

# NANOGrav Status Report

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# NANOGrav

## ❖ NANOGrav

- ❖ Telescopes
- ❖ Hardware
- ❖ Observations
- ❖ Results
- ❖ GW Analysis
- ❖ Future

- North American Nanohertz Gravitational-wave Observatory
- Collaboration of US and Canadian researchers using North American observatories for pulsar timing.
- Primary science goal: Detection of GW using pulsar timing.
- Group formally organized in fall 2007, but built upon long history of pulsar/GW research.
- See also [www.nanograv.org](http://www.nanograv.org)

# *NANOGrav Members*

## ● Faculty / Research Staff

- ❖ Z. Arzoumanian (NASA)
- ❖ D. Backer (Berkeley)
- ❖ P. Freire (Arecibo)
- ❖ F. Jenet (UTB)
- ❖ V. Kaspi (McGill)
- ❖ J. Lazio (NRL)
- ❖ A. Lommen (F&M)
- ❖ D. Lorimer (WVU)
- ❖ M. McLaughlin (WVU)
- ❖ D. Nice (Bryn Mawr)
- ❖ S. Ransom (NRAO)
- ❖ I. Stairs (UBC)

## ● Postdocs

- ❖ P. Demorest (NRAO)
- ❖ V. Kondratiev (WVU)
- ❖ R. Ferdman (CNRS)
- ❖ M. Gonzalez (UBC)

## ● Graduate Students

- ❖ A. Archibald (McGill)
- ❖ R. Lynch (UVa)
- ❖ R. Shannon (Cornell)

# Telescopes

- Arecibo Observatory
  - ❖ 305-m diameter
  - ❖ Fixed dish,  $0 < \delta < 40$
  - ❖ Typical pulsar bands: 327, 430, 1400, 2300 MHz.
- NRAO Green Bank Telescope
  - ❖ 100-m diameter
  - ❖ Fully steerable,  $\delta > -45$
  - ❖ Flexible freq coverage (e.g., 820 MHz), but rcvr changes harder.



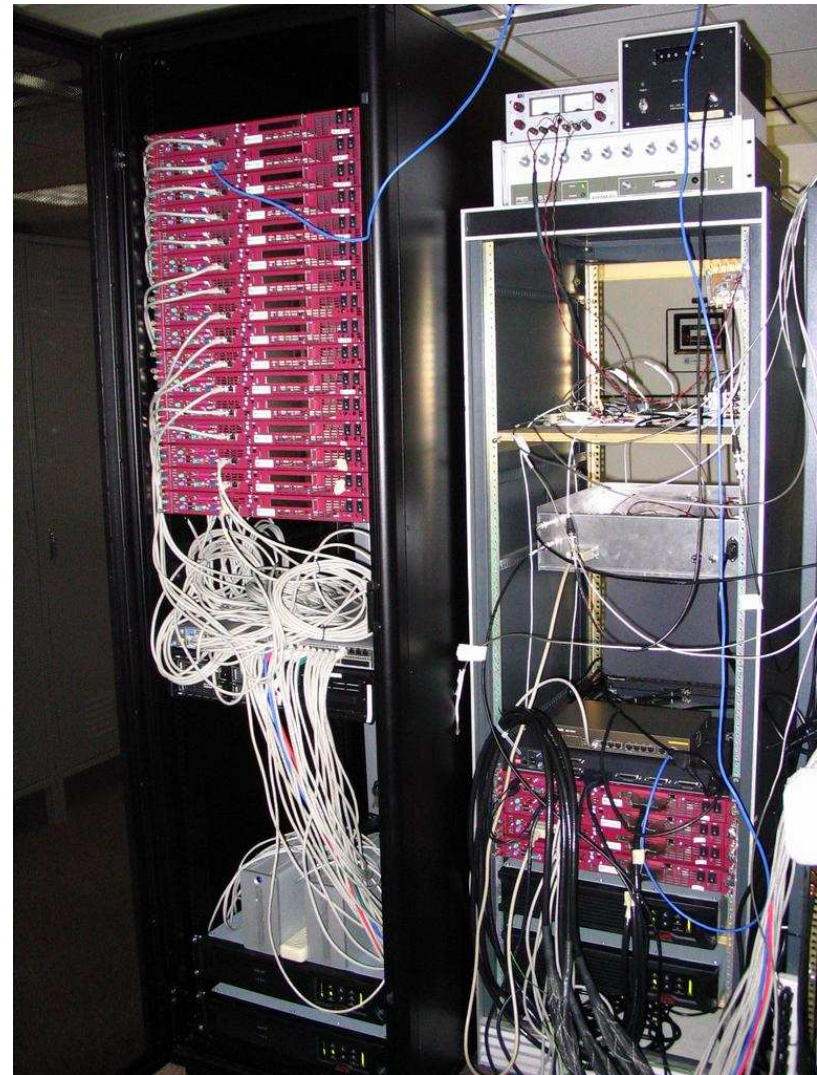
# Current Pulsar Hardware

Coherent dedisp systems:

- ASP, GASP (Berkeley-UBC-Princeton): up to 128 MHz BW ( $32 \times 4$  MHz), 8-bit ADCs, full-Stokes, software-based.

Incoherent systems:

- WAPP (Arecibo): up to  $3 \times 100$  MHz\*, 576 channel,  $20 \mu\text{s}$ , 3-level ADCs, 2 poln.
- Spigot (NRAO): 800 MHz BW, 2048 channel,  $20 \mu\text{s}$  time res, 3-level ADCs, summed polns.



# Current Observing Projects

- ❖ NANOGrav
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- **Arecibo long-term precision timing (Nice et al.)**
- **GBT long-term precision timing (Demorest et al.)**
- “Exploratory” MSP timing at Arecibo (Lorimer et al.) and GBT (Stairs et al.)
- GBT–Arecibo simultaneous timing/VLBI (Demorest et al.)
- Assorted binary pulsar timing (Stairs et al.)
- Ongoing searches: PALFA, GBT 350 MHz drift scan.

# PTA Observations

- ❖ NANOGrav
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- ❖ Results
- ❖ GW Analysis
- ❖ Future

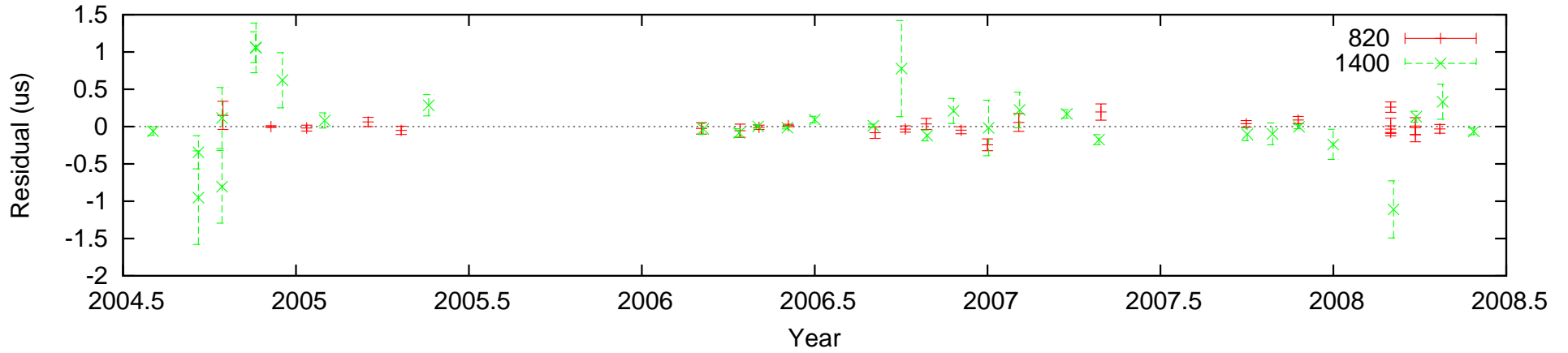
- Regular long-term precision timing observations since late-2004:
- GBT:
  - ❖ Monthly 820 and 1400 MHz sessions, separated by 1-5 days.
  - ❖ 12 MSPs, 0.5 hr per band on each source.
- Arecibo:
  - ❖ Single multifrequency (327, 430, 1400, 2300 MHz) session every 6 weeks.
  - ❖ 7 MSPs, 2 bands/source, 0.5 hr per band.
- Primary backend instrumentation is ASP/GASP coherent dedispersion systems.

# Sources / Results

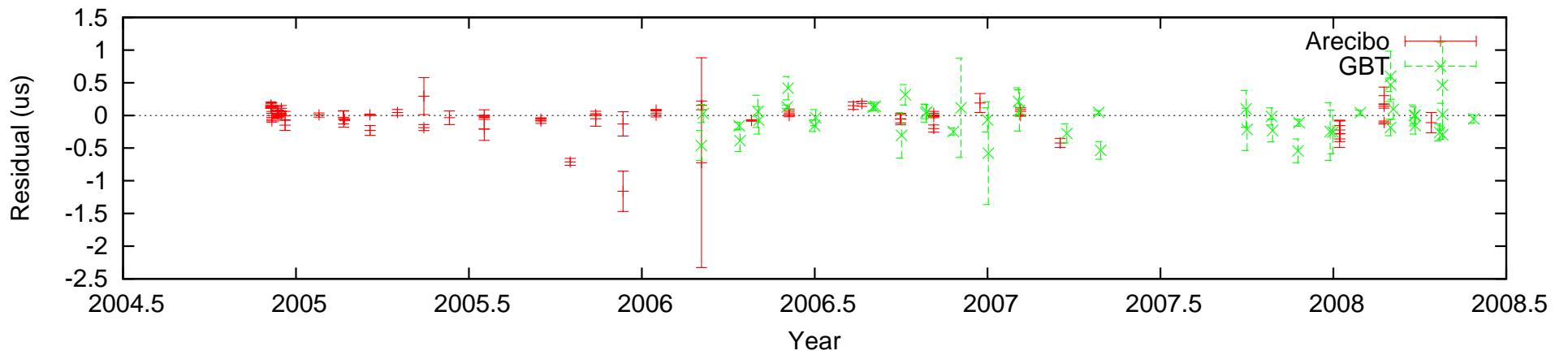
Pulsar	Obs	$P$ (ms)	DM (pc cm $^{-3}$ )	$P_b$ (d)	$S_{1.4}$ (mJy)	$\sigma_t$ ( $\mu$ s)
J0030+0451	AO	4.87	4.3	—	0.6	0.41
J0218+4232	GB	2.32	61.3	2.0	0.9	2.22
J0613–0200	GB	3.06	38.8	1.2	1.4	0.24
J1012+5307	GB	5.25	9.0	0.6	3.0	0.66
J1455–3330	GB	7.98	13.6	76.2	1.2	1.00
J1600–3053	GB	3.61	52.3	14.3	3.2	0.48
J1640+2224	AO	3.16	18.4	175.4	2.0	0.15
J1643–1224	GB	4.62	62.4	147.0	4.8	1.65
J1713+0747	AO/GB	4.57	16.0	67.8	10.4	0.082/0.16
J1744–1134	GB	4.07	3.1	—	5.3	0.19
B1855+09	AO	5.36	13.3	12.3	3.1	0.11
J1909–3744	GB	2.95	10.4	1.5	2.1	0.070
J1918–0642	GB	7.64	26.6	10.9	1.0	1.09
B1937+21	AO/GB	1.56	71.0	—	12.5	0.21
J2019+2425	AO	3.93	17.2	76.5	0.5	1.04
J2145–0750	GB	16.05	9.0	6.8	9.4	0.69
J2317+1439	AO	3.45	21.9	2.5	4.0	0.49

# Residuals

PSR J1909-3744, GBT



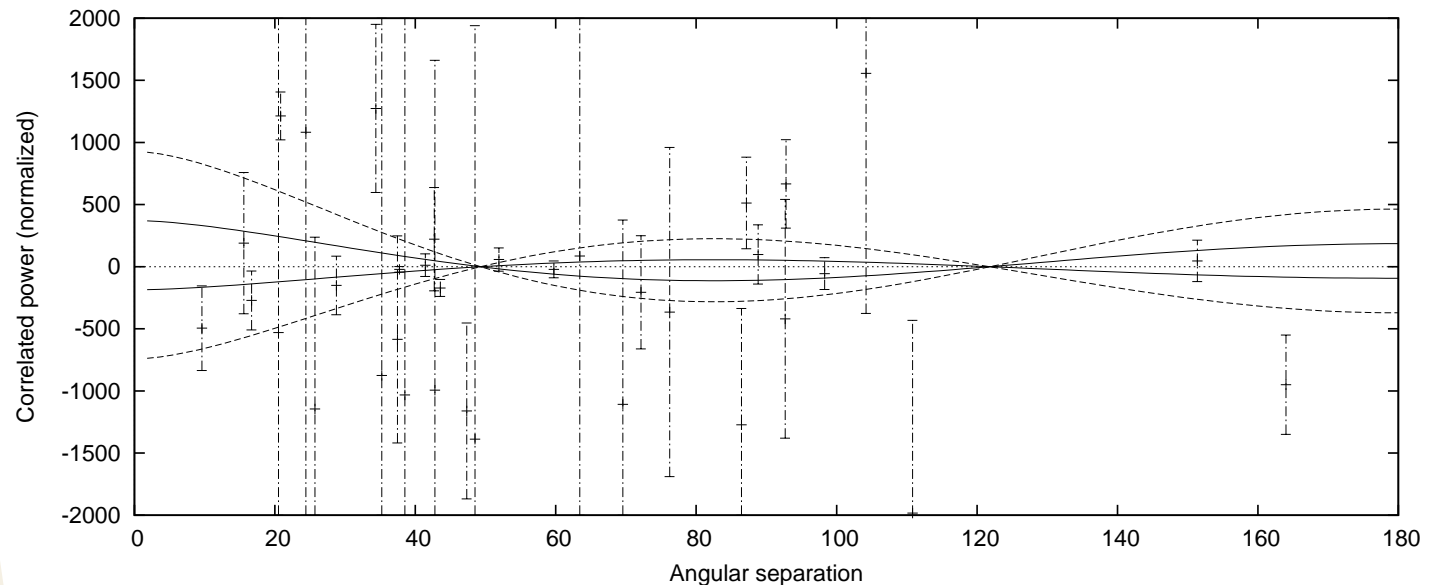
PSR J1713+0747



# GW Analysis Projects

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- ❖ **GW Analysis**
- ❖ Future

- Long-term single pulsar GW limits (Lommen et al.)
  - ❖ PSRs B1855+09, J1713+0747
  - ❖ Combines Kapsi et al. data with newer measurements for  $\sim 20$  year span.
- Full PTA GW correlation analysis (Demorest et al.)
  - ❖ Initial 2.5-year results still above single-pulsar limits.



# Future Pulsar Hardware

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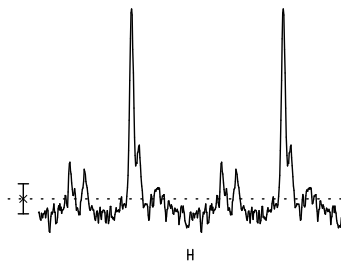
## ❖ Future

- New high-BW backend currently under development at NRAO:
  - ❖ GUPPI = Green Bank “Ultimate” Pulsar Processing Instrument
  - ❖ Up to 1 GHz total BW
  - ❖ 8-bit “real” sampling, dual polarization.
  - ❖ Support for coherent and incoherent modes:
    - Coherent: 0.5–4 MHz channels, folding.
    - Incoherent: up to 4096 channels, 50  $\mu$ s integration (output data rate  $\sim$ 100 MB/s).
  - ❖ Based on Berkeley CASPER suite of FPGA hardware/design tools (IADC/IBOB/BEE2).
  - ❖ Incoherent mode currently “beta”

# GUPPI First Light

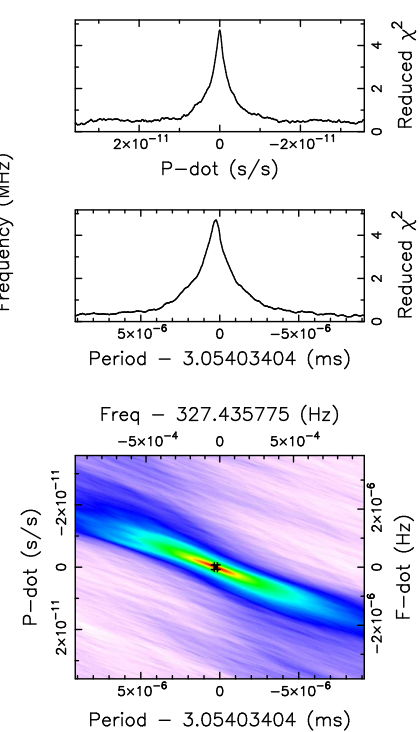
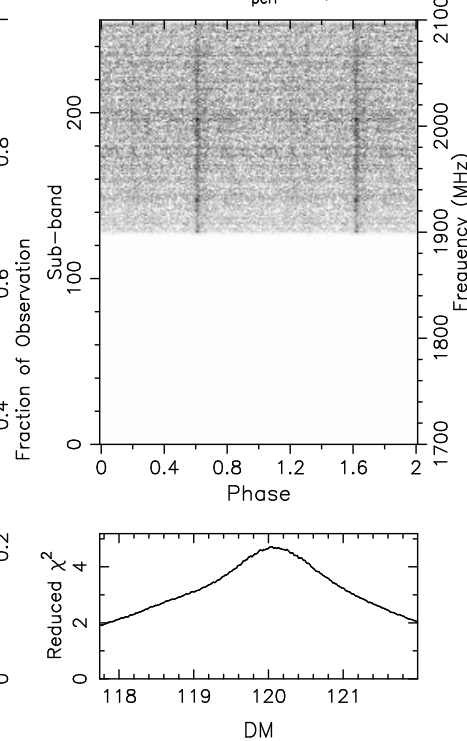
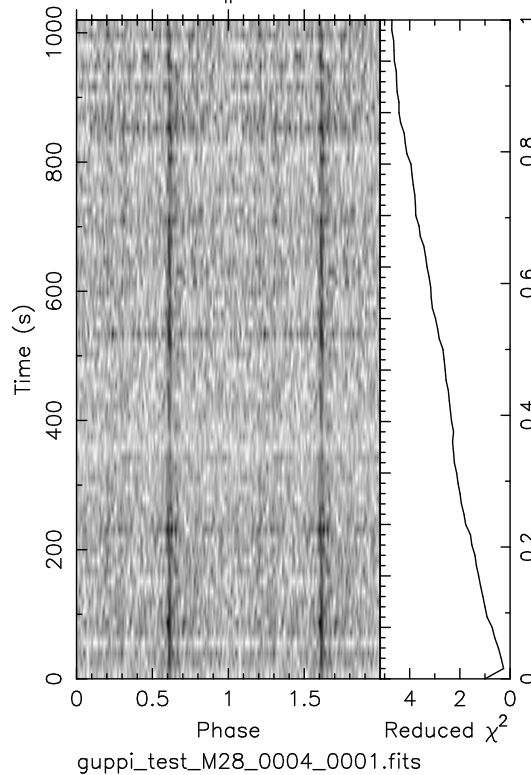
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2 Pulses of Best Profile



Candidate: PSR\_1824-2452A  
 Telescope: GBT  
 Epoch<sub>topo</sub> = 54573.42104166667  
 Epoch<sub>bary</sub> = N/A  
 T<sub>sample</sub> = 4.096e-05  
 Data Folded = 24899584  
 Data Avg = 9.845e+04  
 Data StdDev = 1135  
 Profile Bins = 256  
 Profile Avg = 9.575e+09  
 Profile StdDev = 3.541e+05

Search Information  
 RA<sub>J2000</sub> = 18:24:32.7840      DEC<sub>J2000</sub> = -24:52:12.3600  
 Best Fit Parameters  
 Reduced  $\chi^2$  = 4.711      P(Noise) < 2.05e-122 ( $\approx 23.5\sigma$ )  
 Dispersion Measure (DM) = 120.043  
 P<sub>topo</sub> (ms) = 3.054034285(95)      P<sub>bary</sub> (ms) = N/A  
 P<sub>topo</sub> (s/s) = 0.0(7.2) × 10<sup>-13</sup>      P<sub>bary</sub> (s/s) = N/A  
 P<sub>topo</sub> (s/s<sup>2</sup>) = 0.0(4.6) × 10<sup>-15</sup>      P<sub>bary</sub> (s/s<sup>2</sup>) = N/A  
 Binary Parameters  
 P<sub>orb</sub> (s) = N/A      e = N/A  
 a<sub>1</sub> sin(i)/c (s) = N/A       $\omega$  (rad) = N/A  
 T<sub>peri</sub> = N/A



17-Apr-2008 22:00