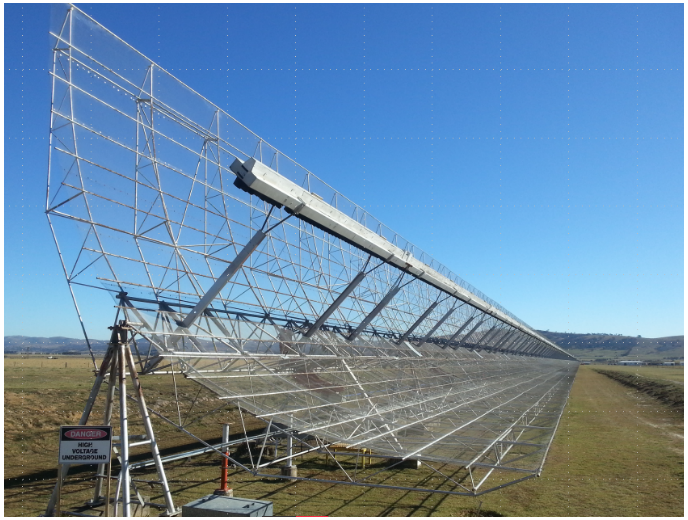
Pulsar Astronomy in Australia



Ramesh Bhat

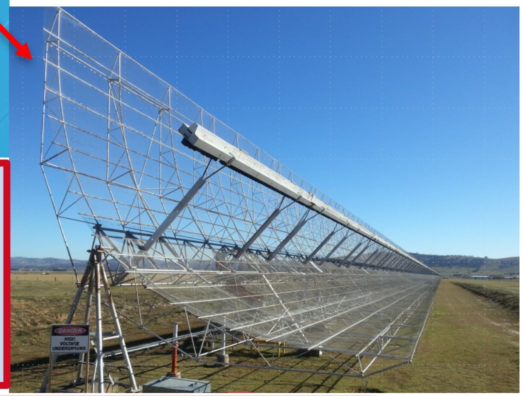
ICRAR, Curtin University

(on behalf of the Australian pulsar community)

With contributions from: George Hobbs, Sammy McSweeney, Chris Flynn, Shi Dai

The ARDRA meeting @ Lonavala, 13-15 November 2019

Pulsar capabilities in Australia



also playing a leading role in the **MeerTIME** project (Swinburne, CASS, Curtin)

Parkes – the good old "Dish"

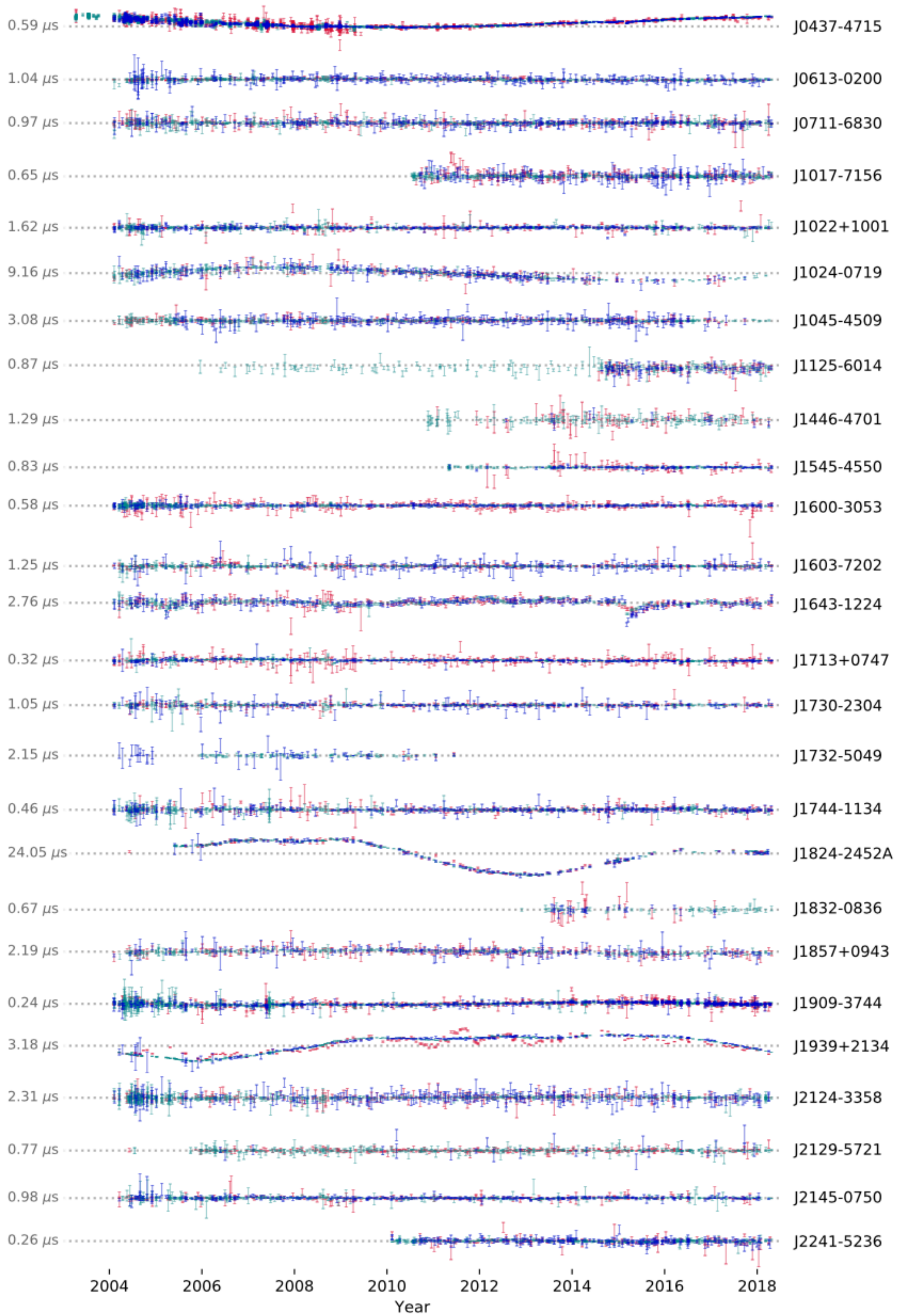
- Long-standing tradition of wide-ranging pulsar astronomy
  - Multiple large-scale search programs (e.g. Multibeam survey, the HTRU survey, and the SUPERB survey, etc.)
  - High-precision timing program > 20 years (e.g. the PPTA project)
  - Binary pulsars, Globular clusters, emission physics, ISM effects

PPTA DR2
(2^{nd} data release)

Kerr et al. (2019), Submitted to PASA

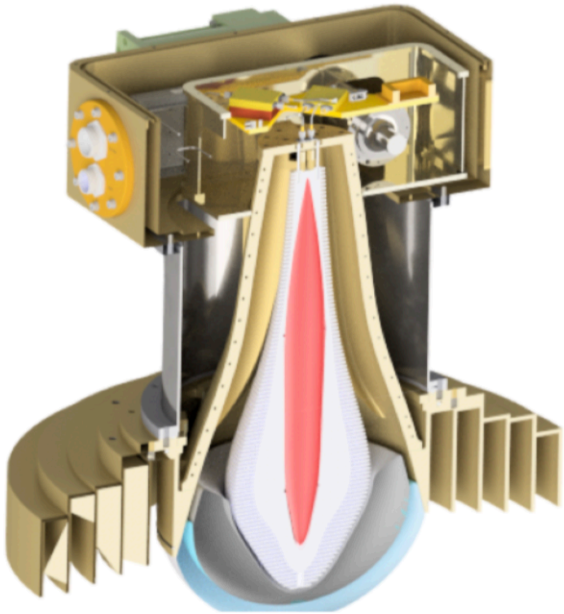
- 14 years of public PPTA data
- 26 MSPs
- 3-weekly cadence
- 3 observing bands: 10cm, 20cm, 50cm (from ~700 MHz to ~3.5 GHz)
- 21,000 hours of recorded data!
- 24,200 TOAs
- 22 MSPs with < 1 us

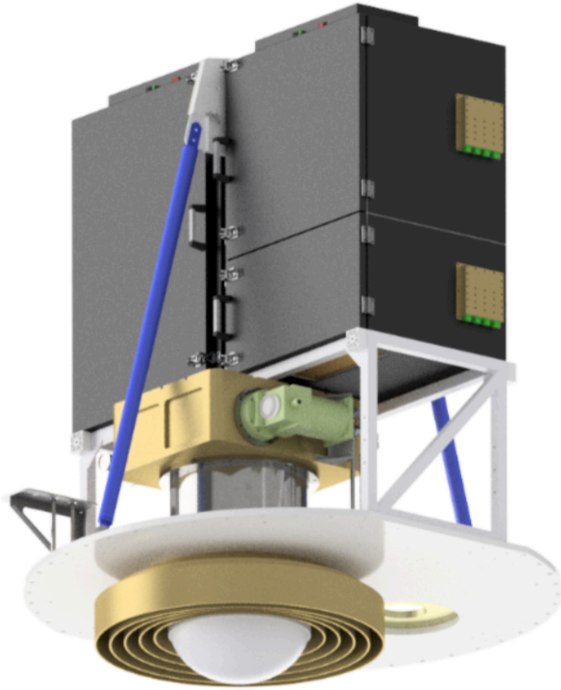
An excellent data set for a large number of projects....



An ultra-wide bandwidth (704 to 4032 MHz) receiver for the Parkes radio telescope

Hobbs et al. (2019), Submitted to PASA
arXiv:1911.00656





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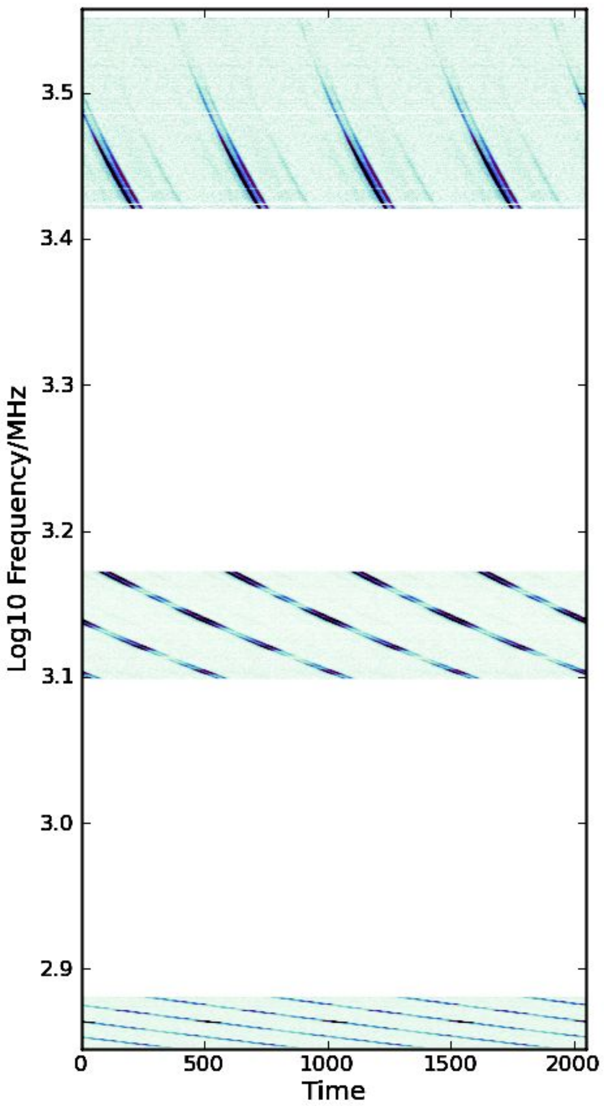
Digitisers, FPGA processer, GPUs (*medusa*), data staging server (*euryale*), new formats, new telescope control, new calibration, new monitoring, …

Pulsar observations before UWL

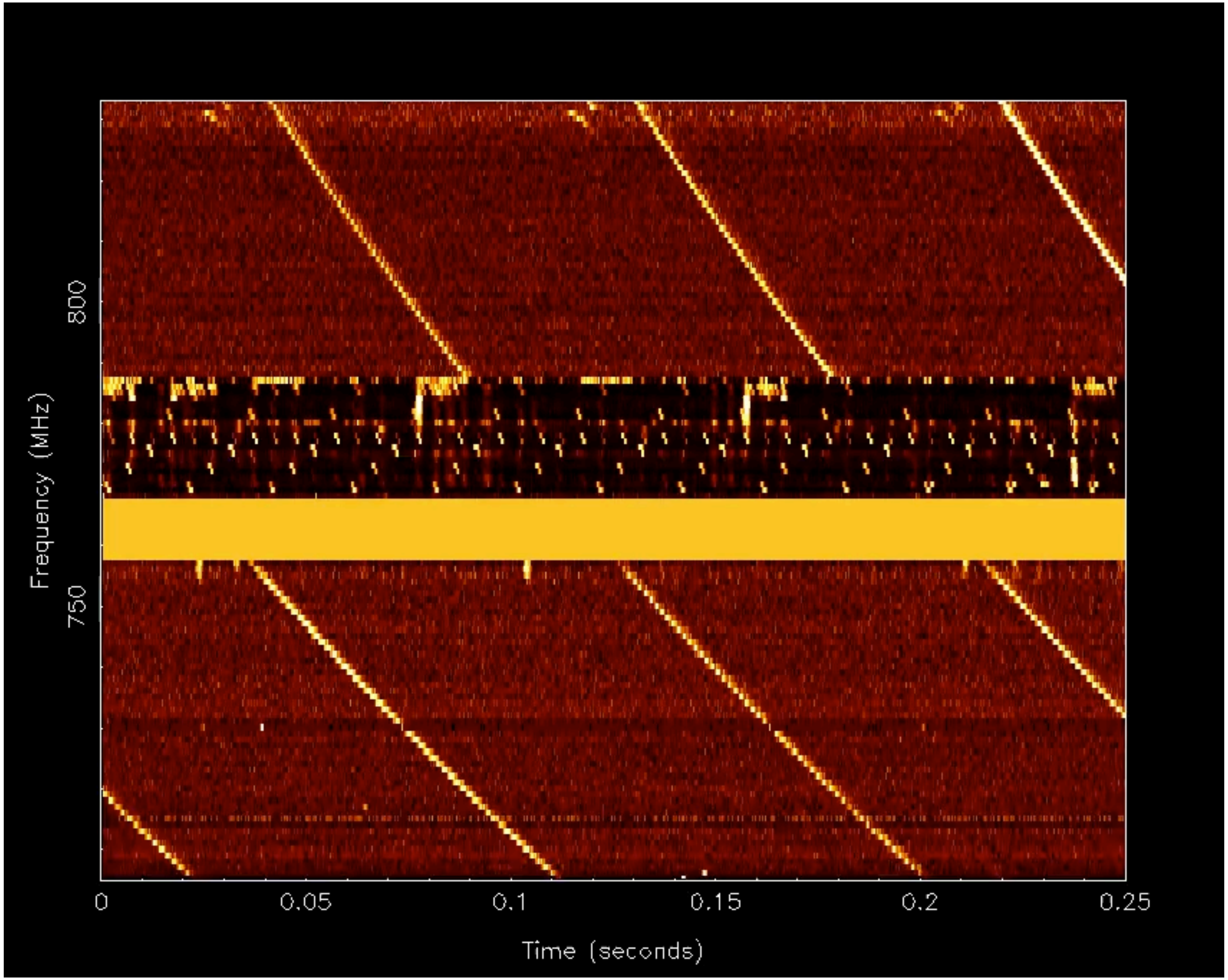


10/40cm Receiver — Bandwidth: 1 GHz, 3.1 GHz

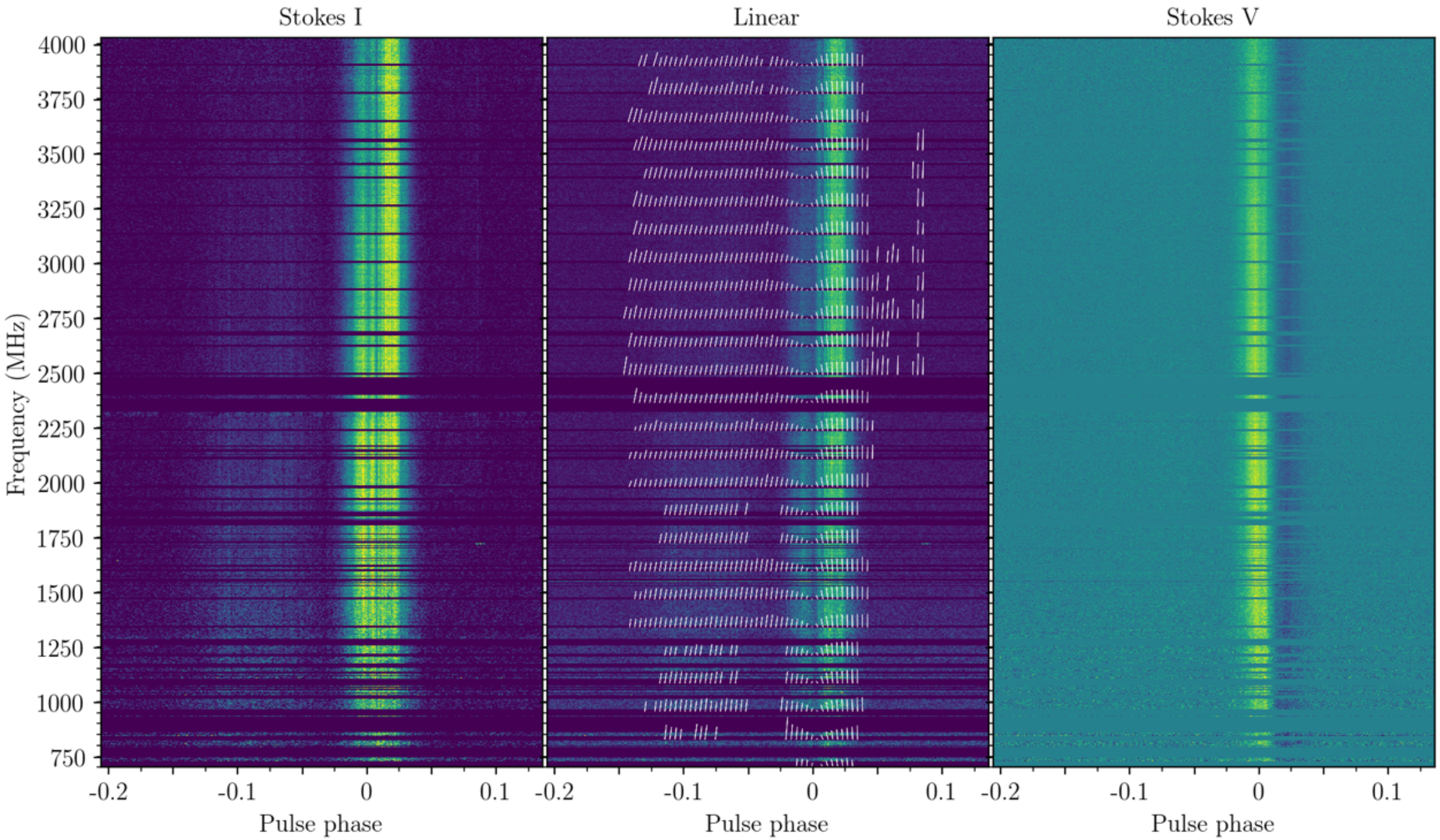
Multibeam Receiver — Bandwidth: 256 MHz, 1369 MHz

10/40cm Receiver — Bandwidth: 64 MHz, 732 MHz

Pulsar observations with UWL



Wide-band observations of the magnetar



- **XTE 1810-197** – the 1st radio magnetar
- Revival after a decade long quiescence
- 2018 December outburst
- Polarisation, single pulses, flux densities

The first UWL paper

Dai et al. (2019)

Pulsars in the GC 47 Tucanae

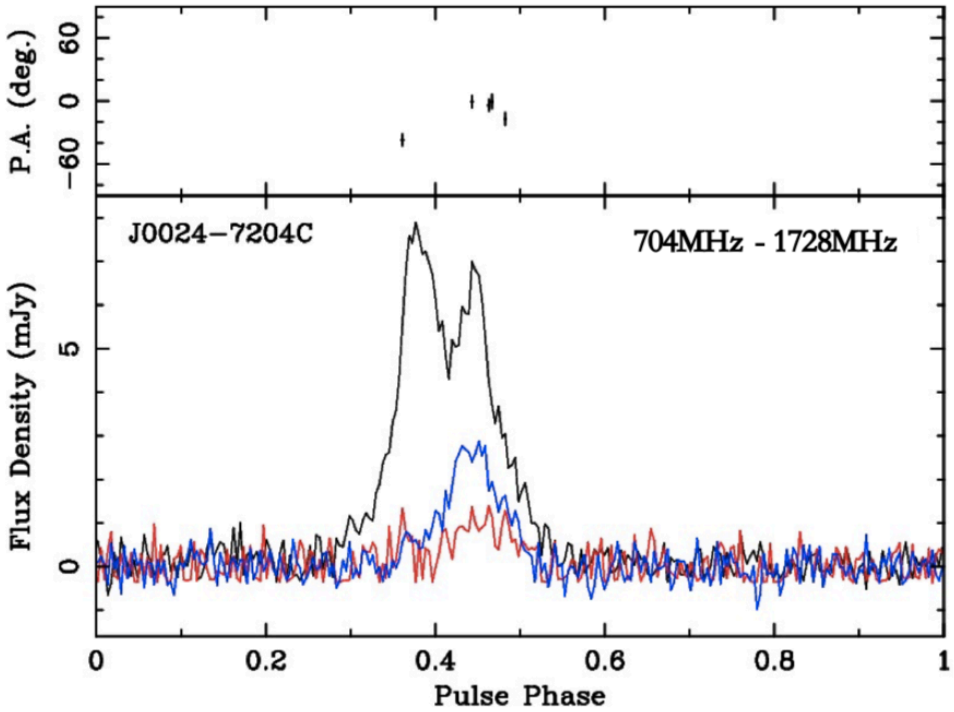


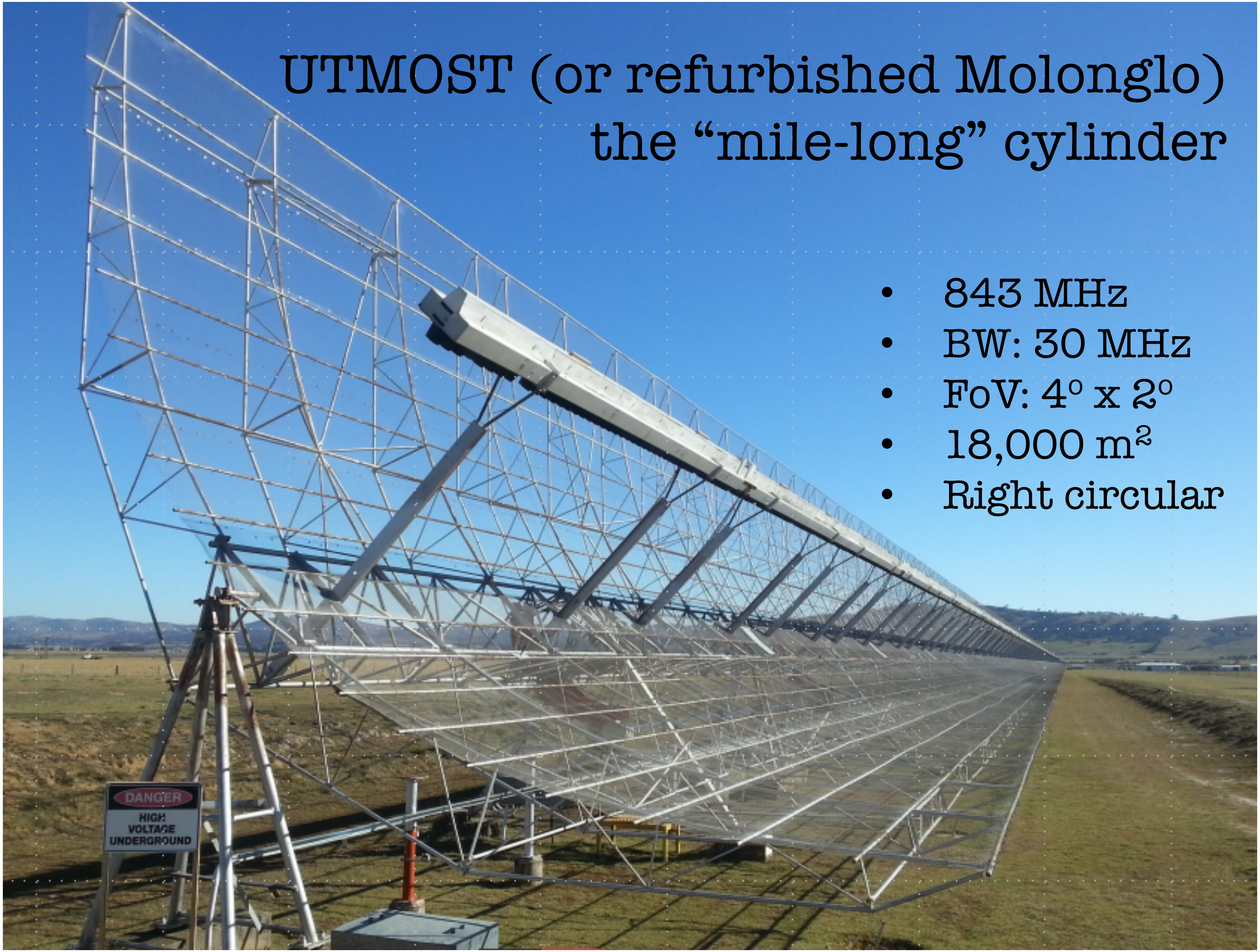
Figure 1: Polarization profile for pulsar 47 Tuc C obtained with the Parkes UWL observation. The thick solid line is the mean flux profile, the thin solid line is the linear polarization profile and the dashed line is the circle polarization profile. Black dots, in the top panel, is the linear polarization angle.

Zhang et al. (2019), Submitted to ApJ, arXiv: 1910.11990

Lei Zhang
PhD student (NAOC/CASS)

- Flux densities
- Polarization profiles
- Faraday rotation
- Precise DMs
- exploring optimal bands for searches

UTMOST (or refurbished Molonglo) the "mile-long" cylinder

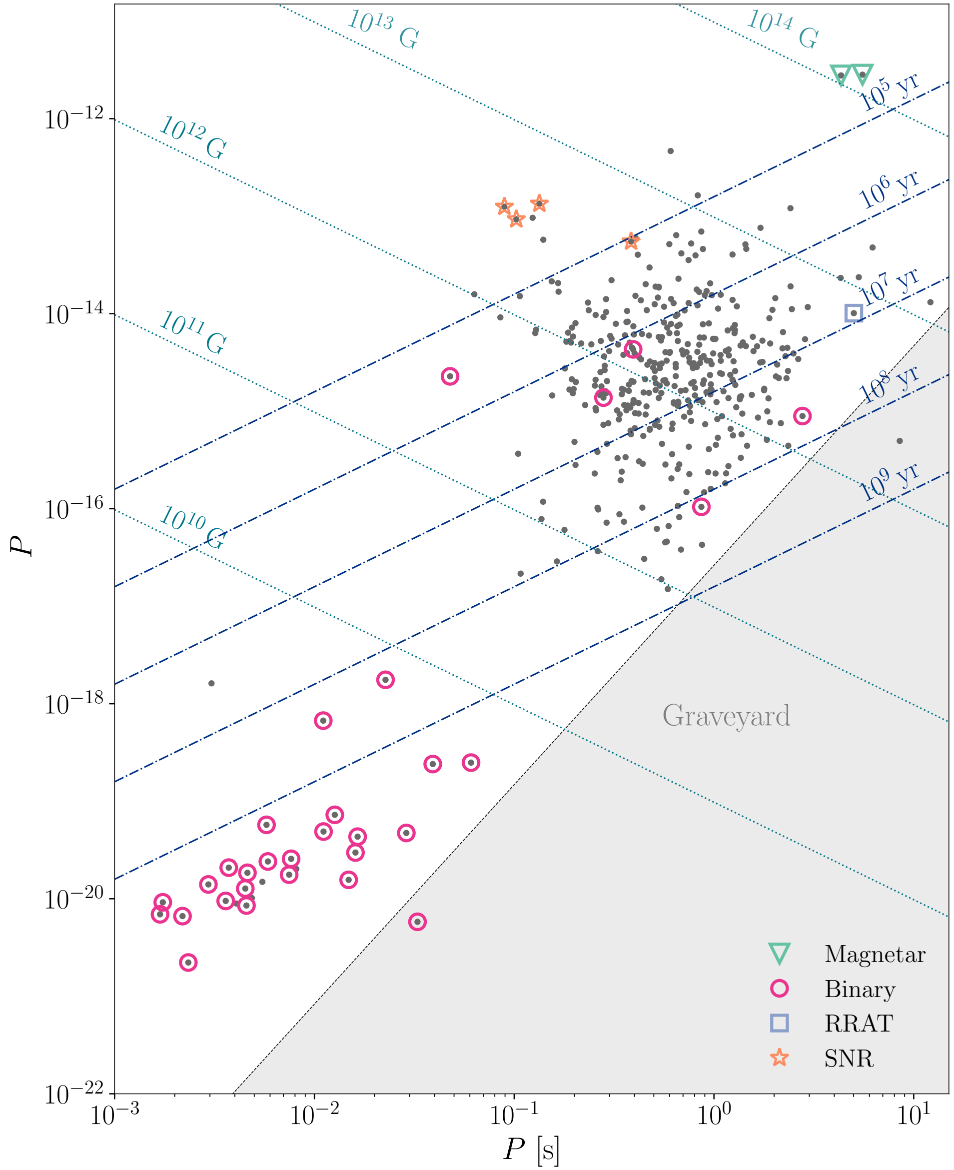


- 843 MHz
- BW: 30 MHz
- FoV: 4^{o} x 2^{o}
- 18,000 m^2
- Right circular

Pulsar monitoring @ UTMOST

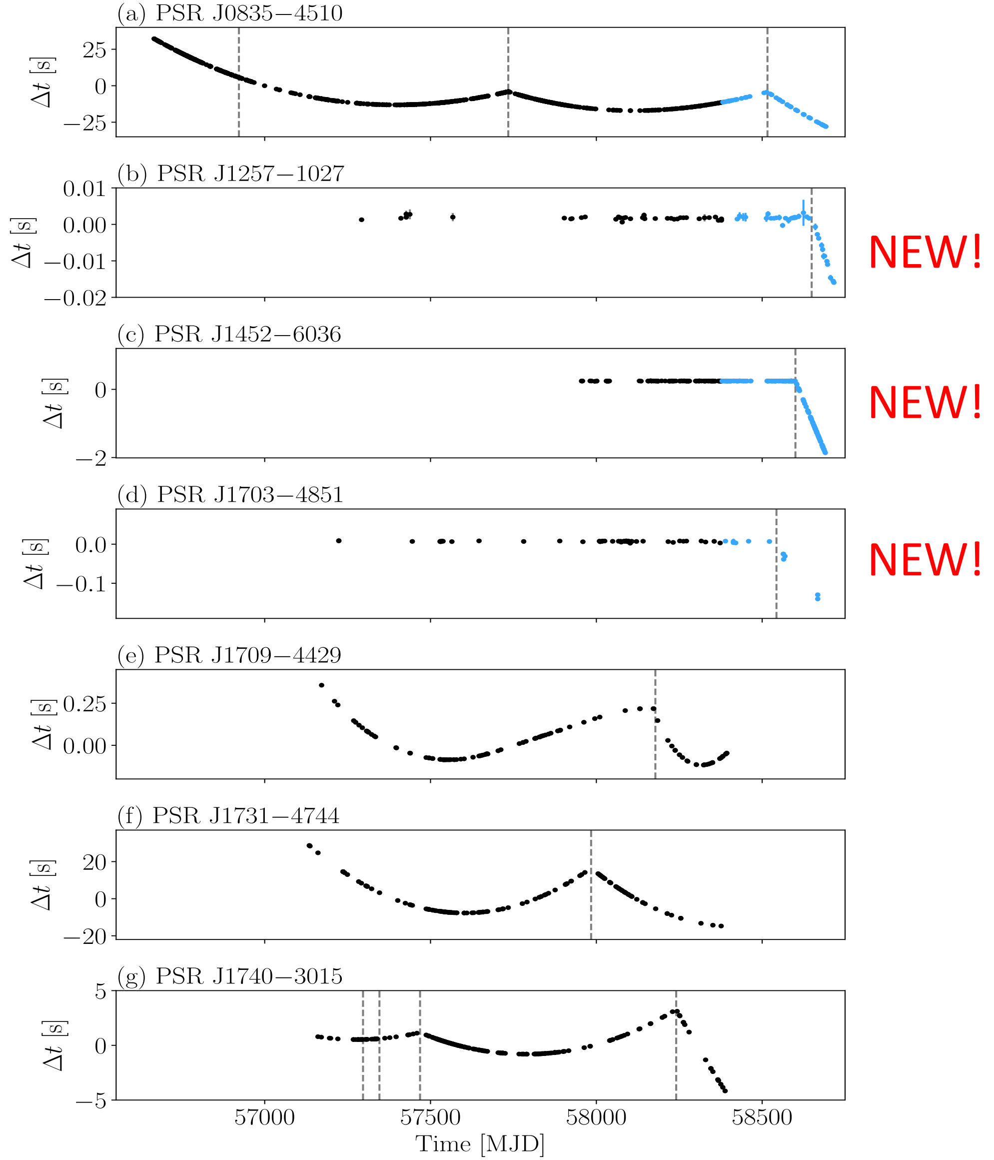
- Long-term, high cadence timing/monitoring of 100s of pulsars.
- Currently monitoring 411 pulsars.
  - 380 slow/non-recycled pulsars.
  - 29 millisecond pulsars.
  - 2 radio loud magnetars (PSR J1622-4950 & XTE J1810-197).
- Can observe ~300 pulsars every 10 days.
- Overview of the system & initial results: Jankowski et al. (2019).
- Studies of pulsar timing noise across the population: Lower et al. (submitted).

Marcus Lower
PhD student
(Swinburne)



Glitches seen by UTMOST

- 12 glitches seen to date, 9 previously reported
- 3 new glitches (Lower et al. submitted)
  - J1257-1027: 1st glitch detection in this pulsar
  - J1452-6036: 2nd and the largest
  - J1703-4851: 1st glitch in this pulsar
- Real-time glitch detection/search pipeline in the works
- ATEL announcements for prompt reporting
- Model selection (inc. accounting for red noise) used to verify the existence of each glitch

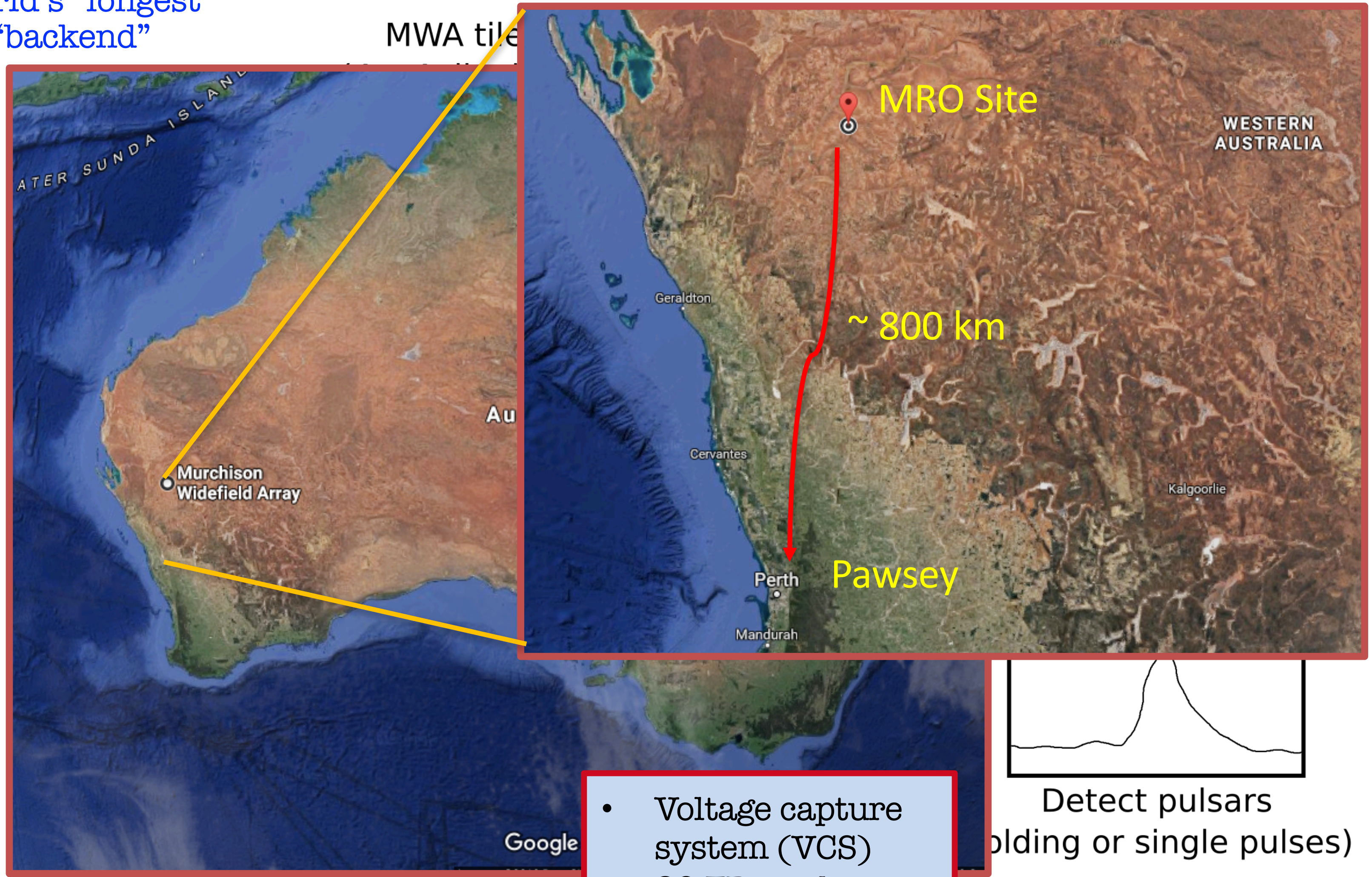


The *young* (next-generation) MWA

- 256 tiles (Phase 2)
- Frequency range: 70 – 300 MHz
- 24 x 1.28 MHz channels (max BW: 30.72 MHz)
- Correlation / voltage recording of max 128 tiles

The MWA “can do” pulsars, but…

The world’s “longest” pulsar “backend”

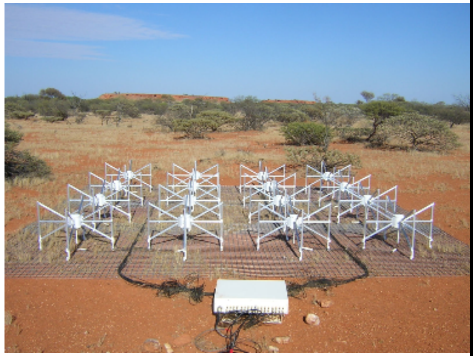


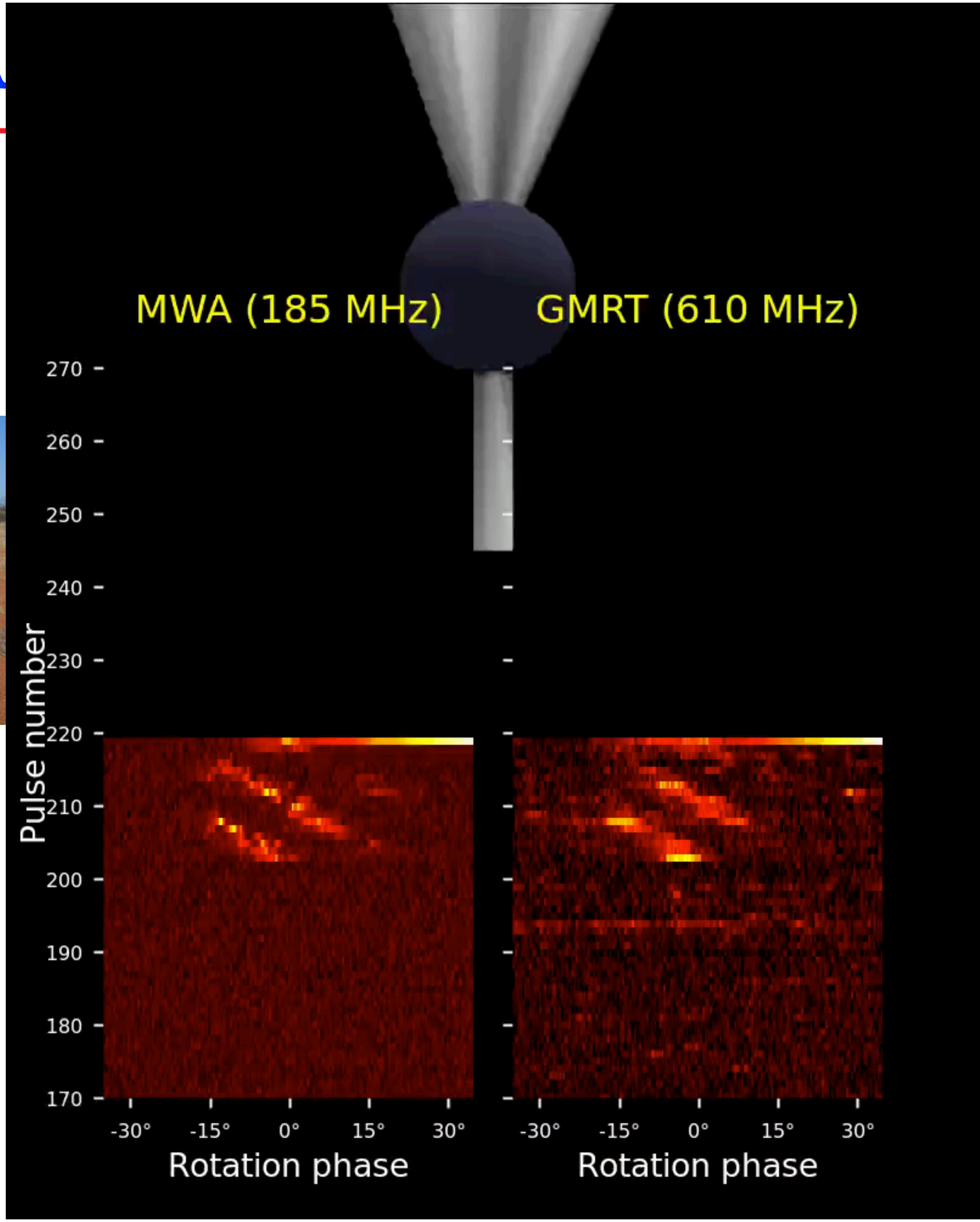
- Voltage capture system (VCS)
- 28 TB per hour
- 12 PB to date!!

Notwithstanding the limitations of VCS and the data/labour-intensive nature of doing pulsar astronomy, *15+ publications + 2 PhD completions* to date.....

MWA GMRT

128 ×



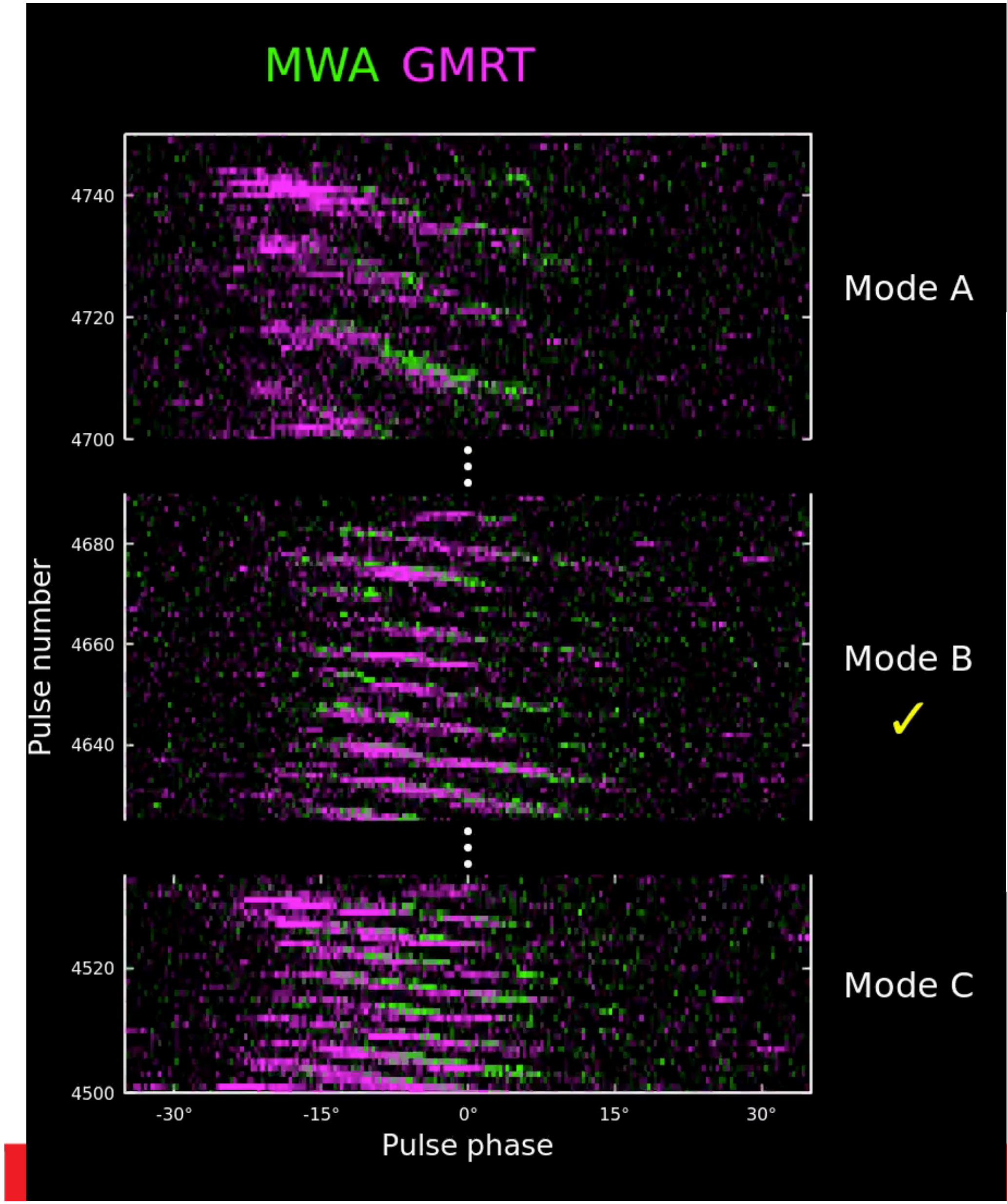


13 ×

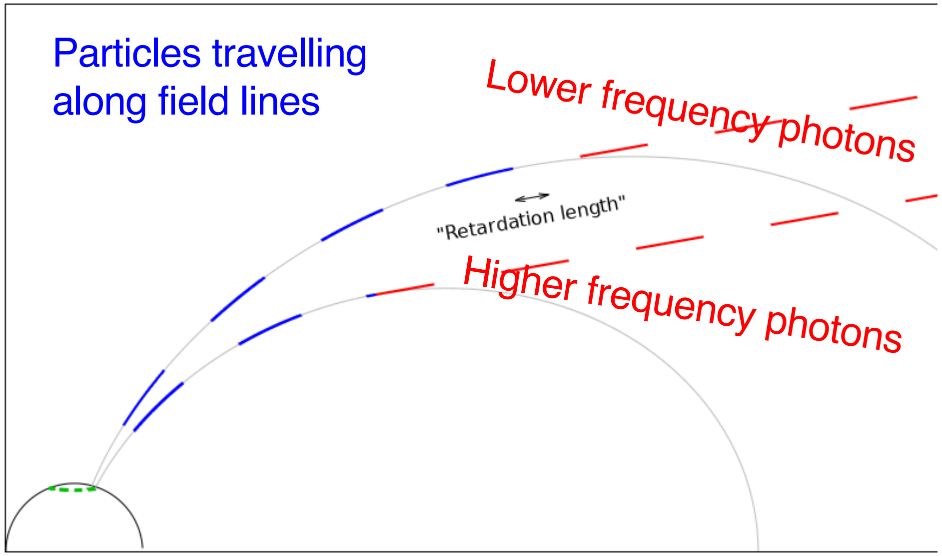
PSR B0031-07
simultaneous observations
MWA @185 MHz
GMRT @610 MHz

Sammy McSweeney (Curtin)

Pulsar emission heights



Different times of arrival of subpulses at different frequencies (185 and 610 MHz) contain information about "relative emission heights"



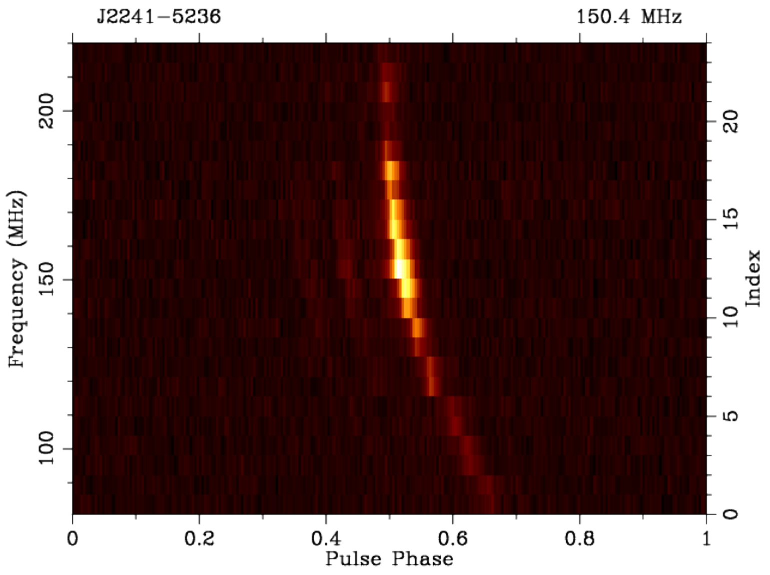
emission height differences ~ a few percent of the light cylinder radius

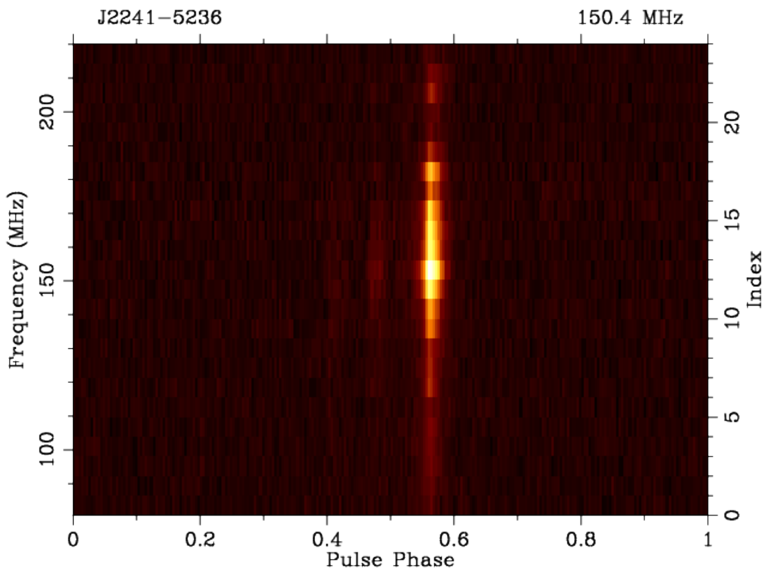
$\lesssim 2000$ km (Mode A); $\lesssim 1000$ km (Modes B & C)

McSweeney et al. (2019)

Breaking the 100-μs barrier of the VCS

MSP J2241-5236, P = 2.18 ms, DM = 11.41 pc cm^{-3}





Dilpreet Kaur
PhD student
(Curtin/CASS)

Kaur et al. (2019)

- Distributed sub-band setup ("picket fence" mode) for simultaneous coverage of the ~70 to 250 MHz band
- Catalog DM = 11.411085 with uncertainties of 3×10^{-05} pc cm^{-3}
- DM sweep of ~ 0.4 ms; Change (excess) DM = 0.000667 pc cm^{-3}
- Measured DM = 11.411505 ± (2-7) × 10^{-06} pc cm^{-3}

MWA + GMRT (Band 3 + Band 4) + Parkes (UWL) observations are underway

The Australian SKA Pathfinder

Discovery of MSP J1431-6328

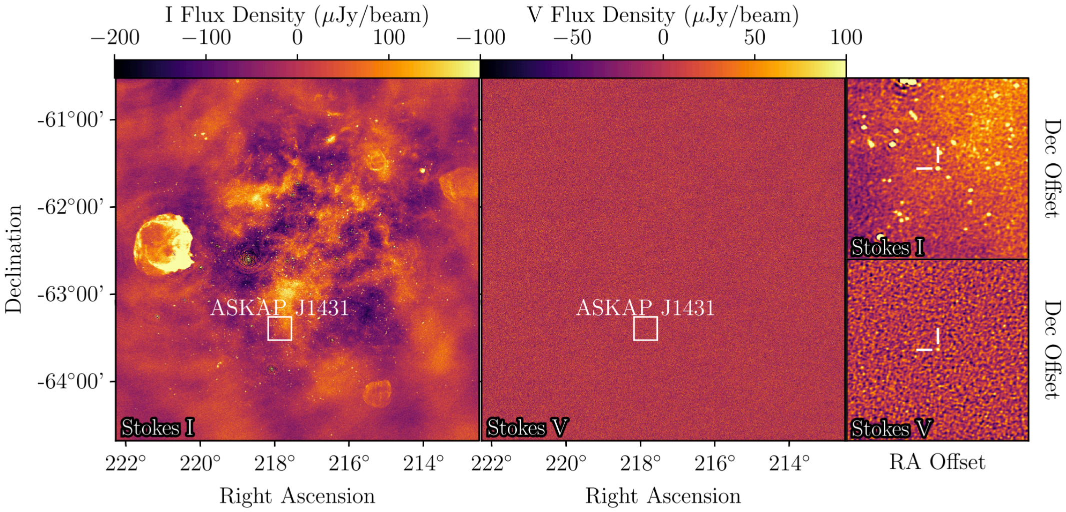
Deep radio continuum surveys can complement SKA pulsar surveys

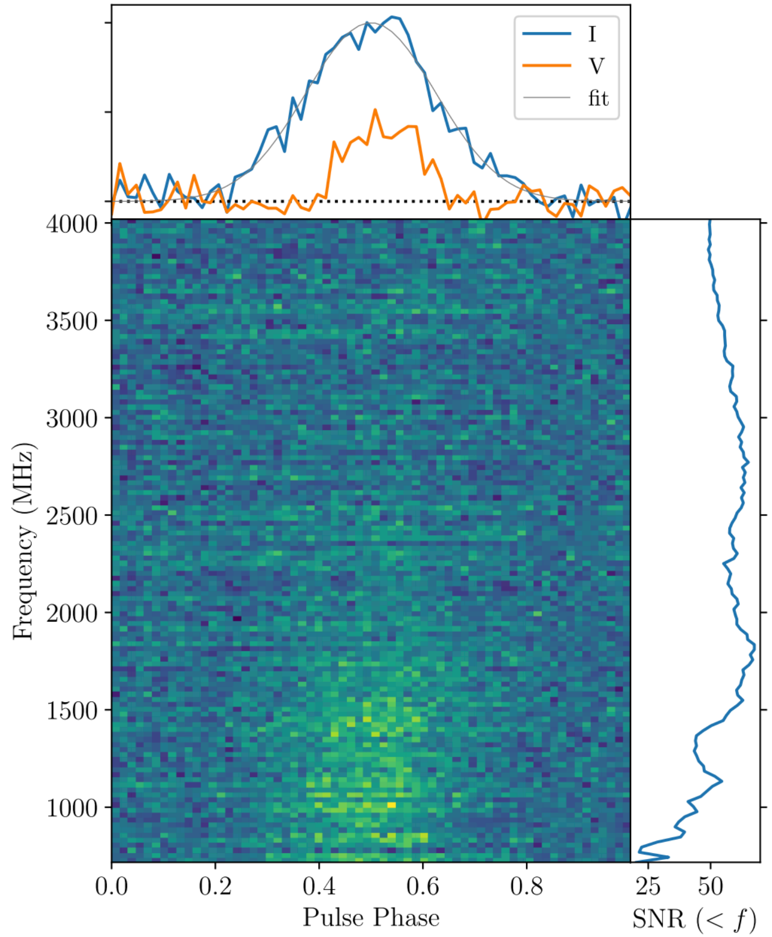
- Enable efficient targeted search
- Identify the most extreme pulsar systems

Recent updates with ASKAP:

- Polarization: Serendipitous Discovery of PSR J1431-6328 (Kaplan et al. 2019)
- Rapid ASKAP Continuum Survey: shallow all-sky survey
- Using interstellar scintillation to identify pulsars with deep continuum surveys (Dai et al. 2016, 2017)

P = 2.77 ms
DM = 228 pc cm^{-3}





Kaplan et al. 2019

Summary

- Longstanding tradition in an amazingly wide range of radio pulsar astronomy, both in science and instrumentation
- Experienced with the use of large dishes, long cylinders, aperture arrays and dish-based interferometers
- Close-knit and actively collaborating groups based in Sydney (CASS), Melbourne (Swinburne), Perth (Curtin) and elsewhere in Australia
- Parkes is cutting-edge, UTMOST is monitoring, the MWA is gearing up, ASKAP's potential
- Excellent synergy (and complementarity) with radio facilities in India (in sky coverage, frequency range)