Pulsar timing arrays

George Hobbs

29 October 2012

CSIRO ASTRONOMY AND SPACE SCIENCE
www.csiro.au

Task description

"…

try to envision the future of the field worldwide in the 2015 time range,

then in that context what the role of Parkes will be,

then what capabilities it will need in order to be a world leading telescope.

With that background and justification, you can describe the optimum system, and then consider which specifications are flexible and which are not. …"

"Your focus is the PTA and other timing arrays."

What is a PTA?

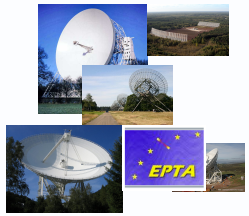
PTA = Pulsar Timing Array

Term first described by Romani (1989) and Foster & Backer (1990)

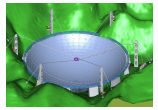
First major realisation of a PTA was the Parkes Pulsar Timing Array project started by R. Manchester

Main goals: 1) **detect gravitational waves**, 2) search for irregularities in terrestrial time standards and 3) improve the Solar System planetary ephemeris

Numerous secondary goals …



PTAs in 2006



CPTA

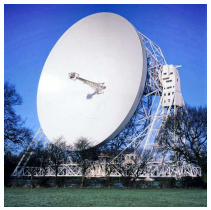
SKA

Interest within pulsar community

Interest within gravitational wave community

NANOGrav

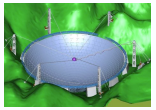
PPTA






PTAs in 2012


ASKAP


CPTA

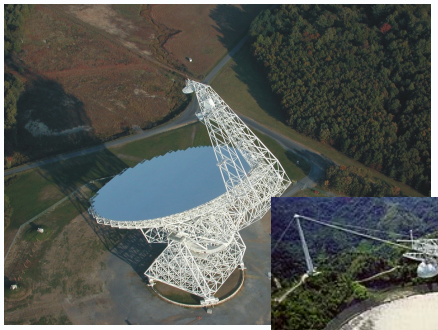

Meerkat

IPTA
International Parcel Tankers Association


SKA

Interest within pulsar community

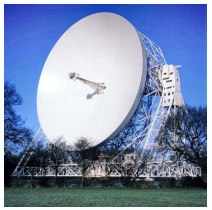
Interest within gravitational wave community



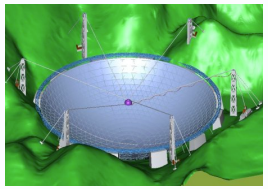
NANOGrav


PPTA

PTAs in 2015



EPTA



CPTA

ASKAP

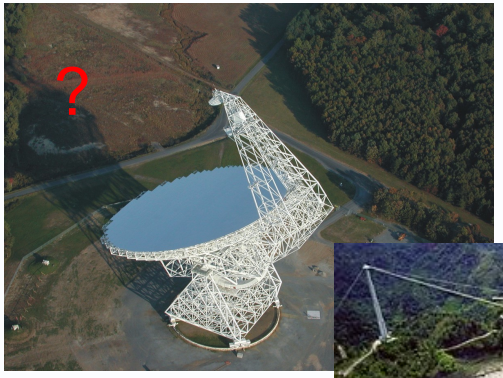
Meerkat

SKA

IPTA

Interest in pulsar community

Interest in gravitational wave community



NANOGrav

PPTA

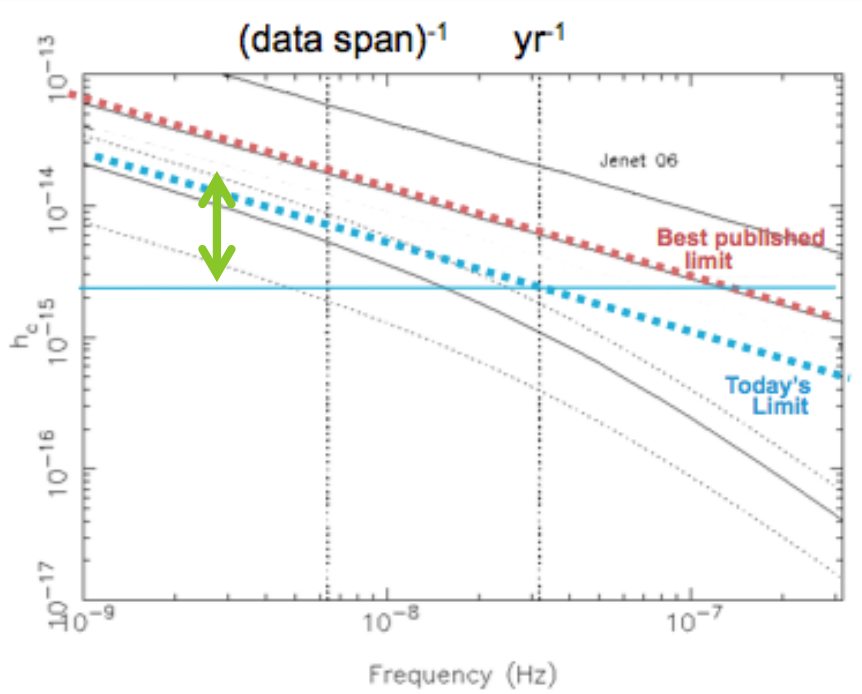
CSIRO

Current status of Parkes PTA

World's best PTA dataset

Reached sensitivity of interest for GW astronomy

Currently preparing a nature paper on implications of our non-detection



Already "ruled out formation of SMBH by merger alone in cores of galaxies" – A. Sesana

Shannon et al., in preparation … 95% of the realisations from the Millennium simulation produce a GWB ruled out by our current limit.

Role of Parkes in 2015 … version 1

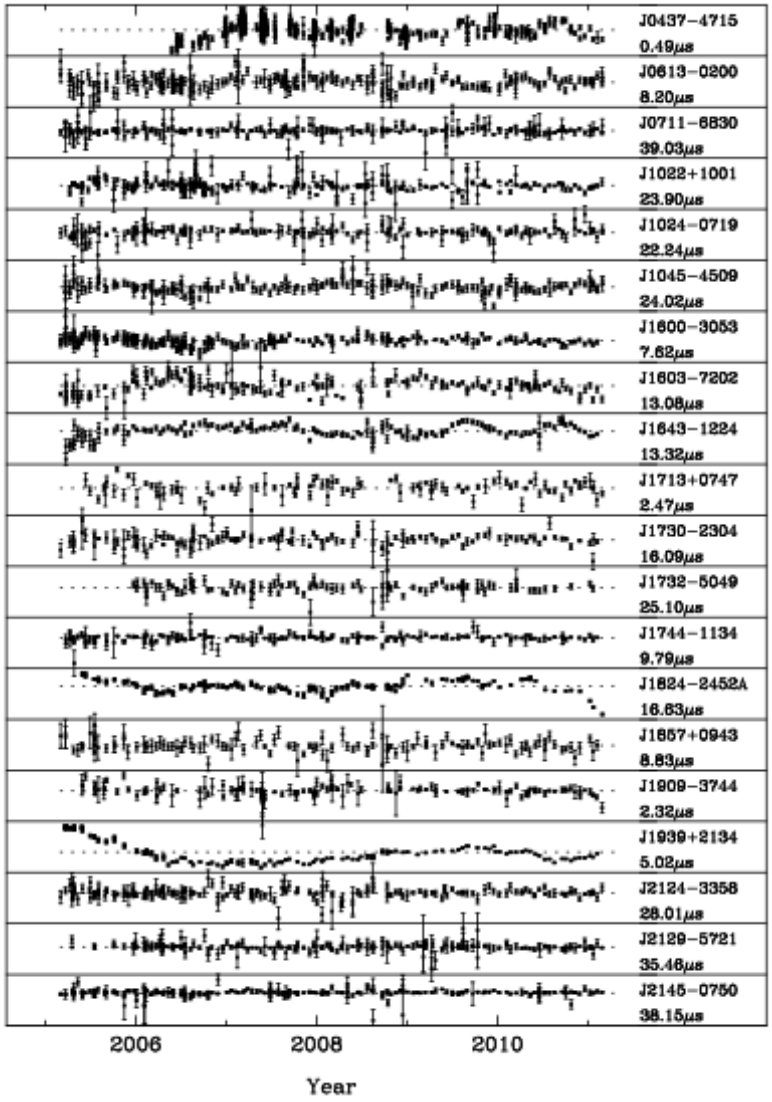
Can we go it alone?

Massive impact for Australian science if Parkes alone can detect gravitational waves

"If we can time 20 pulsars with an rms timing residuals ~100ns over 5 years then we can make a ~3 sigma detection with the gravitational wave background has an amplitude of A = 10^{-15}" – paraphrased from Jenet et al. (2005)

We have more than 6 years of data, we have observed 20 pulsars … where's the GW detection?

Why haven't we detected GWs yet?



Have not achieved 2-week sampling

Have not achieved rms timing residuals of 100ns

Have unexplained low-frequency noise in our data

Predicted amplitude of background has decreased

Mike Keith + collaborators working on making a new prediction of "when will we detect GWs"

Key issues relating to observations

1) Must attempt to remove low-frequency noise from our data

2) Must get more observations

- longer data sets
- observe more often
- observe more efficiently

3) Must reduce the arrival time uncertainties

4) Gravitational wave signal may be “bursty” – for detection need observations on timescales of ~weeks.

Role of Parkes in 2015 … version 2

1) Provide data sets for the International Pulsar Timing Array – combined IPTA data set should lead to GW detection

2) Provide initial solutions for pulsars for Meerkat and SKA PTAs

3) Discover new pulsars suitable for future timing arrays

4) Provide a long lever-arm for data span on Southern millisecond pulsars

How would we provide that role?

Currently only PTA-telescope in Southern Hemisphere!

Continue high-precision timing of Southern pulsars

Continue high-precision timing of some overlap pulsars for calibration/confirmation etc.

Continue surveys to discover new pulsars (Matthew's talk)

Again, to make the best use of observing time at Parkes need to realise the full potential of the telescope!

What do we need to do this?

Removal of dominant non-GW red-noise process

- require regular (and close in time) observations spanning from ~700MHz to ~3GHz

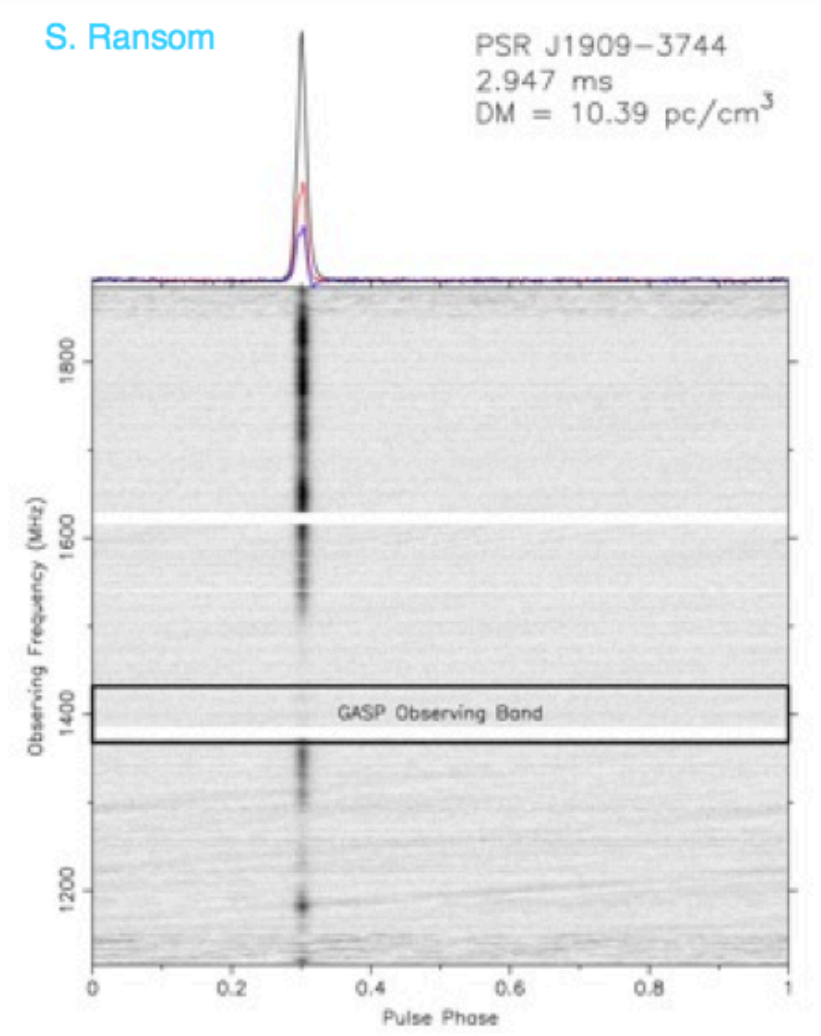
Improved observing efficiency:

- reduce requirement for two separate observations at 20cm and at 10/50cm
- reduce reliance on “lucky” scintillation state => wide-bands

Improve timing precision:

- wider “continuous” bands (with gaps for RFI!)

GBT observation



Importance of PSR J0437-4715

Brightest millisecond pulsar in our observing band

Lowest published rms timing residuals

Dominates upper bounds on gravitational wave searches

Used for calibrating other pulsar observations

…

Until Meerkat, the only PTA-quality data sets on J0437-4715 will come from the Parkes observatory

Comparison of proposed systems

System	Possibility of GW detection alone	Major role in IPTA	Ability to discover new PTA pulsars	Simplify operations for Parkes
Existing MB + 10/50CM				
Focal plane array				
High-frequency wide band receiver				
“Low”-frequency wide band receiver				

Key comments

Parkes will continue to have a major role to play in PTAs in 2015 (and beyond).

Possible that Parkes alone could make the first direct detection of gravitational waves

Essential component to the IPTA as the only Southern Hemisphere telescope

Essential to realise the full potential of Parkes as a pulsar-timing instrument
- must keep up with the development of new receivers and backends – other IPTA members already developing and installing wide-band systems
- must make the most of the new observing model for Parkes => reduce receiver changes => fewer receivers available

Would like to see two wide-band receivers + FPA installed at Parkes!

Will argue that the largest science impact would come from first commissioning the low-frequency wide band receiver.

Thank you

Division/Unit Name
Presenter Name
Presenter Title

t +61 2 9123 4567
e firstname.surname@csiro.au
w www.csiro.au/lorem

Division/Unit Name
Presenter Name
Presenter Title

t +61 2 9123 4567
e firstname.surname@csiro.au
w www.csiro.au/lorem