SPACE TIMES

OzGrav January 2023

STAR'S FATAL ENCOUNTER WITH BLACK HOLE CREATES A LUMINOUS FLASH

page 3

Cover picture: Supermassive black hole rips apart a star. Credit: Carl Knox (OzGrav, ARC Centre of Excellence for Gravitational Wave Discovery, Swinburne University of Technology)

Welcome to the January issue of Space Times!

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

Welcome,

Late last year we had the fantastic news that the Australian Research Council had concluded its selection processes and that OzGrav was to be funded for another 7 years! This achievement is both a testament to the staff, students and admin staff that helped build OzGrav's national and international reputation in its first seven years and the team that put together the 2023 bid. I was always confident that our research leaders and written document were going to be very strong, but was greatly relieved to get the happy news that the team had achieved 100% of the funding it sought, which will enable OzGrav to capitalise on the tremendous opportunities in relativistic astrophysics that lie ahead until 2031!

A special thanks to my new OzGrav 2023 Deputy Directors Tamara Davis and David McClelland, members of the Steering Committee that placed trust in me to lead the bid, our International and Domestic advisory committees and Yeshe Fenner for administrative support and Carl Knox for making everything associated with the bid look a million dollars (or 35 million as it turned out(!)). I drew great confidence during the bid process from the number of people who contributed their ideas, and time to the text, and left no stone unturned. I thought it was the strongest research bid with which I've been associated and the news of its success helped us hold one of the most energizing annual retreats of the Centre at ANU in late November.

The new Centre will be pursuing six major Key Projects, and we will be joined by the University of Queensland and the University of Sydney as this field of science grows. Our female Chief Investigators count is more than double that of the original Centre and we'll probably commence the new Centre's activities in early 2024 when OzGrav version 1 is concluding.

In the meantime, OzGrav is excitedly gearing up for the start of "O4", the fourth major GW observing run, with many team members travelling to the LIGO sites and working on the upgrades. We envisage twice as many discoveries from O4 as all previous runs put together as GW astrophysics continues its exponential growth!

I hope you enjoy this issue of Space Times and read about the successes of our many staff and students.

Regards,

Matthew Bailes.

Editor-in-chief: Ariadna Hernandez Subscribe here.

News in Brief

- The ARC will invest a further $35M to support OzGrav for another 7 years! Well done to Matthew, Tamara Davis, David McClelland and the rest of the OzGrav2 team for putting together a strong proposal that will support the Australian GW community to continue to do world-leading research.

- David Ottaway was appointed Fellow of Optica (Formerly Optical Society of America). Big Congrats!

- Congratulations to OzGrav Chief Investigator Susan Scott for receiving the 2022 Monash Faculty of Science Distinguished Alumni Award; for being awarded the AIP Walter Boas Medal for her leadership in the development of the field of GW science, general relativity, and cosmology, **and** for having received the prestigious 2022 Walter Burfitt Prize from the The Royal Society of NSW for scientific contributions deemed of the highest scientific merit. Amazingly well done!

- We had our first in-person ECR Workshop Annual Retreat since 2019! Around 150 members from all over Australia and beyond attended this event. We were happy to see you all and we appreciate the efforts of all the OzGrav members and staff that made this event a success!

- OzGrav hosted the Gravitational Wave, Physics and Astronomy Workshop (GWPAW) 2022 in December 5-9 at the heart of the city of Melbourne. We had over 200 in-person attendants from all over the world, with incredible contributed talks and great poster presentations. We thank all of the participants, the Local and Science Committees, and everyone who supported and helped us during this event.

Star's fatal encounter with black hole creates rare luminous flash

Astronomers from OzGrav have played an important role in the discovery of a rare luminous jet of matter travelling close to the speed of light, created by a supermassive black hole violently tearing apart a star.

A supermassive black hole rips apart a star, causing a bright optical flare to emerge. Image credit: Carl Knox (OzGrav, ARC Centre of Excellence for Gravitational Wave Discovery, Swinburne University of Technology)

Published in Nature, the research brings astronomers one step closer to understanding the physics of supermassive black holes, which sit at the centre of galaxies billions of light years away.

Swinburne Professor Jeff Cooke, who is also a Chief Investigator for the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav), was a key member of the research team.

"Stars that are literally torn apart by the gravitational tidal forces of black holes help us better understand what exists in the Universe," says Professor Cooke.

"These observations help us explore extreme physics and energies that cannot be created on Earth."

Supermassive, super rare and super far away!

When a star gets too close to a supermassive black hole, the star is violently ripped apart by tidal forces, with pieces drawn into orbit around the black hole and eventually completely consumed by it.

In extremely rare instances – only about one per cent of the time – these so-called tidal disruption events (TDEs) also launch luminous jets of material moving almost at the speed of light.

The co-lead authors of the work, Dr Igor Andreoni from the University of Maryland and Assistant Professor Michael Coughlin from the University of Minnesota, along with an international team, observed one of the brightest ever TDEs. They measured it to be more than 8.5 billion light years away, or more than halfway across the observable Universe.

The event, officially named "AT2022cmc", is believed to be at the centre of a galaxy that is not yet visible because the intense light from the flash still outshines it. Future space observations may unveil the galaxy when AT2022cmc eventually fades away.

It is still a mystery why some TDEs launch jets while others do not appear to. From their observations, the researchers concluded that the black holes associated with AT2022cmc and other similarly jetted TDEs are likely spinning rapidly.

This suggests that a rapid black hole spin may be one necessary ingredient for jet launching—an idea that brings researchers closer to understanding these mysterious objects at the outer reaches of the universe.

These include the Zwicky Transient Facility in California that made the initial discovery, X-ray telescopes in space and on the International Space Station, radio/mm telescopes in Australia, the US, India and the French Alps, and optical/infrared telescopes in Chile, the Canary Islands and the US, including the W. M. Keck Observatory in Hawaii.

Postdoctoral researcher Dr Jielai Zhang, a co-author on the research, says that international collaboration was essential to this discovery.

"Although the night sky may appear tranquil, telescopes reveal that the Universe is full of mysterious, explosive and fleeting events waiting to be discovered. Through OzGrav and Swinburne international research collaborations, we are proud to be making meaningful discoveries such as this one," Dr Zhang says.

This paper, "A very luminous jet from the disruption of a star by a massive black hole," was published in Nature on November 30, 2022

Background picture: Supermassive black hole rips apart a star. Credit: Carl Knox (OzGrav, ARC Centre of Excellence for Gravitational Wave Discovery, Swinburne University of Technology)

CBC Deep Learning

Since 2015, the LIGO Virgo KAGRA (LVK) Collaboration has detected 90 GW events from mergers of compact binaries. These include signals from a binary black hole, binary neutron star and neutron star-black hole mergers - known together as Compact Binary Coalescences (CBC).

Some of these emissions – like the short gamma-ray burst – last for less than a second and require sub-second follow-up by electromagnetic telescopes to be detected.

However, algorithms used by the LVK Collab for sky localization of GW sources have a wide range of latencies - from ~ 10 secs for the localization software BAYESTAR, to anywhere between 6 hours and 6 days for full parameter estimation codes like LALInference and Bilby. Therefore, we need faster techniques that can predict the probability distribution of the sky direction in less than a second.

This is where **Deep Learning** steps in. Deep learning involves the use of algorithms called *'neural networks'* that learn correlations between a labelled input dataset and the output it is trying to predict. For this, the networks need to be 'trained', meaning their parameters need to be tuned, so that errors between the predictions and labels (ground truths) are minimal. While several deep learning models have been developed in the last few years for binary black holes, there are yet no published results for deep learning-based sky localization of binary neutron star and neutron star-black hole binaries.

To address this, we have designed 'CBC-SkyNet' or Compact Binary Coalescence Sky Localization Neural Network - the first deep learning model for sky localization of all CBC sources. CBC-SkyNet achieves comparable localization accuracy to traditional techniques at orders of magnitude faster speeds of a few milliseconds! This can potentially enable rapid follow-up observations as soon as a GW detection is triggered.

Our approach is novel since, unlike other methods that use long simulated gravitational wave signals for training, we use short (0.2 sec long) signal-to-noise ratio (SNR) time series data, which makes inference on all CBC sources feasible. The SNR time series contains the necessary information for sky localization and is generated by cross correlating the raw gravitational wave detector data with millions of template signals.

CBC-Skynet consists of two parts – a Residual Neural Network (ResNet) that extracts features from the SNR time series, and a Masked Autoregressive Flow (MAF) network, which transforms a chosen base distribution into the desired sky direction probability distribution, by learning features extracted by the ResNet.

To test CBC-SkyNet's performance, we have calculated the areas of the 90% credible regions of our model's predicted sky distribution for each event. The 90% credible interval refers to the range of values or sky coordinates within which the probability of having the true sky coordinate is 90%.

The bigger the areas of the 90% credible intervals, the larger the model's uncertainty in predicting the true sky direction. We find that for all CBC sources, our model's 90% credible interval areas, calculated several times faster than other methods, are less than 300 sq. degrees, which is consistent with LALInference/Bilby analyses.

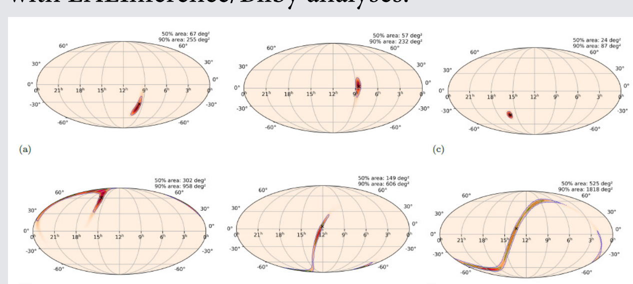
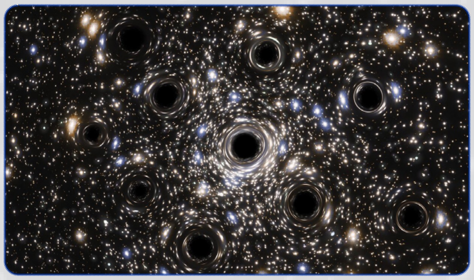


Figure 1: Skymaps showing CBC-SkyNet's localization performance on a binary black hole, a binary neutron star and a neutron star-black hole binary respectively. The areas of the 90% and 50% credible intervals are shown inset.

Written by PhD student Chayan Chatterjee, OzGrav - University of Western Australia, Nov, 2022.

Black hole carnivals may produce the signals seen by gravitational-wave detectors

Since 2015, the LIGO-Virgo-KAGRA Collaboration have detected about 85 pairs of black holes crashing into each other. We now know that Einstein was right: gravitational waves are generated by these systems as they inspiral around each other, distorting space-time with their colossal masses as they go. We also know that these cosmic crashes happen frequently: as detector sensitivity improves, we are expecting to sense these events on a near-daily basis in the next observing run, starting in 2023. What we do not know — yet — is what causes these collisions to happen.

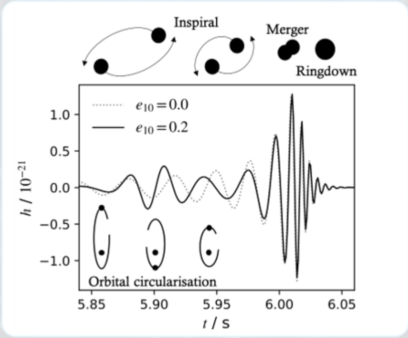


Artist's impression of a collection of black holes in the core of a star cluster. Credit: ESA/ Hubble, N. Bartmann

Black holes form when massive stars die. Typically, this death is violent, an extreme burst of energy that would either destroy or push away nearby objects. It is therefore difficult to form two black holes that are close enough together to merge within the age of the Universe. One way to get them to merge is to push them together within densely populated environments, like the centres of star clusters.

In star clusters, black holes that start out very far apart can be pushed together via two mechanisms. Firstly, there's mass segregation, which leads the most massive objects to sink towards the middle of the gravitational potential well. This means that any black holes dispersed throughout the cluster should wind up in the middle, forming an invisible "dark core". Secondly, there are dynamical interactions. If two black holes pair up in the cluster, their interactions can be influenced by the gravitational influence of nearby objects. These influences can remove orbital energy from the binary and push it closer together.

The mass segregation and dynamical interactions that can take place in star clusters can leave their fingerprints on the properties of merging binaries. One key property is the shape of the binary's orbit just before it merged. Since mergers in star clusters can happen very quickly, the orbital shapes can be quite elongated — less like the calm, sedate circle that the Earth traces around the Sun, and more like the squished ellipse that Halley's Comet races along in its visits in and out of the Solar System. When two black holes are in such an elongated orbit, their gravitational wave signal has characteristic modulations, and can be studied for clues to where the two objects met.



Caption: Plot showing the gravitational-wave signal of an eccentric binary black hole (solid line) versus a non-eccentric binary black hole (dotted). The stages of the inspiral and merger of the binary are shown

A team of OzGrav researchers and alumni are working together to study the orbital shapes of black hole binaries. The group, led by Dr Isobel Romero-Shaw (formerly of Monash University, now based at the University of Cambridge) together with Professors Paul Lasky and Eric Thrane of Monash University, have found that some of the binaries observed by the LIGO-Virgo-KAGRA collaboration are indeed likely to have elongated orbits, indicating that they may have collided in a densely populated star cluster. Their findings indicate that a large chunk of the observed binary black hole collisions — at least 35% — could have been forged in star clusters.

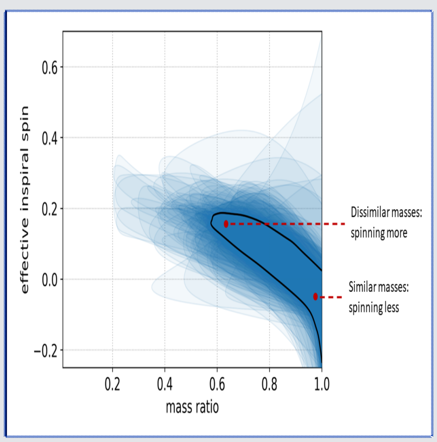
"I like to think of black hole binaries like dance partners", explains Dr Romero-Shaw. "When a pair of black holes evolve together in isolation, they're like a couple performing a slow waltz alone in the ballroom. It's very controlled and careful; beautiful, but nothing unexpected. Contrasting to that is the carnival-style atmosphere inside a star cluster, where you might get lots of different dances happening simultaneously; big and small dance groups, freestyle, and lots of surprises!" While the results of the study cannot tell us — yet — exactly where the observed black hole binaries are merging, they do suggest that black hole carnivals in the centres of star clusters could be an important contribution.

This paper was written by OzGrav members Isobel Romero-Shaw, Paul D. Lasky1,2, and Eric Thrane, "Four Eccentric Mergers Increase the Evidence that LIGO–Virgo–KAGRA's Binary Black Holes Form Dynamically" and published in the Astrophysical Journal, Dec. 2022.

Artist's Impression of the Black Hole Coucentration in NGC 6397. Credit: ESA/Hubble, N. Bartmann

Lopsided black hole mergers appear to spin more: using a tool from finance to investigate how colliding black holes are born

Gravitational wave astronomy allows us to detect collisions between the most compact objects in the Universe: black holes and neutron stars. To date, astronomers have detected over 90 events. At its surface, the fact we observe any at all might seem surprising. For a pair of black holes to merge on a time-scale shorter than the age of the Universe, they must start by orbiting each other with a very short separation distance: less than about 50 times the radius of the Sun. This doesn't sound small at first, but the types of stars that form these black holes are several times larger than this orbital separation.



Caption: Distribution of merging black holes' mass ratios and effective inspiral spins. Notice that as mass ratio decreases (as the masses of the black holes become less similar) their effective inspiral spin increases.

How can stars that are predicted to be overlapping proceed to turn into separate black holes and merge? Astrophysicists have managed to theorise a number of highly specific scenarios or 'formation channels' in which this issue is over-come and the sorts of merger events we see in gravitational waves can take place.

However, a problem remains – astronomers are still not sure which of the many theorised scenarios are common. Fortunately, different formation channels leave distinct fingerprints on how black hole properties are distributed. One notable case is the relationship (or correlation) between mass ratio, a measure of how similar the masses of two merging black holes are, and effective in-spiral spin, a convenient description of how the two black holes are spinning. As an example, one formation method might imply that as masses of merging black holes become more dissimilar – they spin more, as opposed to a different formation method which might imply the complete opposite.

Therefore, if we can identify these features and relationships in the data, we can start to infer which of the theorised formation channels were likely to have produced the events we are observing.

Recently, researchers have been attempting to look for such relationships between mass ratio and effective inspiral spin, but the results have been inconclusive due to overlooked subtleties in their methods. It turns out that measuring correlations can be tricky!

Fortunately, the world of applied statistics and finance had these kinks sorted out long ago – correlations can be well modelled and measured with a mathematical tool known as a copula. In this work, we used this tool to discover that black hole mergers exhibit an anti-correlation between their mass ratio and effective inspiral spins. Repeated without the jargon, we found that mergers between black holes tend to spin more when one of the black holes is much heavier than the other, as opposed to spinning less when their masses are similar. Interestingly, the formation channels that are theorised to be most common are generally not predicted to produce this relationship; we may need to look to less commonly discussed scenarios for an explanation.

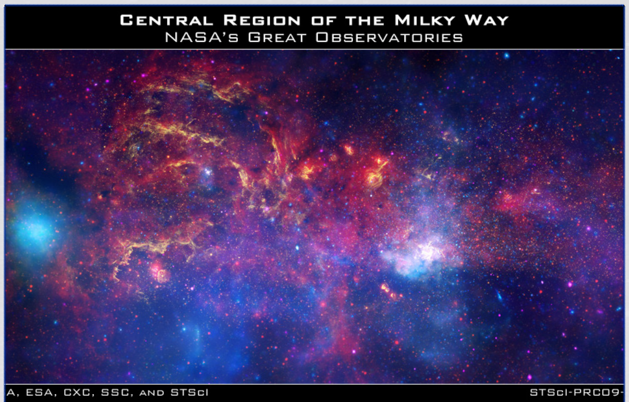
Much work has already been done on this. One study finding this correlation could be caused by black holes forming and merging under certain conditions in parts of galaxies known as "active galactic nuclei". Another study showed that this correlation could imply many black hole mergers undergo a process called "mass ratio reversal," in which the initially lighter black hole accretes enough material to become the heavier black hole of the pair before colliding. It will be very exciting to see what other conclusions about the origins of black hole mergers can be drawn from this discovery in the near future.

Written by Christian Adamcewicz, Eric Thrane, OzGrav - Monash, and published in Montly Notices from the RAS, December, 2022.

Available at: **https://doi.org/10.1093/mnras/stac2961**

A Disruptive New Way to Form Galactic Center Stars

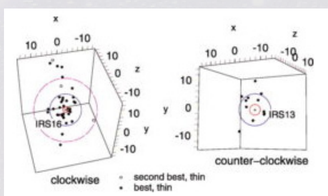
The massive young stars at the center of the Milky Way have long puzzled astronomers. Did these stars form in a supermassive black hole's backyard, or did they travel to the galactic center after their birth? In a recent publication, researchers proposed an entirely new scenario, in which the demise of one star prompts the formation of many more.



The Milky Way at infrared, optical, and X-ray wavelengths, respectively. The Milky Way's supermassive black hole is located within the bright region right of center. [NASA, ESA, SSC, CXC,

Born in a Black Hole's Shadow

At the center of our galaxy, massive young stars trace tight orbits around a supermassive black hole. When researchers charted these stars' paths, a curious pattern emerged: several dozen stars were arrayed in one or more narrow disks that are off kilter from the plane of the galaxy.



Locations of stars belonging to the putative clockwise and counter-clockwise disks at the center of the Milky Way. Distances are given in arcseconds. [Paumard et al. 2006]

The presence of young stars in the hostile inner regions of our galaxy is mysterious enough, and this arrangement is even more perplexing. It's not yet clear how stars might form so close to a black hole — the tidal forces should prevent new stars from coalescing — and the disk-like arrangement shouldn't arise naturally if the stars migrated from elsewhere in the galaxy. How did these stars come to be where they are?

From Disruption to Disk Formation

Rosalba Perna (Stony Brook University and Flatiron Institute) and Evgeni Grishin (Monash University and Australian Research Council Centre of Excellence for Gravitational Wave Discovery) proposed that when a star is tidally disrupted by a supermassive black hole, it creates the conditions for new stars to form.

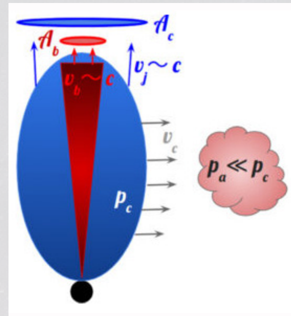


Diagram of the jet–cocoon configuration. Because the pressure within the cocoon exceeds the pressure of the surrounding gas clouds, the cocoon sweeps outward and compresses the clouds nearby. [Perna & Evgeni 2022]

Here's how it works: in rare cases, as a star is being pulled apart by a black hole, it shoots out a jet of material. A cocoon of gas enclosing this jet expands perpendicular to the jet, compressing the surrounding gas and providing enough pressure for gas clumps to overcome the black hole's tidal pull and form new stars.

While the expanding cocoon spurs star formation perpendicular to the jet, the jet itself creates a cone of superheated gas that suppresses star formation along its length. The combination of these factors promotes star formation in a thin disk, and the orientation of the disk is linked to the orbit of the disrupted star. In other words, the team expects that a tidally disrupted star will lead to a disk of stars forming at a random angle with respect to the galactic plane — exactly the arrangement we see at the center of the Milky Way.

More to Learn

The Milky Way's supermassive black hole likely tidally disrupts a star once every 10,000–100,000 years, with jetted tidal disruption events occurring every 1–10 million years. Why, then, have we only found evidence for two misaligned disks of stars at the galactic center? Because this method tends to form massive stars, the disks should disappear quickly; stars formed in the wake of a tidal disruption event would survive only a few million years.

An artist's impression of a tidal disruption event. [ESA/C. Carreau]

While this scenario laid out by Perna and Grishin appears to answer many of the questions regarding the stars arrayed in disks near the center of the Milky Way, the authors acknowledged that their hypothesis needs to be tested thoroughly. Hopefully, future numerical simulations will help us close in on the formation mechanism for these galactic center stars!

This article was written by OzGrav member Evgeni Grishin and Rosa Perna, ApJL 939 L17. doi:10.3847/2041-8213/ac99d8. and featured as published in AAS NOVA, Kerry Hensley, Nov, 2022.

Background picture: the Milky way at infrared optical and X-ray wavelenghts. Credit: NADA, ESA, SSC, CXC, and STScl, 2009.

Understanding the spins of binary black holes

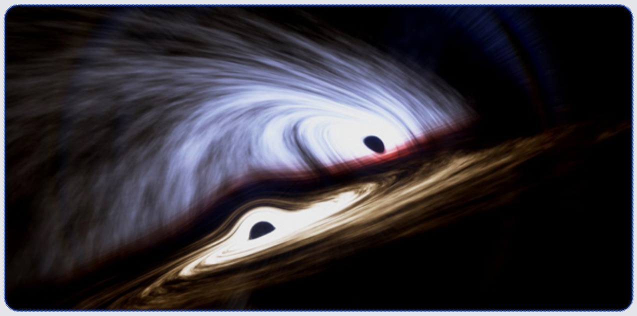


Illustration of two black holes merging. Credit: Mark Myers, ARC Centre of Excellence for Gravitational Wave Discovery

Since the first detection of gravitational waves in 2015, approximately 90 candidate gravitational waves from compact binary coalescences have been detected and recorded in the third LVK gravitational-wave transient catalogue (GWTC-3). The growing catalogue provides the opportunity to study the population properties of BBH systems. Binary black holes formed via different pathways are predicted to have distinct spin properties. Measuring these properties with gravitational waves provides an opportunity to unveil the origins of binary black holes.

Binary black hole systems are thought to evolve via two main channels: either from the isolated evolution of massive binary stars, through a process known as the field scenario; or in star clusters, through a process known as the dynamical scenario. Field binaries tend to have black-hole spins preferentially aligned with the orbital angular momentum due to tidal interactions. On the other hand, the black-hole spin vectors in dynamically formed BBH systems are expected to be distributed isotropically due to dynamical exchanges. These distinct predictions for black-hole spins provide a unique opportunity to study the fraction of current observed binary black hole systems related to each channel.

Inspired by this idea, many recent works seek to reveal the formation of binary black holes through the study of spin distribution in the binary black hole population observed by LIGO--Virgo--KAGRA (LVK). However, some work draws conflicting conclusions. Some analysis suggest that a fraction of the observed black-hole spin vectors are significantly misaligned (by $>90^\circ$) relative to the orbital angular momentum. This has been interpreted to mean that some binaries in the LVK dataset are assembled dynamically in dense stellar environments. Other analyses find support for a sub-population of binaries with negligible spin and no evidence for significantly misaligned spin---a result consistent with the field formation scenario.

We endeavour to help clarify some of the confusion surrounding the distribution of binary black hole spins. Therefore, our work revisited the data and studied the spin properties of binary black holes in GWTC-3.

We perform the hierarchical Bayesian inference using the dataset of roughly ~70 confident binary black hole events in GWTC-3. We highlight two parameters of particular interest in our population model, one of which measures the fraction of binary black hole mergers with non-spinning black holes and the other controls the maximum spin misalignment respective to the binary black hole orbital angular momentum.

In agreement with some previous work, we find that claims of anti-aligned black hole spin vectors are model-dependent. However, unlike their result, we do not find clear evidence for a sub-population of zero-spin black holes; the current data are not sufficiently informative to determine if such a sub-population exists. We find modest support for anti-aligned black hole spins with tilt angles $>90^\circ$.

Putting everything together, we conclude that we are some ways away from determining the dominant channel for the binary black hole mergers observed by the LVK.

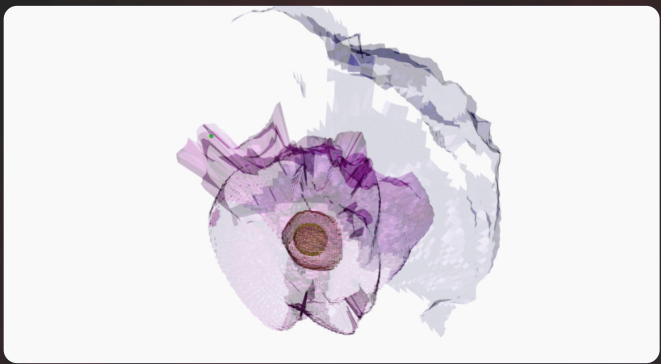
There may or may not be a sub-population of binary black hole systems with negligible spin. There is modest evidence that some binary black hole systems merge with anti-aligned spin, which could indicate dynamical assembly, though this signal could also be attributed to statistical fluctuations and/or model misspecification. The one thing we think we can say confidently is that at least some LVK mergers must be assembled in the field: conservatively > 11% (99\% credibility).

Written by PhD student Hui Tong and Shanika Galaudage, OzGrav -Monash University.

Preprint available on arXiv: The population properties of spinning black holes using Gravitational-wave Transient Catalog 3, https://arxiv.org/abs/2209.02206

Simulating Smashing Neutron Stars: Interview with Dr Ryosuke Hirai

When a neutron star ploughs into its companion, it can steal some matter, forming a new type of star, or even pulsar planets. Space Australia spoke with Dr Ryosuke Hirai from Monash University about his research into these interactions.



Three dimensional visualisation of Dr Hirai's simulation, showing how the newly formed neutron star penetrates through the layers of its companion star. Credit: Ryosuke Hirai & Philipp Podsiadlowski. To see the animated image click here.

People tend to think of scientists as either theorists or experimentalists with the former being stereotyped as bespectacled savants huddled over a mess of papers and books and the latter, a class of lab coat-wearing kooks, confined to basement laboratories filled with bubbling beakers and crackling electrical devices that may or may not be powered by lightning.

In reality, however, the roles or types of scientists are far more varied, with analytical and computational techniques - like numerical modelling and machine learning - becoming standard tools for many researchers.

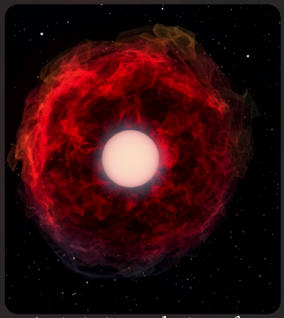
The astronomy community in Australia recently attended the 2022 Astronomical Society of Australia's (ASA) Annual Science Meeting where this reality was very prevalent. Students, early career researchers, senior scientists and collaborators, all proudly showed off the excellent work which they and their teams have been pursuing over the last year.

One great example of this more modern, multidisciplinary research is the work presented by Dr Ryosuke Hirai, which was presented at the ASA meeting.

Dr Hirai has worked extensively on modelling the behaviour of stars that live in pairs, known as binary systems, and how they interact with each other when one of the stars reaches the end of its stellar life as an energetic supernova. These violent events occur when one or both of the pair are high-mass stars, which burn through their nuclear fuel in relatively short timeframes.

More than 80% of the stars we see in the night sky are in fact binary systems, we just need powerful telescopes to differentiate two objects from one distant, twinkling point. Generally speaking, stars in a binary are separated by enough distance to significantly affect their cosmic companion as they orbit a common centre of gravity. But for those stars that stray too close when their partner runs out of nuclear fuel and explodes, the results can produce some exotic stellar objects.

These supernovae can leave behind a core of dense, neutron-rich material from the progenitor star - in a compact remnant object known as a neutron star - which can be kicked towards the companion by the force of the explosion. Some neutron stars tend to produce radio and high-energy emissions which, when observed from Earth, appear to pulsate as they rapidly rotate and have thus earned the nickname of pulsars.



Artististic rendering of a Thorne–Żytkow object, with a neutron star core enveloped by the outer layer of a red giant star. Credit: Space Engine / Cosmoknowledge.com.

Dr Hirai's new work shows how such neutron stars, depending on the speed and direction of their natal kick, can be thrown into the envelope of their companions, disrupting the secondary star due to their strong gravity. As the neutron star follows a trajectory inside the secondary, the system's centre of mass changes. This allows the neutron star to follow a different trajectory, depending on how powerful the original natal kick is.

Sometimes, when moving fast enough, it might pass right through the star, and at other times, when moving slower, it will hang around and start to gravitationally attract enough material to emerge with an additional disc of matter for itself. These interactions allow the neutron star to form planetary disks or even merge with their stellar companion into a strange hybrid star.

This article continues with an interview with Dr Hirai, where he explains his latest work in simulating supernova explosions in binary star systems. To continue reading please head to Spaceaustralia.

This article is featured as published in Space Australia, by Kove Rose and based on OzGrav member Ryosuke Hirai publication on Neutron stars colliding with binary companions, published in ArVix, Aud, 2022.

Artististic rendering of a Thorne–Żytkow object, with a neutron star core enveloped by the outer layer of a red giant star. Credit: Space Engine / Cosmoknowledge.com

OzGrav Postdoctoral Fellow: Yuzhe Robert Song

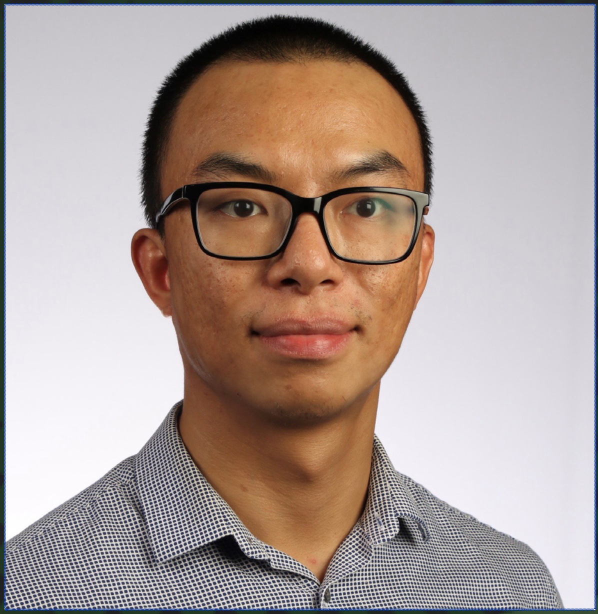


Photo credit: Yuzhe Robert Song

I remember one day in primary school, my mum brought home a DVD box set of Carl Sagan's Cosmos television series. I was immediately taken aback by the image of the beautiful nebula on the cover. From that point, as I journeyed through the Universe with Dr. Sagan, my passion for Astronomy and Science has never waned professionally or personally.

I have been fortunate to study, work and live across different parts of the globe, all driven by that passion. After attending Nanjing University for my Bachelor's degree in astrophysics, I moved to study my Master's at the University of Hong Kong, where I studied the gamma-ray emission mechanism of pulsars. During this time in Hong Kong, I met my husband and then we moved to New York where I completed my PhD at the City University of New York.

My PhD dissertation was focused on using stacking methods to detect unresolved point sources in the survey data of the Fermi Large Area Telescope. This provided a natural transition into my current research as an OzGrav member at Swinburne University of Technology. Here, I am using COMPAS, a rapid binary population synthesis code, to understand the gamma-ray emitting sources from my PhD projects.

Moving to Melbourne was a really great opportunity for my career and OzGrav is such an amazing organisation that provides significant opportunities for expanding the areas of my research. It is also exciting for us to be closer to my husband's family and cherish the opportunities made available to us by living in Australia.

OzGrav at Explore UWA Open Day

It was a warm spring day in Perth for the Explore UWA Open Day on Sunday, 28 August 2022. OzGrav students and staff were engaged with the public using our VR headsets for a Solar System Tour and testing the curvature of space on Einstein First's Space Time Simulator. We also gave away OzGrav stickers and The Legends of Physicists posters. Some 300 posters were given away within the 5-hour event!

This year we added a tabletop interferometer to explain the instruments built and designed to aid in the first discovery of gravitational waves from a pair of coalescing black holes. There was even a chance to take a Black Hole Selfie. The Black Hole Selfie activity was especially enjoyed by our young visitors who repeatedly returned to the large monitor to see their image distorted.

We gratefully acknowledge the use of the Pocket Black Hole app made by Laser Labs at www.laserlabs.org, on behalf of the Gravitational Wave Group at the University of Birmingham, UK.

This piece was written by Ruby Chan, OzGrav-ANU Node Administrator. Photo credits: Weichangfeng GUO, OzGrav-UWA Visiting Research Student

OzGrav Early Career Researcher (ECR) Winter School in Adelaide

A new initiative in July 2022, run by Zac Holmes and Dan Brown (University of Adelaide OzGrav Node) –was a chance for many new OzGrav members to attend their first in-person conference and meet team members.

Around 40 early career researchers from across Australia gathered in Adelaide for 3 days and it was a great opportunity to learn about the instrumentation and astrophysics of gravitational wave science, along with training workshops and an outreach session. It was also a good chance for people from every OzGrav Node to network with potential future collaborators and enjoy some social activities while Adelaide's Illuminate festival was on.

This piece was written by Lisa Horsley OzGrav's Research Coordinator and Outreach Officer, OzGrav-Swinburne University. Photo credits: Lisa Horsley.

Pilot Projection Night at Wolfhound

Carl Knox (Swinburne) has been working on some immersive light projections, as well as some non-touch interactive apps to engage people in the fun side of black hole science.

We held a fun night at Wolfhound Café in Fitzroy with science talks and catching up with colleagues after a long break due to working from home. Shanika from Monash investigates the lives of black holes. Andrew from Swinburne shared info about pulsars and pipelines. Christine from University of Melbourne talked about gravitational wave burst detection.

Written by Lisa Horsley. Photo credits: Lisa Horsley and Carl Knox, OzGrav-Swinburne University.

Regional Queensland World Science Festivals

World Science Festival events are run by the Queensland Museum in towns in regional Queensland, taking science to new audiences and encouraging hands-on participation for all ages, with both school and public event days.

The OzGrav Outreach team took these opportunities to take and train some of our early career researchers (for example PhD and undergraduate students) in science communication. It was a great way to meet lots of people and practice explaining our science to young and old participants. Virtual Reality (VR) is always popular at these events, so sometimes we had long queues waiting to take a virtual trip out to space. This gave us more time chatting to people about space study and careers and show them some black holes games on the iPads. Download your own Pocket Black hole and more apps at www.ozgrav.org/apps. We were really excited to meet Dr Karl in Gladstone!

Written by Lisa Horsley. Photo credits: Lisa Horsley.

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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