SPACE TIMES

OzGrav

March 2021

Cygnus X-1: The most massive black hole near Earth

page 6

Phonons & photons

page 3

Bizarre magnetar

page 8

Missing galactic matter

page 12

Welcome

Dear Colleagues,

For the first time in almost a year I returned to the OzGrav headquarters at Swinburne University of Technology's main campus after various lockdowns and work-from-home requests. It was quite an emotional return. On the upside seeing people again and having a sense of work community was wonderful, but it was also sad to see the pandemic's impact on local businesses with many having changed hands or being boarded up.

I've no doubt that we're more productive when we can brainstorm in person, scribble on white-boards and have relaxed conversations around decent cups of coffee than when we're trying to emulate the office via zoom. On the other hand, perhaps there's a time for eliminating peak hour commutes and working from home to push through to a deadline without interruption?

In the next few weeks OzGrav will be presenting its achievements to the Australian Research Council's mid-term review panel. I'm confident we'll be proud of our efforts as we start to plan for how this field should progress in the 2020s and formulating a bid for an OzGrav 2.0.

I also want to take this opportunity to congratulate Professor David McClelland for his career achievement award (The Thomas Ranken Lyle medal) from the Australian Academy of Sciences announced recently.
I hope you enjoy this issue of Space Times and that I'll see you all soon, not just on zoom.

Regards,
Matthew Bailes
OzGrav Director

NEWS IN BRIEF

- Hot off the press: Check out OzGrav's 2020 Annual Report and new Industry Success Stories
- The OzGrav LIEF bid for 3M in ARC infrastructure funding was successful! This bid was led out of ANU by David McClelland and featured many OzGrav Chief Investigators. It will enable us to continue our involvement in supporting LIGO for the next few years.
- Congratulations to OzGrav researchers Adam Deller, Ryan Shannon, Cherie Day, Stefan Oslowski, Chris Flynn and Wael Farah on receiving the Newcomb Cleveland prize from the AAAS. The award is for the best paper published in Science Magazine in the last year and was awarded for their paper that presented the discovery of the first localised one-off FRB: 'A single fast radio burst localized to a massive galaxy at cosmological distance'.
- Congratulations also to OzGrav AI Ryan Shannon and his LIEF team for their LIEF grant to upgrade ASKAP to find even more Fast Radio Bursts!
- Congratulations to OzGrav PhD student Chayan Chatterjee from UWA on winning the best ANITA21 student talk prize.

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

New technology to improve world's most sensitive scientific instruments

A new technology that can improve gravitational-wave detectors, one of the most sensitive instruments used by scientific researchers, has been pioneered by physicists at The University of Western Australia in collaboration with an international team of researchers.

The new technology allows the world's existing gravitational wave detectors to achieve a sensitivity that was previously thought only to be achievable by building much bigger detectors.

The paper, published in *Communications Physics*, was led by the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) at UWA, in collaboration with the ARC Centre of Excellence for Engineered Quantum Systems, the Niels Bohr Institute in Copenhagen and the California Institute of Technology in Pasadena.

OzGrav Chief Investigator Prof David Blair, from UWA, says the technology merged quantum particles of sound vibration called phonons with photons of laser light, to create a new type of amplification in which the merged particles cycled back and forth billions of times without being lost.

'More than a hundred years ago Einstein proved that light comes as little energy packets, which we now call photons,' says Prof Blair.

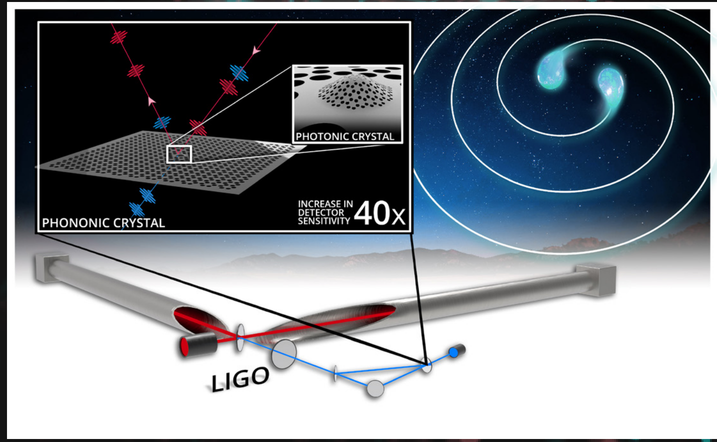
One of the most sophisticated applications of photons are gravitational-wave detectors, which allow physicists to observe ripples in space and time caused by cosmic collisions.

'Two years after Einstein's prediction of photons, he proposed that heat and sound also come in energy packets, which we now call phonons. Phonons are much trickier to harness individually in their quantum form because they're usually swamped by vast numbers of random phonons called thermal background,' says Prof Blair.

OzGrav Associate Investigator and lead author Dr Michael Page says the trick was to combine phonons and photons together in such a way that a broad range of gravitational wave frequencies could be amplified simultaneously.

'The new breakthrough will let physicists observe the most extreme and concentrated matter in the known universe as it collapses into a black hole, which happens when two neutron stars collide,' says Dr Page.

Prof Blair says the waveforms sounded like a brief scream that was pitched too high for current detectors to hear. 'Our technology will make those waveforms audible, and will also reveal whether the neutrons in neutron stars get split up into their constituents called quarks when they are in this extreme state,' he says. 'The most exciting thing



Credit: Carl Knox, OzGrav-Swinburne University

about seeing nuclear matter turn into a black hole is that the process is like the reverse of the Big Bang that created the Universe. Observing this happen will be like watching a movie of the Big Bang played backwards.'

This article is an edited version of the original media release written by UWA media office. Prof David Blair also wrote an article featured in The Conversation.

Background image: Carl Knox, OzGrav-Swinburne

Massive Stellar Triples leading to Sequential Binary Black-Hole Mergers in the field

Time evolution of massive stellar triples: The figure illustrates compact stars in blue, standard evolving stars with red envelopes, black holes in black and merging binary black holes with a surrounding swirl. Black holes formed as sequential mergers are labeled "SM".
Top: the outer tertiary is the most massive star in the system and forms the first black hole in this triple. The inner binary needs to be constituted of compact stars and the tertiary can be either standard evolving or a compact star. Middle: all stars have similar masses. These triples can only lead to sequential mergers if all stars are compact. GW170729 might have experienced this evolution. Bottom: the tertiary is of significantly lower mass than either of the inner binary stars. This configuration does not lead to sequential mergers and is only presented for completion. Credit: T. Rebagliato & A. Vigna-Gomez.

The merger of two black holes in a binary system emits energy that can be detected on Earth by gravitational-wave observatories. The LIGO Scientific Collaboration and the VIRGO Collaboration have announced tens of confident detections of such mergers to date. Now, one of the main questions we can try to address concerns the origin of such merging binaries: do they come from isolated binary stars or from dense stellar environments? The answer might not be that simple.

A recent study published in the *Astrophysical Journal Letters*, led by OzGrav Affiliate Dr Alejandro Vigna-Gómez—and current DARK Fellow at the Niels Bohr Institute—shows that some binary black holes can originate from triple stellar systems. A triple stellar system consists of an inner binary and a triple stellar companion orbiting around it. If the inner binary is close enough, it can become a binary black hole which rapidly merges. The product of a binary black hole merger is a single rotating black hole. The merger of the inner binary black hole transforms the initial triple system to a binary, which itself might be able to merge within the age of the Universe. However, the assembly of these triple systems is not as simple as it sounds, as they need to be formed at low metallicities.

Astronomers consider metals to be all elements except hydrogen and helium. Low metallicity environments are those in which hydrogen and helium compose more than approximately 99% of matter. Scientists believe that rare compact stars exist in low metallicity environments. In these environments, rapid rotation and mixing stir the stellar fuel and restrict chemically homogeneously-evolving stars from expanding. Additionally, metallicity increases alongside the age of the Universe, and therefore compact stars are more likely to be formed in the distant past.

Vigna-Gómez and collaborators studied the properties of such sequential binary black hole mergers and conclude that GW170729, one of the detected signals of a binary black hole merger, might be of triple stellar origin. The progenitor of GW170729 has at least one rapidly spinning black hole, plausibly from a previous merger.

Moreover, the masses are consistent with those of chemically homogeneously evolving stars, and the inferred formation time coincideswith the time it would take a triple system to experience two sequential mergers. Future observations from gravitational-wave observatories will help to further probe this formation channel and, more in general, understand the origin of binary black hole mergers.

Written by OzGrav Affiliate Alejandro Vigna Gomez from Niels Bohr Institute.

Congratulations to OzGrav Deputy Director David McClelland on receiving the prestigious Thomas Ranken Lylle Medal awarded by the Australian Academy of Science. This medal is a career award that recognises outstanding achievement by a scientist in Australia for research in mathematics or physics.

It is terrific to see David's tremendous contributions to quantum squeezing and gravitational wave discovery recognised with this honour on top of the other accolades he has received since the creation of OzGrav!

Upcoming prizes & awards

- The ASA Bok Prize for outstanding research in astronomy by an Honours or eligible Masters student - nominations close 29 March 2021
- AIPS Young Tall Poppy Science Awards - nominations close 6 April
- The National Measurement Institute Prize - nominations close 14 April 2021
- The Barry Inglis Medal - nominations close 14 April 2021
- Australian Optical Society Awards - nominations close 30 April 2021
- Australian Academy of Science Awards - nominations close 1 May 2021
- 2021Australian Museum Eureka Prizes - nominations close 28 May 2021
- The AIP Walter Boas Medal - nominations close 1 June 2021
- The AIPS TH Laby Medal for Excellence in Physics - nominations close 1 July 2021

Background image: JOSH VALENZUELA/UNM

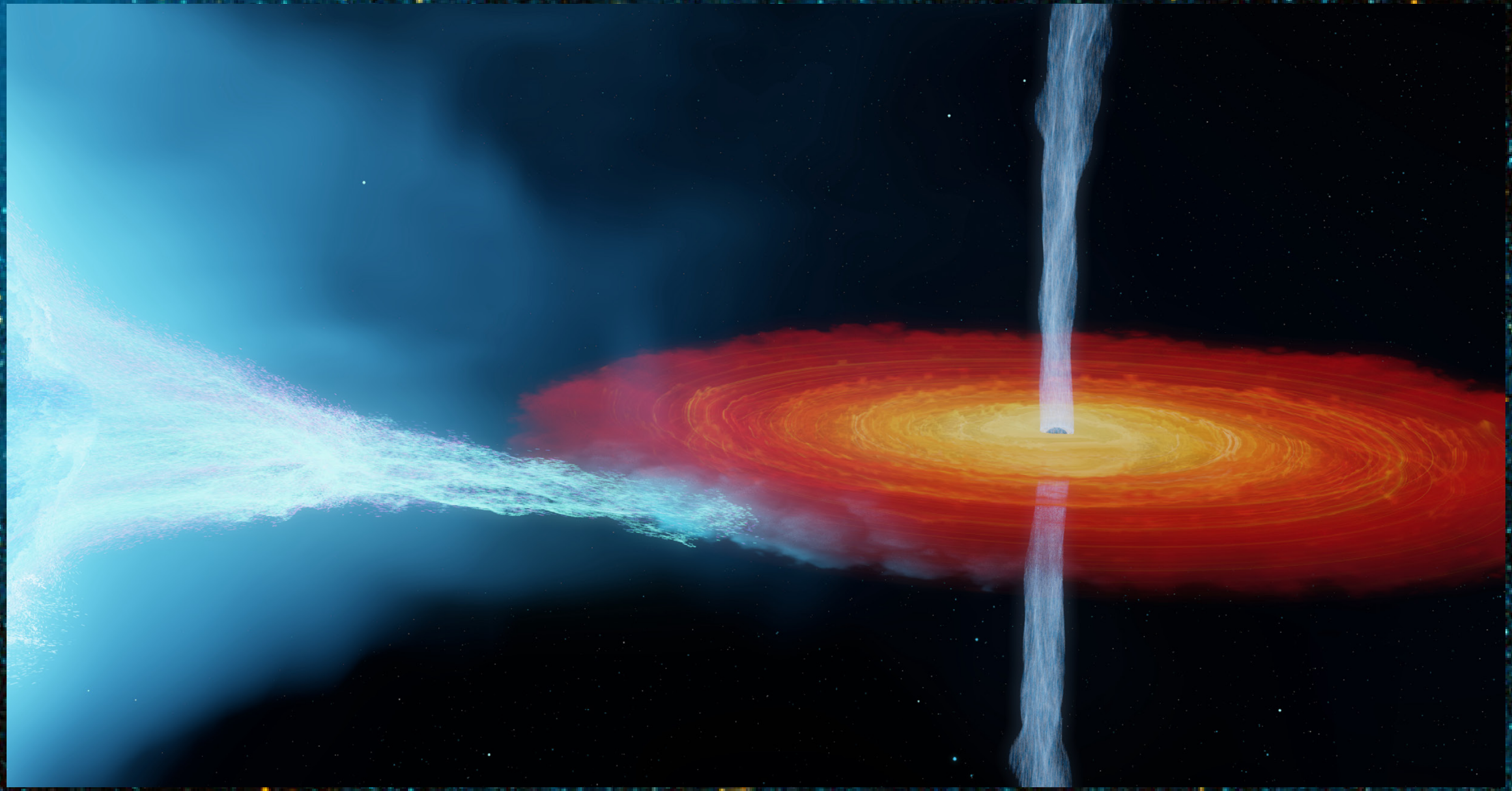
First black hole ever detected is more massive than we thought

New observations of the first black hole ever detected have led astronomers to question what they know about the Universe's most mysterious objects. Published in the journal *Science*, the research shows the system known as Cygnus X-1 contains the most massive stellar-mass black hole ever detected without the use of gravitational waves.

Cygnus X-1 is one of the closest black holes to Earth. It was discovered in 1964 when a pair of Geiger counters were carried on board a sub-orbital rocket launched from New Mexico. The object was the focus of a famous scientific wager between physicists Stephen Hawking and Kip Thorne, with Hawking betting in 1974 that it was not a black hole. Hawking conceded the bet in 1990. In this latest work, an international team of astronomers used the Very Long Baseline Array—a continent-sized radio telescope made up of 10 dishes spread across the United States—together with a clever technique to measure distances in space.

OzGrav Chief Investigator and study co-author Prof Ilya Mandel, from Monash University, says the black hole is so massive it's actually challenging how astronomers thought they formed. 'Stars lose mass to their surrounding environment through stellar winds that blow away from their surface. But to make a black hole this heavy, we need to dial down the amount of mass that bright stars lose during their lifetimes,' says Prof Mandel. 'The black hole in the Cygnus X-1 system began life as a star approximately 60 times the mass of the Sun and collapsed tens of thousands of years ago,' he says. 'Incredibly, it's orbiting its companion star—a supergiant—every five and a half days at just one-fifth of the distance between the Earth and the Sun. These new observations tell us the black hole is more than 20 times the mass of our Sun—a 50 per cent increase on previous estimates.'

Second study author Dr Arash Bahramian from the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR) says this was an exciting discovery, resulting from a collaboration between astronomers focused on different observational and theoretical aspects of black holes, coming together for a new extensive and rigorous look at a known but previously elusive black hole. 'It is exciting that we can measure so precisely so many aspects of the system, like its distance from us, its motion and speed through the Galaxy, and the binary motion of the black hole and the star around each other,' says Dr Bahramian. 'Our new distance estimate caused an interesting domino effect, leading us to new measurements for the mass and spin of the black hole, which in turn led to fascinating new insights about how stars evolve and how black holes form.'



An artist's impression of the Cygnus X-1 system. This system contains the most massive stellar-mass black hole ever detected without the use of gravitational waves, weighing in at 21 times the mass of the Sun. Credit: International Centre for Radio Astronomy Research. Credit: International Centre for Radio Astronomy Research.

Lead researcher James Miller-Jones also from ICRAR says over six days the researchers observed a full orbit of the black hole and used observations taken of the same system with the same telescope array in 2011. 'This method and our new measurements show the system is further away than previously thought, with a black hole that's significantly more massive,' says Prof Miller-Jones.

In a separate but related development University of Birmingham PhD candidate Coenraad Neijssel, affiliated with OzGrav and Monash, led a companion paper to this work simultaneously published in the Astrophysical Journal. 'Using the updated measurements of the system properties, we were able to unwind the previous history of the binary as well as predict its future,' says Coenraad. 'Precise observations like this are critical for improving our understanding of the evolution of massive stars.'

This article is an edited of the original media release written by Silvia Dropulich at Monash University Media Office. Also featured in the New York Times and The Daily Mail.

Background image: NASA/JPL-Caltech

Astronomers spot bizarre, never-before-seen activity from one of the strongest magnets in the Universe

Astronomers from the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) and CSIRO have just observed bizarre, never-seen-before behaviour from a 'radio-loud' magnetar—a rare type of neutron star and one of the strongest magnets in the Universe.

Their new findings, published in the *Monthly Notices of the Royal Astronomical Society* (MNRAS), suggest magnetars have more complex magnetic fields than previously thought – which may challenge theories of how they are born and evolve over time. Magnetars are a rare type of rotating neutron star with some of the most powerful magnetic fields in the Universe. Astronomers have detected only thirty of these objects in and around the Milky Way—most of them detected by X-ray telescopes following a high-energy outburst. However, a handful of these magnetars have also been seen to emit radio pulses similar to pulsars—the less magnetic cousins of magnetars that produce beams of radio waves from their magnetic poles. Tracking how the pulses from these 'radio-loud' magnetars change over time offers a unique window into their evolution and geometry.

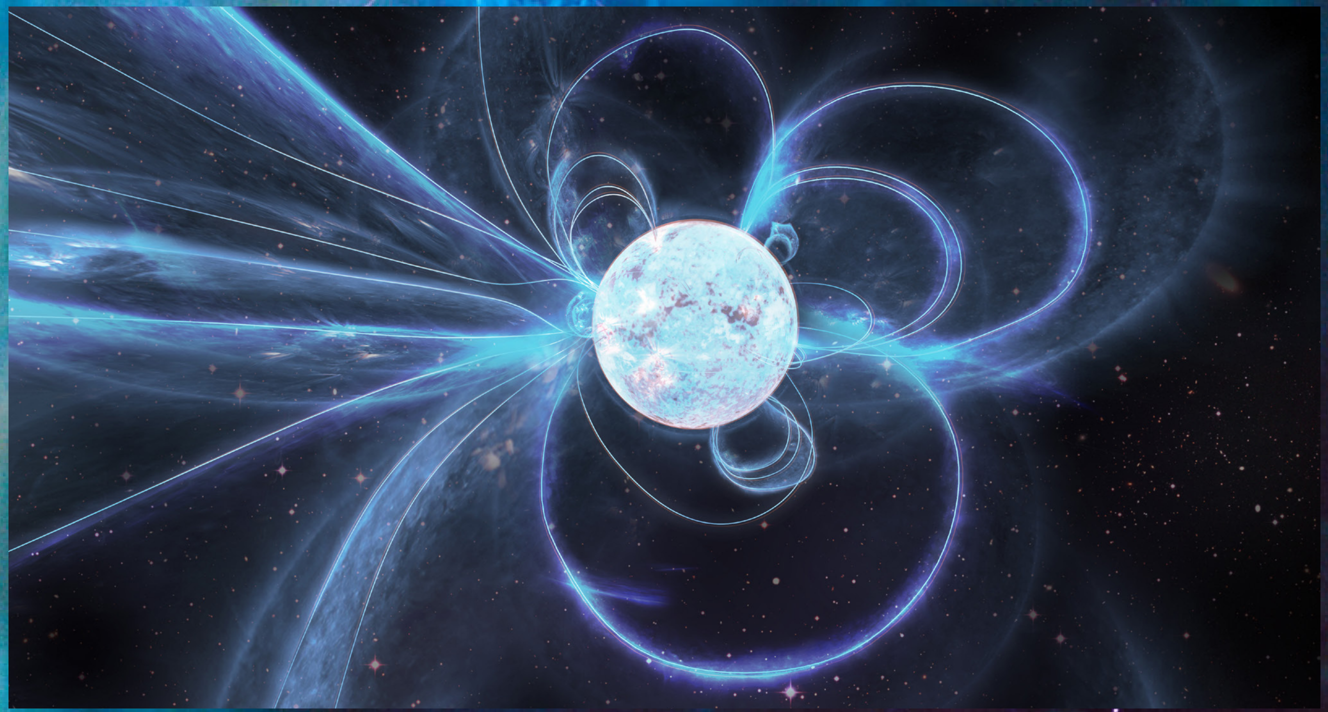
In March 2020, a new magnetar named Swift J1818.0-1607 (J1818 for short) was discovered after it emitted a bright X-ray burst. Rapid follow-up observations detected radio pulses originating from the magnetar. Curiously, the appearance of the radio pulses from J1818 were quite different to those seen from other radio-loud magnetars. Most radio pulses from magnetars maintain a consistent brightness across a wide range of observing frequencies. However, the pulses from J1818 were much brighter at low frequencies than high frequencies – similar to what is seen in pulsars, another more common type of radio-emitting neutron star.

In order to better understand how J1818 would evolve over time, a team led by OzGrav scientists observed it eight times using the CSIRO Parkes radio telescope (also known as Murriyang) between May and October 2020. During this time, they found the magnetar underwent a brief identity crisis: in May it was still emitting the unusual pulsar-like pulses that had been detected previously; however, by June it had started flickering between a bright and a weak state. This flickering behaviour reached a peak in July where they saw it flicking back and forth between emitting pulsar-like and magnetar-like radio pulses.

'This bizarre behaviour has never been seen before in any other radio-loud magnetar,' explains study lead author and Swinburne University/CSIRO PhD student Marcus Lower. 'It appears to have only been a short-lived phenomenon as by our next observation it had settled permanently into this new magnetar-like state.'

The scientists also looked for pulse shape and brightness changes at different radio frequencies and compared their observations to a 50-year-old theoretical model. This model predicts the expected geometry of a pulsar, based on the twisting direction of its polarised light.

'From our observations, we found that the magnetic axis of J1818 isn't aligned with its rotation axis,' says Lower. 'Instead, the radio-emitting magnetic pole appears to be in its southern hemisphere, located just below the equator. Most



Artist's impression of the active magnetar Swift J1818.0-1607, Carl Knox, OzGrav-Swinburne

other magnetars have magnetic fields that are aligned with their spin axes or are a little ambiguous. This is the first time we have definitively seen a magnetar with a misaligned magnetic pole.'

Remarkably, this magnetic geometry appears to be stable over most observations. This suggests any changes in the pulse profile are simply due to variations in the height the radio pulses are emitted above the neutron star surface. However, the August 1st 2020 observation stands out as a curious exception.

'Our best geometric model for this date suggests that the radio beam briefly flipped over to a completely different magnetic pole located in the northern hemisphere of the magnetar,' says Lower.

A distinct lack of any changes in the magnetar's pulse profile shape indicate the same magnetic field lines that trigger the 'normal' radio pulses must also be responsible for the pulses seen from the other magnetic pole. The study suggests this is evidence that the radio pulses from J1818 originate from loops of magnetic field lines connecting two closely spaced poles, like those seen connecting the two poles of a horseshoe magnet or sunspots on the Sun. This is unlike most ordinary neutron stars which are expected to have north and south poles on opposite sides of the star that are connected by a donut-shaped magnetic field.

This peculiar magnetic field configuration is also supported by an independent study of the X-rays pulses from J1818 that were detected by the NICER telescope on board the International Space Station. The X-rays appear to come from either a single distorted region of magnetic field lines that emerge from the magnetar surface or two smaller, but closely spaced, regions. These discoveries have potential implications for computer simulations of how magnetars are born and evolve over long periods of time, as more complex magnetic field geometries will change how quickly their magnetic fields are expected to decay over time. Additionally, theories that suggest fast radio bursts can originate from magnetars will have to account for radio pulses potentially originating from multiple active sites within their magnetic fields.

Catching a flip between magnetic poles in action could also afford the first opportunity to map the magnetic field of a magnetar.

'The Parkes telescope will be watching the magnetar closely over the next year,' says scientist and study co-author Simon Johnston, from the CSIRO Astronomy and Space Science.

Also featured in Sydney Morning Herald, Space Australia and CSIRO News.

Background image: NASA

Sifting out the Universe's first gravitational waves

In the moments immediately following the Big Bang, the very first gravitational waves rang out. The product of quantum fluctuations in the new soup of primordial matter, these earliest ripples through the fabric of space-time were quickly amplified by inflationary processes that drove the universe to explosively expand.

Primordial gravitational waves, produced nearly 13.8 billion years ago, still echo through the Universe today. But they are drowned out by the crackle of gravitational waves produced by more recent events, such as colliding black holes and neutron stars.

Now a team of international scientists, including reasearchers from the Massachusetts Institute of Technology and OzGrav, has developed a method to tease out the very faint signals of primordial ripples from gravitational-wave data. Their results were published in *Physical Review Letters.*

Gravitational waves are being detected on an almost daily basis by LIGO and other gravitational-wave detectors, but primordial gravitational signals are several orders of magnitude fainter than what these detectors can register. It's expected that the next generation of detectors will be sensitive enough to pick up these earliest ripples.

In the next decade, as more sensitive instruments come online, the new method could be applied to dig up hidden signals of the Universe's first gravitational waves. The pattern and properties of these primordial waves could then reveal clues about the early universe, such as the conditions that drove inflation.

'If the strength of the primordial signal is within the range of what next-generation detectors can detect, which it might be, then it would be a matter of more or less just turning the crank on the data, using this method we've developed,' says Sylvia Biscoveanu—MIT graduate student and the study's lead author. 'These primordial gravitational waves can then tell us about processes in the early Universe that are otherwise impossible to probe.' OzGrav researchers Colm Talbot, Eric Thrane and Rory Smith were also co-authors of the study.

The hunt for primordial gravitational waves has concentrated mainly on the cosmic microwave background, or CMB, which is thought to be radiation that is leftover from the Big Bang. Scientists believe that when primordial gravitational waves rippled out, they left an imprint on the CMB, in the form of B-modes, a type of subtle polarization pattern.Physicists have looked for signs of B-modes, most famously with the BICEP Array, a series of experiments including BICEP2, which in 2014 scientists believed had detected B-modes; however, the signal turned out to be due to galactic dust.

As scientists continue to look for primordial gravitational waves in the CMB, others are hunting the ripples directly in gravitational-wave data. The general idea has been to try and subtract away the 'astrophysical foreground'—any gravitational-wave signal that arises from an astrophysical source, such as colliding black holes, neutron stars, and exploding supernovae. Only after subtracting this astrophysical foreground can physicists get an estimate of the quieter, nonastrophysical signals that may contain primordial waves.

The problem with these methods, Biscoveanu says, is that the astrophysical foreground contains weaker signals that are too faint to discern and difficult to estimate in the final subtraction.

In their study, the researchers used a predictive model to describe the more obvious 'conversations' of the astrophysical foreground. The team used this more accurate model to create simulated data of gravitational wave patterns and then characterize every astrophysical signal. Once they identified distinct, nonrandom patterns in gravitational-wave data, they were left with more random primordial gravitational-wave signals and instrumental noise specific to each detector. Applying their new methods, the team was able to fit both the foreground and the background at the same time, so the background signal didn't get contaminated by the residual foreground.

Biscoveanu says she hopes that once more sensitive, next-generation detectors come online, the new method can be used to cross-correlate and analyse data from two different detectors, to sift out the primordial signal. Then, scientists may have a useful thread they can trace back to the conditions of the early Universe.

This article is an edited extract from the original article featured on MIT's news website written by Jennifer Chu.

OZGRAV IN THE MEDIA

Using one hundred-million-year-old fossils and gravitational-wave science to predict the **Earth's future climate**

A group of international scientists, including an OzGrav researcher, has used gravitational wave astronomy to study ancient marine fossils as a predictor of climate change.

The research, *published in the journal Climate of the Past*, is a unique collaboration between palaeontologists, astrophysicists and mathematicians – to improve the accuracy of a palaeo-thermometer, which can use fossil evidence of climate change to predict what is likely to happen to the Earth in coming decades.

OzGrav Chief Investigator Prof Ilya Mandel, from Monash University, and colleagues, studied biomarkers left behind by tiny single-cell organisms called archaea in the distant past, including the Cretaceous period and the Eocene.

Marine archaea in our modern oceans produce compounds called Glycerol Dialkyl Glycerol Tetraethers (GDGTs). The ratios of different types of GDGTs they produce depend on the local sea temperature at the site of formation.

When preserved in ancient marine sediments, the measured abundances of GDGTs have the potential to provide a geological record of long-term planetary surface temperatures.

To date, scientists have combined GDGT concentrations into a single parameter called TEX86, which can be used to roughly estimate the surface temperature. However, this estimate is not very accurate when the values of TEX86 from recent sediments are compared to modern sea surface temperatures.

'After several decades of study, the best available models are only able to measure temperature from GDGT concentrations with an accuracy of around 6 degrees Celsius,' says Prof Mandel. 'Therefore, this approach cannot be relied on for high-precision measurements of ancient climates.'

Prof Mandel and his colleagues at the University of Birmingham in the UK have applied modern machine-learning tools—originally used to create predictive models of merging black holes and neutron stars—to improve temperature estimation based on GDGT measurements. This enabled them to take all observations into account for the first time rather than relying on one particular combination, TEX86. It also produced a far more accurate palaeo-thermometer.

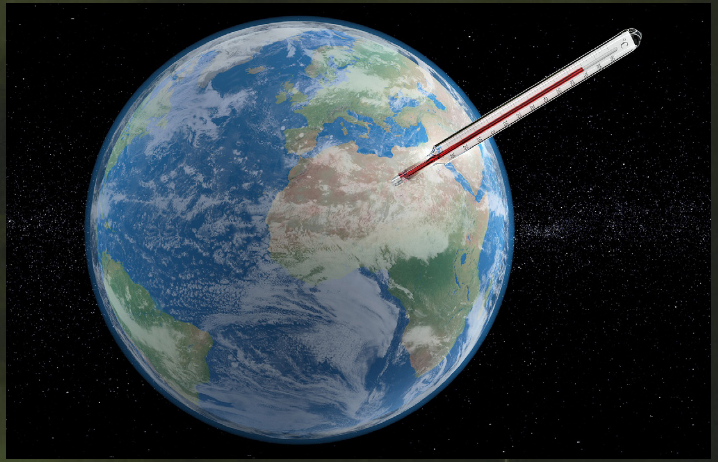


Image sourced from Pixabay

Using these tools, the team extracted temperature from GDGT concentrations with an accuracy of just 3.6 degrees—a significant improvement, nearly twice the accuracy of previous models.

According to Prof Mandel, determining how much the Earth will warm in coming decades relies on modelling, 'so it is critically important to calibrate those models by utilising literally hundreds of millions of years of climate history to predict what might happen to the Earth in the future,' he says.

Also featured in Cosmos magazine., Sci Tech Daily and Phys.org.

Background image: Pixabay

Student astronomer finds missing **galactic matter**

Astronomers have for the first time used distant galaxies as 'scintillating pins' to locate and identify a piece of the Milky Way's missing matter.

For decades, scientists have been puzzled as to why they couldn't account for all the matter in the Universe as predicted by theory. While most of the Universe's mass is thought to be mysterious dark matter and dark energy, 5 percent is 'normal matter' that makes up stars, planets, asteroids, peanut butter and butterflies. This is known as baryonic matter.

However, direct measurement has only accounted for about half the expected baryonic matter.

Yuanming Wang, an OzGrav researcher and doctoral candidate in the School of Physics at the University of Sydney, has developed an ingenious method to help track down the missing matter. She has applied her technique to pinpoint a hitherto undetected stream of cold gas in the Milky Way about 10 light years from Earth. The cloud is about a trillion kilometres long and 10 billion kilometres wide but only weighing about the mass of our Moon.

The results, published in the *Monthly Notices of the Royal Astronomical Society*, offer a promising way for scientists to track down the Milky Way's missing matter.

'We suspect that much of the "missing" baryonic matter is in the form of cold gas clouds either in galaxies or between galaxies,' say Wang, who is pursuing her PhD at the Sydney Institute for Astronomy.

'This gas is undetectable using conventional methods, as it emits no visible light of its own and is just too cold for detection via radio astronomy,' she says.

What the astronomers did is look for radio sources in the distant background to see how they 'shimmered'.

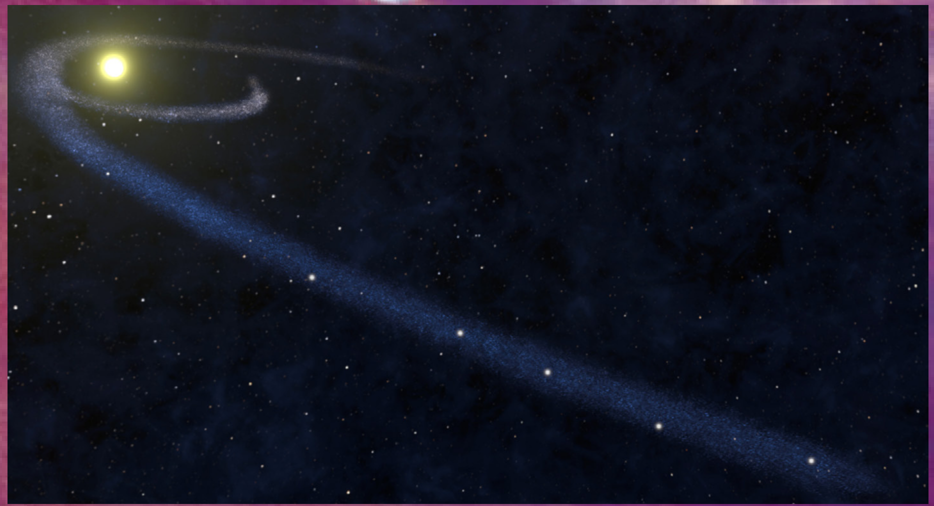
'We found five twinkling radio sources on a giant line in the sky. Their signals show their light must have passed through the same cold clump of gas,' says Wang.

Just as visible light is distorted as it passes through our atmosphere to give stars their twinkle, when radio waves pass through matter, it also affects their brightness. It was this 'scintillation' that Wang and her colleagues detected.

Dr Artem Tuntsov, a co-author from Manly Astrophysics, says: 'We aren't quite sure what the strange cloud is, but one possibility is that it could be a hydrogen "snow cloud" disrupted by a nearby star to form a long, thin clump of gas.'

Hydrogen freezes at about minus 260 degrees and theorists have proposed that some of the Universe's missing baryonic matter could be locked up in these hydrogen 'snow clouds'. They are almost impossible to detect directly.

'However, we have now developed a method to identify such clumps of "invisible" cold gas using background galaxies as pins,' says Wang.



Artist's impression of a thin gas cloud caused by tidal disruption by a star. Mark Myers/OzGrav-Swinburne University

Wang's supervisor, Prof Tara Murphy, says: 'This is a brilliant result for a young astronomer. We hope the methods trailblazed by Yuanming will allow us to detect more missing matter.'

The data to find the gas cloud was taken using the CSIRO's Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope in Western Australia.

Dr Keith Bannister, Principal Research Engineer at CSIRO, says: "It is ASKAP's wide field of view, seeing tens of thousands of galaxies in a single observation that allowed us to measure the shape of the gas cloud."

Professor Murphy says: "This is the first time that multiple 'scintillators' have been detected behind the same cloud of cold gas. In the next few years, we should be able to use similar methods with ASKAP to detect a large number of such gas structures in our galaxy."

The research was done in collaboration with CSIRO, Manly Astrophysics, the University of Wisconsin-Milwaukee and the ARC Centre of Excellence for Gravitational Wave Discovery, OzGrav.

This article is an edited extract from the original article featured on the University of Sydney's News site. Also featured on The Conversation.

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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Image credit: as stated on each page. Front cover by Carl Knox, OzGrav-Swinburne University

Background image: NASA