OzGrav

# SPACE〰TIMES

September 2023

**WHAT IS A NEUTRON STAR MADE OF?
USING CONTINUOUS GRAVITATIONAL WAVES
TO FIND OUT**

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# Welcome to the September issue of Space Times!

I hope you enjoy reading the latest edition of the OzGrav newsletter. As you'll see, there has been considerable activity within the Centre in recent months, including our involvement in a brand-new initiative: the Better Futures Innovation Challenge. This is a science-meets-industry hackathon that represents a unique opportunity to collaborate with industries and other Centres of Excellence to address real-world industry challenges to build a better future.

In addition to the important scientific results described in this newsletter, we have also been busy with our second OzGrav Winter School, kindly hosted by UWA with thanks to lead organiser Damon Beveridge for making it a great event. You can also read about a range of exciting National Science Week events where we engaged with the broader community and hopefully inspired a new generation of future scientists.

We address an important topic in these pages – women's representation in the Australian STEM curriculum. Our members' research in this area highlights the need for increased inclusivity and recognition of women scientists. On that topic, I am delighted to congratulate two of our rising star researchers, Lilli Sun and Shivani Bhandari, who received ARC DECRA awards for their exceptional research contributions. This is a testament to their talent and hard work, and the high impact of our field of research. I am also proud of OzGrav students' achievements at the Annual Scientific Meeting of the ASA, where they featured prominently in the line-up of prize winners for posters and talks.

Lastly, I am looking forward to the 2023 OzGrav Annual Retreat that is drawing near. This year's retreat holds special significance as it marks the last retreat under the OzGrav1 umbrella before we commence the new OzGrav2 in 2024. I look forward to welcoming all our members to Adelaide for this important annual gathering, where we will reflect on our achievements over the past seven years.

## NEWS IN BRIEF

– Congratulations to Lilli Sun and Shivani Bhandari for being awarded a DECRA Fellowship from the ARC!

– Congratulations to David Ottaway on being appointed the new Chair of the LIGO Program Advisory Committee (PAC).

– Thank you to everyone who completed the 2023 OzGrav member survey! This year's survey had a special focus on workplace culture and psychological safety. We were aiming for the ambitious target of over 75% of members completing the survey, and we reached an incredible 87% response rate! The survey results are now being analysed and will be shared with the Centre soon.

– Congratulations to OzGrav PhD student Natasha van Bemmel who received several prizes the ASA Annual Scientific Meeting for student poster and sparkler talk, and to OzGrav students Matt Miles, Jacob Askew and Rowina Nathan for Honorable mentions for student talks.

## UPCOMING EVENTS

– **InSTEM Conference:** 19-21 Sept, Melbourne. More **here**

– **Spooktacular Space:** 31 October, Melbourne. More **here**

– **OzGrav ECR workshop & Annual Retreat:** 13-17 Nov, Adelaide. More **here**

– **Transients Down Under:** 29 Jan - 2 Feb, 2024, Melbourne. More **here.**

–**Gravitational Wave Advanced Detector Workshop (GWADW):**12-18 May 2024, Hamilton island, QLD. More **here.**

– **Gravitational Wave Physics and Astronomy Workshop (GWPAW):** 27-31 May, 2024, Tel Aviv, Israel

Background picture: Artist's view of a supernova explosion, which drives turbulence in the interstellar medium. Credit: Carl Knox, OzGrav-Swinburne University

# INVISIBLE WOMEN: FEMALE SCIENTISTS MISSING FROM AUSTRALIAN STEM CURRICULUM

**A team of researchers have found high school science courses in Australia fail to mention the contributions of women in STEM, and instead focus on a male-centric narrative.**

The study shows Australia's STEM curriculum focuses almost exclusively on historical male scientists, with only three states mentioning a female scientist at all in their literature.

Dr Shanika Galaudage, an OzGrav affiliate researcher and former Monash University PhD student, was a co-author on this study. Having gone through the education system in Australia, she was motivated to see the narrative that was being told about contributions to science through the curricula across various states.
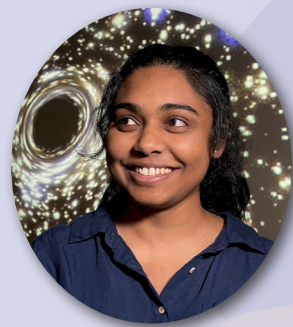
"There are many initiatives aiming to improve the participation of young girls in science subjects, so we wanted to look at the story being told about science in our classrooms," Dr Galaudage said.
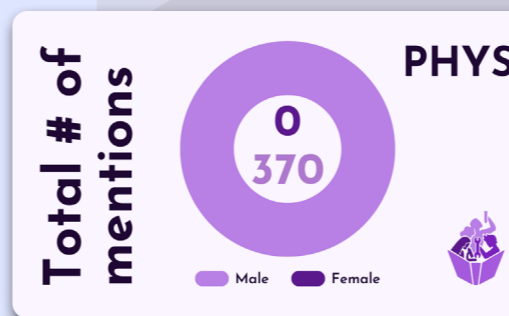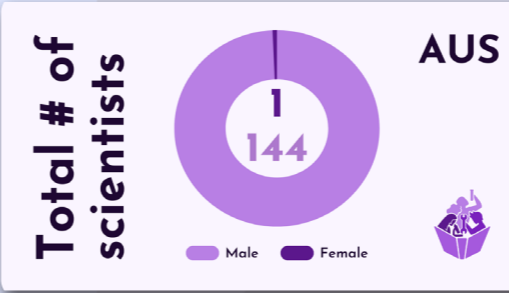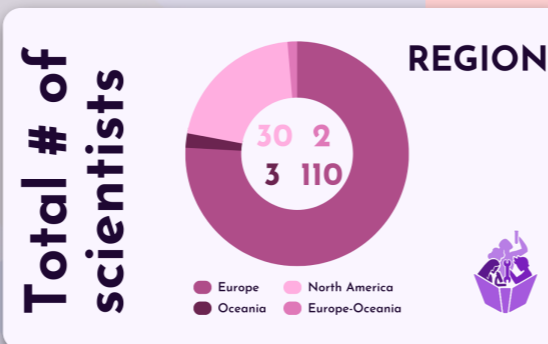
"We found that the majority of curriculums set by education departments lack any mentions of women and their contributions to science. This was incredibly disappointing to see."

*Shanika Galaudage*

Conducted as part of the IncludeHer movement, the study analysed the curriculum of four STEM subjects— biology, chemistry, physics, and environmental science.

Only one female scientist, British chemist Rosalind Franklin, was named in coursework in Queensland, South Australia and the Northern Territory, with all others exclusively referencing male scientists.



**AUS** — Total # of scientists: 1 / 144 (Male, Female)

**PHYS** — Total # of mentions: 0 / 370 (Male, Female)

**REGION** — Total # of scientists: 30, 2, 3, 110 (Europe, North America, Oceania, Europe-Oceania)

Rosalind Franklin. Illustration by Jody Hewgill for TIME

The study also found an almost exclusive focus on European discoveries and research, which could negatively impact students from culturally and linguistically diverse communities and contribute to their lower levels of self-confidence and belonging.

Dr Kat Ross said existing initiatives targeting university students and researchers take place long after perceptions of a male-focused and European-centric STEM community are established.

"For children to develop a positive sense of identity and belonging, it's important for them to have access to accurate and authentic role models related to their gender and cultural backgrounds throughout their lives," Dr Ross said.

*Kat Ross*

"It's critical this type of representation is available throughout their education to help nurture their passion and skills for the future of Australia as an inclusive STEM powerhouse."

"This approach to STEM education in the Australian curriculum could be negatively impacting the engagement of young women in the sciences at school and their desire to pursue science further," Dr Ross said.

# OZGRAV LAUNCHES THE BETTER FUTURES INNOVATION CHALLENGE



We are pleased to announce that OzGrav is a proud organiser of the upcoming Better Futures Innovation Challenge - A Science Meets Industry Hackathon.

In partnership with four other ARC Centres of Excellence - EQUS, Exciton, FLEET, and TMOS, this collaborative initiative is set to catalyse innovation and drive transformative solutions.

The Better Futures Innovation Challenge invites some of Australia's most exceptional scientific minds to converge and address real-world industry challenges through the lens of cutting-edge research. By facilitating interdisciplinary collaboration, this hackathon aims to push the boundaries of knowledge and propel our industries toward a brighter future.

To delve deeper into the Better Futures Innovation Challenge, its objectives, and how you can engage with this event, we invite you to explore the official website at www.betterfuturesaus.org

This hackathon underscores OzGrav's commitment to fostering innovation and leveraging scientific expertise for the betterment of our industries and society as a whole.

Stay tuned for further updates and exciting developments!

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## Six year study of an extreme binary pulsar puts Einstein to the test
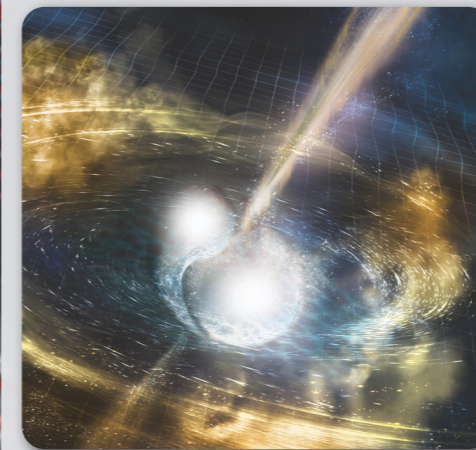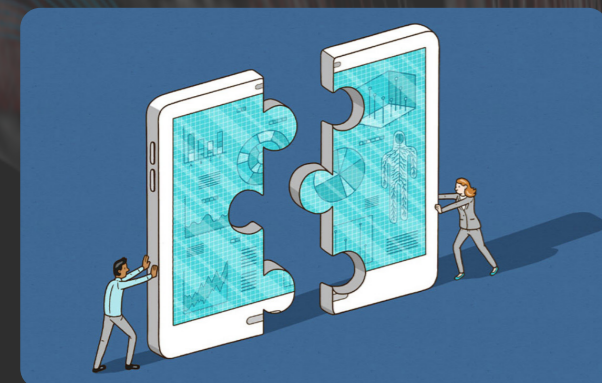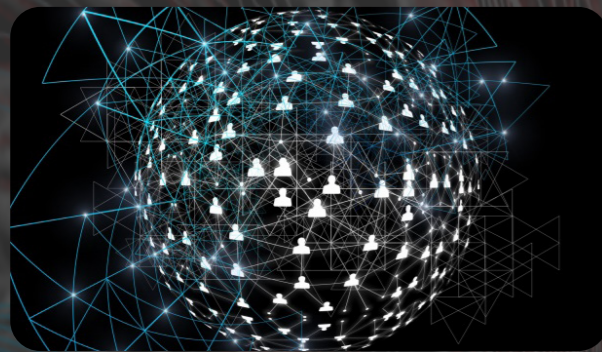


Artist's illustration of a double neutron star merger. Credit: LIGO, Sonoma State University, A. Simonnet.

An international team of researchers, led by members of OzGrav, has published a 6-year study of one of the most extremely relativistic pulsar binary systems known, utilising data from both the 100-m Green Bank Telescope and the 64-m Parkes Telescope "Murriyang" to put Einstein's General Relativity (GR) to the test.

Pulsars, rapidly-rotating neutron stars, are among the densest objects in the universe, and spin with precision akin to atomic clocks. If the pulsar is in orbit around another body, its motion causes its apparent rate of spin to change, a consequence of the Doppler effect. These changes can then be used to determine the properties of the orbit and can be used to probe the effects of relativity that emerge in these intense environments. In particular, the systems can test how the predictions of theories like GR hold up under extreme conditions.

The target of this study, PSR J1757-1854, rotates once every 21.5 milliseconds and orbits another (non-pulsing) neutron star companion every 4.4 hours. The unique properties of its short, compact orbit mean that its relativistic effects are among the most pronounced of any pulsar binary system known, with the detectable magnitude of these effects building over time.

In a paper led by Swinburne University of Technology and OzGrav researcher Dr. Andrew Cameron, and recently published in the Monthly Notices of the Royal Astronomical Society, an international team of researchers analysed 6 years of data in order to determine the new constraints on GR that have emerged from PSR J1757-1854 since its discovery by Murriyang in 2016.

A key finding was the confirmation of geodetic precession in PSR J1757-1854, a rarely-seen relativistic spin-orbit coupling effect which causes a "wobbling" of the pulsar's spin axis. This wobbling was detected in the form of significant changes in both the shape of the pulse and in its polarisation, as the part of the pulsar's emission that we see changes over time. The new detection is not yet strong enough to test GR, but was found to be consistent with its predictions. Assuming GR to be true, the researchers predicted how the profile should continue to evolve, pointing the way towards a stronger test of GR in the next few years. This latest paper also established limits on what PSR J1757-1854 can do. GR can be put to the test through measurements of the relativistic "post-Keplerian" (PK) parameters. Measurements of any two PK parameters along with an assumed theory of gravity allow for both the pulsar and its companion to be "weighed". Every extra parameter then provides a self-consistency check, which can be used to test the accuracy of the theory.

PSR J1757-1854 provides five PK parameters and should therefore provide three tests, but this latest study demonstrates that one of these tests is fundamentally limited in its accuracy due to the pulsar's unknown distance, a restriction which is unfortunately unlikely to improve in the near future. Of the remaining two tests, GR passed with flying colours.

The story of PSR J1757-1854 is far from over, and the pulsar remains the subject of ongoing study by both the Green Bank and MeerKAT telescopes. This study predicts that with more data, new tests of gravity (available in less than a handful of other systems) may be achievable as early as 2026, thanks to the pulsar's uniquely extreme orbit. The companion neutron star, which has so far not shown any evidence of its own pulses, may also tip into view at any time due to its own geodetic precession, which would open up a whole new realm of possible tests.

A D Cameron et al, New constraints on the kinematic, relativistic, and evolutionary properties of the PSR J1757−1854 double neutron star system, MNRAS, August 2023, https://doi.org/10.1093/mnras/stad1712

# OZGRAV EARLY CAREER RESEARCHER (ECR) WINTER SCHOOL IN PERTH

In July, 30 OzGrav early career researchers gathered at the University of Western Australia in Perth for the second OzGrav Winter School. This event built upon the success of last year's winter school in Adelaide to teach OzGrav's students and Early Career Researchers about the underlying physics behind all of the centre's research focuses, as well as fostering an environment for collaboration and networking.

Attendees ranged from students brand new to Gravitational Wave science, all the way to postdoctoral researchers, highlighting that it is never too late to stop learning. Through a combination of intensive learning, lively exchanges and social interactions, this event not only enhanced the scientific knowledge of the attendees but also bridged the gap in forming personal and professional connections and collaborations across the centre and around the country.

The OzGrav Winter School offered an engaging and hands-on approach to learning about gravitational waves, and the tools and skills required to undertake research in the field. The event provided a comprehensive curriculum covering topics such as detector instrumentation and noise sources, binary population modelling, gravitational wave source parameter estimation, and gravitational wave detection algorithms. Additionally, the event provided training workshops for OzGrav's education and public outreach activities, as well as a Python programming best practices workshop hosted by a team from the Astronomy Data and Computing Services organisation.

This piece was written by PhD student Damon Beveridge, OzGrav-UWA. Photo credits: Ruby Chan, OzGrav-UWA Node Administrator.

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## A formula describing how stars mourn

NASA/JPL-Caltech/STScI/CXC/SAO Animation: NASA/JPL-Caltech/Univ. of Ariz./STScI/CXC/SAO

Supernova explosions are one of the most energetic explosions in the Universe, that can outshine a whole galaxy for weeks to months. One of the main types of supernovae is called core-collapse supernova, which marks the death of a massive star: stars heavier than ~8 times our Sun. These massive stars are known to be born in pairs and groups, with one or more partner stars orbiting around them. When a supernova explosion occurs in such pairs (called binaries), the partner star cannot go undamaged.

The main impact of a supernova explosion striking another star is to heat it up, by injecting a huge amount of energy into the star. This creates a huge "blister" on the star, causing it to swell up and become much brighter and redder than it originally was. The star "mourns" for the death of its partner for years to decades in this bright and inflated state before it gradually heals and returns to its original size. The amount of time the star stays inflated strongly depends on how close the stars were when the explosion happened. The closer the stars were, the longer the period of mourning.

In this study, I created an analytical model that can predict how the companion stars respond to being struck by supernova explosions. Previously, we had to run expensive hydrodynamical simulations to predict what happens to the companion star. This makes it difficult to figure out what the distance between the two stars was, based on observations. With this new model, we can very quickly calculate what kind of binary the explosion occurred in, using observations of inflated companion stars.
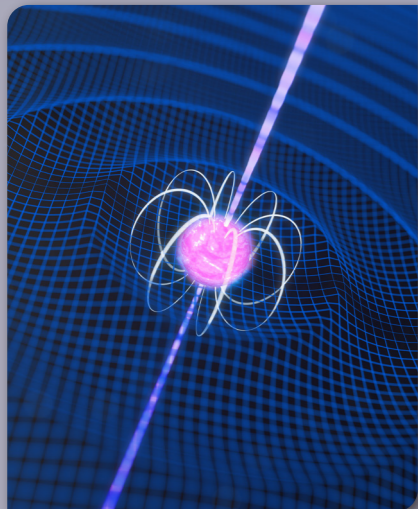
There are only a handful of supernova explosions where a companion star has been detected. Among them, 2-3 of them seem to be inflated, meaning we can use the new model to determine the masses and separations of the binaries before the explosion. This is a completely new way to infer what happened in the past, using current and future observations. If we accumulate more observations of inflated companions after supernovae, we can understand much better how stars evolve in binaries.

Ryosuke Hirai, Constraining mass transfer and common-envelope physics with post-supernova companion monitoring, Monthly Notices of the Royal Astronomical Society, Volume 523, Issue 4, August 2023, https://doi.org/10.1093/mnras/stad1856

# WHAT IS A NEUTRON STAR MADE OF? USING CONTINUOUS GRAVITATIONAL WAVES TO FIND OUT



Pulsar Gravitational Waves. Credit: Carl Knox, Swinburne University - OzGrav.

**Neutron stars are one of the most mysterious and fascinating objects in the Universe. Their interiors are one of the densest regions known, second only to the centres of black holes.**

However, unlike black holes, it is possible to directly probe the interiors of neutron stars and study the behaviour of matter and the physics that occurs under such density and pressure conditions. These extreme conditions cannot be recreated in laboratories ad makes neutron stars particularly valuable as a window to these regimes.

However, despite the scientific interest in their behaviour, very little is understood about the physics inside neutron stars. Even their name may be a misnomer; while it is expected that neutron-rich materials are within neutron stars, there may also exist a variety of other forms of matter, including hyperons, kaon condensates or deconfined quark matter. What neutron stars are actually made of is an open question.

Continuous gravitational waves may offer up key information to better understand neutron stars. Continuous gravitational waves are a type of gravitational wave that are almost constant in frequency and last for long periods of time. While continuous gravitational waves have not been detected yet, they are expected to be emitted by neutron stars which have small deformations, making them less than perfectly spherical.

In a recent paper, scientists from the Australian National University (ANU) and OzGrav members have developed a new technique that can be used to study the properties and physics of neutron stars observed with continuous gravitational waves. A key new idea explored in this research is studying neutron stars that emit both electromagnetic radiation and continuous gravitational waves instead of just considering neutron stars that only emit continuous gravitational waves.

It's found that, despite being more complex systems, it's possible to learn more about the physics and properties of neutron stars that emit energy via both mechanisms (continuous gravitational wave and electromagnetic) compared to just those that emit only continuous gravitational waves. This holds even if the neutron star is only observed with continuous gravitational waves because the observation still provides information about the unseen electromagnetic radiation and, therefore, more can be learnt about the neutron star.

Gravitational wave astronomy has already begun to revolutionise our knowledge of the Universe and the way we can "see" it. The first detection of continuous gravitational waves would be an exceptional scientific discovery. But what we learn through that discovery may be even more extraordinary. Using continuous gravitational waves, we may be able to answer the fundamental question; *what is a neutron star made of?*

## RESEARCH HIGHLIGHT

### The Sun probably does not max out its stress before every solar flare.
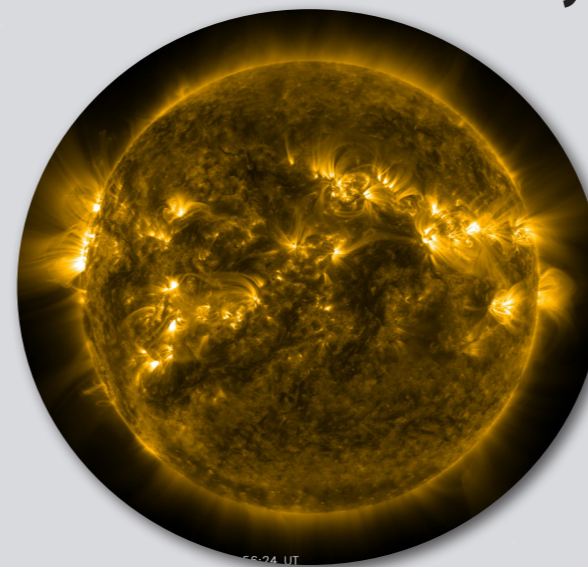


Background picture: Our sun. Credit: NASA/SDO

Do you ever get so stressed that you feel like something has to give? A pessimist might say that when you reach that threshold, sure you'll release some stress, but it'll begin to accumulate again, and the cycle will repeat. A long-standing belief of solar physicists is that solar flares also behave like this: the Sun's magnetic dynamo and fluid flows push energy into "active regions". This causes the magnetic field in these regions to become more and more stressed, until the energy density reaches a breaking point — at which point a flare is triggered, releasing some fraction of that stress and energy, restarting the process.

How do we look for evidence of this kind of stress–relax process? Well, we first build a mathematical model. We use this model to generate statistical predictions about what sorts of sequences of flare sizes, and the waiting times between flares, we should see. Then, we look for those statistics in the data!

For example, if a flare releases a large amount of stress, we should expect the next flare to take much longer to arrive, as the stress needs to build all the way up again. That is, we predict a correlation between flare sizes and the subsequent waiting times. We also predict that over the long term, we should see the same distribution of flare sizes and waiting times, i.e. the proportions of big flares and small flares should match the proportion of long waiting times to short waiting times. However, these predictions are only for if the stress approaches a threshold before every flare, and this threshold doesn't vary over time.

We analyse over 50,000 flares from the last 50 years of solar flare observations and find no strong evidence for the above correlation, or any other statistical signature of the stress hitting a threshold before each flare. This could mean a) the stress threshold varies in time, b) flare databases are missing many small flares, or c) the stress doesn't need to build up to a threshold before a flare is triggered!

What are we doing to work out which of the above possibilities are true? We can build different mathematical models, which describe different ways for the stress to build up and relax and compare those model predictions to the data. We should also reanalyse the historic data, to try and find how many small flares we may be missing. Finally, we should search for whether there are properties of active regions, such as the shape or size, which are typically associated with the few active regions that do have a large size–size-waiting-time correlation. Finding these types of active regions early on in their lifespan could help in future predictions for large (potentially dangerous) flares, but also will help us understand the physics that causes stress to build up in the first place.

# Shreejit Jadhav

As a child, I found many things around me quite intriguing and amusing. I tried constructing my own theories that turned out correct sometimes and quite funny other times. I remember feeling pretty cool when I figured out on my own why the reflections from the concave side of a spoon move in the opposite directions of actual motion. I also remember how embarrassed I felt when an older friend of mine laughed hysterically upon hearing my theory which proposed that winds move trees and lose speed; however, the motion of trees 'recreates winds' to keep them going around the globe. I often disassembled the new toys to understand how they functioned but never remember being yelled at for doing so (probably because I would also reassemble them later). I find myself fortunate that my parents made the best efforts to cultivate the love for science and logical reasoning in me and my brother. They provided us with quality education and books, and tried answering our unending questions without saying, 'Enough! Go, play now!'. I was also lucky to have several passionate teachers whose teachings inspired me to pursue science as a career. Another significant childhood influence came from Jayant Narlikar's science fiction. While reading them, hardly had I imagined that I would end up doing a PhD at the institute he established.

For my bachelor's, I took mechanical engineering but later decided to pursue my calling for a career in research. I went to IIT Bombay for my master's in physics before joining IUCAA (Pune) for a PhD, the degree I was so excited for. I got to work on gravitational-wave astronomy and machine learning, the two fields that best described my research interests even before joining the PhD. I focussed on applying machine learning techniques in the most realistic setting to target practically viable use cases. I also explored ways of improving the reliability of deep learning methods for gravitational wave searches. On the science popularisation side, I got opportunities to lead outreach activities aimed at students from rural areas and experience the delight of sharing my enthusiasm for science with these young learners.

My current postdoc position at Swinburne University of Technology allows me to further my research interests to cover GW signals from supernovae and GW detector controls. During my free time, I like reading books and poetry, listening to music, swimming, and playing keyboard. Moving to Melbourne, Australia's most culturally diverse city has been a lovely experience. I am honoured to be part of a collaboration like OzGrav, whose ethos captures a dynamic and diverse research environment of GW astronomy in Australia.

Background Image credit: X-ray data from NASA, CXC and Northwestern Univ./A. Hajela; visual by NASA/CXC/M. Weiss

## National Science Week Activities by OzGrav

Once again, OzGrav HQ was actively involved in multiple National Science Week events, engaging audiences of all ages with a variety of programs and partnerships. These are the activities we engaged in:

**• National Science Quiz Sponsorship**

OzGrav sponsored the National Science Quiz, a live and online event hosted in Melbourne by Charlie Pickering. This year, the quiz introduced a new feature, allowing schools to field teams and participate. Dr. Rebecca Allen, an OzGrav Affiliate, served as a panellist and, as a runner-up, she and her teammates were slimed at the end of the event! The NSQ website will continue to promote educational materials, including a careers page and a highlight video showcasing the work of sponsoring centres.

**• SciVR at Burley Brewing Event**

In collaboration with the Centre for Astrophysics and Supercomputing (CAS), the SciVR at Burley Brewing live event came together with a SciVR app-guided talk and a gravitational waves pub quiz! Audience members received a small VR headset to use with the SciVR app on their phones. Additionally, CAS student volunteers served as trivia captains for the audience, and the teams battled diligently to reach the top of the pub quiz podium. This event was fuelled by the Red Giant IPA, brewed and canned by Burnley Brewing, especially for this occasion.

**• #STEMLikeAPatsGirl at St. Patrick's Girls College**

OzGrav was invited to participate in the #STEMLikeAPatsGirl event hosted by St. Patrick's Girls College in Townsville, Queensland. At this annual National Science Week event, girls from schools around Far North Queensland come together for a day of STEM workshops and talks. OzGrav delivered two workshops as part of this event, sharing the wonder of neutron stars, black holes, and gravitational waves with over 50 girls from years 6 - 10. The OzGrav VR programs are always a highlight, as are the gravity well activities.

**• Powerhouse Museum Collaboration**

Powerhouse Museum invited OzGrav to be part of the Sydney Science Festival. OzGrav students Ashna Gulati from the University of Sydney and Liana Rauf from the University of Queensland helped lead VR activities with families visiting the event at Powerhouse's Castle Hill location, in Western Sydney. This was a very successful event, not only because it engaged a large and diverse audience but also because it fostered a growing collaboration between OzGrav and Powerhouse Museum.

Photo credits: Science Week and Jackie Bondell.

## ISTE Conference

The International Society for Technology in Education's Annual Conference was hosted in Philadelphia, USA in June, bringing together thousands of educators and technology specialists for four days of talks, roundtables, and hands-on presentations.

A project co-led by OzGrav's Education and Outreach Coordinator Jackie Bondell was selected for a hands-on presentation as part of this international conference. In collaboration with Prof. David Rosengrant of the University of South Florida - St. Petersburg, Jackie presented an interactive augmented reality app STEMinAR, focused on teaching students about how gravitational fields change around astronomical bodies.

This app had been beta-tested with teachers in the USA and Australia as part of the initial pilot study to look at how teachers may incorporate it into their lessons. Updates to the app have added more physics topics and will continue to fine-tune the interactives based on teacher feedback.

At ISTE, attendees trialled the app and learned about lessons that can be used in conjunction with it. Jackie was also able to highlight the body of work already developed by OzGrav, including the Mission Gravity classroom resources. Interested in trying the STEMinAR app? Email jbondell@swin.edu.au for instructions to download the beta version.

Photo credits: Jackie Bondell, Outreach Officer.

## Ningaloo Eclipse Cruise

On the 20th of April 2023, a total solar eclipse crossed over the Exmouth Peninsula in Western Australia. Thousands of people travelled from across Australia and internationally to witness this event.

The Astronomical Society of Australia (ASA) partnered with P&O Cruises to provide the astronomy education program for part of a cruise to observe the eclipse. OzGrav Associate Investigator Professor Tara Murphy from the University of Sydney was an invited speaker on the cruise, delivering a talk titled: '100 years of testing Einstein: from solar eclipses to gravitational waves'. Her talks were a major success, with over 600 people at each lecture!

The full education program for the cruise was developed and managed by OzGrav Affiliate Dr Rebecca Allen and Education and Outreach Coordinator Jackie Bondell, both in conjunction with their roles in the ASA. The program brought together ten astronomy academics, amateur astronomers, and education specialists to lead events such as lectures, pub quizzes, astrophotography workshops, and Q&A panels. This was in addition to the 'big event', the viewing of the eclipse under perfect skies!

Photo credits: Jackie Bondell, Outreach Officer.

# 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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Front cover by Carl Knox, OzGrav-Swinburne University