Gravitational-wave astronomy: capabilities & opportunities

The birth of a new field

The past four years have seen a scientific revolution through the birth of a new field: gravitational-wave astronomy. The first detection of gravitational waves (GW150914)—recognised by the 2017 Nobel Prize in Physics—provided unprecedented tests of general relativity while unveiling a previously unknown class of massive black holes, thirty times more massive than the Sun. The subsequent detection of gravitational waves from a merging binary neutron star (GW170817) confirmed the hypothesised connection between binary neutron stars and short gamma ray bursts while providing an independent measurement of the expansion of the Universe. The discovery enabled precision measurement of the speed of gravity while shedding light on the origin of heavy elements. At the time of writing, the Laser Interferometer Gravitational-wave Observatory (LIGO) and its European partner, Virgo, have announced the detection of more than twenty gravitational-wave events. This fast-growing transient catalogue is expected to yield insights into a number of topics, from the equation of state of matter at supra-nuclear densities to the fate of massive stars.

Current capabilities

1. Australia's eminence in the global gravitational-wave community has been facilitated through a series of LIEF grants, establishing *partnership* status in the LIGO Scientific Collaboration. This funding enables Australian contributions to the upgrade of the LIGO facilities. It also covers the cost of membership, enabling Australian researchers to lead analysis of LIGO data.
2. The construction of the OzStar computing cluster, 30% of which is devoted to gravitational-wave astronomy, has provided computational resources for ambitious new projects.
3. The new $2M NCRIS Gravitational Wave Data Centre leverages the OzStar cluster by providing the personnel necessary to maintain software and database systems required to host and process large volumes of gravitational-wave data.
4. Australian gravitational-wave astronomy is strengthened by leadership in pulsar timing, which seeks to detect gravitational waves at nanohertz frequencies. Our current capabilities in the area include strong programs at the Parkes Observatory and MeerKAT telescopes that have strong synergies with LIGO.

Opportunities and priorities

1. As the current generation of gravitational-wave observatories drive a revolution in astronomy, the global community is looking forward to "third-generation" (3G) observatories. The science potential of 3G observatories is enormous, enabling measurements of gravitational waves from the edge of the Universe and precise determination of the neutron star equation of state. Australia is well-positioned to develop technology required for the measurement of high-frequency gravitational waves needed to yield insights into the nature of nuclear matter at extreme densities. **The mid-term review should prioritise an Australian Gravitational-Wave Pathfinder that develops and validates core technologies required for the**

global 3G detector network. This pathfinder will put Australia in position to host a major facility while creating the technology necessary for the global 3G network.

2. **The midterm review should prioritise support for the Gravitational Wave Data Centre above the current funding levels through 2026, including the establishment of a LIGO Tier-2 data centre.** This support will enable Australia to consolidate the increased influence gained since the detection of gravitational waves, while growing capacity for gravitational-wave analysis of data with radio telescopes such as the SKA.