Chinese Pulsar Timing Array Update

Heng Xu (胥恒) | hengxu@bao.ac.cn On behalf of the CPTA collaboration (PI: Kejia Lee,李柯伽) National Astronomical Observatory of CAS SPSS 2024, Yunnan Uni. | 2024.07.13







SAR

NATIONAL ASTRONOMICAL OBSERVATORIES, CAS



- Gravitational Waves and Pulsar Timing Arrays
- Pulsar Census
- Single Source GWs...
- New Dataset

Outline

Completion of CPTA DR1: Polarimetry, Scintillation, Noise Analysis,

 Million years
 Years

 Years
 Years
Pulsar Timing Array **CMB** Polarization









Big Bang







Pulsar Timing

Pulsars

- Position, parallax, spin-down, orbital motion, etc
- Spin irregularity red
- Pulse jitter white
- Pulse profile changing and glitch
- ISM
 - DM event deterministic
 - DM variations, long-term trends and red noise,
 - Interstellar refraction, diffraction, scintillation, scattering



- Solar system ephemerides
- Instruments
 - Radiometer noise white
- Jumps between and in backends deterministic
 - Clock errors
- Gravitational Wave
 - Individual SMBHBs, continuous GW sources
 - Incoherent superposition of GWs from all SMBHBs (GWB)
 - Relic GWB from inflation, phase transition, etc
 - Mergers of SMBHB, passing-by massive objects - bursts
 - Cosmic strings, loops, cusps, kinks, bursts







2004—





Completion of DR1

Pulsar Census – Search More CPTA Pulsars

- 88 pulsars
- ~40 pulsars TOA uncertainty < 1us
- ~35 pulsars Wrms < 1us
- Many possible candidates for CPTA!
- Evaluations under working

Wang Lin et al., in prep.



Lin Wang









Pulsar Census

- Very high quality polarimetric profiles
- Updated RM and DM



Wang Lin et al., in prep.























<i></i> •			
	ł	•	
3			-
	0.8		1.0

Completion of DR1

CPTA DR1 Overview

- FAST: Tsys~20 K, Gain~16 K/Jy
- 19Beam receiver @1.25 GHz (500 MHz bandwidth).
- 57 pulsars, 17 Isolated pulsars, 40 binary pulsars.
- Data from Apr 2019 (for data release1, to Sep 2022, data span >~3 years)



		• •• •		
1				
		• •		
	•••			
	••			
				•
	•			
	• •			
	••			
				-
	-			
	-			
	•	00000 00		
	-			
		000		
		0 0000 000		
		0 000 00		
	1			
	2019.5	2020.0 20	2020.52021.02021.52022.02022.5	
			Year	

Xu H., et al., in prep.

210

10023-	⊢0923
10020	10723
10020-	FU431
J0034-	-0534
J0154-	+1833
10218	L1737
JUZ10-	F4232
J0340-	+4130
J0406-	+3039
10500	0856
JUJU9-	
J0605-	+3757
J0613-	-0200
10621	1002
JU021-	
J0636-	+5129
J0645-	+5158
10732	1 2 2 1 0
JU/32-	FZ314
J0'/51-	+1807
J0824-	+0028
11012	5207
J1012-	F3307
J1024-	-07/19
J1327-	+3423
11/52	1000
J1433-	F1902
J1630-	⊦3734
I1640-	+2224
J1642	1001
J1043-	-1224
J1710-	⊦4923
I1713-	+0747
11720	10717
J1/30-	+0333
J1741-	+1351
J1744-	-1134
117/5	1017
J1/43-	
J1832-	-0836
J1843-	-1113
11052	1202
J1033-	F1303
J185/4	-0943
J1903-	+0327
11010	1256
J1710-	
J1911-	+1347
J1911-	-1114
11010	0642
J1910-	-0042
J1923-	+2515
J1944-	+0907
110/6	-3/17
J1940-	
J1955-	+2908
J2010-	-1323
12017_{-}	∟0603
J2017-	
J2019-	+2425
J2022-	+2534
12033	L173/
JZUJJ-	FI/J 4 . 1/711
J2043-	+1/11
J2145-	-0750
12150	-0326
$J \angle I J U^{-}$	0020
J2214-	+3000
J2229-	+2643
12221	∟0611
JZZJ#-	
J2234-	+0944
J2302-	+4442
12317	L1430
J <u>4</u> JI/-	11737
10000	1 7057

Polarimetry

- Extremely high quality profiles
- Fitting Rotation Measures (RMs), and derive Galactic Magnetic field.





J0645+5158





J0340+4130





Jiangwei Xu

See Xu J-W's talk





Scintillation

- Scintillation is prevalent
- We measured the scintillation bandwidth, timescale, arcs, and the correlation with DM and timing





Yonghua Xu



See Xu Y-H's talk





Single Pulsar Noise Modeling

Detailed noise analysis using several pipelines and comparisons between DM noise and DMX



Chen Siyuan

Kejia Lee



Yanjun Guo

Heng Xu



Chen et al., in prep.

Single Pulsar Noise Modeling



Comparisons of DM noise and red noise processes

Single Pulsar Bounds for Singe GWs

- We have set bounds on single source GWs in the mHz range using our best millisecond pulsar PSR J1713+0747 (Caballero et al., submitted)
- We are working on full-sky single source blind search and targeted search.









Caballero et al., submitted to RAA.





N. Caballero



New Dataset

New Data Set

- More pulsars (>10) for possible future inclusions
- Extended data set (Tmax>5 years vs DR1 3.4 years)
- More complex timing noise.



			000000000000			
			000000 0 0 0 0 0 0			
			000 0 0 0 00		000 0	
					0 0000 0000	
	000	0 000 0 0	0 0000000 0 00000000 0	•		
	0000			0 0000000000000000000000000000000000000		
				• • ••		
				o o o o o o o o o o o o o o o o o o o		
	0	00 00000 0		0 00 0 00 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
	0 00 00	00 0000 0000 0 00 0000	000 @ 00000 000000 00000 0 0 0000	0000000 000000 0 0000000	000 000 00 0000 00 000 000	
	0 0 0 0000	00 00000000 0 0 0000	00000 00000000000000000000000000000000	000000 000000 0000	000000000000000000000000000000000000000	
	00 0000	00 000000000000000000000000000000000000	880 60 60 60 60 60 60 60 60 60 60 60 60 60			
		0 000 0 0	000000000000000000000000000000000000000	0 0 0 0000	00 0000000 00 00 00	
0000-000		00 000000000000000000000000000000000000	00000000000000000000000000000000000000	000000000000000000000000000000000000000	000000000000000000000000000000000000000	
600	0.0000000	• 000000 000000000	000 @ 0000000000 @ 0000 @ 00000	000000000000000000000000000000000000000	0000 0000 0000 0000 0 000	
			•00000000000000000000000000000000000000	000000000000000000000000000000000000000	00 000000000000000000000000000000000000	
		0 000 0 0	000000000000000000000000000000000000000	000000000000000000000000000000000000000		
	000	0 000 0 0			0 00 0	
00	00000			000000000000000000000000000000000000000		
•	0 000 0	00 000000000000000000000000000000000000				
00	00000	00.000000000000000000000000000000000000				
	00000					
	000	0000000				
	00000					
	000	0.0000000000000000000000000000000000000		0.0000000000000000000000000000000000000		
	0004	0.0000000000000000000000000000000000000				
	0.0000	00.000000000000000000000000000000000000				
				000000000000000000000000000000000000000		
	~ ~ ~ ~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		000000000000000000000000000000000000000		
•		0.00000.0000000000000000000000000000000	0.0.00.00.0000000000.0.0.0000000	000000 00000000000000000000000000000000		
	0.000	0.000.000				
	00 0000					
	00 0000	C 00 000000000000000000000000000000000		0000 0000 00 00 00 00 00 00 00 00 00 00		
	00 0000	000000000000000000000000000000000000000				
	00 0000	00.0 0 00.00 00 00000				
	0.00	0 000 0 0	000 000 000		0 000 0 0	
	000 0 000	00 00000 00 00000	00000-000000000000000000000000000000000	00000 00000 00000	000 0 000 000 000 000 0 000	
	0 0 00	0 00000 00 00000	000000000000000000000000000000000000000	00000 00 000 000000	000 0 000 000 000 000 000 0 000	
	0000 00	00 0000000 00 00000	000000000000000000000000000000000000000	0000 00000 000000	000 0 000 000 000 000 0000 0000	
	0 0 00	0.0000000 0.000000		0000000 0 00 000 00000	000000000000000000000000000000000000000	
•	0000	000000000000000000000000000000000000000	000000000000000000000000000000000000000	0000000 0 00 000 00000	0000 0 00 000 000 000 000 000 000	
•	60000	00 080800 0 000008	00 000000000000000000000000000000000000	00000 00000 000000	0000 000000 000000 000 0 000	
	00000 @	0 0 000 00 0 0 000 000		0000000 0 00 000 00000	000000000000000000000000000000000000000	
	00000 000	0 00000 0 00000	0 0 00000000000000000000000000000000000	0000000 0 00 000 00000	00000 00000000 000 00 0 000	
	0 00 00	0 0 000 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	00 @0@0@0@0@0@0@0@0@0@0	00000 00 00 000000	0000 000000 000-000 000 0 000	
•	00000 @	00 40,000 00 00000		0000000 0 00 000 00000	000000000000000000000000000000000000000	
		00 00000 00 00000	00 000000000000000000000000000000000000	00000 00000 000000	0000 000 00 000 000 000 0 000	
	000	0 0000000000000000000000000000000000000	000000000000000000000000000000000000000	0000000 0 00 0 0 00000	000000000000000000000000000000000000000	
	0 0000 000	00 000 0000 00 00000	00 00000000000000000000000000000000000	00000 00000 000000	0000 000000 000000 000 0 000	
	0000 0	0 0 0000 0 00000				
	0000 0000	00 0000000 0 000000	00 000000000 00000 00000 0	00000 00000 000000	0000 000000 000 000 000 000	
	0 000 000	00 000000000000000000000000000000000000				
			0.00.0000000000000000000000000000000000	0000 00000 000000		
	0000 00	00 000000000000000000000000000000000000		00000 00000 000000		
	000000000					
	0000	00 000000000000000000000000000000000000				
		00 000000000000000000000000000000000000				
				000000000000000000000000000000000000000		
		0.0000000000000000000000000000000000000		000000000000000000000000000000000000000		
		00.000000000000000000000000000000000000		0000 000 000 00000		
		00.000.000.000.000.0000	0000 0000000000000000000000000000000000	000000000000000000000000000000000000000	2000000000 0000000 00 0 0000	
		000000000000000000000000000000000000000	1000 0000000000000000000000000000000000	000000000000000000000000000000000000000	******	1
	2020	2021	2022	2023	2024	

2020

Year



Distances & Post-Keplerian Parameters

- For DR1+1yr data, Significant parallax measurements for 40 pulsars, 6 more compared with DR1, on average, measurement errors reduced by ~15%
- New measurements of post-Keplerian parameters in J0732+2314 (H3), J0751+1807(PBdot), J1643-1224(xdot), J2317+1439(Stig), with significant improvements on lots of former measurements

Pulsar name	$\dot{\omega}$ (deg yr ⁻¹)	\dot{x} (10 ⁻¹⁴)	h ₃ (μs)	5	sin i	т (М
J0218+4232	-	-	-	-	0.9925(6)	0.234
J0613-0200	-	-	0.22(2)	0.62(6)	-	-
J0621+1002	0.010(1)	-	-	-	-	-
J0751+1807	-	-	0.21(1)	0.63(5)	-	-
J1012+5307	-	-	0.13(3)	-	-	-
J1630+3734	-	-	-	-	0.9990(3)	0.26
J1640+2224	-	1.9(6)	0.49(8)	0.58(12)	-	-
J1713+0737	-	-	-	-	0.945(5)	0.31
J1741+1351	-	-0.5(1)	-	-	0.963(8)	0.24
J1853+1303	-	1.5(2)	0.20(2)	0.49(8)	-	-
J1857+0943	-	-	-	-	0.9991(2)	0.25
J1903+0327	0.0002399(7)	-	-	-	0.978(9)	1.05
J1910+1256	-	-2.1(2)	0.10(2)	0.74(14)	-	-
J1918-0642	-	-	-	-	0.9955(7)	0.24
J1946+3417	0.00134(5)	-	0.67(9)	0.74(7)	-	-
J2017+0603	-	-	-	-	0.95(2)	0.18
J2019+2425	-	4.3(2)	0.65(6)	0.55(7)	-	-
J2043+1711	-	-	-	-	0.991(2)	0.18
J2150-0326	-	-	-	-	0.98(1)	0.21
J2145-0750	-	-	0.13(4)	-	-	-
J2229+2643	-	2.4(2)	-	-	-	-
J2234+0611	0.000887(2)	-2.6(1)	0.12(2)	0.51(12)	-	-
J2302+4442	-	-	-	-	0.990(3)	0.31
J2317+1439	-	-	0.16(3)	-	-	-

4(6) 6(1) l(2) 4(3) 5(1) (13)4(1) 3(4) 3(1) l(6) 1(2) **DR1** Results





Noise Analysis

Overall, longer dataset better constrain the low-frequency red and DM noise processes.



-14

Noise

Red

Conclusions

Fantastic timing data.

More pulsars, more data for CPTA.

noise analysis, GWB, single source GWs and etc.



• We are working on the data analysis of data set, including pulsar timing,

	-
	0. 0. 0.
top the second sec	0. 0. -0.
	_
a galation adaptic trademon an	
00 59250 59500 59750	

0.0 -	95 ns
0.5 -	J0636+5129
0 -	
-1 -	202 ns
1 -	J1024-0719
0 -	at approximation of the set
-1 -	50 ns
0.5 -	J1710+4923
0.0 -	4、1741111111111111111111111111111111111
0.5 -	195 ns
.25 -	J1832-0836
.00 -	the a ten demonstrate the
.25 -	45 ns
.25 -	J1911+1347
.00 -	第一個利用相關加利於#
.25 -	81 ns
05-	J1955+2908
0.0 -	本項 등 학생님 상하이 마입니까워하는 상학
0.5 -	190 ns
1 -	J2043+1711
0 -	بارع والمدهيرة وجيدة والمحاري يعقد
-1 -	121 ns
0.5 -	J2234+0944
0.0 -	
05-	54 ns
0.0	58750 59000 59250 59500 59750

.5 J0340+4180

DR1 Timing

Thanks!

