OzGrav

# SPACE TIMES

April 2023

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## Welcome,

There's a lot of excitement at OzGrav as we are now only one month away from the LIGO-Virgo-Kagra's fourth major observing run "O4". O4 will not only be the longest-ever observing run but also the most sensitive. It should detect more mergers than all of the previous runs put together, and OzGrav staff and students have been preparing for it for three years. Their hard work is about to pay off.

It's an exciting time for gravitational wave research. Last week we had the fantastic news that our Indian colleagues have secured (very significant) construction funding for the 4km LIGO-India - the fifth detector in the Northern hemisphere(!) - and momentum is building for the so-called 3G detectors in both Europe and the US.

Many of us in OzGrav are exploring the possible role Australia will play in the 3G detector landscape in the coming years and are planning both national and international workshops to be hosted here.

At nanohertz frequencies, the major pulsar timing array "detectors" are preparing for their 3rd major data releases and OzGrav is hosting the International Pulsar Timing Array Annual meeting in Queensland this June.

I hope you enjoy this issue of Space Times, which has a particular emphasis on our Outreach activities, and I congratulate all the OzGrav staff involved in them.

A unique event celebrating the launch of "Quantum Girls" will take place at the Shine Dome on June 13th, please encourage relevant people to attend this exciting initiative.


Lastly, the OzGrav 2022 Annual Report is now available on our website! Special thanks to Lisa Horsley and Carl Knox as well as everyone that contributed to another great year at the centre. To check out our latest annual report click here.

**Editor-in-chief:** Ariadna Hernandez Subscribe here.

## NEWS IN BRIEF

Congratulations to OzGrav Chief Investigator Prof. Susan Scott on being awarded the prestigious Thomas Ranken Lyle Medal!

Professor Scott has played a critical role in the analysis and detection of gravitational waves, and advancing our understanding of the global structure of space-time.

Well done Susan!

To read about the ASA 2023 awardees article, click here

Distinguished Professor Susan Scott. Photo credit: Tracey Nearmy/ANU

## UPCOMING EVENTS

– **OzFINK workshop**: 3-5 May 2023, Swinburne Uni. More info here.

– **Gravitational Wave Advanced Detector Workshop (GWADW):** 21-27 May 2023, Elba, Italy. More info here.

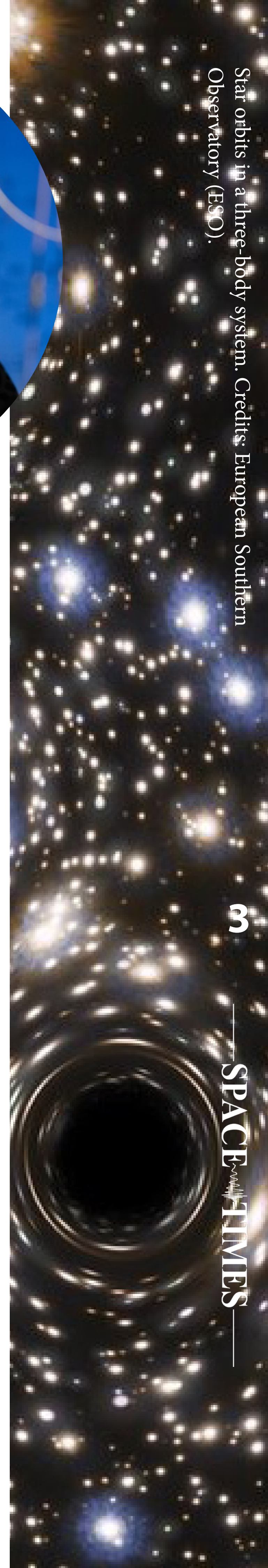
– **Quantum Girls,** June 13, Shine Dome, ACT. More info here.

– **2023 International Pulsar Timing Array Student Workshop and Science Meeting:** 13-16, 19-23 June 2023. More info here

– **ASA Annual Science Meeting:** 3-7 July, 2023, Macquaire University. More info here.

– **OzGrav Early Career Researcher workshop:** 13-14 Nov 2023, Adelaide.

– **OzGrav Annual Retreat:** 15-17 Nov 2023, Adelaide. For questions contact info@ozgrav.org



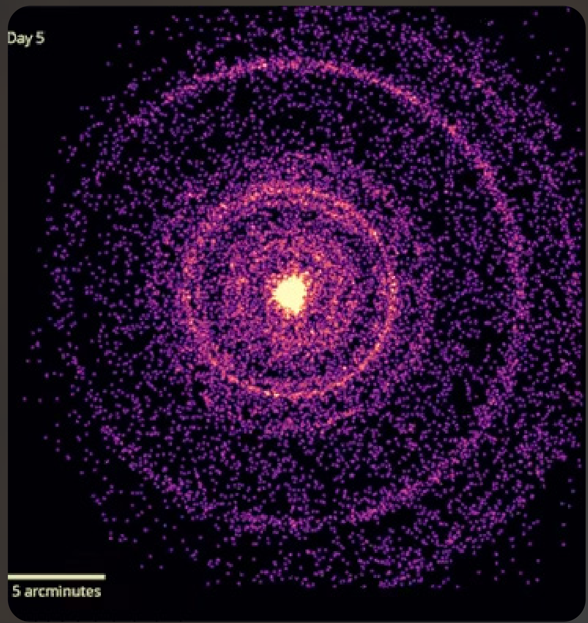

Star orbits in a three-body system. Credits: European Southern Observatory (ESO).

# SCIENTIST ANALYSE BRIGHTEST GAMMA-RAY BURST EVER DETECTED

## But where is the supernova?

Last October, a dying star released a giant gamma-ray burst, directed right towards Earth.

The burst – now called GRB 221009A – is the brightest in thousands of years, and has allowed astronomers a once in 10,000 year chance to study this astronomical phenomenon.




Images captured over 12 days by the X-ray Telescope aboard NASA's Neil Gehrels Swift Observatory were combined to make this movie, shown here in arbitrary colors. Credit: NASA/Swift/A. Beardmore (University of Leicester)

"The exceptional brightness of this gamma-ray burst meant astronomers were able to study it in unprecedented detail in real-time as the light arrived from that distant galaxy," says University of Sydney student and OzGrav affiliate James Leung.

"This gave us a golden opportunity to test intricate physical models that describe what happens before, during and after the death of a star."

Two new sets of papers – one by NASA and another from an international team, analysed the gamma-ray burst in great detail, finding that the burst was 70 times brighter than any seen before.

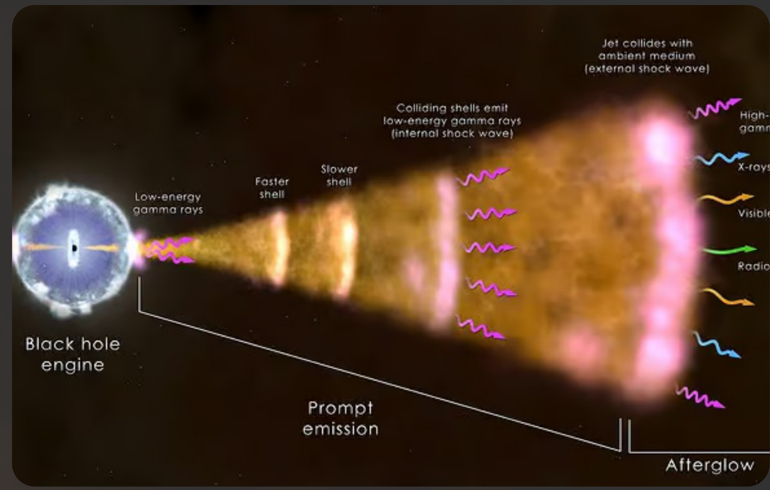
GRB 221009A's signal was traveling for about 1.9 billion years before we could see it from Earth. This makes it among the closest-known 'long' gamma-ray bursts. Long in this case meaning lasting longer than two seconds, while GRB 221009A lasted a whopping 10 hours.

Astronomers think these bursts are a type of black hole 'cry' which form when a huge star collapses. As it quickly ingests the surrounding matter, the black hole blasts out jets in opposite directions containing particles accelerated to near the speed of light.

Oxford and Sydney University researchers – looked at the 'reverse shock' after the initial blast. This is the implosion that occurs at the same time as the explosion. They could map this reverse shock in 'unprecedented detail' for variables such as time, length, size, and energy.








The core of a massive star (left) has collapsed, forming a black hole that sends a jet of particles moving through the collapsing star and out into space at nearly the speed of light. Radiation across the spectrum arises from hot ionised gas (plasma) in the vicinity of the newborn black hole, collisions among shells of fast-moving gas within the jet (internal shock waves), and from the leading edge of the jet as it sweeps up and interacts with its surroundings (external shock). Credit: NASA's Goddard Space Flight Center

"Our observations provide unmatched insights into the reverse shock model for gamma-ray burst emission, showing it is very difficult for existing models to replicate the slow evolution of the energy peaks that we observed," said Leung.

"This means we have to refine and develop new theoretical models to understand these most extreme explosions in the Universe."

The NASA research looked at a number of other parts of the burst, but one in particular highlights an interesting question – where is the supernova?

After an explosion like this, researchers expect to see a supernova which brightens over the first couple of weeks.

However, this hasn't yet happened.

"We cannot say conclusively that there is a supernova, which is surprising given the burst's brightness," said Andrew Levan, a professor of astrophysics at Radboud University in Nijmegen, Netherlands. "If it's there, it's very faint. We plan to keep looking, but it's possible the entire star collapsed straight into the black hole instead of exploding."

This could be because of where the gamma-ray burst happened, as thick dust clouds are in the area and could obscure the view of any light from a supernova.

The team is planning to take more Webb and Hubble observations in infrared over the next few months to check.

With such a rare and well captured gamma-ray burst, there's likely to be much more science we can learn about over the next few years.

The international research is available on preprint server arXiv and has been submitted for publication in Nature Astronomy. The NASA research is part of a focus issue in the The Astrophysical Journal Letters.

Originally published by Cosmos as Scientists analyse brightest gamma ray burst ever detected, March 2023.





Background picture: Powerful gamma-ray burst. Credit: NASA,ESA and M. Kommeser. Click here

# GRANT QUANTUM LEAP FOR WOMEN IN STEM

**The University of Western Australia will help enhance female participation in modern quantum science through Quantum Girls, a Women in STEM and Entrepreneurship project.**

The Australian Government's Department of Industry, Science, Energy and Resources announced funding of $879,000 to support the project.

The project is designed to address a skills shortage and gender imbalance in STEM that leads to many women missing out on the opportunity to participate in some of the most innovative and exciting jobs of the future.

'Quantum Girls' expands on the success of UWA's Einstein-First Project which aimed to redesign, evaluate, and optimise school science across all education levels to reflect the modern understanding of space, time, matter and the universe.

The project aims to train 200 female teachers, who will then teach quantum science and quantum computing to 11–15-year-old girls. It will feature group activity-based learning, short teacher-instruction videos, and female role models who will inspire students through national Quantum-Girls hackathons and Quantum-Girls after school STEM clubs.

Through Quantum Information, Simulation and Algorithms (QUISA), UWA's quantum computing centre directed by Professor Jingbo Wang, the project will provide students with hands-on experience in operating one of the world's first educational quantum computers.

Quantum Girls is a collaboration between QUISA and the Einstein-First Project directed by Emeritus Professor David Blair, from UWA's School of Physics, Mathematics and Computing.

*"The project will use games and toys and lasers and real quantum computers to enable students to develop the quantum intuition needed for understanding almost everything around us,"* Professor Blair said.

The project will be supported by Education and Training Manager Ann Backhaus from Pawsey Supercomputer Research Centre, Bloom — UWA's Centre for Youth innovation, QUECWA, and industry partners including Peter Rossdeutscher, Chair of Quantum Technology Exchange.

This article is featured as written by Annelies Gartner and published in University of West Australia, 2023.





RESEARCH HIGHLIGHT

## How fast do neutron stars move?

Young single pulsars are observed to move in the sky at speeds of many hundreds of kilometres per second. These high speeds are imparted by asymmetries in the supernova explosions that give birth to the neutron stars. Measuring the distribution of these birth kicks is important for understanding supernova explosions. It is also necessary to explain how neutron stars are retained in clusters with escape velocities of only a few tens of kilometres per second, and for predicting how often neutron star birth kicks will disrupt binaries, flinging out a newly born neutron star.

The latter is particularly relevant for the formation of neutron star binaries that can be observed in radio waves, X-rays, or, if merging with another neutron star or black hole, as gravitational waves.

We can generally measure only two components of a pulsar's motion: the projection onto the plane of the sky. This is done by multiplying the proper motion by the distance to the pulsar. The third component of the motion, along the radial direction connecting the Earth and the pulsar, cannot be measured directly. The total speed is generally inferred by assuming that the radial component is not special: that, on average, its magnitude samples the same distribution as the two observed velocity components. However, in a paper published in the Astrophysical Journal in 2023 (ApJ 944, 153), OzGrav CI Ilya Mandel (Monash) and collaborator Andrei Igoshev (Leeds) argued that this is not the case, and the radial motion direction can indeed be special.

This paper, titled "The impact of spin-kick alignment on the inferred velocity distribution of isolated pulsars", points out that if pulsar kick direction is preferentially aligned with the pulsar rotational (spin) axis, then the very detectability of the pulsar — which requires that the beam of the pulsar sometimes, but not always, sweeps past our radio telescopes on Earth — creates a special direction.

Consider, for example, a pulsar that is emitting two narrow beams of radiation at 90 degrees to its spin axis. This pulsar could only be detected by an observer located in the pulsar's equatorial plane. Suppose that the pulsar's rotation axis is perfectly aligned with the spin axis. In that case, the pulsar has no radial velocity component: the projected 2-dimensional velocity on the plane of the sky represents the full pulsar speed. Alternatively, if we imagined that the 2-dimensional velocity we see was a random projection of the full velocity, we would systematically over-estimate the pulsar's speed by a factor of sqrt(3/2).

The exact level of such a bias depends on the degree of misalignment between the pulsar spin and its radio beams, the size of these beams, and the level of kick-spin alignment. While some of these quantities are uncertain, Mandel & Igoshev conclude that pulsar velocities may be over-estimated by up to ~15% by methods that don't account for this systematic bias.

*This brief was written by OzGrav researcher Ilya Mandel, Monash University, 2023. To read the full paper by Ilya Mandel and Andrei P. Igoshev, click here.*

## Nandhinie Supramanian

As a child growing up in an Asian family, doctors, lawyers, and engineers were the main career aspirations that I was exposed to by my parents. So, studying hard and excelling in studies was never an option. I was a bright student in school, and I always had a special love for physics and wanted to pursue Physics when I grew up. However, when I completed my schooling, instead of becoming a physicist, I opted to become an engineer. Back then, I had no choice because I was offered a scholarship for that particular course in aeronautical engineering. When I enrolled in the course, I developed a significant interest in the field.

Following the completion of my bachelor's degree, I set out to develop my professional career. I worked as a Quality Engineer in the Aerospace, Medical, and Electrical Manufacturing industries for over 6 years. Unfortunately, I felt unaccomplished and diverted from my field of interest. That is when I decided to quit my job and pursue my Masters in Aeronautical Engineering. While I was completing my Master's, I noticed a PhD position on Seek.com with the title "PhD in Finding Buried Treasure" that caught my attention and I applied. Today, I am here at UWA, pursuing my PhD in Physics, focusing on my area of interest Aeronautical Engineering. It can never get more exciting and challenging than this. My research is on Magnetic Compensation in Airborne Mineral Exploration, where I get to apply my knowledge of both disciplines of Aeronautical Engineering and Physics.

My hobbies outside of academics include dancing and exercising. I enjoy jogging or walking along the river on weekends, which is my favourite thing about Perth, with its picturesque rivers and nature blending perfectly with the city view. Besides that, I enjoy travelling a lot. My travels have taken me to most countries in Asia and the United States. Animal rescue is one of my passions, and I have done a lot of it back in Malaysia. I also have three rescue dogs back home with whom I spent most of my time before moving to Australia. I miss them the most when I'm away from home.

Background picture by Carl Knox, Swinburne University-OzGrav.





## Wallal Eclipse Centenary celebrations

### Did you grab your special coin from the Royal Mint?

100 years ago the eyes of the world were focused on an expedition of international and Australian scientists to Wallal, 300km south of Broome in Western Australia, where conditions would be ideal for photographing a total eclipse due on 21 September 1922. The photographic images taken during this ground-breaking expedition allowed for the precise measurements of the apparent position of the stars near the eclipsed Sun, giving scientists the evidence proving Albert Einstein's revolutionary Theory of General Relativity as correct!

The UWA Wallal expedition Centenary celebration lasted two weeks throughout September 2022. The two-week celebration catered for people who have a passion for science, art, history and education. It consisted of multiple public talks, an exhibition, workshops, art sculptures, posters, videos, and the Royal Australian Mint Wallal coin launch. UWA joined the Perth Observatory, Gravity Discovery Centre and Scitech who offered their own exhibition and talks in celebration of the Wallal Expedition 100 years ago.

The Hon Robert French AC, UWA Chancellor, launched the fully illustrated book "Uncovering Einstein's New Universe" by David Blair, Ron Burman and Paul Davies, published by UWA Publications. The book describes the adventures of many people who between them changed humankind's common understanding of our universe and the nature of physical reality. In their work, you will find the history of the Wallal Eclipse expedition, then goes on to describe the later verification of Einstein's theory of gravity, culminating in the discovery of gravitational waves.

There were free STEM talks and workshops for students in Years 3-12. More than 1000 students attended the sessions. Speakers included lecturers from UWA's School of Physics, Mathematics and Computing, Einstein First Project, Jackie Bondell - OzGrav Education Public Outreach Coordinator and ABC Catalyst presenter of "Black Hole Hunter" Professor Tamara Davis - University of Queensland.

Many thanks to our volunteers who trained, managed and contributed to this great event. It was also a fantastic chance to showcase the educational work happening in the Einstein First project!

UWA acknowledges the generosity and support of sponsors of whom the centenary celebration of the Wallal Expedition would not have been possible.

Article compiled by Ruby Chan and Lisa Horsley, OzGrav.

Photo credits: UWA Brand Marketing and Recruitment

## Monash Maker Faire

After a lockdown break, the Monash Maker Faire was back in person for 10,000 people at Monash University's Clayton campus. The Maker Faire brought together 300 artisans, developers, hackers, inventors and tinkerers of all descriptions converging to share their passions with attendees of all ages.

OzGrav shared Virtual Reality (VR) guided tour of the solar system and beyond, AMIGO interferometer, stickers, posters and games. For more info click here.

Article written by Lisa Horsley.
Photo credits: Lisa Horsley.

## Space Camp

OzGrav works with many partner organisations, including SciScouts for their week-long Space Camp in Canberra this year. We worked on the lives of stars, neutron stars and black holes, uncovering properties of space and time.

The VR is always popular, both the tethered Vive (showing Carl Knox's planet throwing game) and untethered Mirages (showing Mark Myers's Guided Tour of the solar system, neutron stars, black holes and gravitational waves).

For this event we had plenty of time for scouts to create their own space design that we made into a badge with the badge machine. Other activities run during the camp included stargazing, robotics and a visit to Canberra Deep Space tracking station.

Article written by Lisa Horsley. Photo credits: Lisa Horsley.

## School sessions and Work Experience

The OzGrav Outreach team continue to take our Virtual Reality (VR) headsets and custom-built programs to schools around Australia. We are excited to partner with OzGrav early career researchers to share the research they are working on, and show students interesting visualisations explaining difficult concepts.

Rowina (PhD student at Monash) gave a talk and helped run the "Mission Gravity" program in Melbourne. Maddy, Amy and Sammi have been busy at Adelaide schools, running "Mission Gravity" and showing how we use a laser interferometer to detect gravitational waves with AMIGO. We also had 6 groups of Year 10 students come through the Swinburne CAS Work Experience program (Centre for Supercomputing and Astrophysics) across the year, discovering properties of stars, black holes and gravitational waves.

Article written by Lisa Horsley. Photo credits: Lisa Horsley.

## Welcome Week

OzGrav and the Swinburne Physics and Outer-space Club (SPOC) joined forces during Orientation and Welcome Back Week activities as we welcomed new and returning students to Swinburne campus for Semester 1, 2023.

It was a wonderful two weeks with an incredible vibe around campus and we appreciate all the astronomy students and researchers from OzGrav and CAS (Swinburne Centre for Astronomy and Astrophysics) being a part of it all.

Over the course of Orientation and Welcome Back Week we had:

- 9000+ unique students engaged
- 6,000 + club memberships
- 450,000+ impressions on our related social media content

It was an epic way to start the year. We're excited to see what the semester holds.

Article written by Kirstyn Paul, Events & Experience Officer, Swinburne Student Life
Photo credit: Swinburne Student Life

Background picture by Carl Knox, Swinburne University-OzGrav.

# 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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Background picture by Carl Knox, Swinburne University-OzGrav.