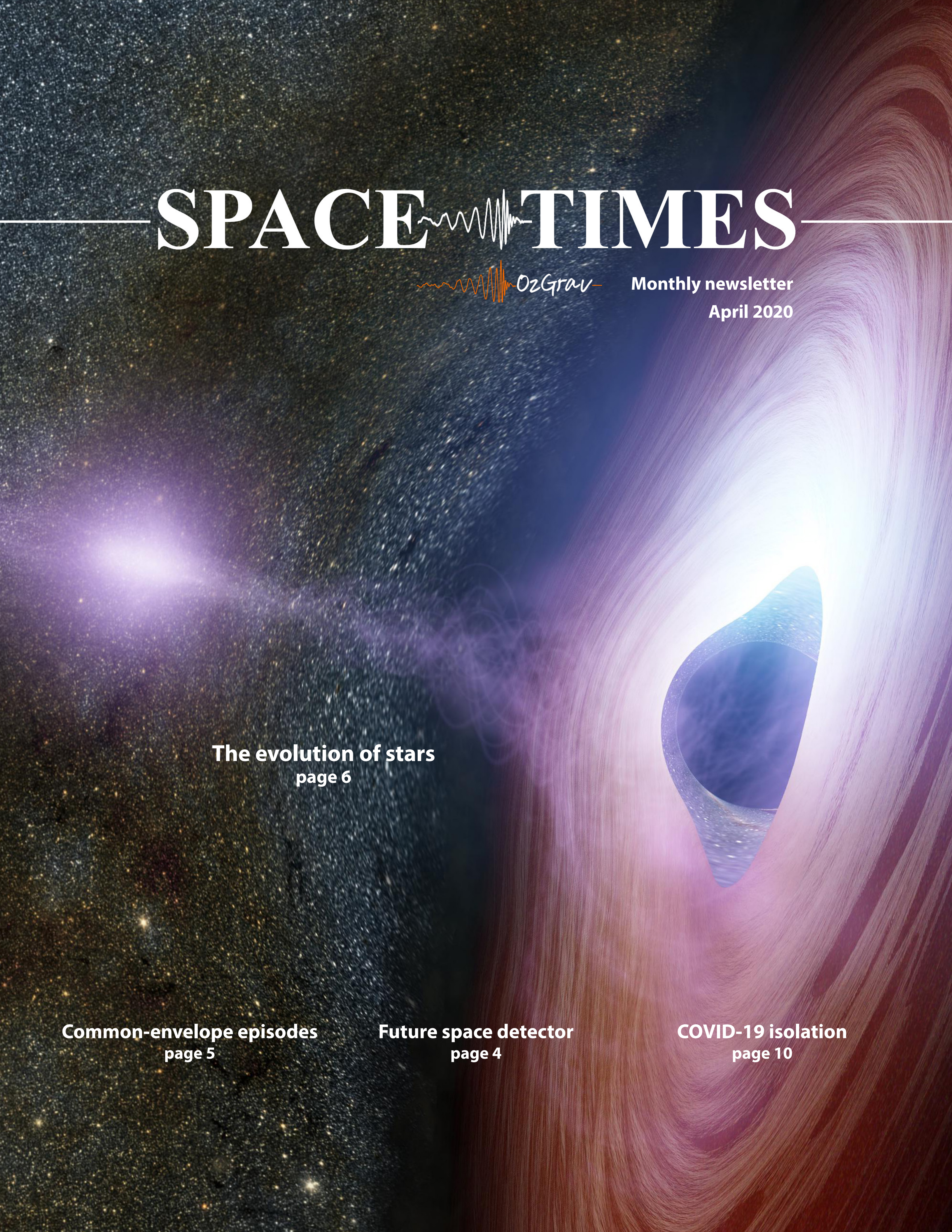

SPACE TIMES

OzGrav

Monthly newsletter

April 2020

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Welcome

Welcome to the April edition of *Space Times*

It is hard to believe the transition that has been forced upon us with the outbreak of the COVID-19 pandemic in such a short time, despite our knowledge of exponential growth! OzGrav's number one priority at this time is the mental health and well-being of our members, especially those of you from distant shores where the virus may already be well advanced and you are away from family.

We are fortunate to have built a sense of community in the three years since OzGrav's initial launch, with our regular Friday videocons, a web of scientific collaborations and our memorable annual retreats. The Directorate made the decision to increase the frequency of these electronic newsletters to help further build that sense of community during these trying times. We are also launching OzGrav's first epic documentary online, created by Carl Knox, on OzGrav's 3rd birthday as a celebration of the people and science of OzGrav. You all had a role in the creation of this Centre's identity and reputation and I hope that the documentary can be a source of pride for you, as it is for me!

I myself have been lending my team's services to the Centre for Global Health and Equity at Swinburne University, helping them to develop the databases and apps/websites necessary for their COVID-19 symptom-checker survey—Beat-COVID-19Now. This survey will be a useful source of information for governments and health professionals as they tackle this pandemic. BeatCOVID-19Now originated from a hackathon held at OzGrav HQ and now involves a range of professionals across the university and health sectors.

Please take care over the next few weeks and months, be good citizens and use your OzGrav network to get you past the curve. See you online!

Yours sincerely,
Matthew Bailes - OzGrav Director

News in brief

- The current COVID19 situation will present many additional challenges and will keep us more physically isolated from friends, family and colleagues. OzGrav encourages its members to prioritise and take care of their mental health and wellbeing. Please visit our mental health and wellbeing page for more information and resources.
- Help Beat COVID-19 Now! Use the symptom tracker app co-developed by OzGrav Director Matthew Bailes. More on page 9.
- OzGrav turns three (6 April 2020)! In celebration, we launched our inaugural short documentary 'OzGrav: A new wave of discovery'. Watch here to learn about our story and innovative research contributions.
- Congratulations to Associate Investigator Adam Deller on being awarded the prestigious Pawsey Medal by the Australian Academy of Science. More on page 8.

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

New study reveals possible formation of massive neutron stars from stellar collision

17th August 2017: a date marked down in the history books—the day the LIGO/Virgo collaboration made the first detection of gravitational waves from the death spiral of two neutron stars.

Just 1.7 seconds later, astronomers observed a short burst of high-energy gamma rays known as a gamma-ray burst (GRB). Global efforts by thousands of astronomers later identified the host galaxy and a supernova-like thermal transient called a kilonova. This event gave astronomers insight into several fundamental and important questions, including an unprecedented understanding of where gold and other heavy elements are produced in the Universe, as well as our best measurement of the speed of gravity. Among other things, it confirmed that neutron star mergers originate from short-duration GRBs. Despite the numerous observations, an important question remains unanswered. What was the outcome of this merger?

Typically, one expects the merger of two neutron stars to immediately produce a black hole—an object so dense, that light itself cannot escape; however, observations of other GRBs show evidence for the immediate formation of a massive, rapidly-spinning neutron star. Such merger remnants, if they exist, have important implications for the physical composition of neutron stars.

Neutron stars are the only place in the Universe where we can study the behaviour of matter at temperatures up to 100 billion times hotter than on Earth and densities greater than an atomic nucleus—these conditions could never be reproduced on Earth. Nikhil Sarin, Paul Lasky, and Gregory Ashton—three researchers from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) at Monash University—recently published a study analysing all short-duration GRBs observed by NASA's Neil Gehrels Swift Satellite. Out of 72 GRBs analysed, 18 show evidence for the immediate formation of a massive neutron star which later collapses into a black hole.

'Neutron stars are the only place in the Universe where we can study the behaviour of matter at temperatures up to 100 billion times hotter than on Earth and densities greater than an atomic nucleus'

Combining information from all 18 observations, the team were able to accurately describe the physical composition of these neutron stars. The results indicate that these neutron stars are consistent with having a freely-moving 'quark' composition and a composition like regular matter, i.e. composed of atomic nuclei—the building blocks of the Universe. Quarks are elementary particles that contain protons, neutrons and atomic nuclei. In regular matter, these quarks are confined inside protons and neutrons, but in the high density and high-temperature regimes seen in neutron stars, they may move around freely. Scientists must first determine the temperature and density of neutron stars to understand the movement and behaviour of quarks and matter.

'The results indicate that these neutron stars are consistent with having a freely-moving 'quark' composition and a composition like regular matter, i.e. composed of atomic nuclei—the building blocks of the Universe.'

OzGrav PhD student and first author Nikhil Sarin says: 'Our observations show a slight preference for freely-moving quarks. We look forward to getting more observations to definitively solve this puzzle'.

The research also found that, before collapsing into black holes, most neutron stars produce faint gravitational waves which are not likely to be individually detected by LIGO.

'With the construction of more sensitive gravitational-wave detectors, such as the Einstein Telescope in Europe and the Cosmic Explorer in the US, we're confident that we'll eventually detect individual gravitational waves from these systems,' explains Sarin.

As featured on Space Australia.

Background image credit: University of Warwick/Mark Garlick

Future space detector LISA could reveal the secret life and death of stars

A team of astrophysicists led by PhD student Mike Lau, from the ARC Centre of Excellence in Gravitational Wave Discovery (OzGrav), recently predicted that gravitational waves of double neutron stars may be detected by the future space satellite LISA.

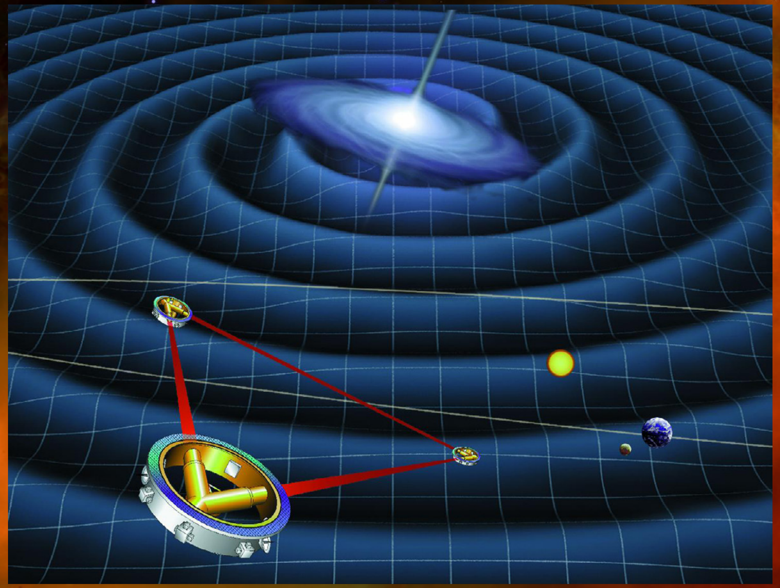
The results were presented at the 14th annual Australian National Institute for Theoretical Astrophysics (ANITA) science workshop 2020. These measurements may help decipher the life and death of stars.

Lau, first author of the paper, compares his team to 'astro-palaeontologists': 'Like learning about a dinosaur from its fossil, we piece together the life of a binary star from their double neutron star fossils.'

A neutron star is the remaining 'corpse' of a huge star after the supernova explosion that occurs at the end of its life. A double neutron star, a system of two neutron stars orbiting each other, produces periodic disturbances in the surrounding space-time, much like ripples spreading on a pond surface. These 'ripples' are called gravitational waves and made headlines when the LIGO/Virgo Collaboration detected them for the first time in 2015. These gravitational waves formed when a pair of black holes spiralled too close together and merged.

However, scientists still haven't found a way to measure the gravitational waves given off when two neutron stars or black holes are still far apart in their orbit. These weaker waves hold valuable information about the lives of stars and could reveal the existence of entirely new object populations in our Galaxy.

The recent study shows that the Laser Interferometer Space Antenna (LISA) could potentially detect these gravitational waves from double neutron stars. LISA is a space-borne gravitational-wave detector that is scheduled for launch in 2034, as part of a mission led by the European Space Agency. It's made of three satellites linked by laser beams, forming a triangle that will orbit the Sun. Passing gravitational waves will stretch and squeeze the 40 million-kilometre laser arms of this triangle. The highly sensitive detector will pick up the slowly-oscillating waves—these are currently undetectable by LIGO and Virgo.



Artist's conception of LISA spacecraft. Image credit: NASA

Using computer simulations to model a population of double neutron stars, the team predicts that in four years of operation, LISA will have measured the gravitational waves emitted by dozens of double neutron stars as they orbit each other. Their results were published in the Monthly Notices of the Royal Astronomical Society.

A supernova explosion 'kicks' the neutron star it forms and makes the initial circular orbit oval-shaped. Usually, gravitational wave emission rounds off the orbit—that is the case for double neutron stars detected by LIGO and Virgo. But LISA will be able to detect double neutron stars when they're still far apart, so it may be possible to catch a glimpse of the oval orbit.

How oval the orbit is, or the eccentricity of the orbit, can tell us a lot about what the two stars looked like before they became double neutron stars. For example, their separation and how strongly they were 'kicked' by the supernova.

Our understanding of binary stars—stars that are born as a pair—is plagued with many uncertainties. Scientists hope that by the 2030s, LISA's detection of double neutron stars will shed some light on their secret lives.

As featured in Phys.org and Space Australia.

A pocketful of stars: New research on common-envelope episodes forming double-neutron stars

When giant stars die in supernovae and their cores collapse, the protons and electrons melt into each other and neutron stars are born. Double neutron stars are two neutron stars orbiting each other in a binary system and were initially discovered as radio pulsars in our own galaxy. In 2017, the LIGO Scientific Collaboration and the VIRGO Collaboration announced the first detection of a double neutron star merger which led to the largest-ever global campaign to use telescopes around the world and in space to see if this merger also produced light radiation. This merger was associated with the most energetic astronomical flashes of light: short gamma-ray bursts. Following this major achievement in astronomy, theorists were prompted to question how much we know about how pairs of neutron stars form.

A recent study led by Dr. Alejandro Vigna-Gómez—alumnus from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) and currently DARK Fellow at the Niels Bohr Institute—highlights one key stage in the formation of double neutron stars: the common-envelope phase. The results were presented 31 March 2020 at the PHAROS Conference 2020 in Greece.

The common-envelope phase begins when the gas surrounding the core of a star engulfs, or 'envelopes', the whole pair of stars.

'It's a bit like having the two stars move through molasses – they slow down, and any orbiting objects come closer together' explains Professor Ilya Mandel, senior author and OzGrav Chief Investigator at Monash University.

During a common-envelope phase, the envelope drags the binary system, significantly reducing the separation between its components. The phase can end in two ways: either when the envelope is ejected which leaves the binary system with a much smaller orbital separation; or when the two stars come close enough to merge and form a single star.

Astronomers theorise that the common-envelope phase occurs in most stellar binary systems which then form into double neutron stars. The study found that the orbital evolution of a binary system, before the common-envelope phase, might be different than previously thought.

Vigna-Gómez explains: 'The orbit might remain eccentric until the common-envelope forms. This means the orbit deviates from a perfect circle and is somewhat "squashed"'.

The study also looked at different ways in which two double neutron stars can be formed. In the dominant formation channel, one star experiences a common-envelope episode with a neutron star companion. In the second channel, both stars are giants when the common-envelope phase begins.

'This study has opened doors for us to further explore the conditions in which common-envelopes are expected to form using sophisticated models' adds Mandel.

Also featured in Space Australia

Background image by Gerd Altmann from Pixabay

Ticking cosmic clocks reveal the evolution of stars over millions of years

Pulsars—a type of rotating neutron star—are well-known for their use as incredibly stable astrophysical clocks. Their regularity, used to measure their radio pulses, has led to some of the most exciting tests of Einstein's general theory of relativity and allowed scientists to examine the behaviour of the extremely dense matter inside neutron stars.

Artist View of Pulsar Planet System. Credit: NASA/JPL (NASA)

But just like ordinary clocks here on Earth, pulsars are not perfect keepers of time. Much like how a watch loses track of a few seconds each year, the exact rate at which pulsars spin appear to randomly wander by tiny amounts over month- to decade-long timescales.

The spins of a small fraction of pulsars have also been seen to rapidly speed up—they start 'ticking' slightly faster than usual. These effects, called 'spin noise' and 'glitches', change from pulsar to pulsar and may tell us how neutron stars evolved over millions of years; however, this requires precision tracking of hundreds of pulsar spins over many years.

These effects, called 'spin noise' and 'glitches', change from pulsar to pulsar and may tell us how neutron stars evolved over millions of years; however, this requires precision tracking of hundreds of pulsar spins over many years.'

Thanks to a series of upgrades over the last decade, the Molonglo Telescope—which celebrated its 50th birthday in 2015—can perform spin-tracking observations of hundreds of pulsars every two weeks! This enabled researchers, from the ARC Centre of Gravitational Wave Discovery (OzGrav), to find three new glitch events and measure the strength of the spin noise in 300 pulsars.

In a recently published study, led by OzGrav PhD student Marcus Lower, researchers examined 280 pulsars that are most representative of normal pulsar evolution and developed a statistical method similar to the one used for analysing gravitational-wave events detected by LIGO and Virgo. The results, presented at CSIRO's Australia Telescope National Facility colloquium, showed that spin noise seems to decrease with pulsar age and that there is a scaling relationship between spin noise strength, how quickly a pulsar spins and how fast its spin is slowing down over time.

Marcus explains: 'As spin noise becomes more obvious the longer you stare at a pulsar, we may be able to add additional pulsars to a re-analysis of the Molonglo data set in the future. We can also apply the statistical method to data from telescopes that have been tracking pulsar spins over multiple decades'.

The combination of additional pulsars and longer data sets would improve the study's current measurements and allow researchers to determine the exact cause of spin noise in pulsars.

As featured on Phys.org, Space Australia and ARC News.

OzGrav Alumni: Magdalena Kersting

I am an educational researcher, physics educator, and science communicator working to bring great science education to as many people as possible. Currently, I hold a position as a postdoctoral researcher in science education research at the University of Oslo.

I have a life-long goal of getting students excited about modern physics and I collaborate with the Einsteinian Physics Education Research Collaboration (EPER) and the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) to make that happen.

I am naturally curious and have always been fascinated by science. When I was 12 years old, I read Stephen Hawking's 'A Brief History of Time' and I was immediately hooked. From then on, I decided I would study physics to understand the Universe. Over the years, I have become equally intrigued by humans and their ability to make meaning of the world. In my research, I study this meaning perspective to find better ways of teaching science.

There are so many cool things about my job: I love to excite the inner scientist in others and it's just plain fun to stretch everyone's minds with concepts of modern physics. Plus, I really enjoy all the travelling that comes with working in academia. For example, my PhD research brought me to the University of Western Australia in Perth and the Swinburne University of Technology in Melbourne. I literally moved to the other end of the world in the name of science!

My joint research projects with the OzGrav Education and Public Outreach (EPO) team are also exciting: I look at challenges and opportunities of using virtual reality in science education. Virtual reality allows you to push the limits of reality and that's just perfect if you want to experience the extreme physics of black holes or warped time.

Some fun facts about me:

- One of my secret talents is that I can sit cross-legged on an airplane seat which makes travelling a breeze.
- I love any food with sweet potatoes and chickpeas. Also, coffee.
- If I could be anyone in the world for just 24 hours, I'd be an octopus. An octopus distributes its cognition over its eight arms. Just imagine how different the world must look like for a being that doesn't have just one, but many little brains!

Awards and Prizes

- The Barry Inglis Medal - close 14 April
- Young Tall Poppy awards - close 30 April
- Australian Optical Society awards - close 30 April
- AAS Nancy Millis Medal for Women in Science - close 1 May
- AAS Thomas Ranken Lyle Medal - close 1 May
- AAS Matthew Flinders Medal and Lecture - close 1 May
- 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

Background image by Art Tower on Pixabay

Adam Deller awarded Pawsey Medal **for scientific excellence**

OzGrav Associate Investigator Adam Deller has been awarded the prestigious Pawsey Medal by the Australian Academy of Science. The Pawsey Medal recognises outstanding research in physics by early-mid career scientists.

Based at Swinburne University of Technology, Adam uses radio imaging to study neutron stars and black holes, the most compact objects in the Universe.

To do so, he has developed new instrumentation capable of jointly processing signals received by radio antennas spread across the Earth and even on orbiting satellites. This instrumentation has been adopted by major astronomy facilities worldwide.

Adam's use of these facilities had led to breakthroughs in astronomy including directly imaging the explosive aftermath of a merger of two neutron stars in a galaxy 125 million light years away. This ultra-high zoom radio movie determined the orientation of the stars as they collided, and fed new insights into the analysis of the burst of gravitational waves emitted when they coalesced.

Closer to home, he has pinpointed the location of neutron stars within the Milky Way galaxy with unprecedented precision, using radio observations so precise they could discern motion no greater than the width of a human hair at a distance of 2,000 kilometres.

'I love the challenge of radio astronomy in particular – it has a tight relationship with engineering which is something that I studied as an undergraduate,' he says.

'But the main thing that draws me in is the search for discovery. It doesn't often happen all at once in a classic lightbulb moment, but when you get that breakthrough, or see that first image, and you know that at that instant you're the only person in the world that has that information – it's incredibly exciting and you can't wait to get out there and share it with everyone else.'

'Science is a question multiplier,' he adds. 'Every new answer you find tends to lead to not one, not two, but usually five more questions. It's very rare that we get to the end of a study and everything is wrapped up in a neat little bow and we think 'ah, now we understand'. But that's also the beauty of it. There's always more to understand about the Universe.'

Distinguished Professor at Swinburne's Centre for Astrophysics and Supercomputing and Fellow of the Australian Academy of Science, Professor Karl Glazebrook, says Adam is an amazing astronomer and computer scientist.

'We are especially proud of him as he studied here as a Swinburne undergraduate and also for his PhD, and he is the first of those students to return here as a permanent member of the astronomy staff.'

'Adam's research and work on interferometry software has had an enormous impact on the worldwide community and the Pawsey Medal is very well deserved,' Professor Glazebrook adds.

Adam says he is honoured to be awarded the Pawsey Medal by the Australian Academy of Science and acknowledges his fellow researchers.

'Science is always a team effort, and all of these results have been dependent on my collaborators, my mentors, and my students, and so this award is as much a recognition of their work as it is of mine,' he says.

OzGrav Associate Investigator Adam Deller

As featured on Swinburne News.

Watch the video by the Australian Academy of Science.

BEAT COVID-19 NOW

OzGrav Director Matthew Bailes, along with Professor Richard Osborne from the Centre for Global Health and Equity at Swinburne University of Technology, pulled their teams into OzGrav (prior to the campus lockdown) for a hackathon to help distribute Professor Osborne's respiratory symptoms survey. The survey has already been validated as an effective tool in determining the efficacy of flu vaccines and used by 500,000 people around the globe.

The hackathon attracted other staff from Swinburne University of Technology and Monash University, and they were soon joined by the Arq Group (experts at scaling apps and databases) and even international marketing agencies. The website launched on March 20th and has already attracted over 15,000 users. The data collected will inform public health decision-makers on early developments with the virus, which may help to plan and develop interventions against COVID-19.

The app allows you to track your symptoms daily over time. Once you complete the survey, you are provided with a report based on the most up-to-date Australian Government recommendations. Even if you have no symptoms, it would be helpful for you to participate.

Both healthy and symptomatic people are invited to complete the symptom tracker. As more people engage with the tool, we will come closer to finding local, national and global solutions. OzGrav encourages you to invite members of your family and communities to actively engage with this new tool.

Try for yourself today: **beatcovid19now.org** (don't forget to share on social media!)

BeatCOVID19Now will soon have an app for your phone to send you daily reminders and more astronomers have joined in the team (e.g. Swinburne's Karl Glazebrook's team has taken on the visualisation challenge and staff from the Australian Gravitational Wave Data Centre have been essential in the development).

The pandemic has created new industry engagement links and if you would like to contribute please email Matthew Bailes (matthew.bailes@gmail.com) . Access to the data and its use are strictly governed by the Swinburne University Ethics Committee rules and regulations (which make the LSC rules look fairly relaxed in comparison!).

BEAT COVID-19 NOW

Background image by Pixabay

What we do in isolation

Social-distancing and isolation during COVID-19 lockdown is necessary, but it can get lonely and impact on our mental health. To combat this, OzGravvers are encouraged to contribute content about activities while working from home, even just fun facts and pictures to share. This is an opportunity for our community to keep up-to-date with each other's lives and share things that bring us joy.

PhD student Joshua McCann is enjoying spending more time with his wife and almost 5-month-old daughter, Holly.

OzGrav PhD student Ben Grace creates stunning art from old bike wheels. This one was inspired by the black hole image taken by the Event Horizon Telescope in 2019!

While taking a break from research, PhD student Avi Vajpeyi is making online videogames. You can find some of Avi's games here: https://avivajpeyi.itch.io/ There's an international online game hackathon coming up on the weekend of 20 April. More info here: https://ldjam.com/

Associate Investigator Chris Flynn is a master at quilting (who knew!) and is working on making a 20x20cm Fast-Radio-Burst quilt. *Fun fact:* The Royal Astronomical Society is making Aa 200th anniversary commemorative quilt this year. The last one they made was a century ago Read more here.

EPO Coordinator Jackie Bondell spent the day with her family making homemade pierogi (Polish dumplings), following a recipe handed down from her mum.

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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