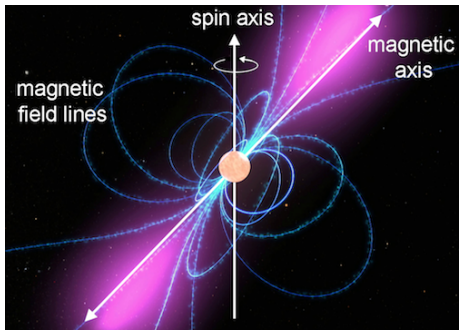
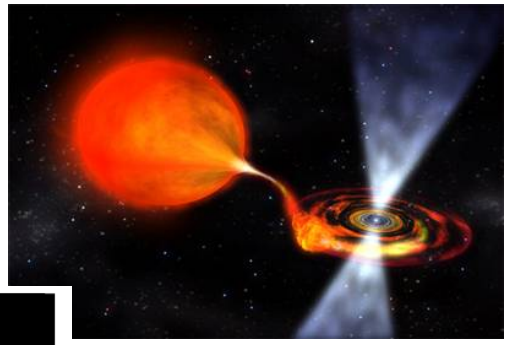
MWA PULSAR SCIENCE AND SURVEY PLANS

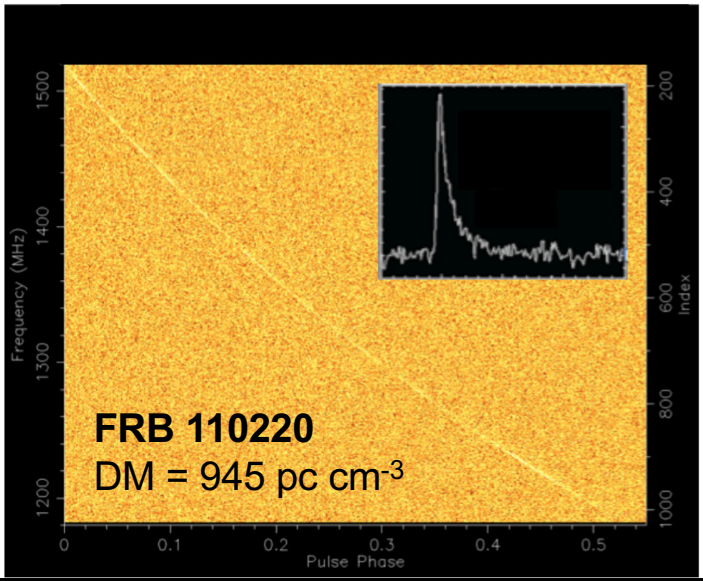
Ramesh Bhat

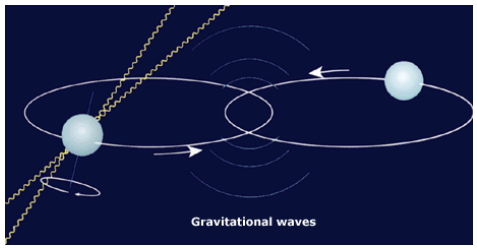
Science at Low Frequencies IV, Sydney, 13 – 15 December 2017

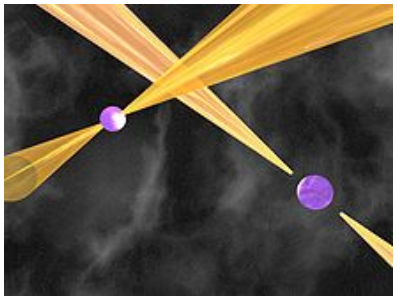
Why more pulsars?



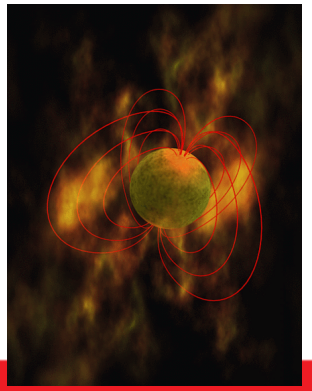








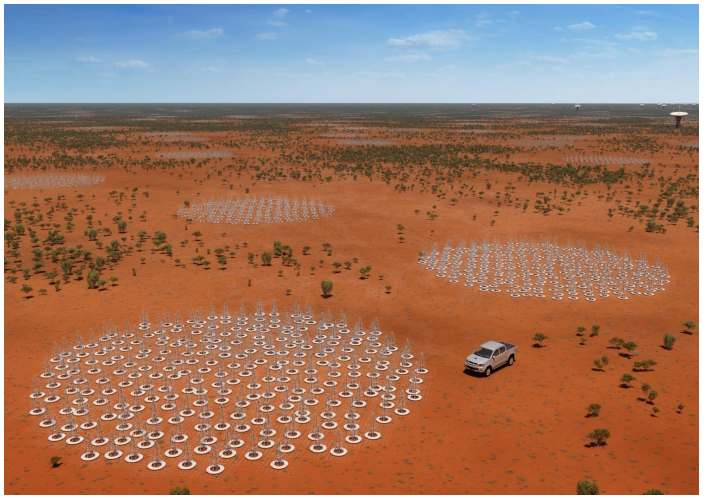
e.g. the Parkes HTRU Survey
Thornton et al. (2013)
Champion et al. (2016)



Why with the MWA?

- MWA is the Precursor for SKA-Low
- Pulsars a key science driver for SKA
  - Cosmic census
    Keane et al. (2015)
  - Strong-field gravity
    Shao et al. (2015)
  - nanoHertz Gravitational Waves
    Janssen et al. (2015)

- SKA-Low has the potential to be a key pulsar finding machine
- MWA is moving rapidly in the path to SKA-Low
- MWA strategically best-positioned for demonstrating SKA-Low key science



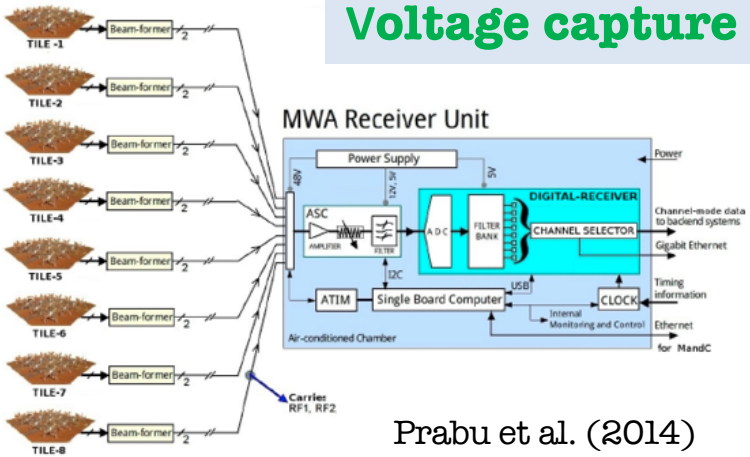
Can the MWA do it?

In the Next ~10 mins

- Pulsar observing with the MWA
- Current science capabilities
- Potential for pulsar surveys
- Preparatory work + pilot search

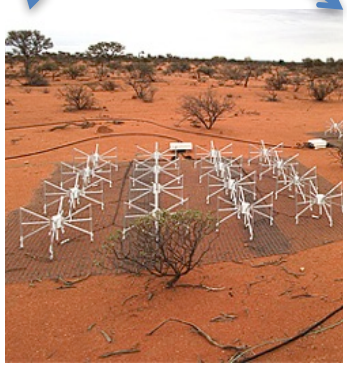
MWA for Pulsar Observations

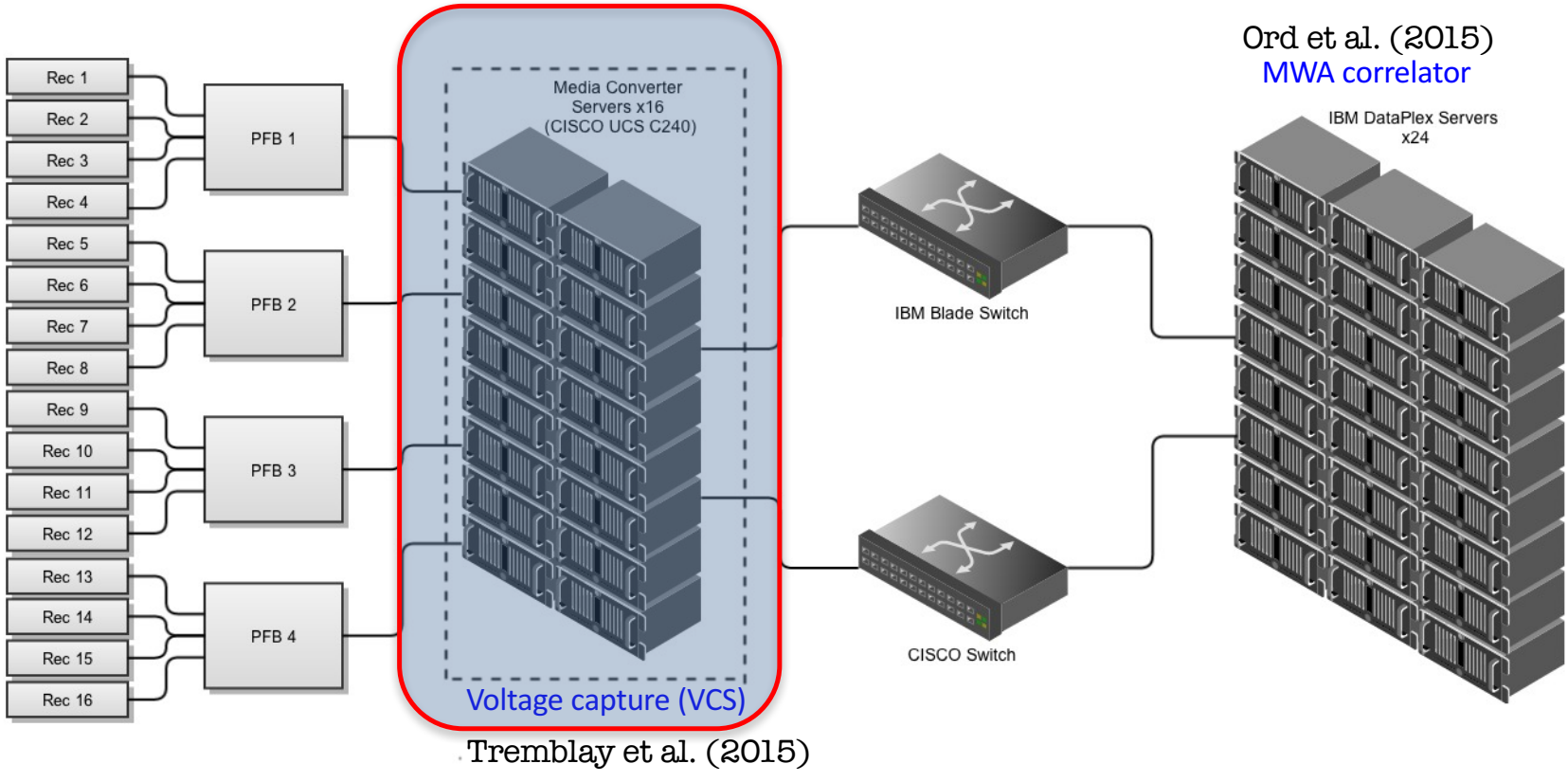
Voltage capture from ALL 128 tiles + post-processing at Pawsey



Prabu et al. (2014)

- VCS mode: a **functionality to capture raw voltages** streaming into the correlator, from ALL 128 tiles, at 100-us, 10-kHz resolutions, over a BW = 30.72 MHz
- Aggregate data rate = 24 x 242 MBps (or 7.8 GBps) = 28 TB per hour!

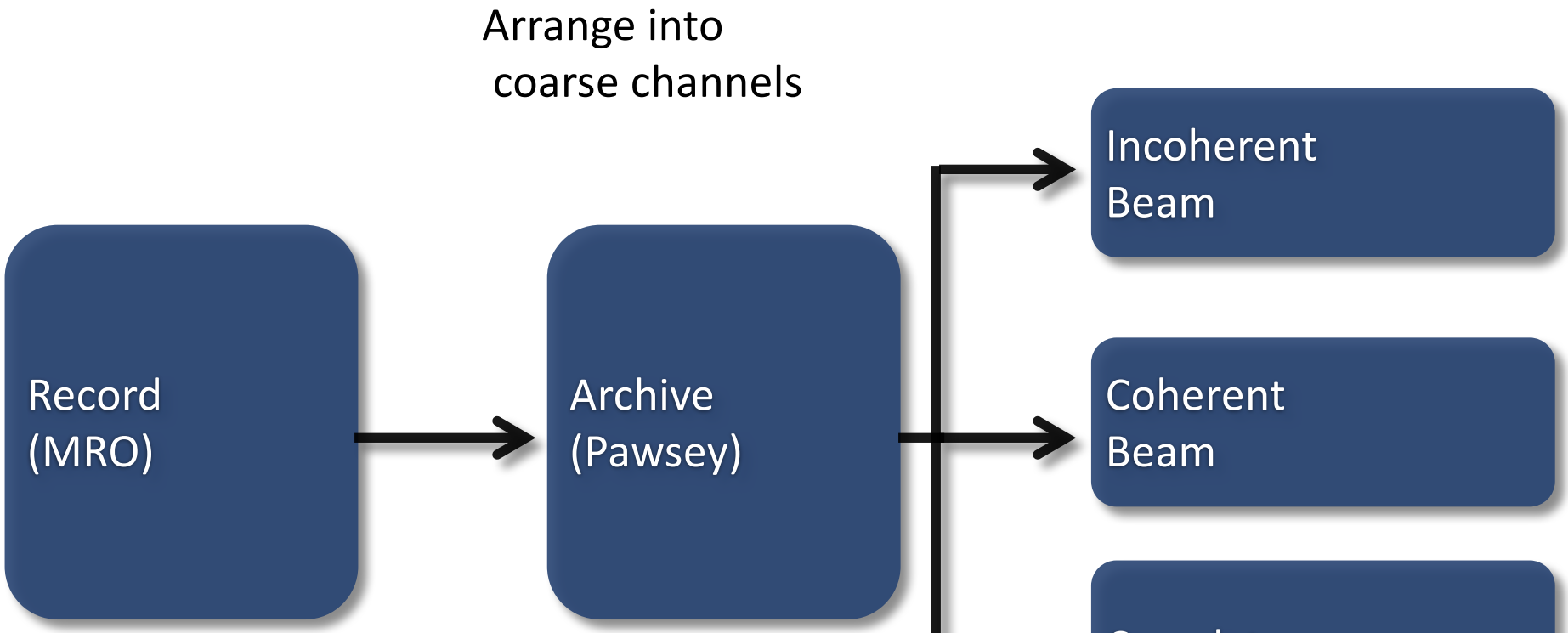




Ord et al. (2015)
MWA correlator

Tremblay et al. (2015)

VCS Data Processing

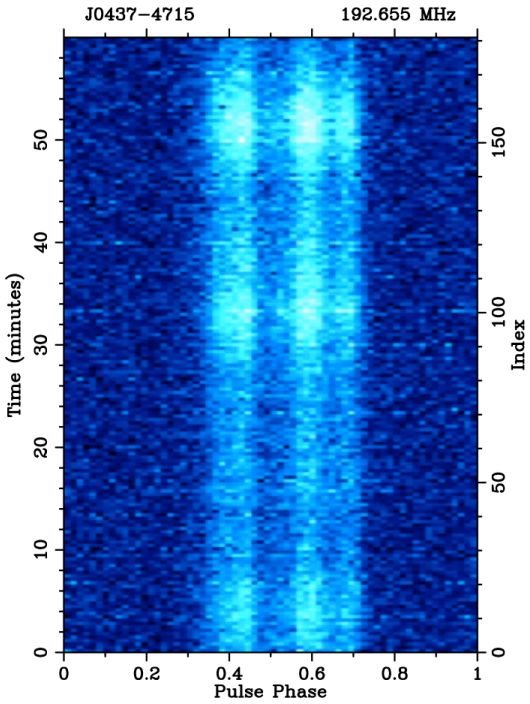


Science:

Pulsars, Fast Transients, FRBs, spectral lines, SETI, passive radar. etc.

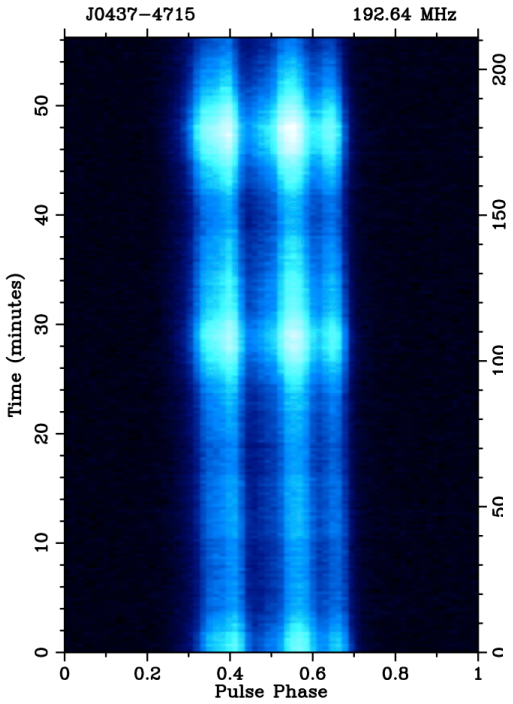
Coherent beam → 10 x improved sensitivity

PSR J0437-4715 @ MWA 200 MHz



Incoherent addition

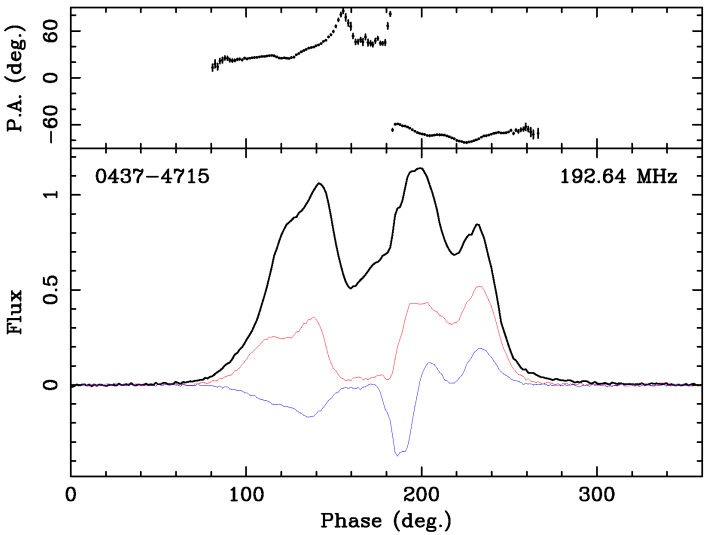
Bhat et al. (2016)



Coherent addition

And enables polarimetry

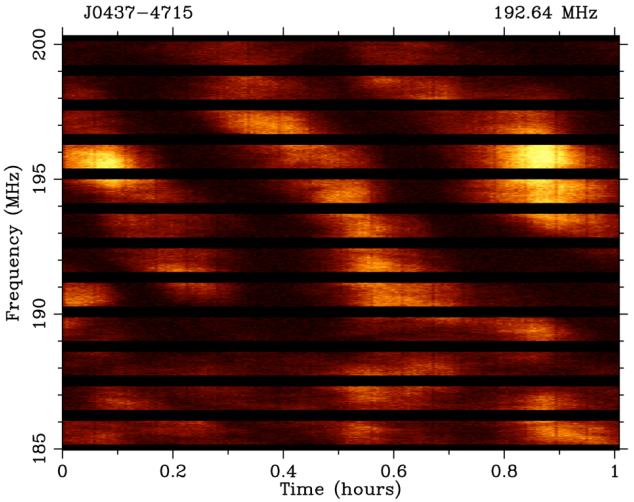
Ord et al. (2017) in prep.



Polarimetric calibration and stability checks
MWA vs GLOW/LOFAR verification underway
(see Mengyao's talk)

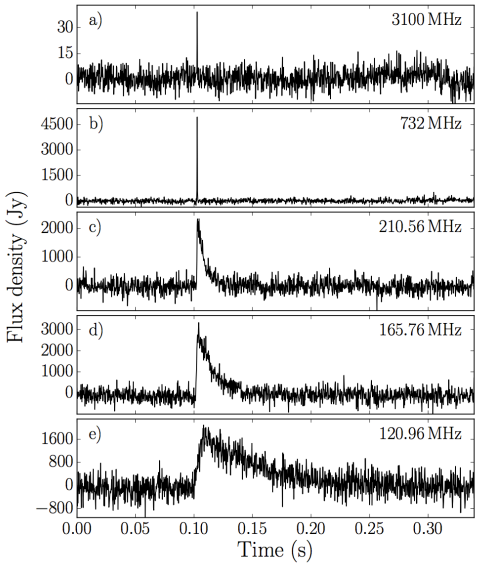
MWA Pulsar science ramping up

Scintillation bands PSR J0437-4715



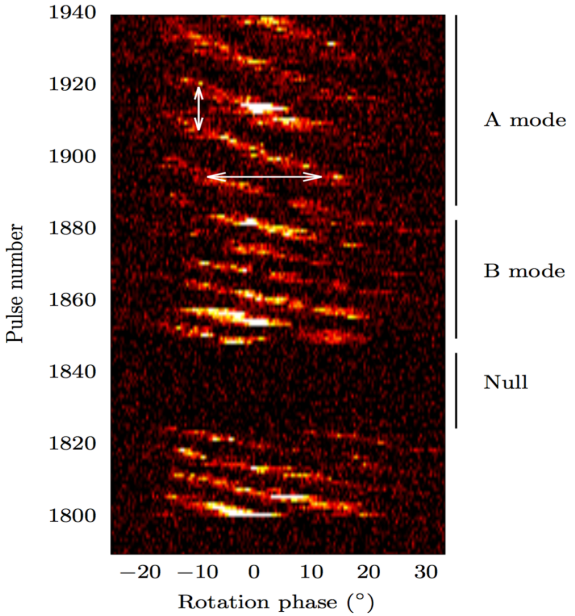
Bhat et al. (2016), ApJ, **818**, 86

Giant pulses from the Crab



Meyers et al. (2017), ApJ, **851**, 1

Drifting of sub-pulses J0034-0721



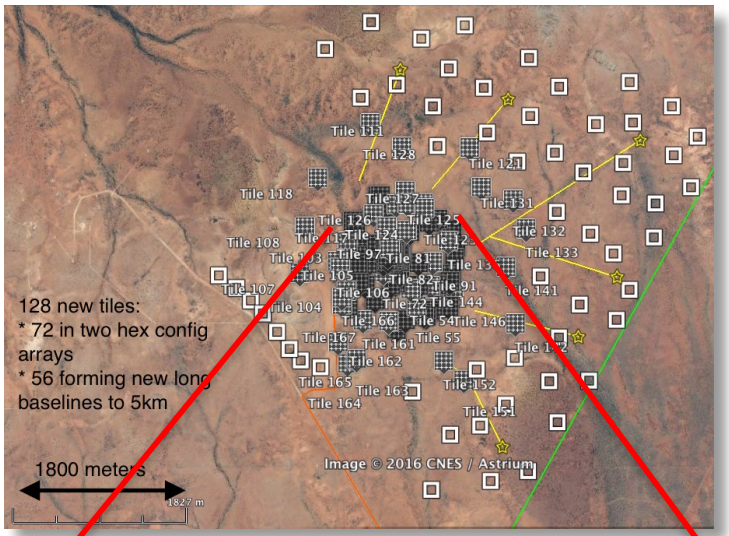
McSweeney et al. (2017), ApJ, **836**, 224

See posters:

Bradley Meyers, Sammy McSweeney

Phase 2 MWA for Pulsar Survey

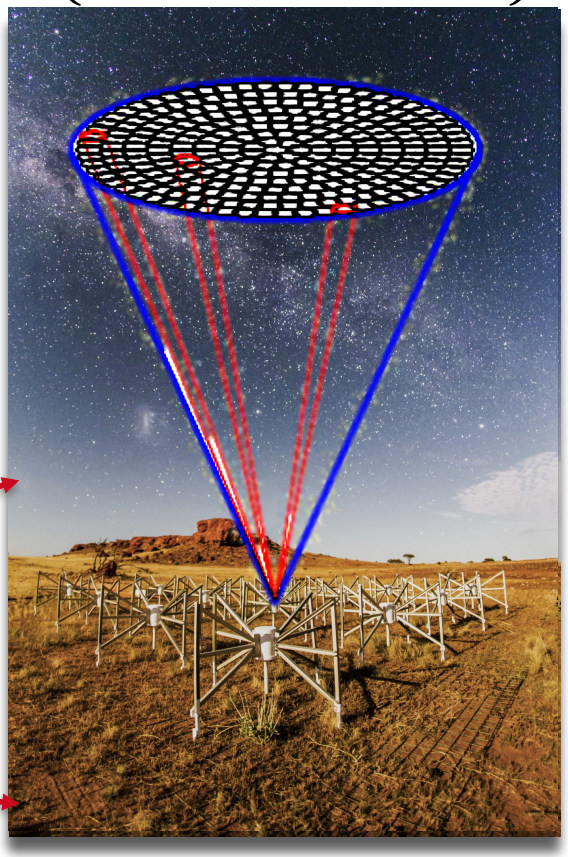
Phase 2: periodically reconfigurable between a *compact* array and *long-baseline* array

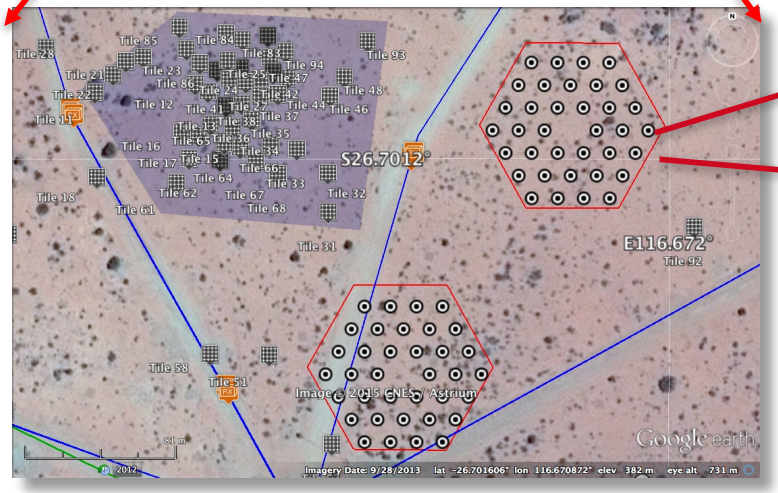


Phase 2 compact – the "EOR" array

- *Tied-array* beam size ~ 20 arcminutes
- Beam-forming cost (for the full FoV) is reduced by a factor ~100
- Large-area (or full-FoV) high-sensitivity pulsar searches more tractable

(see Randall's talk)





also a " *Pulsar-friendly* " array!

Each tile sees ~ 600 deg^2 of sky (and we record in the VCS mode)

Benefits of Phase 2 + VCS

- Rapid localisation via imaging or gridding, or long baseline Phase 2
- Accelerated convergence to the timing solutions
- Exploration of alternate (*image-based*) techniques for candidate targets (see talks by Lenc, Huib and J-P)

Developments in the post-processing chain

MWA pulsar (VCS) data involves a fairly elaborate post-processing chain

Sammy McSweeney
(PhD student)

The post-processing pipeline: Ord et al. (2017) in prep.

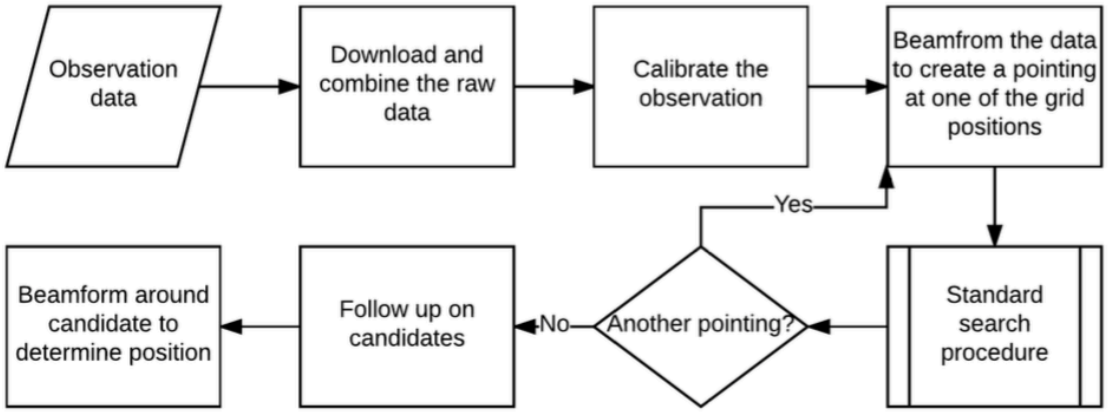
1. MWA voltage capture system (VCS) for data recording: data transport to Pawsey (Perth) via 10Gb link
2. Calibrate (generate visibility solutions) via an offline version of the MWA correlator: runs on the Galaxy cluster @ Pawsey
3. Generate Jones matrices the use of MWA RTS (calibration + imaging software)
4. Generate a *tied-array* beam toward the target (pulsar) – by applyng the beam model to get the antenna Jones matrices
5. Data in PSRFITS / VDIF formats for downstream processing software – DSPSR or PRESTO

For ~1.5 hour VCS recording (48 TB): 20 hours → 4 hours

Improved efficiency at all stages – most notably a **5 x speed-up** in the beamformer

Next step: *GPU parallelization + making use of the NBN 100Gb link for data*

VCS processing on Swinburne gSTAR

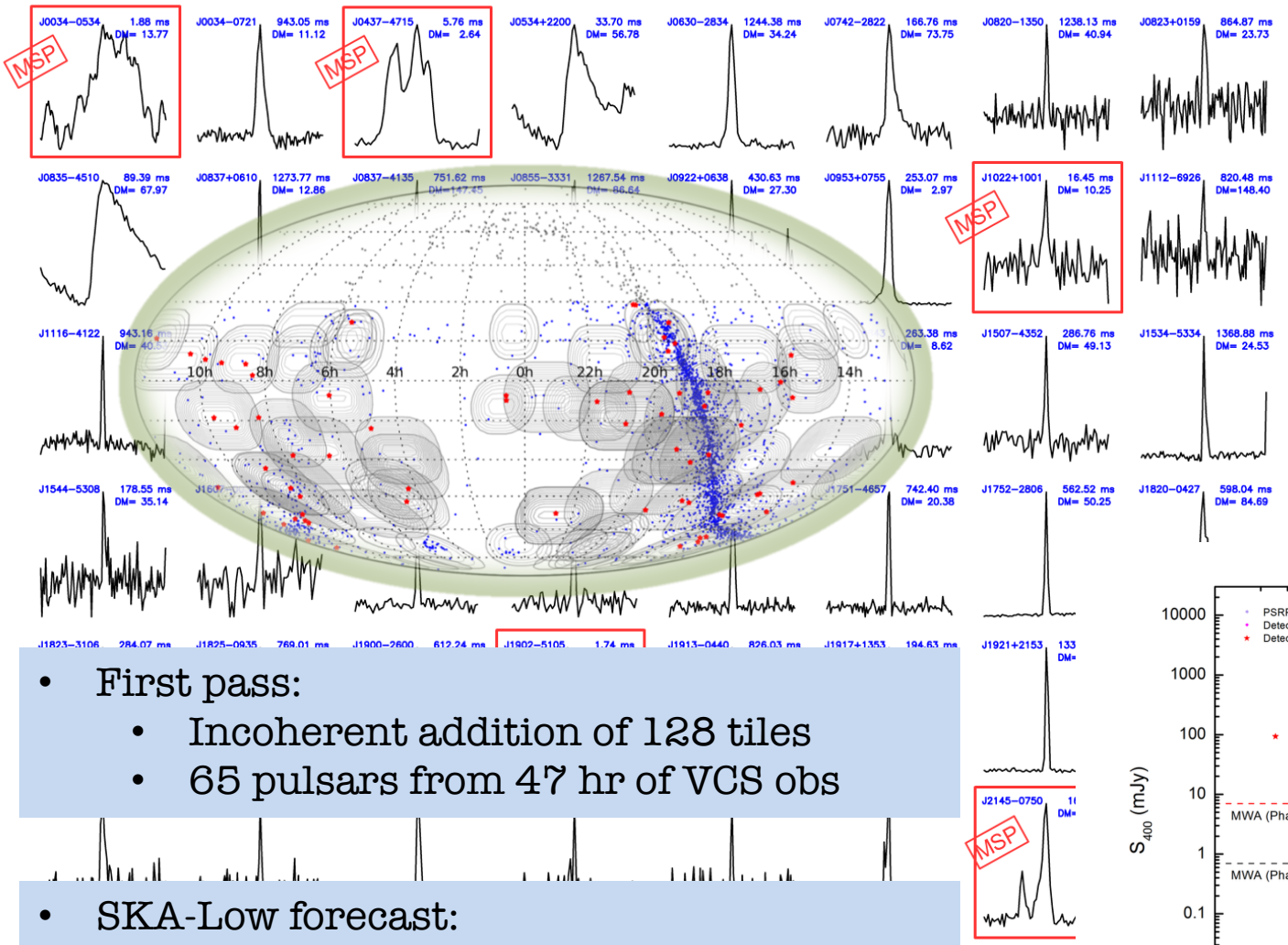


Nick Swainston

- The full suite of MWA VCS processing pipeline (including a *rudimentary* search pipeline) now ported and tested on Swinburne's gSTAR HPC (Nick Swainston's Honours project)

A shallow (and partial) census of Southern Pulsars

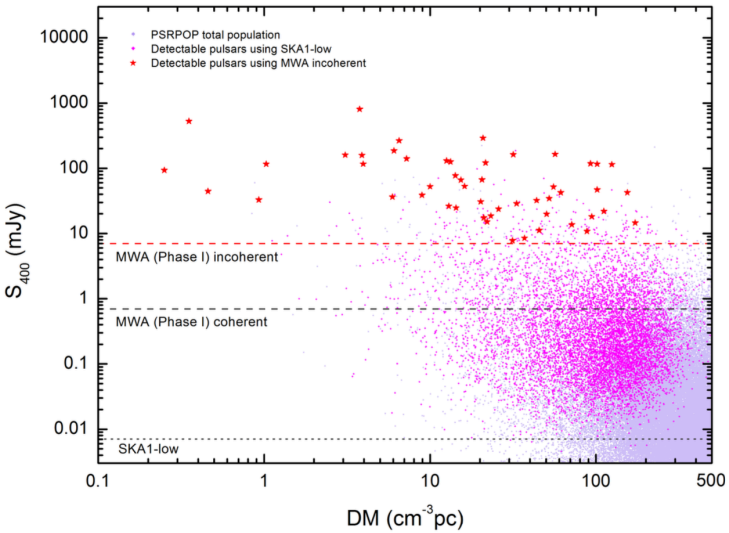
Archival VCS data are being used to conduct a low-frequency census of Southern pulsars



Mengyao Xue
(PhD student)

Xue et al (2017), PASA, Accepted,
arXiv:1711.08933

- First pass:
  - Incoherent addition of 128 tiles
  - 65 pulsars from 47 hr of VCS obs
- SKA-Low forecast:
  - ~ 9400 ± 1200 (using PsrPopPy)
  - Consistent with Keane et al. (2015)

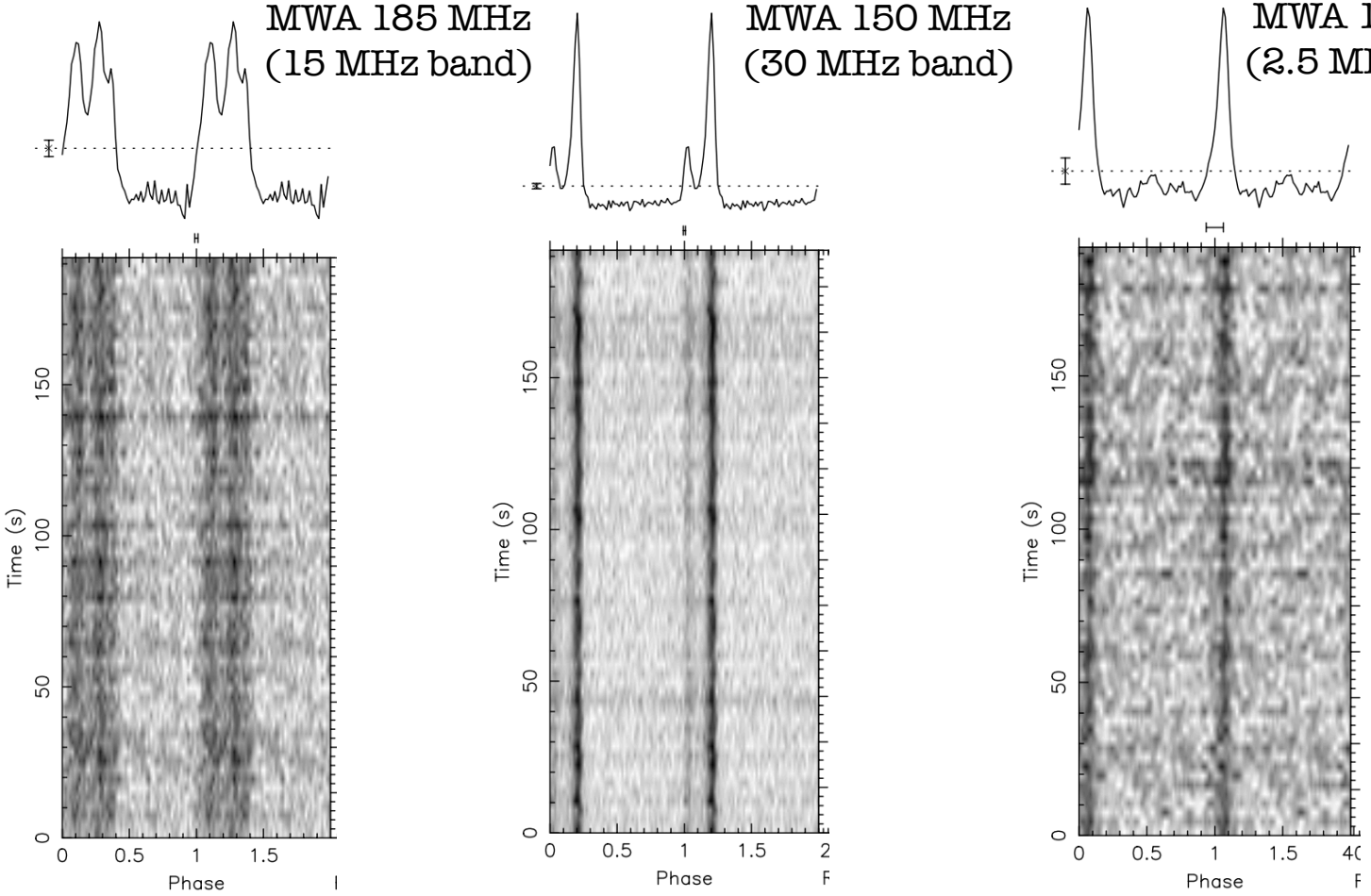


Millisecond Pulsars in the MWA band

PSR J0437-4715
MWA 185 MHz
(15 MHz band)

PSR J2145-0750
MWA 150 MHz
(30 MHz band)

PSR J2241-5236
MWA 158 MHz
(2.5 MHz band)



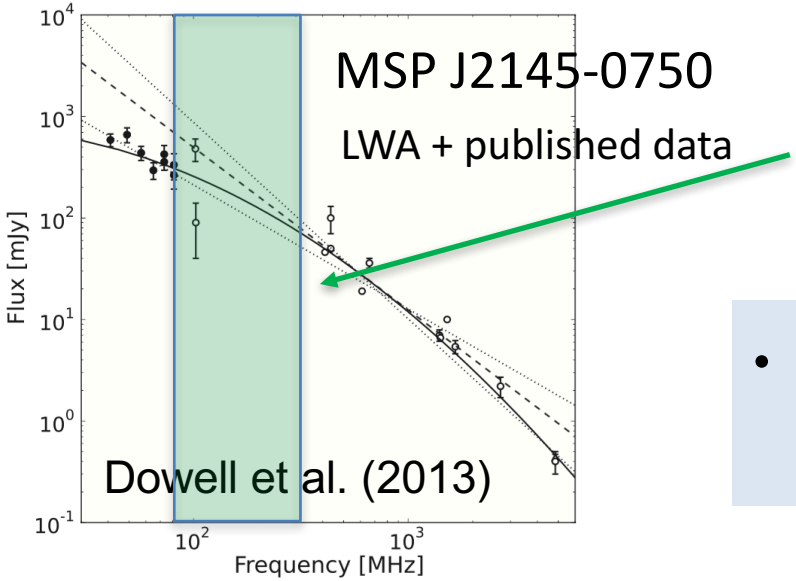
- MSP detections across the MWA band (70-220 MHz)
- See Dilpreet Kaur's poster for more on MSP J2241-5236

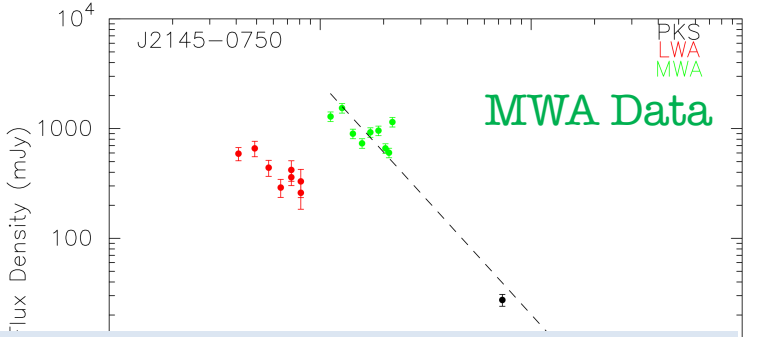
Dilpreet Kaur
(PhD student)

- Pleasingly good sensitivity for MSP detections even in *very short* observations
- Large flux variations (typically by a factor ~ 2-3, and some up to ~ 6) owing to (refractive) scintillation

Spectral turn-over in MSPs?

- MSP spectra are slightly steeper (e.g. Toscano et al. 1998)
- No low-freq spectral turnover in MSPs (Kuzmin et al. 2001)

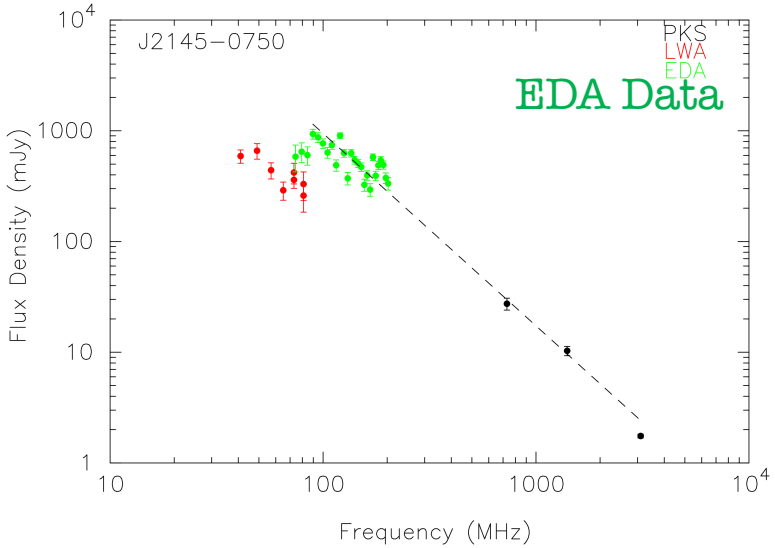




- No evidence for a spectral turnover within the MWA band [*preliminary*]

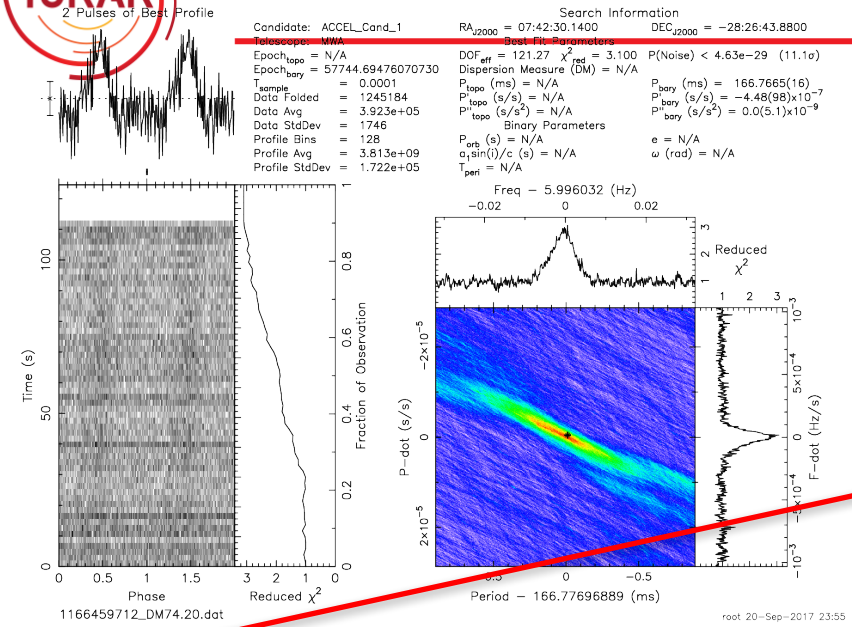
MWA Flux calibration using Bradley's full beam simulation (see Meyers et al. 2017 for details)

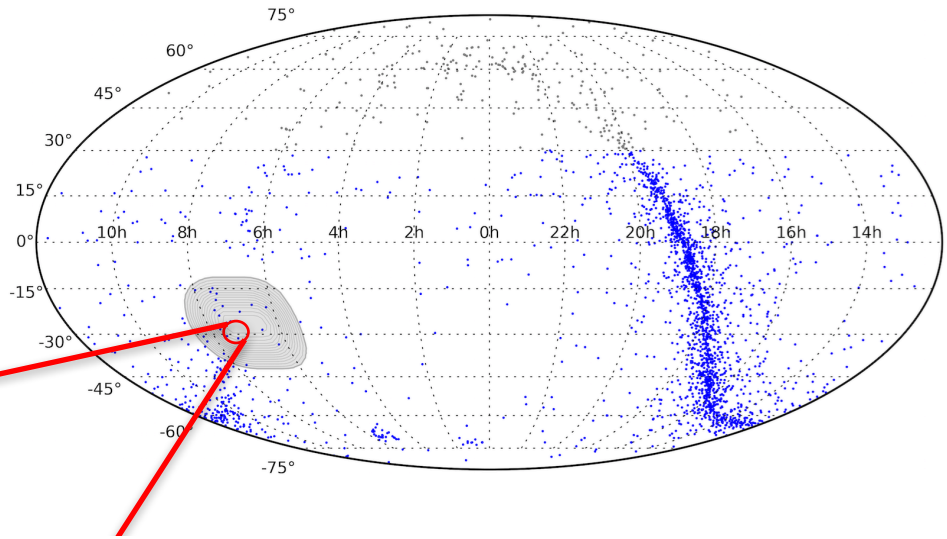
EDA Flux calibration using Marcin's beam simulation (see Marcin's talk; Wayth et al. 2017)

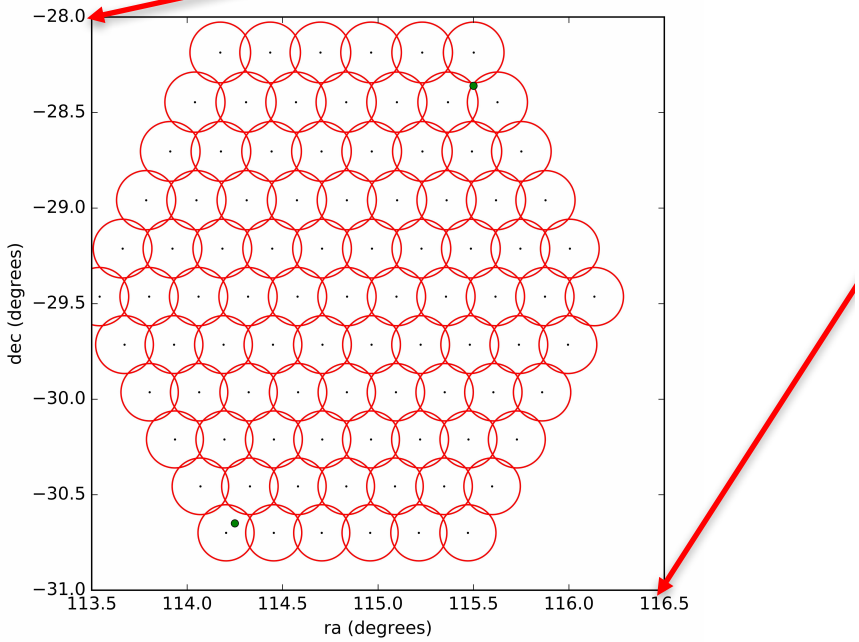


Bhat et al. in prep.

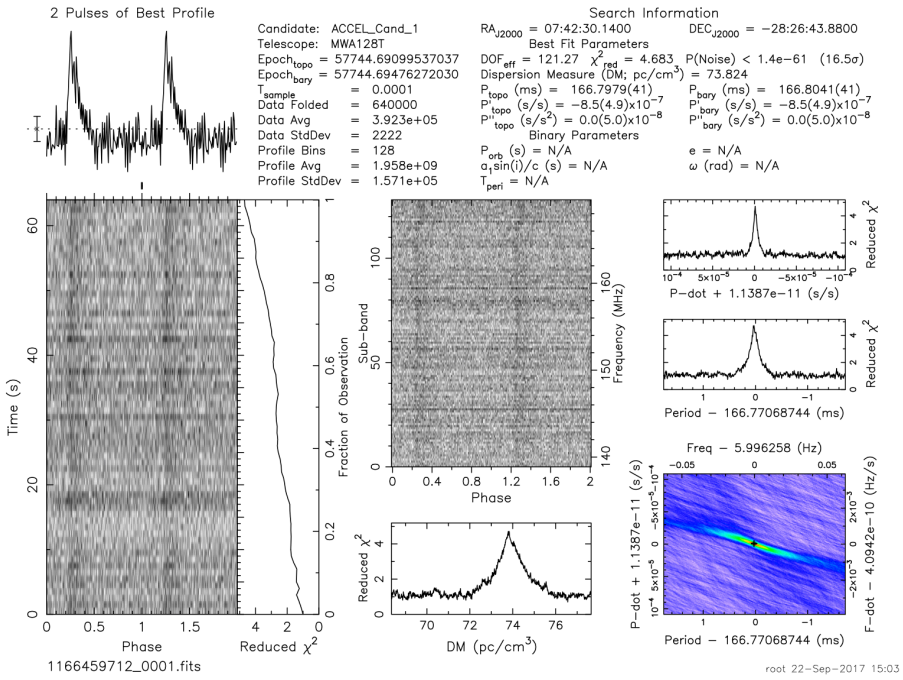
A Pilot Pulsar search with Phase 2



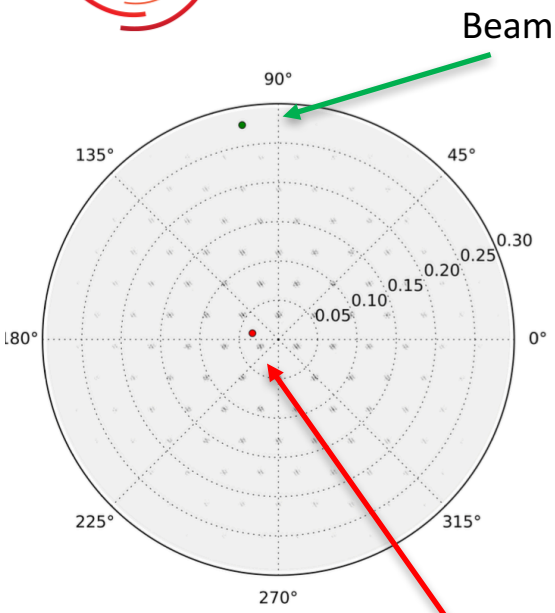




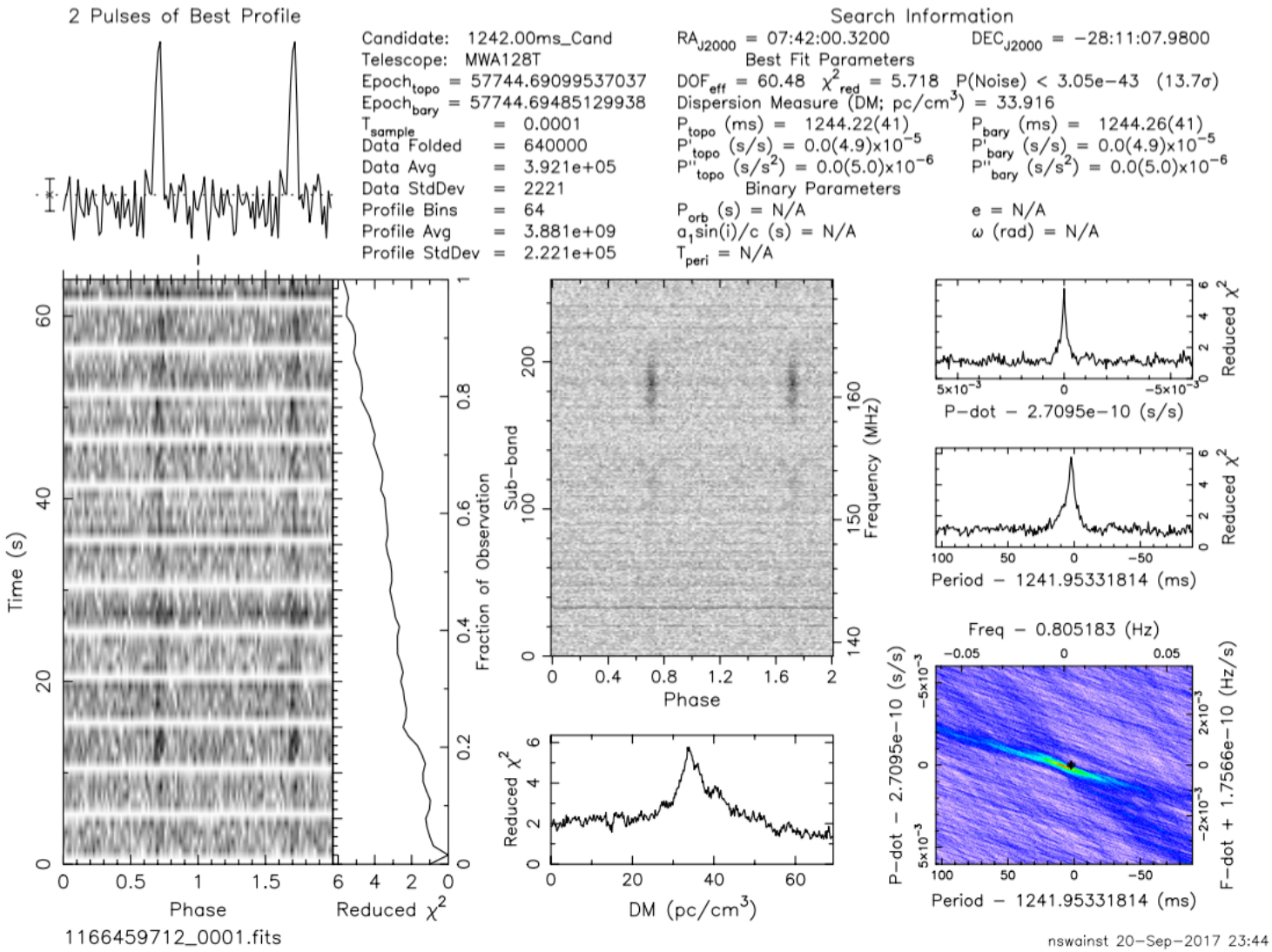
Nicholas Swainston



Side lobe detection of another known pulsar



Beam simulations
(cf. Meyers et al. 2017)



Nick Swainston

Summary

- MWA is fast emerging as a promising low-frequency facility for pulsar astronomy in the southern hemisphere
- Science ramping up: single-pulse work (emission physics), co-ordinated observations with other facilities (e.g. the GMRT, Parkes, UTMOST), low-frequency pulsar census, MSP monitoring, ISM scintillation studies, etc.
- Phase 2 MWA + Voltage capture capability brings excellent opportunity: full-sensitivity, wide-field pulsar searches are now more tractable: pilot search efforts progressing well
- Besides all the multitude of science prospects, such a survey will also be an important SKA-Low demonstrator survey (survey efficiency, search processing requirements)