



OzGrav

ARC Centre of Excellence for Gravitational Wave Discovery

Australia and 3G Detectors: Lessons from the SKA

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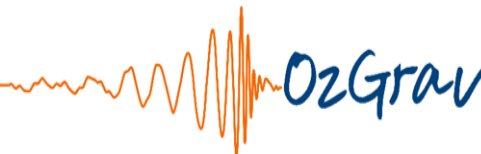


THE UNIVERSITY OF
WESTERN AUSTRALIA



Australian Research

- **Universities (x39)**
- Health a national priority
- Physical Sciences
 - Physics mainly at the “Sandstones” (Go8)
 - Older Universities – ANU etc
 - Funded by Australian Research Council + Universities
- **Government-funded**
- CSIRO ~500M AUD/year
- Defined areas
 - Wheat, wool
 - Biotech
 - Radio Astronomy!
 - Parkes 64 m telescope
 - Australia Telescope Compact Array
 - Australian SKA Pathfinder



University Research in Australia



- Universities are big businesses!
 - 500-2000+M per year turnover
- Profit proportional to the number of students
 - Profit funds labs/research infrastructure/researchers
- High-impact research drives international rankings
 - Science and Nature papers
 - Press Releases
 - Graduate Outcomes
 - Research Income
- Rankings drive recruitment

Astronomy in Australia

- Universities

- ~500 astronomy-related Profs, Postdocs, PhD Students
- Circa 13 Universities with significant research efforts

- WA: 2 (80?)
- SA: 1 (10?)
- Tas: 1 (15?)
- Victoria: 3 (150?)
- ACT: 1 (100?)
- NSW: 4 (150?)
- Queensland: 1 (15?)

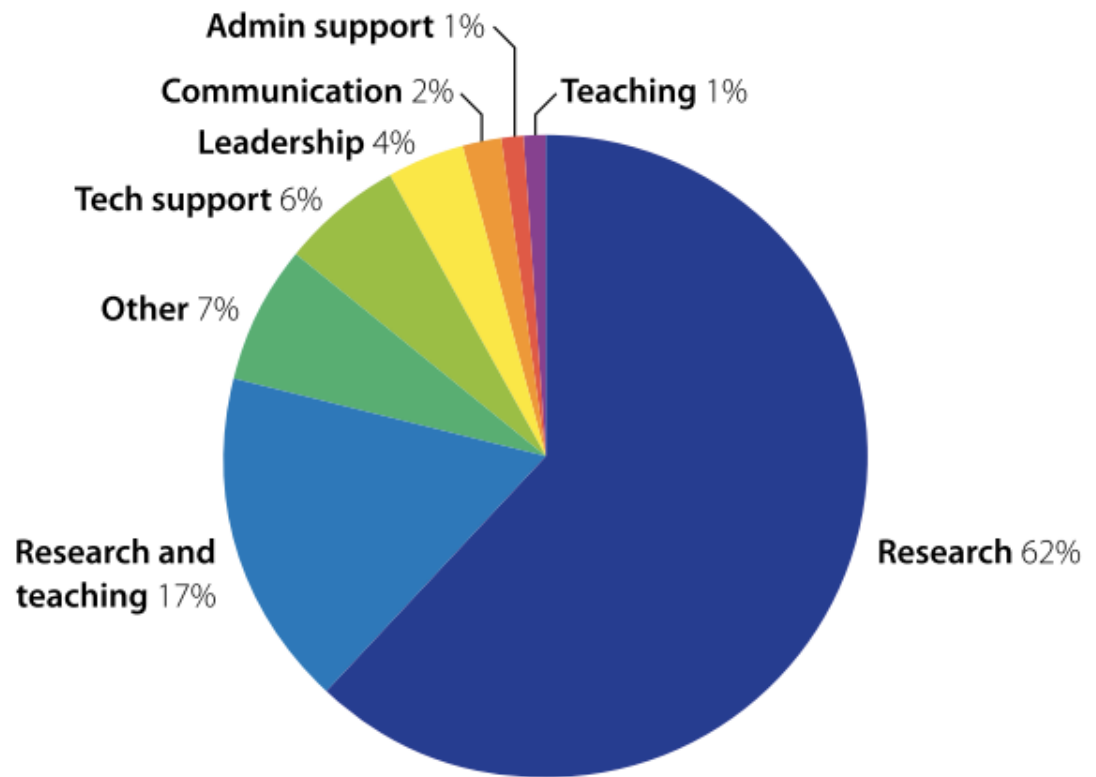
- CSIRO

- Centre for Astronomy and Space Sciences (CASS/Australia Telescope): ~150



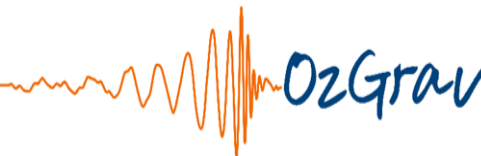
537
People

Figure 4.1: Graphical summary of the primary roles of Australian astronomers according to the survey data gathered in 2014



Australian Astronomy

- Acknowledged by government as the leading national research effort in the non-health sciences.
- Amazingly cohesive community
 - Legendary for united public face
 - Decadal plans
 - Mid-term reviews
- Periodic investments in major research infrastructure
 - Parkes 64 metre telescope (~50M) – 1960s
 - Anglo Australian Telescope (~50M) – 1970s
 - Australia Telescope (~60M) – 1980s
 - Australian SKA Pathfinder + site (~200M) – 2010s
 - Giant Magellan Telescope (~100M) – 2010s
 - SKA (300M) – 2010s
 - ESO-lite (110M) – 2010s
- Universities also invest in infrastructure



Astronomy Infrastructure Spending

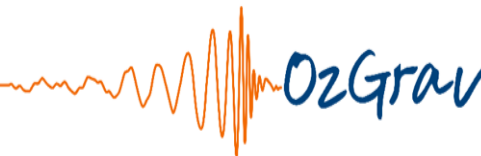
- Total circa 90M/year
- ESO 11M/year
- AAO 5M/year
- CSIRO 35M/year (Parkes, ATCA, ASKAP)
- Astronomy Australia Ltd 9M/year
- Giant Magellan Telescope ~10M/year
- Update numbers



Case Study: The Square Kilometre Array

- Radio Astronomy received ~500M in Australian government funding
 - Australian radio quiet reserve
 - ASKAP telescope
 - 300M to site SKA-low?

HOW???

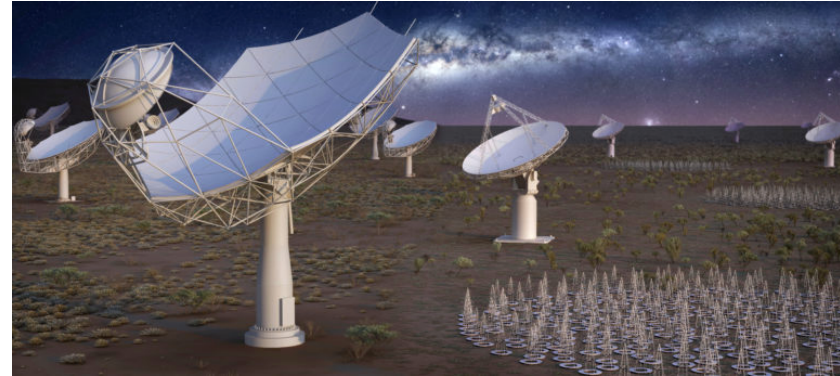


The SKA – What is it exactly?

- Original concept:
 - Billion-dollar radio telescope with a collecting area of 1 km²
 - DC to daylight! 50 MHz – 50 GHz
 - Conceived by astronomers more than engineers
 - 15-year engineering R&D effort
 - Concepts:
 - Dielectric spheres
 - Balloons + active surface
 - Parabolic Cylinders
 - Dishes – Large N-small D concept
 - Dipoles
 - Phased array feeds
 - Science case developed
 - Moore's law drove down costs
 - Price of metal virtually unchanged



Finally “SKA-1” and “SKA-2”



- SKA – 1
 - SKA-mid and SKA-low
 - Cost cap = 680 M Euros
- Concentrating on Pulsars and the Epoch of Reionisation
 - Was Einstein Right? Pulsars are sensitivity limited objects
 - The first stars? Can't get dynamic range to do EoR easily
- SKA-mid
 - 192 x 13.7m dishes = (0.03 SKA)
- SKA-low
 - 128,000 dipoles ~ (0.1 SKA)



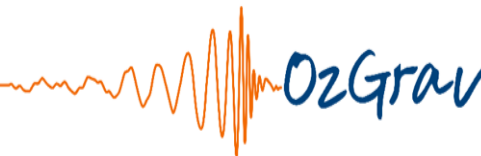
SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Choose your local minisite



- Australia
- South Africa
- UK
- The Netherlands
- ~~Germany~~
- China
- India
- New Zealand
- Canada
- Sweden
- Italy



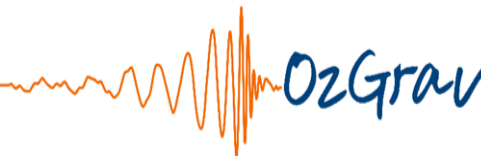
Site Selection Process

- Wanted:
 - Southern Hemisphere location (Pulsars are mostly Dec<0)
 - Radio Quiet Location
 - Low winds/infrequency storms
 - Away from ionospheric issues (South Atlantic Anomaly)
- A local engineering/science base
 - History of radio astronomy
- Stable government, economy
- \$ from Host government

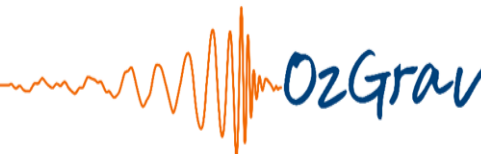
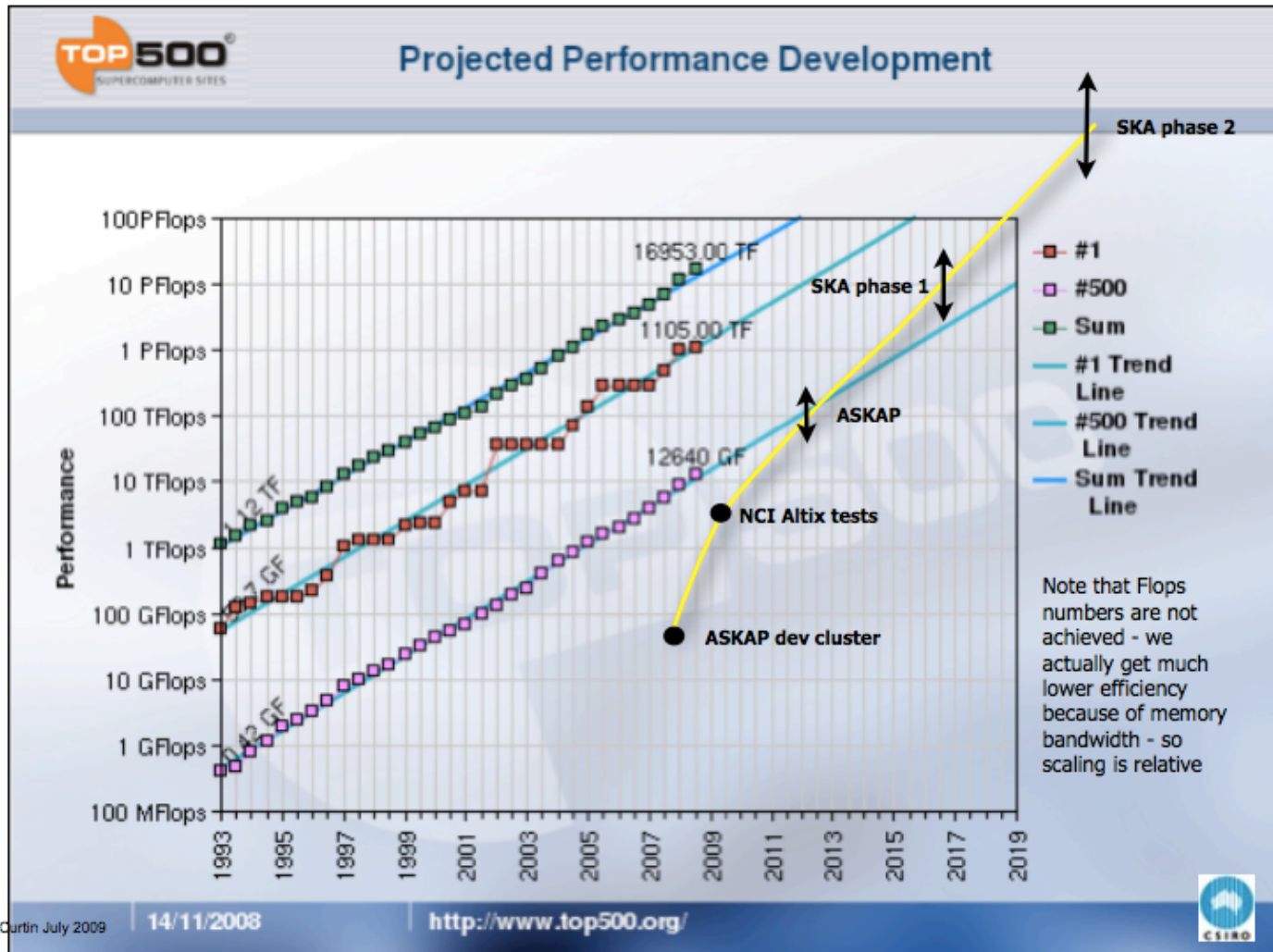


The Political Arguments

- CSIRO
 - Next “logical” radio astronomy project
- Astronomy Community
 - Could see the advantage of a billion dollar project built upon “local soil”
 - Significant fraction (30-40%) were radio astronomers
 - Achieved “joint billing” with ELT in decadal plan
 - No way an ELT will ever be built in Australia – no decent sites
- State Governments
 - Major infrastructure project in the state
 - Jobs and growth
- Federal and State Governments
 - STEM-friendly, STEM “crisis” in youth
 - Billion AUD \$ OS investment
 - SKA requires major ICT R&D “climbing Mt Exaflop” – next “WiFi”?
- World-class Science
 - Next Nobel Prizes

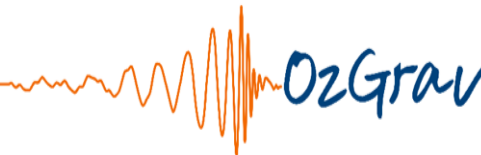


Climbing Mount Exaflop



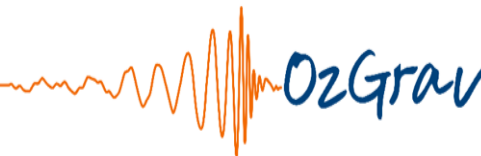
SKA Issues

- Site determined so late both Sth Africa and Australia mortgaged to the hilt
 - 200M invested in both sites – *too big to fail!*
- A telescope dimension in search of a science case not vice versa
 - The name plagued the engineering
 - Initial science cases irrelevant without 10x budget
- Costings had a ridiculous degree of optimism
 - Pushed by astronomers not engineers – *Moore's law applies to everything!?*
- Running costs
 - Most moveable telescopes cost circa 10% capital to run per year

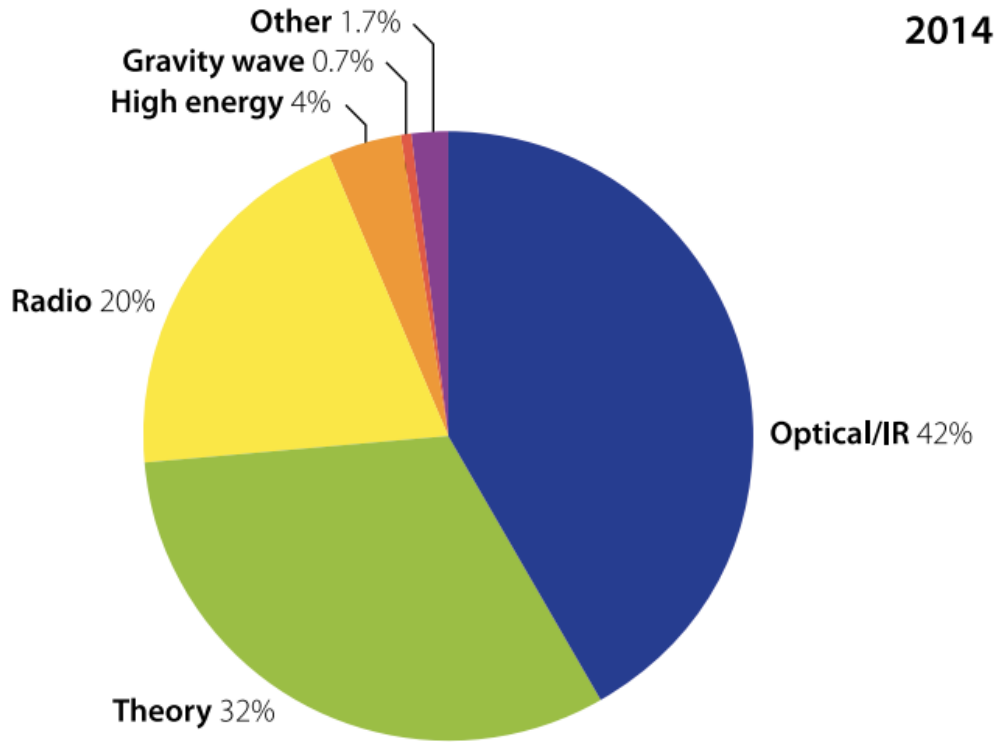


A 3G Detector for Australia?

- Global Site:
 - If we want to localise GWs, best to maximise distance from other sites
 - 1 x Europe (UT + 2h)
 - 1 x USA (UT – 6h)
 - 1 x Southern Hemisphere? (UT + 9h?)
- Australia as a Site:
 - Geologically sedate
 - Dry
 - Land is cheap and often with a low population density
- Culturally:
 - Politically stable (25 years without a recession)
 - Existing GW community
 - Likes science, STEM

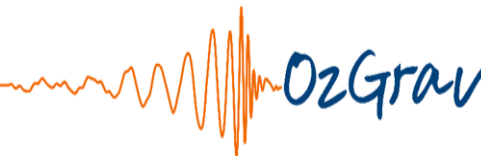


GW Research in Australia by citation



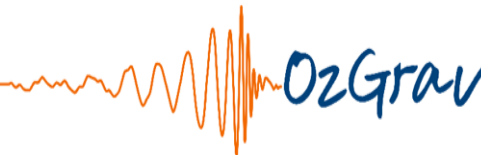
Cons:

- For the SKA Australia pays a premium to be a “host”
 - Complicated negotiation, GDP, #IAU members, GNP, host country benefits
- Australia has to “pick and choose” its “pure science” investments carefully
 - Government not running a fiscal surplus at present
 - What is a 3G detector’s “spin-off” appeal beyond construction?
 - What is 3G’s “Mt Exaflop”?
 - The SKA has not delivered a “river of gold” (as yet)
- What are the running costs of a billion-dollar facility?
 - If Australia required even 20M/year that would be a significant issue.
- GWs in Australia do not have the astronomical community’s support for a large capital investment nor occupy positions of strong political power and influence



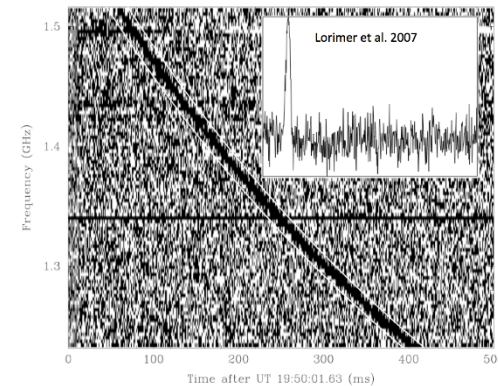
3G and SKA – what's to learn?

- Science needs to drive the apparatus dimension
 - not the other way around
- Global partnerships appeal greatly to some governments but the US likes to control/lead projects
 - ALMA highlighted cross-cultural issues
 - TMT, GMT all face funding issues
- Site selection has to take place very early
- “We’re going to find the unexpected” is a poor argument



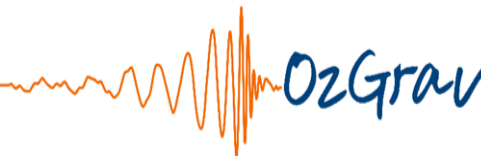
Fast Radio Bursts vs GW bursts

- Unexpected “radio bursts” of duration 0.1-few ms.
- Probably trace the star formation rate
- Only 30 known, 6 years until the 2nd one found
- New ones are often “boring” in isolation
- Now people want to know:
 - Which galaxy they come from?
 - Count the free electron content of the universe – missing baryons etc.
 - What causes them?
 - If we have 1000s, can we do cosmology?



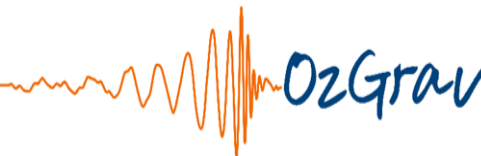
GW Science case weak points

- I build detectors and I want to build another one
- GR might well very well work
- 100 Mpc isn't very far
- Confirming other people's science isn't very interesting
- GRBs already provide optical/radio triggers to ns+ns mergers
- We know the Hubble constant already
- Calibration to $< 1\%$ is always hard
- If you wait long enough, aLIGO will get a very high SNR event and a ns+ns merger, ns+BH merger



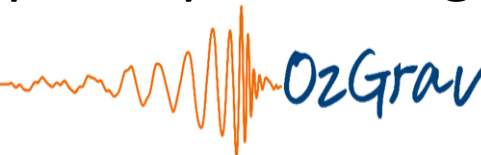
3G GW Science strong points

- Gravity at its most extreme
 - Was Einstein right?
 - Quantum gravity etc
- Watching neutron stars get ripped apart
- Possibly early asymmetry of neutron stars
- Possibly CW sources
- Seeds of supermassive BH?
- Stochastic background



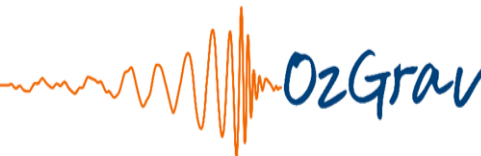
For Australia to host a facility:

- Need a well defined international project and partners and a brand name (eg IGWOO) – SKA was a 20+ year crusade
 - eg 3 global detectors, 50 year operational lifetime, target budget, global R&D process
- Need to grow the number of GW astronomers in the country/Universities involved in GW science – currently 15% of astronomy – *publication model fails youth*
- Need a science case not a sensitivity limit to promote IGWOO's place in the Australian decadal plan
- Need economic impact/spin-off arguments



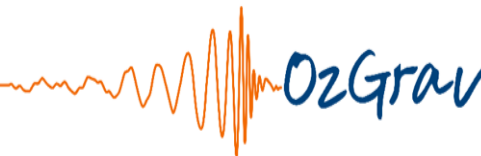
Alternatives:

- An “Asian” 3G detector
 - Growing international scientific powers – eg China etc
- An “Asian” 2G+ detector
 - “AAGO” – Blair et al. 8 km arms, aLIGO tech
- Philanthropy
 - “Breakthrough” model



OzGrav's 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.



OzGrav Opportunities

- 600K to engage in 3G engagement!
- Launch this November – federal minister present
- PhD places (>50)
- Postdocs – Many open positions GW data processing
- 3G Science case
 - Sabbatical@Swinburne \$\$\$ - dedicated postdoc/ ECR?
- 3 Pflop supercomputer
- ARC Future Fellowships
 - 4 year research only
- ARC Laureate Fellowships
 - 5 years, +4 postdocs, very generous salary
- Tenured positions (forthcoming)

