Pulsar Observations Using the First Station of the Long Wavelength Array

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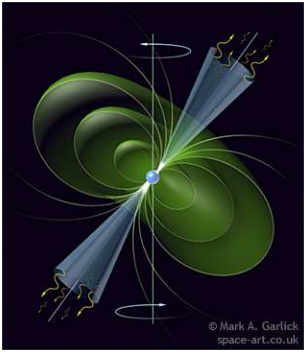
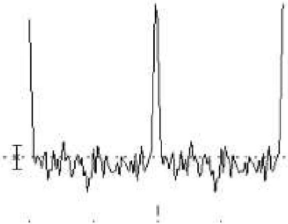
LWA1

- 10-88 MHz usable bandwidth (24-87 MHz Galactic noise dominated >4:1)
- 4 independent beams, 2 tunings, 2 pol.; $\sim$16 MHz bandwidth
- SEFD $\sim$ 9 kJy (zenith) (See poster by Frank Schinzel)
- All sky (all dipoles) modes: TBN (70 kHz-bandwidth; continuous), TBW (78 MHz-bandwidth, 61 ms burst)
- Five "outrigger" antennas at up to 500 m baselines
- LWA1 science emphasis: transients, pulsars, Sun, Jupiter & Ionosphere
- Open skies – LWA1 is funded by NSF as a University Radio Observatory

Background

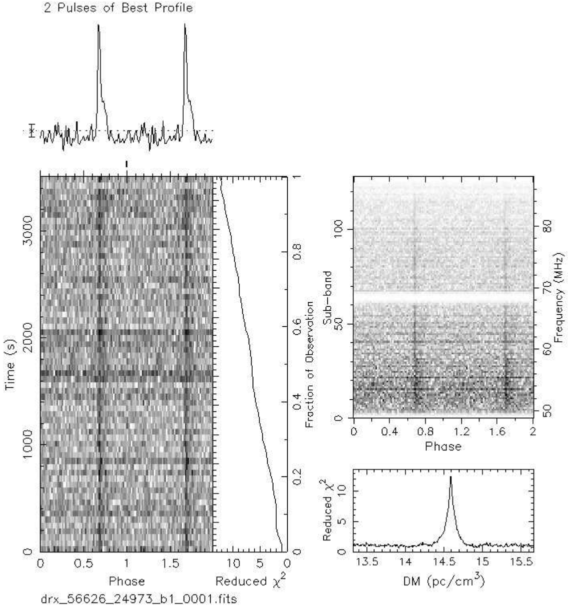
- The first pulsar was discovered in 1967 at ∼80 MHz.
- Pulsar astronomy moved to primarily being performed at higher frequencies (300 MHz and above) for the next several decades.
- Interstellar medium (ISM) effects are significantly greater at low frequencies.
- Pulsar spectra are generally modelled as power law with spectral indices of about -1.8. However, many pulsars show a break in their spectra at around 100 to 200 MHz.





Combined tunings

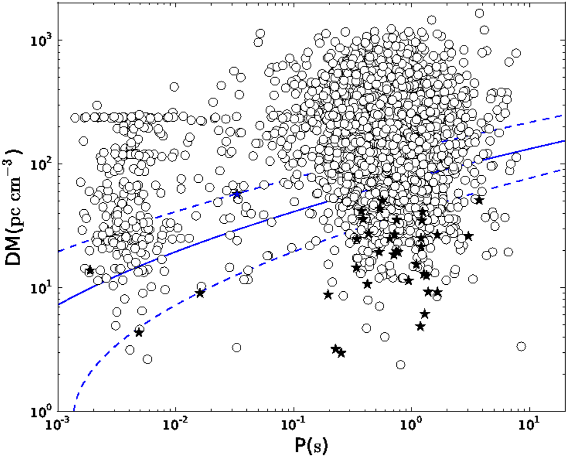
Individual tunings are 19.6 MHz (16 MHz usable) wide.
Two tunings from the same beam can be combined if spaced appropriately to get ∼32 MHz of bandwidth.



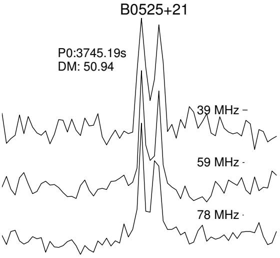
Pulsar Detections

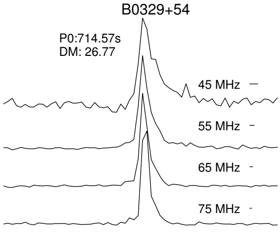
J0030+0451	B1237+25
B0031-07	B1508+55
J0034-0534	B1540-06
B0138+59	B1541+09
B0320+39	B1604-00
B0329+54	B1612+07
B0450+55	B1642-03
B0525+21	B1706-16
B0531+21	B1749-28
B0655+64	B1822-09
B0809+74	B1839+56
B0818-13	B1842+14
B0823+26	B1919+21
B0834+06	B1929+10
B0919+06	B2020+28
B0943+10	B2110+27
B0950+08	J2145-0750
B1112+50	B2217+47
B1133+16	

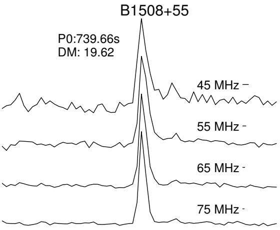
37 Pulsars detected (36 pulsations, 1 GPs*)
3 MSPs detected
Periods from 1.9 ms to 4.3 s

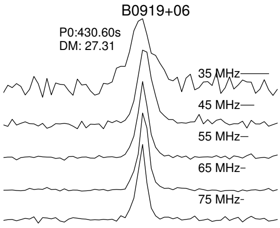


Profiles


B0525+21
P0:3745.19s
DM: 50.94
39 MHz
59 MHz
78 MHz

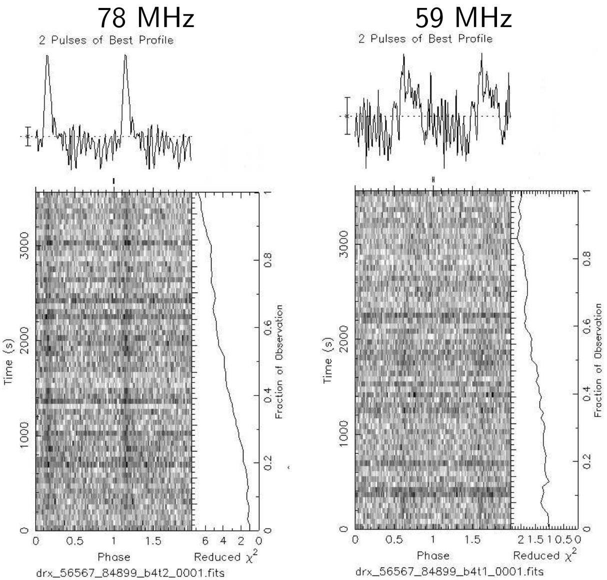

B0329+54
P0:714.57s
DM: 26.77
45 MHz
55 MHz
65 MHz
75 MHz


B1508+55
P0:739.66s
DM: 19.62
45 MHz
55 MHz
65 MHz
75 MHz


B0919+06
P0:430.60s
DM: 27.31
35 MHz
45 MHz
55 MHz
65 MHz
75 MHz

B1749-28

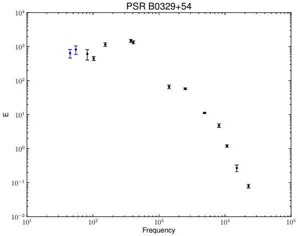
Similar direction as the Galactic center region ($\ell,\beta \sim 1.5,1.0$), yet still detectable by LWA1. Strong scattering at $\sim$60 MHz.

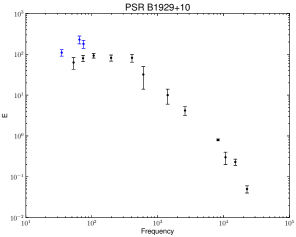


Mean Flux Densities

	Izvekova 1980		LWA1	
Pulsar	f_{cen} MHz	Flux mJy	f_{cen} MHz	Flux mJy
B0031−07	39	490 ± 210	48	440 ± 90
	61	460 ± 100	64	440 ± 90
B0138+59	61	90 ± 30	58.6	150 ± 30
	85	260 ± 50	78.2	220 ± 30
B0329+54	39	360 ± 280	45	900 ± 180
	61	430 ± 170	55	1150 ± 230
B0525+21	61	150 ± 40	39	220 ± 50
	85	350 ± 90	58.6	190 ± 40
			78.2	210
B0950+08	61	1070 ± 400	62	810 ± 160
	88	1820 ± 400	74	1370 ± 270
B1508+55	61	840 ± 200	68.4	490 ± 100

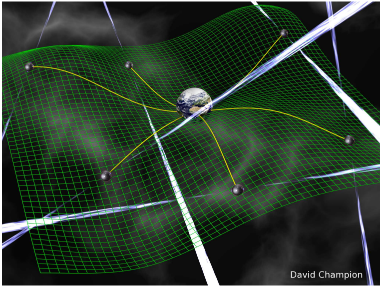
	Izvekova 1980		LWA1	
B1642−03	40	<260	48	<30
	61	410 ± 130	64	150 ± 30
B1706−16	61	180 ± 60	48	90 ± 20
			64	170 ± 30
B1919+21	40	250 ± 80	42	1480 ± 300
	61	2100 ± 430	56	1730 ± 350
			67	1430 ± 290
			75	1610 ± 320
B1929+10	102.5	220	35	110 ± 20
			65	230 ± 50
			75	180 ± 40
B2020+28	39	<60	39	40 ± 10
	61	30 ± 20	58.6	100 ± 20
	85	40 ± 20	78.2	80 ± 20

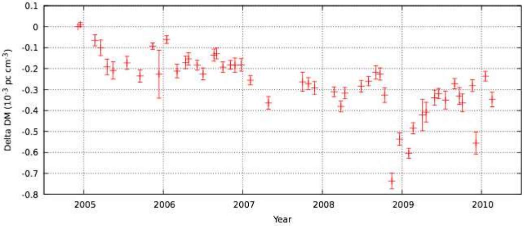




Millisecond Pulsars

- Pulsars with spin periods of a few tens of milliseconds.
- Very stable clocks, arrival times of pulses can be predicted to within tens to hundreds of nanoseconds.
- An array of very precise MSPs can be used to detect nanohertz gravitational waves.



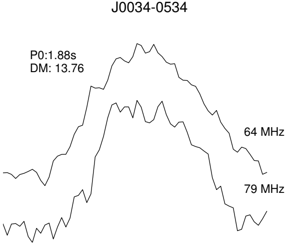


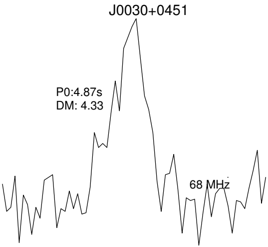
- One of the issues is how to handle DM variations with time.
- Current method is to fit for DM for each observation epoch. This could end up removing part of the signature of a GW signal.

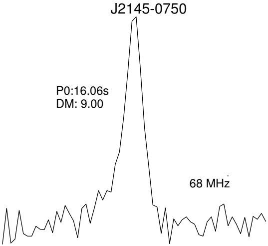
Millisecond Pulsars

Pulsar	MJD	DM	DM_{err}
		pc cm^{-3}	pc cm^{-3}
J0034−0534	56631	13.765017	0.000063
J0030+0451	56606	4.332741	0.000077
J2145−0750*	56588	9.004393	0.000059

*Dowell et al. 2013, ApJL 775, L28

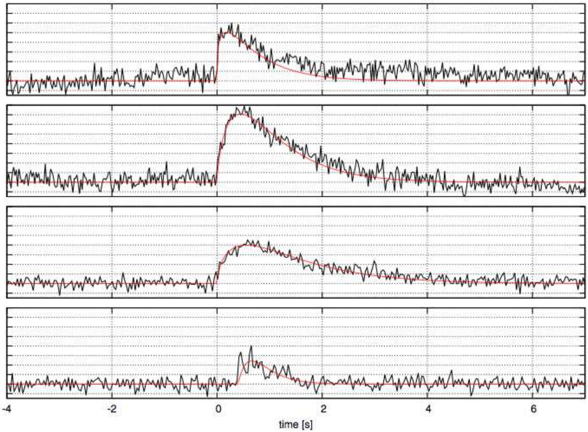






Crab Giant Pulses

- In initial analysys, CGPs seen at a rate of about 10 per hour.
- Have taken >100 hours of data on the Crab, analysis ongoing.



Ellingson et al. 2013, ApJ 768, p. 136

Ongoing LWA1 Pulsar/Transient Projects

- All Sky Pulsar and Short Transient Survey
- Study of Giant Pulses from other sources.
- Follow-up of FERMI discovered pulsars and unassociated point sources.
- Search for Fast Radio Bursts (FRBs) and Rotating Radio Transients (RRATs).
- Radio follow-up of LIGO triggers.
- Radio follow-up of Gamma Ray Burst (GRB) triggers.