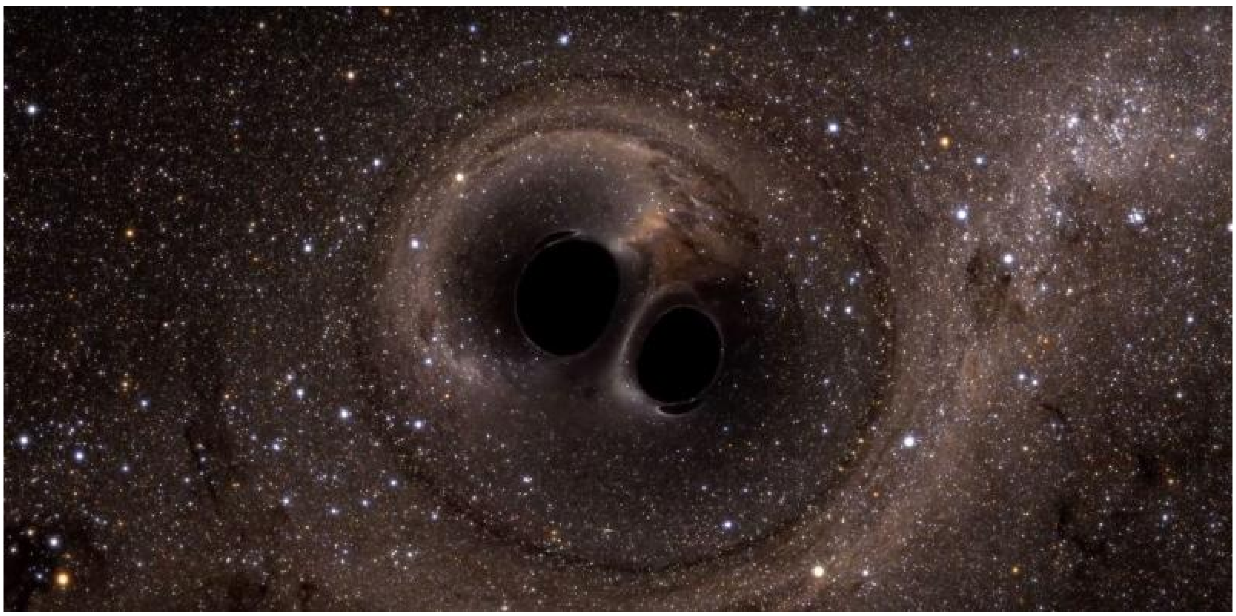
Australia to embrace the new era of gravitational wave astronomy

September 13 2016, by Matthew Bailes



Gravitational waves are produced by some of the most extreme events in the universe. Credit: NASA/SXS Lensing

Four hundred years ago Galileo pointed a telescope at Jupiter and saw electromagnetic waves (light) being reflected off its moons.

This profound observation displaced Earth from its position at the centre of the universe to just one planet among many. It also sparked a new golden era of optical astronomy, which continues to this day.

In September 2015 the Advanced Laser Interferometer Gravitational-Wave Observatory (aLIGO) detected the gravitational waves emitted by two coalescing black holes. This remarkable discovery opened up a new window on the universe, using gravitational waves rather than electromagnetic waves to peer into the far reaches of the cosmos.

A little before aLIGO's successful detection, I was invited to put together a team to bid for an Australian Research Council Centre of Excellence for Gravitational Wave Discovery, to be known as "OzGRav".

Centres of Excellence are a scientist's idea of funding nirvana because they provide guaranteed funding for seven years. So instead of writing annual grant applications with a slim chance of success of getting a fraction of what you asked for, you can plan and execute a serious scientific agenda with critical mass.

But the competition is fierce, and the chances of success are small, and funding rounds are only held every three years or so. To be successful, Centres need bold visions and ambitious objectives.

Our main problem when we submitted our pitch was that no-one had detected gravitational waves yet, and we were relying on the promise of new instruments like aLIGO to deliver in an area that was still void of positive results.

But unbeknown to any of us, the enormous burst of gravitational waves from GW150914 was *en route* to Earth and due to strike it just two months after our initial application was submitted.

The gravitational waves were generated more than a billion years ago when two enormous black holes merged after a death spiral. And shortly after the aLIGO gravitational wave detector was turned on it saw the characteristic "chirp" as space time shook during its passage.

Many of my OzGRav team had aided in the construction of aLIGO, and its precision is mind-blowing. When the first source of gravitational waves ever detected (GW150914) were impacting the four kilometre long arms of the detector, they shook by the equivalent of less than the width of a human hair at the distance of the nearest star!

So when our grant was being assessed, gravitational waves were still just a twinkle in the scientific community's eye. One of our assessors even made it very clear that physicists were always promising to detect gravitational waves but none had been found.

With some luck we were selected to submit a full proposal; one of only 20 teams to do so.

By this time, many of my collaborators were fully aware that the first gravitational waves had been discovered. But they were bound by the strict rules of the LIGO Scientific Consortium that prohibited them from telling me (the proposed Director of the Centre) or putting this news in our proposal, or the rejoinder. It must have been killing them.

All we could say was the data were looking really exciting!

Fortunately for us, the discovery of gravitational waves was announced just prior to the interviews of the final 20 Centre of Excellence teams, and many of my team were invited to parliament house to describe their role in the discovery.

Last week we heard that we were one of the nine Centres fortunate enough to gain funding. I'm certain this is at least partly attributable to the fact that a billion years ago in a galaxy far, far away, two black holes, some 30 times the mass of our sun tore each other apart, releasing gravitational waves in the process.

The impact of this discovery has been remarkable. In only six months the discovery paper has already gathered 641 citations. Another black hole merger event was published by the LIGO consortium in June and the (now) "telescope" is gearing up for its second major run after some tweaks to its hardware that seems certain to discover more events.

Our role

OzGRav has three major themes that will be driving its research programmes: instrumentation, data and astrophysics.

The instrumentation behind these gravitational wave detectors is truly remarkable. OzGRav scientists will aid in the enhancement of aLIGO so that it is even more sensitive, using amazing tricks such as quantum squeezing. We will also help design and ultimately construct the next-generation detectors that aim to detect thousands of events per year.

To minimise the possible locations of these events, it would also make a lot of sense to build one of these new detectors in Australia.

But aLIGO isn't the only detector capable of discovering gravitational waves. Radio astronomers can use neutron stars (pulsars) that rotate many hundreds of times per second to sense "disturbances in the space-time continuum" induced by the gravitational waves coming from super-massive black holes.

OzGRav engineers are currently designing the supercomputers that will monitor dozens of these stars using the Square Kilometre Array. The CSIRO's Parkes telescope is also having a powerful new receiver fitted to continue its leading role in this area of science.

Swinburne University of Technology will host the Centre headquarters and design a supercomputer custom-built to process the data coming from the gravitational wave detectors.

These data will be processed to look for not just merging black holes, but also neutron stars. And the closest neutron stars will be monitored to see if tiny "magnetic mountains" on their surfaces cause them to generate detectable gravitational wave emission.

OzGRav's astronomers will also use a network of telescopes at traditional frequencies (optical and radio) to search for evidence of gravitational wave events at other wavelengths to help identify the host galaxies (or lack thereof?) to help understand where the sources of gravitational waves come from.

Finally, our astrophysicists will attempt to explain what our detectors see, and whether Einstein's theory of general relativity is correct or needs some tweaks.

Fortunately Australian scientists can fully engage with this new window on the universe and participate in the first decade of this exciting new era of gravitational wave astrophysics thanks to the Australian Research Council's Centre of Excellence programme.

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