Massive-scale pulsar timing with the ATNF

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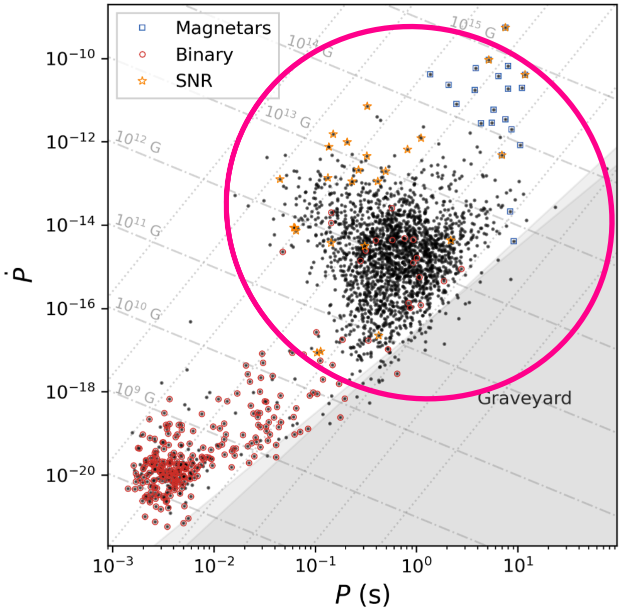
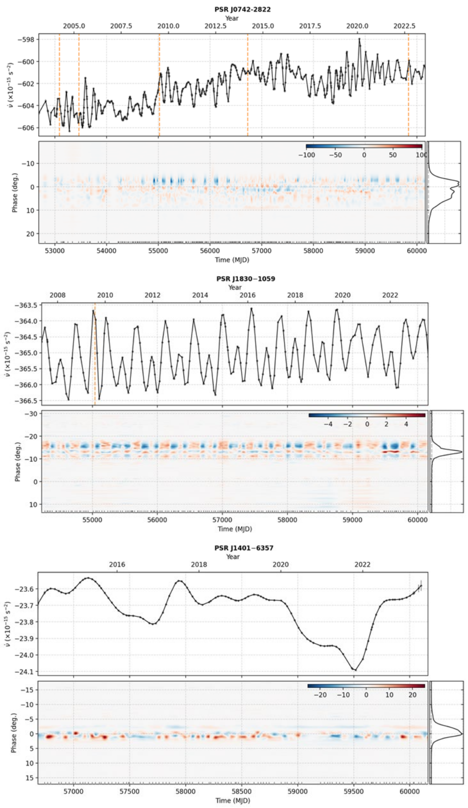
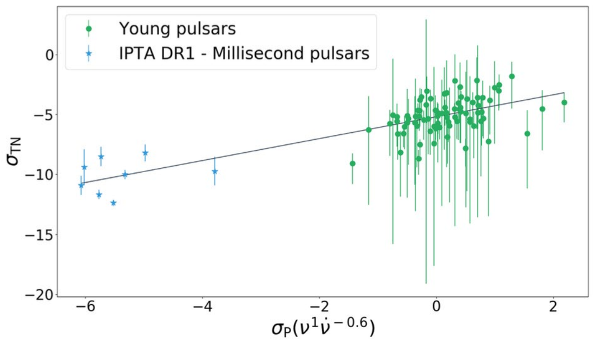
Why observe lots of *slow spinning* pulsars?

Population properties & long-term evolution





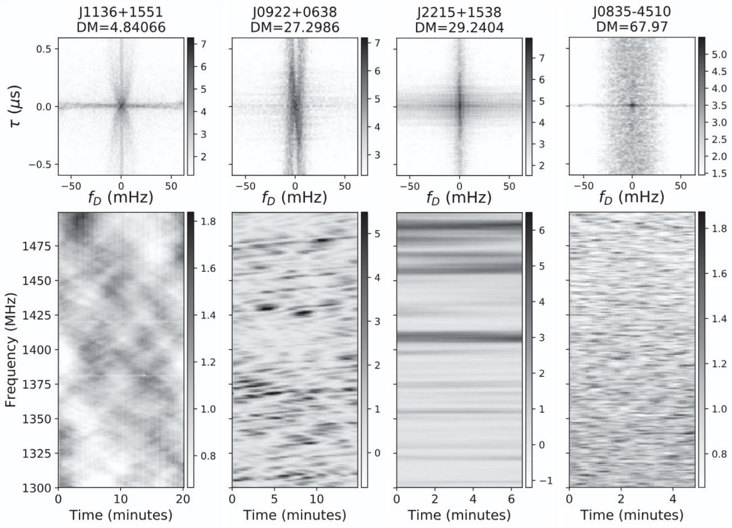
Rotational and emission variability
(Lower et al. 2025)

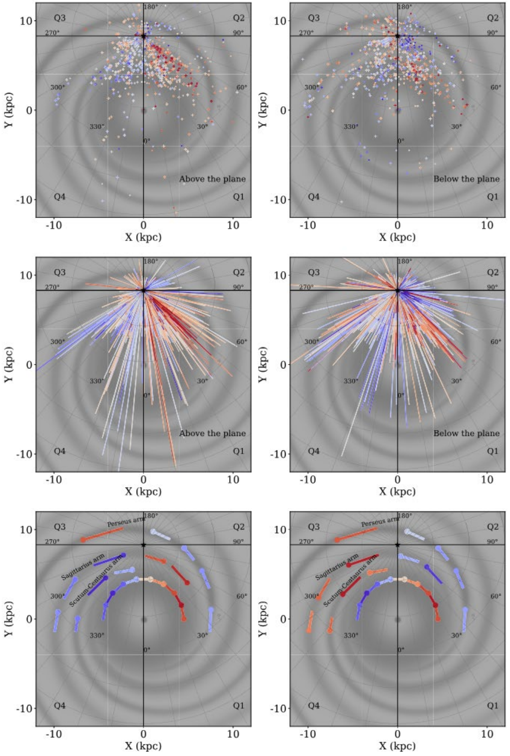


Informing PTA-based GW searches
(Parthasarathy et al. 2019)

More reasons to observe lots of slow spinning pulsars

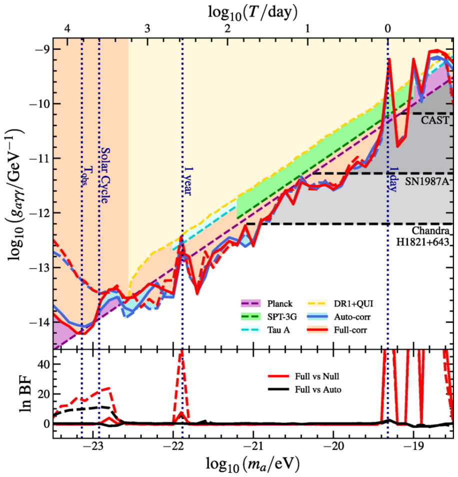
Structures in the ISM (Main et al. 2023)



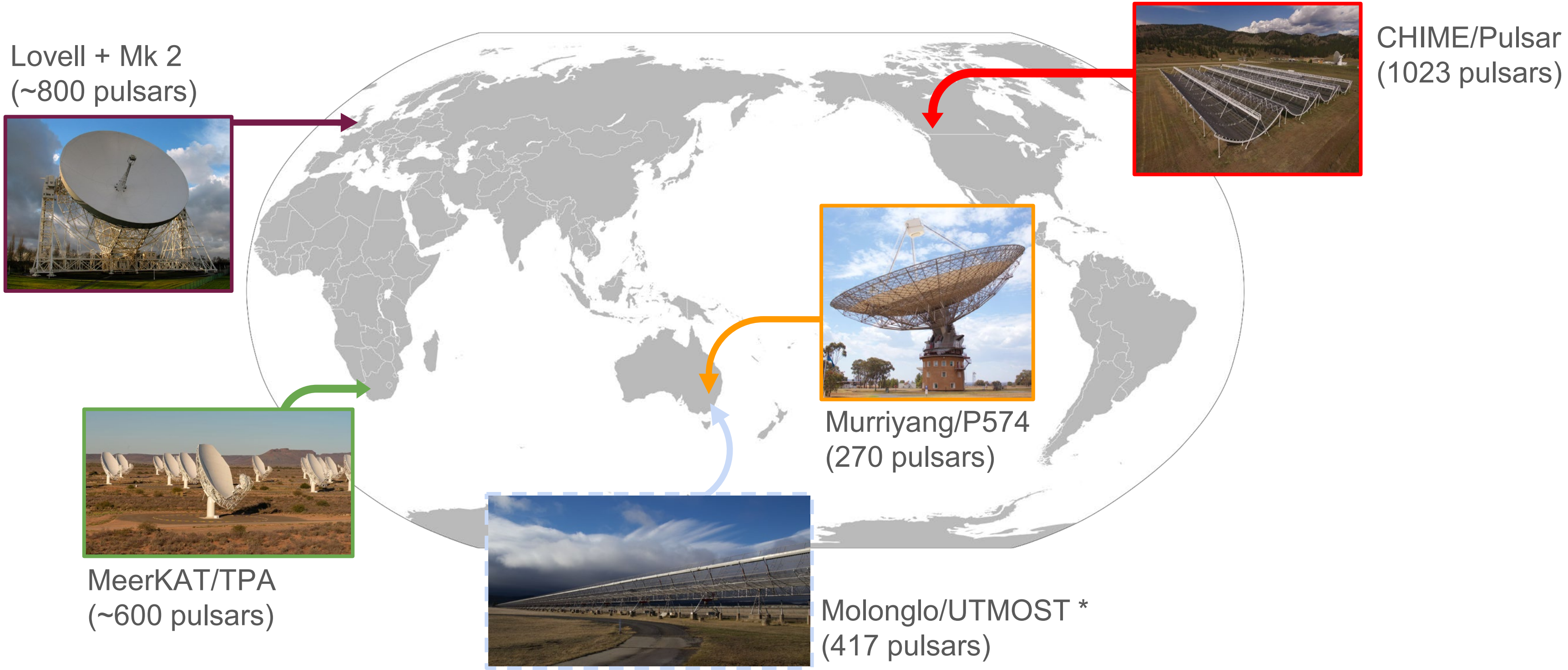


Mapping Galactic B-fields
(Oswald et al. 2023)

Search for exotic dark matter particles
(Xue et al. + PPTA 2026)



Large pulsar timing programmes around the world



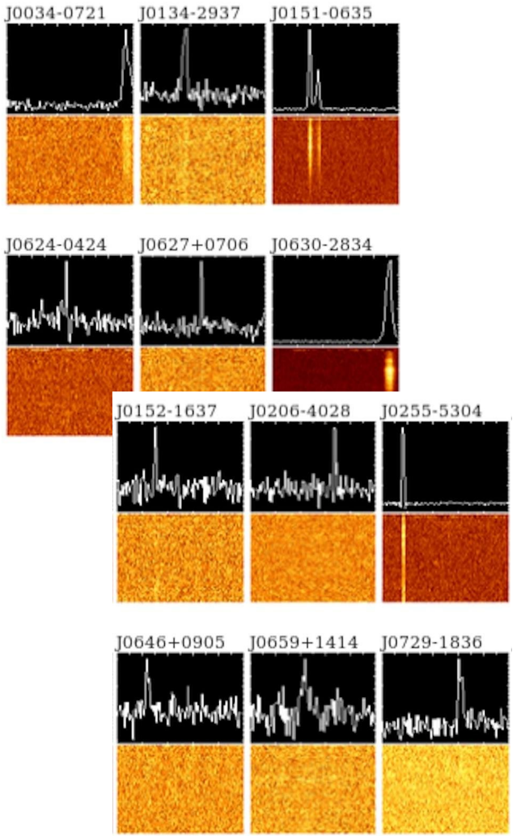
* No longer running…

Key considerations for pulsar timing programmes

- How many pulsars can be observed for a given amount of telescope time?
    - Transit telescopes limited by beam size & no. tied beams

$$S/N = \frac{S_\nu G}{T_{\rm sys}} \sqrt{n_p t_{\rm int} \Delta\nu} \sqrt{\frac{P-W}{W}}$$

- Key telescope params: Gain, $T_{\rm sys}$ & bandwidth
- Choice of observing frequency
- Timing baseline (ideally many years to decades)



Pulsars with upgraded ASKAP?

- How many slow/young pulsars could be detected with S/N > 10 ... 5 min long observatio...?

Little added benefit over existing projects on Murriyang and MeerKAT!

- 1.8 ... rriyang
- 580...
- Lim... UWB (0.7 - 4 GHz) receivers?

- Large FoV = more efficient pulsar timing with multiple tied beams
- But observing cadence is limited by telescope availability… (1 obs per month?)

Aperture arrays: All the pulsars, all the time

- Extremely wide FoV + huge number of tied beams (10’s, 100’s, 1000’s?)
- No longer limited by telescope time constraints!
- **Murriyang sensitivity = 400+ pulsars PER DAY!!!**

- 400-800 MHz = suboptimal for Galactic plane (scattering + DM variations)
- Polarisation could be tricky to solve…

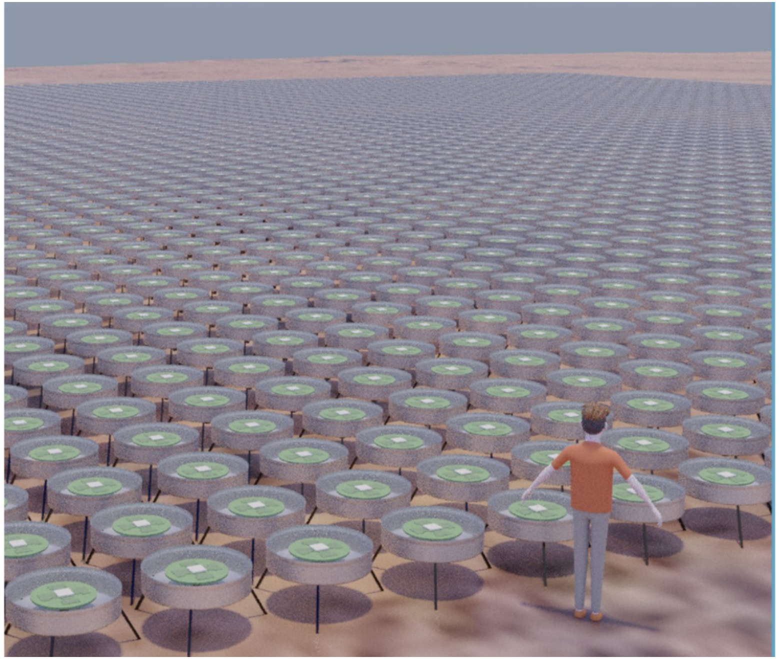


Image credit: G. Hobbs

What could we do with an aperture array?

- HUGE leaps in understanding pulsar emission via daily observations:
    - Emission state-switching, intermittency, profile variations, polarisation fluctuations and spin-down measurements.
- Profile jitter-optimised observing -- disentangling secular profile changes from stochastic pulse-to-pulse variability (*impossible with current programmes!*)
- Space-weather & *Interstellar* space-weather monitoring (e.g. ICARUS/P1189)
- Observations of pulsars inaccessible to most projects via long, multi-hour tracks

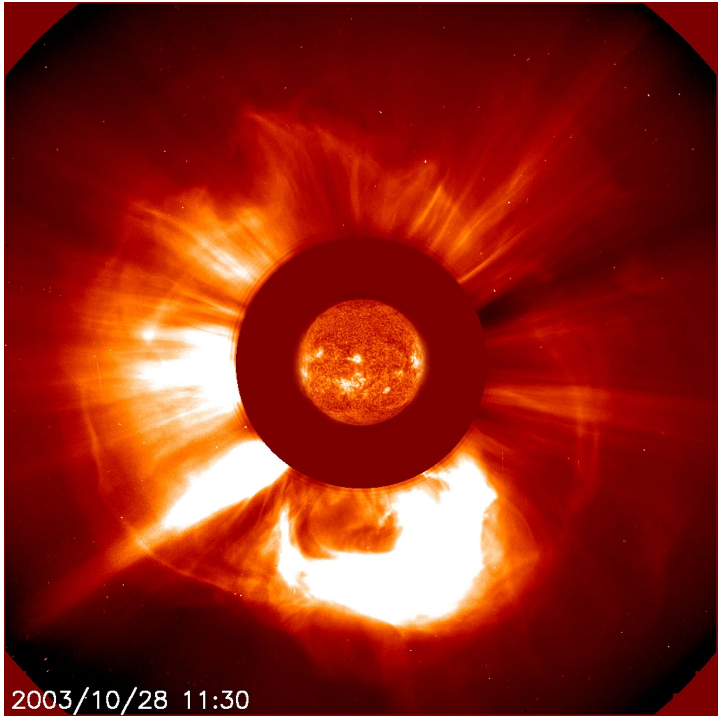
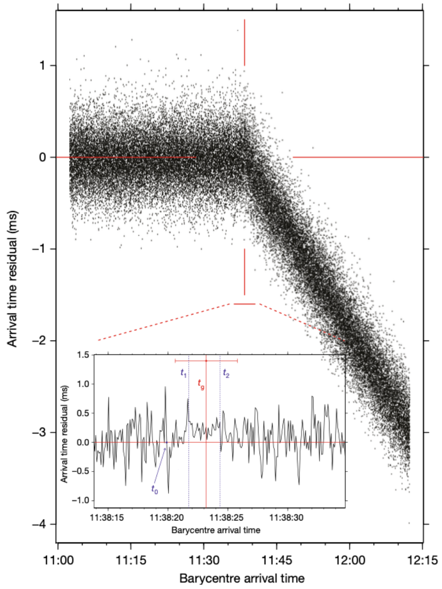
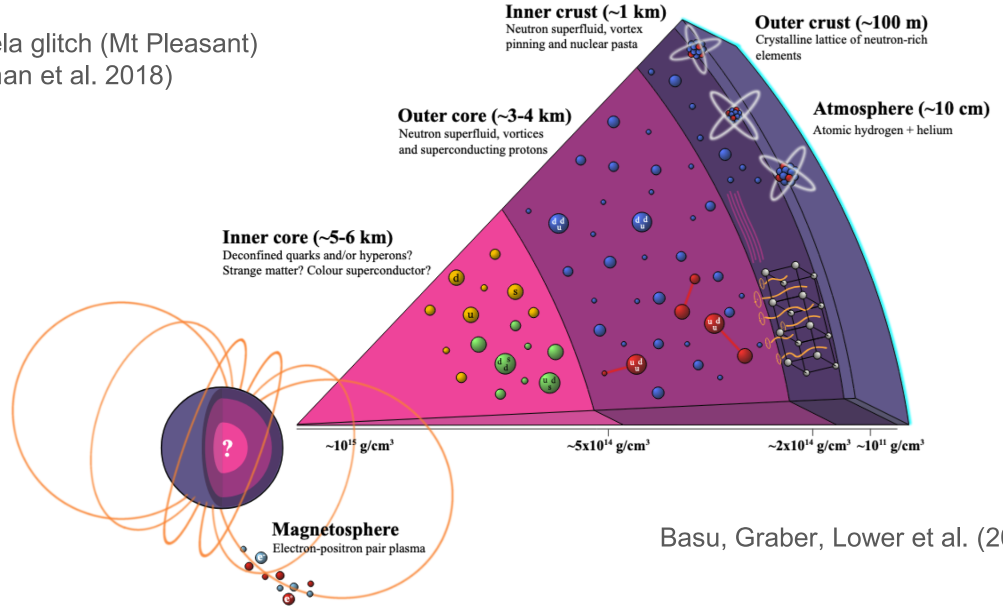


Image credit: SOHO/LASCO, SOHO/EIT (ESA & NASA)

Key science goal: Catching glitches as they happen



2016 Vela glitch (Mt Pleasant)
(Palfryman et al. 2018)



Basu, Graber, Lower et al. (2025)

- Enabled by continuous rise-to-set observations of bright glitchy pulsars
- Single-pulse data dumps triggered by semi-real-time detections

Summary

- Massive-scale timing of slow pulsars have enormous scientific potential
- Upgraded/extended ASKAP offers little benefit over existing programmes
- Aperture arrays would be an absolute game changer!
  - Electronic pointing! Many tied beams! Long per-pulsar integration times!
  - Polarisation calibration may be problematic…
- HUGE potential from daily pulsar observations
  - Emission/spin-down stability on <u>all</u> timescales, local + interstellar space-weather monitoring
  - Testing theories of nuclear matter by catching glitches as they happen
- **Instrument longevity is also an essential consideration!!**