



European Research Council Established by the European Commission Supporting top researchers from anywhere in the world

University of Amsterdam

Jason Hessels

(ASTRON/U. of Amsterdam)

Olsztyn, Poland - June 15th, 2023



Nederlandse Organisatie voor Wetenschappelijk Onderzoek



NEUTRON STAR

ROTATION

AXIS

RADIATION BEAM Pulsars are natural laboratories to study...

Gravity

RADIATION

BEAM

- Particle physics
- Stellar evolution
- Interstellar medium
 Accretion

Saxton / NRAO

FRBs are natural laboratories to study...

- Intergalactic medium
- Galaxy halos
- Lensing
- Extreme astrophysics

Dispersion

Scintillation & Scattering

Faraday rotation



Lorimer et al. 2007



high for the second sec

Total electron column density

Clumpiness

Line-of-sight magnetic field

Why Pulsars & FRBs at < 300MHz?

Emission mechanism

- Steep spectral indices
- Spectral turnover
- Profile evolution
- Moding

Talks by: Szary Dyks Basu

Why Pulsars & FRBs at < 300MHz?

Emission mechanism

- Steep spectral indices
- Spectral turnover
- Profile evolution
- Moding

Talks by: Szary Dyks Basu

ISM, IPM & Ionosphere

- Precision dispersion measure
- Scattering
- Precision rotation measures
- "Scintellometry"

Talks by: Rożko Gopinath Rothkaehl O'Sullivan

Why Pulsars & FRBs at < 300MHz?

Emission mechanism

- Steep spectral indices
- Spectral turnover
- Profile evolution
- Moding

Talks by: Szary Dyks Basu

ISM, IPM & Ionosphere

- Precision dispersion measure
- Scattering
- Precision rotation measures
- "Scintellometry"

Surveys & Populations

- Huge field-of-view
- Ultra-steep-spectrum sources

Talks by: Rożko Gopinath Rothkaehl O'Sullivan

Talks by: Chawla Rowlinson Vohl



Pulsar magnetospheres



Hassall et al. (2012)



van Haarlem et al. (2013)

DM law works to 1/100,000

LOFAR has detected >300 pulsars so far

	٨	mattilda, A	Λ	I	1	4	1 de la com	1	I	٨	1	1	1	1		B0950)+08
0006+1834	B0011+47	10033+57	B0037+56	B0045+33		B0053+47	0106+4855	 B0105+65	B0105+68	B0114+58	مىسىم مىسىم 0137+1654	B0136+57	مریدید. ارتحاد ارتحاد میلاد. ارتحاد 100 (100 (100 (100 (100 (100 (100 (100	B0153+39		j j	1380 MHz
manne	mulum				www.	A the state of t		MANANIA				-hopelylylylylylyl					328 MHz
J0205+6449	J0212+5222	B0226+70	B0301+19	B0320+39	0324+5239	J0329+1654	B0331+45	10413+58	B0402+61	B0410+69	J0417+35	J0419+44	J0435+27	B0450+55	-	m	184 MHz
B0458+46	B0523+11	B0525+21	B0531+21	B0540+23	J0611+30	B0609+37	B0626+24	J0646+0905	J0647+0913	B0643+80	B0656+14	B0655+64	J0711+0931	B0751+32		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	176 MHz 168 MHz
B0809+74	J0815+0939	B0823+26	B0841+80	B0917+63	B0940+16	J0943+22	B0943+10	J0947+27	B1112+50	B1133+16	J1238+21	B1237+25	J1246+22	J1313+0931	1		160 MHz
B1322+83	J1503+2111	/B1508+55	B1530+27	B1541+09	J1549+2113	بەرمۇر مەلىرد. 1612+2008	J1627+1419	B1633+24	J1645+1012	J1649+2533	J1652+2651	J1720+2150	J1740+1000	B1737+13	1	\sim	152 MHz
J1741+2758	J1746+2245	J1746+2540	مربیا ہیں۔ 1752+2359	B1753+52	l	J1806+1023	J1813+1822	B1811+40	J1814+1130	۲ ۹۹۰۰۲۰ (۱۹۹۰ ۰۰ J1819+1305	J1821+1715	J1822+1120	J1828+1359	J1834+10			145 MHz 137 MHz
J1837+1221	 J1838+1650	B1839+56	B1839+09	J1842+1332	J1843+2024	B1842+14	J1848+0826	J1849+2423	н еник ж. 4 8н B1848+13	 B1848+12	J1853+0853	B1852+10	J1859+1526	J1900+30	1		129 MHz
-	yern litering	and the second		1. AND THE REAL PROPERTY OF	wine by an	ner al mark	and the second		marine francisco	san har			444441AIN	_\	1	\frown	121 MHz
1901+1306	J1903+2225	J1906+1854	B1905+39	J1908+2351	J1909+1859	1911+1758 Million Million	B1910+20	J1912+2525	J1913+3732	B1915+22	B1918+26	B1919+21	J1927+0911	B1929+10	1	$\sum_{i=1}^{n}$	113 MHz
B1930+13	J1937+2950	J1941+1026	J1941+1341	B1942+17	B1944+17	J1947+0915	B1946+35	J1951+1123	B1949+14	J1953+1149	B1953+50	J1956+0838	J1959+3620	J2002+1637	1		67 MHz
B2000+40	12007+0809		12008+2513	M/P MM		B2016+28		B2021+51	B2022+50	P024+48	B2025+21	P027+4557	B2028+22	12030+55	1		60 MHz
		Marty Attack	,2000+2515		1201772045			Mundhala		,2024140	14444 Maran	HIM AND	,	WANNAM	•••••	\sim	52 MHz
J2036+2835	B2034+19	B2036+53	J2040+1657	J2043+2740	J2045+0912	B2044+15	B2045+56	J2047+5029	J2048+2255	B2053+21	B2053+36	J2102+38	J2111+2106	J2111+40			44 MHz
B2110+27	B2113+14	B2122+13	J2139+2242	B2148+63	J2151+2315	J2155+2813	j2156+2618	B2154+40	J2203+50	J2205+1444	J2206+6151	B2210+29	J2215+1538	B2217+47		www.	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
2222+2923	B2224+65	B2227+61	2234+2114	B2241+69	2243+1518	2253+1516	B2303+30	B2303+46	2307+2225	B2306+55	B2310+42	B2315+21	2319+6411		0.35 0.4	0 0.45 0.5	0 0.55 0.60

Bilous et al. 2016

Pilia et al. 2016

Low-Freq Pulsar & FRB Telescopes



MWA Australia



LWA New Mexico



GMRT India



LOFAR

Europe



LOTAAS

LOFAR Tied-Array All-Sky Survey http://www.astron.nl/lotaas 219 coh. beams 3 incoh. beams

LOFAR Tied-Array All-Sky Survey (LOTAAS)



LOFAR Tied-Array All-Sky Survey (LOTAAS)



· safe star

Sanidas et al. 2019

50

LOFAR super-slow (23.5-sec) pulsar discovery



LoTSS `on' and `off' images

Futselaar / ASTRON

Tan et al. 2018



"Happy?"

LOFAR fast pulsar





1.4 ms / 707 Hz radio pulsar



LOFAR NSP Discoveries



Bassa, Pleunis & Hessels 2017 Bassa et al. 2017 Pleunis et al. 2017





Very Bright MSPs





S₁₅₀ ~ 0.5Jy

Found in 2010

Hessels et al. 2011

Kondratiev et al. 2016

LOFAR on the P-Pdot



707Hz 1.41ms



2 Pulses of Best Profile 2 Pulses of Best Profile 0 Pulses of Best Profile 0 Pulses of Dest Profile 1 Pulses of Dest P

0.042Hz 23,533.6ms

Cooper - see also van der Wateren et al. 2023



plarised sources



Sobey et al. 2022

FRBs with LOFAR



Futselaar / ASTRON

FRB 20180916B ("R3")





Tendulkar, Gil de Paz, Kirichenko, JH et al. 2021

Bursts detectable down to at least 110 MHz



Periodic activity from FRB 180916.J0158+65

P = 16.4 days



CHIME/FRB Collaboration et al. 2020

Frequency-dependent activity cycle



Pleunis, Michilli, Bassa, JH et al. 2021 See also Pastor Marazuela et al. 2021

Boldly Go Where No Telescope Has Gone Before



Boldly Go Where No Telescope Has Gone Before



Boldly Go Where No Telescope Has Gone Before











European Research Council

Established by the European Commis

Supporting top researchers from anywhere in the world

Pulsars & FRBs with LOFAR

- > 80 LOFAR pulsar discoveries
- First ultra-low-frequency FRBs
- > 50 LOFAR pulsar & FRB papers
- 17 of these cited > 50 times

Pulsars & FRBs with LOFAR

- >80 LOFAR pulsar discoveries
- First ultra-low-frequency FRBs
- > 50 LOFAR pulsar & FRB papers
- 17 of these cited > 50 times



Pulsars & FRBs with LOFAR

- > 80 LOFAR pulsar discoveries
- First ultra-low-frequency FRBs
- > 50 LOFAR pulsar & FRB papers

Tenormous latent potential

to unlock with LOFAR2.0!

• 17 of these cited > 50 times