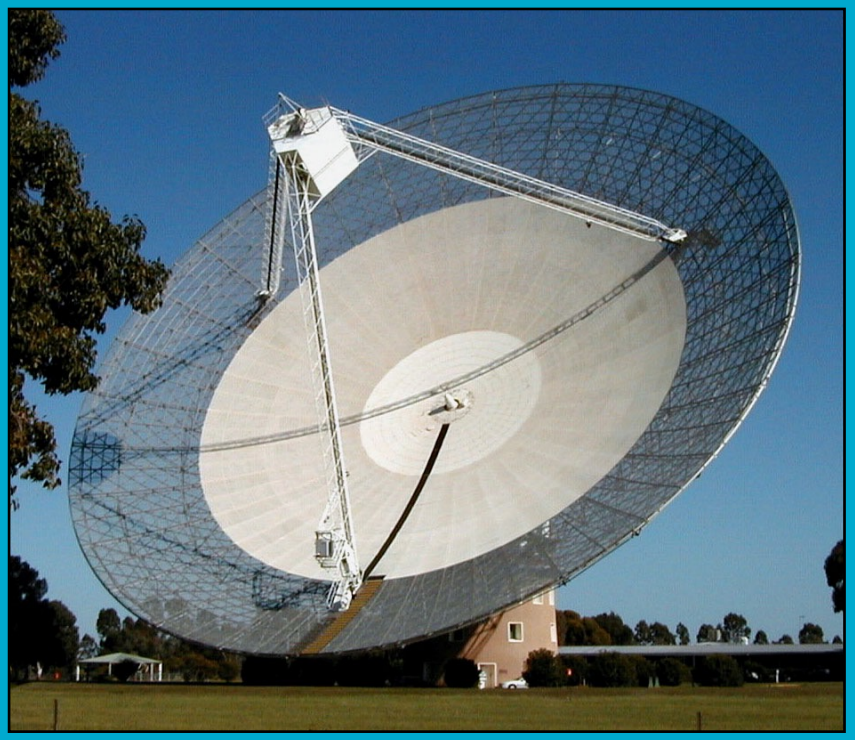


The Parkes Pulsar Timing Array

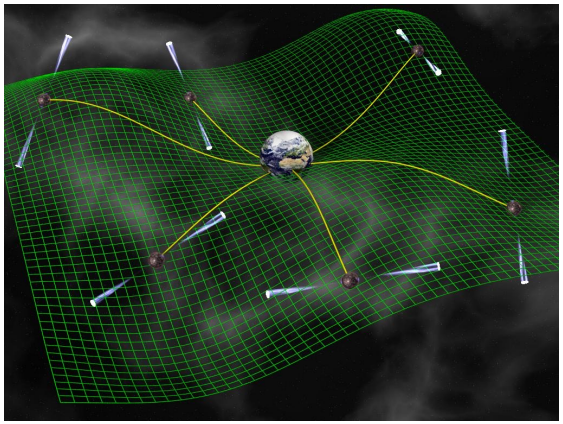
Co-learnium: 3 August 2023

Dick Manchester

CSIRO ASTRONOMY AND SPACE PHYSICS
www.csiro.au

The Parkes Pulsar Timing Array Project

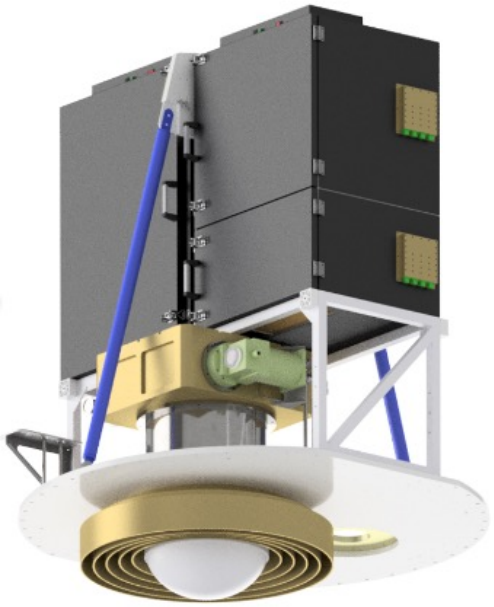
- Concept of a PTA for nanoHertz GW detection first proposed by Romani (1989) and Foster & Backer (1990)
- PPTA project commenced in July 2003 with support from RNM's Australian Research Council Federation Fellowship and from CSIRO
- Two post-docs (George and Russell Edwards) employed, construction of 10cm/50cm receiver began
- Initial collaboration between ATNF and Swinburne University (Matthew Bailes' group); later collaborations formed with other groups, both Australian and international
- Scheduled observations at Parkes (aka "Murriyang") commenced in February 2004



Credit: David Champion

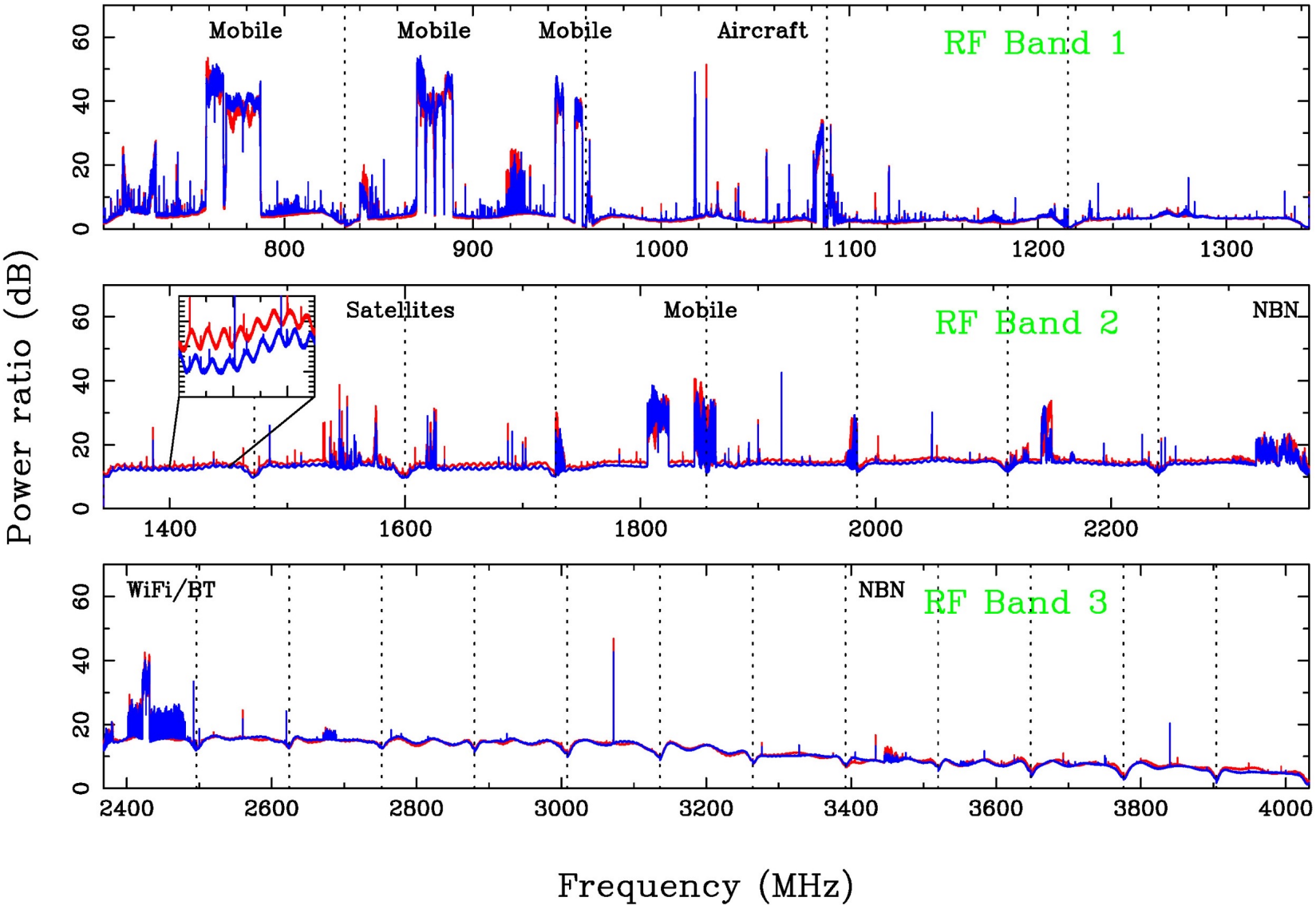
PPTA Observations

- All observations use Parkes 64-m radio telescope
- Until 2018, all observations in three bands, two receivers:
  - 50/40cm band (700/64 MHz) 10cm/50cm receiver
  - 20cm band (1370/256 MHZ) Centre beam of MB receiver
  - 10cm band (3100/1024 MHz) 10cm/50cm receiver
- Ultra-wide Low (UWL) receiver commissioned in 2018 (704 MHz – 4032 MHz in 26 x 128-MHz sub-bands). Now in regular use for PPTA observations
- 37 MSPs in PPTA sample; 20 - 25 regularly observed, 1hr for each pulsar
- On average, two observing sessions per month, some short (e.g., 8 hrs), some long (e.g., 2 days)
- ~15,500 hrs of observation time since 2003



The UWL Receiver

UWL Observed Spectrum



Sky Distribution of PPTA Pulsars

- PPTA pulsars are widely distributed in Galactic longitude (over the range visible to Parkes) and mostly at mid- to high-latitudes
- In Celestial coordinates, most of the PPTA pulsars are in Galactic time (16 – 20 hrs) which is in high demand
- This leads to very uneven observational coverage of the PPTA sample and ultimately to reduced sensitivity of the PPTA data set

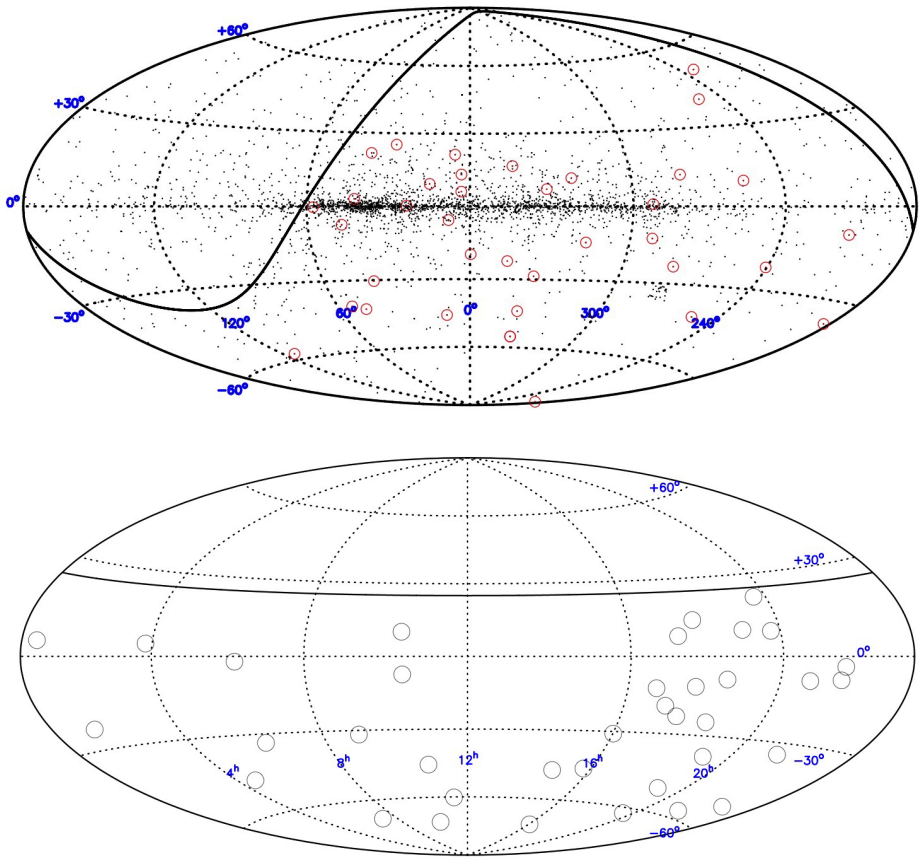


Image credits: George Hobbs

PPTA Membership (2023)

- Nine Australian institutions, 26 members (incl. 3 students)
- Ten international institutions, 10 members
- Members are co-authors on papers if they have made a significant contribution to the particular paper
- PPTA managed by a Steering Committee, currently consisting of eight people, including a student representative and a post-doc representative
- Current Chair: George Hobbs
- Two PPTA representatives are on the Steering Committee for the International Pulsar Timing Array (IPTA), currently Andrew Zic and Daniel Reardon
- The IPTA has various Working Groups and the PPTA is represented on most of them.

Latest GWB Results

- Latest PPTA result on isotropic GWB published on July 1 as part of coordinated IPTA data release

  Reardon, Zic, Shannon et al. ApJL, July 1 2023

- Big PR event 29 June, led by Daniel and Andrew for the PPTA

- NANOGrav 15-yr data set, 68 pulsars > 3yr, gives

  ~3.5σ result: $h_c(f) = 2.4 +/- 0.7 \times 10^{-15}$; Agazie et al. ApJL, July 1 2023

- EPTA DR2 + InPTA – 24 yrs, 42 pulsars, gives $h_c(f) = 2.5 +/- 0.7 \times 10^{-15}$; ~3σ (tentative) result – issues with combining different data sets Antoniadis et al. arXiv, June 28 2023

- CPTA DR1 – 3.5 yrs, 57 pulsars using FAST, gives $h_c(f) = 1.0 +/- 0.3 \times 10^{-14}$; ~4.6σ (tentative) result – issues with signal-processing method Xu et al. RAA, July 1, 2023

The most important factor giving high significance is the number of pulsars regularly observed

OzGrav

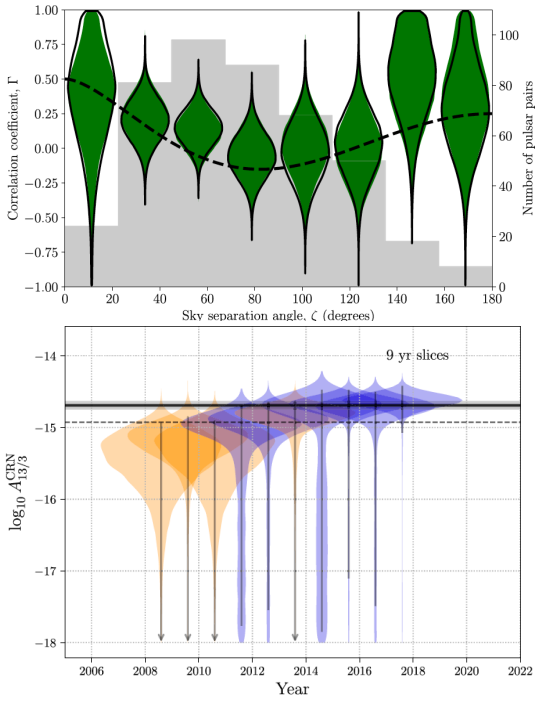
PPTA Isotropic GWB Paper

The Astrophysical Journal Letters, 951:L6 (15pp), 2023 July 1 https://doi.org/10.3847/2041-8213/acdd02

Search for an Isotropic Gravitational-wave Background with the Parkes Pulsar Timing Array

Daniel J. Reardon[1,2], Andrew Zic[3,4], Ryan M. Shannon[1,2], George B. Hobbs[3], Matthew Bailes[1,2], Valentina Di Marco[5,6], Agastya Kapur[3,4], Axl F. Rogers[7], Eric Thrane[5,6], Jacob Askew[1,2], N. D. Ramesh Bhat[8], Andrew Cameron[1,2], Małgorzata Curyło[9], William A. Coles[10], Shi Dai[11], Boris Goncharov[12,13], Matthew Kerr[14], Atharva Kulkarni[1,2], Yuri Levin[5,15,16], Marcus E. Lower[3], Richard N. Manchester[3], Rami Mandow[3,4], Matthew T. Miles[1,2], Rowina S. Nathan[5,6], Stefan Osłowski[17], Christopher J. Russell[18], Renée Spiewak[19], Songbo Zhang[3,20], and Xing-Jiang Zhu[21]

- Part of IPTA "3P+" coordinated release of GWB search and data results from major PTAs
- Tentative detection of GWB at 2σ level,
  $h_c(f) = 2.04 +/- 0.25 \times 10^{-15}$ for $\alpha = -2/3$
- Evidence for time variation in signal – weaker at earlier times; consistent with earlier PPTA limit of
  $h_c(f) < 1 \times 10^{-15}$ Shannon et al., Science, 2015



PPTA Ultra-Light Dark Matter Paper

PHYSICAL REVIEW D **106,** L081101 (2022)

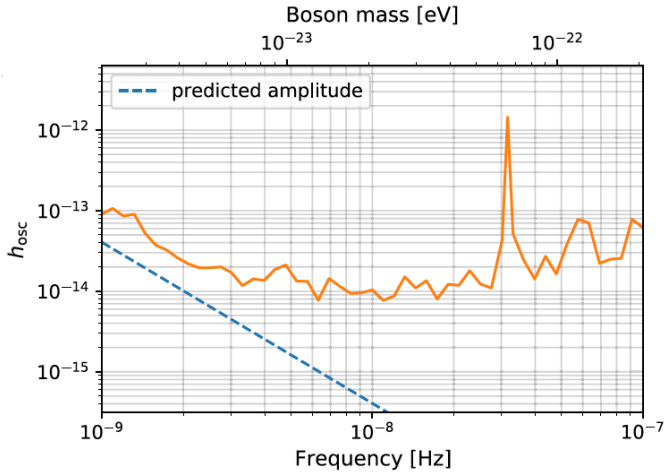
Letter

Constraining ultralight vector dark matter with the Parkes Pulsar Timing Array second data release

Yu-Mei Wu,[1,2,3,*] Zu-Cheng Chen,[4,5,†] Qing-Guo Huang,[1,3,2,‡] Xingjiang Zhu,[5,§] N. D. Ramesh Bhat,[6] Yi Feng,[7] George Hobbs,[8] Richard N. Manchester,[8] Christopher J. Russell,[9] and R. M. Shannon[10,11]

(PPTA Collaboration)

- PTAs can constrain local density of ultra-light bosons (m ~ 10^{-23} eV ~ 10^{-56} g) (!)
- PPTA DR2 used to set limit $h_c(f) = \sim 10^{-14}$
- At low frequencies (1 – 5 x 10^{-9} Hz), PPTA limit is ~ five times expected value
- Limit is similar to that set by PPTA for scalar dark matter (Poraykov et al., Phys Rev D, 2018)



PPTA Outreach

- Led by Rob Hollow (ATNF)
- Rob's tireless promotion of the ATNF and, in particular, Parkes and its pulsar research has brought awareness of our activities in these areas to many groups both in Australia and internationally
- An important component of ATNF's Outreach is the PULSE@Parkes project
- Initiated by George and Rob about 17 years ago
- Groups of 20-30 high-school students (Yr 10-12) observe pulsars using Parkes, 2hr sessions
- Some international groups, China, Japan, Thailand
- Analyse Parkes data, measure DMs; data freely available on ATNF archive
- Over 3500 students from more than 300 schools have participated
- About 100 papers published in refereed journals

PULSE@Parkes observing session

Summary

In summary:

- Over its 20-year lifetime, the PPTA has had ~15,000 hrs of observation time on the Parkes Radio Telescope ("Murriyang")
- Using these data, the project has produced a large number (many hundreds) of important papers, mostly in refereed journals
- It has fostered an extensive Outreach program that has reached thousands of school students and the general public both in Australia and internationally

Overall, an extremely successful project!