Recent results from Pulsar Timing Arrays

Siyuan Chen*（陈偲源）
KIAA, Peking University

03/07/2023
SPSS2023/FPS12

*Email: sychen@pku.edu.cn

Evidence for gravitational waves from Pulsar Timing Arrays ?

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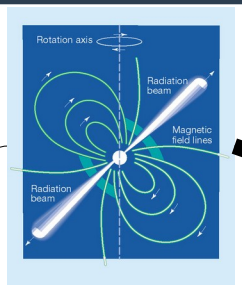
Searching for gravitaitonal waves with Pulsar Timing Array



Dispersion Measure variation

Interstellar medium

Gravitational Waves from cosmological / astrophysical sources

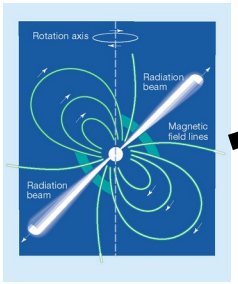
White noise, clock errors

Pulsar with companion

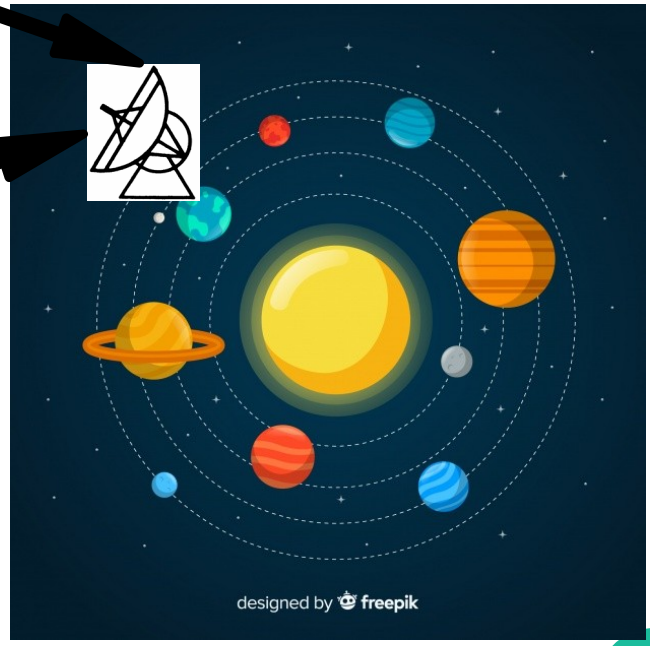
Radio telescopes on Earth

Timing model / red noise

Other pulsars



Solar System



International Pulsar Timing Array coordination

- **IPTA agreement between four PTAs: European PTA, Indian PTA, NANOGrav and Parkes PTA to publish the results of gravitational wave background (GWB) searches in a coordinated process**
- **Chinese PTA worked independently and joined the agreement later (see talks from Lee KJ, Xu Heng)**
- **29/06/2023: 18 simultaneous papers on arxiv, 12 are accepted/published: 2306.16213 – 2306.16230**
- **More papers are to come**

EPTA DR2 + InPTA DR1 – Four data sets

- **DR2full:**

  full EPTA only with all systems

  24.7 years

- **DR2new:**

  short EPTA only with new systems

  10.3 years

- **DR2full+:**

  full EPTA DR2 + InPTA DR1

  25.4 years

- **DR2new+:**

  short EPTA DR2 + InPTA DR1

  11.0 years

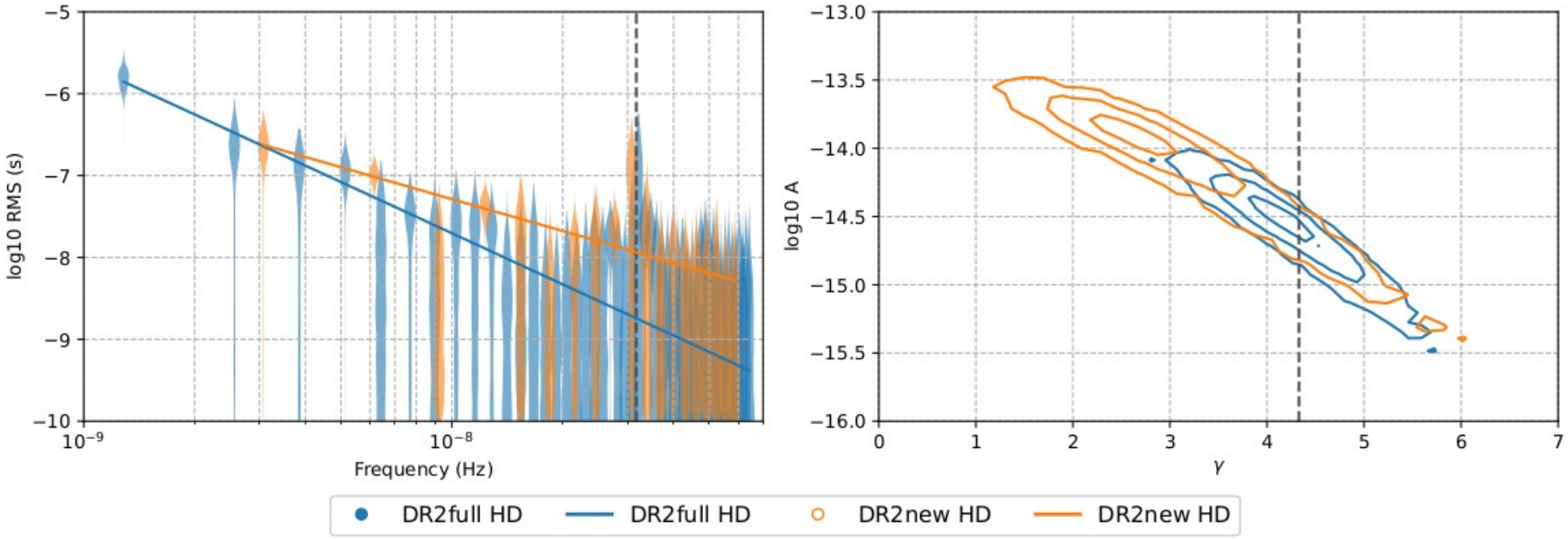
Arxiv: 2306.16214, 2306.16224, 2306.16225

EPTA

InPTA Indian Pulsar Timing Array

Power distribution of the common signal

Fixed SSE DE440

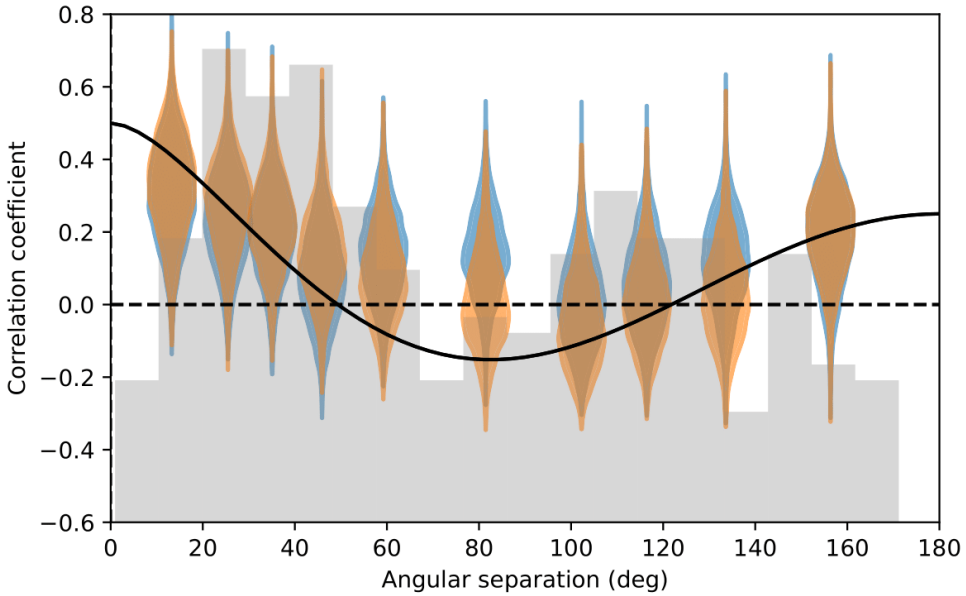


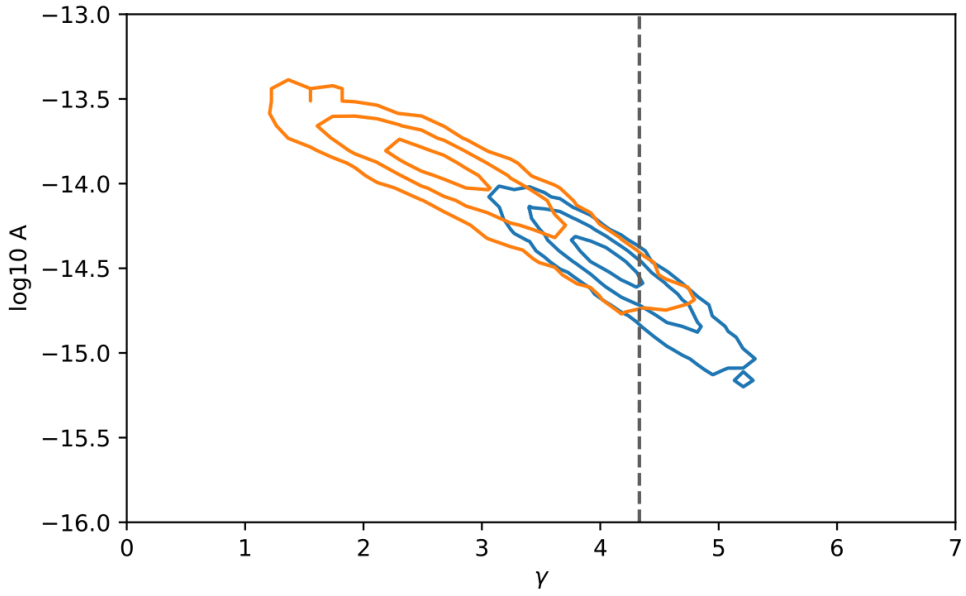
At gamma=13/3: A ~ 2.5 x 10^{-15}

Arxiv: 2306.16214, 2306.16224, 2306.16225

Spatial correlations of the common signal

Fixed SSE DE440





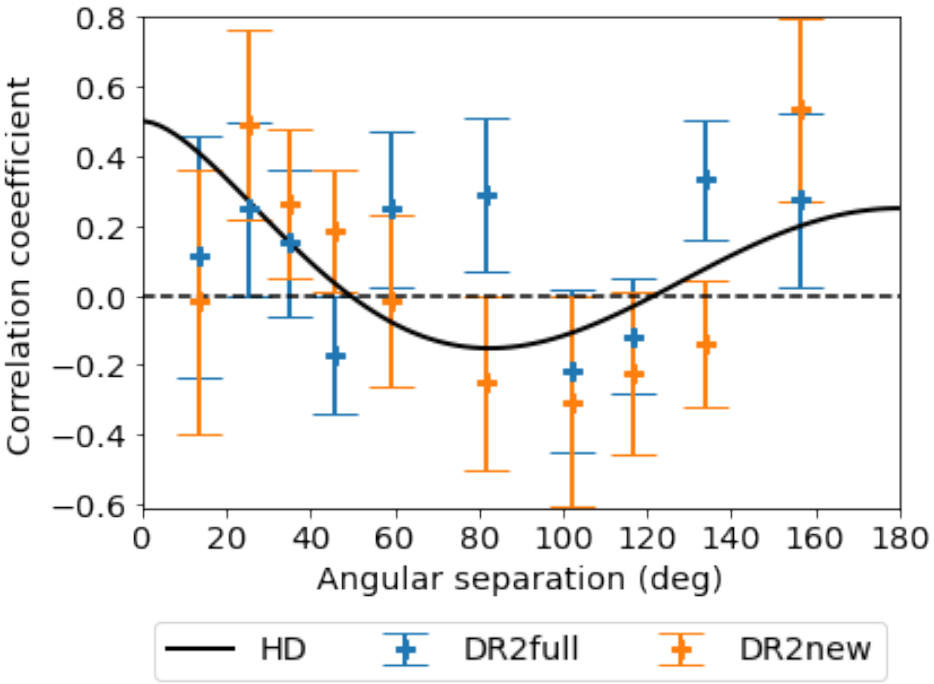
DR2full Binned ORF DR2new Binned ORF

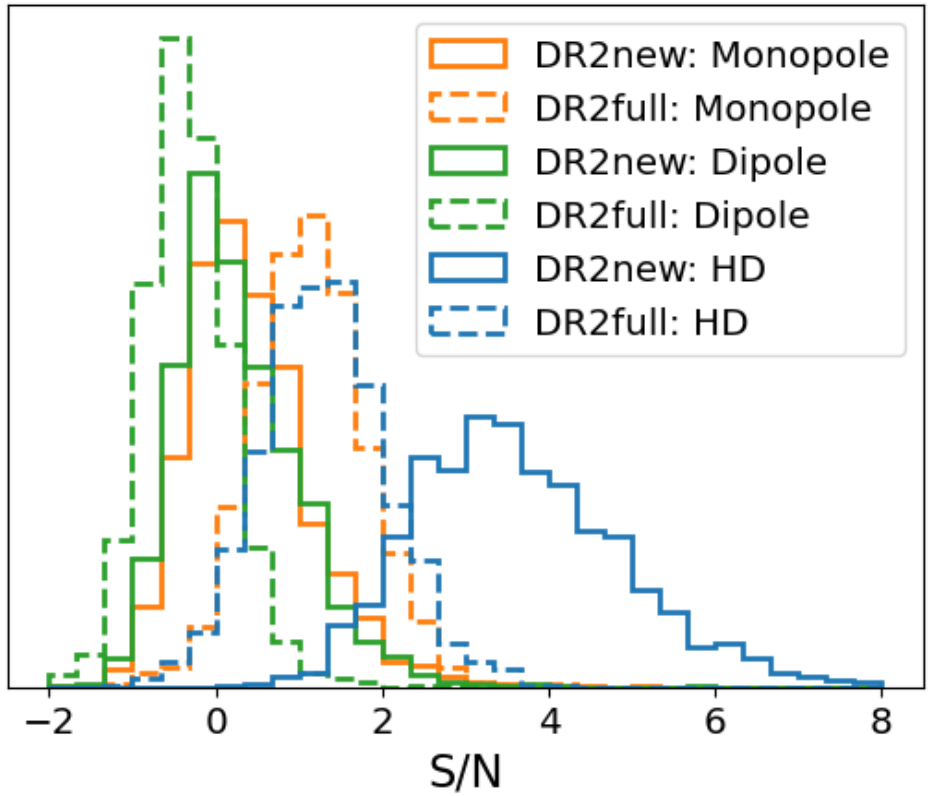
At gamma=13/3: A ~ 2.5 x 10^{-15}

Arxiv: 2306.16214, 2306.16224, 2306.16225

Signal-to-noise ratios – Optimal statistics

Fixed SSE DE440,
fixed gamma=13/3





Arxiv: 2306.16214, 2306.16224, 2306.16225

Model comparison – Bayes factors

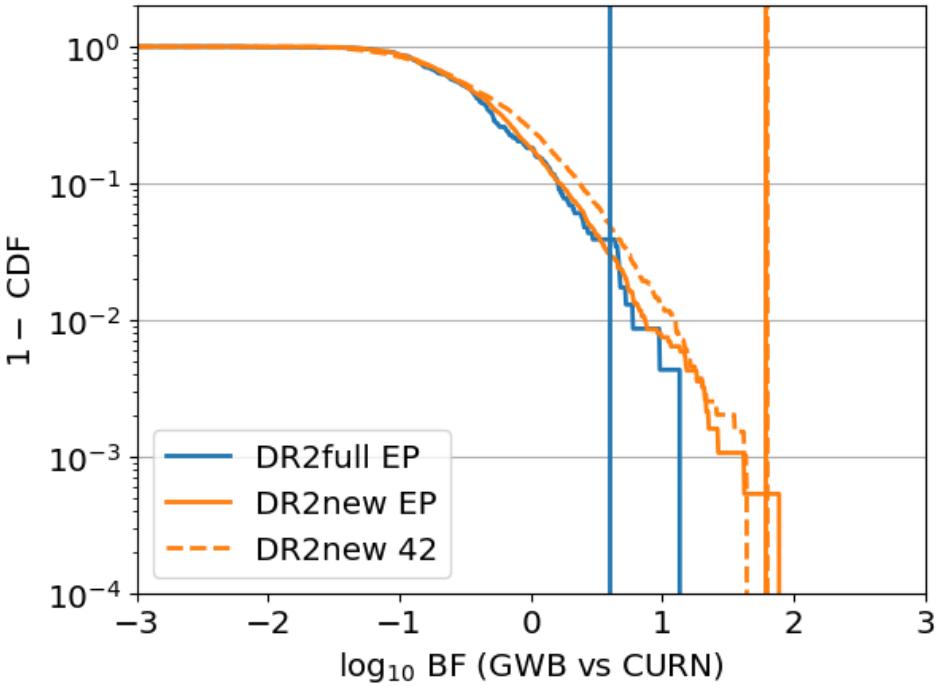
Fixed SSE DE440

Model	DR2full	DR2full+	DR2new	DR2new+
PSRN+CURN	–	–	–	–
PSRN+HD	4	4	60	65
PSRN+MP	< 0.01	<0.01	0.2	0.3
PSRN+DP	< 0.01	<0.01	0.2	1.3
PSRN+CURN+MP	2	3	0.8	1.6
PSRN+CURN+DP	1	1	1	1.6
PSRN+HD+CURN	3	4	27	25
PSRN+HD+MP	5	7	28	57
PSRN+HD+DP	3	4	33	43

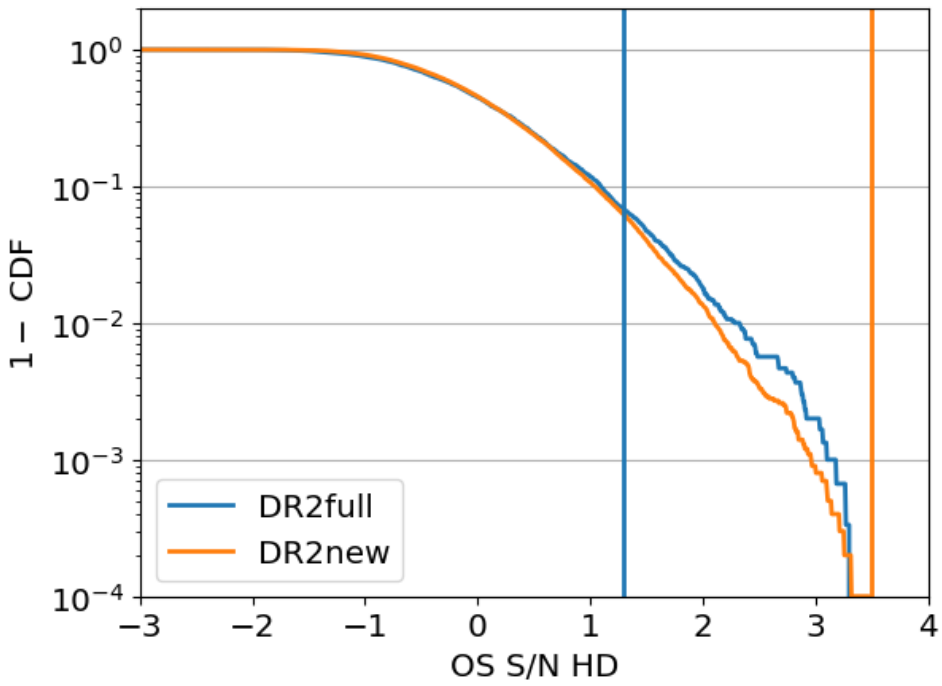
Arxiv: 2306.16214, 2306.16224, 2306.16225

Estimation of significance – phase shift

Bayes factor



S/N of HD

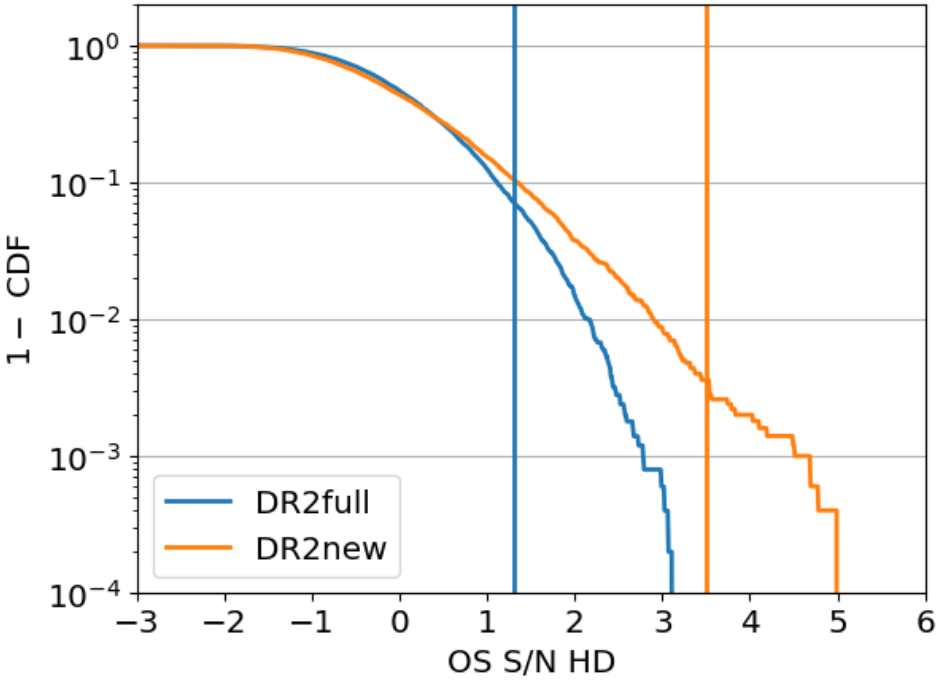


Bayes factor: about 200 / 2000 random phase shifts
OS S/N: 10000 phase shifts

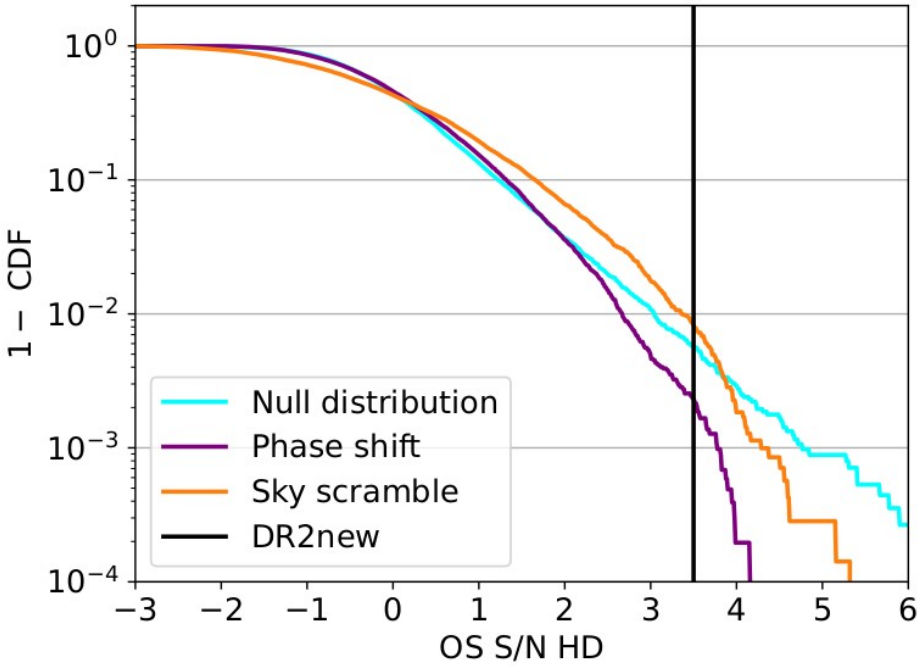
Arxiv: 2306.16214, 2306.16224, 2306.16225

Estimation of significance – sky scramble

Real DR2 data



Simulated DR2new-like data

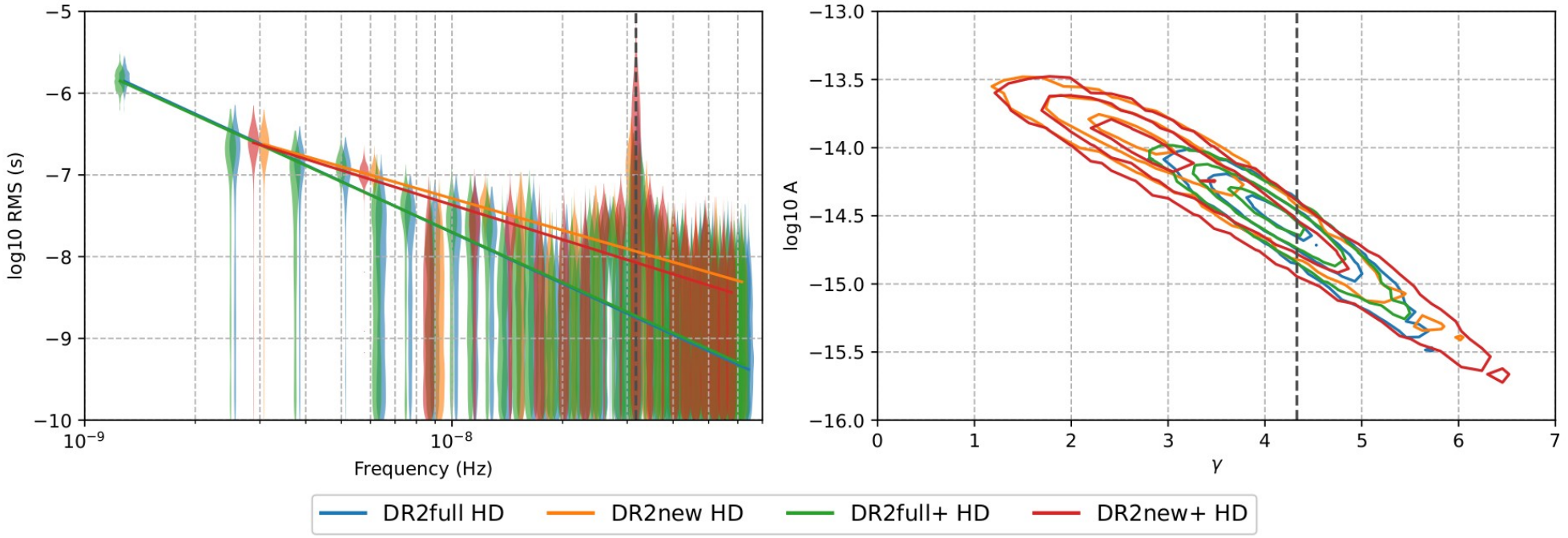


No noise weighted match statistic used, M<0.2 for all scrambles
We have tested with weights and different thresholds and simulations of the expected null distribution

Arxiv: 2306.16214, 2306.16224, 2306.16225

Addition of the InPTA data

Fixed SSE DE440



Arxiv: 2306.16214, 2306.16224, 2306.16225

Evidence for a GWB with PTAs?

- **Four main papers published on the GWB search on 29th June 2023: CPTA (RAA, 23, 075024), EPTA+InPTA (A&A, 10.1051/0004-6361/202346844), NANOGrav (ApJL, 951, L8) and PPTA (ApJL, 951, L6)**
- **Significance reported: ~2 – 4.5 sigma**
- **Arxiv: 2306.16213 – 2306.16230**
- **IPTA project to compare the results from the different PTAs**
- **IPTA DR3 is being assembled**

淸阳桥

淸阳桥 – Hellings-Downs curve ?

Possible differences between DR2full/+ and DR2new/+

- **Lower quality of the early data:**

  lack of radio frequency coverage

  lack of polarisation calibration

- **Improper weights for the power law fitting:**

  different time spans for different pulsars, but each frequency bin is weighted equally

- **Excess noise:**

  low and/or high frequencies

- **Non-stationarity:**

  pulsar noise and/or GW signal