SPACE TIMES

OzGrav

May 2020

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Welcome

Welcome to the May edition of *Space Times*.

Dear Friends,

This is the second newsletter where we find ourselves under lockdown. I hope that you are taking time to maintain your mental and physical health in these extraordinary times, especially those of you with caring responsibilities.

Australia's lockdown has been exceptionally effective in preventing new cases, at least in part due to the cooperation of many levels of government and the adoption of the best scientific advice.

The OzGrav community continues to reach incredible feats despite global adversities, including: the first public release of the COMPAS rapid binary population synthesis code (page 4); a new type of deformable mirror that could improve gravitational-wave detectors (page 8); and the monitoring of space probe BepiColumbo as it passes Earth on its way to Mercury (page 3).

The lockdown's halt on travel has allowed many of us to focus on tasks that required some much needed attention—I myself completed the MeerTime system description paper that has been on my radar for too long. LIGO recently concluded its third observing run and OzGrav not only contributed to the record haul of discoveries in O3, but will also help interpret and publish the results.

I hope that you enjoy this edition of Space Times and that you get to see family and friends soon.

Regards,
Matthew Bailes - OzGrav Director

News in brief

- The OzGrav 2019 annual report is officially live! Check it out here.
- New online monthly lecture series organised by the Australian Institute for Physics (AIP). There will be at least one spot for an OzGrav member to present. If you're interested please email coo@ozgrav.org - Deadline 15th May.
- OzGrav online lecture series continuing with Isobel Romero-Shaw at 12pm AEST on Tues 12th May, and Ilya Mandel in the following week. Watch live on the OzGrav YouTube channel. Volunteers welcome! If you'd like to present your research, please contact Lisa Horsley.
- Tell us what you're up to in isolation—we'd love to share it with the OzGrav Community (more on page 10).

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

UWA Zadko Telescope helps track ambitious space mission to Mercury

OzGrav scientists from The University of Western Australia (UWA) have worked with the European Space Agency to provide continuous imaging of a space probe passing Earth while on a journey to Mercury.

The scientists used the powerful robotic Zadko Telescope in Gingin to capture imagery of the space probe, named BepiColumbo.The probe was launched in 2018 and has since completed one and a half orbits around the Sun, travelling a distance of roughly 1.4 billion kilometres.

Space probe, BepiColumbo

OzGrav postdoctoral researcher Bruce Gendre said BepiColombo would study Mercury's magnetic field and its interaction with the solar wind, offering insight into how the Earth and solar system formed.

'In order to keep the space probe on track to reach Mercury in 2025, BepiColumbo performed a "fly-by" past Earth on 10 April 2020, utilising a gravity assist manoeuvre, which reduces the amount of propellant and thrust needed to complete the mission,' said Gendre.

'Space navigation is a complex task and requires large quantities of fuel. To reduce fuel consumption and the resulting cost of the mission, space agencies often use gravitational assistance from planets.'

Due to the regional travel restrictions imposed by the WA Government following the COVID-19 outbreak, Gendre was unable to control the Zadko telescope on-site in Gingin and instead operated the telescope remotely from his home in Claremont.

'This important contribution to space research helps inspire the engineers and scientists of tomorrow, continuing the legacy of UWA philanthropist James Zadko, who passed away in early 2020,' Gendre said.

OzGrav Chief Investigator and Zadko Telescope Director David Coward said tracking the space probe represented a small part of a greater project.

'Providing ongoing assistance is part of a broader partnership with the European Space Agency to monitor the space around Earth for potential hazards, including near-earth asteroids,' said Coward.

Detlef Koschny, a European Space Agency scientist, said the Zadko Telescope was an important part of 'Providing ongoing assistance is part of a broader partnership with the European Space Agency to monitor the space around Earth for potential hazards, including near-earth asteroids,'

'Providing ongoing assistance is part of a broader partnership with the European Space Agency to monitor the space around Earth for potential hazards, including near-earth asteroids.'

ensuring the success of the mission.

'ESA's Planetary Defence Office is using this fly-by as a test for its capabilities to coordinate the observation of possibly dangerous asteroids,' Koschny said. 'In the southern hemisphere, there are not many telescopes available for this purpose.'

The Zadko Telescope is partially supported by the UWA Faculty of Engineering and Mathematical Sciences and the Australian Research Council Centre of Excellence for Gravitational Wave Discovery (OzGrav).

As featured on UWA news.

Background image from Pixabay

Scientists announce first public release of COMPAS code

Team COMPAS (Compact Object Mergers: Population Astrophysics and Statistics) has announced the first public beta release of their rapid binary population synthesis code (available for download here).

Initially, the code—co-developed by researchers from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav)—was created to explore gravitational-wave observations. Gravitational waves are ripples in space-time that radiate out from the collision of two accelerating masses, such as neutron stars or black holes. COMPAS uses models of binary stellar evolution to make predictions for the rates and properties of these collisions.

OzGrav Postdoctoral Researcher Simon Stevenson from Swinburne University of Technology says: "COMPAS allows us to understand how the binary neutron stars and black holes being observed in gravitational waves are formed."

COMPAS has since expanded to include other observational signatures of binary evolution, including Galactic Double Neutrons Stars, X-ray Binaries and Luminous Red Novae. Different observations provide new insights into gravitational-wave research and help to complete the picture of binary astrophysics.

Most massive stars are known to be born in binary systems. Interactions between companion stars alter the evolution of the stars and binary system. The physical processes involved in binary formation and evolution are currently uncertain; however, scientists are starting gain a better understanding through observations of astrophysical phenomena in different stages of binary evolution. The COMPAS code combines tools for statistical analysis and model selection with rapid population synthesis, allowing scientists to dig deeper into stellar and binary evolution.

OzGrav Chief Investigator Ilya Mandel from Monash University explains: "I am very excited that we've reached this milestone in the development of the COMPAS binary population synthesis modelling and astrostatistics code, thanks to the hard work of a dedicated group of students and collaborators. I hope that the public release will allow other colleagues interested in this topic to become involved and accelerate the pace at which we can address key questions in the evolution of binary stars."

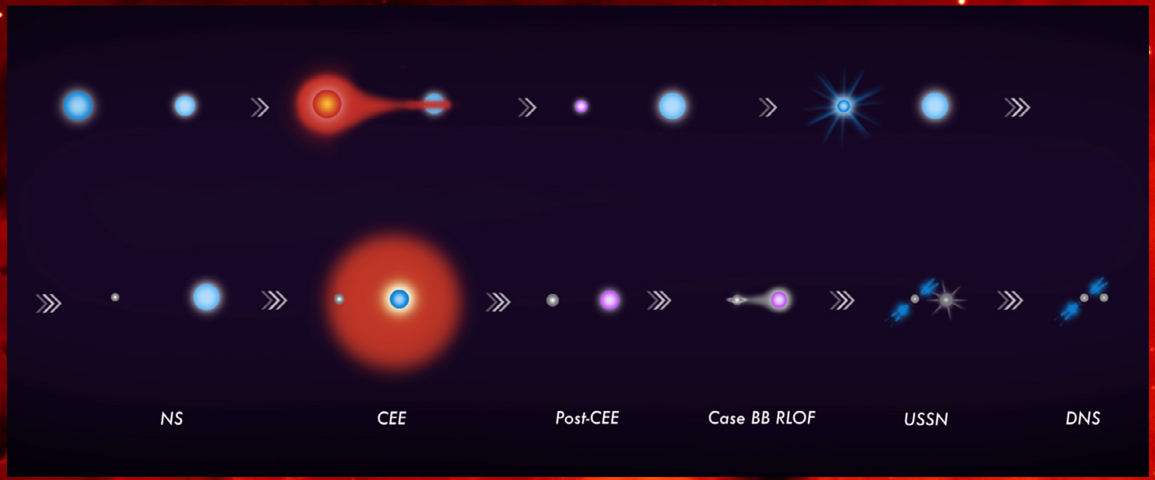
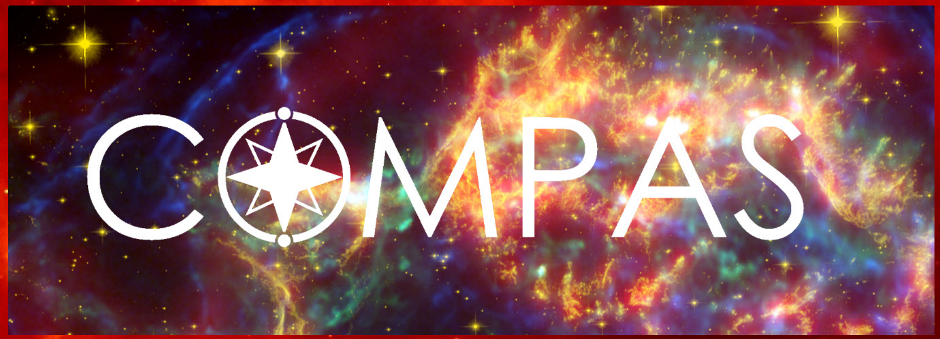


Illustration of the evolution of a massive stellar binary leading to the formation of a double neutron star. Credit: T. Rebagliato and Team COMPAS (Vigna-Gómez et al., 2020)

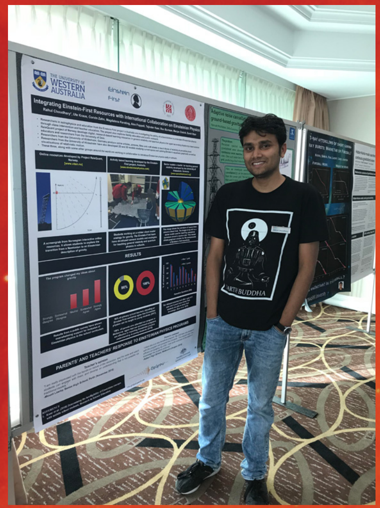
OzGray PhD student Jeff Riley from Monash adds: "A lot of people have worked hard to develop COMPAS over a number of years. I'm very happy to have contributed, and very excited about the public release – now we call all get some sleep!"

The COMPAS team encourages users to contribute and improve the code, ranging from better evolutionary models to more sophisticated emulation techniques. Please contact compas-user@googlegroups.com with any queries.

As featured in Phys.org and Space Australia.



Faces of OzGrav: Rahul Choudhary



As a child, I remember being intrigued by the very sight of books in my school library. At that time, I could not afford to buy many books, but I used to explore my town library and find as many good books as I could. Those were the early phases when I developed an interest in science. One of the most influential books I read when I was a high school student was A Brief History of Time by Stephen Hawking. This had a huge impact on me and I started exploring more about the Einsteinian world of physics. This was the beginning of my journey towards gravitational-wave science.

My interest in teaching led me to join the Einstein-First project and become a part of the OzGrav outreach team.

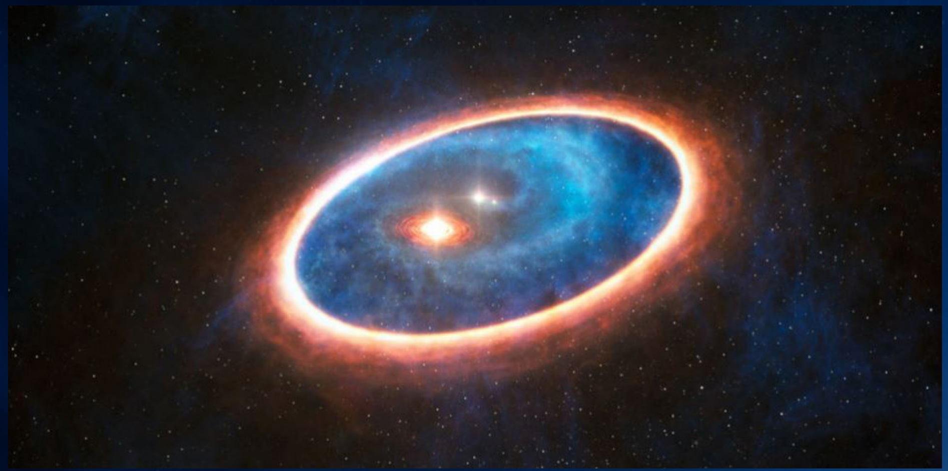
Currently, I am a Ph.D. student at the University of Western Australia developing ways for teaching Einsteinian physics to school students. I have done my Masters in Physics from Tezpur University, India.

In my free time, you will find me listening to rock music, particularly exploring prog albums. I like reading books, both fiction and non-fiction. I am also a passionate quizzer. My other hobbies include travelling and watching movies. You can connect with me on Facebook here.

Background image by Wikilmages on Pixabay

Hungry stars feed on each other in 'Be X-ray' systems

Humans have been studying the light of stars since the beginning of our history; however, we've only just discovered in the last few decades that stars don't like to be alone. Binary systems—containing two stars—represent one of the most frequent gravitationally-bound collections of stars and are probably the easiest to comprehend, although their evolution is complex..



Artist impression of a double-star system. Credit: ESO/L. Calçada

Astronomers are trying to piece the puzzle of different stellar observations to gauge the bigger picture. Using the limited understanding of binary evolution, scientists can simulate populations of stellar binaries with algorithms called stellar population synthesis codes, or COMPAS—mostly developed by researchers from the ARC Centre of Gravitational Wave Discovery (OzGrav).

OzGrav researchers, in collaboration with the Max Planck Institute of Hannover, Monash University and University of Birmingham, recently conducted a study to understand the origin of the properties of 'Be X-ray' binaries observed in the Small Magellanic Cloud.

Be X-ray binaries are star systems typically composed of a neutron star orbiting around a rapidly rotating :massive star. This rotation causes the massive star to produce a disk of outflowing material—some of this is accumulated by the neutron star. The neutron star then shoots off X-ray radiation that scientists can observe and measure.

The study, led by OzGrav Affiliate Serena Vinciguerra, applied a synthesis code to simulate an environment like the Small Magellanic Cloud. By comparing the orbital properties of the simulated Be X-ray binaries with the observed ones, researchers revealed the probable evolution of these star systems:

Initially, two stars are born in a tight binary system. The most massive star evolves quicker and expands. Because of the proximity between the two stars, the inflated massive star feeds its material to the smaller star. Over time, the massive star may feed and lose most of its mass; however, the smaller star may get too 'full' and not accept all the 'food' (material).

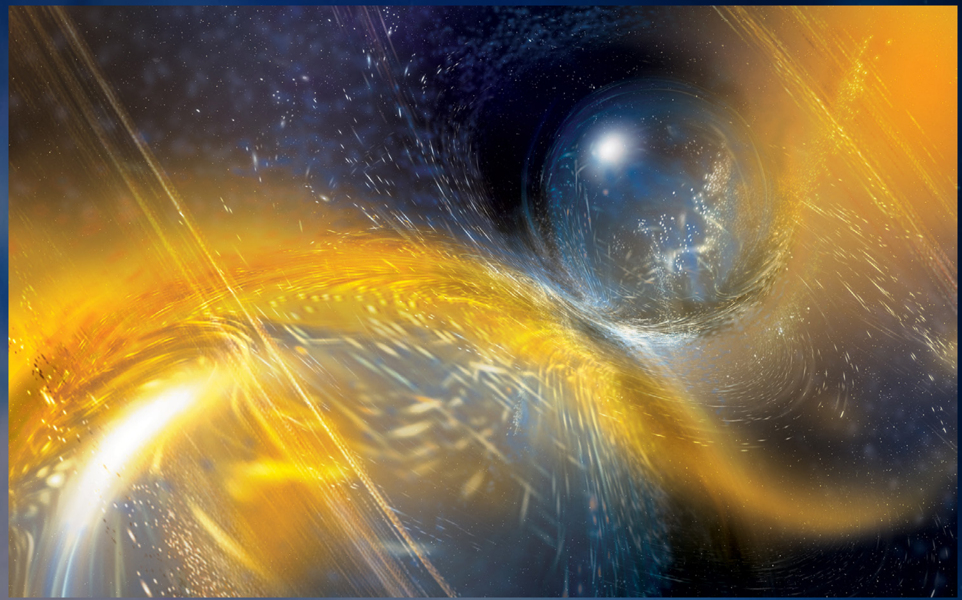
Each star's individual 'diet' depends not only on their constitution and age, but also on the massive star feeding them. In Be X-ray binaries, the stars' diets are more generous than what astronomers previously assumed. Consequently, the well-fed stars become massive and spin rapidly.

Later in their evolution, the original most massive star may explode as a supernova, leaving behind a small but very dense neutron star. If the stars survive the explosion, they form a Be X-ray system, with a neutron star orbiting a massive and rapidly rotating star.

Also featured in Space Australia.

Signatures of double neutron stars in ***radio and gravitational waves***

On the 17th of August 2017, the world of astronomy bore witness to an unprecedented event: the LIGO/Virgo collaboration recorded the vibrations of a merging pair of neutron stars. The event was observed in electromagnetic waves across the spectrum, from gamma rays, optical, ultraviolet, infrared, through to radio. The Universe was being seen and heard simultaneously, for the very first time.



Gravitational waves; Credit: Carl Knox, Swinburne University of Technology

Astronomers have discovered binary neutron stars before, as a part of pulsar surveys—pulsars are rapidly rotating neutron stars. They're the size of a city (~10km radius); have extremely strong magnetic fields; rotate up to 1000 times per second; and emit beams of radiation along their poles. As they spin, these beams may point towards the Earth like a lighthouse, allowing them to be observed by radio telescopes.

Due to their extremely periodic motion, pulsars can serve as accurate clocks to test Einstein's theory of General Relativity. All pulsars are neutron stars but not vice versa. Radio telescopes have detected pulsars in binary systems with other neutron stars (and in one case, another pulsar).

Given the dynamic and mysterious nature of binary neutron stars, a team of researchers from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) decided to study their formation, evolution and merger, examining the underlying uncertainties. In trying to investigate these mechanisms, astronomers' observations are clues to solve the puzzle.

In the study, led by OzGrav PhD student Debatri Chattopadhyay, the team used COMPAS—a population synthesis code (co-developed by OzGrav) that generates and evolves a group of isolated binary stars to create millions of isolated binaries in the supercomputer OzSTAR. It is assumed every neutron star is born as a pulsar in a supernova (a powerful and luminous stellar explosion), but magnetised pulsars, with their misaligned rotation and radio emission, slow down over time. Losing its rapid rotational motion, slow pulsars become less magnetised and eventually die; however, they can be revived with the help of their partner star.

'Under specific conditions, matter from the still-evolving companion star may fall onto the pulsar and refuel its rotation. These "zombie pulsars" start to emit radio waves again, spinning fast, but with much lower surface magnetisation,' explains Chattopadhyay.

Implementing the physics of pulsar evolution in COMPAS, the researchers modelled different binary neutron star systems and found a `best-fit' model, analysed in both radio and gravitational waves.

'We underline how the "radio alive"' pulsar-neutron star binaries may have a different signature than double neutron stars, decipherable from only gravitational wave measurable parameters,' says Chattopadhyay.

These findings provide a better understanding of binary pulsar evolution and their formation channels. The COMPAS code can also be used to study other exotic binary systems, like pulsar-black holes or millisecond pulsar-white dwarfs.

Background image by ESO/L. Calcada/M. Kommesser on Pixabay

Precision mirrors poised to improve sensitivity of gravitational wave detectors

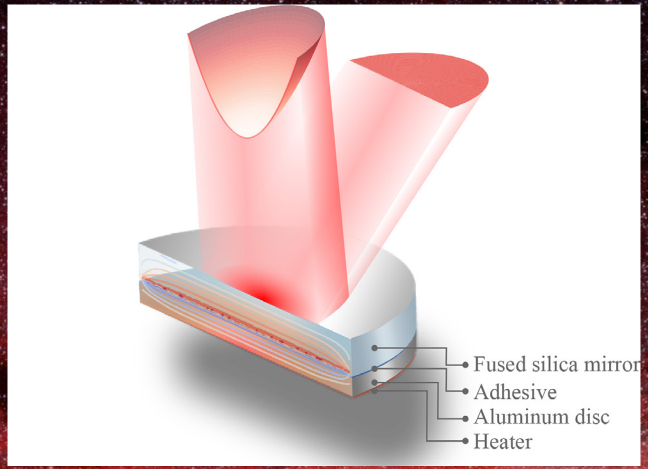
Researchers have developed a new type of deformable mirror that could increase the sensitivity of ground-based gravitational wave detectors, such as the Advanced Laser Interferometer Gravitational-Wave Observatory (LIGO). Advanced LIGO measures faint ripples in space time called gravitational waves, which are caused by distant events such as collisions between black holes or neutron stars.

'In addition to improving today's gravitational wave detectors, these new mirrors will also be useful for increasing sensitivity in next generation detectors and allow detection of new sources of gravitational waves,' said research team leader Huy Tuong Cao from the OzGrav node at the University of Adelaide.

Deformable mirrors, which are used to shape and control laser light, have a surface made of tiny mirrors that can each be moved, or actuated, to change the overall shape of the mirror. As detailed in The Optical Society's (OSA) journal Applied Optics, Cao and colleagues have, for the first time, made a deformable mirror based on the bimetallic effect in which a temperature change is used to achieve mechanical displacement.

'Our new mirror provides a large actuation range with great precision,' said Cao. 'The simplicity of the design means it can turn commercially available optics into a deformable mirror without any complicated or expensive equipment. This makes it useful for any system where precise control of beam shape is crucial.'

The new technology was conceived by Cao and Aidan Brooks of LIGO as part of a visitor program between the University of Adelaide and LIGO Laboratory, funded by the Australian Research Council and National Science Foundation.



Thermal-driven mirror for gravitational wave detectors: The illustration shows the cross-section of a thermal bimorph mirror and its constituents. Controlling the temperature of the mirror changes the curvature of the reflected wavefront. Overlaid on the cross-section is the simulated radial stress, showing a concentration of stress at the boundary of the two layers, where the adhesive holds the structure together. Credit: Huy Tuong Cao, University of Adelaide

Building a better mirror

Ground-based gravitational wave detectors use laser light traveling back and forth down an interferometer's two arms to monitor the distance between mirrors at each arm's end. Gravitational waves cause a slight but detectable variation in the distance between the mirrors.

Detecting this tiny change requires extremely precise laser beam steering and shaping, which is accomplished with a deformable mirror.

'We are reaching a point where the precision needed to improve the sensitivity of gravitational wave detectors is beyond what can be accomplished with the fabrication techniques used to make deformable mirrors,' said Cao.

Most deformable mirrors use thin mirrors to induce large amount of actuation, but these thin mirrors can produce undesirable scattering because they are hard to polish. The researchers designed a new type of deformable mirror using the bimetallic effect by attaching a piece of metal to a glass mirror. When the two are heated together the metal expands more than the glass, causing the mirror to bend.

The new design not only creates a large amount of precise actuation but is also compact and requires minimum modifications to existing systems. Both the fused silica mirrors and aluminum plates used to create the deformable mirror are commercially available. To attach the two layers, the researchers carefully selected a bonding adhesive that would maximize actuation.

'Importantly, the new design has fewer optical surfaces for the laser beam to travel through,' said Cao. 'This reduces light loss caused by scattering or absorption of coatings.'

Precision characterisation

Creating a highly precise mirror requires precision characterization techniques. The researchers developed and built a highly sensitive Hartmann wave front sensor to measure how the mirror's deformations changed the shape of laser light.

'This sensor was crucial to our experiment and is also used in gravitational detectors to measure minute changes in the core optics of the interferometer,' said Cao. 'We used it to characterize the performance of our mirrors and found that the mirrors were highly stable and have a very linear response to changes in temperature.'

The tests also showed that the adhesive is the main limiting factor for the mirrors' actuation range. The researchers are currently working to overcome the limitation caused by the adhesive and will perform more tests to verify compatibility before incorporating the mirrors into Advanced LIGO.

As featured on Phys.org, Space Connect and Science Daily

Awards and prizes

- Australian Museum Eureka Prizes - close 15 May
- The NMI Prize - close 20 May
- Walter Boas medal - close 1 June
- The AIP Award for Outstanding Service to Physics in Australia - close 1 June
- The Bragg Gold Medal - close 1 July
- The TH Laby Medal - close 1 July
- The AIP Women in Physics Lecturer - close 1 August

Virtual events

- New online monthly lecture series organised by the Australian Institute for Physics (AIP). There will be at least one spot for an OzGrav member to present. If you're interested please email coo@ozgrav.org - Deadline 15th May.
- Online GROWTH astronomy school - Aug 17-21
- OzGrav online lecture series continuing with Isobel Romero-Shaw at 12pm AEST on Tues 12th May, and Ilya Mandel in the following week. Watch live on the OzGrav YouTube channel.
- The ASA has a centralised listing of Australian astronomy presentations and seminars.

Background image by Wikilimages on Pixabay.

What we do in isolation

Here's what some of our OzGrav members have been getting up to in isolation

Our digital media officer/tech artist Carl Knox has been working on some cool animations and sketches, like these ones of his furry muse, Zen.

PhD student Shanika Galaudage has been paper-crafting—from card-making to scrapbooking! Her next project will be scrapbooking pictures of her trip to Japan in 2019.

In between fostering office plants and reading adorable books about dogs, PhD student Disha Kapasi loves dancing with people online via Cult.Fit. She's also been catching the recent meteor showers.

Postdoc Jielai Zhang enjoys spending time with her plant babies and wearing her collection of magical cat dresses around the house!

Node Administrator Sareh Rajabi has been having fun WFH with her feathered girls. But she stays on mute in zoom meetings in case of random chicken arias!

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.

The Kamioka Gravitational Wave Detector (KAGRA), formerly the Large Scale Cryogenic Gravitational Wave Telescope (LCGT), is a project of the gravitational wave studies group at the Institute for Cosmic Ray Research (ICRR) of the University of Tokyo. It will be the world's first gravitational wave observatory in Asia, built underground, and whose detector uses cryogenic mirrors. The design calls for an operational sensitivity equal to, or greater, than LIGO. The project is led by Nobelist Takaaki Kajita who had a major role in getting the project funded and constructed.

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