Pulsars@OzGrav

Highlights, challenges and opportunities

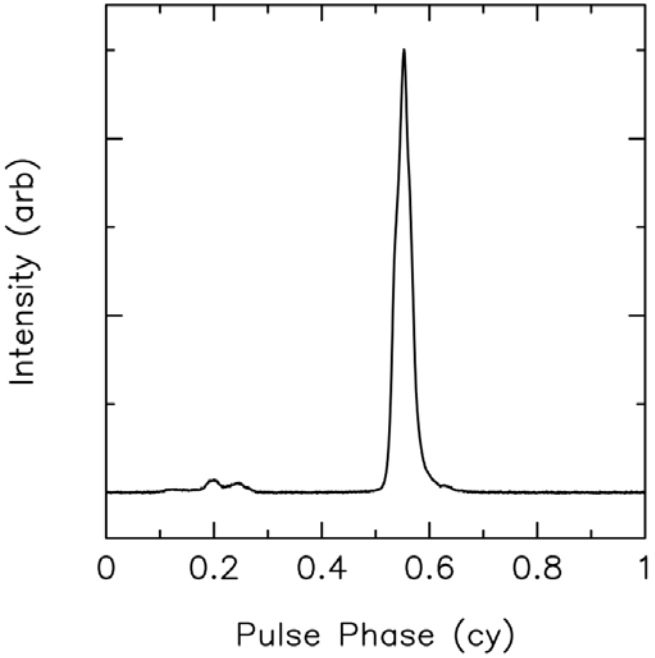
Ryan Shannon & Hannah Middleton, co-chairs

ARC Centre of Excellence for Gravitational Wave Discovery

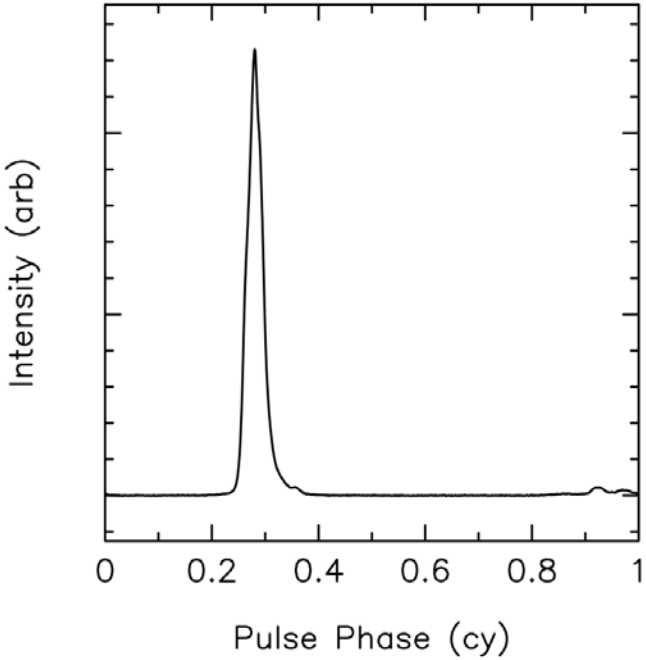
#pulsar-inference (ozgrav slack)
#ppta (ozgrav slack)
meertime.slack.com
PPTA telecon
Australasian monthly pulsar telecon
- Clash with Melbourne astronomy seminar
IPTA-Gravitational Wave Analysis (East) telecon

MeerKAT: A powerful pulsar telescope

5 days of PKS



30 minutes of MK



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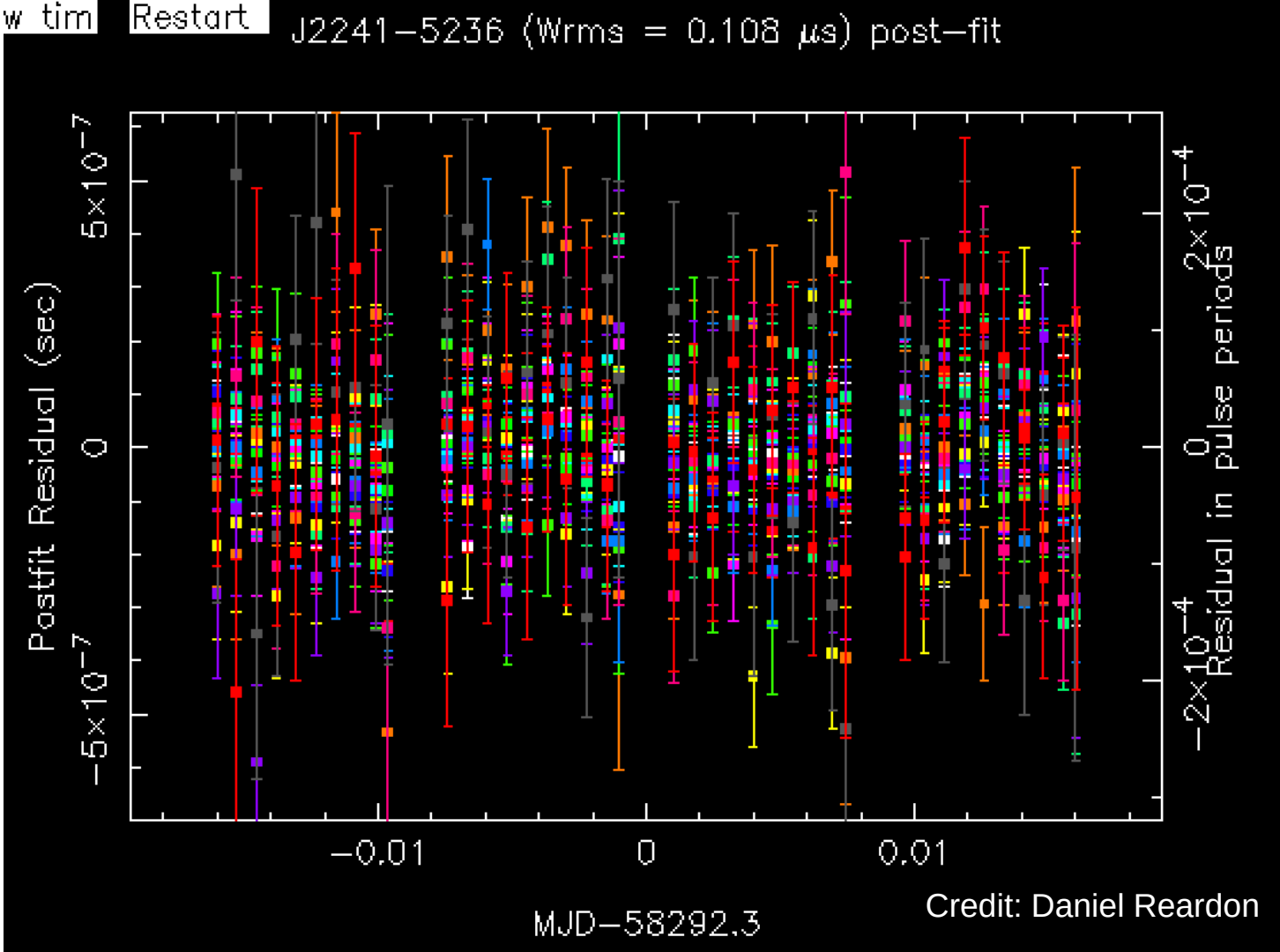
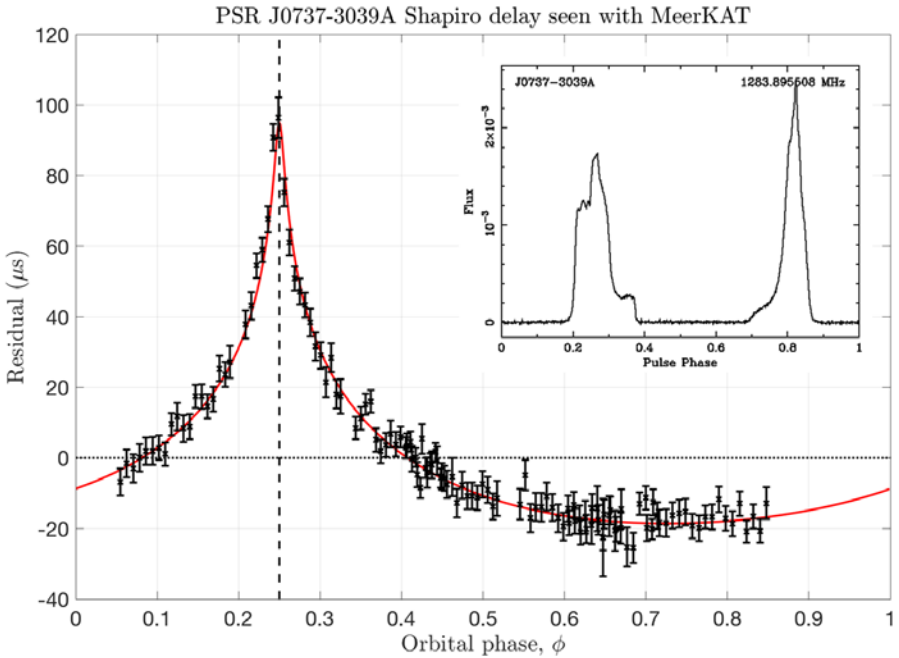
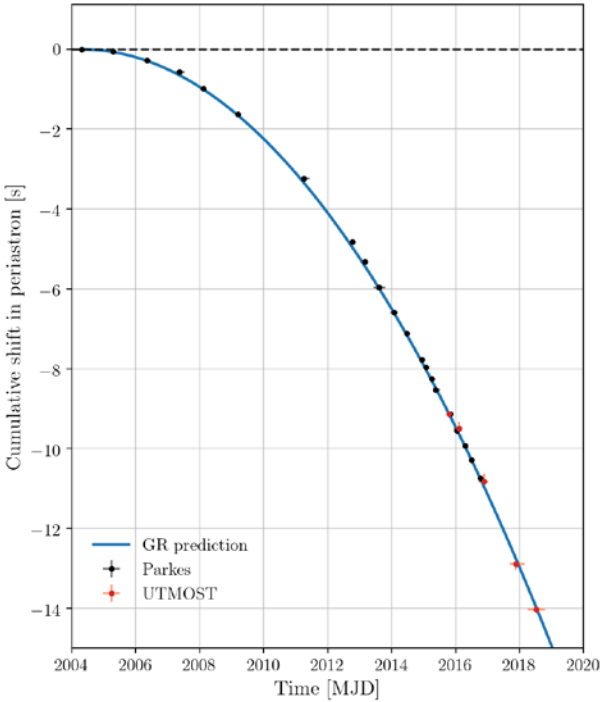
PSR J2241-5236
108 ns
64 s subints
15 sub-bands
5 ns Jitter limit in an hour
Best nanohertz gravitational wave radiometer we know of
(Funky orbital variations)



The double pulsar at new and “gently used” telescopes



Credit: D. Reardon



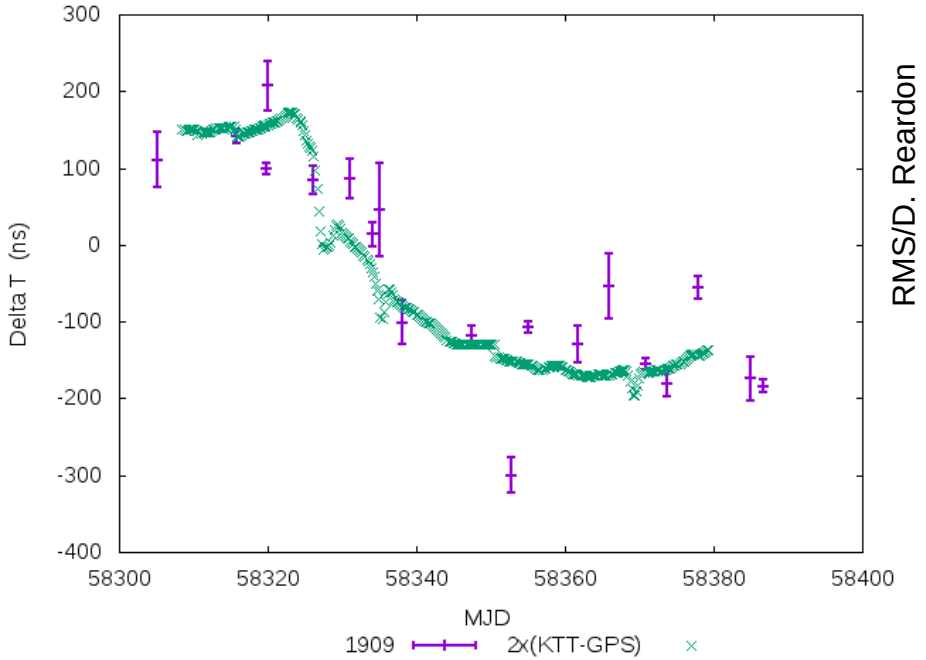
UTMOST+PKS public data: Credit: M. Lower

OzGrav

MeerKAT

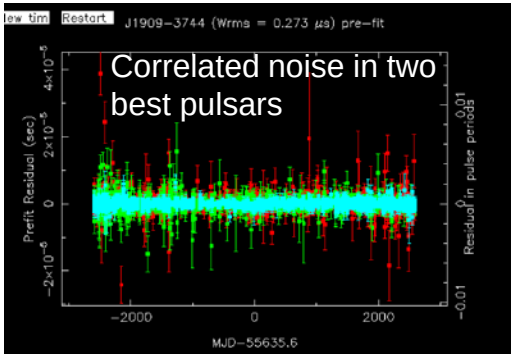
- Impressive raw sensitivity
- World-beating clock system
- Commissioning works in progress (Polarization calibration/channelization and firmware)
- Telescope access (will we get 5000 hrs)
- How does MeerKAT fit into IPTA efforts?

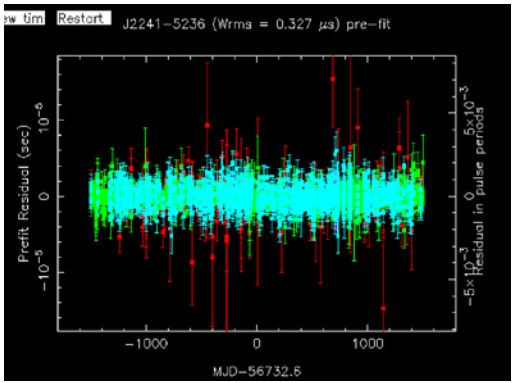
Commissioning data on J1909-3744 can see the very small MeerKAT clock drift



Parkes Pulsar Timing Array: The Future

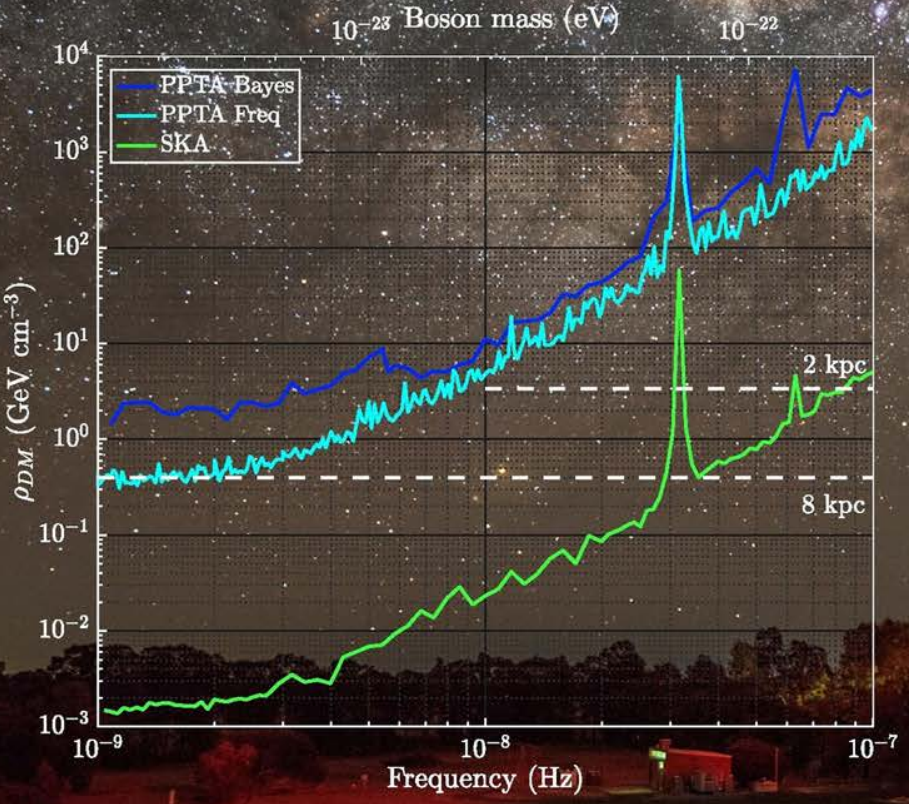
- Ultra-wideband system: 0.7 - 4 GHz
  - Need new methods to time-tag pulses
    - Common machinery will be needed for MeerKAT
- Data sets:
  - Approaching a second data release
  - Curation essentially complete
  - Timing analysis ongoing (in OzStar queue…)
  - GW search by Sunday?
- Vision:
  - How does PPTA fit in w.r.t IPTA and meerkat?





Credit: D. Reardon

PPTA constraints on fuzzy dark matter



Credit: X. Zhu

✓Physical Review D Editor's Suggestion

- PPTA DR1.9, >20 pulsars for > decade
- Constrain dark matter density in the Earth vicinity; < 6 GeV cm^{-3} for $m<10^{-23}$ ev --> probably not all dark matter is made from ultralight bosons
- Improve on previous results by a factor of ~5
- High cadence timing of Galactic Centre pulsars will produce the most promising results at the cosmologically favourable mass range $m\sim10^{-22}$ eV

Young Pulsar Timing

Regular monitoring of **260 young and energetic pulsars** with the Parkes radio telescope having timing baselines of ~**10 years**.

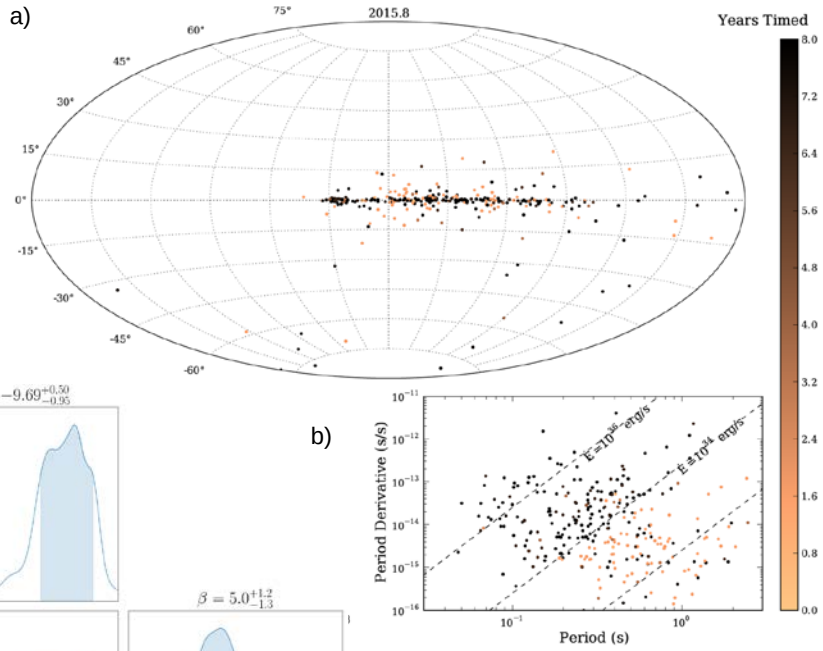
Provides several unique insights into neutron star (NS) science:

1. Rotational irregularities in NS: **Timing noise**
2. Probes into NS interiors: **Glitches**
3. Understanding NS spin-down: **Braking indices**
4. Astrometry: **Proper motion measurements**
5. Planetary companions: **Reflex motion**

The Bayesian inference approach to disentangle the various phenomena - applied to a large sample of young pulsars:

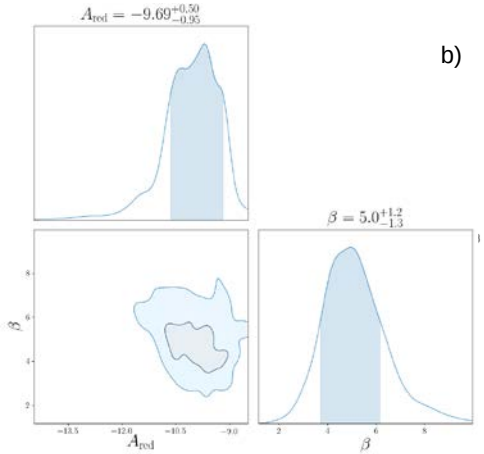
1. **New timing solutions.**
2. **Characterised timing noise in young pulsars.**
3. **5 new proper motions.**
4. **19 new braking index measurements.**

Future: The 1000 pulsar array with MeerKAT



a) Sample of young pulsars monitored by Parkes shown on the Galactic plane.
b) Distribution of Edot values for the same pulsar sample.

Credit: A.Parthasarathy



Integrated posterior distributions of red-noise amplitude and spectral index for a large sample of young energetic pulsars.

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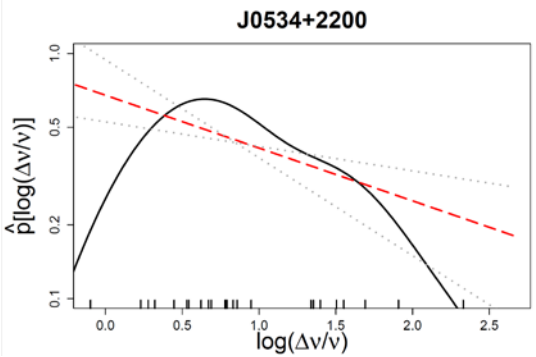
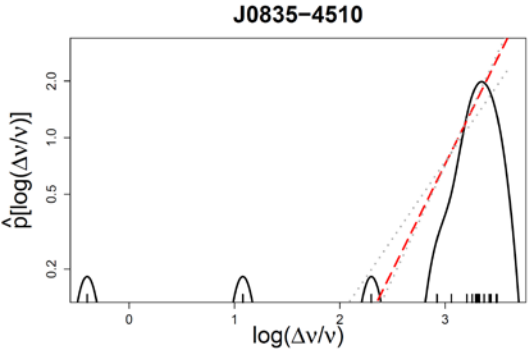
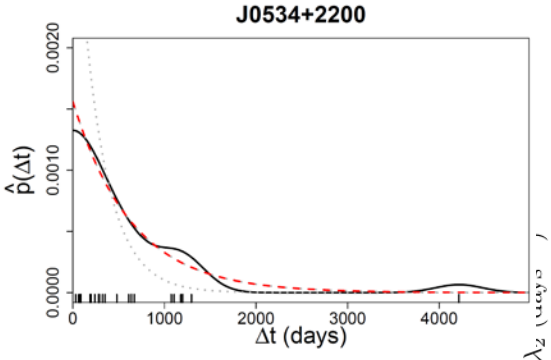
Glitches

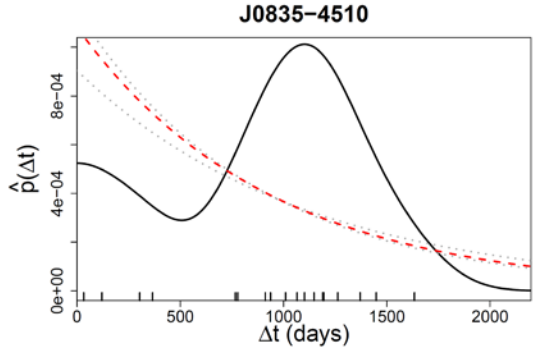
Amplitude



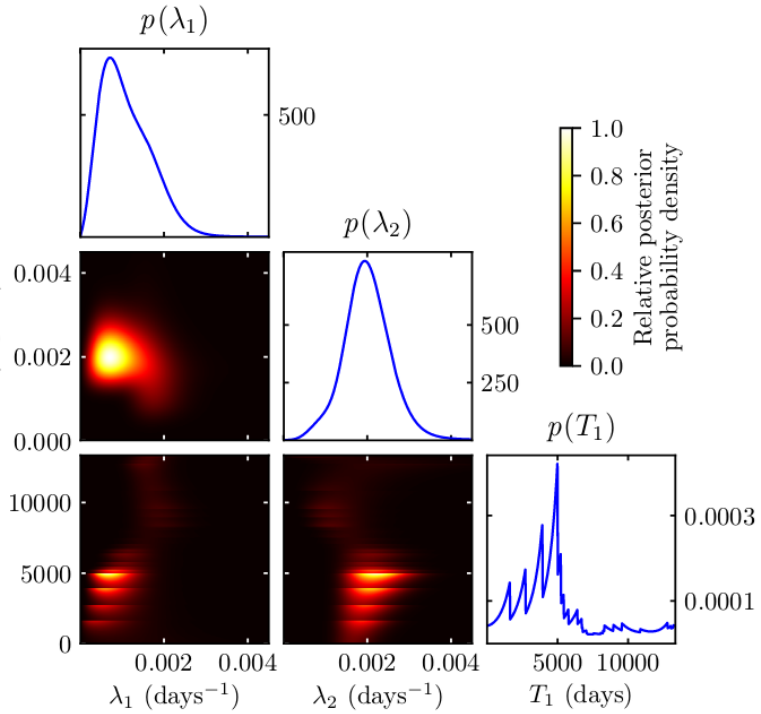


Waiting time





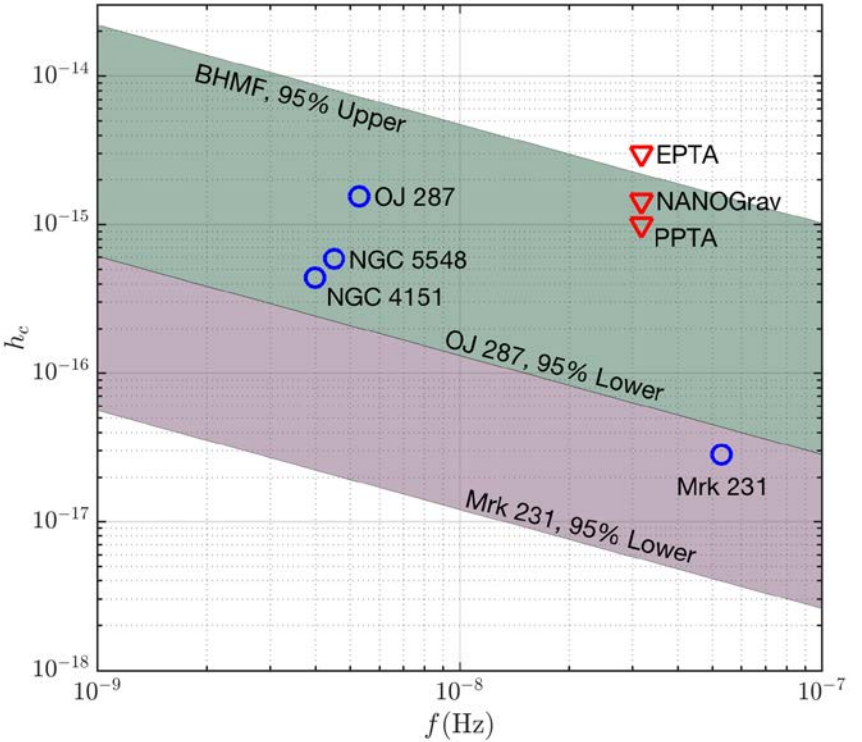
Size and waiting time statistics Howitt, Melatos & Delaigle 2018



Glitch correlations in the Crab Carlin, Melatos & Vukcevic 2018

The minimum and maximum GWB from SMBBHs

- Zhu, Cui & Thrane MNRAS 2019
- The **maximum** signal $A_{yr} < 2.4 \times 10^{-15}$ with 95% C.L. with black hole mass function
- The **minimum** signal based on OJ 287: $A_{yr} > 6 \times 10^{-17}$ with 95% C.L.
- **3C 66B ruled out as a SMBBH!**
- $A_{yr} > 6 \times 10^{-18}$ with 95% C.L. if *at least one of OJ287, NGC 5548, NGC 4151 and Mrk 231 host a true SMBBH*
- A novel framework to quickly evaluate GWB implications for new SMBBH candidates/discoveries



Credit: X. Zhu

Plans for the retreat

- Start gravitational wave searching in PPTA dataset
- Collaboration: IPTA, PPTA, OzGrav, and MeerTime: how do they all fit together (with Chiara M.)
- Young pulsars stuff: connecting theory to observations
- Inference plans: Pulsar timing in Bilby, Profile-domain methods
- Pulsar searching

- Please contact us if you are interested in meeting this weekend.

- Key for success: identify OzGrav projects to contribute to international/domestic efforts
    - Swin, Monash, Melbourne Uni nodes

Plans for the next year

- Data sets
  - Complete PPTA data release
  - MeerKAT early results
    - J2241-5236
  - Young pulsar datasets: Glitching pulsars @ UTMOST/PKS
- Inference
  - Apply existing GW search codes (enterprise, PAL2, temponest, NX01?)
  - Developing GW search code (bilby)
  - Wide-band timing
  - Profile domain timing
  - Timing noise and glitch and modelling
- Pulsar Searching
  - Applying Viterbi continuous wave search to pulsar search