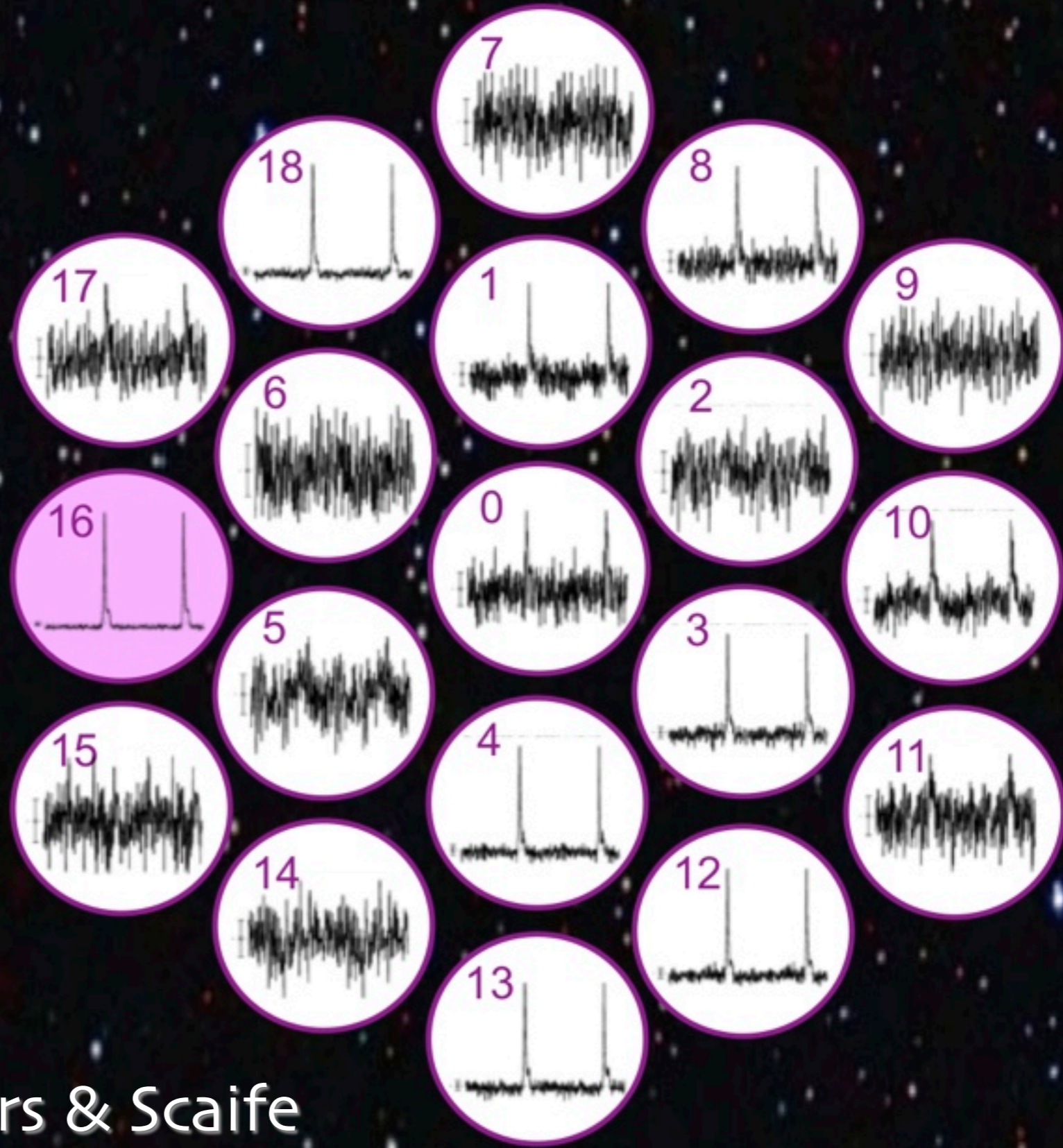
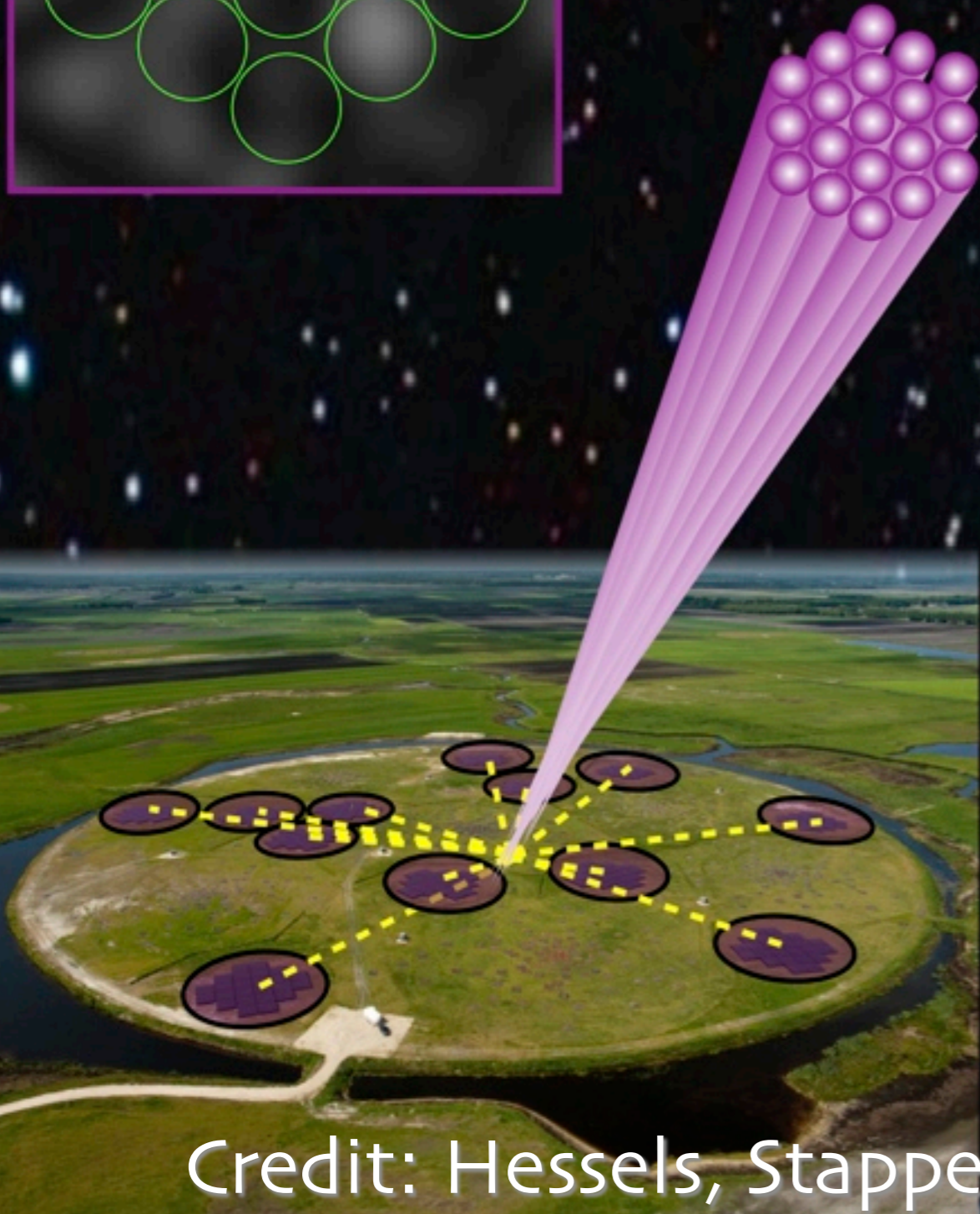
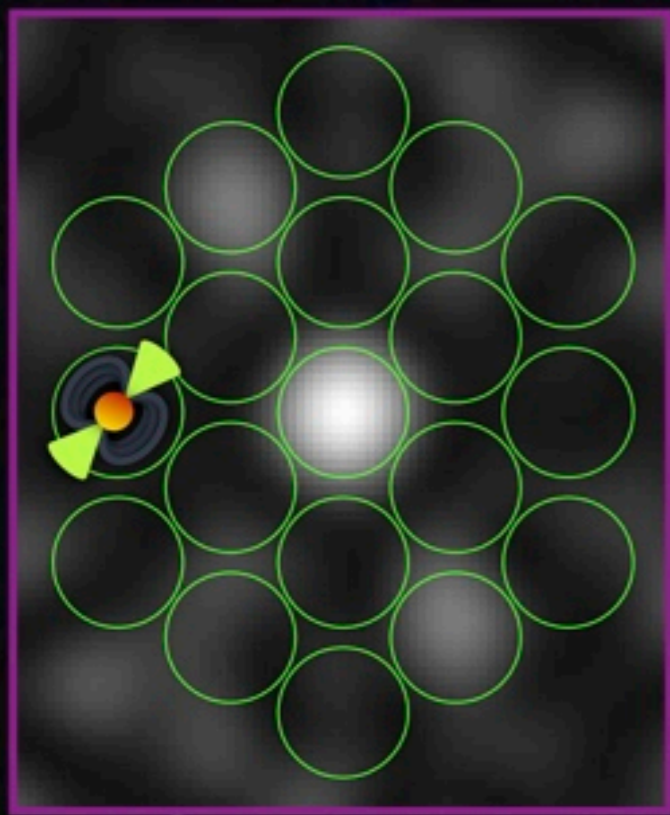
bws 26-Aug-2011 13:20

Credit: Green, Hassall & Stappers

LOTAS

- Coherent addition of LOFAR Superterp.
- 19 beams, 48 MHz bandwidth per beam, 1.3 ms sampling time.
- 17 minutes integrations.
- 3.7 square degrees of sky per pointing.
- Almost 200 observations taken so far.
- 10 times the sensitivity of LPPS

LOFAR Tied-Array Multi-Beam



Credit: Hessels, Stappers & Scaife

Future

- LPPS re-processing:
 - Mostly automated!
 - Will likely find new pulsars.
- LOTAS processing:
 - Re-use search software.
 - 10x more sensitive than LPPS
- Bet: 256 new pulsars by 12-12-2012