



OzGrav

ARC Centre of Excellence for Gravitational Wave Discovery

OzGrav

*Matthew Bailes (Director)*

*Swinburne University of Technology*

*ARC Laureate Fellow*



THE UNIVERSITY OF  
WESTERN AUSTRALIA



# Our Mission

*OzGRav's mission is to capitalise on the historic first detections of gravitational waves to understand the extreme physics of black holes and warped spacetime, and to inspire the next generation of Australian scientists and engineers through this new window on the Universe.*

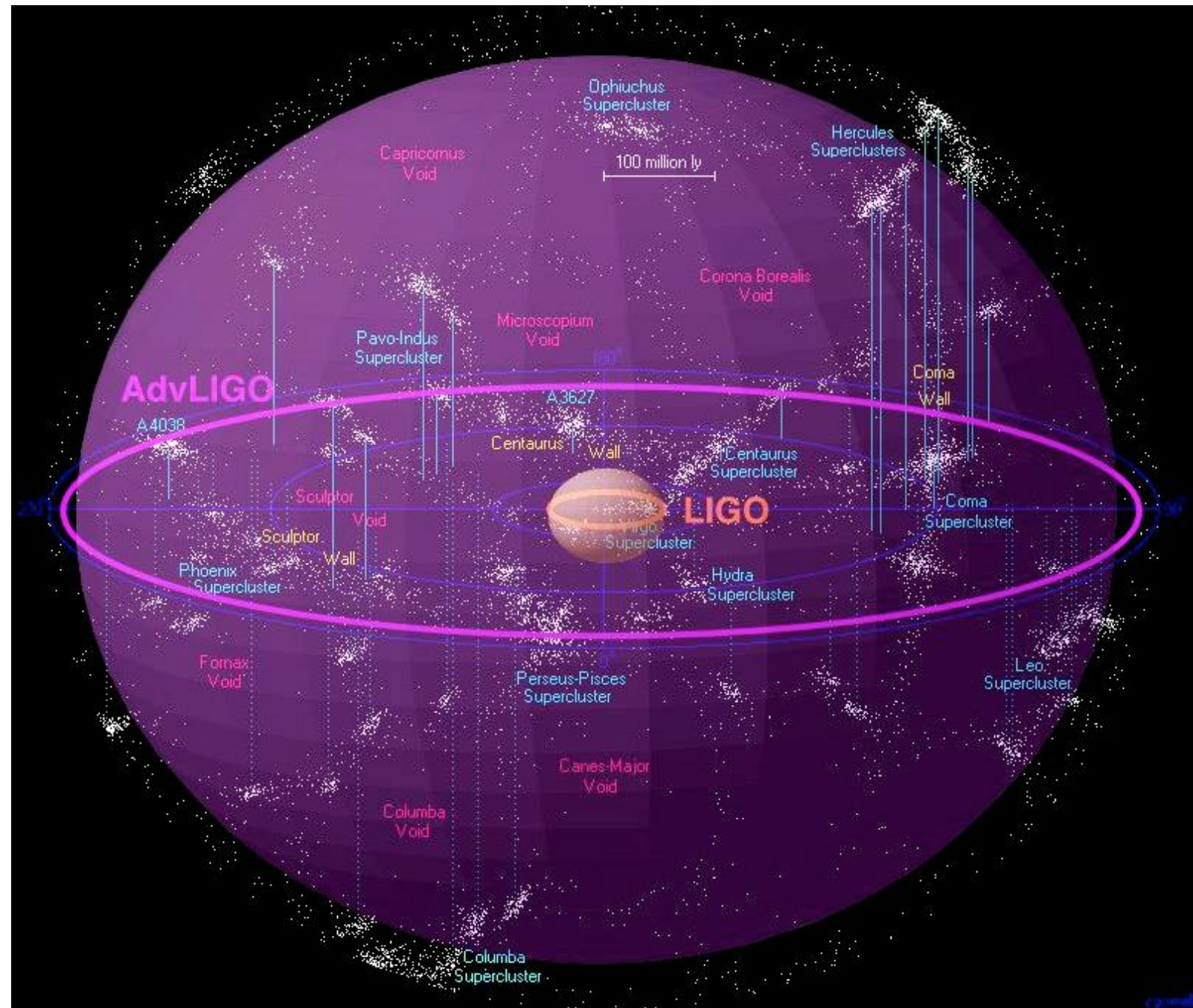


Advanced LIGO:

Design  
sensitivity 10x  
LIGO.

1000x merger  
rate.

ns+ns target  
rate uncertain





# The Gravity Wave Discovery

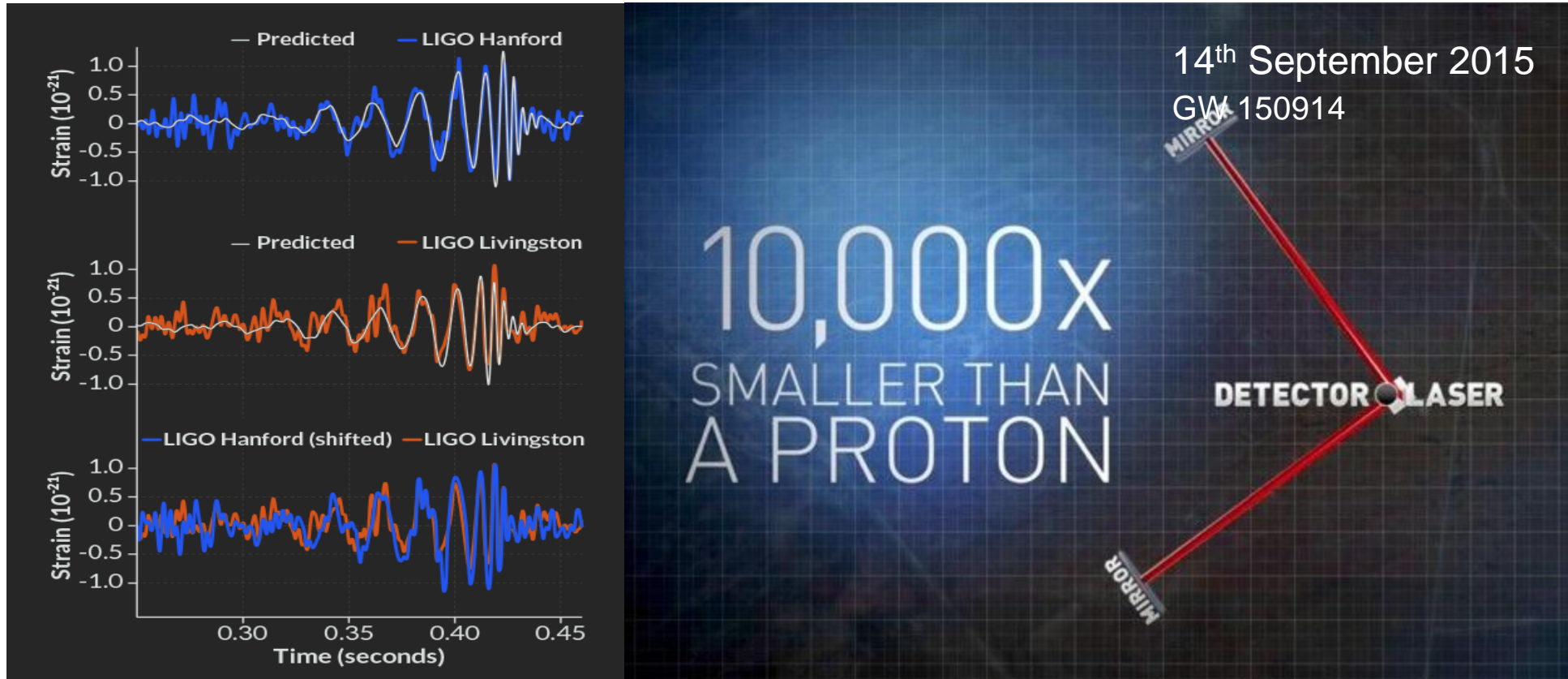
Ripples in Space-time detected by LIGO\*



\*Laser Interferometer Gravitational-wave Observatory

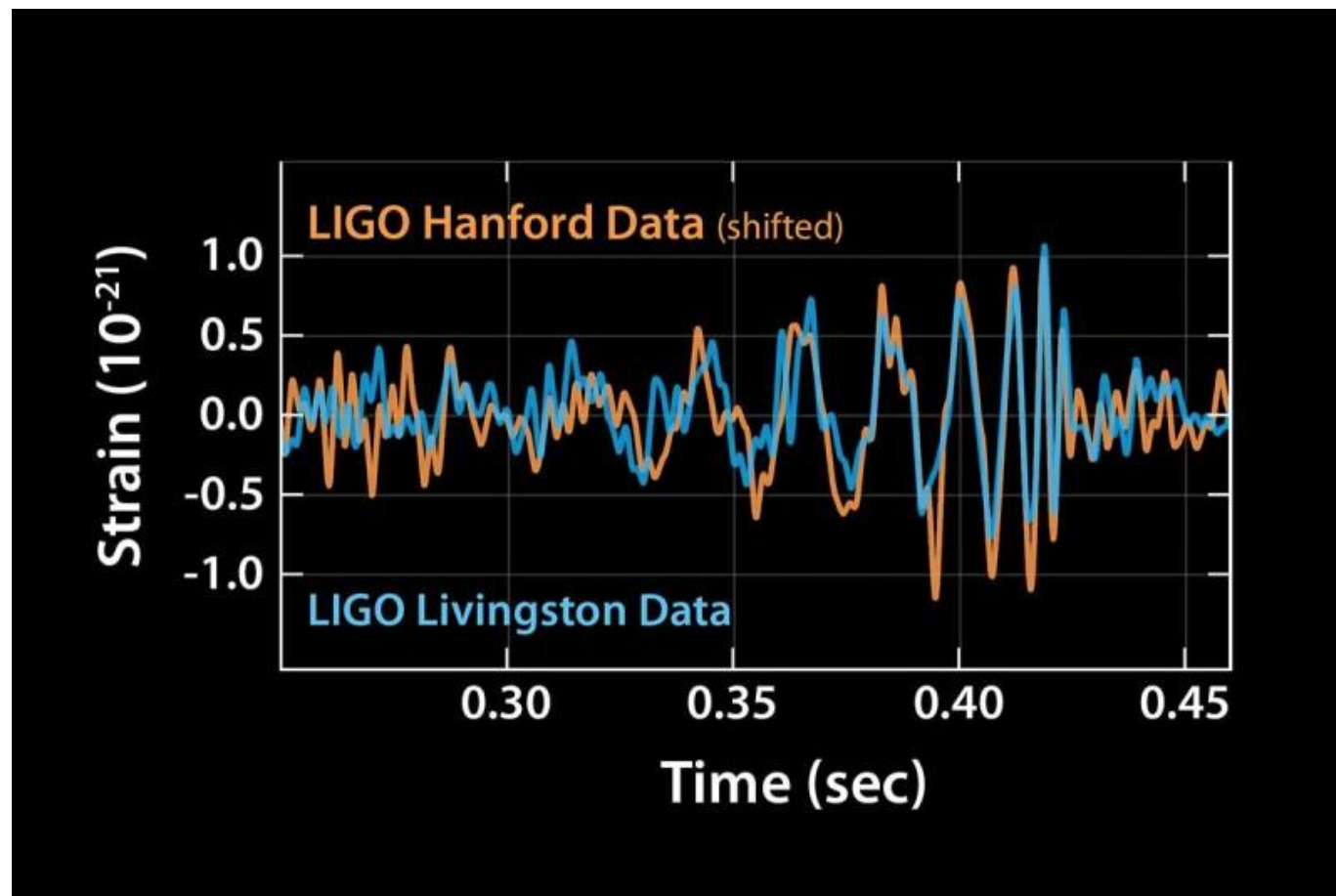
# The Gravity Wave Discovery

Most extreme event since the Big Bang



Width of a human hair at alpha centauri!

# Real data!





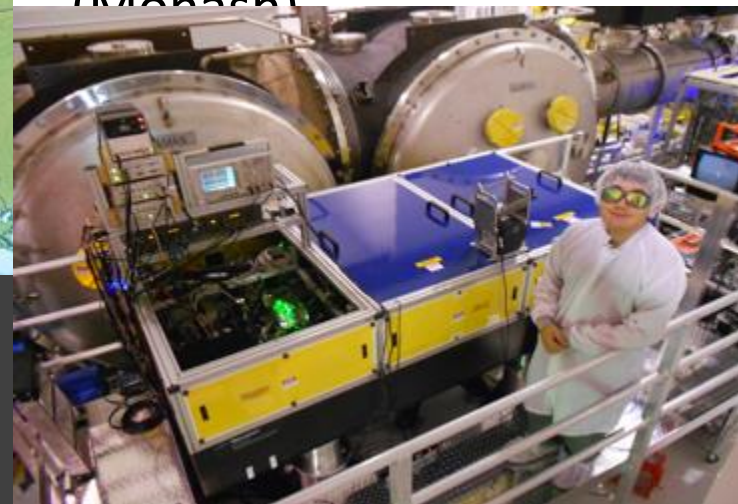
# Advanced LIGO interferometer



Breakthrough instrumentation = A\$900 M  
4km-long, L-shaped detectors. 3000km apart

## OzGRav CIs provided:

- Lock Acquisition System (ANU)
- Hartmann Cameras (Adelaide)
- Instability Control (UWA)
- Blind injection system (Monash)



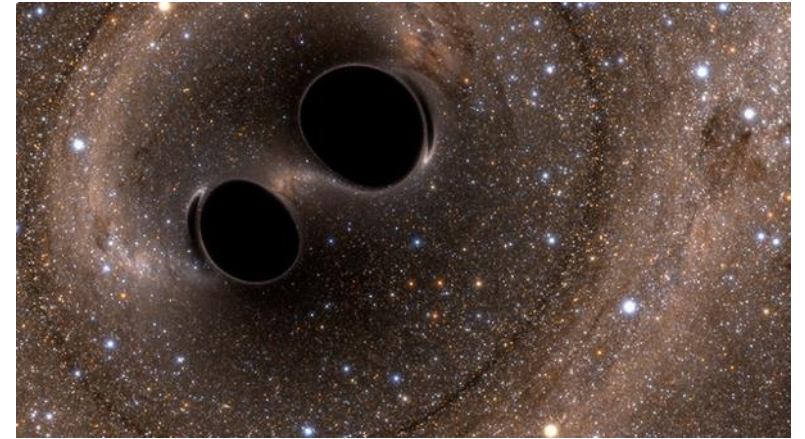
# Black hole merger (SXS lab)





# GW150914

- 230-570 Mpc ( $z=0.054-0.136$ )
- SNR = 24
- Total Mass 60-70 Mo,  $36(4)+29(4)$  Mo
- Time delay 7 ms
- Likely Sky Position “Southern Hemisphere” !!!
- Strain  $10^{-21}$  !!!
- GW Energy 3Mo –  $3.6 \times 10^{56}$  ergs/s
- 250 Hz at coalescence
- Rate  $1/(2-400)$  Gpc<sup>-3</sup> yr<sup>-1</sup>



# Announcement & Impact

LIGO Press Release: 11<sup>th</sup> Feb 2016

- Six significant news days
- Social media and news frenzy



#EinsteinWasRight



- Paper downloaded 10,000 times per minute! (166 Hz!)
- Special US\$3M Breakthrough Prize
- 2016 Gruber Cosmology Prize

*“the most significant discovery in my lifetime.”*

*– Dr. Alan Finkel (AO), Australia’s Chief Scientist*



# Why OzGRav and Why Now?

- **Instrumentation**

- Advanced LIGO about to get even better
- Square Kilometre Array pathfinders imminent

- **Future instrumental advances require large international teams**

- OzGRav + (MIT, Glasgow, Caltech, Max Planck Institute, Chinese Academy of Sciences)

- **New Sources of Gravitational Waves**

- Unique combination of pulsar and GW communities
- Continuous wave sources, backgrounds
- Triggers: supernovae, starquakes, bursts

- **Astrophysics**

- Revealing Warped Space Time
- Understanding black holes
- Expecting the unexpected

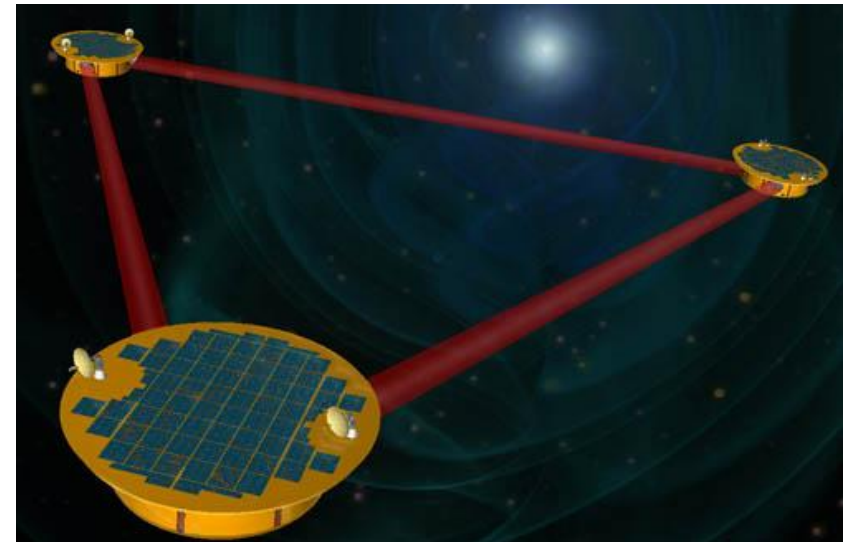




# OzGrav's Instrumentation Program

## - Making aLIGO better, and beyond

- Instrumentation Theme (Leader David McClelland)
  - Quantum
    - Quantum Squeezing (sacrifice knowledge of amplitude for phase)
  - Low Frequency
    - Noise elimination
  - Instabilities and Distortions
    - Higher fidelity
  - Space
    - LISA resurrected
  - Radio
    - Pulsar Timing Instrumentation



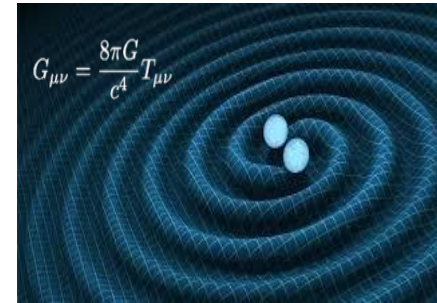
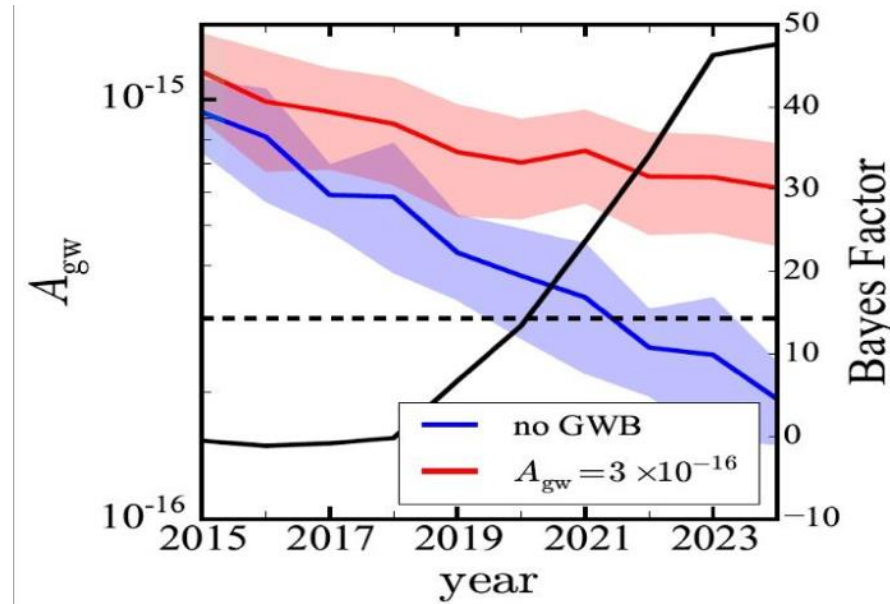
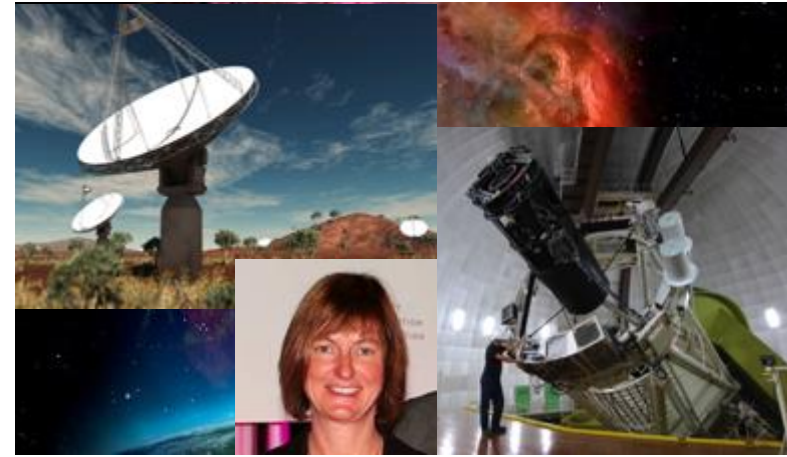
# OzGrav's Data Program

- Data Theme (Leader Matthew Bailes)
  - LIGO Pipelines (Melatos/Wen/Thrane/Scott)
    - Rapid Detection
    - CW sources
    - Parameter Estimation
    - Stochastic Background
  - Supercomputing (Hurley)
    - New [Supercomputer@Swin.edu.au](http://Supercomputer@Swin.edu.au)
    - ~3 Petaflops
  - Pulsar Timing Arrays
    - GW background
  - The merger progenitor population
    - Pulsar surveys for binaries
  - Tests of GR
    - SKA vital



# OzGrav Astrophysics

- Observations
  - Multi-wavelength Follow-up (Cooke/Scott)
  - Skymapper
  - ASKAP, MWA?
  - PKS+UWB, MeerKAT, SKAs
  - Zadko Telescope (Coward), etc
  - Inverse Searching
    - Local SNe, FRBs, etc
- Sources (Levin)
  - Understanding the events
  - Continuous wave sources
- Gravity (Bailes/Kramer)
  - Pulsar timing arrays
  - Tests of GR using pulsars





# Our Science Team



Theorists



Pulsar Astronomers



Instrumentation Scientists



Observational Astronomers



Gravitational Wave Astronomers

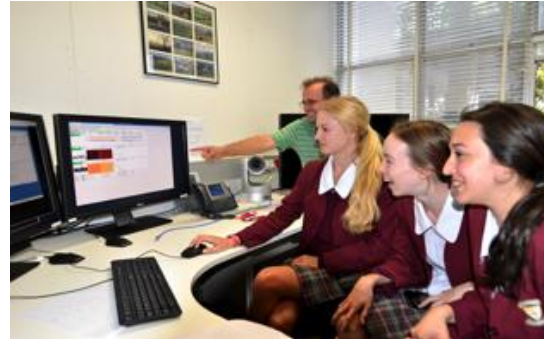
Science Communicators & Educators

Big Data & Advanced Computing Experts



# Education & Outreach (Blair)

- Face to face:
  - Gingin Gravity Discovery Centre
  - Pulse@Parkes
  - Public lectures
- Mass media
  - The Conversation
  - Press releases
  - Social Media
- Ambassadors
  - Cameron McEvoy
  - Alan Duffy
- Target under-represented STEM groups



# IP & Commercialisation

- Prof Dan Shaddock to lead OzGRav's research translation program
- Parallel commercialisation entity "OzGrav.com"
  - Consultancy





# OzGrav Timeline (7 years)



# Gravitational Wave Astronomy Future

- Add VIRGO (soon), KAGRA (3y), LIGO-India (6y)
  - Positions “better”
- Beyond 2G Detectors
  - 3G = 10x more sensitive (to  $h$ ) 1000x volume
    - GWIC working group forming
  - 1 event/month - 10,000 events/year! (1/year)
    - Star formation rate of BH+BH tracer
- SKA-mid
  - G/T  $\sim$  15x PKS – 225x as many pulsars/hour at same SNR as PKS
- LISA
  - Space-based GW detectors