

# LOFAR Tied-Array All Sky Survey

## Update on the Pulsar and Fast Transient Survey

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The University of Manchester

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# Pulsar Working Group

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Kimon Zagkouris	University of Oxford

# Commissioning

## LPPS

7 incoherent station beams

75 square degrees FoV

57 minutes dwell time

**Incoherent addition of station beams  
maintains large FoV of single station**

**Sensitivity increases as square root of  
number of stations added**

## LOTAS

19 tied array beams

3.9 square degrees FoV

17 minutes dwell time

**Sensitivity scales linearly with number  
of stations added**

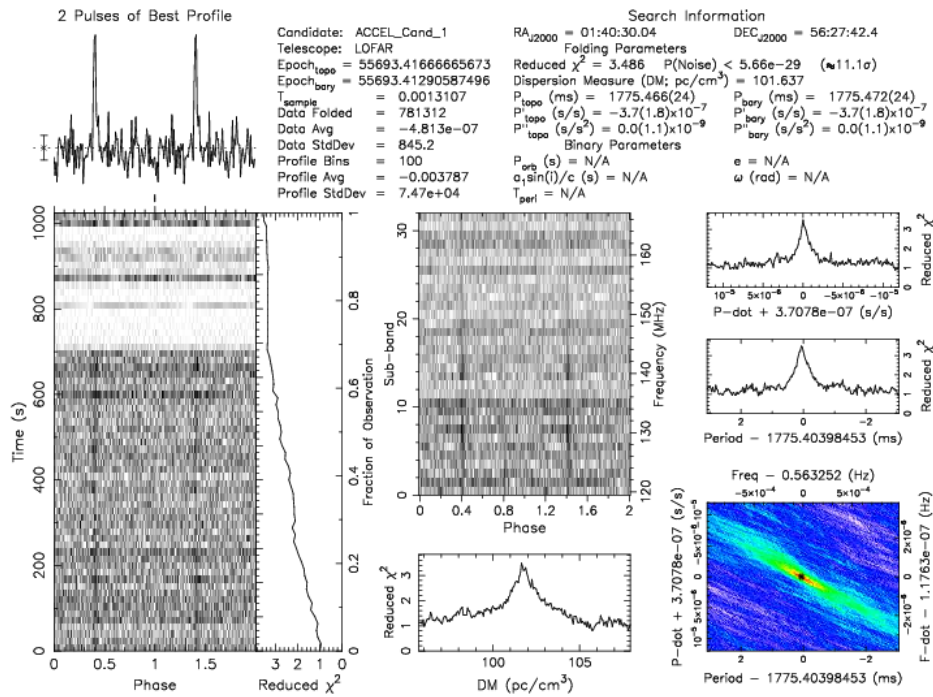
**However FoV scales as the inverse of  
the distance between stations**

# LPPS and LOTAS Results

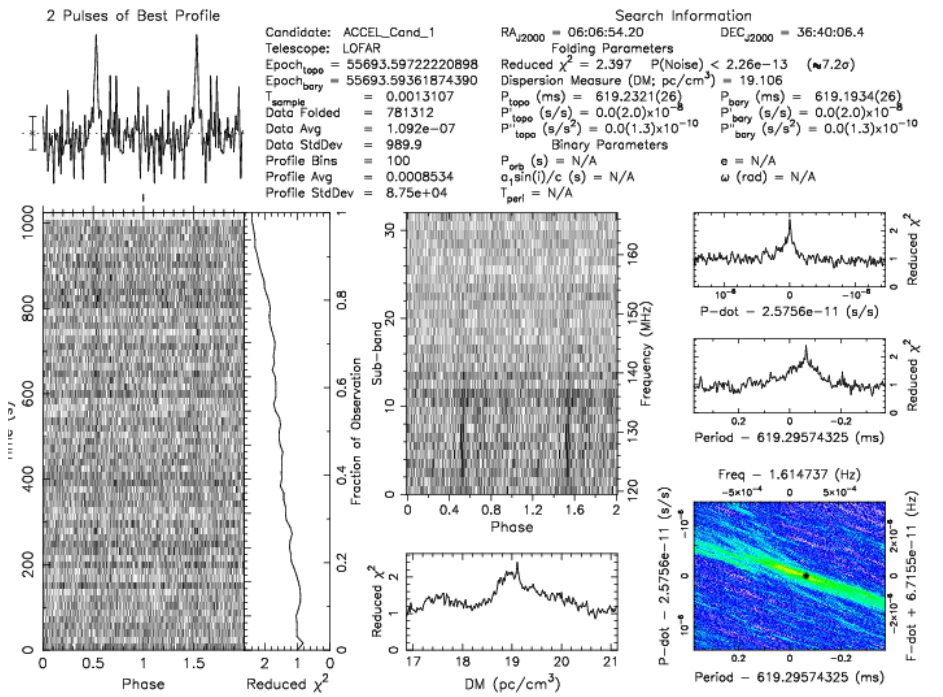
- **Periodic** and **single pulse** searches were performed for both LPPS and LOTAS.
- LPPS redetected **54 pulsars**
- LOTAS redetected **23 pulsars**
- **Independent** discovery of J2317+68 in LPPS (GBT)
- LOTAS had **5 more** independent discoveries (GBT/Palpha)
- LOTAS made **2 new** pulsar discoveries

# LOTAS Discoveries

Paper coming soon  
Thijs Coenen



J0140+5621



J0613+3731

B0136+57\_L26167\_RSP6.fits

B0136+57\_L26167\_RSP6\_IM101.82\_250\_ACCEL\_Cand\_1.coordinates\_fixed.pf4

14-Jan-2013 11:13

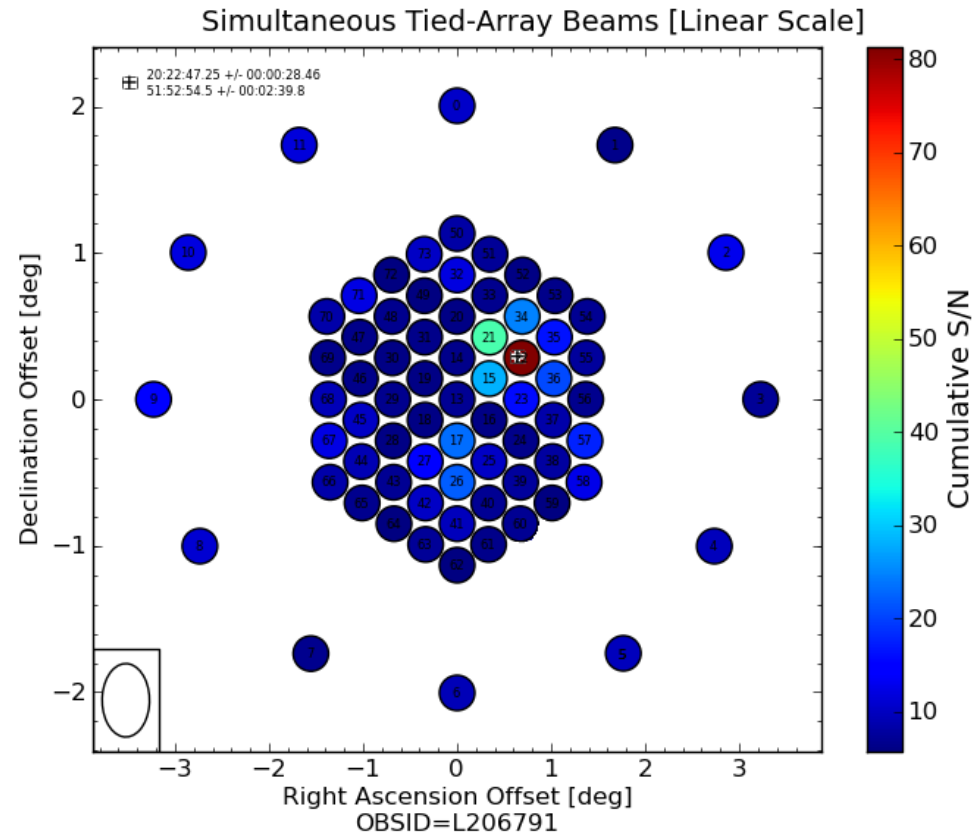
B0609+37\_L26208\_RSP4.fits

B0609+37\_L26208\_RSP4\_IM19.00\_Z0\_ACCEL\_Cand\_1.coordinates\_fixed.pf4

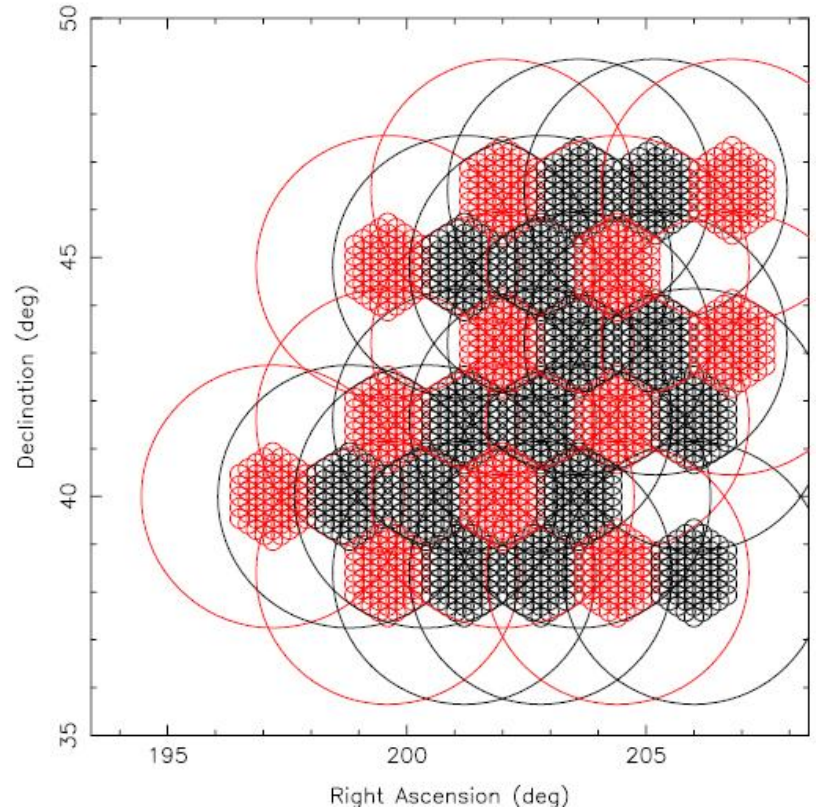
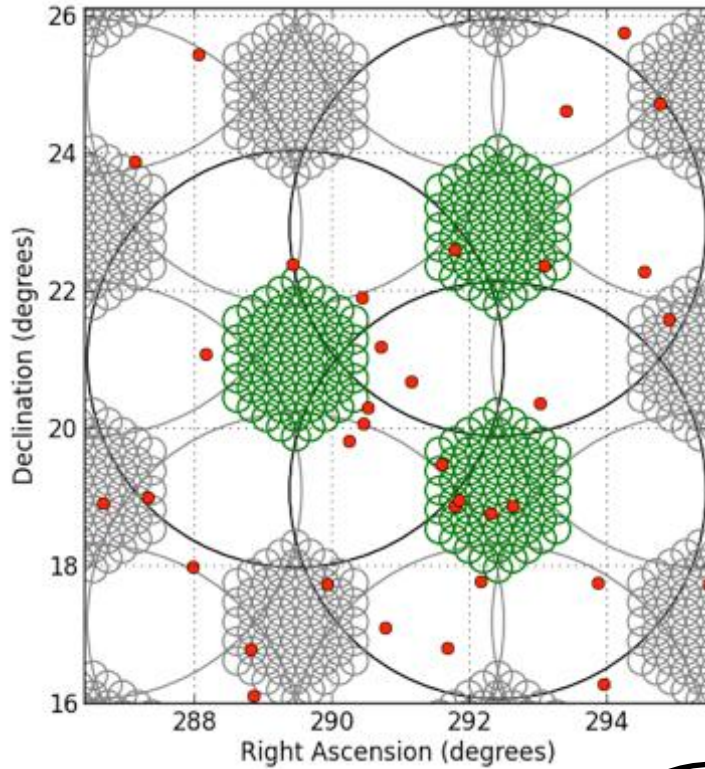
14-Jan-2013 11:03

# LOFAR Tied-Array All Sky Survey (LOTAAS)

- Superterp HBA stations
- All Northern sky
- 3 incoherent beams (SAP)
- 67 tied-array beams per SAP
- 12 additional TABs on known sources
- 119 – 151 MHz
- 1 hour observations
- 0.49 ms sampling time
- 32 MHz bandwidth per SAP



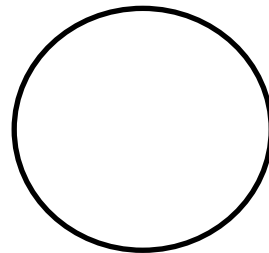
# LOTAAS Survey



[Credit: Jason Hessels]

● Known pulsars

○ Tied-Array Beam



Incoherent Beam



# Processing

- 225 completed pointings
- 4TB of 8-bit data per pointing
- Original processing at Manchester: Hydra 15 hours per beam (24hr per pointing)

Since November 2013:

- Granted 10,000,000 CPU hours on Cartesius
- 4 hours (on single node with 24 CPUs) to process a beam
- Periodic and single pulse searching

## DATA TRANSFER

Stage data directly from Grid to Cartesius.

Download 1 beam in ~2mins

Download full pointing takes ~7hours

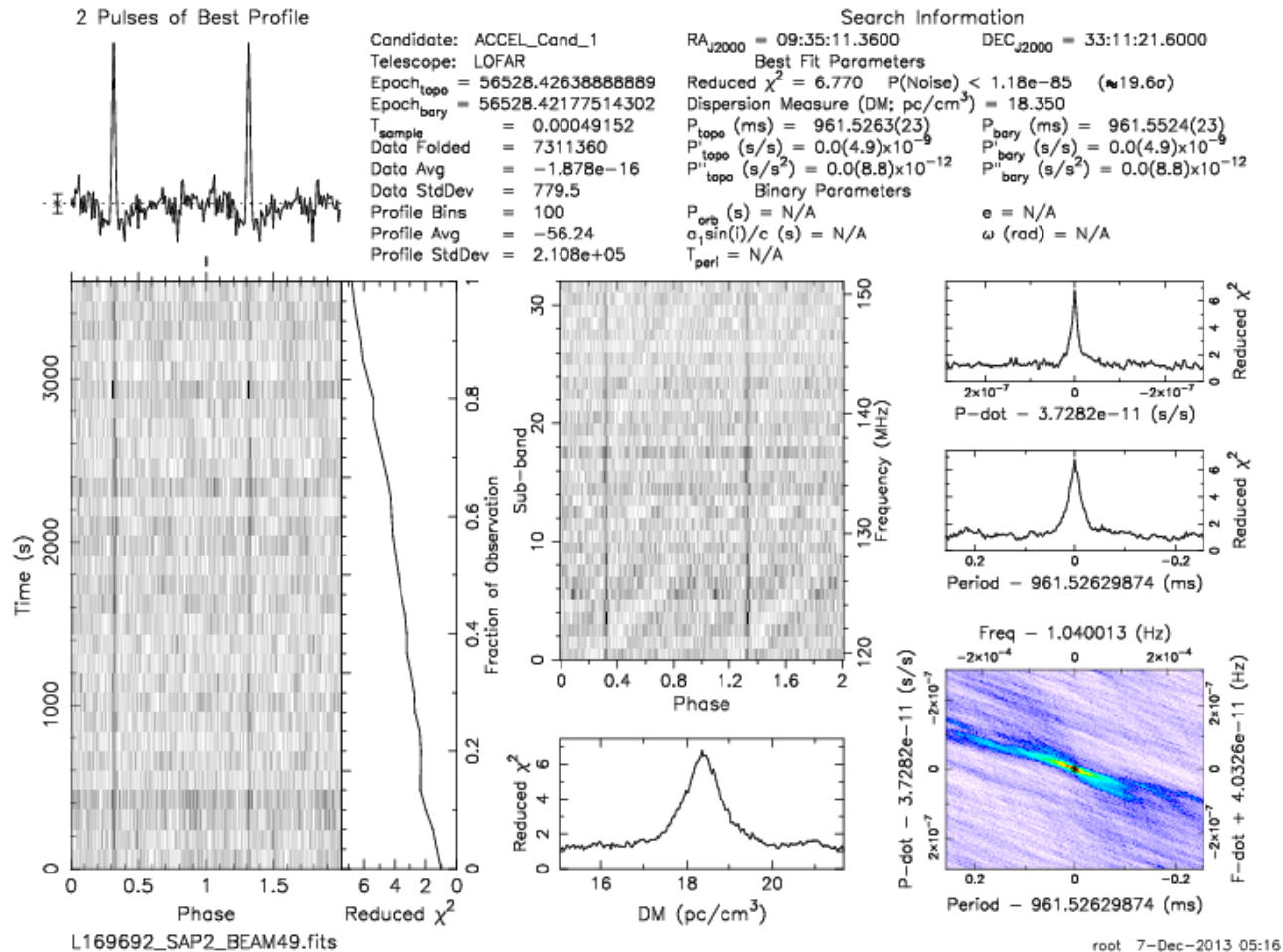
Can run multiple downloads simultaneously

# Current Status

- Processed 100 pointings (80 with Cartesius)
- Period and single pulse searching
- Total number of candidates = 2 million (Hydra + Cartesius)
- Cuts made on basic candidate criteria: DM, period, SNR
- Only shallow search: 2% of all candidates
- Known pulsars blind detected = 50
- Redetection of GBNCC pulsar J1815+55

Discovered 2 new pulsars

# J0935+3311 Discovery

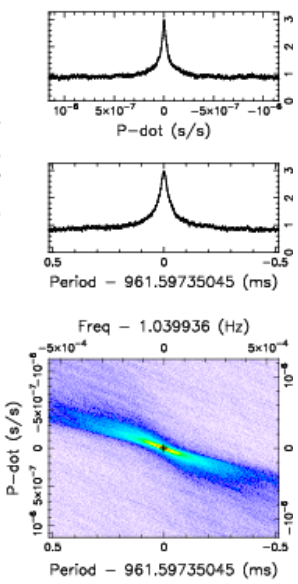
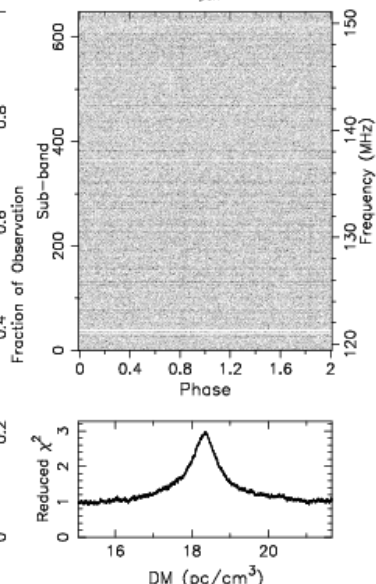
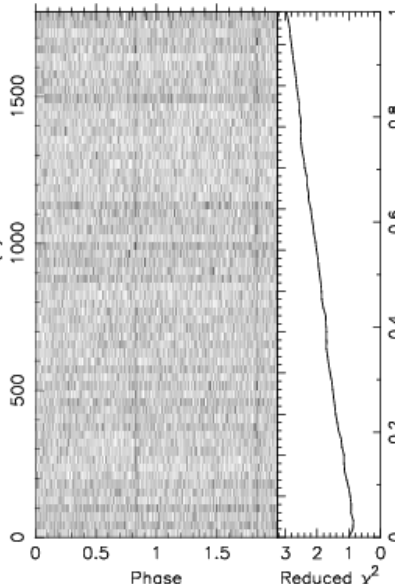


# J0935+3311 Confirmation

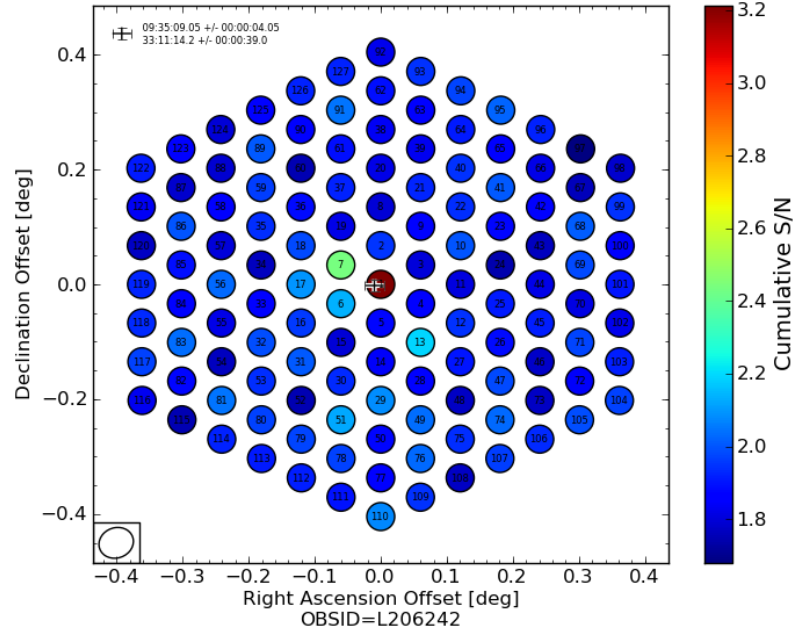
2 Pulses of Best Profile

Candidate: PSR\_J0935+3311  
 Telescope: LOFAR  
 Epoch<sub>topo</sub> = 56721.98888888889  
 Epoch<sub>bary</sub> = N/A  
 T<sub>sample</sub> = 0.00049152  
 Data Folded = 3637248  
 Data Avg = 3.065e+05  
 Data StdDev = 3686  
 Profile Bins = 1024  
 Profile Avg = 1.089e+09  
 Profile StdDev = 2.197e+05

Search Information  
 RA<sub>J2000</sub> = 09:35:11.0000 DEC<sub>J2000</sub> = 33:11:22.0000  
 Best Fit Parameters  
 Reduced  $\chi^2$  = 2.970 P(Noise) < 1.25e-198 ( $\approx 30.0\sigma$ )  
 Dispersion Measure (DM; pc/cm<sup>3</sup>) = 18.337  
 P<sub>topo</sub> (ms) = 961.59937(73) P<sub>bary</sub> (ms) = N/A  
 P<sub>topo</sub> (s/s) = 0.0(3.2) × 10<sup>-9</sup> P<sub>bary</sub> (s/s) = N/A  
 P<sub>topo</sub> (s/s<sup>2</sup>) = 0.0(1.1) × 10<sup>-11</sup> P<sub>bary</sub> (s/s<sup>2</sup>) = N/A  
 Binary Parameters  
 P<sub>orb</sub> (s) = N/A e = N/A  
 a<sub>1</sub> sin(i)/c (s) = N/A  $\omega$  (rad) = N/A  
 T<sub>perl</sub> = N/A



SAP #0. Cumulative S/N of PSR J0935+3311 in 127 (out of 127) Simultaneous Tied-Array Beams [Log Scale]

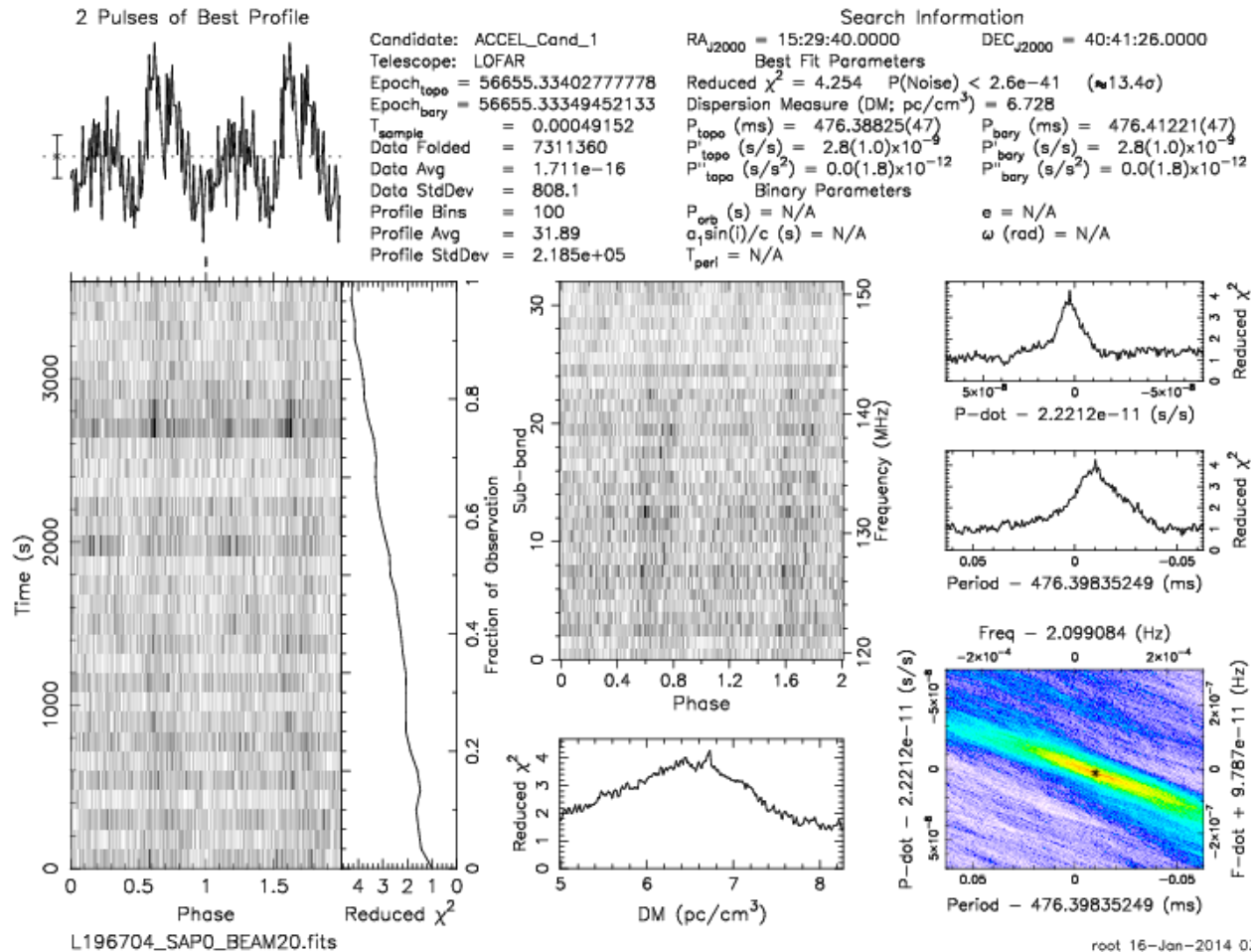


L206242\_SAPO\_BEAM1.fits

kondratiev 7-Mar-2014 01:25

127 beams using Full Core

# J1529+4049 Discovery



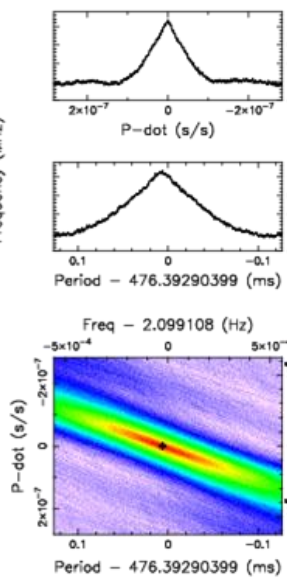
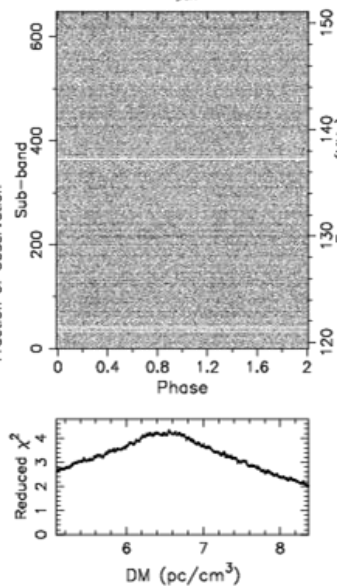
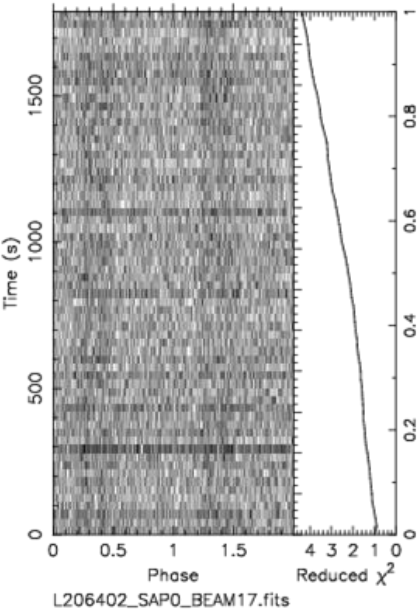
Originally found in 2 neighbouring beams

# J1529+4049 Confirmation

2 Pulses of Best Profile

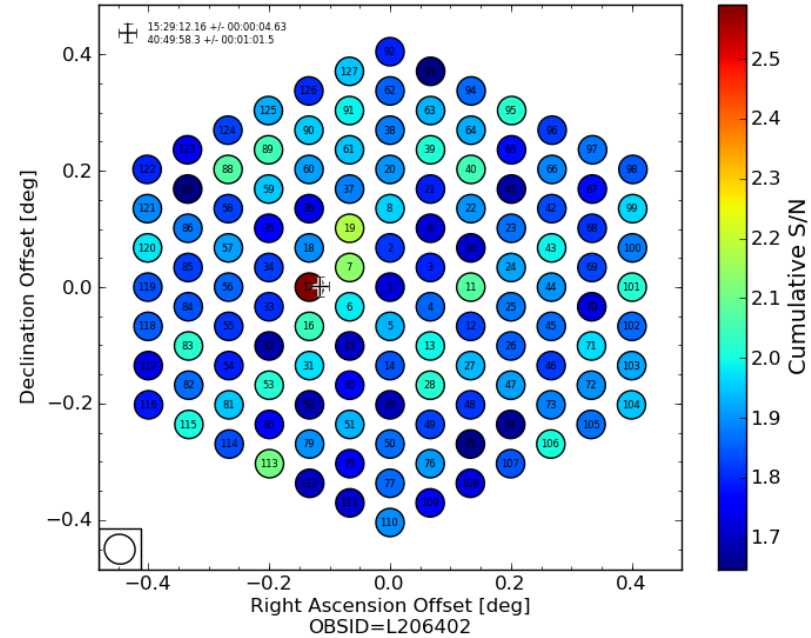
Candidate: PSR\_J1529+4049  
 Telescope: LOFAR  
 Epoch<sub>topo</sub> = 56722.13541666666  
 Epoch<sub>bary</sub> = N/A  
 T<sub>sample</sub> = 0.00049152  
 Data Folded = 3637248  
 Data Avg = 3.061e+05  
 Data StdDev = 3695  
 Profile Bins = 512  
 Profile Avg = 2.174e+09  
 Profile StdDev = 3.114e+05

Search Information  
 RA<sub>J2000</sub> = 15:29:08.0000      DEC<sub>J2000</sub> = 40:49:55.0000  
 Best Fit Parameters  
 Reduced  $\chi^2$  = 4.348      P(Noise) < 2.73e-211 (≈31.0σ)  
 Dispersion Measure (DM; pc/cm<sup>3</sup>) = 6.552  
 P<sub>topo</sub> (ms) = 476.39910(49)      P<sub>bary</sub> (ms) = N/A  
 P<sub>topo</sub> (s/s) = 0.0(2.1)×10<sup>-9</sup>      P<sub>bary</sub> (s/s) = N/A  
 P<sub>topo</sub> (s/s<sup>2</sup>) = 0.0(7.6)×10<sup>-12</sup>      P<sub>bary</sub> (s/s<sup>2</sup>) = N/A  
 Binary Parameters  
 P<sub>orb</sub> (s) = N/A      e = N/A  
 a<sub>1</sub> sin(i)/c (s) = N/A      ω (rad) = N/A  
 T<sub>peri</sub> = N/A



6-Mar-2014 09:47

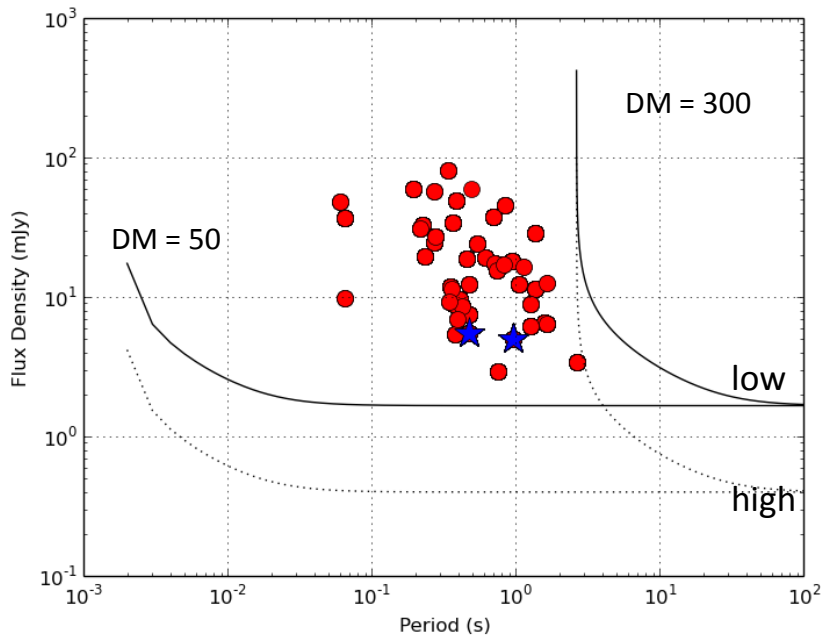
SAP #0. Cumulative S/N of PSR J1529+4049 in 127 (out of 127) Simultaneous Tied-Array Beams [Log Scale]



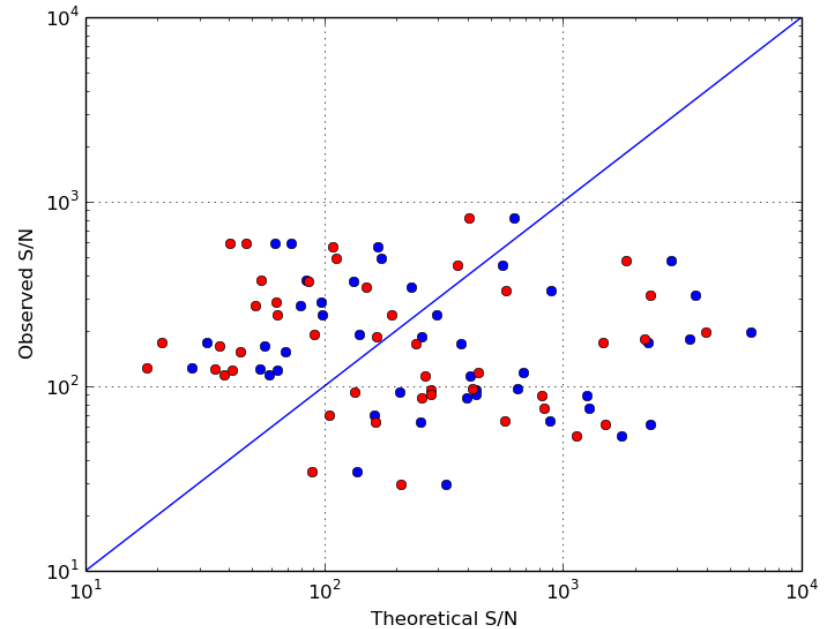
127 beams using Full Core

# Sensitivity

$$S_{min} = \frac{(S/N_{min}) 2k T_{sys}}{A_{eff} \sqrt{n_p t_{obs} \delta\nu}} \sqrt{\frac{W_{eff}}{P - W_{eff}}}$$



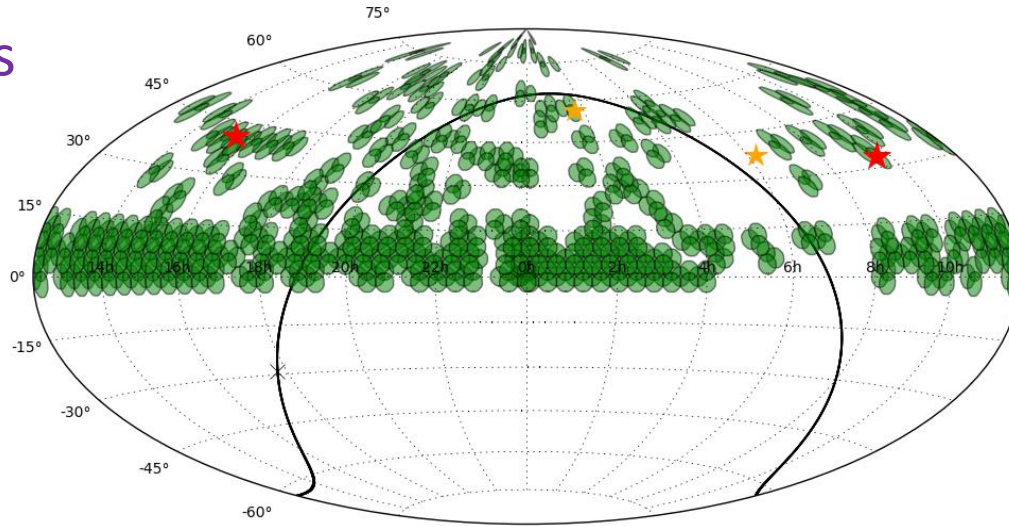
Assumed Bhat 2004 scattering



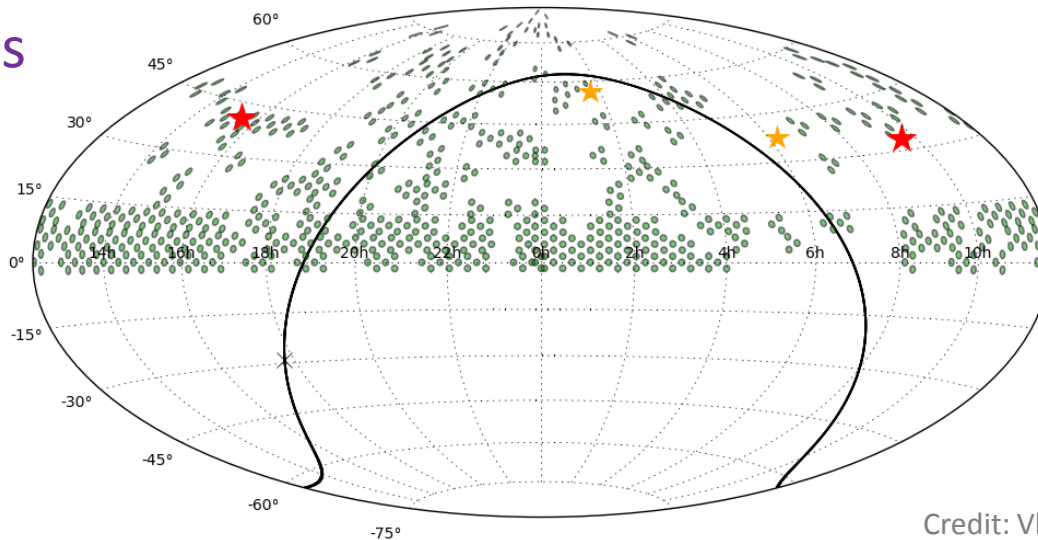
Theoretical value extrapolated from 400 MHz using spectral index of -1.8 (blue) and -1.4 (red)



# Completed Pointings

## Incoherent Beams



## Tied-Array Beams



-  LOTAAS pulsars
-  LOTAS pulsars



# Ongoing and Future

- Fixed most data processing issues
- Candidates: 2 million – only *skimmed* the surface
- Expect to make most discoveries close to our sensitivity limit
- Machine learning
  - original score system has been revised
  - 50 known pulsars to make training set
- Analyse single pulse search output
- Observations with Lovell at L-band of J1529+4049
- Long term proposal submitted cycle 2-5 for 1001 hours
- Our discovery webpage <http://www.astron.nl/lotaas>