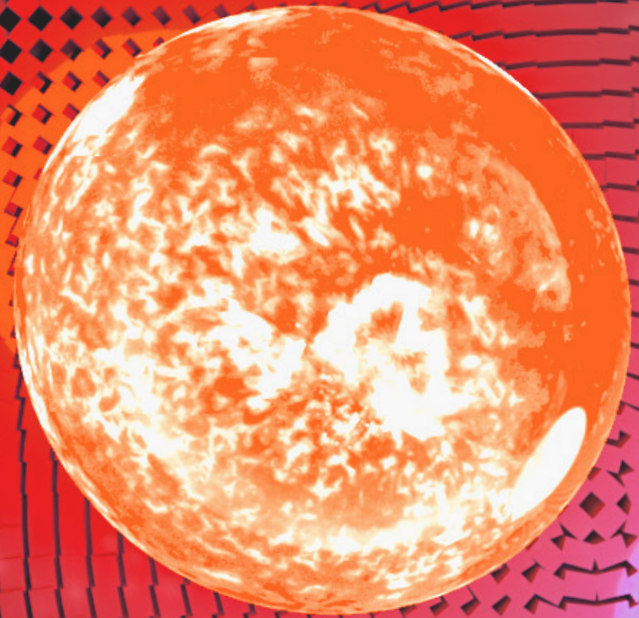


SPACE TIMES

 OzGrav — Bi-monthly newsletter
August 2019



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Welcome

Welcome to the latest edition of the refreshed and relaunched OzGrav newsletter!

In putting this edition together, we were delighted to see many recent OzGrav accomplishments garnering media attention, as well as a few prestigious prizes being awarded to our members. Congratulations to everyone who has been working hard to disseminate our science to colleagues and the public, and the Einstein First team landing a large Linkage grant.

LIGO/Virgo's third observing run (O3) is now in full swing and the Universe is not letting us down with events happening about once a week! It seems hard to believe that just a little less than four years ago gravitational waves had yet to be discovered, despite almost a century of the development of the theory and experimental techniques. Recently I heard someone exclaim 'just another black hole binary!' Such is the nature of science. It's nice to

see the increased range of the detectors in O3 which are partly due to OzGrav's Instrumentation team's efforts on the squeezer and trips to the sites by our node members and plenty of results for the astrophysicists to sink their teeth into.

This has really been the decade of the black hole—first with LIGO's discovery of 30 solar mass binaries and then the Event Horizon Telescope (EHT) making the historic first image of the shadow of a supermassive black hole. I was particularly thrilled to learn that the DiFX software correlator used in the EHT image was written by one of our own Associate Investigators, Adam Deller, back when he was a PhD student. Adam's team recently won the Peter McGregor prize for instrumentation for DiFX, but a greater feeling of joy must have transpired from seeing the image of M87's black hole.

On the pulsar front, the MeerKAT telescope in South Africa is firing on all cylinders and the 20-year campaigns from Parkes have produced some big pulsar results, which we will report on in future newsletter editions. Adam

Deller and Postdoc Researcher Ryan Shannon have had their FRB discoveries highlighted in Science and Nature papers since our last newsletter.

On the personnel front, Chief Investigator Ilya Mandel has commenced his position at Monash and is building a strong team, and ANU has been conducting interviews for a new gravitational wave position. Associate Investigator Paul Lasky has also moved to a tenured position at Monash. This field has a bright future.



OzGrav Director - Matthew Bailes

News in brief

- OzGrav was delighted to receive a Bronze Pleiades Award for commendable efforts in implementing and promoting an equitable workplace.
- Congratulations to OzGrav Associate Investigator Adam Deller and the Distributed FX Correlator (DiFX) team on receiving the Peter McGregor Prize awarded by the Astronomical Society of Australia (ASA).
- Congratulations to OzGrav PhD student Isobel Romero-Shaw for being awarded 'Best student talk' by ASA.
- Congratulations to OzGrav PhD student Jyoti Kaur who was recently interviewed on [ABC Radio's The Science Show](#), with Robyn Williams, about her work with young school students learning Einsteinian physics.
- The Annual OzGrav climate survey has officially launched. This will be an important way for all our members to provide feedback on strengths and weaknesses in the centre, so that we can make improvements to benefit our members.



Editor-in-chief: Luana Spadafora
Submit your contributions to lspadafora@swin.edu.au

Adelaide's AMIGO demonstrates space-time warping

The Laser Interferometer Gravitational-Wave Observatories (LIGO) are the world's largest gravitational wave observatories and a marvel of precision engineering. First predicted by Albert Einstein a century ago, gravitational waves are ripples in space-time.

LIGO was responsible for the first direct detection of gravitational waves in 2015 and this led to the 2017 Nobel Prize in Physics being awarded to the three of the co-founders of the LIGO experiment. The LIGO detectors consist of two interferometers spaced 3,000 kilometres apart in the US. Each L-shaped facility has two four-km arms positioned at right angles to the central building. Lasers traverse along each arm and bounce back from mirrors and, by exploiting the wave nature of light, these ripples in space-time can be detected. The sensitivity of these devices is such that scientists can measure a change in length as small as 1/10,000 the width of a proton, representing the incredibly small scale of the effects imparted by passing gravitational waves. Essentially, LIGO can be thought of as ears listening for gravitational waves, or even as a skin trying to feel the slightest of movements.

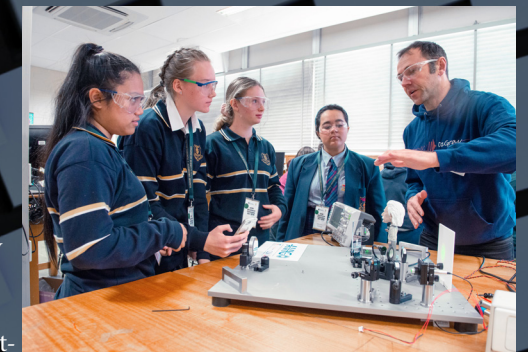
Students from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) in Adelaide, have developed a 'mini LIGO' dubbed AMIGO (Adelaide's Mini Interferometer for Gravitational-wave Outreach) through the generous support in part by OzGrav and the University of Adelaide. They use AMIGO to demonstrate the properties of light and principles of precision measurement to students of all ages. Craig Ingram, a post-graduate student at the University of Adelaide said: 'Many [students] would normally run a mile if you tell them that you were going to talk to them about physics. Instead [with AMIGO] we end up with the students wide-eyed and engaged.'

In the 12 months since the outreach program started in Adelaide, the researchers have delivered the program to thousands of students across the country. This includes a highly successful

exhibition at the World Science Festival in Brisbane. During this two-day event, Deeksha Beniwal and Georgia Bolingbroke—two integral members of the AMIGO outreach team—interacted with over a thousand members of the general public.

In January this year, Ingram was invited to Google X headquarters in California (home to the developers of technologies such as Google Glass and WAYMO driverless cars) to explain the fundamental properties of light using AMIGO. According to Ingram, it is only after understanding the fundamental nature of light that we can develop new technologies that Google X are investigating, such as quantum computing.

The AMIGO interferometer consists of an eye-safe laser which is split and bounced through the use of strategically placed mirrors and laser beams. The desktop AMIGO, along with less technical props like ropes, is used to illustrate the wave nature of light and '...in turn what gravitational waves are and how they are detected,' Beniwal said.



'It's a really cool way to show how the fundamentals of physics can be used to teach us about how the Universe works.'

As featured in the Adelaide Advertiser

A glimpse into the past, present and future: Hubble constant measured by neutron star fireball

The Hubble constant is one of the most fundamental pieces of information that describes the state of the Universe in the past, present, and future. It tells us how fast the Universe is expanding—a valuable piece of information in science’s search for answers.

The two best ways of estimating the Hubble constant are based on: the background hiss of the Universe left over from the big bang (the ‘Planck’ observations of the cosmic microwave background radiation) and on massive stars blowing themselves to pieces in the distant Universe (‘type Ia supernovae’ observations). According to the measurements of the exploding stars, the Universe is expanding a bit faster than the measurements of the background hiss would indicate, and the difference is now very significant. So, either one of them is incorrect or something is missing in our understanding of physics and cosmology. We’d like to know what is really happening in the Universe, so we need a third, independent check.

This is where the merger of two neutron stars can shed some light. Neutron star mergers are phenomenally energetic events—two stars, each more massive than the Earth’s Sun, whip around each other hundreds of times per second before colliding and producing an enormous blast of material, light and gravitational waves. In 2017, gravitational waves and light were first detected from a neutron star merger that had occurred 130 million years ago, in an event scientists refer to as GW170817.

Scientists realised that a burst of gravitational waves can be used as a ‘standard siren’: based on the shape of the gravitational wave signal, we can tell how ‘bright’ the event should have been in gravitational waves. We can then measure the actual brightness of the event and work

out what the distance must have been. However, this only works well if we know how the merging stars were oriented on the sky (edge on, face on, or somewhere in between).

The gravitational wave data itself can’t accurately tell whether a merger was nearby and edge on, or distant and face on. To answer that question, a team including OzGrav Associate Investigator Adam Deller used radio telescopes to take a super-high-resolution movie of a narrow but powerful jet of material left behind after two neutron stars merged in the GW170817 event. The resolution of the radio images was so high, if it was an optical camera, it would see individual hairs on someone’s head 10 km away. By examining the minuscule changes in this radio-emitting bullet of gas (compared against models developed by super-computers), the angle of the jet and the orientation of the merging neutron stars was found.

Using this information, Deller and the team could tell how far away the merging neutron stars were and, by comparing this with how fast their host galaxy is rushing away from the Earth, they could finally work out the prized Hubble constant. Despite this incredible result, which is published in *Nature Astronomy* today, the current measurement is still not good enough to distinguish between ‘Planck’ vs ‘Type Ia supernovae’. Further observations of merging neutron stars will soon lead to a more accurate Hubble constant.

“Neutron star mergers are phenomenally energetic events—two stars, each more massive than the Earth’s Sun, whip around each other hundreds of times per second before colliding and producing an enormous blast of material, light and gravitational waves.”

As featured in Cosmos Magazine, The ABC, ONET and Phys Org

Upcoming conferences

- LVC meeting 2019, 2-6 September 2019, Warsaw
- [Gravitational Wave Physics and Astronomy Workshop \(GWPAW\)](#) 14 - 17 October 2019, Tokyo
- [Yokohama-GRB meeting](#) 28 October - 1 November 2019, Yokohama
- [OzGrav ECR workshop](#) 18 - 19 November 2019, Lorne, (Mantra resort)
- [OzGrav Annual Retreat 20](#) - 22 November 2019, Lorne, (Mantra resort)
- [KOZWaves 4th Australasian Conference on Wave Sciences](#), 17 - 19 February 2020, The University of Melbourne

Upcoming prizes & awards

- [Fresh Science 2019](#) - nominations close 18 August 2019
- [The Edgeworth David Medal](#) - nominations close 30 September 2019
- [Australian Institute of Physics awards and prizes](#) - nominations now open until April 2020

Faces of OzGrav

Vaishali Adya

On my first day in 6th grade in a new school, my Physics teacher introduced me to astronomy in the form of pictures from NASA. She always went out of her way to introduce us to concepts beyond a planned curriculum. That, coupled with a course on general relativity and a talk by Prof. Bala Iyer on the LIGO detectors, motivated me to pursue a career in gravitational wave astronomy.

Moving my life from India to Germany was one of the biggest career changes for me, and now I'm a postdoc with OzGrav at the Australian National University, in Canberra. I've always liked working in a lab so naturally, I chose to work on instrumentation to play around with parameters that are crucial in the design of a gravitational wave detector. For instance, for my PhD, I worked on designing and controlling the Einstein Telescope—a future gravitational wave detector planned in Europe—and now I work on quantum noise-related experiments. I also help out with the design of OzHF: a potential gravitational wave detector planned by the OzGrav community, in Australia.

Having worked with precision interferometry for so long, it's no surprise what I enjoy doing—baking! In my spare time, I love baking all forms of cakes, cookies and other desserts. When I'm not baking, I enjoy walking and hiking around all sorts of hilly and mountainy terrains!

PS: I love Batman!



Joshua McCann

I'm a PhD student with Ozgrav, based at the University of Western Australia (UWA), studying the suppression of low frequency seismic noise in advanced gravitational wave detectors.

I became interested in science and engineering from a young age, building home projects with my dad. However, I didn't take the typical academic route to where I am now. While in my final years of high school, I couldn't concentrate and be efficient in class. So, I decided to leave school and become an electrician. I did this for 6 years, in which time I was lucky enough to work around the world on large ships. I then started working directly with the engineers for the ships. This spurred me to enrol into university where I studied electrical and control systems engineering. During my undergraduate degree, I developed a strong interest in physics (as I was not always satisfied with the approximated equations used in engineering) and as a result, added it to my studies

Once I graduated, I began working as a control systems engineer for a ship manufacturing company. Two years into this role, I found myself looking for the next challenge. I was lucky enough to find an advertisement for PhD students with the UWA Gravity Group which allowed me to combine my love of space and physics with my engineering skills. I've thoroughly enjoyed my PhD so far, and I'm excited to see where my career goes from here.

Upcoming outreach events

Particle/Wave planetarium shows

- 15 August at Science Space Planetarium, Wollongong
- 17 August at Melbourne Planetarium

SciVR talk at Mountain Goat Brewery

- 15 August at 6:30pm (Melbourne)

Harry Potter and Science Trivia Night

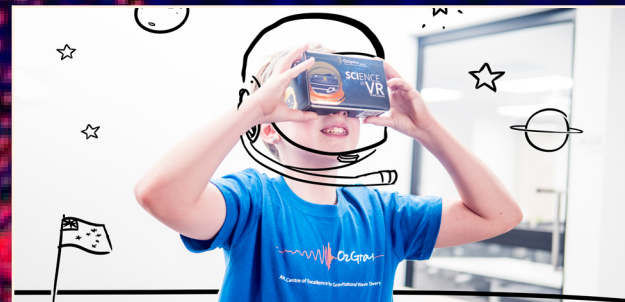
- 16 August 6:30pm (Melbourne)

SciVR Event for National Science Week, Gravity Discovery Centre

- 17 August (Perth)

SciVR live viewing parties

- 17 August 1:30pm to 3pm (or catch the livestream from home):
 - ANU Menzies Library, GDC
 - Gold Coast
 - Wagga
 - Bendigo,
 - Romsey
 - Lalor
 - Lilydale
 - Wangaratta
 - Emerald/Mt Burnett



Download the free app to your smartphone
www.scivr.com.au

Hunting for Gravitational waves

Dozens of researchers from the Australian Research Council Centre of Excellence for Gravitational Wave Discovery (OzGrav) are part of an international team of scientists making significant discoveries in the emerging field of gravitational-wave astronomy.

Gravitational waves carry unique information about their dramatic origins and the nature of gravity. In 2015, scientists detected gravitational waves for the first time and concluded they were produced during the final moments of the merger of two black holes to produce a single, more massive spinning black hole. This collision of two black holes confirmed the predictions of Albert Einstein's 1915 general theory of relativity.

In 2018, scientists detected the most massive binary black hole merger ever witnessed in the Universe. The black hole that resulted from this cataclysmic event is over 80 times more massive than the Sun. The discovery—along with evidence of nine other black hole mergers—came just over one year since scientists announced they had witnessed, for the first time, the violent death spiral of two dense neutron stars via gravitational waves. Scientists use the extremely sensitive detectors LIGO (two interferometers in the states of Louisiana and Washington, USA) and VIRGO (an interferometer in Cascina, Italy) to survey space for gravitational waves arriving at the Earth from a cataclysmic event in the distant Universe. Both these detectors have recently been

upgraded and have almost doubled their sensitivity which means that they can survey an even larger volume of space for powerful, wave-making events, such as the collisions of black holes.

One of the key upgrades to the LIGO detectors employs a technique called 'squeezing' to reduce levels of quantum noise that can mask faint gravitational-wave signals. The technique was developed at the Australian National University, and has been routinely used since 2010 at the GEO600 detector.

In April 2019, not long after the LIGO and VIRGO detectors were upgraded, there was much excitement around the world when astronomers revealed the first ever images of a black hole, created in the United States by Massachusetts Institute of Technology's Dr Katie Bouman using enormous volumes of telescope data.

Detection data streams are analysed using high performance computing at the LIGO and VIRGO nodes. Some of this data is transferred to international collaborators over research and education networks for further analysis and discovery, including OzGrav nodes at partner institutions in Australia.

OzGrav is hosted at Swinburne University in

partnership with the Australian National University, Monash University, University of Adelaide, University of Melbourne, University of Western Australia, CSIRO and the Australian Astronomical Observatory and collaborators in Europe and the USA.

Colm Talbot, an OzGrav scientist from Monash University says gravitational wave astronomy requires a global approach.

'By studying black hole collisions and other wave-making events, we act as cosmos archaeologists to understand how the Universe works. From detecting events through to analysis and discovery, working together nationally and globally improves the quality of individual tasks and leads to better research outcomes.' - Colm Talbot

Jane Gifford
Director, Marketing & Communications
Australia's Academic and Research Network (AARNet)

As featured in In The Field stories

The global search for Fast Radio Bursts continues

Fast Radio Bursts (FRBs) are one of the most puzzling astrophysical discoveries in recent years. Bursts faster than a blink of an eye (but so bright and powerful they can be seen half way across the Universe); they're thought to originate from galaxies billions of light-years away, somewhere outside the Milkyway. Scientists still don't know what causes them, but continuous investigations have revealed more clues. Before 2013, many astrophysicists doubted FRBs even existed. In the years since, researchers have invented dozens of possible explanations for what might be causing them.

'It's a millisecond burst that goes off once, unpredictably. And you have no idea when. Trying to catch that—it's hard,' says Jeff Cooke, Chief Investigator at the ARC Centre of Excellence in Gravitational Wave Discovery (OzGrav).

As part of the global coordinated search, called the Deeper Wider Faster program, dozens of astrophysicists gathered in 'the program's Mission Control room' at Swinburne University of Technology, from 24 to 29 June, to look for these radio bursts, in real-time, using telescopes that detect every possible wavelength of light.

Professor Cooke and PhD student Sara Webb, both from OzGrav, and their team of nearly 100 researchers and collaborators from all over the globe, searched for any counterparts to FRBs, along with several other fast and exotic explosions.

According to Professor Cooke, FRBs are important because they 'represent a new, very unusual, unexpected phenomenon. The bursts come from other galaxies, meaning incredible amounts of energy are required to produce them—some bursts contain more energy than our Sun produces in decades. Moreover, FRBs have the potential to be a new tool that we can use to understand the structure of matter in the Universe,' he said.

Over the six days, more than 30 telescopes worldwide and in space were coordinated to observe the same part of the sky at the same time, with a few of the world's largest telescopes prepared to

follow up the discoveries within minutes. Processing all these data and discovering these events required the use of the Swinburne supercomputer and sophisticated visualisation technology.

The telescopes involved are some of the world's best, including the Cerro Tololo Inter-American Observatory Blanco telescope in Chile, the new MeerKAT radio telescope array in South Africa, the Australian Square Kilometre Array Pathfinder in Western Australia, the South Pole Telescope in the Antarctic, and the HXMT space telescope. The Chilean telescope, equipped with the Dark Energy Camera, is ideally designed to look for visible counterparts to FRBs and other very fast galaxy events.

The team hoped that, by looking with about 64 sets of different eyes, when an FRB fired off the other telescopes would spot something hinting as to what the FRB really is. However, the team will need to revise some of the results due to problems with a telescope not providing required data—there's also a lot of turbulence in the atmosphere affecting the brightness measurements.

As featured in The Age and The Sydney Morning Herald

About OzGrav

The ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) is funded by the Australian Government through the Australian Research Council Centres of Excellence funding scheme. OzGrav is a partnership between Swinburne University of Technology (host of OzGrav headquarters), the Australian National University, Monash University, University of Adelaide, University of Melbourne, and University of Western Australia, along with other collaborating organisations in Australia and overseas.

The mission of OzGrav 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 is part of the international LIGO-Virgo collaboration. LIGO is funded by NSF and operated by Caltech and MIT, which conceived of LIGO and led the Initial and Advanced LIGO projects. Financial support for the Advanced LIGO project was led by the NSF with Germany (Max Planck Society), the U.K. (Science and Technology Facilities Council) and Australia (Australian Research Council-OzGrav) making significant commitments and contributions to the project. Nearly 1300 scientists from around the world participate in the effort through the LIGO Scientific Collaboration. The Virgo Collaboration is composed of approximately 350 scientists from across Europe. The European Gravitational Observatory (EGO) hosts the Virgo detector near Pisa in Italy, and is funded by Centre National de la Recherche Scientifique (CNRS) in France, the Istituto Nazionale di Fisica Nucleare (INFN) in Italy, and Nikhef in the Netherlands.

Website: www.ozgrav.org

Email: info@ozgrav.org

Editor-in-chief: Luana Spadafora, lspadafora@swin.edu.au