Chinese Pulsar Timing Array Update

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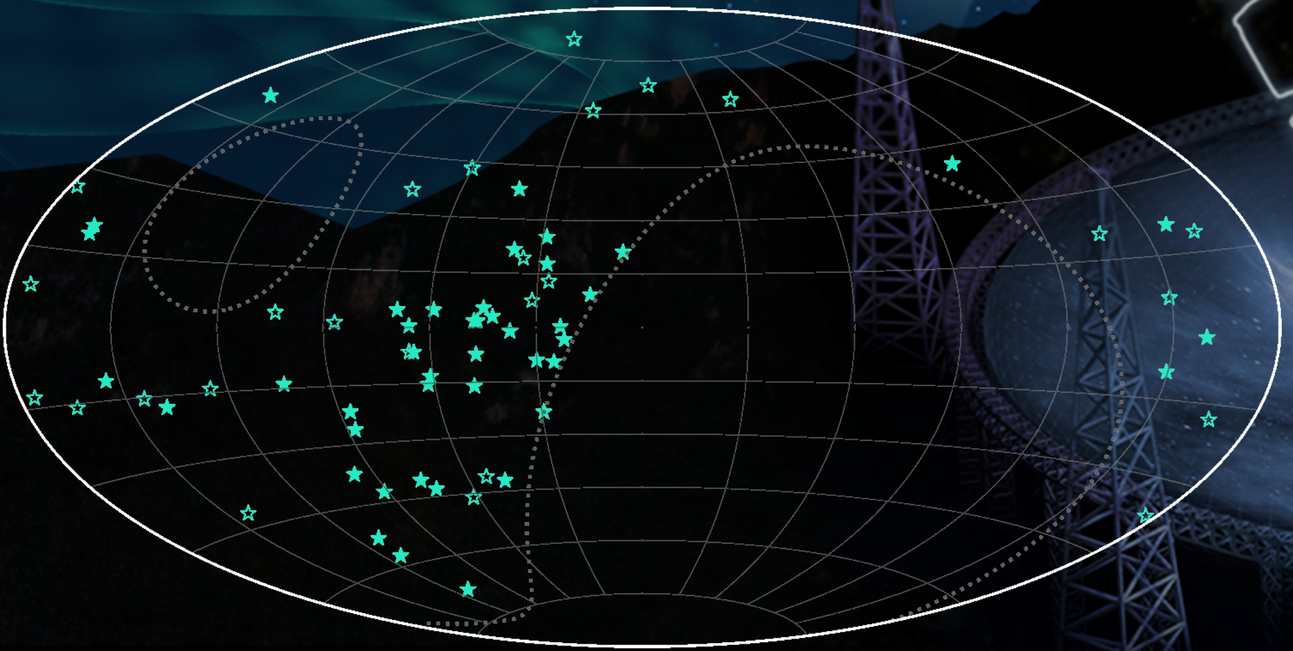
On behalf of the CPTA collaboration (PI: Kejia Lee,李柯伽)

National Astronomical Observatory of CAS

SPSS 2024, Yunnan Uni. | 2024.07.13

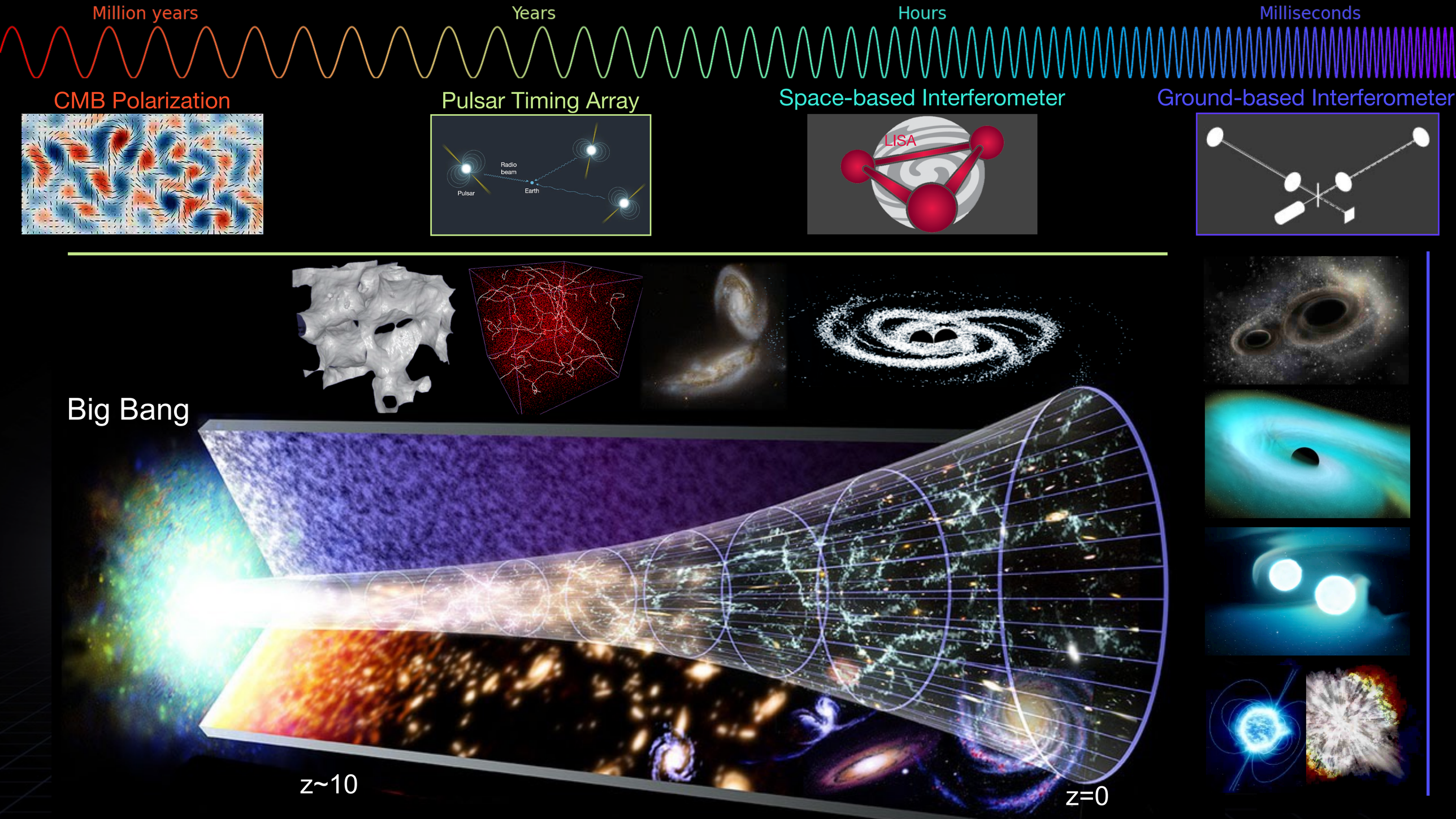


CPTA

NAOC 中国科学院国家天文台 NATIONAL ASTRONOMICAL OBSERVATORIES, CAS

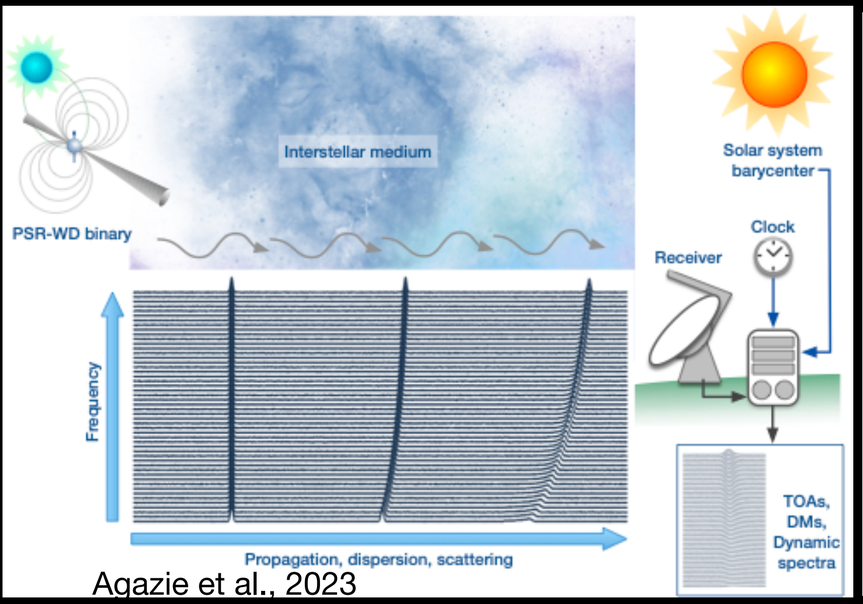
Outline

- Gravitational Waves and Pulsar Timing Arrays
- Pulsar Census
- Completion of CPTA DR1: Polarimetry, Scintillation, Noise Analysis, Single Source GWs…
- New Dataset

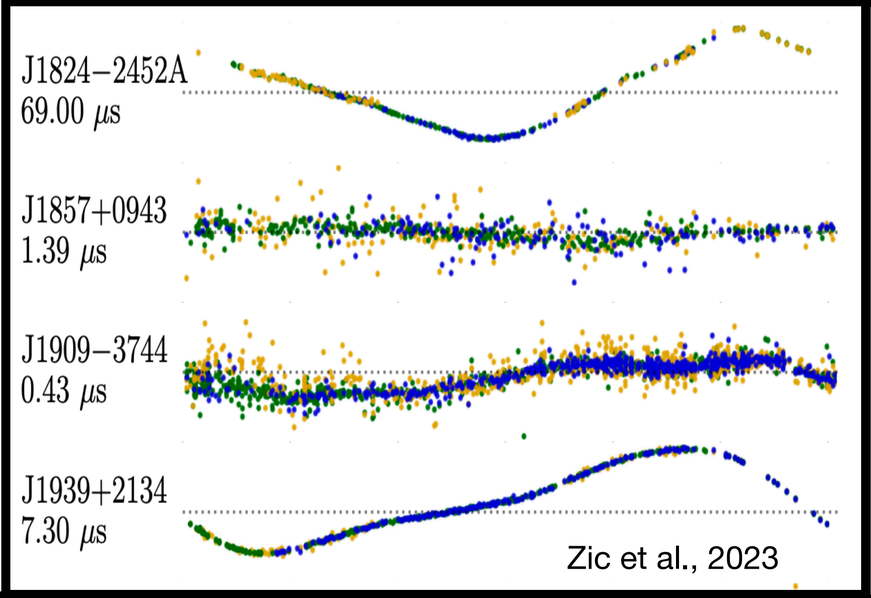

Million years
Years
Hours
Milliseconds
CMB Polarization
Pulsar Timing Array
Radio beam
Pulsar
Earth
Space-based Interferometer
LISA
Ground-based Interferometer
Big Bang
z~10
z=0

Pulsar Timing

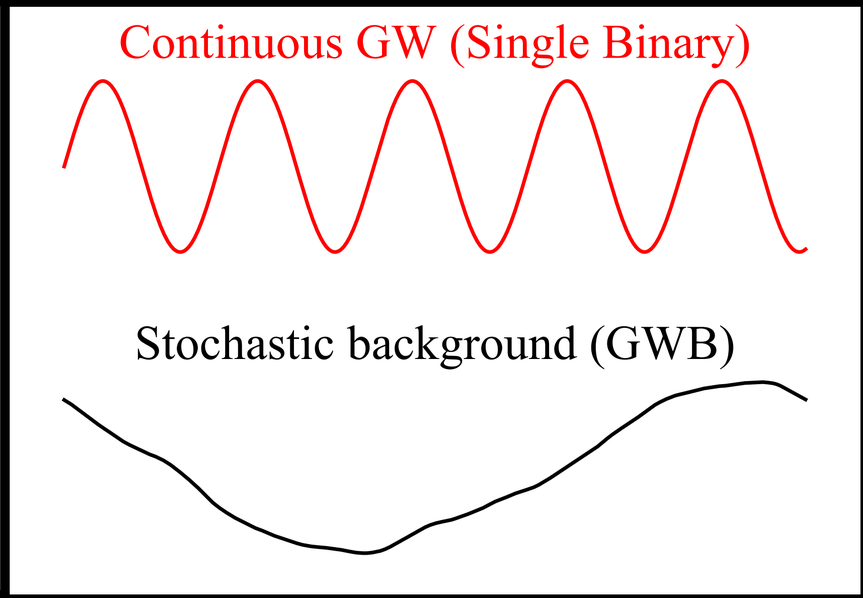
- Pulsars
  - Position, parallax, spin-down, orbital motion, etc
  - Spin irregularity - red
  - Pulse jitter - white
  - Pulse profile changing and glitch
- ISM
  - DM event - deterministic
  - DM variations, long-term trends and red noise,
  - Interstellar refraction, diffraction, scintillation, scattering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



Agazie et al., 2023



Zic et al., 2023



Pulsar Timing Arrays

NANOGrav
2004—

EPTA
~1996—

CPTA
2019—

PPTA
2004—

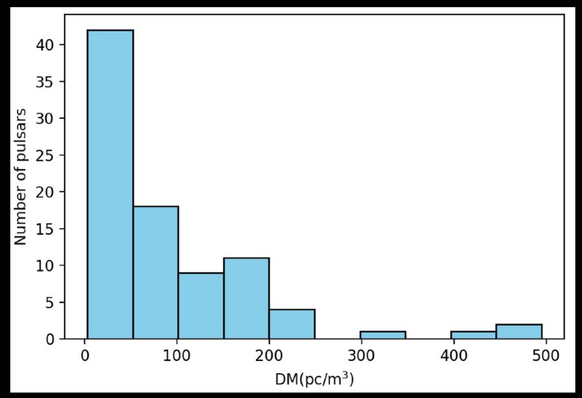
SAPTA
2019—

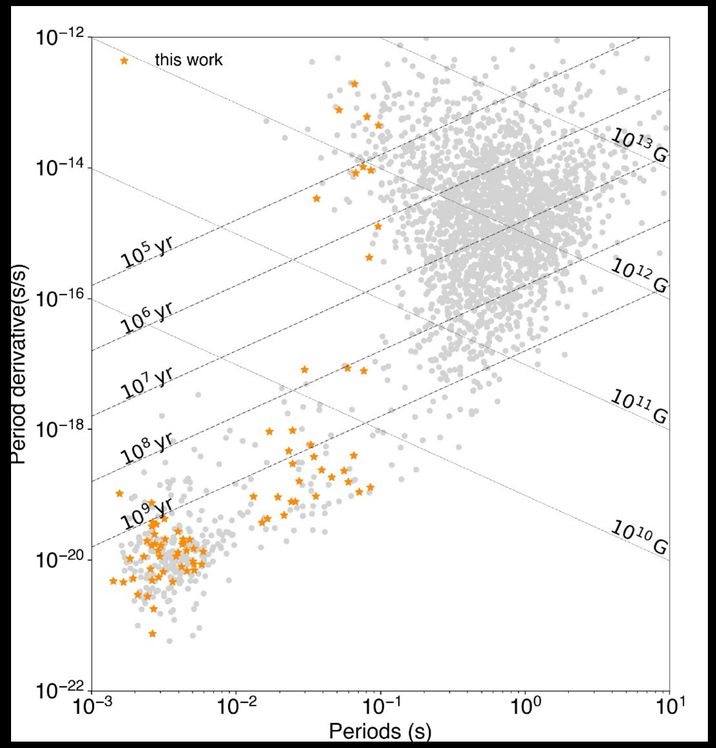
InPTA
2004—

Completion of DR1

Pulsar Census—Search More CPTA Pulsars

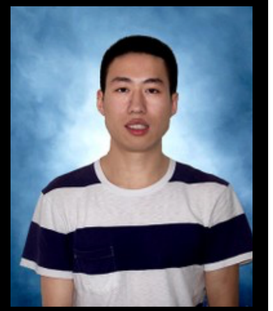
- 88 pulsars
- ~40 pulsars TOA uncertainty < 1us
- ~35 pulsars Wrms < 1us
- Many possible candidates for CPTA!
- Evaluations under working



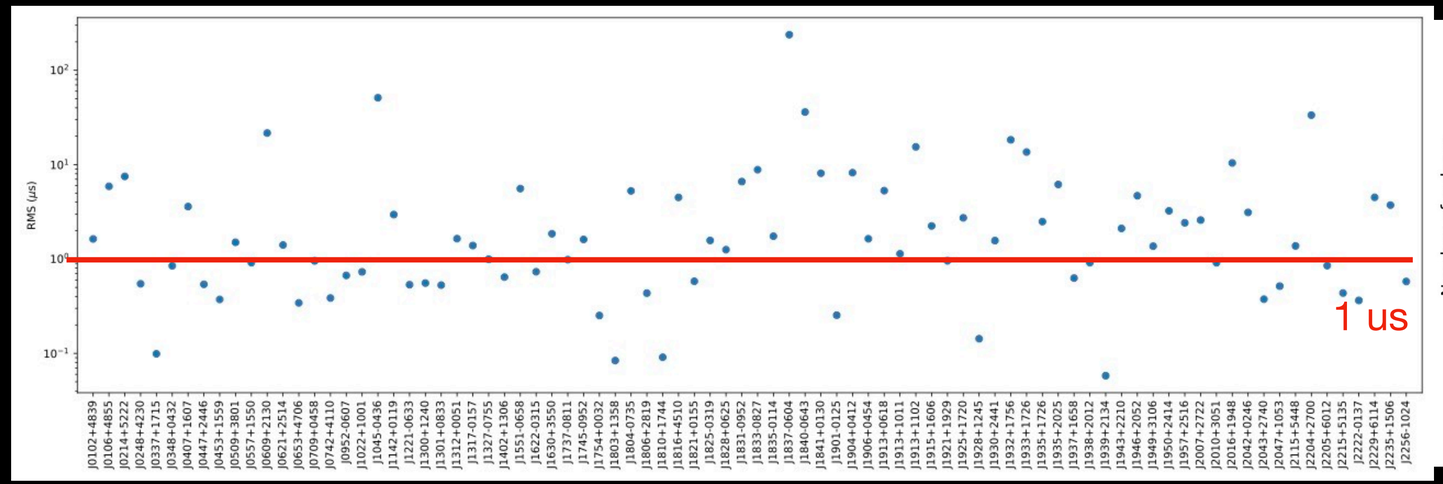


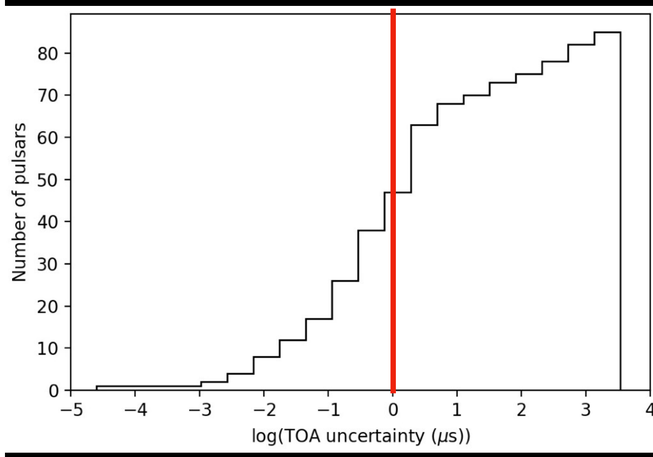
Wang Lin et al., in prep.

Lin Wang



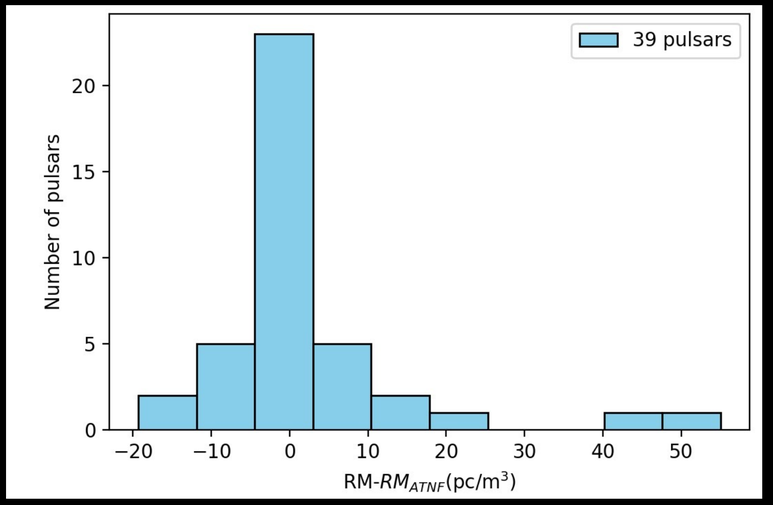
Heng Xu



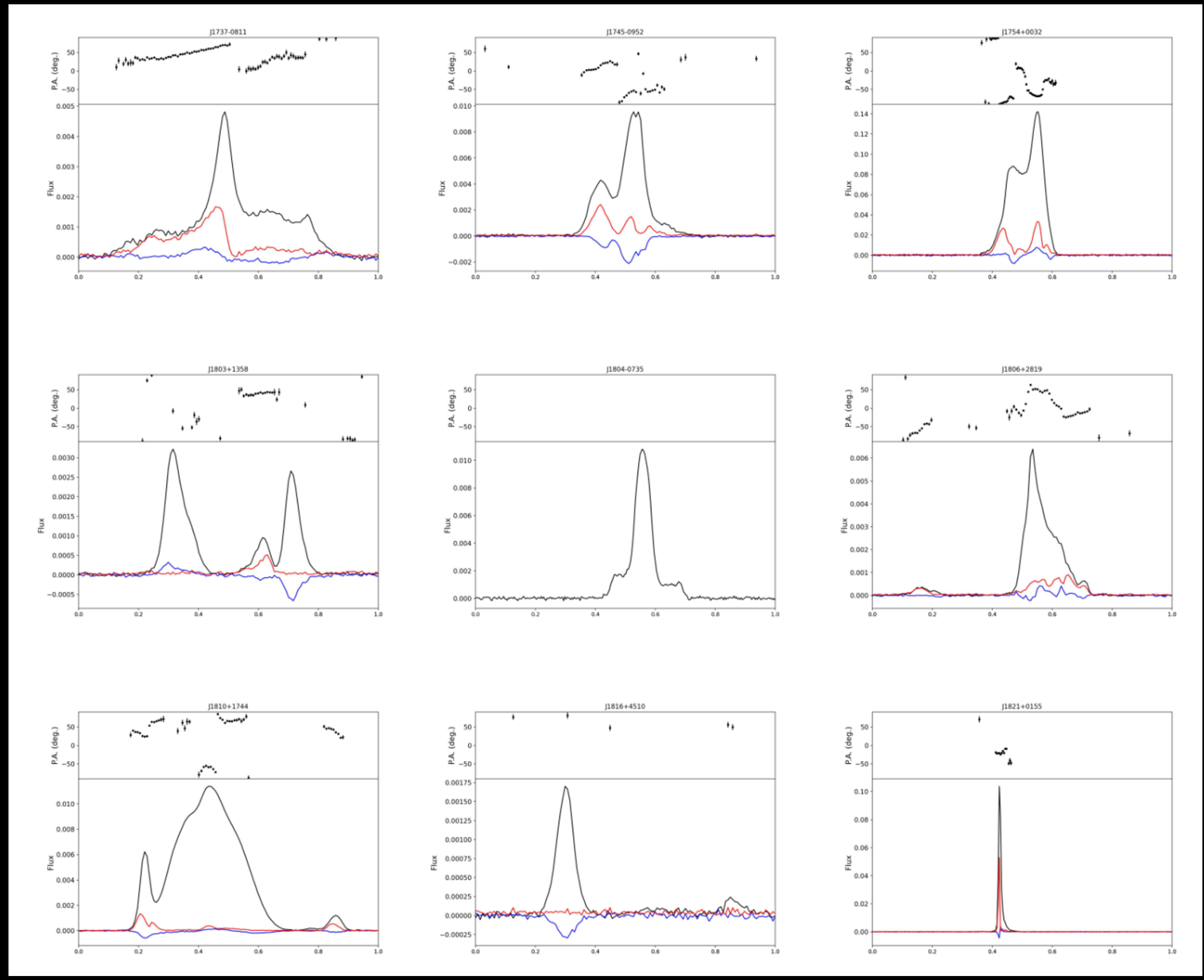


Pulsar Census

- Very high quality polarimetric profiles
- Updated RM and DM



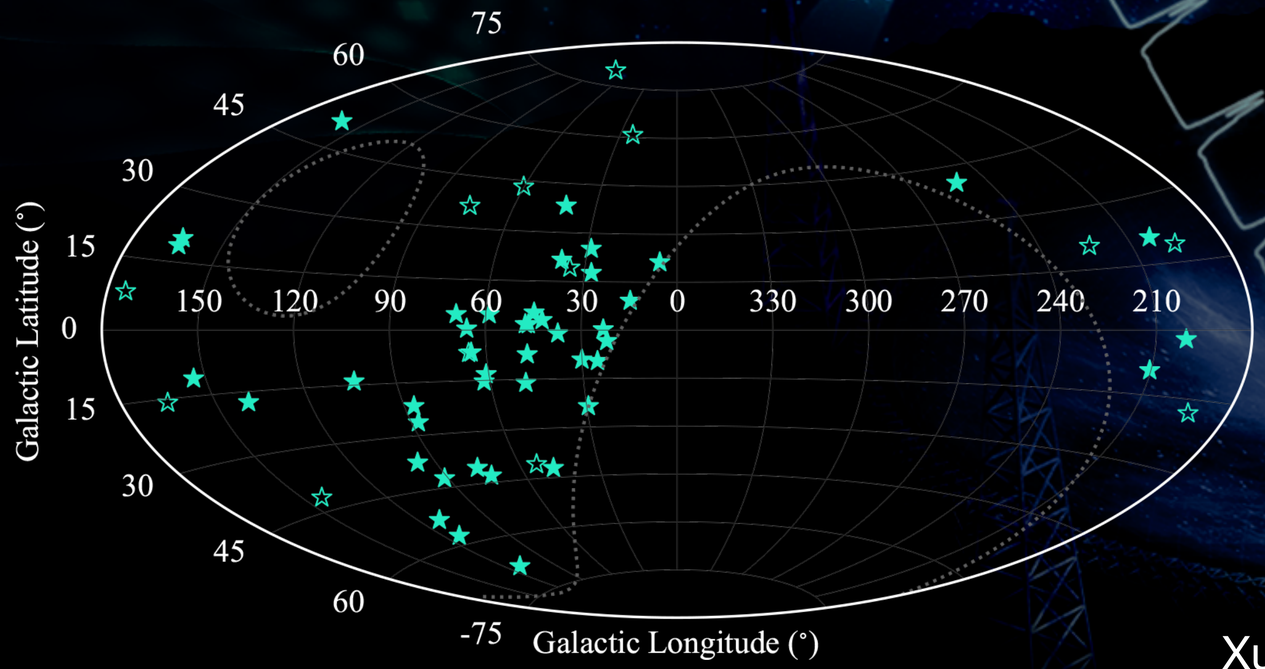
Wang Lin et al., in prep.

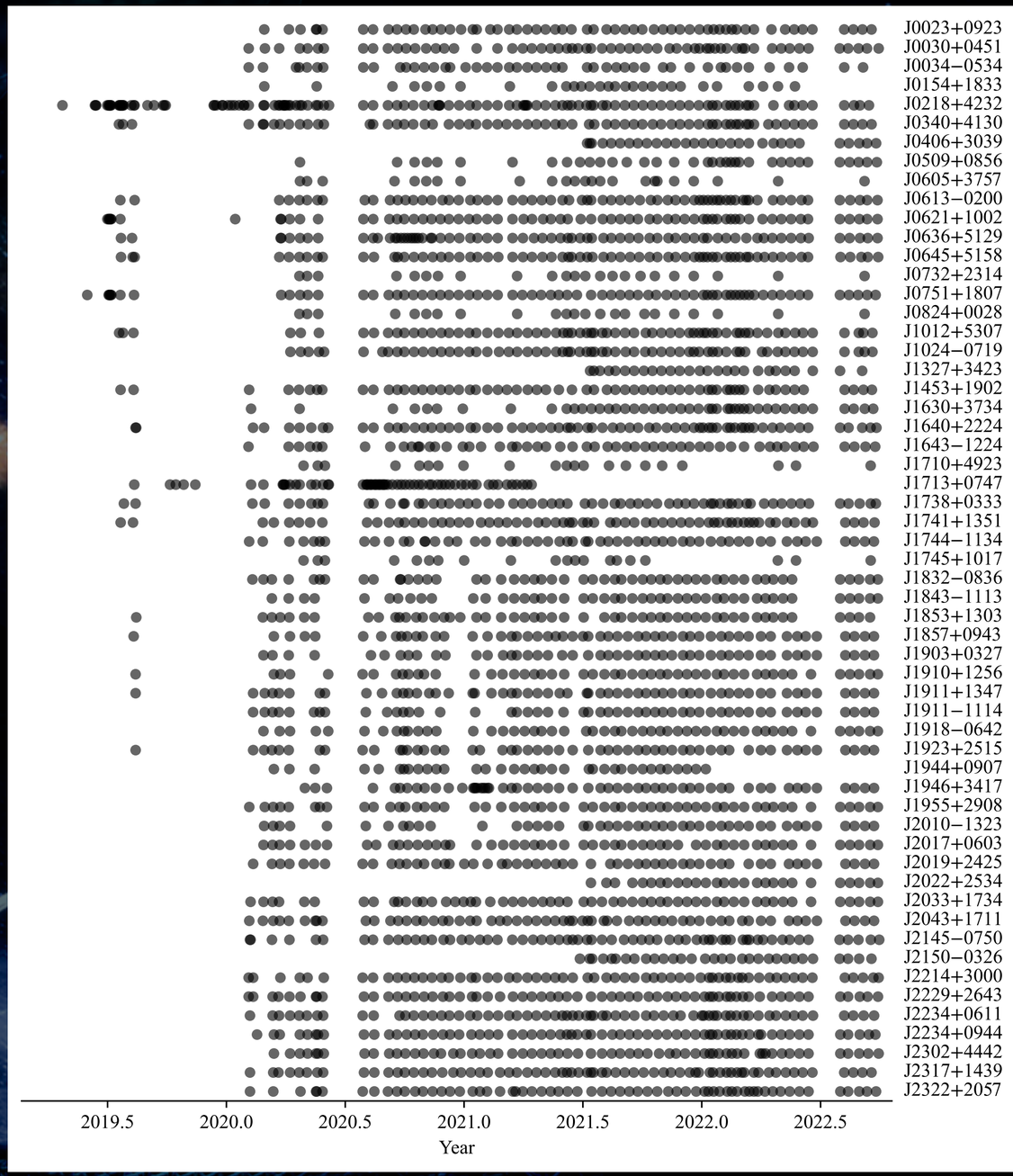


Completion of DR1

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)

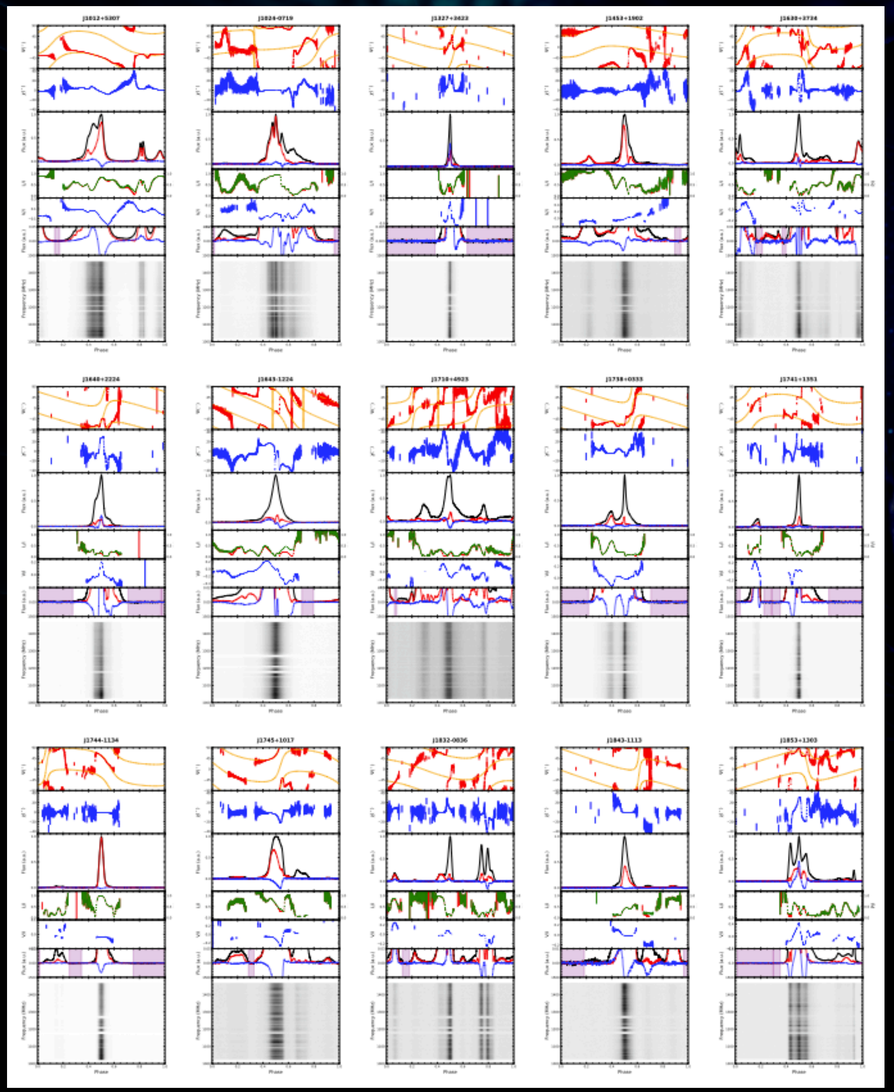


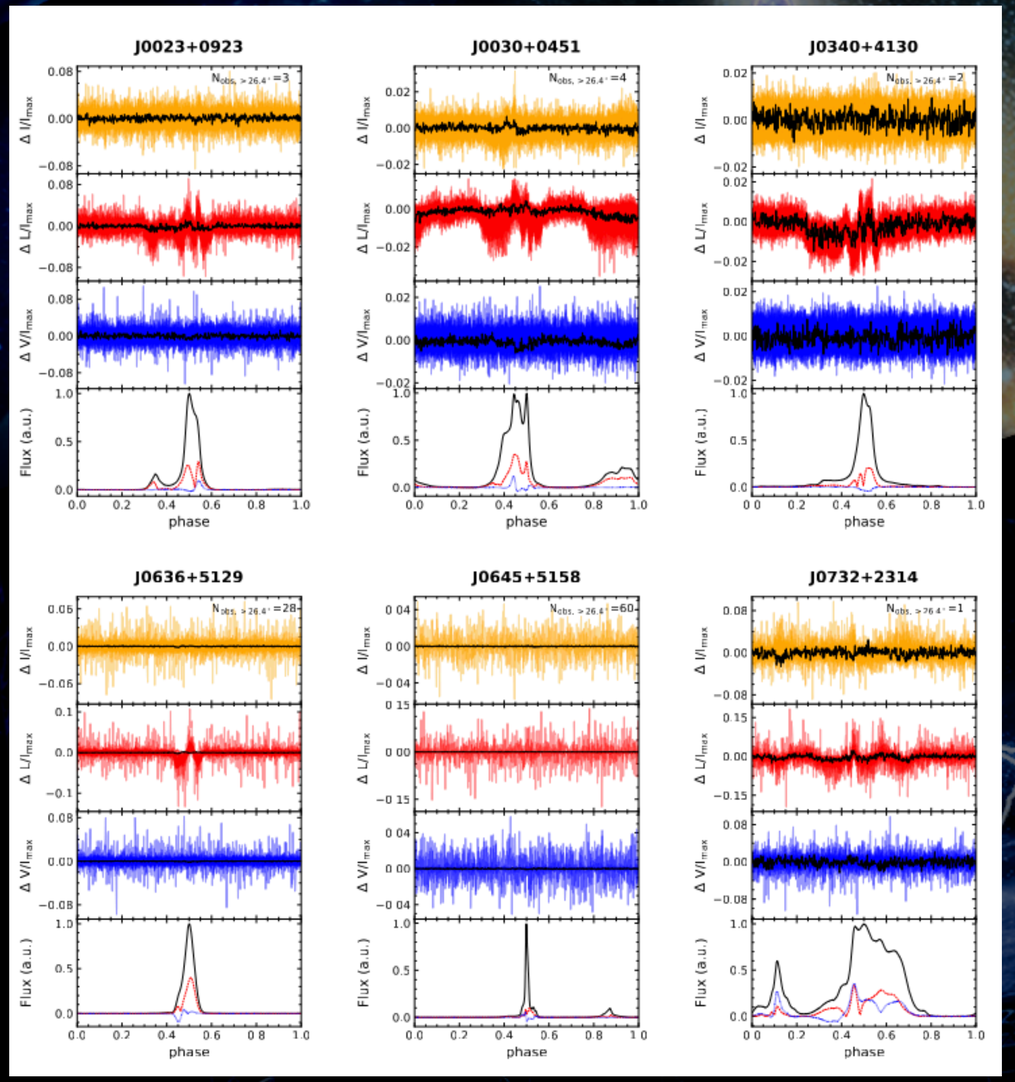


Xu H., et al., in prep.

Polarimetry

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





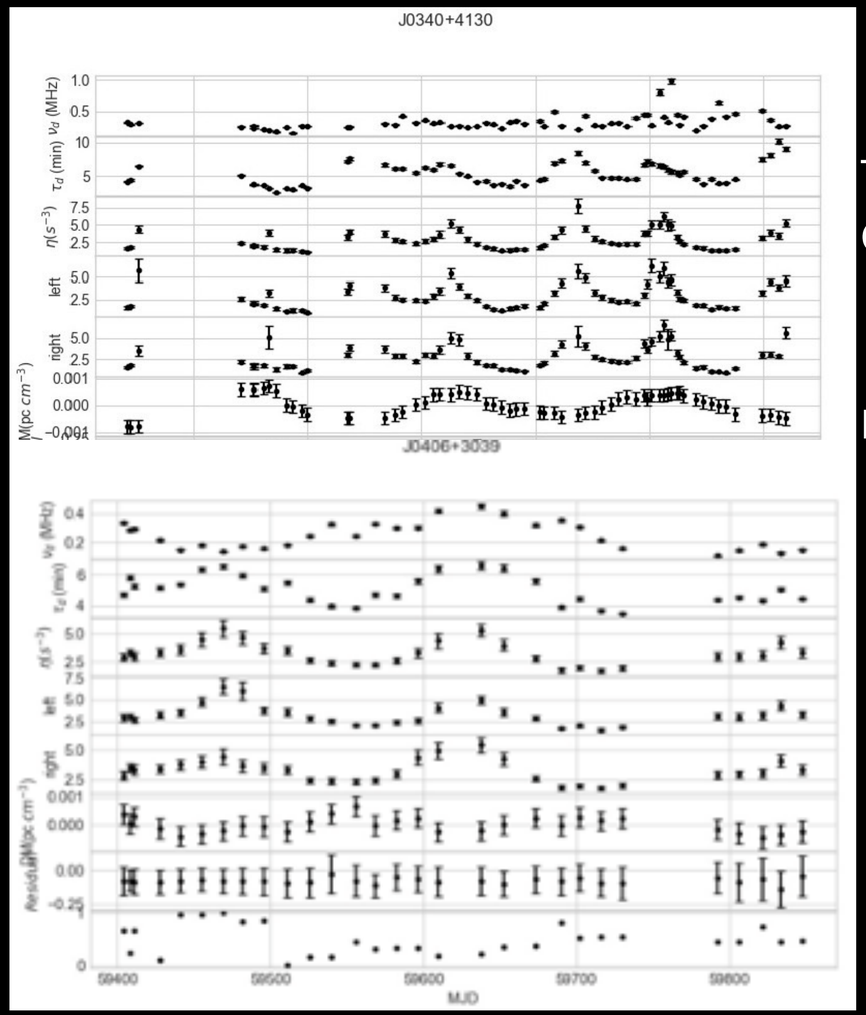
Jiangwei Xu

Jinchen Jiang

See Xu J-W's talk

Scintillation

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

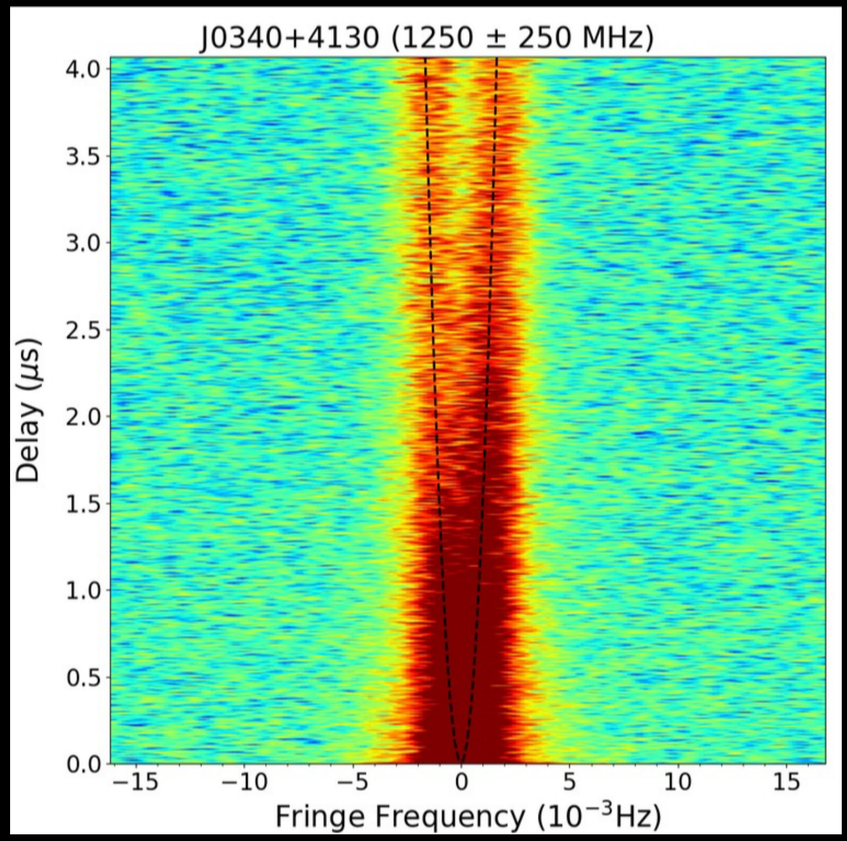


Bandwith

Timescale

Curvature

DM

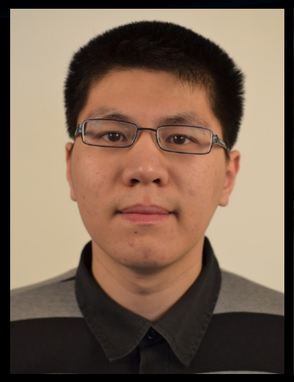


Yonghua Xu

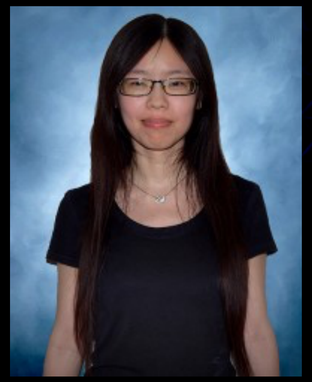
See Xu Y-H's talk

Single Pulsar Noise Modeling

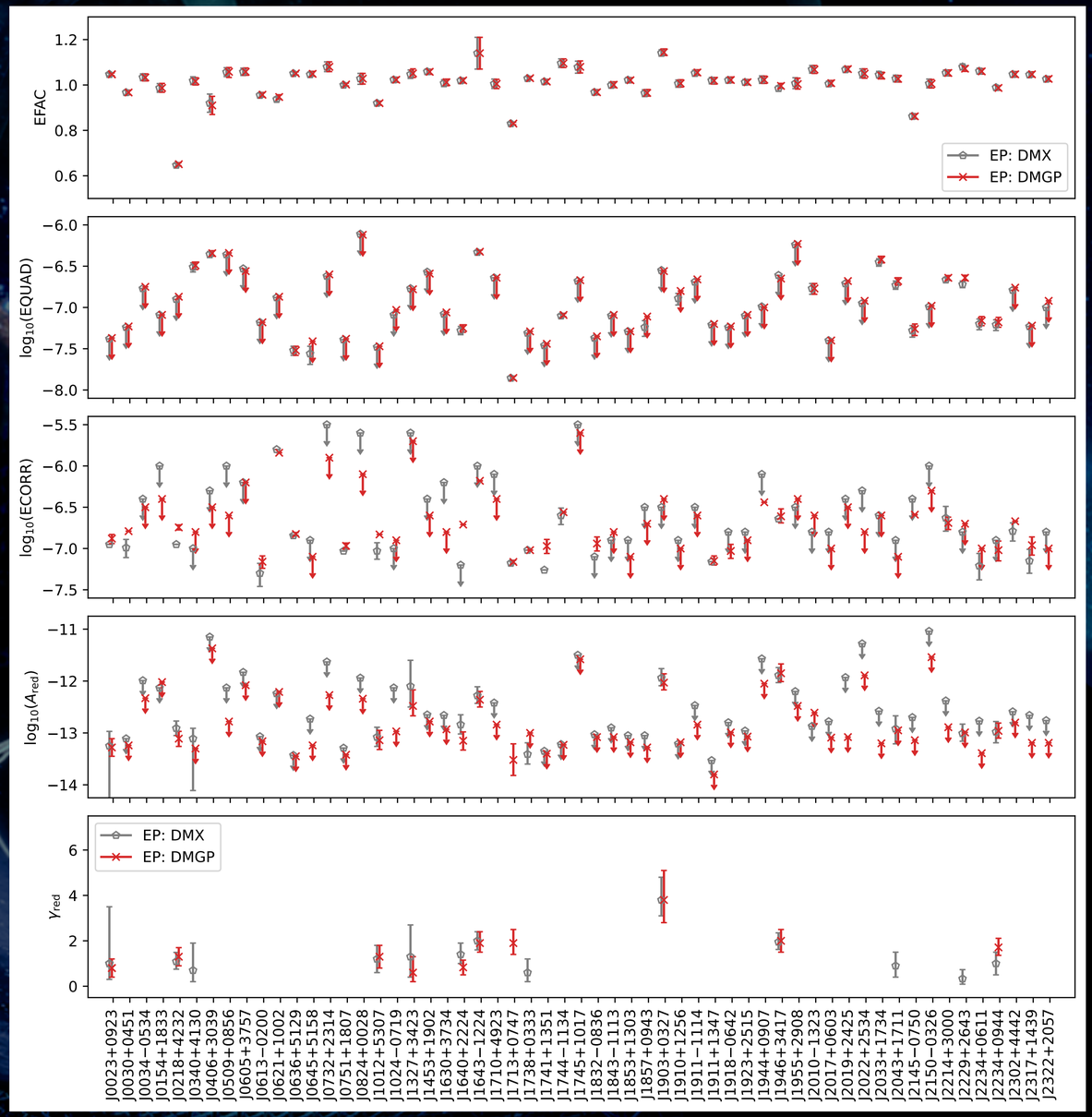
- Detailed noise analysis using several pipelines and comparisons between DM noise and DMX


Chen Siyuan


Kejia Lee

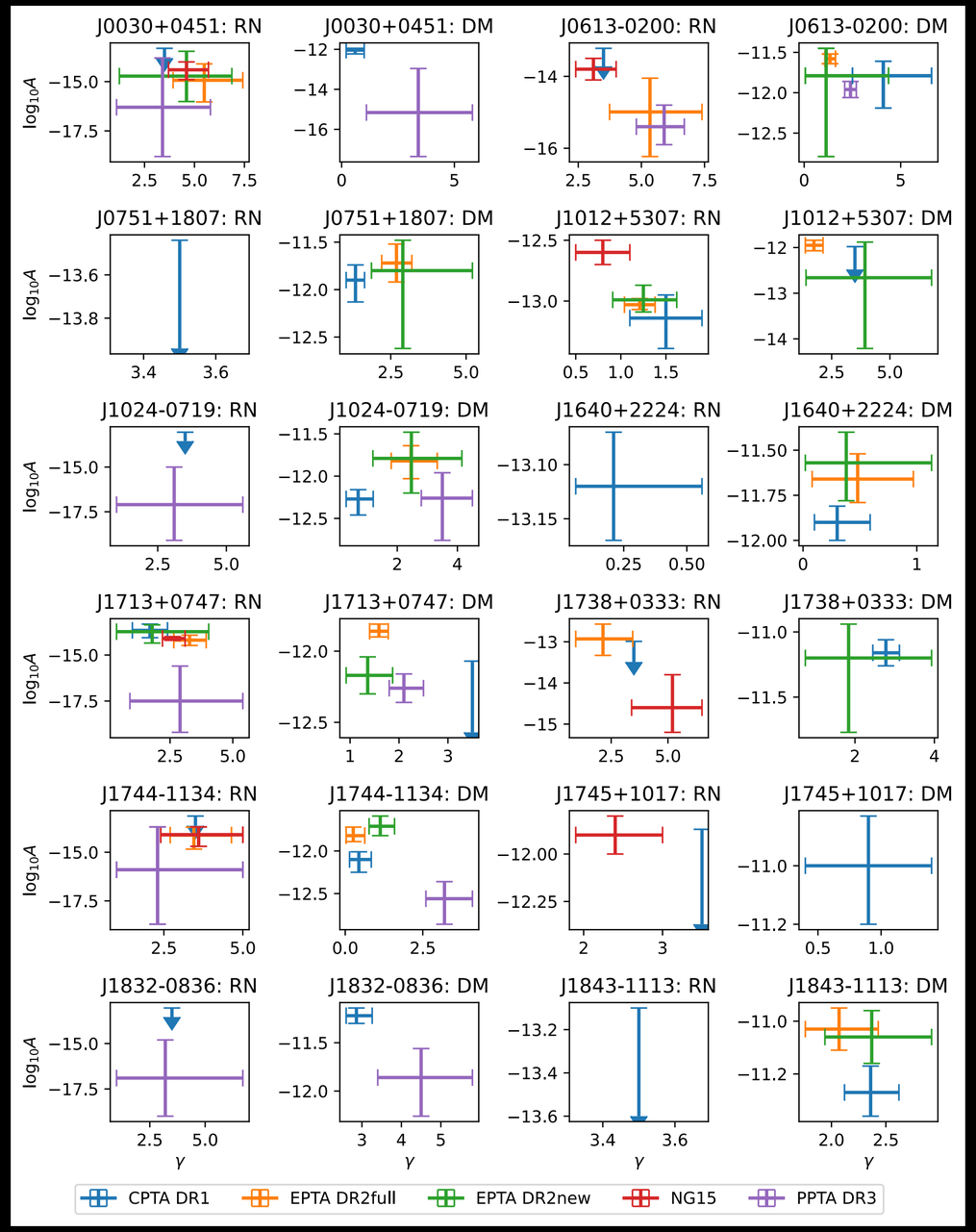

Yanjun Guo


Heng Xu

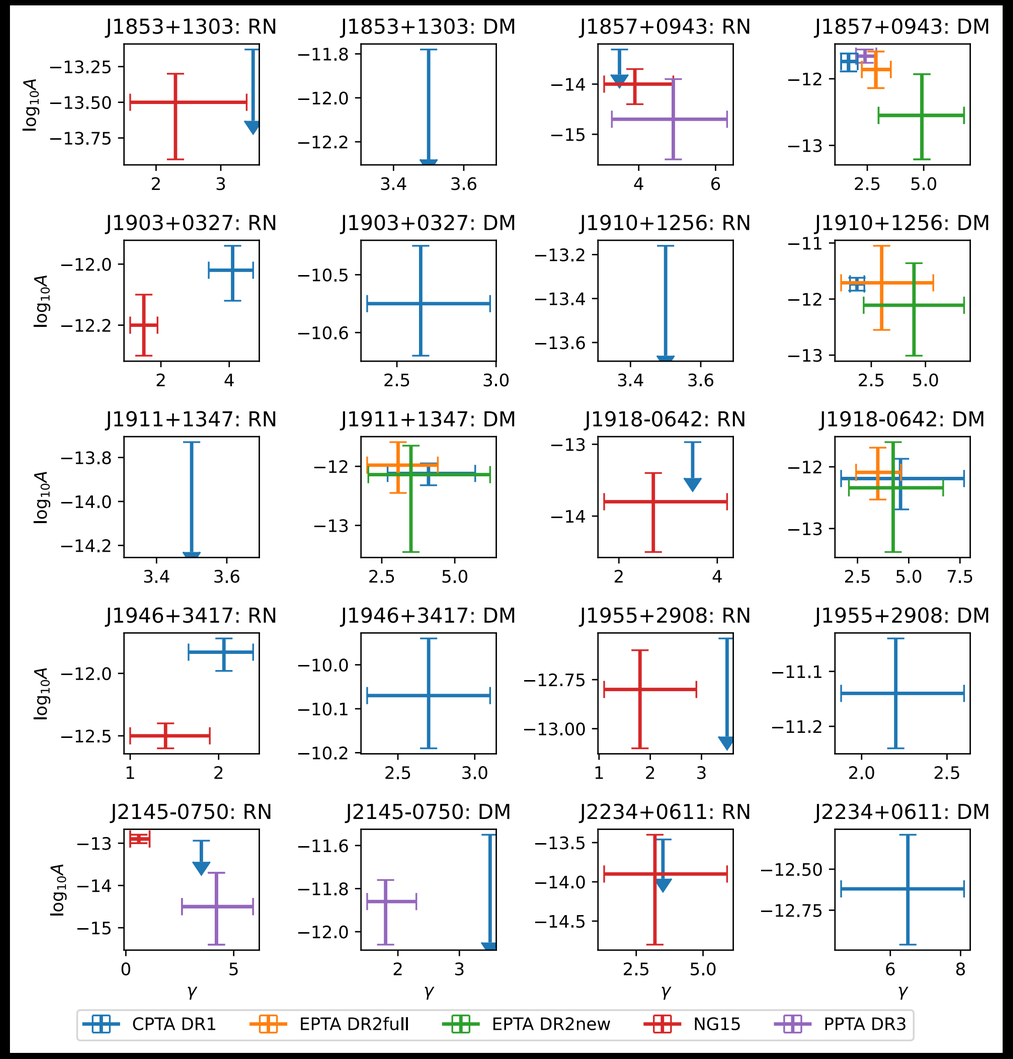


Chen et al., in prep.

Single Pulsar Noise Modeling

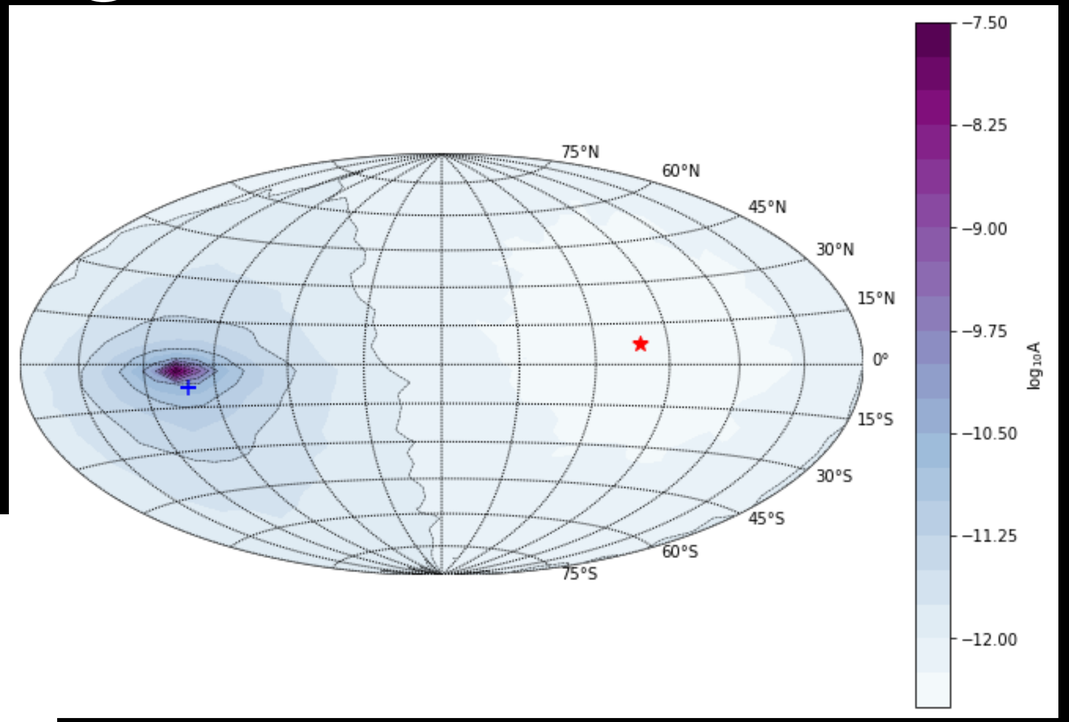


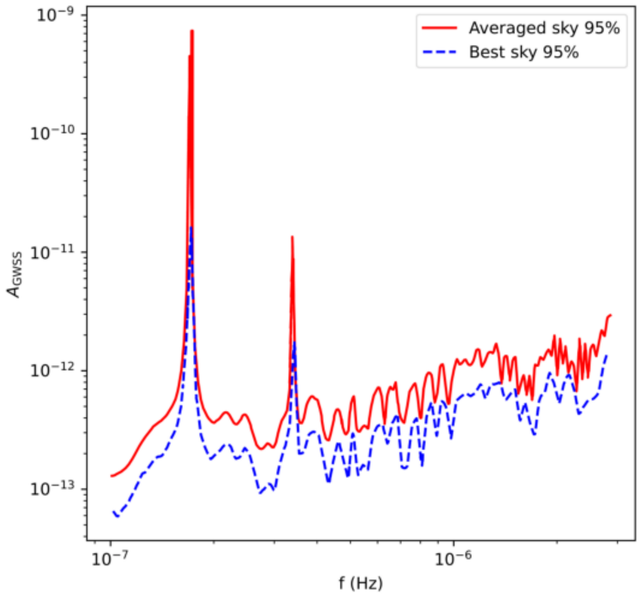
- Comparisons of DM noise and red noise processes between CPTA with other PTAs.

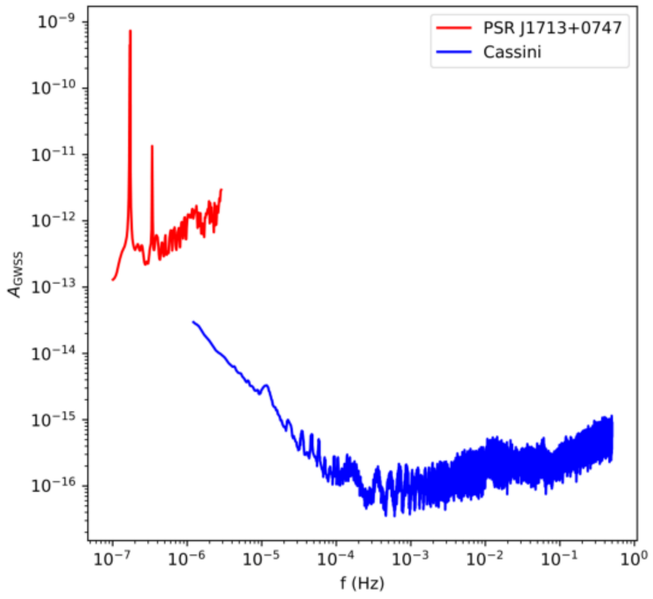


Single Pulsar Bounds for Singe GWs

- 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.

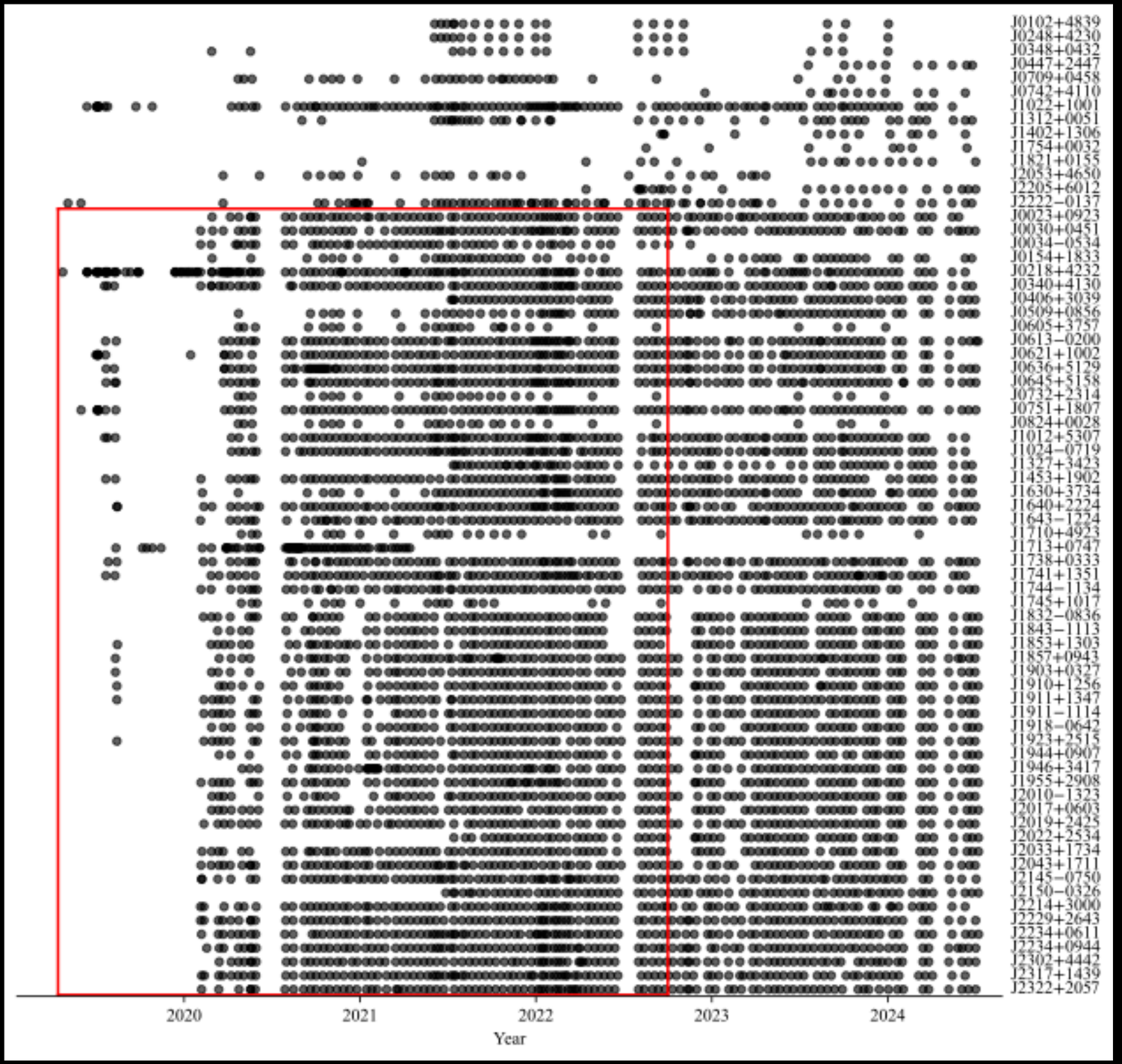
N. Caballero

Zihan Xue

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.

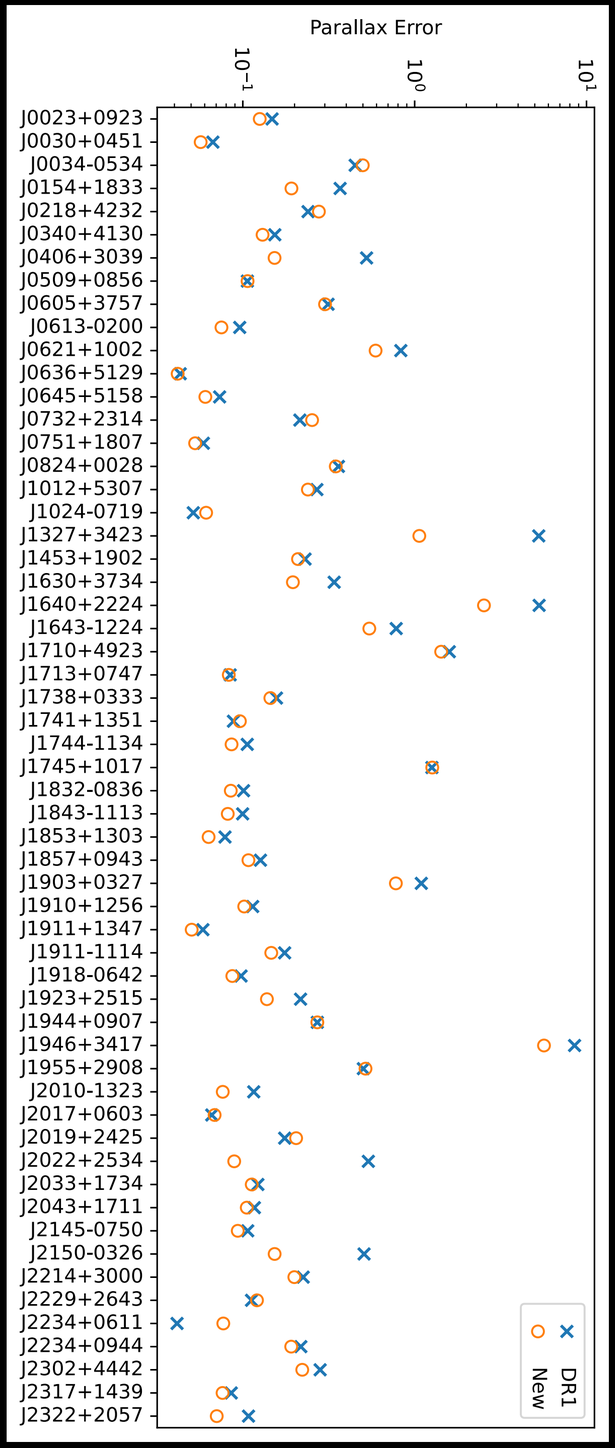


Distances & Post-Keplerian Parameters

- 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)	ς	sin i	m_2 ($M_\odot$)
J0218+4232	-	-	-	-	0.9925(6)	0.234(6)
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(1)
J1640+2224	-	1.9(6)	0.49(8)	0.58(12)	-	-
J1713+0737	-	-	-	-	0.945(5)	0.31(2)
J1741+1351	-	-0.5(1)	-	-	0.963(8)	0.24(3)
J1853+1303	-	1.5(2)	0.20(2)	0.49(8)	-	-
J1857+0943	-	-	-	-	0.9991(2)	0.25(1)
J1903+0327	0.0002399(7)	-	-	-	0.978(9)	1.05(13)
J1910+1256	-	-2.1(2)	0.10(2)	0.74(14)	-	-
J1918−0642	-	-	-	-	0.9955(7)	0.24(1)
J1946+3417	0.00134(5)	-	0.67(9)	0.74(7)	-	-
J2017+0603	-	-	-	-	0.95(2)	0.18(4)
J2019+2425	-	4.3(2)	0.65(6)	0.55(7)	-	-
J2043+1711	-	-	-	-	0.991(2)	0.18(1)
J2150−0326	-	-	-	-	0.98(1)	0.21(6)
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(2)
J2317+1439	-	-	0.16(3)	-	-	-

DR1 Results



Noise Analysis

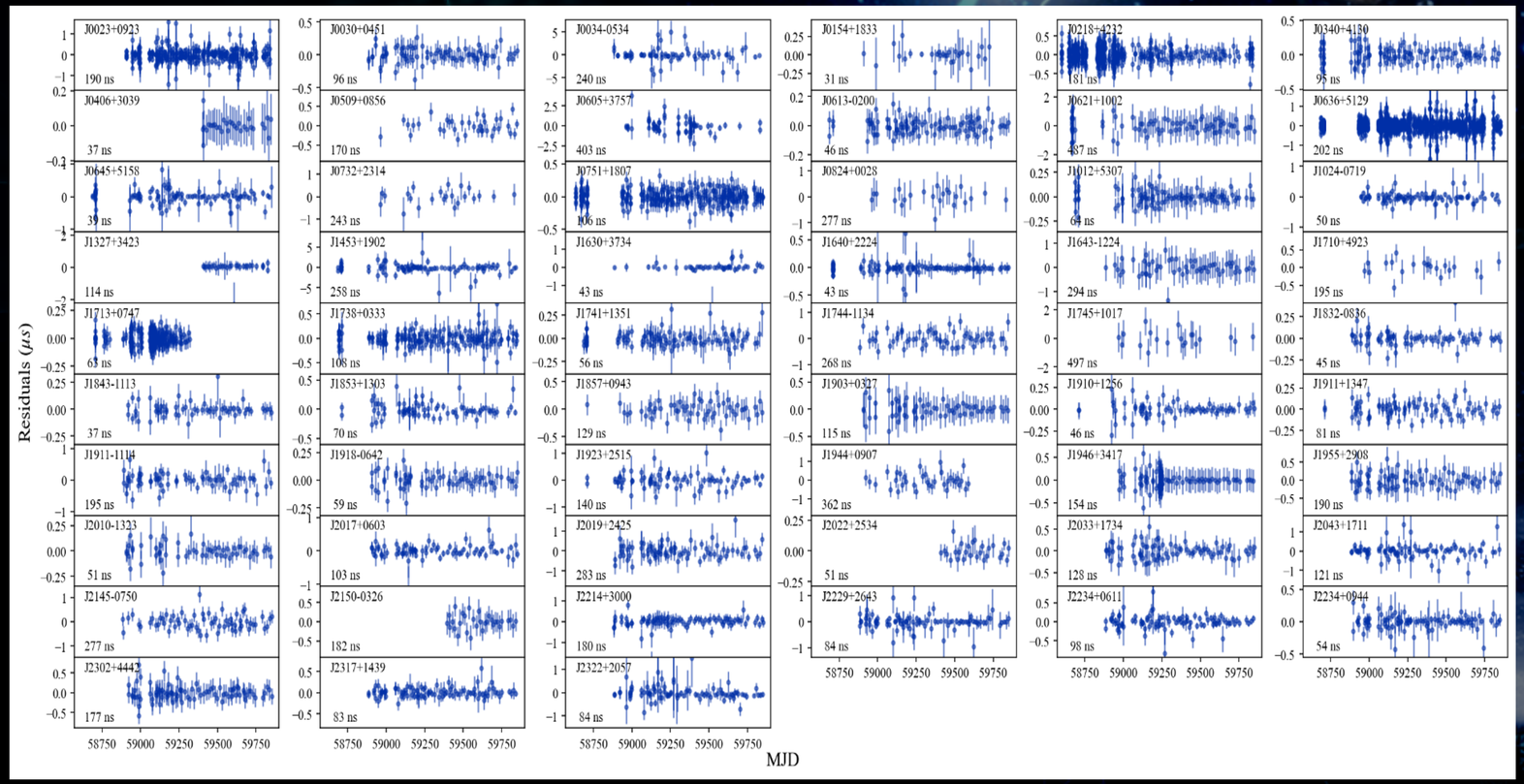
- Overall, longer dataset better constrain the low-frequency red and DM noise processes.

Red Noise

DM Noise

Conclusions

- Fantastic timing data.
- More pulsars, more data for CPTA.
- We are working on the data analysis of data set, including pulsar timing, noise analysis, GWB, single source GWs and etc.



DR1 Timing

Thanks!