

LOFAR

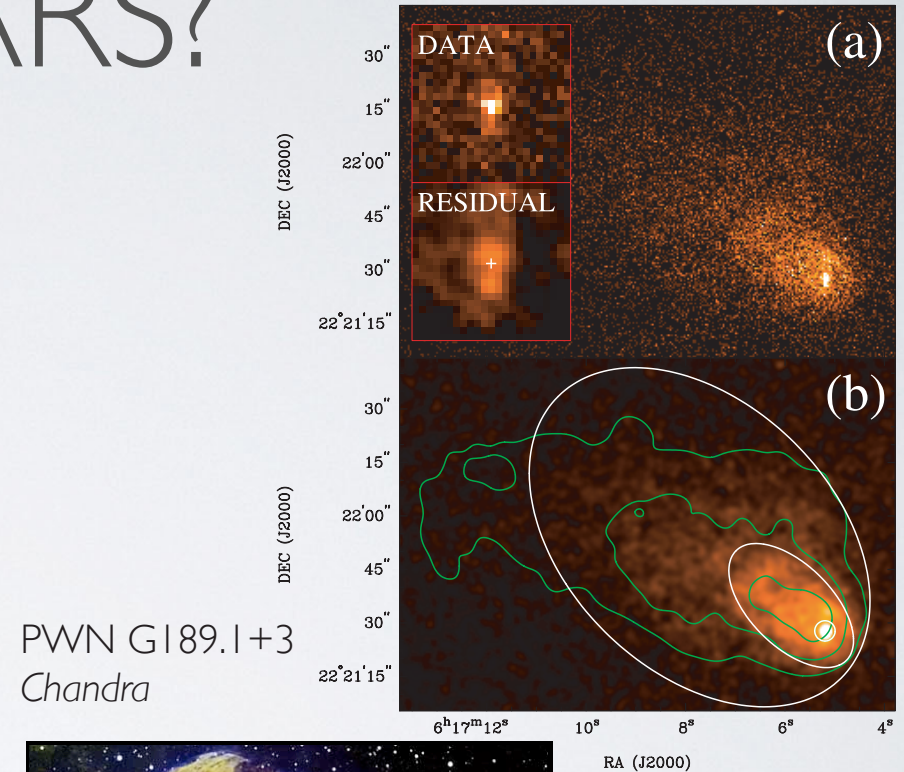
A QUEST FOR MISSING
PULSARS

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WHAT ARE “MISSING” PULSARS?

- ~ half of PWN are associated with a pulsar (32/56)
- less than 25% of all SNRs are associated with a pulsar (60/294)



IC 443
Abdo et al. 2010

WHY SEARCH FOR “MISSING” PULSARS?

- Independent age estimates
- Kick velocity measurements
- Energetic input of pulsar into environment (PWN)

HOW TO FIND MISSING PULSARS?

- Search “deeper” → Lower sensitivity limits
 - Observe longer
 - Observe with bigger telescopes
 - Observe larger surface
- Observe at different frequency

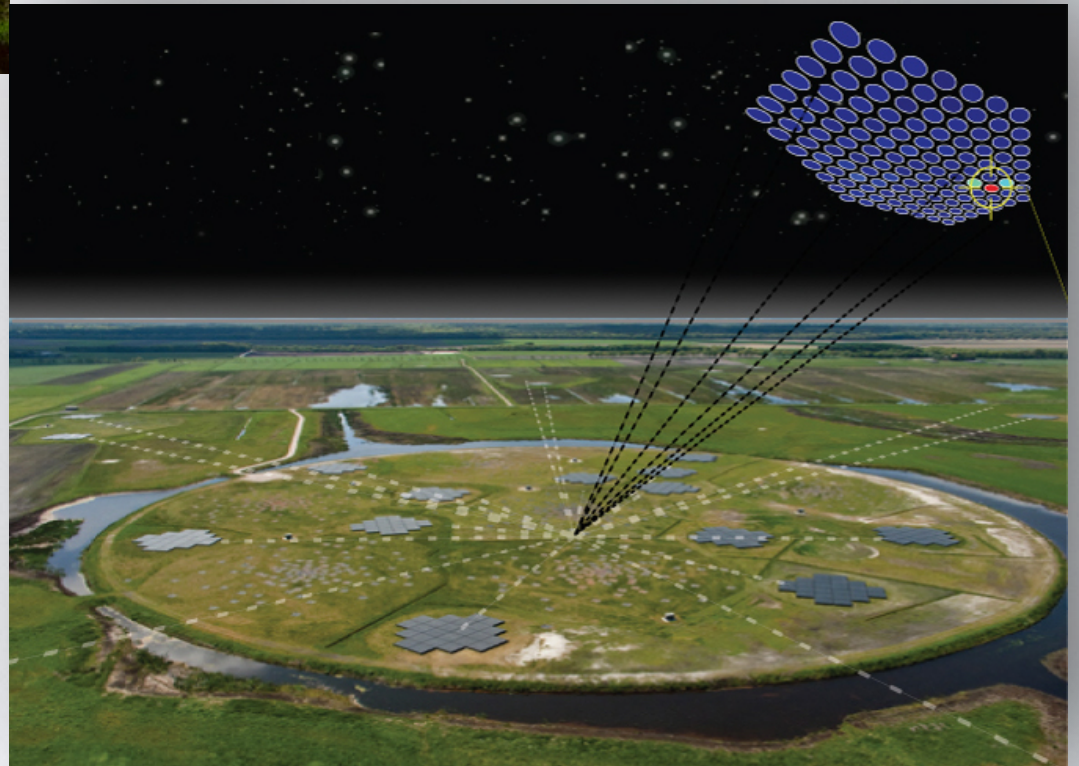
HOW TO FIND MISSING PULSARS?

- **Search “deeper” → Lower sensitivity limits**
 - **Observe longer**
 - **Observe with bigger telescope**
 - **Observe larger surface**
- Observe at different frequency



Search core of SNR

Search entire SNR



HOW TO FIND MISSING PULSARS?

- Search “deeper” → Lower sensitivity limits
 - Observe longer
 - Observe with bigger telescope
 - Observe larger surface
- **Observe at different frequency**

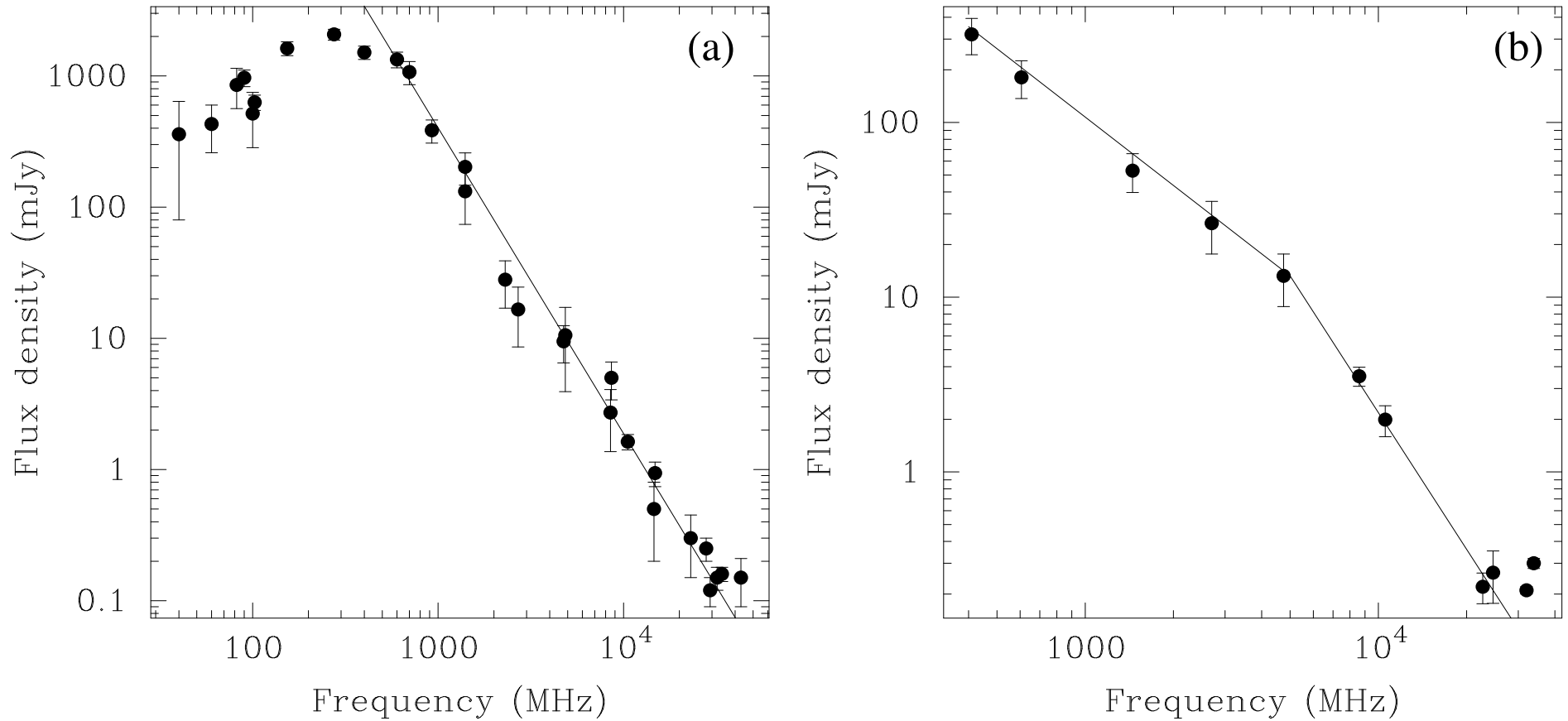
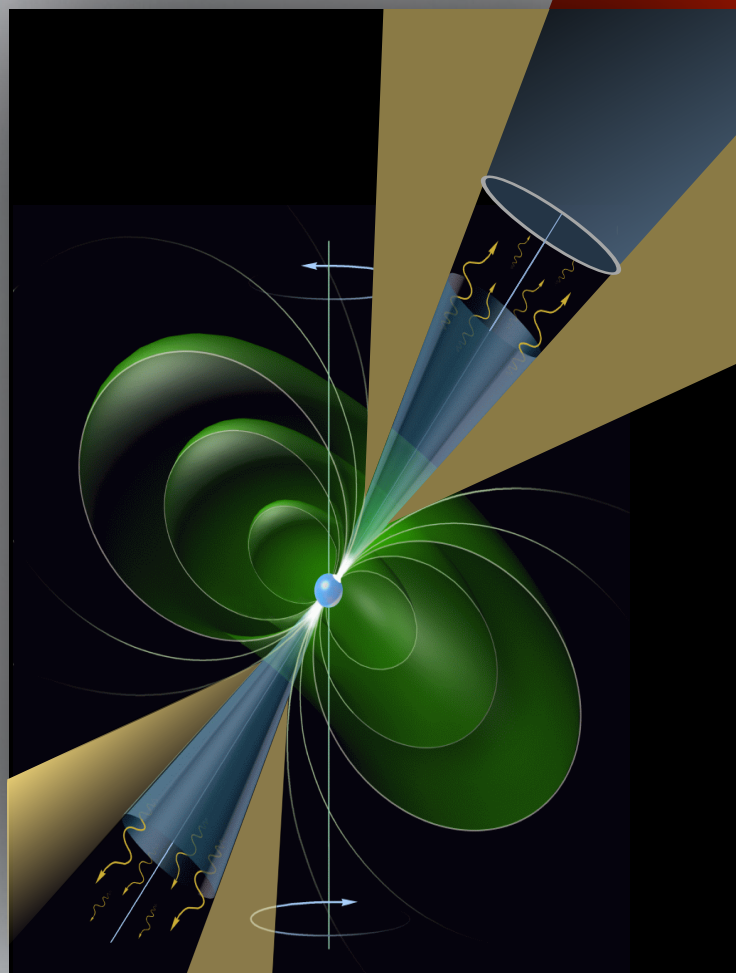


Fig. 1.4. Sample flux density spectra for two pulsars showing different types of spectral behaviour. (a) A low-frequency turnover in PSR B0329+54. (b) A broken power law fit and possible high-frequency turn-up in PSR B1929+10.



SOURCES - $d < 5$ kpc

Source	Object	Diameter	Beams	Distance (kpc)
G049.2-0.7	SNR + PWN (?)	25 '	91	4.1
G063.7+1.1	SNR + PWN	8 '	7	3.8 ± 1.5
G065.3+5.7	SNR	310 ' X 240 '	91	0.9
G074.9+1.2	SNR + PWN	8 ' x 6 '	1	0.77
G093.3+6.9	SNR + PWN (?)	27 ' x 20 '	91	3.5
G141.2+5.0	PWN + NS	3.5 '	7	4.0 ± 0.5
G150.3+4.5	SNR	~150 '	91	-
G189.1+3	SNR + NS	30 ' x 36 '	1	2

SOURCES - ANALYZED

500.000 CPU hrs. @ Cartesius

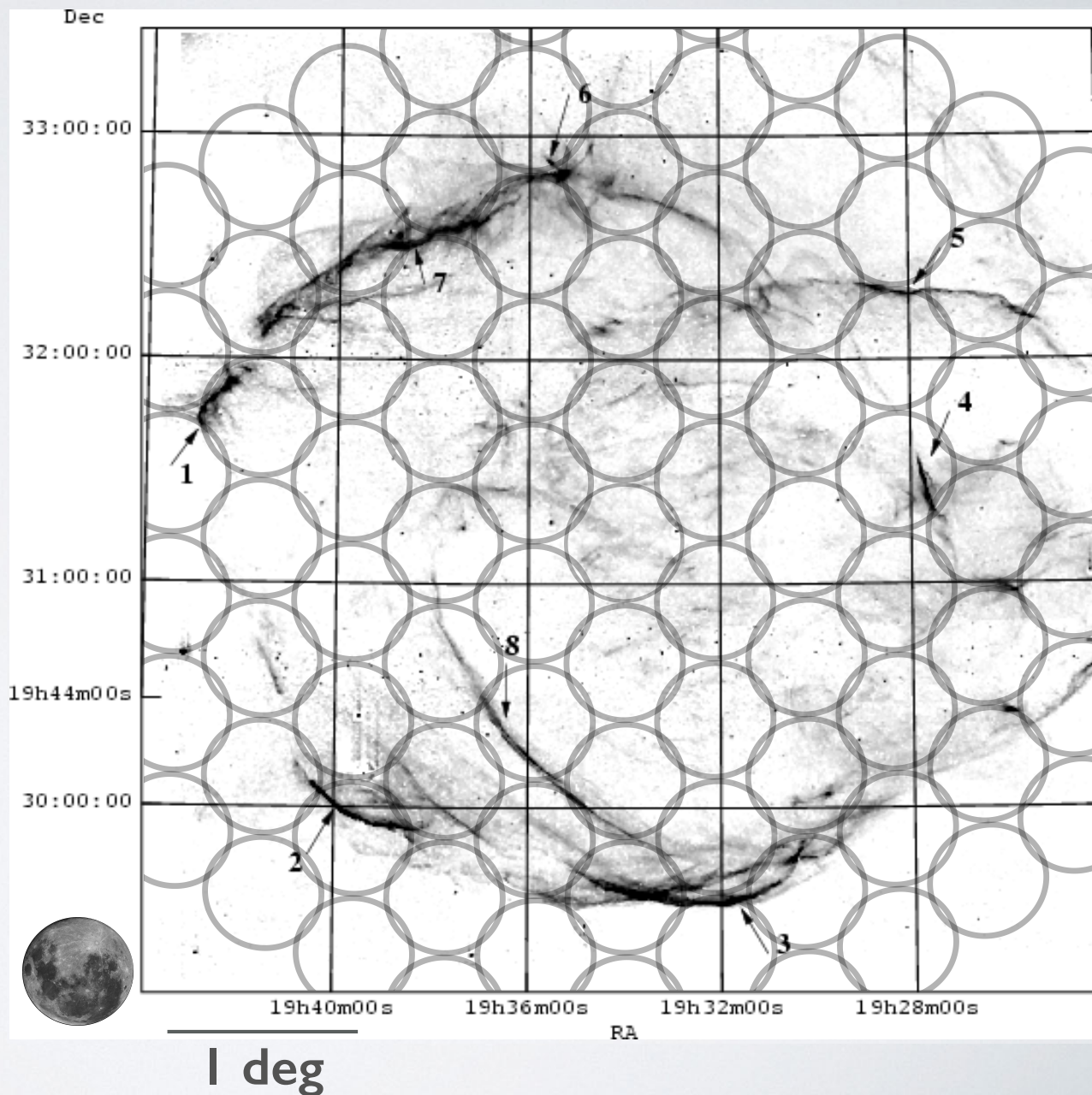
Source	Object	CCO	Diameter	Beams	Distance (kpc)
G049.2-0.7	SNR + PWN (?)		25 '	91	4.1
G063.7+1.1	SNR + PWN		8 '	7	3.8 ± 1.5
G065.3+5.7	SNR		310 ' X 240 '	91	0.9
G074.9+1.2	SNR + PWN	V	8 ' x 6 '	1	0.77
G093.3+6.9	SNR + PWN (?)		27 ' x 20 '	91	3.5
G141.2+5.0	PWN + NS _(new)	V	3.5 '	7	4.0 ± 0.5
G150.3+4.5	SNR		~150 '	91	-
G189.1+3	SNR + NS	V	30 ' x 36 '	1	2

SOURCES - RESULTS

Source	Object	Diameter	Beams	Cands	Pulsar?
G049.2-0.7	SNR + PWN (?)	25 '	91	-	-
G063.7+1.1	SNR + PWN	8 '	7	5k	no
G065.3+5.7	SNR	310 ' X 240 '	91	30k	no
G074.9+1.2	SNR + PWN	8 ' x 6 '	1	7k	no
G093.3+6.9	SNR + PWN (?)	27 ' x 20 '	91	-	-
G141.2+5.0	PWN + NS _(new)	3.5 '	7	2k	no
G150.3+4.5	SNR	~150 '	91	-	-
G189.1+3	SNR + NS	30 ' x 36 '	1	1k	no
Total			380	45k	

G065.3+5.7

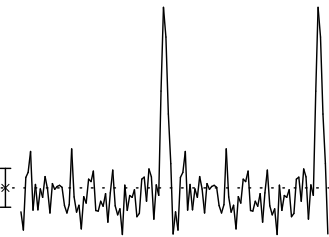
- “Break-out” SNR
- 5 x 4 degrees
- Previously searched only for 1% - 12%
- covered by superterp



PSR CANDIDATE

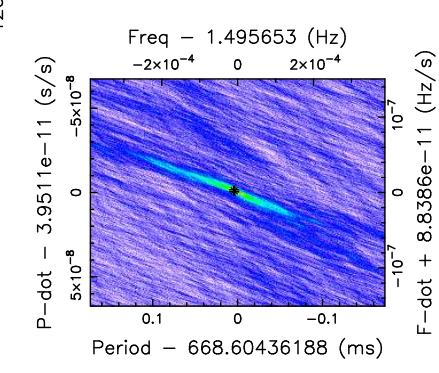
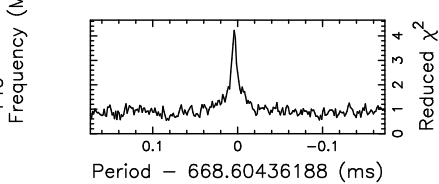
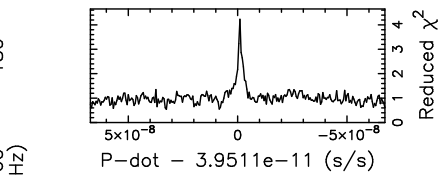
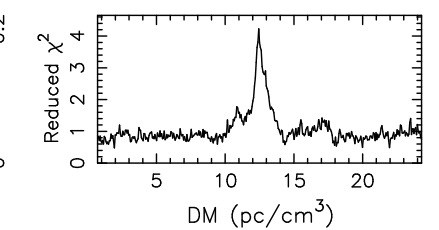
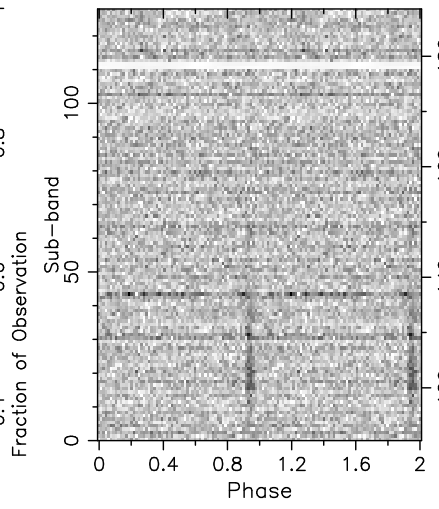
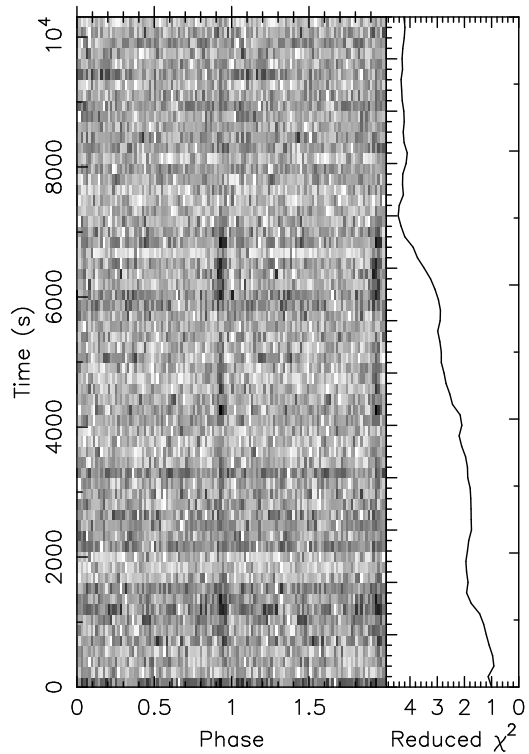
P=668.64 ms

2 Pulses of Best Profile



Candidate: 668.64ms_Cand
 Telescope: LOFAR
 Epoch_{topo} = 57128.21759259259
 Epoch_{bary} = 57128.21789638141
 T_{sample} = 0.0013107
 Data Folded = 7864320
 Data Avg = 1.625e+06
 Data StdDev = 8520
 Profile Bins = 64
 Profile Avg = 1.997e+11
 Profile StdDev = 2.987e+06

Search Information
 RA_{J2000} = 19:32:10.0000 DEC_{J2000} = 31:58:46.0000
 Best Fit Parameters
 DOF_{eff} = 59.71 χ^2_{red} = 4.226 P(Noise) < 8.25e-27 (10.7 σ)
 Dispersion Measure (DM; pc/cm³) = 12.439
 P_{topo} (ms) = 668.60843(71) P_{bary} (ms) = 668.64807(71)
 P_{topo} (s/s) = -1.01(53) $\times 10^{-9}$ P_{bary} (s/s) = -1.05(53) $\times 10^{-9}$
 P_{topo} (s/s²) = 0.0(3.3) $\times 10^{-13}$ P_{bary} (s/s²) = 0.0(3.3) $\times 10^{-13}$
 Binary Parameters
 P_{orb} (s) = N/A e = N/A
 a₁sin(i)/c (s) = N/A ω (rad) = N/A
 T_{peri} = N/A



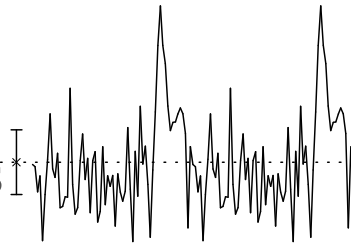
L340118_SAP0_BEAM19.fits

30-Mar-2016 16:40

PSR CANDIDATE

P=191.04 ms

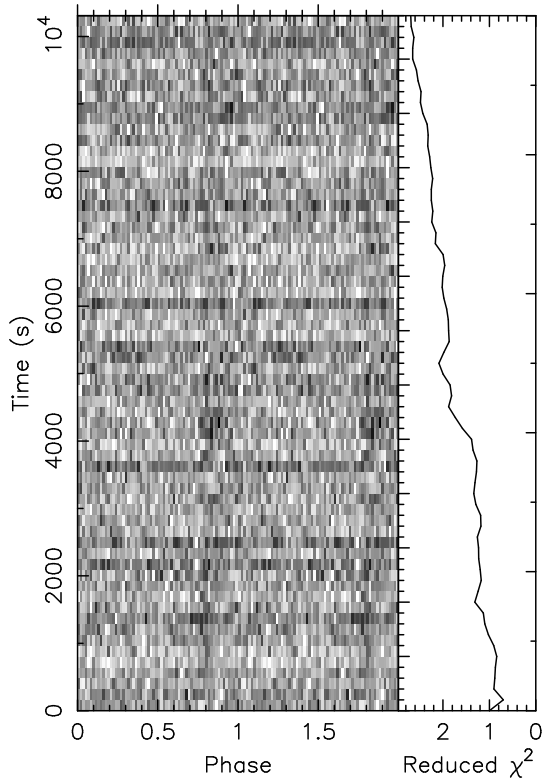
2 Pulses of Best Profile



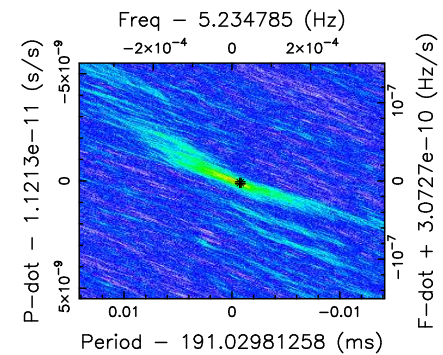
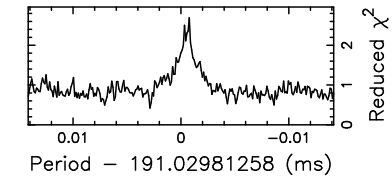
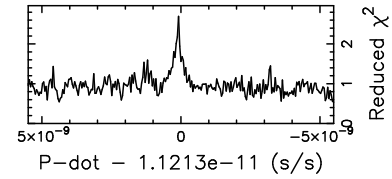
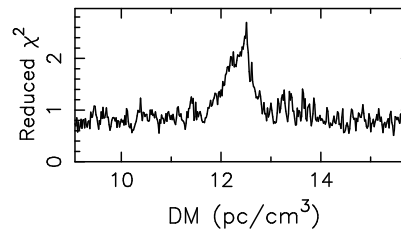
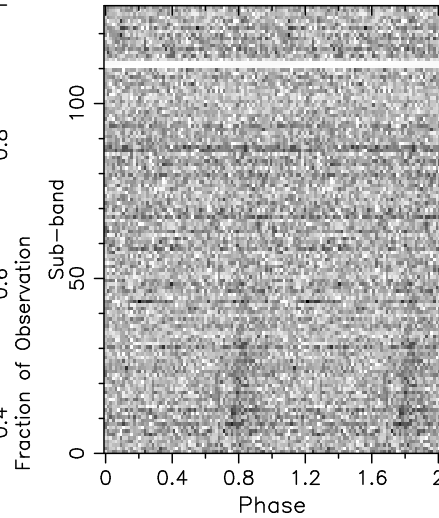
Candidate: 191.04ms_Cand
 Telescope: LOFAR
 Epoch_{topo} = 57128.21759259259
 Epoch_{bary} = 57128.21788871723
 T_{sample} = 0.0013107
 Data Folded = 7864320
 Data Avg = 1.599e+06
 Data StdDev = 8583
 Profile Bins = 64
 Profile Avg = 1.965e+11
 Profile StdDev = 3.009e+06

Search Information

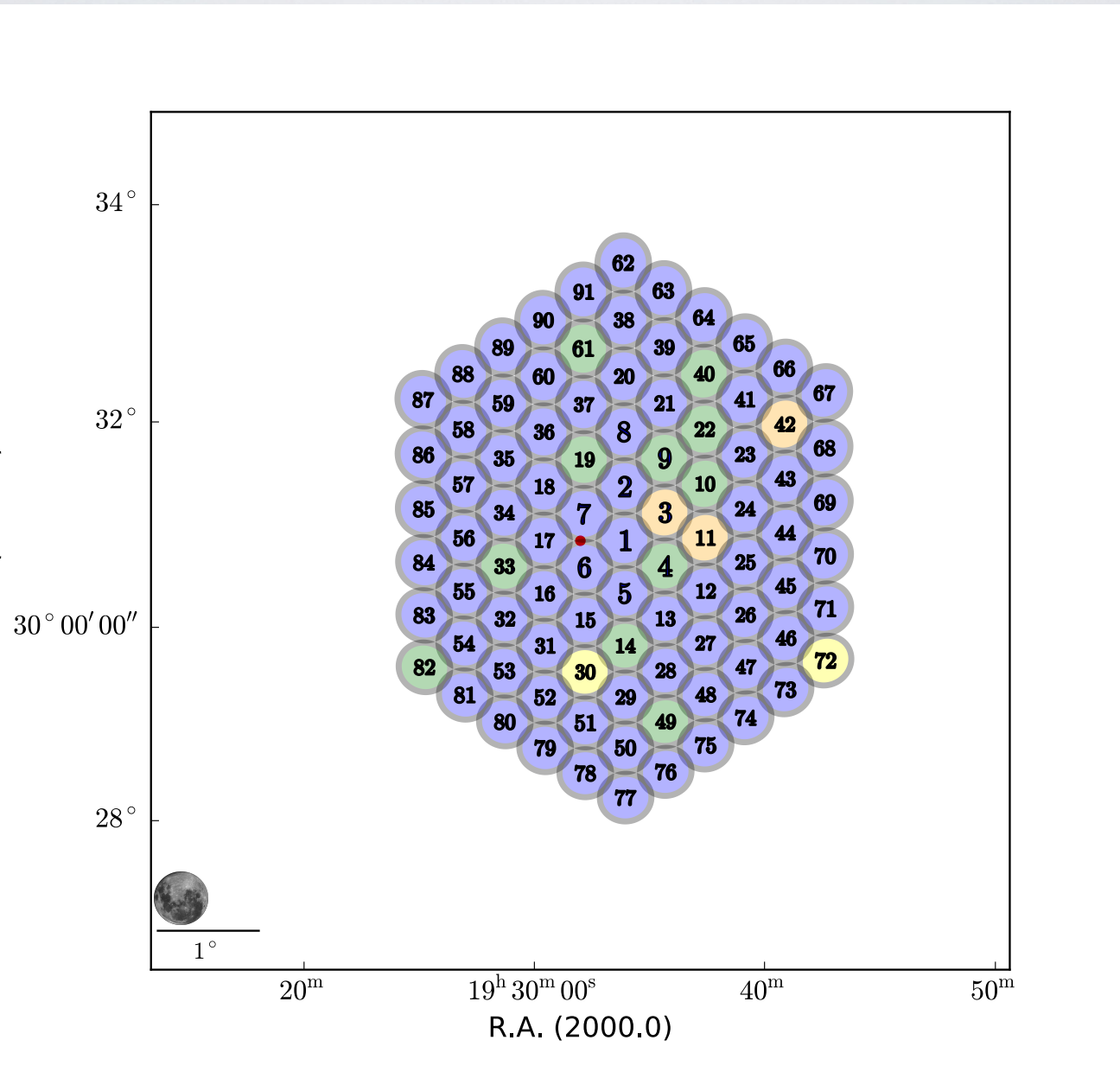
RA_{J2000} = 19:32:09.0000 DEC_{J2000} = 32:29:57.0000
 Best Fit Parameters
 DOF_{eff} = 54.02 χ^2_{red} = 2.694 P(Noise) < 9.92e-12 (6.7 σ)
 Dispersion Measure (DM; pc/cm³) = 12.510
 P_{topo} (ms) = 191.029038(62) P_{bary} (ms) = 191.040226(62)
 P \dot{topo} (s/s) = 9.7(4.6)x10⁻¹¹ P \dot{bary} (s/s) = 8.6(4.6)x10⁻¹¹
 P \ddot{topo} (s/s²) = 0.0(2.9)x10⁻¹⁴ P \ddot{bary} (s/s²) = 0.0(2.9)x10⁻¹⁴
 Binary Parameters
 P_{orb} (s) = N/A e = N/A
 a₁sin(i)/c (s) = N/A ω (rad) = N/A
 T_{peri} = N/A



L340118_SAP0_BEAM37.fits



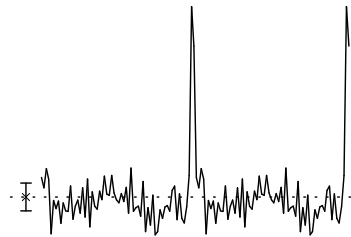
TELL-TALE



PSR CANDIDATE

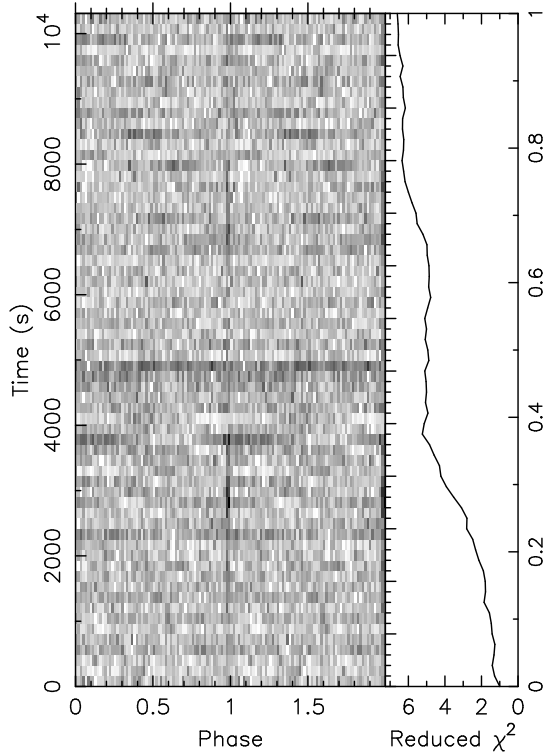
P=1.3373 s

2 Pulses of Best Profile

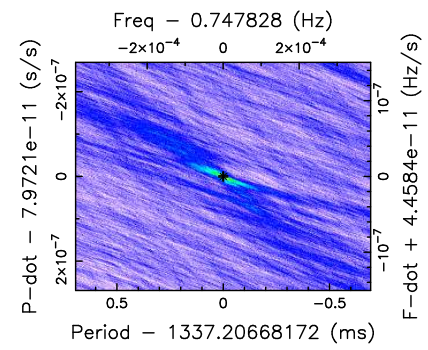
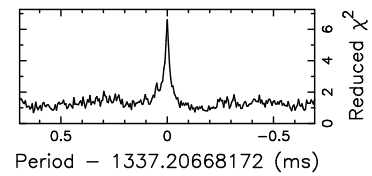
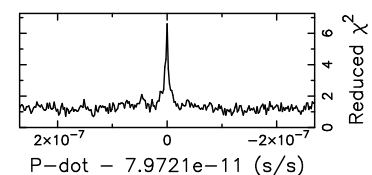
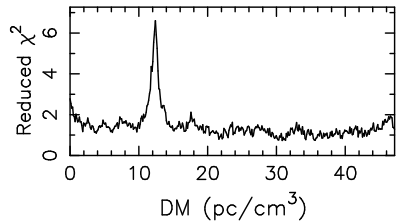
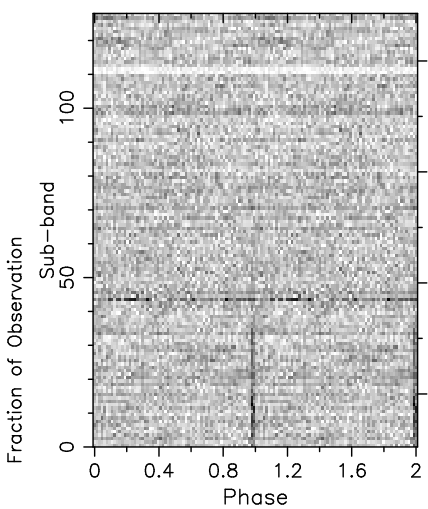


Candidate: 1337.29ms_Cand
 Telescope: LOFAR
 Epoch_{topo} = 57128.21759259259
 Epoch_{bary} = 57128.21769617822
 T_{sample} = 0.0013107
 Data Folded = 7864320
 Data Avg = 1.572e+06
 Data StdDev = 8467
 Profile Bins = 64
 Profile Avg = 1.931e+11
 Profile StdDev = 2.968e+06

Search Information
 RA_{J2000} = 19:42:59.0000 DEC_{J2000} = 29:54:03.0000
 Best Fit Parameters
 DOF_{eff} = 60.26 χ^2_{red} = 6.606 P(Noise) < 1.72e-53 (15.4 σ)
 Dispersion Measure (DM; pc/cm³) = 12.407
 P_{topo} (ms) = 1337.2067(18) P_{bary} (ms) = 1337.2900(18)
 P'_{topo} (s/s) = 0.1(1.3)x10⁻⁹ P'_{bary} (s/s) = 0.0(1.3)x10⁻⁹
 P''_{topo} (s/s²) = 0.0(8.4)x10⁻¹³ P''_{bary} (s/s²) = 0.0(8.4)x10⁻¹³
 Binary Parameters
 P_{orb} (s) = N/A e = N/A
 a₁sin(i)/c (s) = N/A ω (rad) = N/A
 T_{peri} = N/A



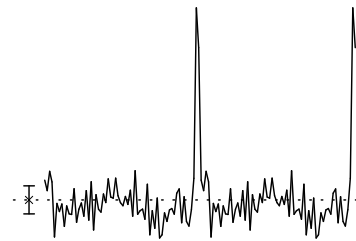
L340118_SAPO_BEAM72.fits



PSR CANDIDATE

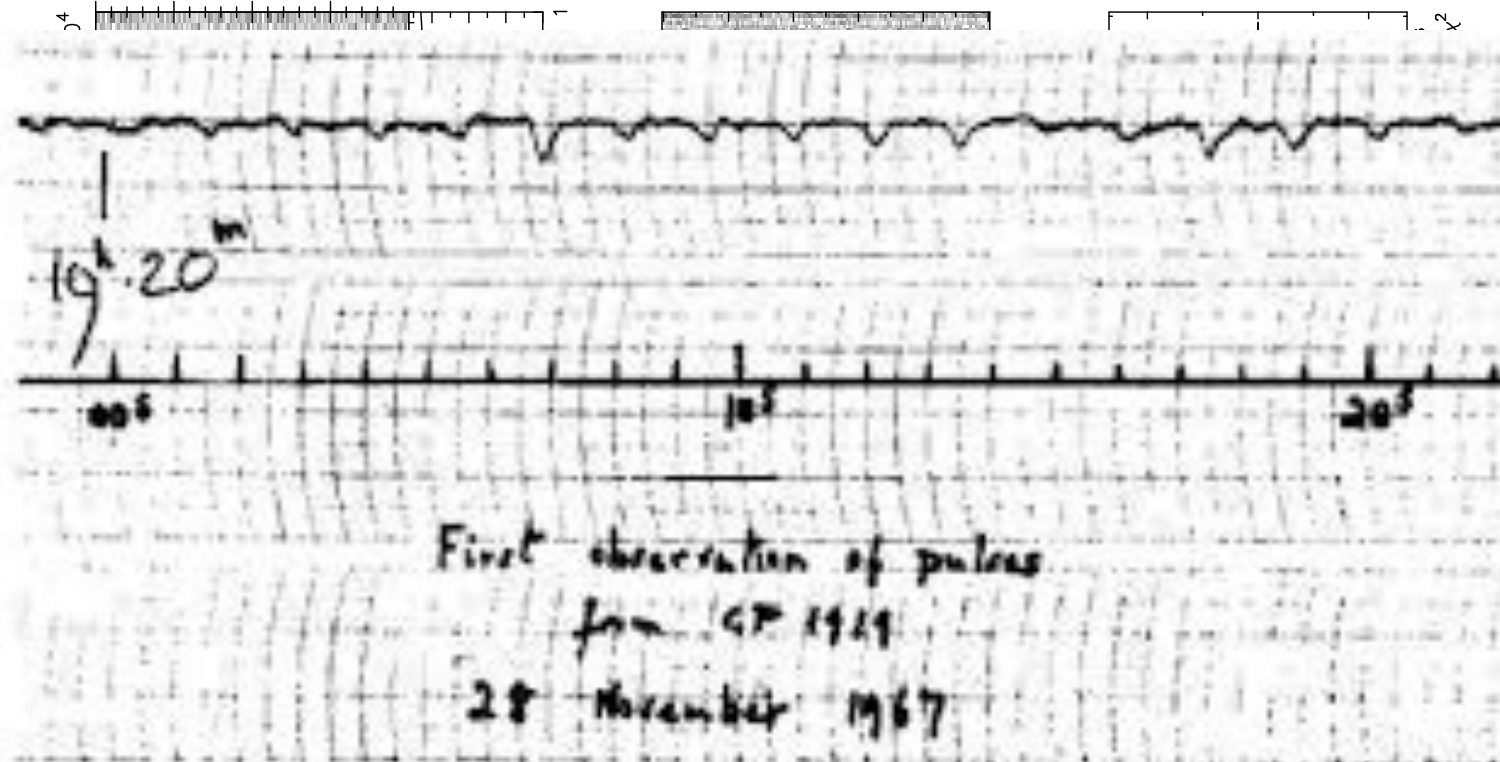
P=1.3373 s

2 Pulses of Best Profile



Candidate: 1337.29ms_Cand
 Telescope: LOFAR
 Epoch_{topo} = 57128.21759259259
 Epoch_{bary} = 57128.21769617822
 T_{sample} = 0.0013107
 Data Folded = 7864320
 Data Avg = 1.572e+06
 Data StdDev = 8467
 Profile Bins = 64
 Profile Avg = 1.931e+11
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 P''_{topo} (s/s²) = 0.0(8.4)x10⁻¹³ P''_{bary} (s/s²) = 0.0(8.4)x10⁻¹³
 Binary Parameters
 P_{orb} (s) = N/A e = N/A
 a₁sin(i)/c (s) = N/A ω (rad) = N/A
 T_{peri} = N/A



> 10 degrees

SENSITIVITY - LIMITS

Source	Object	CCO	Diameter	Pulsar?	Sensitivity
G049.2-0.7	SNR + PWN (?)		25 '	-	-
G063.7+1.1	SNR + PWN		8 '	no	~ 4 mJy
G065.3+5.7	SNR		310 ' X 240 '	no	~ 12 mJy
G074.9+1.2	SNR + PWN	V	8 ' x 6 '	no	~ 4 mJy
G093.3+6.9	SNR + PWN (?)		27 ' x 20 '	-	-
G141.2+5.0	PWN + NS	V	3.5 '	no	~ 4 mJy
G150.3+4.5	SNR		~150 '	-	-
G189.1+3	SNR + NS	V	30 ' x 36 '	no	~ 4 mJy

SENSITIVITY - LIMITS

Source	Object	Diameter	Previous searched	Sensitivity 400-1420MHz	Sensitivity LOFAR
G049.2-0.7	SNR + PWN (?)	25 '	2%-15%	0.5-0.6 mJy	-
G063.7+1.1	SNR + PWN	8 '	-	-	~ 4 mJy
G065.3+5.7	SNR	310' X 240'	< 1 %	0.9-0.1 mJy	~ 12 mJy
G074.9+1.2	SNR + PWN	8' x 6'	full	0.4-1.1 mJy	~ 4 mJy
G093.3+6.9	SNR + PWN (?)	27' x 20'	full	0.8 mJy	-
G141.2+5.0	PWN + NS	3.5'	new	-	~ 4 mJy
G150.3+4.5	SNR	~150'	new	-	-
G189.1+3	SNR + NS	30' x 36'	full	0.4 mJy	~ 4 mJy

WORK IN PROGRESS

- Finish reduction last three sources
- Determine upper flux density limits
- Obtain beaming fraction limits at low frequencies (110-180 MHz)