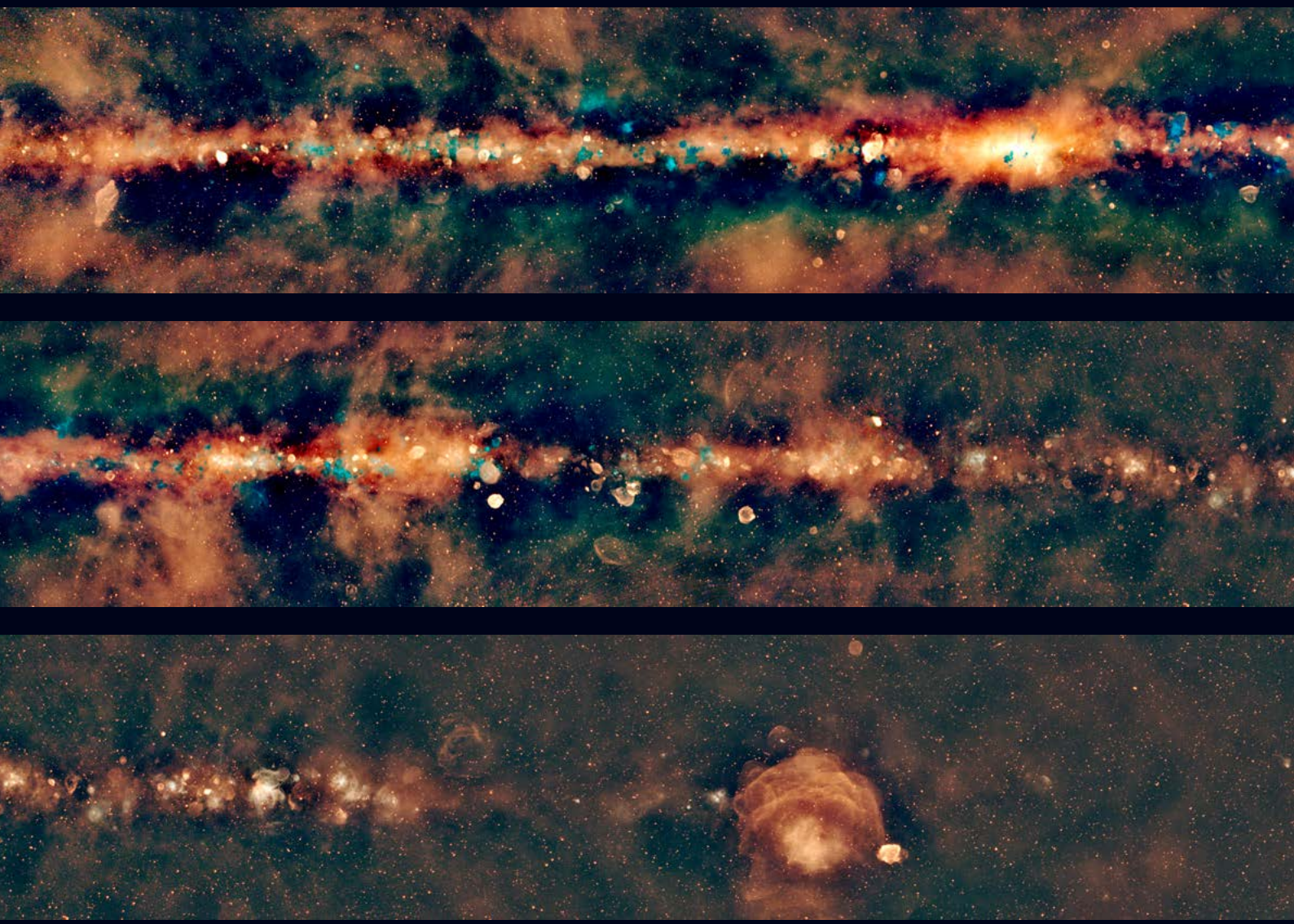
CIRA 2025

CURTIN INSTITUTE OF RADIO ASTRONOMY



Curtin University

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This annual report covers the calendar year 2025.

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ON THE COVER
The cover image shows a new radio image of our own Milky Way galaxy, formed by combining both the GaLactic and Extragalactic All-sky Murchison Widefield Array (GLEAM) survey, and its successor, GLEAM-eXtended (GLEAM-X). The false colour palette weights the full frequency range of the two surveys, 72 to 231 MHz, in a way that simulates the colour response of the human eye.

Image: Mantovanini et al. 2025

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Executive Director's Report

PROFESSOR STEVEN TINGAY
CIRA EXECUTIVE DIRECTOR

The 2025 calendar year saw a significant period of change for CIRA, continued success as a consequence, and substantial steps to ensure future activities.

After a five-year effort, the Murchison Widefield Array (MWA) Phase III upgrade was completed, bringing the facility to its full operational capacity. In a monumental effort by the CIRA engineering and operations teams, along with similar efforts from MWA partners overseas, the telescope now boasts 256 tiles fully serviced by digital receivers (the upgrade provisioning 16 new receivers) and a new correlator. The upgrade has resulted in double the instantaneous sensitivity, approximately four times the number of baselines, renewed flexibility via software-defined operations, and a big boost in the MWA's ability to support searches for the weak and challenging signals from the Epoch of Reionisation.

In many ways, the MWA has been the engine room for CIRA science and engineering; but it is also the capability from which has stemmed a great many of our opportunities to work with industry that we have followed over the years. The upgrade has resulted in substantial additional international demand for the facility, and a range of new science directions. This is very exciting and, in an increasingly competitive and constrained funding environment, an impressive feat for a university group to establish, operate, and upgrade multiple times an international facility over now more than 13 years.

You will read about the many CIRA achievements based on the MWA and MWA data in the pages of this annual report.

In mid-2025, the ICRAR Transition Year came to a close, and the ICRAR4 program commenced, following a comprehensive and constructive co-design of the five-year funded program of work between the ICRAR leadership and the Western Australian State Government. As noted in the Program Director reports, the concept of Translation and Impact has more prominence in ICRAR4, underpinned by a continuing need to push fundamental research in astronomy and engineering. CIRA has been, and continues to be, well placed to engage in such activities, and I've been very pleased with the response of CIRA's management,

staff, and students in embracing ICRAR4. At the end of 2025, we are well on the way to bedding in the program, noting that this has entailed some difficult decisions regarding some of our priorities and directions. But this is not unusual and has been the case at the end of ICRAR1, ICRAR2, and ICRAR3/Transition Year. One of the great things about ICRAR has been its evolution and adaptation to changing circumstances and imperatives over the last 17 years. As always, we have the support of the Western Australian State Government, Curtin University, and The University of Western Australia to thank.

The CIRA node of the Australian SKA Regional Centre (AusSRC) was in full swing in 2025, contributing to global SKA goals. More generally, the SKA telescopes in Western Australia and South Africa continue to power through their construction programs; by the end of the ICRAR4 period, it is likely that CIRA astronomers will have their hands on some of the first SKA data, which will be exciting for those of us who have spent most of our careers working on or adjacent to the SKA journey.

So, across CIRA's access to funding for science and engineering, opportunities to broaden our horizons in Translation and Impact, our access to and leadership of the MWA's fantastic upgraded facilities, and with the SKA finally on the horizon, we have exciting and productive times ahead. This is a privilege we do not take for granted, especially considering increasingly tight funding for science in Australia and many other countries around the world (significant recent cuts in the US and UK, for example), as well as the world itself being in something of a state of flux at the moment.

To have resources at our disposal, and the ability to make decisions about our future, is a great position to be in. It is not by chance, however, and is built on a track record of excellent scientific decision-making, prudent financial management, great people taking their opportunities to build world-leading skills and international leadership, and a steady stream of fantastic research students who each make a big contribution to CIRA and then go on to do amazing things around the world.

As an Institute happy to be judged on our performance in multiple dimensions, we have great opportunities tinged with an appropriate level of challenge ahead of us. I thank the staff, students, and fellow Executive team members of CIRA for working hard to realise the opportunities and face the challenges, in 2025, as always.



Director's Report: Science

PROFESSOR JAMES MILLER-JONES
DIRECTOR SCIENCE

The middle of 2025 marked the end of the ICRAR Transition Year, and a move into a new five-year ICRAR IV program. As such, 2025 has seen significant evolution in the capacity, organisation, and high-level goals of the CIRA Science group. One of the best attributes of the Science team over the past several years has been the ability of our staff and students to work across the somewhat artificial Project-level (and even Program-level) boundaries imposed by our ICRAR structure, drawing skills from across the group to set up new collaborations and tackle interesting problems. Coupled with the evolution of our staff cohort, this has led to an organic evolution of the group, with new focus areas emerging. Moving into ICRAR IV, the group has been reorganised to reflect these groupings, ensuring that each project has a critical mass of continuing staff members with mutually intersecting interests. It has been great to see how the group has adjusted to this new structure, and I would like to thank the ICRAR IV project leads, Cath Trott, Natasha Hurley-Walker, and Clancy James, as well as the outgoing project lead Ramesh Bhat, for their work to effect such a smooth transition.

Scientific excellence remains one of our core mandates within ICRAR IV, and it has been exciting to see the breadth of work that the team has engaged in over the past year. 2025 was our most prolific calendar year to date, with the Science group publishing 131 refereed papers. This included a high-impact publication by Andy Wang and collaborators in the prestigious journal *Nature*, detailing the detection of X-ray pulsations from one of the mysterious new long-period radio transients. This paper continued CIRA's leadership in this exciting new field, and was the subject of a highly-successful media release. The Science team also put out media releases on two high-impact results from the Murchison Widefield Array; the deepest limits to date on the signal from the epoch of reionisation (Ridhima Nunhokee, Cath Trott and collaborators); and the most detailed low-frequency image of the southern Galactic Plane (Silvia Mantovanini and collaborators). This work emphasises the importance of MWA to our ongoing work, and demonstrates how well CIRA is positioned to take advantage of both the new Phase III upgrade to the MWA and, eventually, SKA-Low, for which Science Verification is set to begin in 2027.

CIRA's reputation for excellence in radio astronomy and our longstanding focus on the SKA were further reflected in our strong representation at the SKA science conference in Görlitz in June. Of the 219 talks at the meeting, 29 were

from Australian researchers, of which 7 were from CIRA, including 2 plenary talks. It was fantastic to see so many of our staff and students presenting their work and networking with members of the global SKA community.

Our staff and students were also recognised externally, receiving awards for their presentations, research work, or career achievements. Most notably, Natasha Hurley-Walker was awarded both the Australian Academy of Science's Nancy Millis Medal and the University of Melbourne's David Syme Research Prize, recognising her impressive achievements in delivering world-leading science with the MWA and opening up the new field of long-period transients.

Given the somewhat more constrained funding environment in ICRAR IV, it was encouraging to see the efforts of our staff rewarded with grant success. Beyond a funded ARC Discovery Project, Kristen Dage won a prestigious ARC DECRA Fellowship, and Aman Chokshi won a highly-competitive Forrest Fellowship that he will bring to CIRA in mid-2026.

Much of our research is driven by our PhD students (who published 22 of the 41 CIRA-led papers in 2025), and we were very proud to see six of our students complete their PhDs in 2025, along with five more who submitted their theses. This exodus of our senior students was balanced by a spectacularly successful RTP recruitment round, where CIRA were awarded 10% of the University's RTP scholarships for 2026. We look forward to welcoming this new cohort of talented students. It has also been encouraging to see some of our PhD students broaden their skill sets by undertaking internships with external organisations—most notably CSIRO and SKA. We hope to see more students take up such opportunities over the coming years.

Beyond our student graduations, we also bid farewell to Gemma Anderson (to CSIRO), Apurba Bera (to ASTRON), Edwin Dickinson, Anshu Gupta (to DBCA), Sam McSweeney and Susmita Sett (both to SKAO). We thank them for all their contributions to CIRA, and wish them every success in their new roles. We welcomed Rini Angreani to the AusSRC team as a Senior Software Developer, completing the CIRA complement of AusSRC staff.

ICRAR IV has seen a significant shift in focus, with more expectation of translation of our research into domains beyond astronomy, and less formal emphasis on undergraduate teaching and public outreach. It has been encouraging to see so many of the group engaging with the Translation & Impact team, and I look forward to seeing this develop further over the coming years, increasing the scope of these efforts as the team builds its expertise in translating their core research skills to related fields in and beyond academia. Recognising the importance of our link with the broader University, our staff have maintained their contributions to the delivery of Physics, Astrophysics and Statistics units as part of the School, providing access to enthusiastic and motivated undergraduate students, many of whom choose to undertake research projects with us, from summer projects through to PhD programs.

With an established core group of senior staff, a talented cohort of early-career researchers and PhD students, access to some of the world's best radio astronomy instrumentation, stable funding for the next few years, and the SKAO under commissioning, the prospects for the group are bright. I thank the team for their efforts over the past twelve months, and look forward with confidence to the year ahead.



Director's Report: Engineering Research & Operations

TOM BOOLER
DIRECTOR ENGINEERING & OPERATIONS

2025 was marked by the transition to ICRAR4. We are privileged that for many it represented the dawning of a new five-year horizon, to continue to pursue the work and goals that drive them. But we said goodbye to others, whose time at ICRAR came to an end. Marcin Sokolowski and Dave Kenney were CIRA stalwarts who made significant contributions across a broad range of activities over a long period of time; Jaiden Cook and Jishnu Thekkeppattu were CIRA HDR alumni that transitioned into staff positions and worked to deliver innovative research; Chitru Srestha and Mouriyan Rajendran were important members of the Murchison Widefield Array (MWA) Software and Systems team, providing attentive and responsive support to the MWA's user community; and Rob Howes joined to help establish the Peterborough Space Domain Awareness facility, and provided much-needed support in the management of the CIRA Labs. All were greatly appreciated and will be sincerely missed.

A standout milestone of 2025 was the finalisation of the 'Phase 3' upgrade of the MWA, realised through the successful deployment and integration of 16 new digital receivers. This achievement—the culmination of several years' work by the CIRA Operations team—laid the foundation for a productive and impactful epoch of science with the MWA through to its retirement planned for 2030.

The two primary engineering research groups both had funding successes in 2025. The US Government funded 'Transponders for Ionospheric Measurement' (TIMs) project achieved their phase 1 objectives and secured a two-year continuation. And funding was won from Geoscience Australia's AuScope Opportunity Fund to undertake a scoping study of remote infrastructure for an Australian research sensor network, leveraging CIRA's extensive experience in building and operating sensor arrays. In general, the Engineering Research

and Operations teams embraced the challenge of translating core business into domains outside of astronomy.

Highlights across a range of engineering domains and applications demonstrate the diversity of activity that the CIRA Engineering team was engaged in through 2025. This annual report features articles contributed by the Engineering Team on topics including mitigating the harmonics of wideband power amplifiers to reduce RF interference; deriving a robust general method for efficient storage of embedded element patterns for SKA-Low station calibration; using deep learning models to make complex electromagnetic array simulations more efficient; using commercial HPC to undertake advanced electromagnetic simulations to quantify mutual coupling between SKA-Low stations; using in-field calibration techniques developed for the Desert Fireball Network to overcome technical challenges faced by a company monitoring wildlife-disturbing artificial light; developing the capability to measure and analyse electrostatic discharge to ensure that CIRA can build devices capable of operating in demanding electromagnetic environments; and the development of a portable test device to enable more efficient field maintenance for the MWA.

As I look ahead to the opportunities and challenges of 2026, I'm confident that the Engineering Research and Operations Team, through their tireless energy and engagement, will continue to rise to the occasion, and maintain CIRA's hard-earned reputation for research and operational excellence.



Director's Report: Translation & Impact

AOIFE STAPLETON
DIRECTOR TRANSLATION & IMPACT

After six years as a formal ICRAR program, the requirement to **"Translate and implement research findings for the benefit of the Western Australian community and economy"** now stands alongside "world-class research" as an expected outcome of ICRAR IV funding.

The State Government has long signalled its appetite for translation to be a key output of the work we do at CIRA, as the Curtin node of ICRAR. Predicated on our engagement and collaboration with local industry for mutual benefit in constructing the MWA and supporting SKAO pre-construction activities during the 2010s, Translation and Impact (T&I) was formalised as an ICRAR III program in 2019 under the visionary directorship of Tom Booler and professional management of Andrew Burton. Over the course of ICRAR III, CIRA invested in the growth of what is now the T&I team, dedicated to enabling CIRA researchers and staff to translate their significant expertise and capabilities for economic and community impact.

In positioning translation as a core ICRAR outcome, there is an expectation that CIRA will generate funding from translation activities to sustain some of its ongoing activities meaningfully. The T&I budget for 2025-2030 exemplifies this in forecasting that from 2028, the employment of the existing T&I team will be contingent on having secured sufficient funding from translation activities to support T&I salaries.

I am immensely proud of the team's maturity, agility, and drive in pursuit of ICRAR IV goals. I want to commend Emmaline, Jacob, and Courtney on their professionalism, energy, and creativity in targeting and fostering new ways of working, new client relationships, and new team dynamics.

From identifying external funding opportunities for your next postdoc or student, to navigating Research Master, the Translation and Impact team can support CIRA researchers to deliver ICRAR's translation objective.

A flavour of some of the team's activities is set out on pages 70 to 72. Beyond enabling and supporting many of the activities reported in this year's Annual Report, including the active project management of the TIMs project, writing grant applications and responding to EOIs, our work is often neither visible nor reportable.

One such example arose from the detection of a nanosecond-duration radio pulse by Clancy James and his collaborators, whose origin was traced to a long-defunct satellite. Their detection created the opportunity for us to explore the potential for our passive array with Nova Systems, to detect electrostatic discharge (ESD) events, which are a significant cause of in-orbit satellite damage. To understand the commercial appetite for investment in developing this capability, we engaged with Curtin's actuarial scientists, as well as global insurance companies and underwriters with an interest in the space industry. That engagement is ongoing, and the potential is still being assessed.

Looking forward, the detection of satellite ESD in astronomy data exemplifies the real opportunity for CIRA to translate our capabilities for broader impact.

With some effort, CIRA can leverage novel data for impact in understanding climate change, improving emergency communications, and potentially bushfire analysis.

This capability could be enhanced by analysing 'new' data generated by novel instrumentation developed by our Engineering team: the passive array built at the Nova Systems Space Precinct, the Desert Fireball Network, the Engineering Development, and potentially the TIMs under design.

I'm excited for 2026 to explore these and other opportunities, and I look forward to continuing to work with you to deliver impact for the benefit of the wider community and the economy.

Diversity, Equity & Inclusion

THE CIRA DEVELOPMENT COMMITTEE

The CIRA Development Committee (DevCom) provides advice to the CIRA Directors and aims to foster an environment where all staff can flourish irrespective of role, age, gender, sexual orientation, disability, race, religion etc. It recognises that a way to promote diversity and representation, at all levels, is through development and support of existing, and future, staff and students. It draws on University and other resources to provide initiatives to develop CIRA's talent and to improve the overall working environment. The committee is also a portal to provide advice for academic and non-academic staff on career development, progression and recognition.

DEVCOM MISSION STATEMENT

REVIEW OF THE YEAR

2025 was a year of significant change for DevCom, with a large turnover and the departure of several long-standing members of the committee, as well as the first appointment of two student co-chairs. Whilst activity of the committee saw stagnation for a time when new faces were put into unfamiliar roles, we got back on our feet and into the planning and delivery of new workshops and events focused on increasing the institute's facilitation of diversity, equity and inclusion, as well as personal and professional development of its staff and students. For 2025, our initiatives and activities generally sought awareness and understanding of others' mental health, fostering cohesion and positive workplace relationships, and reaffirming the institute's stance against harassment and discrimination, so that CIRA can be a place where any staff or student member can feel supported and empowered regardless of who they are.

HIGHLIGHTS OF DEVCOM ACTIVITY IN 2025

In February, there was the UN International Day of Women and Girls in Science. Adelle organised a movie screening for "Picture A Scientist" followed by some discussion and implementable ideas to foster a more inclusive science workplace that welcomes and appreciates the contributions from women.

DevCom hosted a Profile-Writing Workshop in April which delivered a practical session including industry tips and inside advice on how to best promote yourself professionally, both via online platforms and in job applications. We hope to run more of these kinds of personal or professional development workshops and see increased engagement from students and Early Career Researchers (ECR)s!

In July, Dr Isabel Perez from the University of Granada joined ICRAR as a Visiting Fellow for Senior Women+ in Astronomy. She presented a research colloquium and engaged with students and early-career researchers on topics like work–life balance, DEI, and caregiver experiences.

CIRA celebrated the start of Pride Month with a vibrant Rainbow Afternoon Tea, featuring educational resources on LGBTQIA+ terms, flag displays, and Pride-themed stickers to show support for our diverse community. DevCom followed up with an engaging Ally Training Seminar, encouraging open discussion and learning on how to be an effective ally. We also partnered with the Stronger Together: Women in STEM program to host a thoughtful workshop on "How to Build Meaningful Mentoring Relationships," offering practical insights into creating supportive professional networks.

CIRA also saw engagement with its staff and students during Wear it Purple Day, celebrating and supporting LGBTQIA+ youth, inclusion, visibility, and pride to the year's theme of 'Bold Voices, Bright Futures.'

DevCom also sought to communicate awareness for other globally significant or 'special' days and remind ourselves how we can



Awash in tones of purple for Wear it Purple Day, in support of the LGBTQIA+ community.

engage with others and the world in fairer, better ways. These included:

- **International Day of Peace** (the year's theme of 'Act Now for a Peaceful World') reminding everyone that building peace starts with everyday actions
- **International Transgender Day of Visibility**, focused on recognising transgender, gender diverse and non-binary experiences and achievements
- **International Day Against Homophobia, Biphobia, Intersexism and Transphobia (IDAHOBIT)**, which is a day to stand with the LGBTQIA+ community and shed light on their experiences and resilience historically and presently the year's theme being 'The Power of Communities'

To celebrate and showcase CIRA's racial and cultural diversity, DevCom continues to organise activities and spread information on recurring significant cultural events throughout the year, such as Easter, Lunar New Year, and Diwali. Members of DevCom also shared with the institute other culturally significant events such as Holi (Phagwah or Dol Jatra) the festival of colours, marking the arrival of spring and the victory of good over evil, and Navaratri (nine nights) a Hindu festival honouring the divine feminine and featuring Garba, a joyful circle dance around a lamp or deity symbolising the cycle of life. Some of these were accompanied by traditional foods from the respective cultures. These events were well attended and enjoyed by CIRA members. Finally, we held the annual end-of-year Christmas-themed cultural potluck, in which CIRA members were encouraged to bring a dish culturally significant to them.

A growing impact from DevCom that significantly benefits the institute and everyone who works here is cohesion and making all members of the institute more connected with one another. Whilst the above initiatives and events already greatly support this, we also aimed to build towards this further with social events and encouraging institute-wide openness and support for mental health. In March, we held a BBQ for the new staff and student mixer, accelerating the formation of new connections and acceptance into CIRA – also featuring a show-and-tell segment and human bingo.

Early in the year DevCom provided arts/craft supplies for anyone to disconnect from the constant mental pressure/focus of work, de-stress and unwind with a 'mindful' activity. The outgoing chair, Susmita, also acquired both a table tennis table and several bean bags for the institute, which received much use from the students at CIRA and connected many of the oldest students to the newest, maintaining a healthy and supportive cohort (and in-shape from the hours of table tennis matches!). In the mid-year, we held a Mental Health Checkup BBQ breakfast jointly with Rob, an outgoing staff member who always valued inter-connectedness at the institute. Later in September, a morning tea was held to acknowledge R U OK? Day, reminding us to check in with friends, colleagues, and loved ones (year-round), and to start meaningful conversations that can make a difference. It was a wonderful opportunity to pause, connect, and share meaningful conversations around each other's wellbeing. There was also some light fun with a sweets-filled Halloween morning tea in October.

AREAS IN NEED OF STRENGTHENING NEXT YEAR

Following from the strategic 2025-2026 focus areas defined in 2024, we engaged with the outlined actions and realised directions that we wish to significantly improve:

- **Professional Development** – Continue to regularly host workshops and offer support to the career growth and opportunities for students and ECRs.
- **Cultural Awareness** – Extend our cultural events to focus on additional cultures within CIRA, reflective of our staff and student demographics. Also investigate ways we can more effectively engage with Indigenous people and their knowledge systems, enhancing for each member of the institute the understanding of the significance, and the incorporation of, Indigenous cultural perspectives.

2025 was a relatively quiet year for feedback and suggestions directed to DevCom, but we maintain a strong stance that the institute can – and should – still see continued improvement. Reminders that DevCom facilitates feedback and suggestions directly to the CIRA executive will be announced more regularly in 2026, and we assure that any concern or issue is worthwhile. We look forward to the planned events in 2026 and anticipate how the institute can improve following the 2026 Staff and Student Climate Surveys.

ALEXANDER HEDGE

The 2025 CIRA Development Committee consisted of Alexander Hedge (Co-chair), Fergus McFarlane (Co-chair), Adelle Goodwin (ECR Rep; outgoing), Cathryn Trott (Senior Staff Rep; outgoing), Garvit Grover (Vice-chair; outgoing), Susmita Sett (Chair; outgoing), Venus Chico (Engineering Rep), Bradley Meyers (UWA-DEI Liaison; outgoing), Angiraben Mahida (Editor), Ravi Jaiswar (Student Rep; outgoing), Thomas Crowther (Scribe), Courtney Carr (UWA-DEI Liaison), Jennifer Hardwick (Engineering Rep) and Eric Jong (Student Rep).

Listening to Star Formation: Calibrating Cosmic Radio Signals with JWST

NICK SEYMOUR

Based on Seymour et al. (2026) ApJ in press.

How fast galaxies form stars is one of the central questions in modern astronomy. Radio telescopes are powerful tools for this task because radio waves pass straight through dust, which can hide star formation at other wavelengths. But to rely on radio emission as a trustworthy "star-formation meter," astronomers must first calibrate it against more direct tracers of newly formed stars—especially in the distant Universe.

In this study, the authors combine observations from the James Webb Space Telescope (JWST) and the MeerKAT radio telescope to test how well radio emission traces star formation in galaxies about 9 billion years ago (at redshift $z \approx 1.3$). JWST provides a particularly clean reference via the Paschen-α emission line, which is produced by gas directly illuminated by the youngest, most massive stars and is only weakly affected by dust.

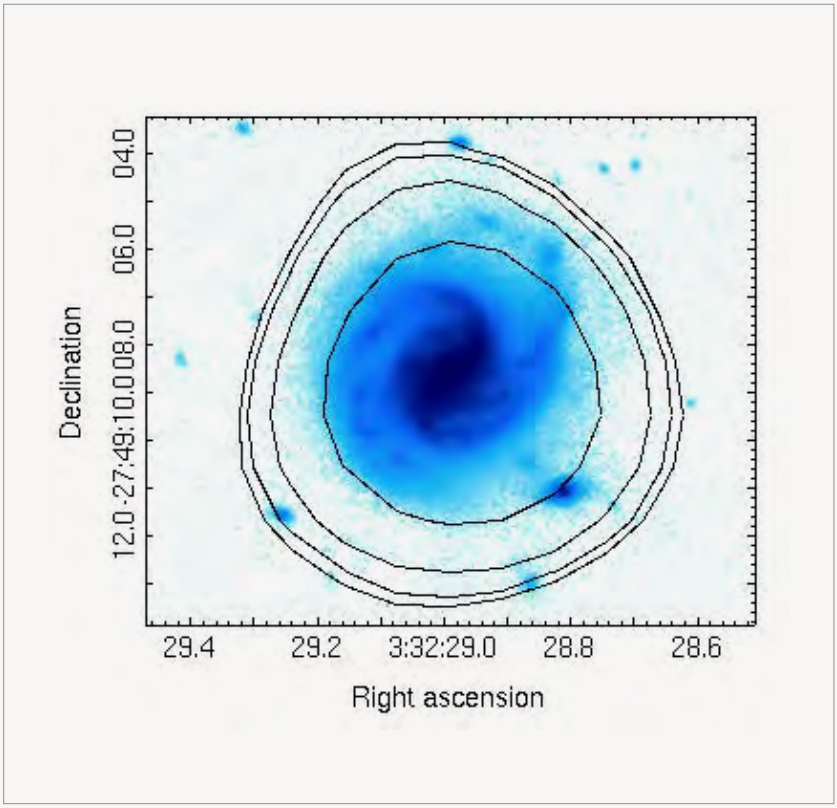


Figure 1. Radio emission from a star-forming galaxy
Example near-infrared (4.4 μm) JWST image of a distant star forming galaxy overlaid with the lower resolution contours from MeerKAT 1.23 GHz radio observations. The radio emission is diffuse and arises from the whole galaxy as the electrons from the synchrotron emission hang around for tens of millions of years. (Image: N. Seymour, 2026)

The team began with 506 galaxies in the GOODS-South field identified by JWST as Paschen-α emitters. They then matched these galaxies to deep 1.23 GHz radio images from the MIGHTEE survey. After carefully removing active galactic nuclei—whose radio emission is powered by black holes rather than star formation—and accounting for source blending, the final star-forming sample consisted of 11 clear radio detections, 18 fainter radio sources, and 298 galaxies too faint to detect individually.

To extract information from the faintest galaxies, the authors used stacking, combining the radio signal at the positions of many undetected galaxies. This revealed a statistically significant average radio signal, demonstrating that even galaxies invisible one by one in the radio still follow the same underlying trends.

Across nearly four orders of magnitude in luminosity, the galaxies align with previously established relations between radio power and star-formation rate. The authors derive a new calibration at $z \approx 1.3$ that is fully consistent with local and intermediate-redshift results. This confirms that radio emission remains a reliable tracer of star formation well into the cosmic past.

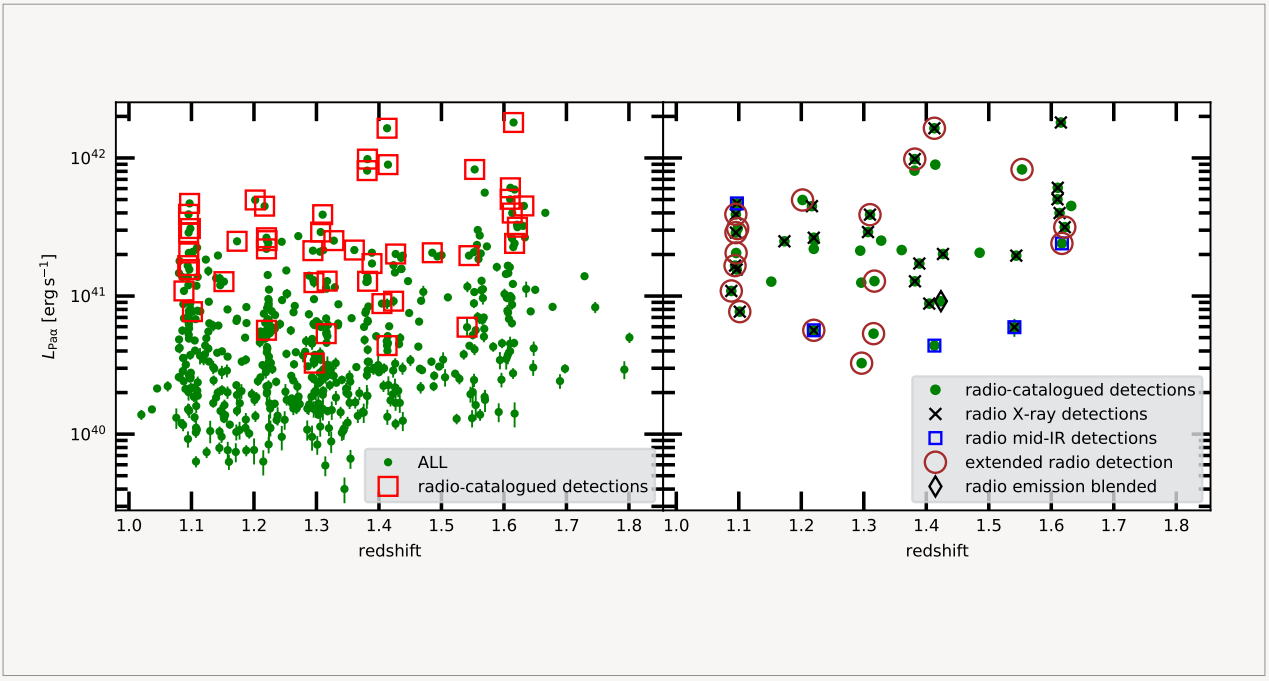


Figure 2. Identifying clean star-forming galaxies
Paschen-α luminosity versus redshift for all JWST-selected galaxies, highlighting which ones are detected in the radio and which are excluded as active galactic nuclei (AGN). After removing AGN and blended sources, only genuinely star-forming galaxies remain for the radio–star-formation analysis. (Image: Seymour et al., 2026)

Importantly, the paper also sheds light on why individual galaxies scatter around the average relation. A simple physical model shows that radio emission—dominated by synchrotron radiation from supernova-accelerated electrons—responds more slowly to changes in star formation than Paschen-α emission. This natural time delay, of tens of millions of years, explains much of the observed spread.

Overall, the results provide strong reassurance that future radio surveys with facilities like the SKA can robustly map the universe's star-formation history, using radio waves as a dust-free cosmic chronicle.

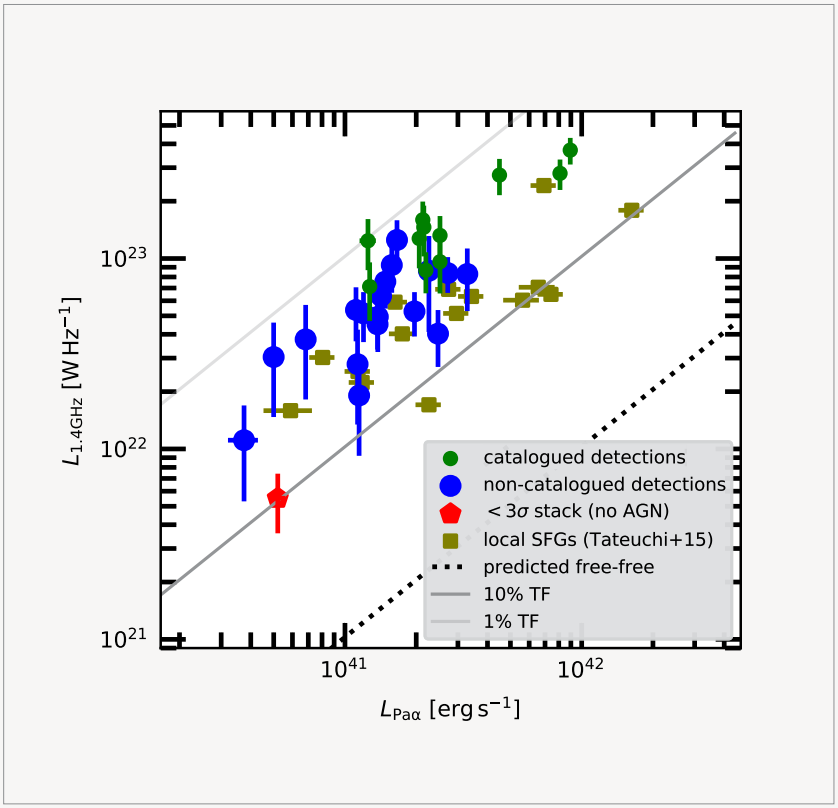
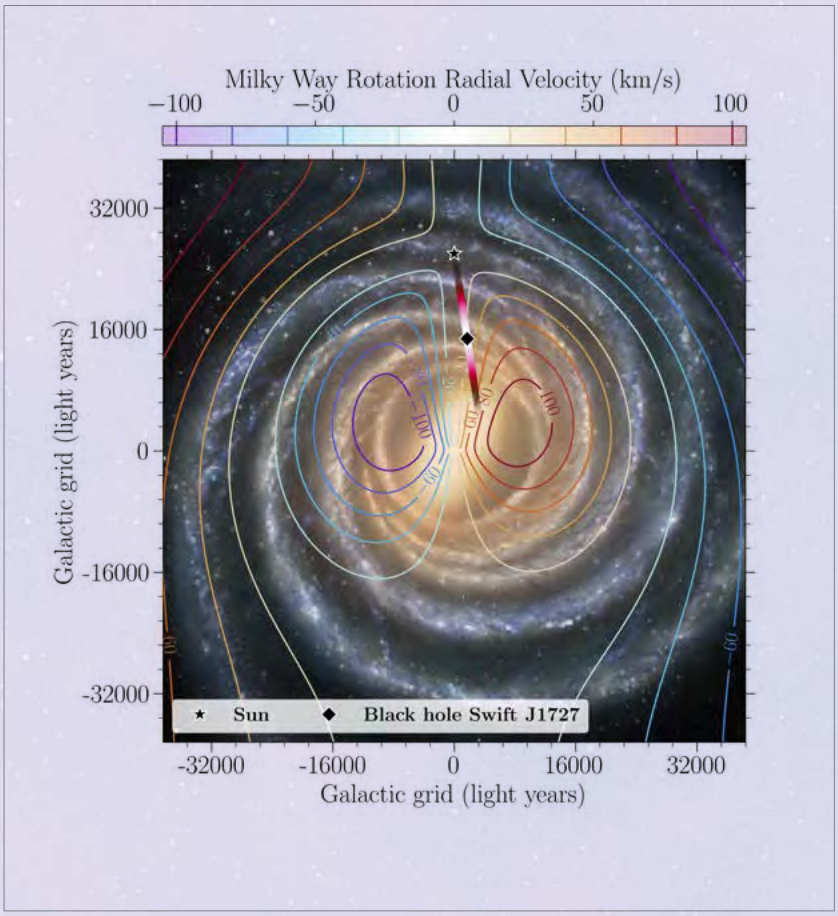


Figure 3. Radio power versus star formation
Caption: Radio luminosity at 1.4 GHz plotted against Paschen-α luminosity for individual galaxies, stacked faint sources, and a local comparison sample. The tight overall trend shows that radio emission reliably traces star formation, while the scatter reflects physical delays between star formation and radio emission. (Image: Seymour et al., 2026)

Locating a Galactic Black Hole Through Gas and Dust

BEN BURRIDGE
JAMES MILLER-JONES
ARASH BAHRAMIAN
STEVE PRABU

When a bright explosion of electromagnetic radiation is detected from a black hole in our Milky Way Galaxy, the distance to the black hole becomes an important measurement to make. Not because this radiation acts as the harbinger of a space-borne catastrophe like in some science-fiction movie, but because events like these offer an opportunity to study black hole systems, for which the distance is a key parameter.



↗ **Figure 1.** The line of sight to Swift J1727 plotted against a rotational velocity map of the Milky Way. The distance between the red regions of the line of sight represents the 68.3% confidence interval. (Image: Arash Bahramian)

One such explosion or "outburst" was detected in August 2023 by the Swift X-ray telescope and was named Swift J1727.8−1613 (Swift J1727) for its coordinates. It is a low-mass black-hole X-ray binary (BH-XRB) system, comprising a stellar-mass black hole and a companion star. They orbit close enough to each other that matter can fall from the ordinary star towards the black hole, glowing intensely and coinciding with the production of bright, relativistic jets of material—powerful streams of particles ejected at significant proportions of the speed of light from the region around the black hole. These jets can be detected using sensitive radio telescopes such as MeerKAT, the Square Kilometre Array precursor in South Africa.

Despite the data spanning a limited period, we were still able to improve upon the estimated distance

Traditional methods for determining Galactic distances rely on observations that span lengthy periods of time. Parallax, for example, provides the best measurements of Galactic

This increased distance implies an outburst that was even more intrinsically luminous than previously thought.

distances from observations taken over the course of an entire year. BH-XRB outbursts, however, are sporadic, unpredictable, and often dim below detection limits after mere months or even weeks. In a paper published in *The Astrophysical Journal* in December 2025, we reviewed previous distance estimates for Swift J1727 and presented new findings using radio data from the MeerKAT telescope in South Africa and near-ultraviolet data from the Hubble Space Telescope. Despite the data spanning a limited period, we were still able to improve upon the estimated distance to Swift J1727, which impacts the determination of other parameters more accurately, such as the size of the relativistic jets.

First, we used MeerKAT data to look for signatures of cold, neutral hydrogen (HI) gas along the line of sight toward Swift J1727. These gas clouds imprint absorption features on the observed radio spectrum, Doppler-shifted by their Galactic rotation velocities. By measuring the greatest positive or negative velocity absorption line we detect toward the source and comparing it with a nearby extragalactic reference source, we can set limits on the distance. This H I absorption method showed clear absorption both toward Swift J1727 and at greater velocities toward the reference source, demonstrating that the BH-XRB lies on the near side of some additional gas along the line of sight, and is at least 3.6 kiloparsecs away. However, this limit was unfortunately made weaker by significant systematic uncertainties caused by the line of sight being close to the Galactic Centre but offset from the Galactic Plane, the opposite of the best-case scenario for the application of this method.

Second, we used the Hubble near-UV data to quantify the amount of "colour excess" or "reddening" along the line of sight, caused when interstellar dust causes the light from the source to redden by preferentially scattering shorter wavelengths. Comparing our result with predictions from 3D dust maps of the Milky Way, we were able to improve on the estimated amount of reddening toward Swift J1727. Reddening is inversely proportional to distance, so replicating the distance-modulus calculations of prior studies resulted in an increased distance to Swift J1727.

Using Monte Carlo simulations to account for parameter uncertainties, we calculated a distance of 5.5 (+1.1/−1.4) kiloparsecs, or approximately 18,000 (+3,600/−4,600) light years away. This increased distance implies an outburst that was even more intrinsically luminous than previously thought. This also places Swift J1727 at a significant distance—more than 2,000 light years—above the Galactic Plane, suggesting that the system was born in an asymmetric supernova occurring in a binary star system, which both formed the black hole and delivered a substantial "natal kick" that launched the system towards its present location outside the Galactic Plane.

The Growing Impact of Unintended Starlink Broadband Emission on Radio Astronomy in the SKA-Low Frequency Range

DYLAN GRIGG
STEVEN TINGAY
MARCIN SOKOLOWSKI

This work investigates the growing impact of radio emission from Starlink satellites on radio astronomy observations in the nominal frequency range of the low-frequency half of the Square Kilometre Array (SKA-Low).
The study presents the largest survey to date of both intended and unintended emissions from Starlink satellites. Observations were collected with two SKA-Low prototype arrays - the Engineering Development Array 2 and the Aperture Array Verification System 2 – both located at the SKA-Low site in Western Australia.

The analysis examined approximately 76 million full-sky images collected over approximately 29 days, enabling a comprehensive assessment of satellite interference across multiple frequencies. The results show that Starlink satellites are a significant and increasing source of radio-frequency interference in the SKA-Low band. In total, the study identified 112,534 detections from 1,806 unique Starlink satellites, representing approximately 28% of the constellation at the time of the observations. In some datasets, a detectable Starlink satellite was observed in up to 30% of images, demonstrating how frequently these satellites affect astronomical observations.

The survey also found that satellites emit both broadband and narrowband signals across a wide range of frequencies, from roughly 73–235 MHz, with the broadband emission detected at frequencies specifically protected for radio astronomy. Notably, detections were made in International Telecommunication Union (ITU) protected bands at 73.00–74.60 MHz and 150.05–153.00 MHz. Additionally, some signals were identified as reflections of terrestrial FM radio transmissions from satellite surfaces. These findings indicate that satellite emissions can originate from multiple sources, including onboard electronic components and reflected signals.

The study highlights that newer satellite models, particularly the v2mini series, dominate the detected emissions and show widespread broadband signals across the observing band.

Overall, the research demonstrates that the rapid expansion of satellite megaconstellations is creating substantial challenges for radio astronomy. Current regulations primarily address intentional transmissions but do not adequately cover unintended electromagnetic radiation from satellites. The authors conclude that improved mitigation strategies and regulatory frameworks will be necessary to ensure that future astronomical observations, particularly with highly sensitive facilities like SKA-Low, can coexist with large satellite constellations.

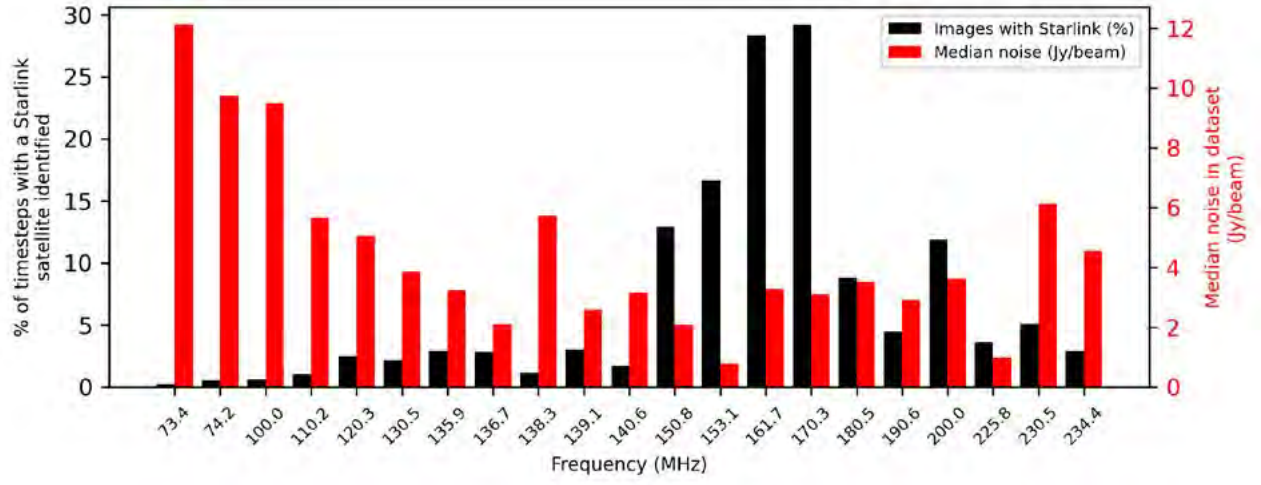


Figure 1. Percentage of images in each dataset with at least one Starlink satellite identified. Image noise was calculated by performing two passes of pixel excision above 3σ and calculating the standard deviation of pixel values across a central box in the image whose size is 10% that of the image. This is similar to the procedure used in Hancock et al. (2018).

Designing Early Universe Experiments with SKA-Low

CATHRYN TROTT

Exploration of the early Universe with the 21cm hydrogen line remains a field of research with considerable observational and theoretical effort. As the most abundant element in the Universe, neutral hydrogen is an excellent tracer of the physical conditions in the cosmos, encoding the thermal and radiative state of the gas that fills the Universe as a function of space and time.

The future SKA-Low will have the advanced design and the sensitivity to fully explore this first billion years of the Universe's history. Unlike most existing telescopes, which have a fixed design, SKA-Low will be the most flexible low-frequency telescope to date, allowing scientists to 'build' their own telescope to shape their science. For early Universe science, the combination of excellent instantaneous sensitivity and integrated sensitivity to clouds of gas on scales of arcminutes to degrees, its broadband frequency coverage, and its flexibility to shape and resize the sky response function, all make SKA-Low an ideal telescope for early Universe experiments. We have worked to shape the telescope to be capable of undertaking our experiments.

Substations

Each SKA-Low 'station' consists of 256 individual dipole antennas, much like TV antennas. Each antenna is individually controllable, allowing a beamformed 'station' to be flexibly defined across different numbers of antennas. Reducing the station size with fewer antennas yields larger fields-of-view of the sky and shorter baselines. The characteristic size of hydrogen gas early in the Universe is expected to have comparable angular size to the field-of-view of SKA-Low. As such, forming larger fields-of-view with shorter baselines provides access to larger scales that are of scientific interest. We propose to divide each full station in the core of the telescope into a small number of substations (3–4), with 15–18 m diameters, compared with the full 38 m diameters. Figure 1 shows an example of the 18m substation configuration and its corresponding footprint on the sky at 100 MHz. This configuration would allow us to image primordial hydrogen gas.

Beam shaping

Each dipole is also individually flexible, allowing for the ability to shape the primary beam. Early Universe experiments require the telescope to provide data without imprinting signals inherent to the telescope on top (e.g., via the signal chain or details of the antenna design). Shaping the telescope's response to the sky by weighting the contribution of each of the antennas provides the most flexibility for the observer to adjust the beam to match their science. This includes the ability to produce a spectrally achromatic beam in some parts of the sky (sky response is constant over frequency), a key feature for early Universe experiments.

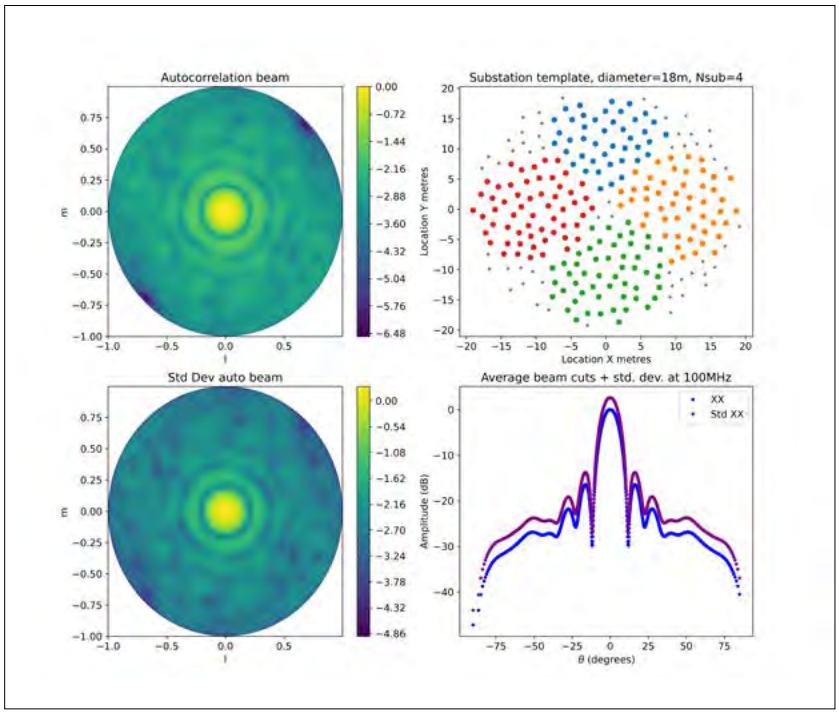
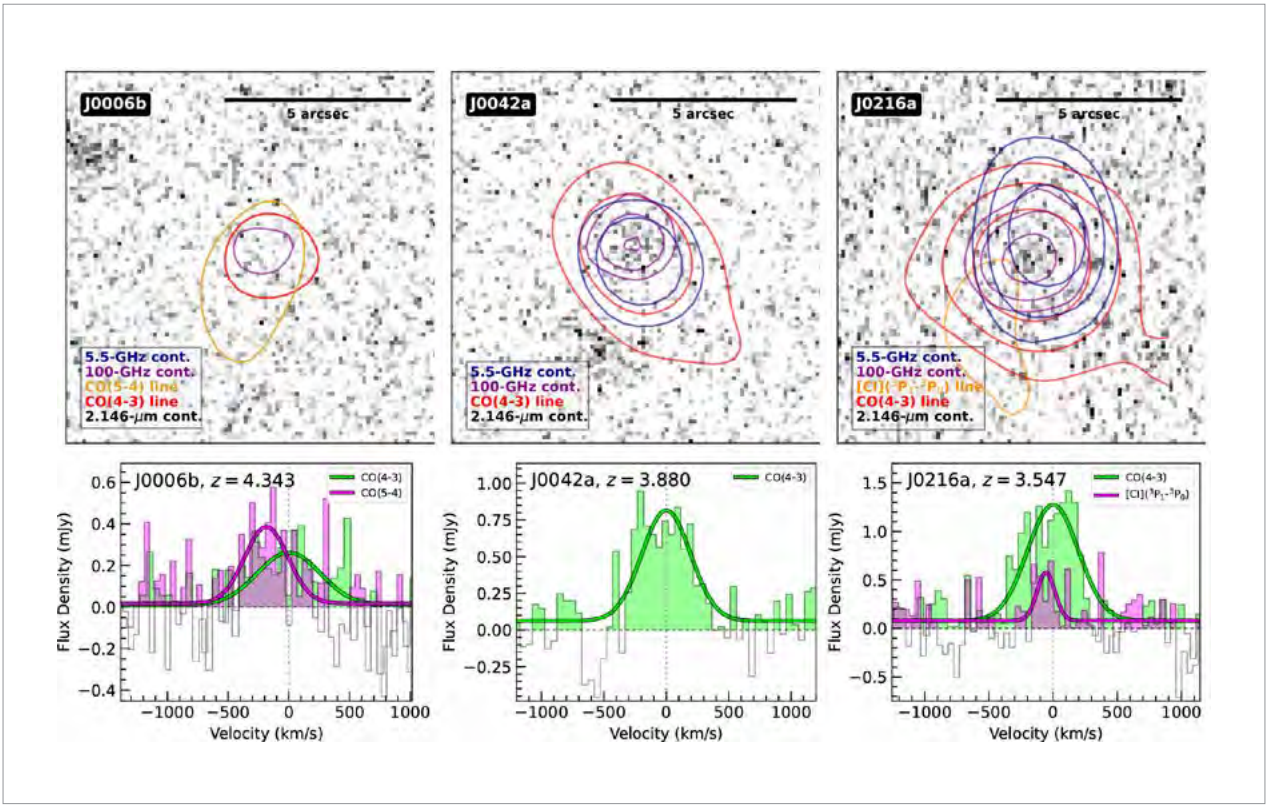


Figure 1. Potential substation configuration for studies of hydrogen gas, one billion years after the Big Bang. Here, 18m diameter substations are composed from a full station (top-right), with the increased primary beam response shown in the top-left, and its variability across the four substations in the bottom-left (all at 100 MHz). The bottom-right plot shows a cut through the beam response.

Radio Galaxies in the Early Universe: Redshift Constraints on GLEAM-Selected Candidate High-Redshift Radio Galaxies



A. J. HEDGE
NICK SEYMOUR
JESS BRODERICK
ANSHU GUPTA
JORDAN COLLIER

Figure 1. Postage stamp zooms (10" ×10") of cutouts from HAWK-I Ks-band images of candidate HzRG fields (top) and respective line fitting (bottom) for each astrophysical source with emission line(s) contributing to the identification of a spectroscopic redshift (z). The stamps are overlaid with contours representing both radio continuum and line emission corresponding to the coloured keys inset. All continuum contours start at 4×σRMS, whilst line emission contours start at 3×σRMS. Both sets of contours increase geometrically by a factor of 2.

Unlocking the secrets of the early universe requires hunting down its most extreme inhabitants, and few are as extreme as the first supermassive black holes (SMBH). While many early black holes are visible as incredibly bright quasars, a vast population remains shrouded behind thick veils of dust and gas in both the torus around the accreting SMBH and its host galaxy. These hidden giants reveal themselves as high-redshift radio galaxies (HzRGs) – massive galaxies hosting the engines for powerful, radio-emitting jets of plasma. In our recent work, we set out to uncover these hidden titans from the early universe, combining observations from across the electromagnetic spectrum to constrain their distances and properties.

Finding these elusive objects is the ultimate cosmic "needle in a haystack" problem, requiring a novel approach. Traditionally, astronomers have searched for distant radio galaxies by looking for a specific, ultra-steep slope in their radio light. However, with a novel selection technique using the Murchison Widefield Array (MWA) telescope at very low radio frequencies, we specifically looked for radio sources with curved spectra in the GLEAM survey. Such low-frequency spectral turnovers are the hallmark of young, compact jets that have barely pushed their way out of their host galaxies and are beginning to expand into lobes.

We then cross-referenced these radio hotspots with shallow near-infrared surveys, keeping only the sources that were completely invisible.

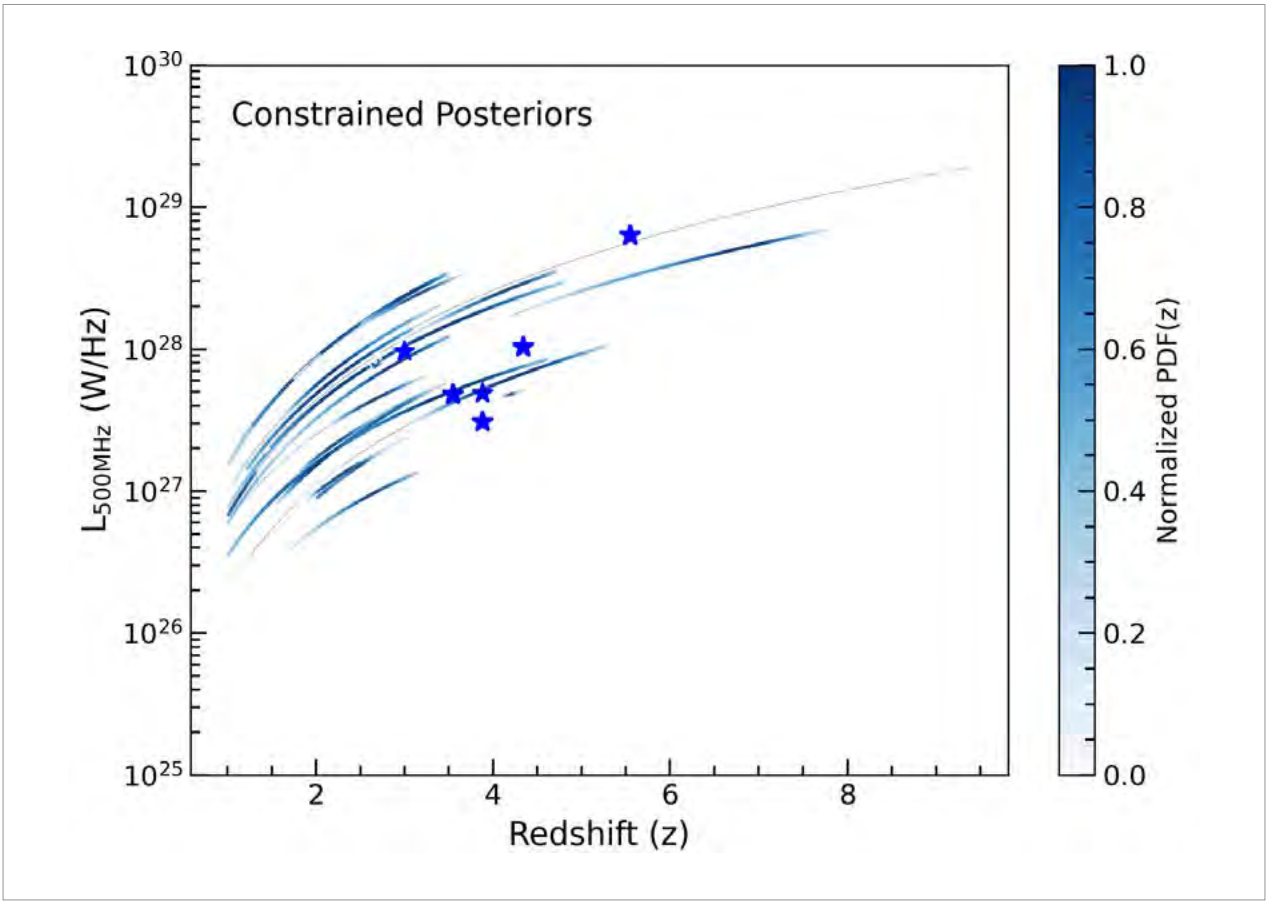
This “invisibility” implies the host galaxy is either incredibly dusty or pushed so far away by cosmic expansion that its light has stretched beyond the reach of those infrared telescopes. Our ultimate goal with this novel technique is to push the frontier of discovery, identifying ultra-high-redshift radio galaxies at z>5 and into the Epoch of Reionisation, when the universe was merely a toddler, less than a billion years old.

To confirm the true distances to these invisible galaxies, we turned to the Atacama Large Millimetre/submillimetre Array (ALMA) to “listen” for the faint signatures of molecular gas. By tuning ALMA to high radio frequencies, we searched for spectral fingerprints of carbon monoxide emitting within the molecular gas fuelling these galaxies. This approach was successful, allowing us to pinpoint the exact distances, via spectroscopic redshifts, for three newly confirmed galaxies residing between z~3.5 and z~4.4. The presence of these highly secure detections, as highlighted in Figure 1, proves that our selection technique successfully targets genuinely distant and massive radio galaxies.

For the remaining candidates in our sample without direct ALMA confirmations, we employed a process akin to cosmic profiling. By gathering the deepest available images from public data, we modelled the "spectral energy distribution" (SED) of each host galaxy. This allowed us to estimate their distances, stellar masses, and dust content. With good estimates of their distance, we are able to calculate how powerful the radio galaxies may be, and we compare to those with known distances in Figure 2.

To further understand the physical nature of these galaxies without needing a telescope the size of the Earth to resolve them, we utilized a phenomenon called Interplanetary Scintillation (IPS). Just as optical light from stars twinkles when it

Figure 2. Tracks of 500-MHz luminosities predicted by the modelled redshifts that are constrained to roughly Δz=2. The tracks are plotted with intensity proportional to the marginalised redshift likelihoods for each source, with a thin grey spine present for segments of the distribution that were discarded from the burn-in. Spectroscopically confirmed sources from the whole sample are overlaid as stars for comparison.



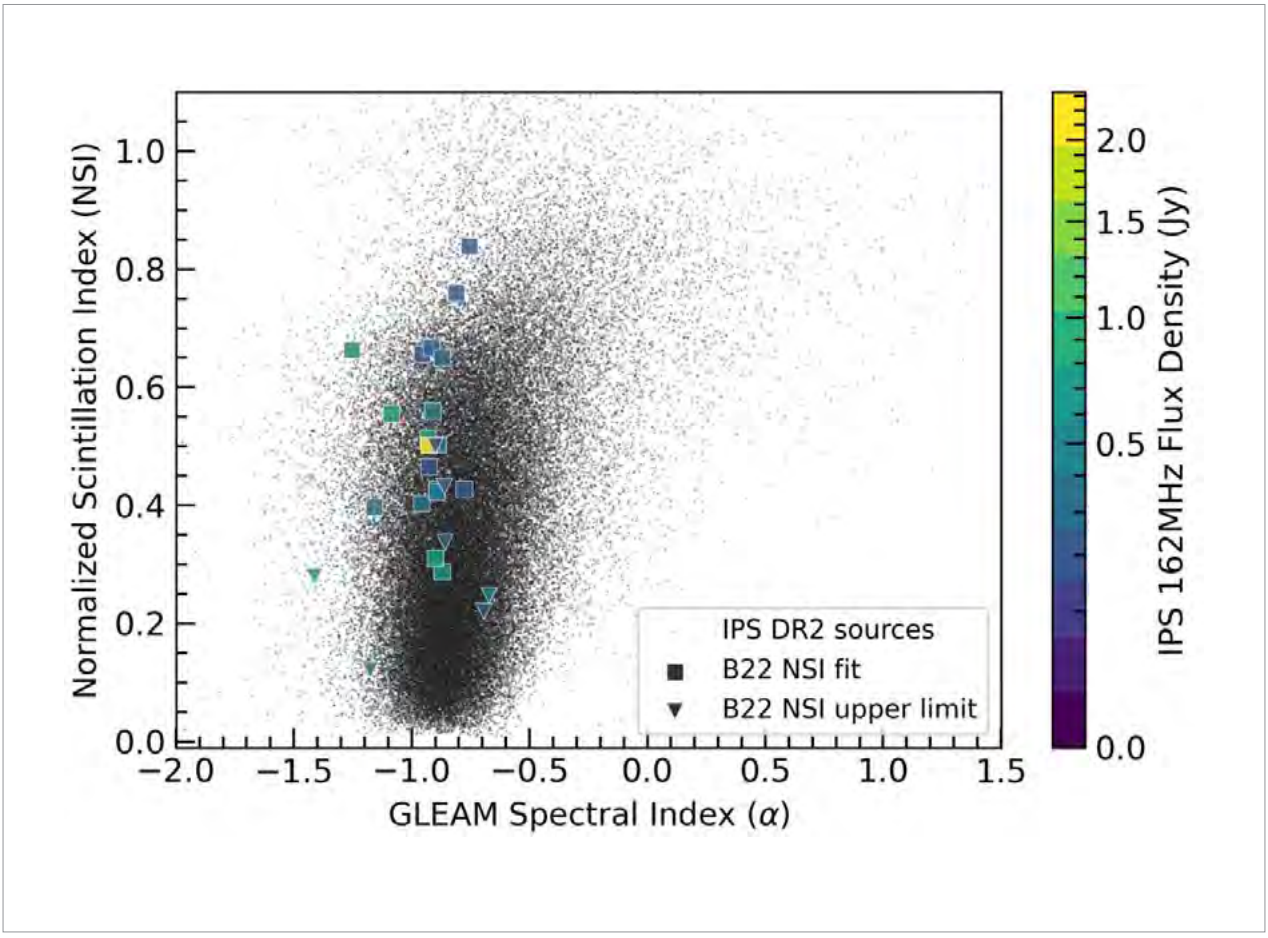
passes through the Earth's turbulent atmosphere, low-frequency radio waves twinkle as they pass through the solar wind in our own solar system. Crucially, only the most physically compact radio sources will exhibit this twinkling effect. MWA IPS data confirms that our sample is largely composed of highly compact, tightly confined radio jets, as shown in Figure 3, reinforcing the idea that we are capturing high-redshift radio galaxies in a young, explosive phase of their evolution.

When we synthesise these multi-wavelength constraints, the success of our novel low-frequency selection becomes clear. We estimate that between 25% and 60% of our targeted sample lies at z≥3. Even more excitingly, we found that up to 28% of our candidates could be the elusive, ultra-high-redshift radio galaxies at z>5. This potential high-redshift yield suggests that our method of relaxing strict traditional spectral criteria in favour of curved, compact radio signatures is highly competitive, and perhaps more representative of the true early-universe radio population.

Ultimately, we have successfully refined our list of the most promising powerful radio galaxies in the early universe, weeding out lower-redshift imposters and highlighting the true cosmic gems. While our low-frequency radio selection has proven its ability to find these rare targets, the final step in completely unveiling them will require the next generation of astronomical facilities. Future follow-up utilising deep space-based infrared imaging from the James Webb Space Telescope, alongside ultra-high-resolution very long baseline interferometric radio arrays, will be vital to fully characterize the host galaxies and understand how our most extreme candidates evolve and interact with their environment.

Figure credits: All figures are from Hedge et al. 2026a (submitted), with the work completed in 2025.

Figure 3. Interplanetary scintillation (IPS) normalised scintillation indices (NSI) for GLEAM radio sources in the MWA Phase II IPS survey internal data release 2 (Waszewski et al. in prep.), including a subset of the sample, against their GLEAM spectral steepness (α). Markers for B22 sources are coloured according to a linear stretch of their 162-MHz flux densities. B22 sources with fitted NSIs are shown as squares and upper limits are shown as triangles.



A Step Closer to Unveiling the Epoch of Reionisation

RIDHIMA NUNHOKEE
DEV NULL
CATHRYN TROTT

One of the major scientific goals of the Murchison Widefield Array (MWA) is to explore a key period in the history of our Universe known as the Epoch of Reionisation (EoR). This era marks the time when the first stars and galaxies formed and began to light up the cosmos. As these early objects formed, they emitted radiation that gradually ionised the surrounding intergalactic medium, the vast space between galaxies that was once filled mostly with neutral hydrogen gas.

To study this distant period of cosmic history, astronomers observe the 21 cm emission line of neutral hydrogen (HI). This faint radio signal provides a powerful way to trace how hydrogen in the early Universe evolved as the first cosmic structures formed. Detecting this signal is extremely challenging. The expected strength of the 21 cm signal is only about 10 mK, making it thousands of times fainter than foreground radio emission from our own galaxy and other astrophysical sources. In addition, measurements are affected by instrumental effects from the telescope itself.

Over the years, the MWA has undergone several upgrades designed to improve its ability to detect this faint signal. Changes to the antenna configuration and a recent upgrade to the correlator have significantly improved the telescope's frequency resolution. This improvement helps reduce contamination in the 'EoR window', the region of observational data where the cosmological 21 cm signal is expected to be detectable (highlighted in blue in Figure 1).

Figure 2 shows the average power measured within this EoR window. Encouragingly, the improvements to the instrument have reduced contamination by about an order of magnitude, bringing us closer to detecting the signal from the early Universe.

We have been processing observations collected during the most recent observing season in 2025, following the instrument upgrade. The team has gathered 285 hours of data across several sky fields and frequency ranges.

Analysis of the optimal field, EoR0 (RA = 0 h; Dec = −27°), in the high-frequency band (182.395 – 197.755 MHz) has produced results comparable to our previously published limits at redshift z = 6.5. In Nunhokee et al. (2025), we reported an upper limit of $(30)^2$ mK² using 286 hours of data. With the newly processed dataset, we currently reach an upper limit of $(41)^2$ mK².

While these limits are still above the predicted signal level, continued observations and integrating more data will further improve sensitivity. Each improvement brings us one step closer to directly observing the moment when the first stars and galaxies transformed the Universe.

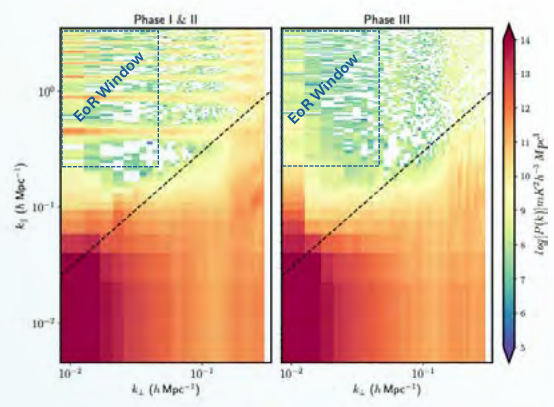


Figure 1. Two-dimensional power spectra constructed from 32 observations. *Left* Power spectra obtained from MWA Phase I and Phase II observations. *Right* Power spectra obtained from Phase III observations.

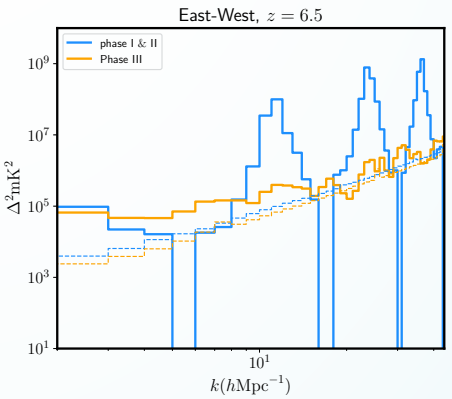
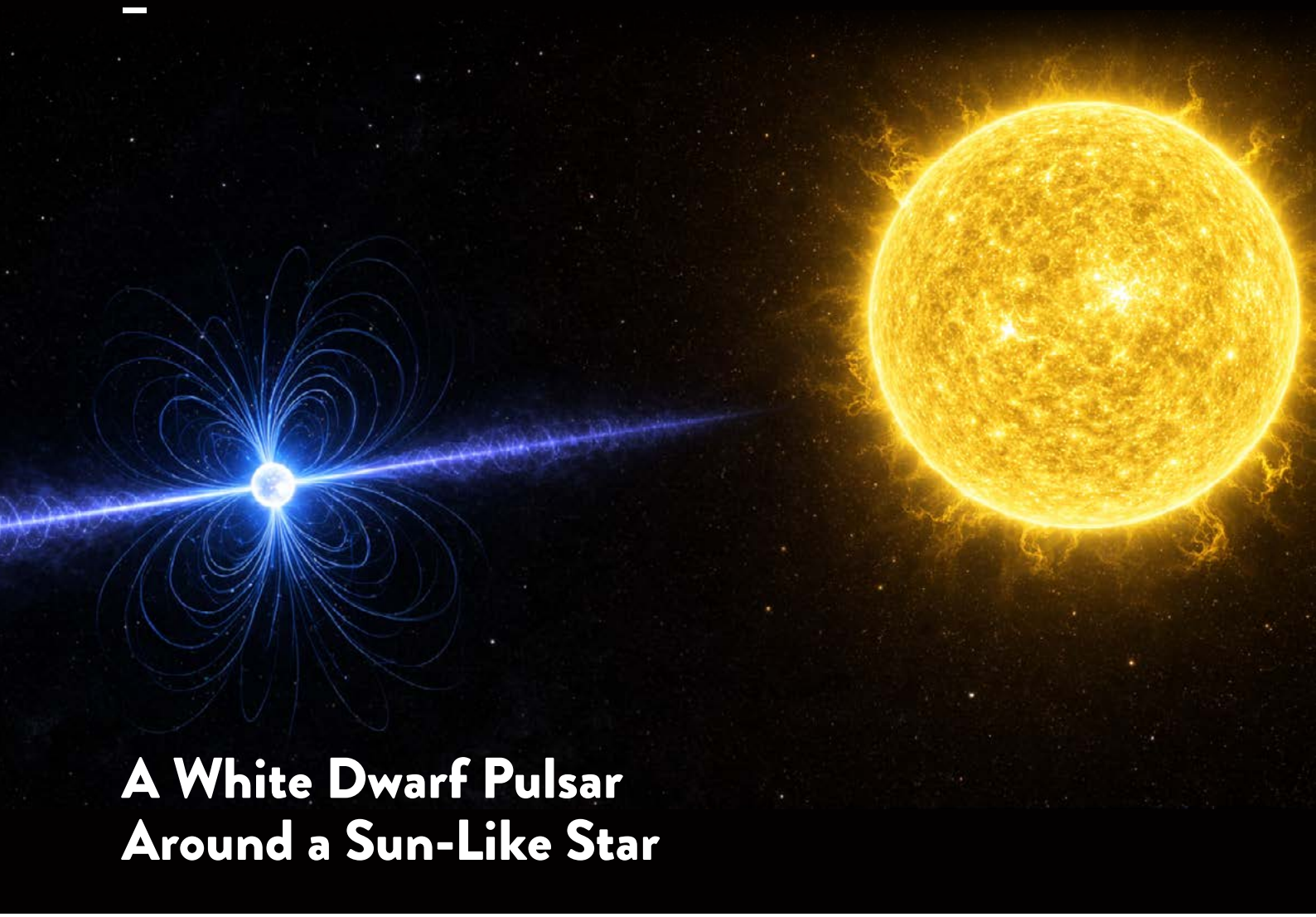


Figure 2. Spherical power spectra constructed from 32 observations, averaged over the blue region shown in Figure 1. The blue line represents the spectra obtained from MWA Phase I and Phase II observations, while the orange line shows the result from Phase III observations. The dotted lines indicate the expected thermal noise levels.



A White Dwarf Pulsar Around a Sun-Like Star

A/PROF NATASHA HURLEY-WALKER
DR SAM MCSWEENEY (SKAO)

Figure 1. Artist's impression of a magnetic white dwarf pulsar (left) around a Sun-like star (right). ChatGPT was used in the process of generating this image.

Long-period radio transients are a new class of astrophysical objects that we discovered with the Murchison Widefield Array in 2021. The first, GLEAM-X J162759.5-523504.3 (Hurley-Walker et al. 2022a, Nature) was discovered in the GaLactic and Extragalactic All-sky MWA eXtended (GLEAM-X) survey by the Murchison Widefield Array, it produced radio waves that repeated every 18 minutes for several months in early 2018. The second, GPM J1839-10, was found with a bespoke MWA search campaign covering our galaxy, the Milky Way. The radio pulses repeat every 22 minutes, and unlike the first source, it has apparently been active for over thirty years.

Pulsars, a type of magnetic neutron star, can also produce repeated radio bursts, and slow down as they age. However, once their rotation rate is slower than about one minute, they are not expected to produce radio waves. So, what could these strange sources be? Potentially an ultra-long period magnetar, a theorised type of neutron star with a very strong magnetic field. Or perhaps, an unusually magnetic white dwarf, the compact stellar remnant of a smaller star like our Sun, which is defying expectations and producing pulsed radio waves. Or, the radio pulses could be formed by the interaction of two objects orbiting each other in a tight orbit.

We have been scanning the skies with the MWA for several years now, and in late 2024, we discovered a new object. The pulses from this source were frustratingly intermittent, at first appearing every eight minutes, but then disappearing for weeks. Fortunately, we picked up the object in our regular observations, and commenced a follow-up campaign. After more than 80 hours

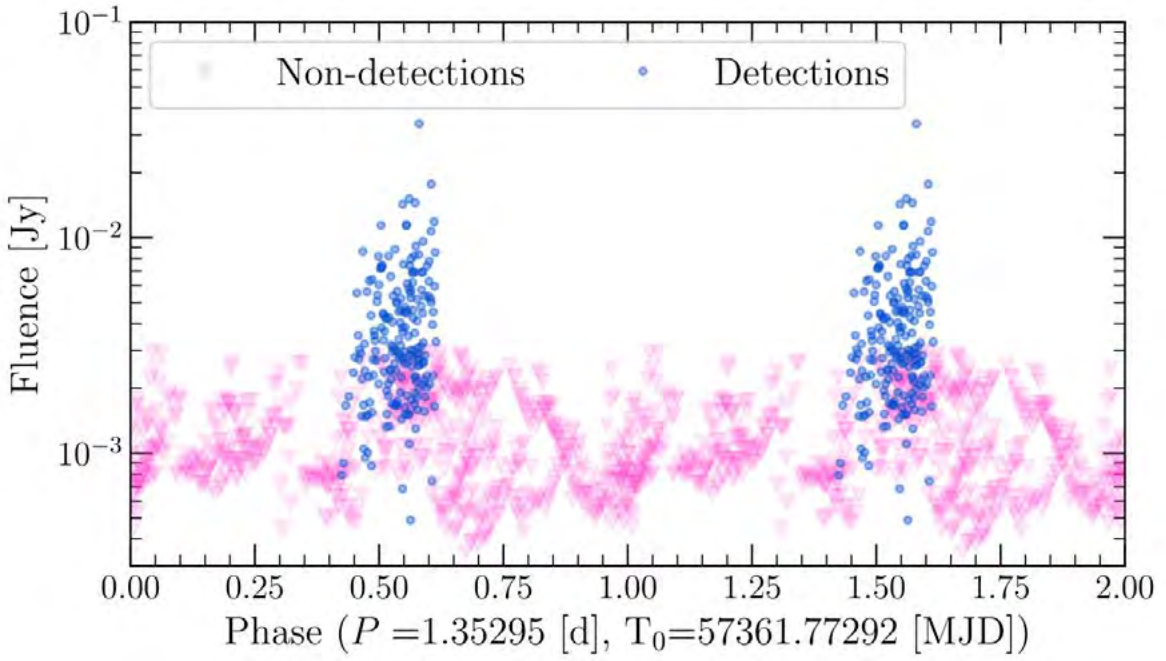


Figure 2. 80 hours of MWA observing, folded on a 32-hour period. The pink triangles show when pulses should have occurred but were not detected, and the blue circles are detected pulses. These arrive in a short window within the longer 32-hour period, which we interpret as an orbit. (McSweeney et al. *Nature Astronomy*, in review)

of MWA observing, we finally solved the pattern. The source produces bright, narrow pulses, separated by eight minutes, lasting about six hours, and repeating every 32 hours (Figure 2). This implies that we have one object spinning every 8 minutes, orbiting another object every 32 hours, and only in certain orbital configurations can we see the pulses. These appear to emanate from a distant star.

Working with a team at the W.M. Keck Observatory in Hawai'i, we found that the optical (visible) spectrum of the star matches that of our own Sun—a "G" type star, and is about 4,000 light-years away. This is unusual because eight minutes is too slow a spin period for a neutron star, so the radio emitter is probably a white dwarf pulsar (Figure 1). But the only white dwarf pulsars discovered so far are orbiting much smaller stars, so-called 'red dwarfs'. These are very common and live for a long time. Our own Sun is much rarer, and will have a much shorter lifespan. To find a white dwarf pulsar around such a star means that it must have formed its strong, radio-generating magnetic field quite quickly — and indeed, there is no physical theory as to how this can even happen for such a large system.

This discovery also shows that white dwarf pulsars must be fairly common in our Galaxy, and can form through a wider range of mechanisms than previously thought. If the long-period radio transients are all white dwarf pulsars, then radio searches have already quadrupled the number of white dwarf pulsars compared to over a decade of searches at optical wavelengths. The future is bright and full of potential for further discoveries, using MWA, other radio telescopes, and soon SKAO.

Needles in a Cosmic Haystack: Identifying Astronomical Transients with Novel Statistical Techniques

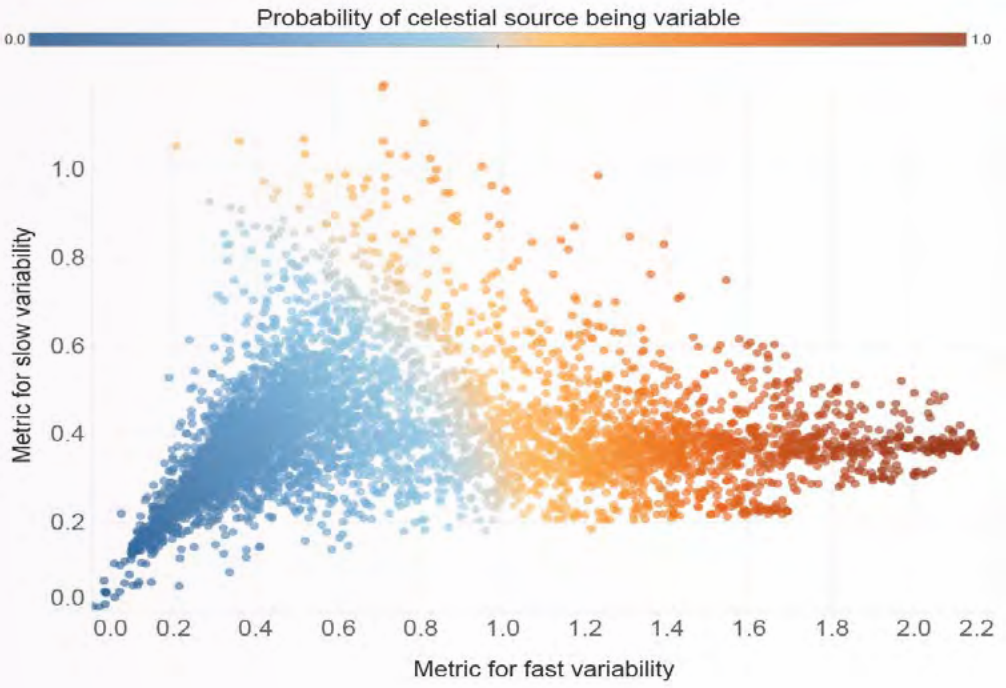


Figure 1. Plot of the likelihood of a source being variable as a function of two hyperparameters. Each point represents a light curve observed by MeerKAT. The horizontal and vertical axes represent high- and low-frequency variability, respectively. As either or both metrics increase, the likelihood of the candidate being variable also increases.

SHIH CHING FU
ARASH BAHRAMIAN
ALOKE PHATAK

Imagine that you are trying to identify a particular flickering lightbulb among millions of streetlights, except that those lights are scattered across the entire sky, blink at different rates, and you can only check on them occasionally. This is the challenge we face as astronomers when searching for variable and transient objects in space.

Variable objects are cosmic sources whose brightness changes over time; in contrast, transients are typically brief, explosive events that flare up and fade away. These phenomena include everything from distant exploding stars to black holes devouring nearby matter. Finding and studying them is crucial for understanding how the universe works, but as telescopes grow more powerful and we survey larger portions of the sky, this task becomes increasingly difficult. In a new study (Fu et al. 2025), we present a statistical solution to this cosmic needle-in-a-haystack problem and apply our method to

data from 6,394 celestial objects collected over five years by the South African Square-Kilometre Array precursor, MeerKAT.

The main challenge lies in the messy nature of astronomical data: observations are often sparse and irregularly spaced, with various technical issues affecting data quality. Many statistical methods struggle with these imperfect datasets, and the enormous variety of cosmic objects means we cannot make simplifying assumptions about how their brightness should change.

The main challenge lies in the messy nature of astronomical data: observations are often sparse and irregularly spaced, and various issues affect data quality

Our solution employs a mathematical technique called Gaussian process regression, which is particularly well-suited for handling irregular, sparse data and can incorporate information on measurement uncertainty. Think of it as drawing a smooth, flexible curve through scattered data points without assuming what shape that curve should take. This flexibility is crucial because different astronomical phenomena produce vastly different light curve patterns, for example, a slowly pulsating star looks nothing like an exploding supernova.

Finding and studying transients is crucial for understanding how the universe works, but as telescopes grow more powerful and we survey larger portions of the sky, this task becomes increasingly difficult

It is the distribution of the so-called hyperparameters (see Figure 1) from these statistical models that lets us distinguish between stable sources and potential variables or transients. What makes this method particularly powerful is that we do not need to know in advance what kind of object we are looking for. The same technique can potentially identify multiple types of variable and transient sources. Our method enabled us to identify dozens of new transients that previous studies missed.

Compared with commonly used radio astronomy metrics, our new approach demonstrated greater discriminatory power and interpretability. In other words, it was more effective at separating genuinely interesting cosmic events from unchanging background sources. We also demonstrated how our method can serve as an initial screening tool for detecting transient sources, a typical use case for upcoming megasurveys like those planned for the Vera C. Rubin Observatory and the Square Kilometre Array, which will monitor millions of objects and generate enormous amounts of data that require automated analysis.

As we enter an era of massive sky surveys, scalable and flexible tools will become increasingly essential for discovering the universe's most dynamic and mysterious phenomena.

Our method can serve as an initial screening tool for detecting transient sources in upcoming megasurveys, such as those planned for the Rubin Observatory and the Square Kilometre Array.

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Link Between Long-Period Transients and White Dwarf Pulsars

CSANÁD HORVÁTH
NATASHA HURLEY-WALKER
SAM MCSWEENEY

In 2021, GLEAM-X J1627-52, a source producing 30-second radio pulses repeating every 18 minutes, was detected from deep in the Milky Way (Hurley-Walker et al., 2022). Since then, 10+ such sources have been discovered, with periods up to several hours, becoming known as long-period transients (LPTs). Their bright, polarised pulses were reminiscent of pulsars, a type of magnetic neutron star, remnants of dead stars. They are detected as repeating (on the scale of milliseconds to seconds) radio pulses due to a rotating radio beam sweeping our line of sight like a lighthouse.

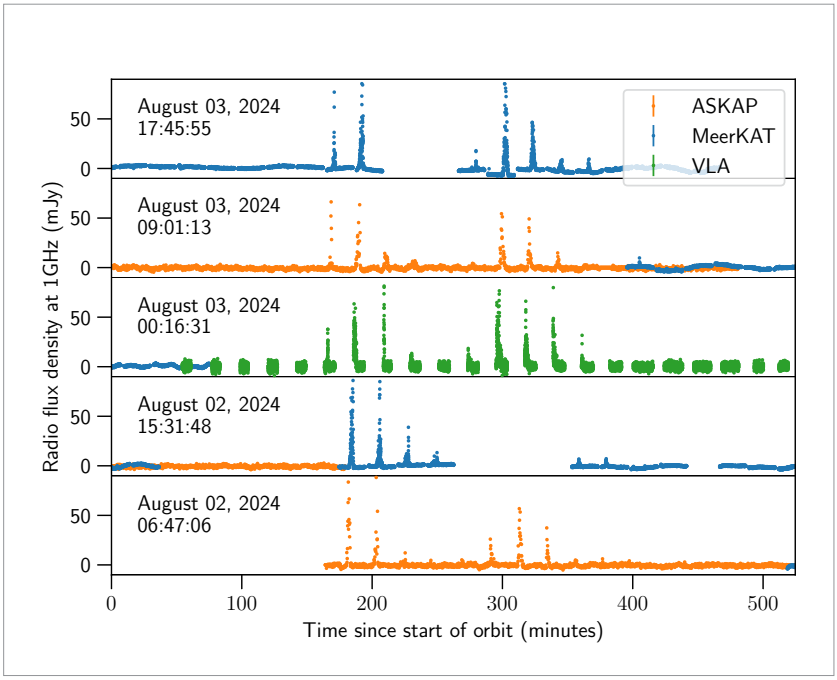

Figure 1. Radio light curves of GPM J1839-10 recorded by ASKAP, MeerKAT, and VLA. Five consecutive orbits are stacked to align the heart-beat pattern. The colour represents the telescope used.

The comparatively slow rotation of LPTs, however, is in conflict with canonical theory. It has been difficult to confirm their nature due to their distance and embedding in our Galaxy. Only in 2025 were two LPTs identified as white dwarf (WD)–M-dwarf (MD) binaries, rather than neutron stars, based on multi-wavelength counterparts (de Ruiter et al., 2025; Rodriguez 2025). White dwarfs are, like neutron stars, the remnants of dead stars: about the size of Earth, but with an entire Sun's worth of mass packed in. No isolated white dwarf has been observed to emit radio pulses, but paired with an M-type dwarf (a regular star about half the Sun's mass) they may have the necessary ingredients to generate powerful radio beams.

GPM J1839-10, discovered in 2022 with a 21 minute period (Hurley-Walker et al., 2023), was the second found LPT. Unlike its predecessor, which disappeared after 3 months, GPM J1839-10 has been active for at least 37 years. Pulses were found in archival data going back as far as 1988, but only about 20% of the times it should have been detected, given the 21 minute period. Since it is over 15,000 light-years away, we can only see it in radio, so the seemingly random intermittency might be the only clue to its nature. To obtain continuous data, we employed three telescopes, each passing the source to the next as the Earth rotated over the 36-hour campaign: the Australian SKA Pathfinder (ASKAP), the MeerKAT radio telescope in South Africa, and the Karl G. Jansky Very Large Array (VLA) in the United States. The light curves are shown in Fig. 1.

The intermittency turned out not to be random at all; the pulses arrive in groups of four or five, and the groups come in pairs separated by two hours. The whole pattern repeats every nine hours, implying orbital motion. Checking back, not only are the archival detections consistent with the same pattern, but we were able to use the combined data to refine the orbital period to a precision of 0.2 seconds, confidently identifying GPM J1839-10 as another binary LPT.

Meanwhile, another WD–MD system, AR Scorpii, has been dubbed a white dwarf pulsar in 2016 for its two-or-so-minute periodic radio variation (not as puzzlingly bright as LPTs). Inspired by work on AR Scorpii's emission (Potter & Buckley, 2018), we modelled GPM J1839-10 as a WD

generating a radio beam as its magnetic pole sweeps through its companion's stellar wind, with the varying alignment throughout the orbit accurately predicting the modulation pattern. Fig. 2 depicts the best-fit geometry, a distinctive property of which is the near-perpendicular orbit with respect to the spin axis.

This work (Horváth et al., 2026) achieves two things: First, it bridges the gap between LPTs and WD pulsars, opening the door to collective study. The formation of magnetic fields in WDs has been debated in the literature for decades, and if (some) LPTs host magnetic WDs then we both have a new way of studying them, and a new way of detecting them.

Second, it shows that a surprising amount of information can be extracted from radio data alone when carefully examined, even in the absence of other information. The alignment of GPM J1839-10 with respect to the line of sight is fortunate for constraining its geometry, but each LPT is unique, and each gives different clues (optical, X-ray, spectral structures, etc.). When combined, they have the potential to build a complete picture of the underlying physics in these extreme astrophysical environments.

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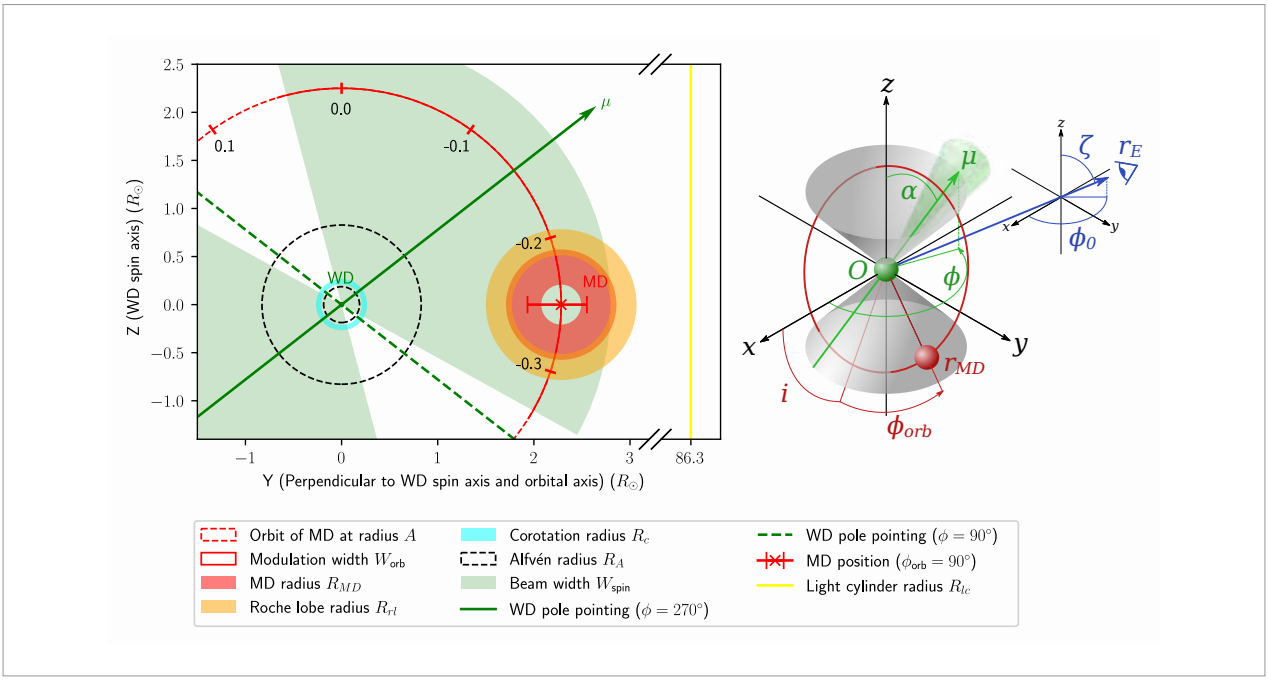

Figure 2. Diagram of the binary system, in a moving reference frame centred on the WD. At right is a not-to-scale diagram of the system with the WD at the origin, the MD at rMD with its orbit in red, and the Earth in the direction of rE. The magnetic moment and radio beam are along the μ vector, which traces the grey cone as it rotates. At left is a to-scale projection on the y-z plane, with orbital phases marked. The green sector indicates the modelled beam width, and the red shading indicates possible MD radii.

No Evidence for Accretion Around the Intermediate-mass Black Hole in Omega Centauri

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ARASH BAHRAMIAN
JAMES MILLER-JONES
SUSMITA SETT
KRISTEN DAGE

X-ray observations and gravitational wave detections have identified a population of stellar-mass black holes with masses up to 200 times that of the Sun. This complements the well-established population of supermassive black holes (SMBHs) at the centre of galaxies and quasars. By contrast, we have comparatively little observational evidence for a population of intermediate-mass black holes (IMBHs, with masses between ~200 and 10^5 solar masses), which are the missing link in our understanding of black hole evolution. IMBHs observed today offer critical insights into the origin and early growth channels of SMBHs.

For over a decade, both theoretical predictions and observational studies have debated whether Omega Centauri (ω Cen) harbours an intermediate-mass black hole. ω Cen is the brightest and most massive Milky Way globular cluster, containing approximately 10 million stars in a dense sphere. It has been extensively studied across the electromagnetic spectrum, from radio to gamma rays. Earlier this year, after analysing 20 years of Hubble Space Telescope optical data, researchers found fast-moving stars at the centre of ω Cen, providing the strongest evidence to date for the existence of an IMBH. The most likely explanation for these stars remaining in the cluster's central region despite unusually high velocities is the gravitational influence of the central IMBH; otherwise, they would have escaped the cluster. Their analysis determined the IMBH mass to be at least 8,200 solar masses, consistent with an intermediate-mass black hole.

One of the key questions in the study of IMBHs is their accretion efficiency, which determines their radio and X-ray signatures. X-Ray emission arises from the accretion flow, while jets produce radio continuum emission via synchrotron radiation.

Our deep radio continuum observations of ω Cen, using approximately 170 hours with the Australia Telescope Compact Array at 7.25 GHz found no radio emission from any proposed cluster centre. This stringent result indicates that the accretion efficiency is exceptionally low for the central IMBH. This highlights these elusive IMBHs as a class of black holes that may behave distinctly from both stellar-mass and supermassive black holes.

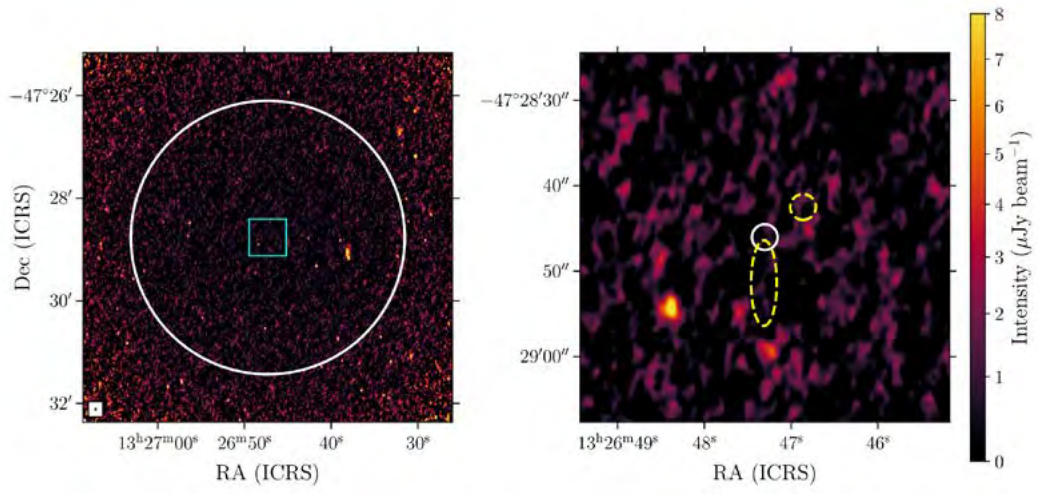


Figure 1. The image on the left shows the core region of ω Cen (white circle). The zoomed-in region in the image on the right is indicated by the cyan box. The right image shows the recent centres proposed for ω Cen by other researchers.

Preparing for Epoch of Reionisation Science with the SKA-Low

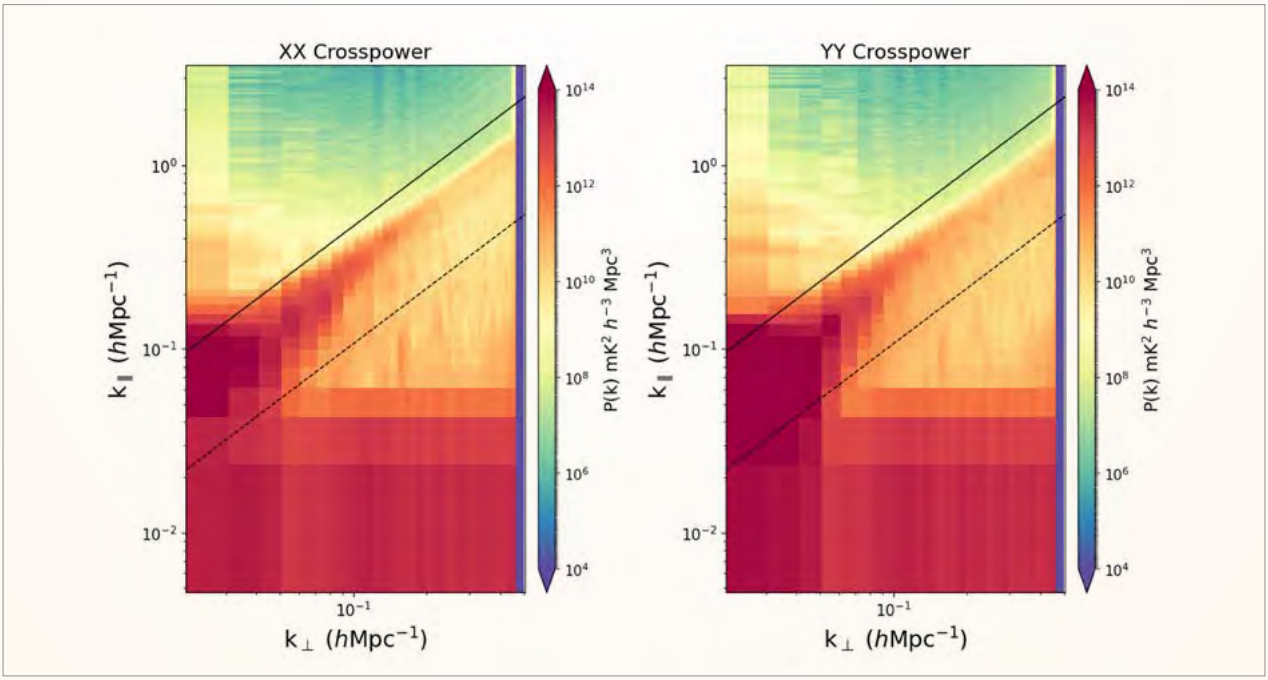
ERIC JONG
CATHRYN TROTT
RIDHIMA NUNHOKEE
DANIEL PRICE

The Epoch of Reionisation is a period in the Universe in which it experienced immense change. It began with a mostly smooth distribution of neutral gas, evolving into the complex and ionised Universe we observe today. As a result, it has been a major science goal of many radio interferometers around the world. To probe the EoR, the 21 cm line is an extremely faint signal, only on the order of hundreds of millikelvin, while foregrounds are on the order of kelvin. Additionally, current-generation radio interferometers are limited in their sensitivity. Therefore, probing the EoR with the 21 cm line proves an extremely difficult challenge. The next-generation, low-frequency Square Kilometre Array (SKA-Low) radio interferometer will provide the sensitivity required to make a measurement of the 21 cm line. It is expected to enter Cycle 0 of its operations within the next 5 years. Hence, it is crucial that we prepare now for a future EoR experiment with the SKA-Low.

In this work, we aim to simulate observations of various candidate EoR fields with SKA-Low, using OSKAR. These simulations include diffuse emission in the sky model, and gain and phase errors in the stations during observation. From the simulated observation data, we can further calibrate the data and produce 2D power spectra, which are one of the main statistics used in EoR science. Comparing these power spectra across the different fields will help us determine which part of the sky is ideal for EoR observation with SKA-Low. Example power spectra can be found in Figure 1.

From these preliminary power spectra, we can see that fields used by current-generation instruments behave differently with SKA-Low. This is due to the small field of view possessed by SKA-Low compared to current-generation instruments, which means SKA-Low receives more contribution from sidelobes than current instruments. These power spectra also suggest that including a bright source within the main lobe during observation is beneficial for calibrating SKA-Low. Efforts are under way to ensure that all inputs to the simulation are as correct as they can be, and further testing of these fields is also progressing.

Figure 1. XX (left) and YY (right) power spectra from calibrated OSKAR simulations of SKA-Low observing the EoR0 field (RA = 0 deg, Dec = −30 deg). Included in this simulation are diffuse emission in the sky model, and gain and phase errors during observation.



Preparing for the SKA Era: Science Support and Innovation with the AusSRC

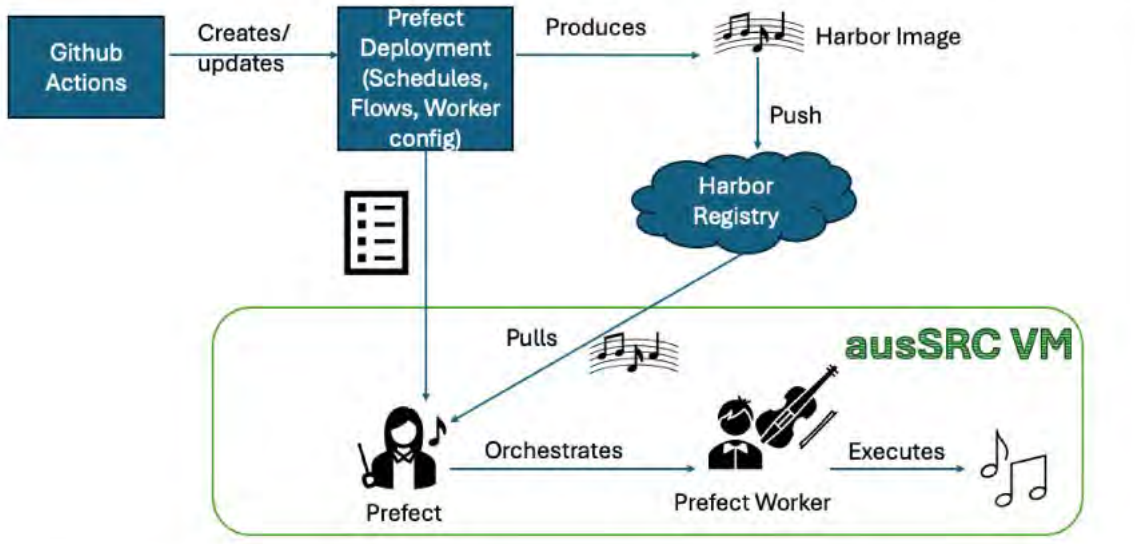


Figure 1. The updated POSSUM workflow, as developed within an AusSRC Science Enabling Project (ASEP). The improved workflow uses GitHub Actions to update container images and automatically update code running on a Prefect server, allowing for automation, scheduling, and manual triggers. (Image: Rini Angreani)

JORDAN COLLIER

During 2025, the Australian SKA Regional Centre (AusSRC) continued to strengthen its role in enabling data-intensive radio astronomy and supporting the Australian community in preparing for science with the SKA telescope. Through science support, software development, and international collaboration, AusSRC has worked alongside researchers using SKA precursor telescopes, while contributing to the global SKA Regional Centre Network (SRCNet), with CIRA personnel playing a central role in science leadership, workflow development, and large-scale data analysis.

One of AusSRC's major initiatives in 2025 was the launch of the AusSRC Science Enabling Projects (ASEPs), a merit allocation program for supporting community-led research using SKA precursor telescopes. Following a call for proposals, eight projects were selected across the Murchison Widefield Array (MWA), Australian SKA Pathfinder (ASKAP), and MeerKAT telescopes. Several projects began during 2025 across a variety of domains, with science and development including searching for OH masers, searching for pulsars, 3D image cube cutouts, and triggering MWA from ASKAP detections of Fast Radio Bursts. One project supported ASKAP's Polarisation Sky Survey of the Universe's Magnetism (POSSUM) project by improving automation and reliability of post-processing pipelines using workflow management tools and improved database integration (see Figure 1). Another project supported the development of new real-time coherent beamforming capabilities within the MWA correlator backend, which will enable fast-transient and pulsar science as well as low-frequency VLBI observations (see Figure 2).

In 2025, AusSRC played a significant role in advancing the international SRCNet collaboration. Throughout the year, personnel participated in global planning and

development activities, focused on defining detailed science cases and workflows for the SKA telescopes at various stages of its capability rollout. A key milestone was the SRCNet PI29 planning and related workshop week, hosted by AusSRC in Perth. These two weeks brought together international collaborators to test science workflows and demonstrate emerging capabilities. The event included live field tests for implementing detailed science cases within SRCNet, and a 'system demo', during which a demonstration of SRCNet systems and the implementation of detailed science cases was showcased to the Australian astronomy community.

Developing tools and workflows for analysing extremely large radio astronomy datasets remained a major focus. AusSRC personnel contributed to the software development and user support for the Cube Analysis and Rendering Tool for Astronomy (CARTA), including the documentation and automation of workflows designed to support SKA science cases. Additional work explored compression of visibility data to significantly reduce the size of interferometric datasets, while preserving their scientific value.

CIRA researchers also played an important role in large-scale data analysis for SKA precursor facilities. Processing of MWA observations continued on high-performance computing resources such as the DUG facility, with the final stages of the GLEAM-X calibration, imaging and cataloguing being undertaken.

The AusSRC team expanded during the year with new appointments; at CIRA, Rini Angreani joined the team as a Senior Software Developer. Together, these activities highlight the growing role of AusSRC in developing the tools, workflows, and expertise needed to support SKA science and prepare the community for the next generation of radio astronomy.

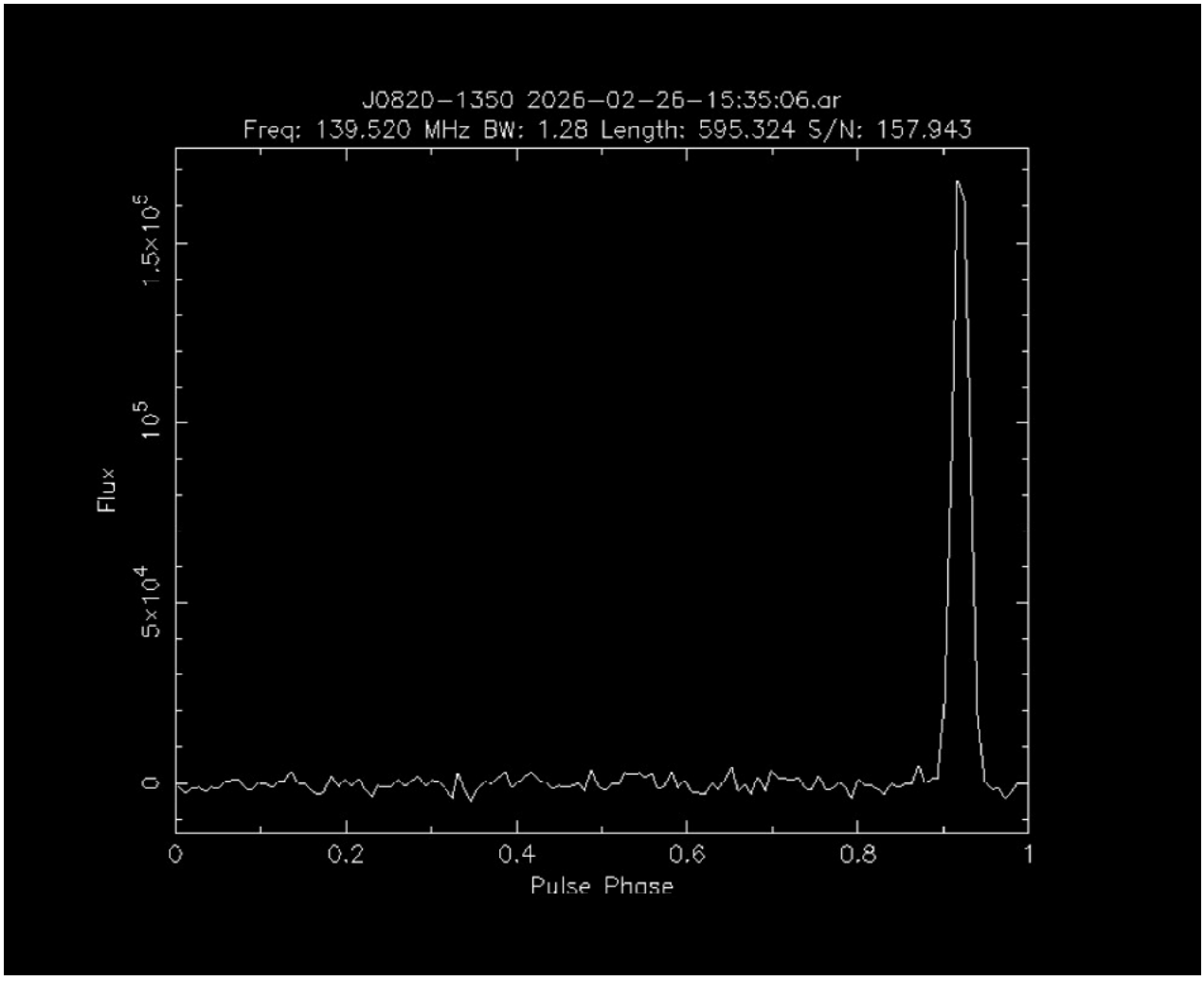


Figure 2. A 10-minute observation of a bright test pulsar using MWA's new real-time beamforming capabilities, supported within an AusSRC Science Enabling Project (ASEP). The observation matches expectations compared to MWA's Voltage Capture System, while significantly reducing the data size and accessibility to non-experts. (Image: Bradley Meyers)

Discovery of a 24 Millisecond Pulsar in a Very Long Binary Orbit by the SMART Survey

CHIA MIN TAN
RAMESH BHAT
CHRISTOPHER LEE
BRADLEY MEYERS

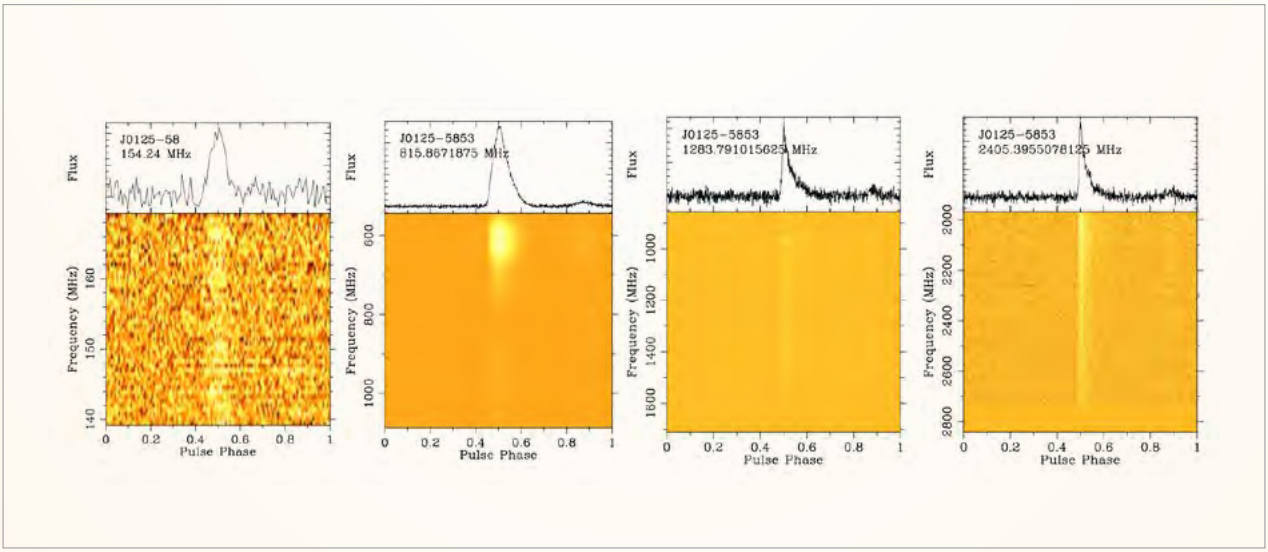
The Southern-Sky MWA Rapid Two-Metre (SMART) pulsar survey aims to search through the whole southern sky with the Murchison Widefield Array (MWA) to uncover previously unknown pulsars. While more than 4000 of these neutron stars that originate from the collapse of stars much larger than our Sun are known across our Galaxy, SMART aims to survey the whole sky uniformly to better characterise the pulsar population in our Galaxy. As a project conducted with the SKA precursor MWA, SMART will also be the best reference to a future pulsar survey conducted with SKA-Low, one of the SKA's key science projects.

We started the deep-pass processing of SMART in mid-2024, where the full 80-minute observations taken between 2018 and 2023 were searched for pulsars. After processing roughly 20% of our data, we have discovered 20 new pulsars. Amongst these is PSR J0125-5854, with a spin period of 24 milliseconds. The spin period of PSR J0125-5854 is much faster than typical pulsars, which have periods on the order of several hundred milliseconds to seconds.

A follow-up campaign began with both the MWA and the MeerKAT telescope in South Africa over 290 days between the end of 2024 and mid-2025. These observations revealed that the observed spin period of the PSR J0125-5854 is varying in a manner that is consistent with Doppler shifts of its signal arrival time due to motion in a binary system with an unknown object. We modelled the variation in spin period over the 290-day observing epoch and found that the pulsar is likely to be in a circular, 833-day long orbit with an object that has a mass that is at least 40% of our Sun. This orbital model is verified by the fact that the predicted spin periods of the pulsar at three epochs around 2018 – the observations that resulted in its discovery – are consistent with the observed spin periods (see Figure 2.). A cursory look at the optical images from the Dark Energy Spectroscopic Instrument Legacy Surveys unveiled a faint and blue object coinciding with the position of the pulsar.

These findings suggest that PSR J0125-5854 is in a binary system with a white dwarf, a stellar remnant that is formed when stars with masses similar to our Sun reach

Figure 1. Detections of PSR J0125-5854 with the MWA and three frequency bands of the MeerKAT telescope. The data are folded to the spin period of the pulsar, showing the integrated pulse profiles at the top and the frequency evolution of the profiles at the bottom.



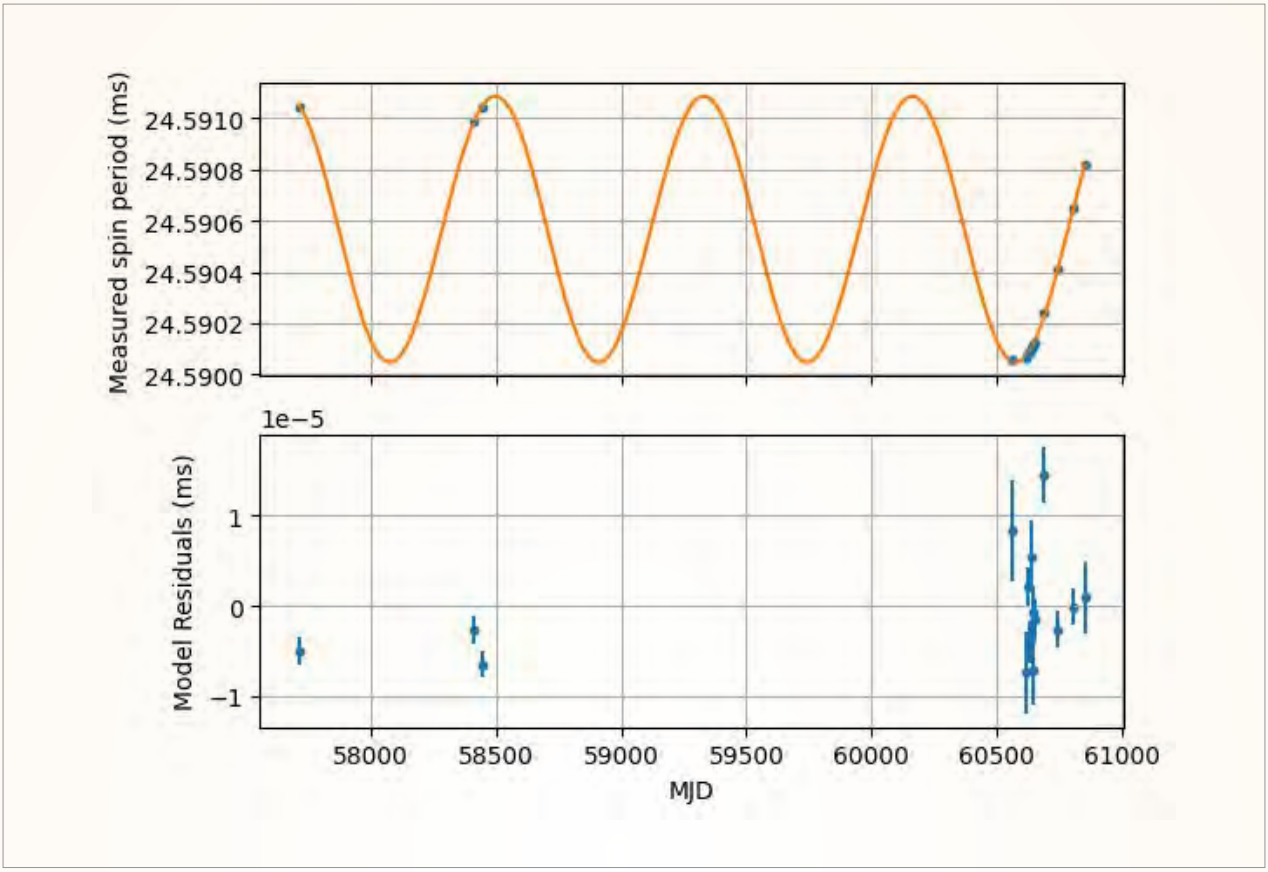


Figure 2. *Above*: The predicted spin periods of the PSR J0125-5854 over time from our 833-day orbital model (orange line) compared to the observed spin periods of the pulsar in those observations (blue dots). *Below*: The difference between the predicted and observed spin periods, showing that our modelled orbital properties agree well with the observations.

the end of their life. The system is formed through a process known as accretion. The system initially consists of two stars, with one more massive than the other. The more massive star first exhausts its fuel and undergoes supernova, leaving behind a pulsar. The pulsar then accretes material from the less massive companion star, which spins up the pulsar to its current spin period of 24 milliseconds, and circularises the orbit. The companion star eventually evolves into a white dwarf. This system is unique as most other pulsar-white dwarf binary systems known have orbital periods from less than a day up to several days only.

PSR J0125-5854 is found at a location in the Galaxy that is far away from the Galactic plane. This is a region of the Galaxy that is not surveyed by most other pulsar surveys, due to their limited survey speed resulting in them focusing on regions along the Galactic plane. Our discovery suggests that there are many more fast spinning pulsars that lie outside the Galactic plane waiting to be found, with SMART at the forefront of surveying this space. A publication detailing the discovery of PSR J0125-5854 is to be submitted to *The Astrophysical Journal*.

Hunting for Millisecond Pulsars at SKA-Low Frequencies

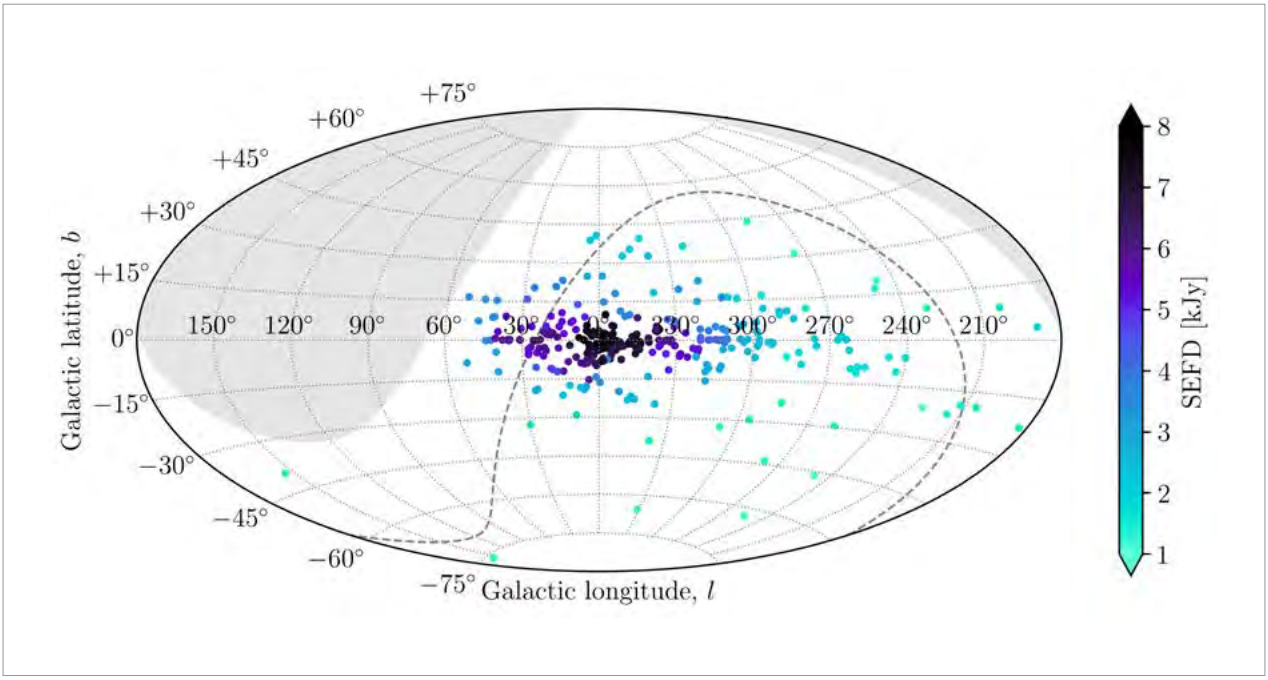


Figure 1. A Galactic map of *Fermi* sources included in our targeted pulsar survey. The colours indicate the relative sensitivity that we achieve for each source, which depends on the brightness of the Galactic synchrotron emission and how close the source was to zenith when observed. The sensitivity is lower near the Galactic centre. The shaded region indicates the northern declinations beyond the reach of the MWA, and the dashed line is the southern declination limit of LOFAR.

CHRISTOPHER LEE
RAMESH BHAT
BRADLEY MEYERS

Pulsars are the rapidly spinning cores of dead massive stars. They emit beams of electromagnetic radiation that appear like a lighthouse when crossing our line of sight. The time between pulses is so predictable that they act like natural cosmic clocks. By recording when the pulses arrive at a telescope, it is possible to measure subtle astrophysical phenomena, such as the ripples in space-time known as gravitational waves. The most precise measurements can be made using millisecond pulsars (MSPs), an older population of pulsars that have been spun-up to millisecond spin periods by the accretion of matter from a companion star. Discovering new MSPs will increase the sensitivity of pulsar timing arrays, which are essentially Galactic-scale detectors for gravitational waves. With each new discovery, we also develop a better understanding of the population of Galactic MSPs, which teaches us about the evolution of stellar binaries and how pulsars produce their radio emission.

Less than 1 per cent of the 600+ known Galactic MSPs have been discovered at radio frequencies below 300 MHz

As of 2025, less than 1% of the 600+ known Galactic MSPs have been discovered at radio frequencies below 300 MHz, the frequencies at which SKA-Low will operate. This is due to frequency-dependent time delays and distortions imparted on signals while travelling through interstellar plasma that make it challenging to search for signals at low radio frequencies. In particular, pulses arrive at the telescope with a delay that is inversely proportional to the square of the frequency, and proportional to the total number of electrons that the signal encounters as it travels through interstellar space (called the dispersion measure or DM). To search for pulsars, this ‘dispersive delay’ must be corrected for thousands of trial DMs, and for each DM, a periodicity search is performed. The major challenge at low frequencies

is that complete (or 'coherent') dispersion removal is prohibitively expensive for large-scale surveys, so a trade-off must be made by settling for imperfect correction of the dispersive delay. MSPs, however, often require near-perfect dispersion removal to be detected at these frequencies. For targeted surveys, where more computational resources can be spent on each search, this can be attained with 'semi-coherent' dispersion removal. This method enabled the discovery of the second-fastest-spinning known pulsar with the LOFAR telescope in 2017 (with a spin period of just 1.4 milliseconds).

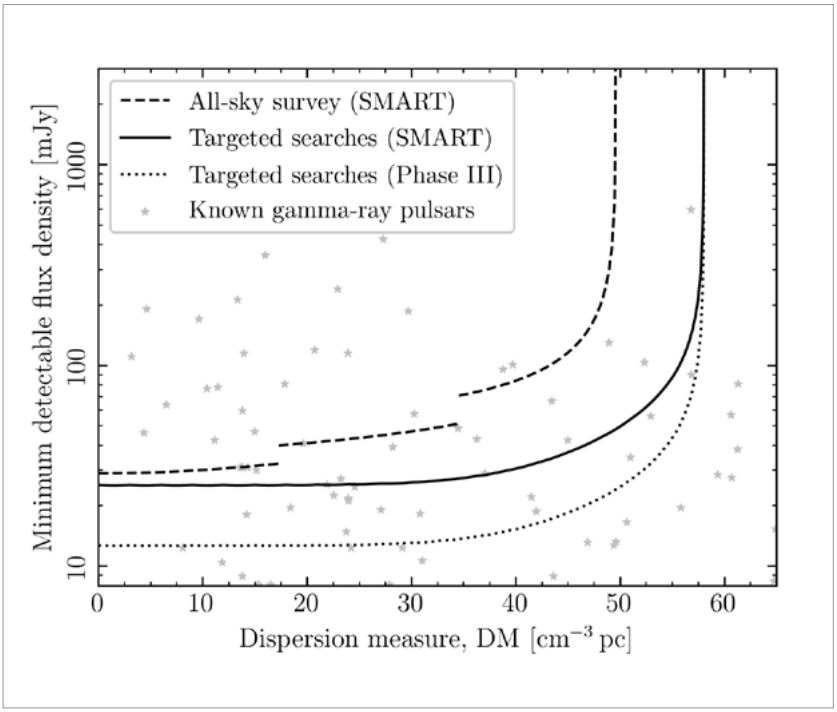
This is the largest radio survey to date targeting Fermi-selected sources

The LOFAR searches were targeting gamma-ray sources detected by the *Fermi* satellite with no known association (such as a pulsar or a galaxy); a proven search strategy that is responsible for around a fifth of all MSP discoveries to date.

Motivated by the success of the LOFAR searches of *Fermi* sources, we developed a new pulsar search pipeline for the Murchison Widefield Array (MWA) that leverages the power of voltage data and semi-coherent dispersion removal. The data processing involves the efficient use of GPUs, building on the original framework developed for LOFAR. We deployed the pipeline on the DUG supercomputer in Perth, a commercial HPC facility with a range of node types that enable us to perform searches quickly and efficiently. The culmination of the work so far has been a pilot survey of 308 unidentified *Fermi* sources in archival observations from the Southern-sky MWA Rapid Two-metre (SMART) pulsar survey. This is the largest radio survey to date targeting *Fermi*-selected sources. The searches have an effective time resolution of 0.14 milliseconds, providing sensitivity to millisecond and even sub-millisecond pulsars. Being a shallow survey (20-minute observations), the searches were mainly sensitive to brighter pulsars. No new pulsars have been discovered so far, indicating that more sensitivity is required. Therefore, our next steps will be upgrading our pipeline to deal with longer observations. The advent of MWA Phase III offers significant promise in this area, with its much higher sensitivity and digital beamforming capability. This will enable more sensitive searches, with better prospects of finding fast-spinning pulsars. The pipeline and survey are described in an upcoming publication, to be submitted to *PASA*.

The advent of MWA Phase III offers great promise in this area, with its much higher sensitivity and digital beamforming capability

Figure 2. Pulsar search sensitivity of the all-sky SMART survey (dashed line), our targeted searches in SMART observations (solid line), and future targeted searches in Phase III MWA observations (dotted line). The vertical axis is the minimum flux density that a pulsar with a spin period of 2 milliseconds would need to be detectable. The horizontal axis is the dispersion measure (DM), a proxy for the distance to the pulsar. The sensitivity loss at higher DMs is due to scattering in the interstellar medium. The grey stars show the flux density and DM of all known gamma-ray pulsars detected at radio frequencies.



Streaming the Sky: A New Algorithm for Wide-field Transient Searches

CRISTIAN DI PIETRANTONIO

Fast radio bursts (FRBs) are among the most extreme astrophysical phenomena known. Yet, detecting them at low radio frequencies remains computationally challenging. A new algorithm developed in collaboration between the Curtin Institute of Radio Astronomy (CIRA), the Pawsey Supercomputing Research Centre, and the Square Kilometre Array Observatory (SKAO) is helping to overcome this challenge. The method, called Streaming high Time-Resolution Imaging DEdispersion (STRIDE), enables astronomers to search wide-field archival observations from the Murchison Widefield Array (MWA) for millisecond radio bursts that were previously too computationally expensive to detect.

Why dedispersion matters

Radio signals travelling through the universe are delayed by the ionised plasma they encounter along the way. Lower frequencies arrive later than higher ones, producing a characteristic sweep across the radio band known as dispersion. This effect is particularly pronounced at the low frequencies observed by the MWA, below 300 MHz, where signals can be smeared across tens of seconds. Figure 1 demonstrates the effect on a giant pulse from PSR B0531+21, also known as the Crab pulsar.

To detect a burst, this effect must be reversed through a process called dedispersion, aligning the signal across frequency channels so that the pulse can be reconstructed as it was emitted. Traditionally, dedispersion algorithms operate on beamformed data and produce a single time series representing the total signal power across the band.

However, imaging-based searches, which preserve information across the entire field of view, present a much greater computational challenge. Instead of analysing one time series, the algorithm must search millions of image pixels

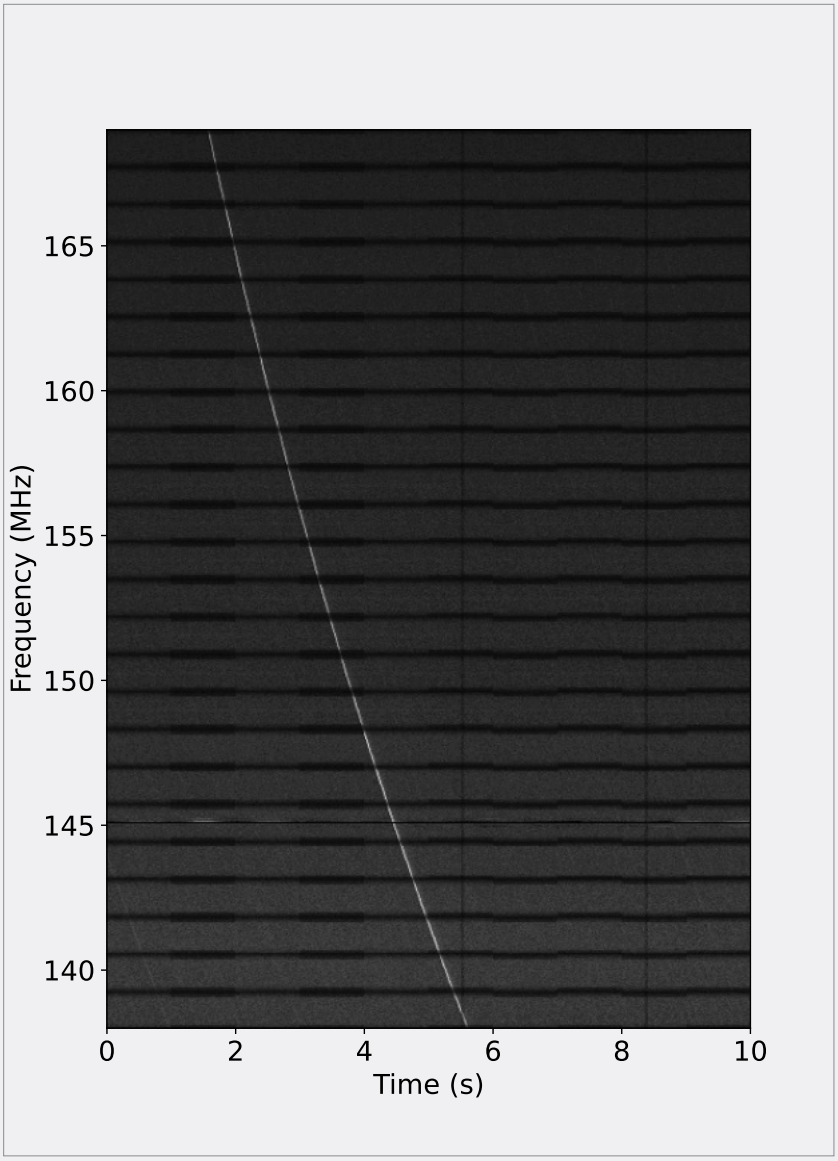


Figure 1. A giant pulse from the Crab pulsar detected with the Murchison Widefield Array. The dynamic spectrum shows the signal intensity as a function of observing frequency and arrival time. Astrophysical radio signals appear as quadratic sweeps across the band, caused by dispersion in ionised plasma between the source and Earth. The amount of dispersion is quantified by the dispersion measure (DM); the Crab pulsar has a DM of approximately 57 pc cm^{-3}. Across the 30.72 MHz bandwidth centred at 154.25 MHz, this produces a dispersive delay of about 4 seconds between the highest and lowest observed frequencies.

simultaneously, each potentially containing a transient source.

A supercomputing challenge

Imaging-based searches for fast transients require data with millisecond time resolution and kilohertz frequency resolution. Combined with the significant dispersive delays at low frequencies, this means that algorithms must handle extremely large data volumes. In practice, processing a wide-field observation from the MWA can require handling up to a terabyte of data per minute of observation, pushing the limits of available computing resources.

The STRIDE approach

STRIDE addresses this challenge through a streaming, incremental approach to dedispersion. Instead of requiring all images covering the full observing band and dispersive delay to be stored simultaneously, the algorithm processes small subsets of images as they are produced by the BLINK imaging pipeline [1].

These images are streamed to the dedispersion routine, processed, and then discarded. The algorithm only retains a few seconds of the dedispersed time series for each pixel at any given time to determine whether a transient signal is present. By breaking the computation into smaller time-ordered segments, STRIDE dramatically reduces the memory requirements of the search.

In a test on the Setonix supercomputer at Pawsey, STRIDE was used to analyse a 20-minute MWA observation of the Crab pulsar with 20 ms time resolution and 40 kHz spectral resolution. The search covered a 64-square-degree field of view using 1024 × 1024-pixel images. The BLINK pipeline, extended with STRIDE, detected 358 giant pulses from the Crab pulsar, as well as 78 pulses from a second source 1.2° away, PSR B0525+21, sometimes nicknamed the ‘Crab’s cousin’. Figure 2 shows all the candidate pulses detected in the observation, whereas Figure 1 shows the brightest Crab pulse.

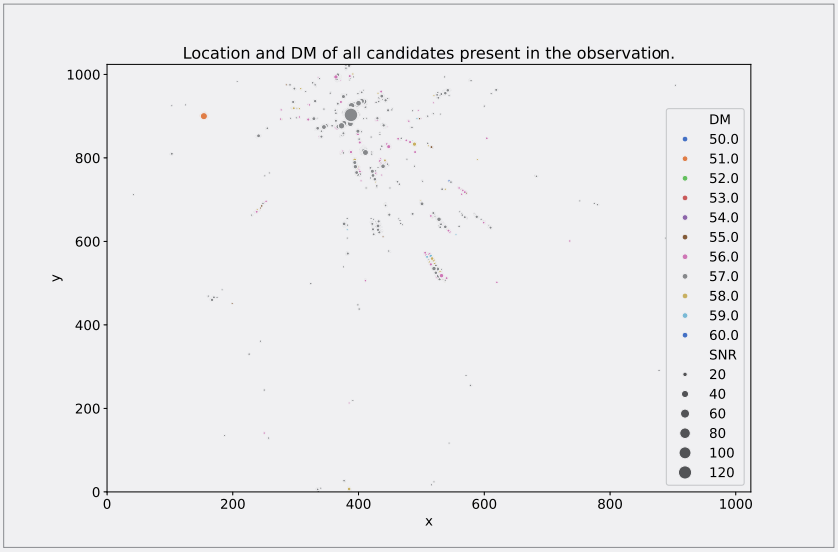


Figure 2. Detection map of transient candidates identified in the observation. Candidates with a signal-to-noise ratio (SNR) greater than 10 are shown in a scatter plot, where each point represents a detected event. The (x, y) coordinates correspond to the candidate’s position in the image, the marker size scales with SNR, and the colour encodes the dispersion measure (DM). Two main clusters are visible. The grey cluster, characterised by a DM of about 57 pc cm^{-3} and maximum SNR value of around 120, coincides with the position of the Crab pulsar (PSR B0531+21). Smaller surrounding clusters arise from side-lobe detections of the same source, also found at nearby DMs. A second, distinct orange cluster on the left of the map corresponds to detections with DM ≈ 51 pc cm^{-3} and SNR ≈ 40. Its position matches the pulsar PSR B0525+21, located about 1.2° away from the Crab pulsar.

Crucially, the estimated memory requirement for a conventional image-based dedispersion approach would have been 684.5 GB, whereas STRIDE required only 14.4 GB – a 97.9% reduction.

Looking ahead

STRIDE opens the door to systematic searches for fast radio transients in the enormous archive of MWA observations. By enabling wide-field imaging searches at millisecond time resolution, the algorithm allows astronomers to probe the low-frequency transient sky in new ways.

These observations can complement discoveries made at higher radio frequencies and provide valuable insight into the population of FRBs, pulsars, rotating radio transients (RRATs), and other exotic sources. With the growing availability of powerful supercomputers and large radio datasets, algorithms such as STRIDE will play a key role in unlocking new discoveries in the dynamic radio universe.

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[1] Di Pietrantonio C, Sokolowski M, Harris C, Price D, Wayth R. BLINK: An end-to-end GPU high time resolution imaging pipeline for fast radio burst searches with the Murchison Widefield Array. *Publications of the Astronomical Society of Australia*. 2025;42:e074. doi:10.1017/pasa.2025.10043

RELATED PUBLICATION

Submitted to *Astronomy and Computing* journal for review and publication. Preprint available on arXiv (https://doi.org/10.48550/arXiv.2603.02931)

Pulsar Census with an SKA-Low Prototype Station

PRATIK KUMAR
MARCIN SOKOLOWSKI
RANDALL WAYTH

Pulsars are rapidly rotating highly magnetized neutron stars observed across the electromagnetic spectrum, but they mainly emit radiation at radio frequencies. They were first observed as periodic bursts at 81.5 MHz; however, most pulsar studies thereafter have remained limited to higher frequencies, primarily above 300 MHz. This was due to three primary reasons:

1. the higher system noise due to brighter background radiation and inversion in pulsar spectra affecting the ability to detect faint signals,
2. highly frequency-dependent effects like dispersion and scattering smearing the observed signal, and
3. challenges with instrumentation, high data rates and signal processing, which together made it challenging to study them at these low frequencies, especially below 100 MHz.

However, the wealth of information that can be inferred by low-frequency studies makes these studies very interesting. To name a few, the evolution of pulsar flux density as a function of frequency and the shape of pulse profiles can give insights into the physical processes that govern the emission from pulsars and help improve the models of emission – a long-standing, unsolved problem of almost six decades.

Similarly, because of the higher sensitivity to dispersion effects in the interstellar medium (ISM), low-frequency studies can give unique insights into the variation in Galactic electron density, improve models for scattering and inform about the structure of the Galactic magnetic field via Faraday rotation of polarized pulsar radiation.

The past decade has seen the inception of many low frequency observatories, which has led to major advancements in pulsar studies at low frequencies. However, the upcoming low-frequency Square Kilometre Array (SKA-Low) planned to operate between 50 and 350 MHz will offer an unparalleled tool to advance the field. In preparation for this, a prototype station was deployed at Inyarrimanha Ilgari Bundara, namely the Engineering Development Array 2 (EDA2). EDA2 consists of 256 well characterised MWA bowtie dipoles with modified low-noise amplifiers to improve sensitivity down to ~50 MHz. The system can make real-time beamformed observations unlike the MWA, thus reducing the data volume significantly, allowing for faster processing and analysis. It can also record observations with a bandwidth of ~100 MHz at a time. Using this instrument, we have performed observations of known pulsars in the 50-250 MHz range. Among the 240 sources observed, we were able to detect 120 pulsars, shown in Figure 1, and made detections in five sub-bands, centered at 71, 131, 169, 196 and 226 MHz to study the evolution of pulsar profiles, pulsar spectra, and scattering properties. Among these, 23 detections were made for the first time below 150 MHz and five below 100 MHz. Non-detection of other sources can be accounted for by overestimation of expected flux density, loss of sensitivity with elevation or signal degradation due to propagation effects.

The study of pulsar spectra using this dataset, along with existing data in literature shows that the spectral turnover at low frequencies occurs around 115 ± 10 MHz where the mean spectral index is -1.78±0.17 compared with the empirical value of -1.4 reported around 1.4 GHz. Spectral analysis with this new data also warranted a revision of the spectral property of 20 of these pulsars, hinting at the importance of low-frequency observations for characterizing spectra. We also refined the measured DM of these pulsars and used this to study the electron density fluctuations in the ISM by comparing it against catalogue values. We found these density fluctuations to be consistent with prior studies. Finally, we also performed phase-resolved RM-synthesis on these pulsars, where we obtained RM-values for 40 pulsars, shown in Figure 2, mostly consistent with prior measurements, however, for three pulsars namely J2155-3118, J1543-0630, and J1825-0935, we obtained new, improved RM measurements upon rejecting the possibility that these differences arise from ionospheric variations. In some cases, we also obtained variation in pulsar RM over the pulse phase, hinting at magnetospheric origins.

These results hint at the importance of pulsar studies at low frequencies, especially in the era of next-generation instruments like the SKA-Low with unprecedented sensitivity, which will help advance pulsar astronomy.

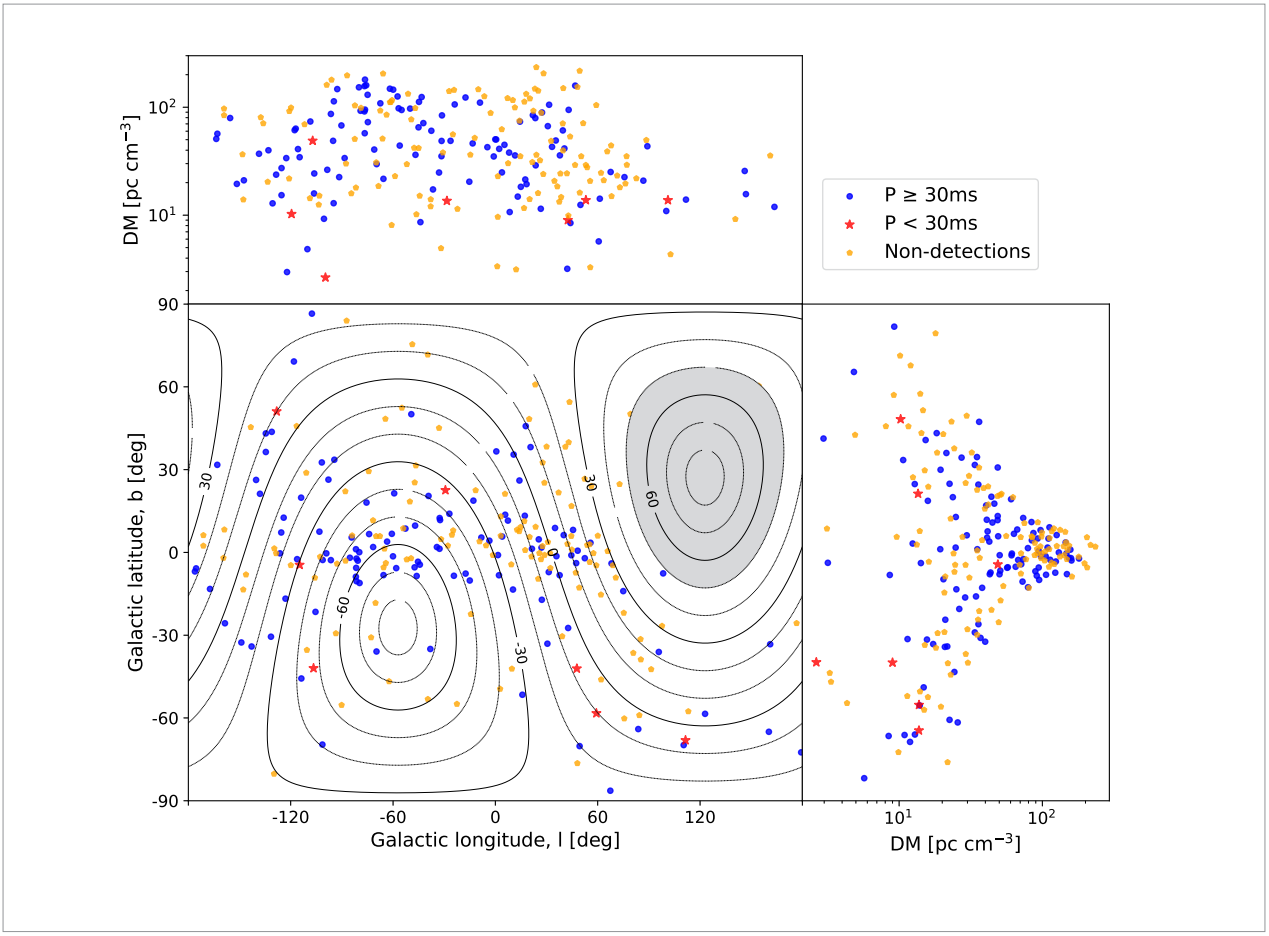

Figure 1. Distribution of census targets in Galactic coordinates. Red and blue indicate the detected targets, with periods below and above 30 ms, respectively, and undetected targets are shown in yellow. Contours show the line of equal declination, and the shaded region shows the region inaccessible because of low elevation.

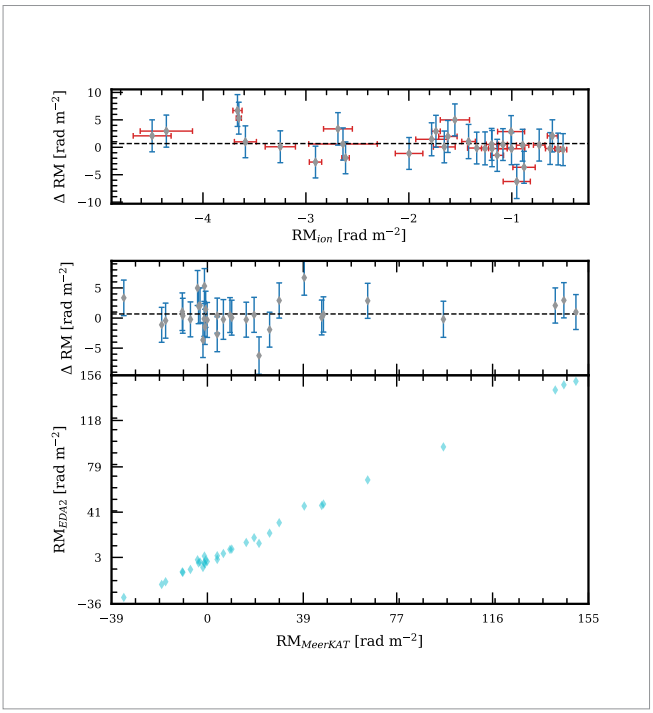

Figure 2. The top panel of the figure shows the difference between RMISM from EDA2 and MeerKAT telescopes (Δ RM) versus the ionospheric RM (RMion) measured for EDA2 for each of those pulsars. The bottom panel shows the one-to-one comparison of RMISM for pulsars in Table D4 for EDA2 and MeerKAT. The central panel shows Δ RM vs RMISM for MeerKAT. The dashed line in both the top and central panels indicates the mean value of ΔRM.

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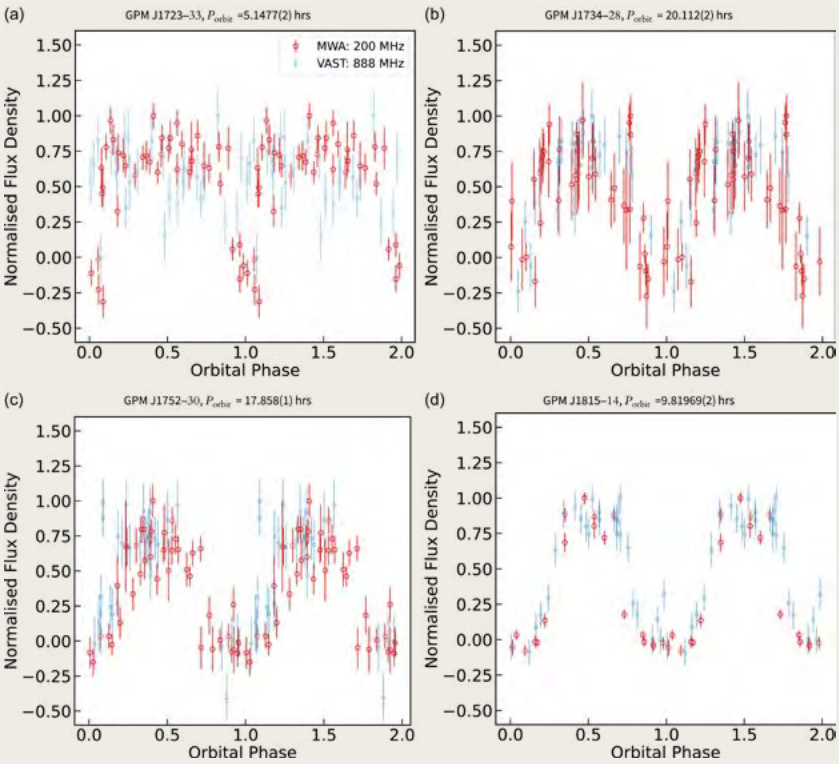
Discovering Eclipsing Binary Millisecond Pulsars in Image-Plane Surveys

A/PROF NATASHA HURLEY-WALKER
FLORA PETROU

From 2022 to 2025, the Galactic Plane Monitor (GPM) used the Murchison Widefield Array (MWA) to scan the sky for long-period radio transients, unusual objects that produce bursts of radio waves every few minutes or hours. to Serendipitously, we also found seven other transient radio sources—not bursting, but instead switching periodically between visible and invisible. All were found near bright, previously unclassified, gamma ray sources: mysterious sources of high-energy radiation in our Galaxy.

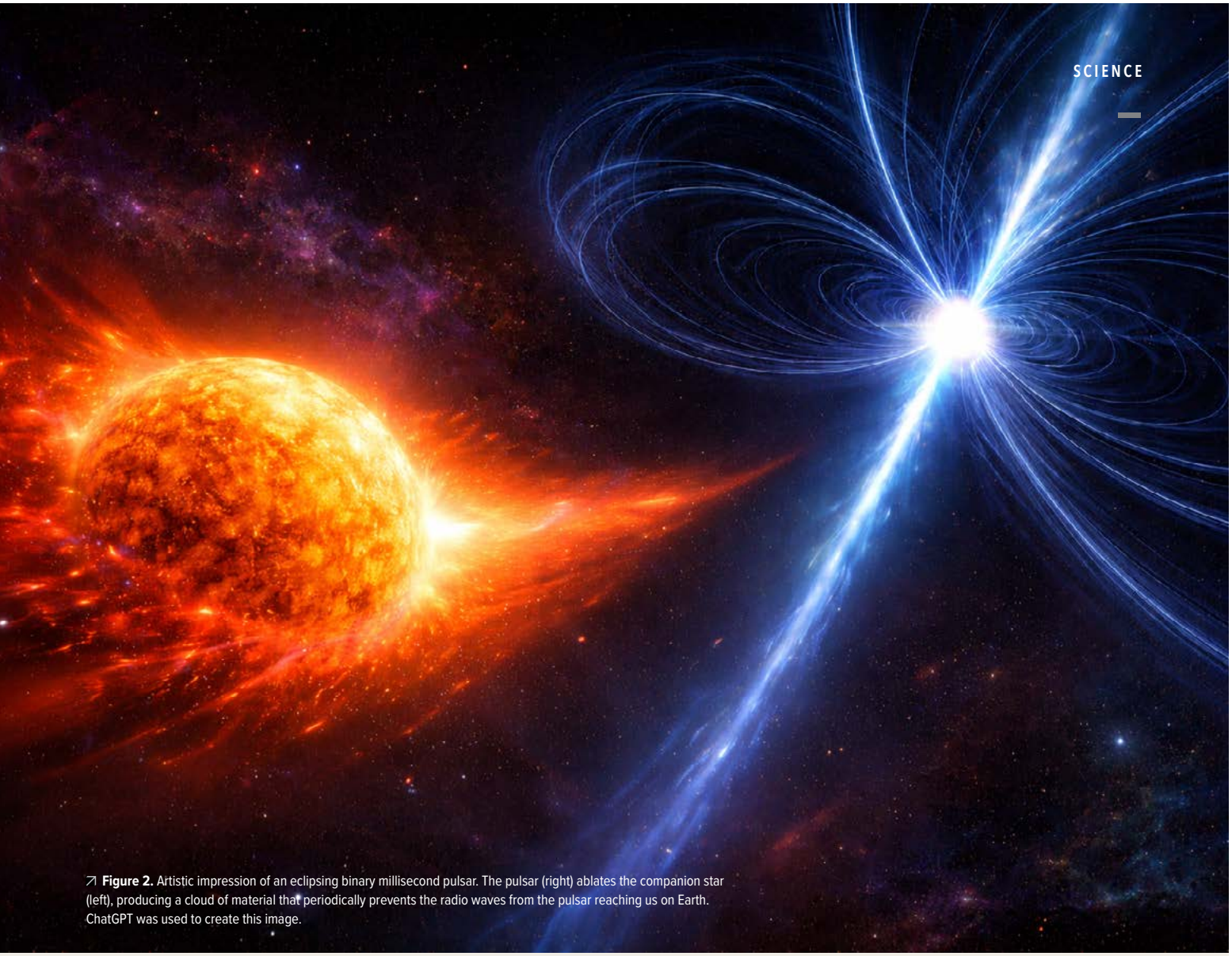
Our investigations revealed that these objects are redback millisecond pulsar systems. Redbacks are binary systems in which a rapidly rotating millisecond pulsar orbits a low-mass companion star that is being ablated by the pulsar wind. It is this wind that periodically *eclipses* the radio emission from the pulsar, causing it to appear to switch on and off over time, and also generates powerful gamma rays. These systems are key laboratories for studying pulsar recycling, binary evolution, and interactions between pulsar winds and companion outflows. Our two studies demonstrate how modern wide-field radio telescopes can identify such systems directly in imaging data, rather than through traditional time-domain pulsation searches.



↗ **Figure 1.** The MWA's new upper limits on the 21 cm power spectrum, compared with previous experiments, exclude models with excessive signal power. This provides the first observational evidence of a heated intergalactic medium (IGM) at redshifts z ≈ 6.5–7, supported by constraints on the IGM spin temperature (Nunhokee et al. 2025).

The first paper, "Investigating four new candidate redback pulsars discovered in the image plane," reports the identification of four candidate systems—GPM J1723−33, GPM J1734−28, GPM J1752−30, and GPM J1815−14—using imaging observations from the MWA GPM. These sources were flagged as redback candidates based on several observational signatures, including strong variability consistent with eclipses, steep radio spectra typical of pulsars, and in some cases spatial coincidence with unidentified gamma ray sources detected by the *Fermi* telescope. Follow-up pulsation searches using the MeerKAT Radio Telescope successfully detected pulsations from one system, confirming its pulsar nature, while the remaining candidates likely evade pulsation detection due to scattering or absorption by ionised material from the companion star.

Detailed analysis of the radio light curves in this study revealed periodic variability consistent with compact binary orbits. By folding the radio imaging time series, we inferred likely orbital periods shorter than about 24 hours for



↗ **Figure 2.** Artistic impression of an eclipsing binary millisecond pulsar. The pulsar (right) ablates the companion star (left), producing a cloud of material that periodically prevents the radio waves from the pulsar reaching us on Earth. ChatGPT was used to create this image.

all four systems, consistent with the known population of redback binaries. The eclipse behaviour and spectral properties suggest that dense material driven off the companion star periodically obscures the pulsar emission, producing the characteristic variability seen in the MWA data. These results demonstrate that widefield imaging surveys can efficiently identify interacting pulsar binaries even when pulsations are difficult to detect directly.

In our second paper, "Discovery of the redback millisecond pulsar PSR J1728–4608 with ASKAP," we present the discovery of a new confirmed redback system identified in imaging data from the Australian Square Kilometre Array Pathfinder (ASKAP). Subsequent follow-up observations revealed a 2.86-ms pulsar in a 5.05-hour orbit with a companion star. The pulsar exhibits a steep radio spectrum and shows eclipses for roughly 42% of its orbit at 888 MHz. Multi-frequency observations show that the duration of the eclipse depends strongly on frequency, with longer eclipses at lower radio frequencies, indicating that the obscuration is caused by ionised plasma surrounding the companion.

Together, these papers highlight the growing power of image domain searches for compact binary pulsars using widefield radio interferometers. By combining variability analysis, spectral measurements, and multi-wavelength follow-up observations, the studies demonstrate that imaging surveys can uncover redback systems that are challenging to detect using traditional pulsation searches alone. This approach is likely to become increasingly important as next-generation radio surveys expand the accessible parameter space for discovering interacting pulsar binaries in the Galaxy.

PUBLICATION DETAILS

"Investigating four new candidate redback pulsars discovered in the image plane" Petrou, Hurley-Walker et al. 2025. *Publications of the Astronomical Society of Australia*, Volume 42, id.e139, 22 pp.

"Discovery of the redback millisecond pulsar PSR J1728–4608 with ASKAP" Petrou, Wang, Hurley-Walker et al. 2026. *Publications of the Astronomical Society of Australia*, Volume 43, id.e007, 13 pp.

A Nanosecond Radio Pulse from the Relay 2 Satellite

CLANCY W. JAMES

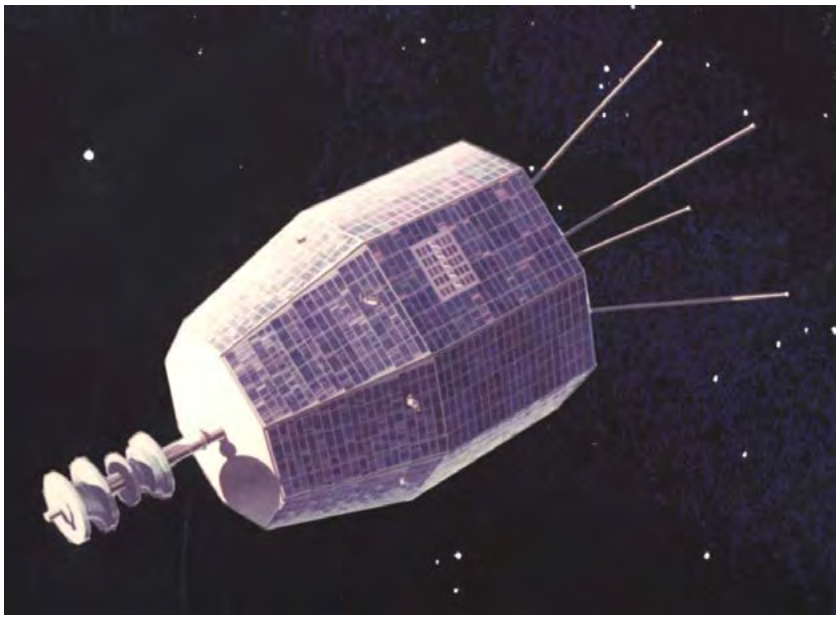


Figure 1. Artist's vision of NASA Relay 1 satellite, which was similar to Relay 2. (Image: Public Domain, https://commons.wikimedia.org/w/index.php?curid=2380329)

On 13 June 2024, the new 'CRACO' coherent upgrade to the Australian Square Kilometre Array Pathfinder (ASKAP) identified an intriguing signal. This system had recently been commissioned by CRAFT, and it opened up a whole new parameter space of interesting objects. The signal it detected was interesting because it had a very low dispersion measure, meaning that it had to originate from within a few tens of light-years of Earth.

Discovering the origin of this sudden burst was long and painstaking work, however, by a team including CIRA's Apurba Bera, Marcin Glowacki, Clancy James, Steven Tingay, and Andy Wang. For one thing, when we tried to image the burst using our offline analysis software–it didn't work! The source of the problem was that the burst origin was too close to Earth. This meant that the radio wavefront appeared curved to ASKAP's 6 km baselines, and the image came out blurred, just like a camera's zoom lens blurring objects which are too close and out of focus.

We developed a dedicated near-field analysis pipeline specifically to account for this wavefront curvature, and what did we find? It originated merely 4,500 km away, in mid-Earth orbit. It was a satellite. But not just any satellite – the Relay 2 satellite, which had ceased operations in 1965 (see Figure 1). How could Relay 2 have produced this burst?

It is known that satellites regularly produce electrostatic discharge (ESD), due to the accumulation of charge in the Earth's magnetosphere. However, the most similar ESD yet observed lasted tens of microseconds, whereas this burst lasted tens of nanoseconds (see Figure 1) – and we believe that the intrinsic signal was less than 3 nanoseconds, with the remaining structure being analogue and digital artefacts. Another possible cause is a micrometeorite impact, which generates plasma that de-excites by emitting radio waves. However, laboratory studies of this emission also find bursts lasting far longer than 3 nanoseconds.

Ultimately, we couldn't come up with a definitive answer to the question of the source of the emission - but it did get a lot of media attention! News of 'zombie satellites' apparently sparked huge interest, with our work being picked up by 158 news outlets. It also suggests that radio telescopes can be used to monitor satellite health, since both ESD and micrometeorite impacts are known to damage onboard systems – an application that we expect to become more relevant as the satellite count grows with every passing year.

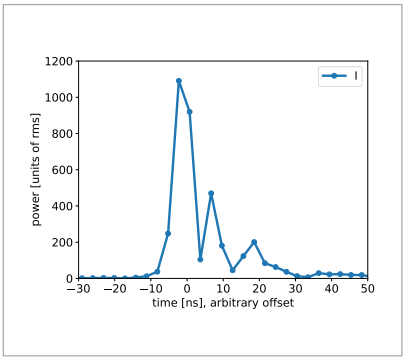


Figure 2. Burst power as a function of time. The intrinsic signal is thought to have been less than 3 nanoseconds in duration, with the multiple peaks indicative of 'ringing' caused by the extreme brightness of the signal. (Image: C. W. James et al., *The Astrophysical Journal Letters* 987 (2025) L16)

Decreasing the Harmonics of Wideband High-Frequency Power Amplifiers

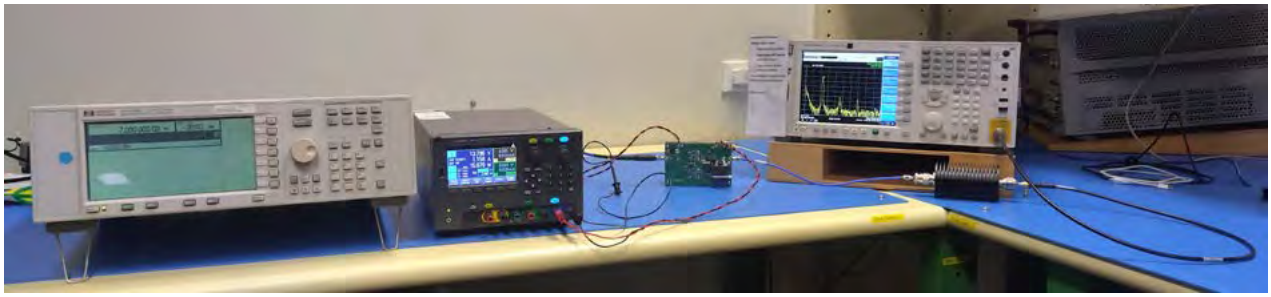


Figure 1. Test bench setup to observe the PA harmonics generated by a single tone input signal. (Image: C.Macpherson 2026)

CHRIS MACPHERSON
ADRIAN SUTINJO
FERRY LANTER

The Electromagnetic (EM) spectrum is getting increasingly congested as we look for more ways to communicate wirelessly. Add to this that we are trying to pass more data with the existing spectrum by using higher modulation schemes, which require higher signal-to-noise ratios. For us to make the best use of the available spectrum it is critical that each user only transmits, as much as possible, only within their allocated channel. The limits on interference are outlined by the International Telecommunication Union (ITU).

We are interested in unwanted emission from transmitters as it is difficult to protect against. Noisy circuitry can be somewhat mitigated with the right shielding. Any unwanted emission from the transmitter will propagate from the antenna through free space and potentially interfere with other users of different parts of the spectrum. This becomes an electromagnetic compatibility (EMC) issue, defined as:

> *"the ability of equipment or a system to function satisfactorily in its EM environment without introducing intolerable EM disturbances to anything in that environment."*

In our case we are looking at disturbances (or interference) in the radio frequency environment between the transmitting system of one user and the receiving systems of other users. The EMC Society of Australia aims to raise awareness of EMC issues and has shown interest in our research. To support our research they have provided top-up funding in exchange for sharing our research with their members through a report and presentation.

Our research began by looking at unwanted emission from radio frequency transmitters in the context of satellites interfering with radio astronomy observatories. During the literature review it was found that the interference detected from satellites was not from the transmitter, so the focus was shifted to another case where unwanted emission from transmitters had been observed. A team at CIRA working on an ionospheric measurement project had observed that the High Frequency (HF) Power Amplifier (PA) in their transmitter was generating harmonics, a type of unwanted emission, that they had trouble reducing below the limits from the ITU.

An interesting part of this problem is the wideband nature of the PA required by the team; it needed to operate across the entire HF band from 3–30 MHz. The large bandwidth makes it difficult to use filters to reduce the harmonics, a series of filters are required which are switched between based on the transmit frequency. A PA operating over a much smaller relative frequency range can use a single filter to reduce the harmonics and then other noise types will dominate. To make the filter design easier the harmonics need to be as low power as possible.

To decrease the harmonics there are two areas of interest being investigated. The first is how different transistor materials and architectures impact the linearity of the PA. By increasing the linearity of the PA the distortion of the output can be decreased. The second is implementing feed-forward cancellation, which is an advanced linearisation method, to decrease the distortion from the PA before filtering.

Using Graph Neural Networks to Quickly Predict Beams for Automated Layout Design

CHUYAN CHEN
MARIA KOVALEVA
KEVIN VINSEN

Modern radio telescopes and large antenna arrays rely on accurate beam forming to observe the sky with high sensitivity. However, generating high-resolution beam patterns through full electromagnetic simulations is extremely computationally expensive, especially for systems containing thousands of antenna elements. This creates a major bottleneck for design, calibration and real-time operation. To address this challenge, we explored a machine learning approach to predict complex-valued beam patterns much faster while maintaining high accuracy.

In this work, we introduced a Transformer-Enhanced Graph Isomorphism Network with edge features (TE-GINE) designed to model the geometry and electromagnetic behaviour of small sub-arrays within a larger phased-array antenna. The motivation behind this approach is to capture the rich spatial relationships between antenna elements without relying on costly physics-based simulations. The model used both node features (representing individual antenna elements) and edge features (representing pairwise geometric relationships) to learn fine-grained structural information. Transformer layers were then applied to refine the graph-level representation, allowing the network to understand broader geometric context across multiple connections within a sub-array.

We trained and evaluated TE-GINE using sub-arrays extracted from the SKA-Low Aperture Array Verification Systems: AAVS2, AAVS3 and AAVS3P. Despite the diversity and complexity of the beam patterns, the model achieved impressive agreement with ground truth electromagnetic simulations. For zenith-pointing beams, the prediction was less than or equal to 1 dB within the field of view, and across a wide beam domain, the absolute average error remained around 5 dB for seven different steering angles. Importantly, inference times were on the order of seconds, demonstrating a substantial speed-up compared to traditional simulation methods.

This approach offers a practical path toward scalable beam prediction for large-scale systems where rapid and accurate modelling is essential. It can be seen in the provided figure that for AAVS2 sub-array #173 a strong agreement between predicted and simulated beams was achieved at both boresight and 40-degree zenith beam pointing.

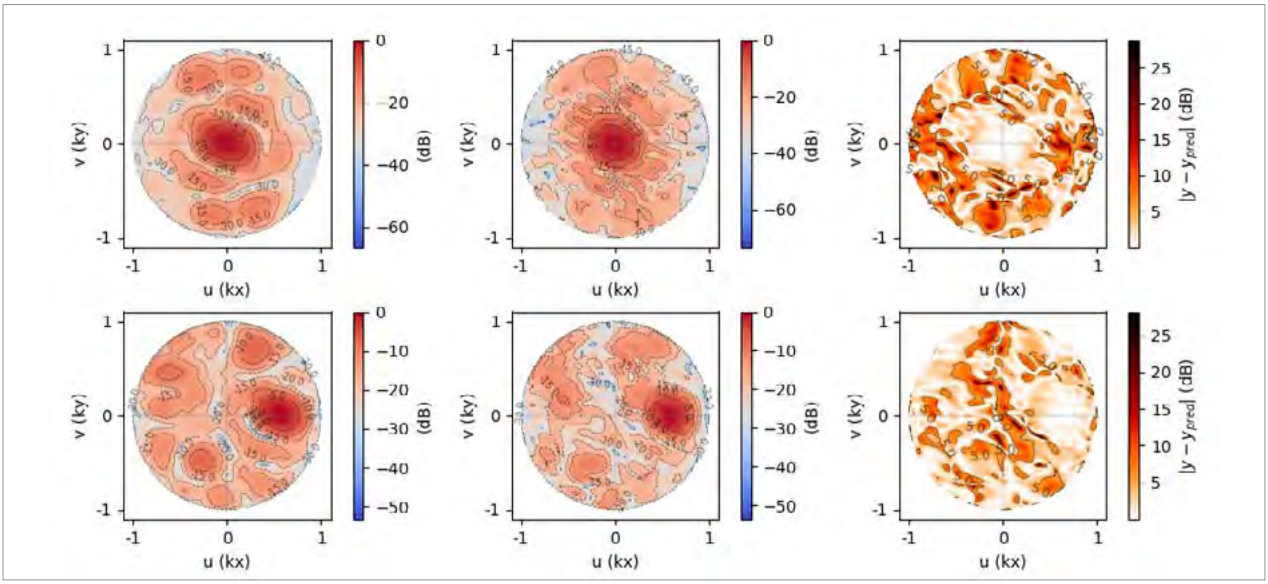


Figure 1. Combined normalised log-scale beam: (left) the ground truth beam obtained from FEKO-simulated EEPs and (middle) its prediction for AAVS2 layout sub-array #173 pointing at (top) zenith and (bottom) 40 deg. On the right is the point-wise absolute error (in dB) between prediction and ground truth with contour lines. It can be clearly seen that the main lobe location was well captured, with minor variations; however, some finer features in the side lobe levels were missed. Most of the predicted beams have a demonstrated error less than 5 dB.

The Recovery of Pindarri Punju Puri: the Mother's Day Meteorite

ELLIE SANSOM

Around 6 am on 11 May 2025, an incredible 9-second-long fireball streaked through the skies of Western Australia. Eyewitness reports came flooding in from across the state, spanning from Perth to Kalgoorlie, as far north as Leonora and as south as Wagin.

The Desert Fireball Network's autonomous camera systems captured the event from two stations positioned more than 400 km away. These passive, all-sky cameras operate continuously and unattended, automatically detecting and triangulating fireballs 24/7 without human intervention. The two cameras formed only a 15-degree convergence angle on the trajectory, and observational conditions were challenging. The lowest data points only 2 degrees above the horizon and no visible termination point. Despite these limitations, the team triangulated the trajectory over the Breakaways east of Hyden. They then calculated a preliminary fall area of approximately 50 km^2 over Lake Hope on Ngadju boodja. Following initial analysis, the fall area was publicly released, generating extraordinary public engagement and media interest. On 17 May, team members Hadrien Devillepoix and Ellie Sansom conducted an aerial reconnaissance mission, flying systematic search grids over the southern salt lakes and identifying several promising impact 'splashes'. Later that day, local meteorite enthusiast Marcus Scott successfully recovered the first fragment, validating the trajectory calculations. The public find generated significant excitement and national media coverage. A few days later, after Indigenous permissions were sought to access the area, a four-person team conducted a ground expedition to follow up the aerial targets. They successfully recovered two additional intact fragments from the locations identified during the aerial survey. They were accompanied by a team from Channel 9 News crew who documented this expedition, broadcasting the story nationally and showcasing Curtin University's world-leading capabilities in automated meteorite recovery. A subsequent collaborative search with meteorite specialists from Monash University explored additional sections of the fall area.



Figure 1. Location of DFN cameras, the fireball and the fall site of the meteorite.

The mission recovered three meteorite fragments with a total mass of 1.2 kg, classified as an L chondrite. The senior Ngadju knowledge holders were enthusiastic and supportive, naming the meteorite 'Pindarri Punju Puri', meaning 'black rock star' (pronounced Bindarri Bunju Buri).

Instrumentally observed falls like this one are valuable for researchers as they can match the rock type to its origins in the Solar System by calculating the impacting orbit. There are only approximately 60 meteorites globally with known orbital information. This is the tenth in Australia tracked and recovered by the Desert Fireball Network, demonstrating the network's unique capability to autonomously detect, track, and enable recovery of fresh meteorite falls. The extensive national media coverage significantly raised Curtin University's profile in space science and planetary research, with a fragment now on display at the WA Museum Boola Bardip.



Figure 2. DFN image taken from Perenjori.

Electromagnetic Simulation of Mutual Coupling Between Adjacent SKA-Low Stations

MARIA KOVALEVA
DAVID DAVIDSON

SKA-Low is the low-frequency part of the Square Kilometre Array (SKA), one of the world's most ambitious radio astronomy projects. Operating between 50 and 350 MHz, SKA-Low will use around 130,000 antennas spread across a spiral-shaped layout with a maximum baseline length of approximately 74 km. These antennas are grouped into stations, each containing 256 dual-polarised log-periodic dipole antennas connected through RF-over-fibre links and tile-processing modules. Nearly half of all antennas are located in the dense central core, with the rest extending outward along three spiral arms. Construction began in 2022 at the Murchison Radioastronomy Observatory in Western Australia, and one of the first major milestones, Array Assembly 0.5 (AA0.5), brought several stations close together. This raised an important engineering challenge: inter-station mutual coupling, where nearby stations unintentionally influence each other's received signals. Quantifying this unintentional coupling is essential for producing clean, accurate astronomical observations.

SKA-Low uses a station layout known as AAVS3 P-Vogel (Perturbed Vogel). This layout distributes antennas in a way that reduces mutual coupling within the station by avoiding regular geometric patterns. Electromagnetic simulations of embedded element patterns (EEPs) for this layout have been completed across a wide frequency range: 71.875–237.5 MHz in 3.125-MHz steps, and 280–350 MHz in 1-MHz steps. These EEPs describe how each antenna behaves when surrounded by all others in the station. A station beam, such as in Figure 1, is formed by summing all 256 EEPs after applying geometric phase shifts to steer the beam in a chosen direction (θ,ϕ), as shown in the equation below:

$$E_{station}(\theta,\phi) = \sqrt{\sum_{1}^{256}\left|E_{\phi}(\theta,\phi)\cdot e^{jk\cdot r}\right|^2 + \sum_{1}^{256}\left|E_{\theta}(\theta,\phi)\cdot e^{jk\cdot r}\right|^2}$$

In this work, we present simulation results of inter-station coupling between two neighbouring stations within the six-station S8 cluster (Figure 2). Using Altair FEKO, we generated a mesh file representing the 521-element array of dual-polarised SKALA4.1 antennas discretised into 285,696 segments and 1,321,472 triangles. The electromagnetic simulation solved for a scattering-parameters matrix containing coupling coefficients for all pairs of dual-polarised antennas and all 1024 EEPs. These simulations required significant computational resources, provided by DUG's high-performance computing systems.

These results provide essential insights into the SKA-Low's performance. Figure 3 shows a boxplot of all coupling coefficients (S_{ij}), revealing that the mean S_{ij} is about -62 dB and 10 antenna pairs have $S_{ij} \in [-37, -40]$ dB. This confirms the expected existing inter-station coupling. A clear difference between an isolation station beam and two S8 beams can be observed. Station beam analysis quantifies the effects of neighbouring stations on each other's beams, and further analysis of these effects on the observed sky is underway.

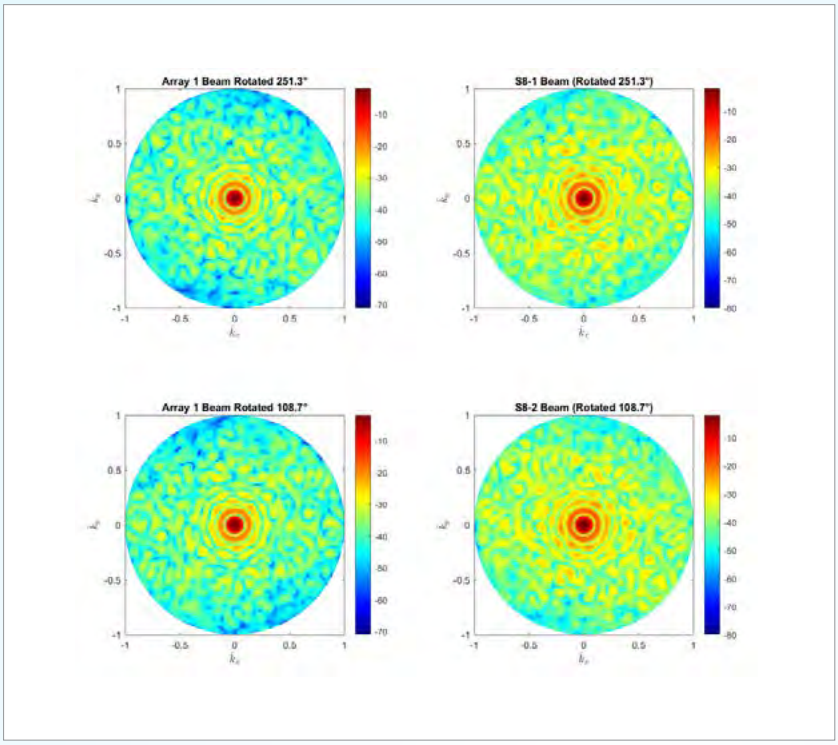


Figure 1. AAVS3P Station beams: (top left) isolated station beam rotated to 251.3 deg; (bottom left) isolated station beam rotated to 108.7 deg; (top right) S8-1 beam and (bottom right) S8-2 Beam. If mutual coupling between station S8-1 and S8-2 did not exist, then the figures on the left and on the right were identical.

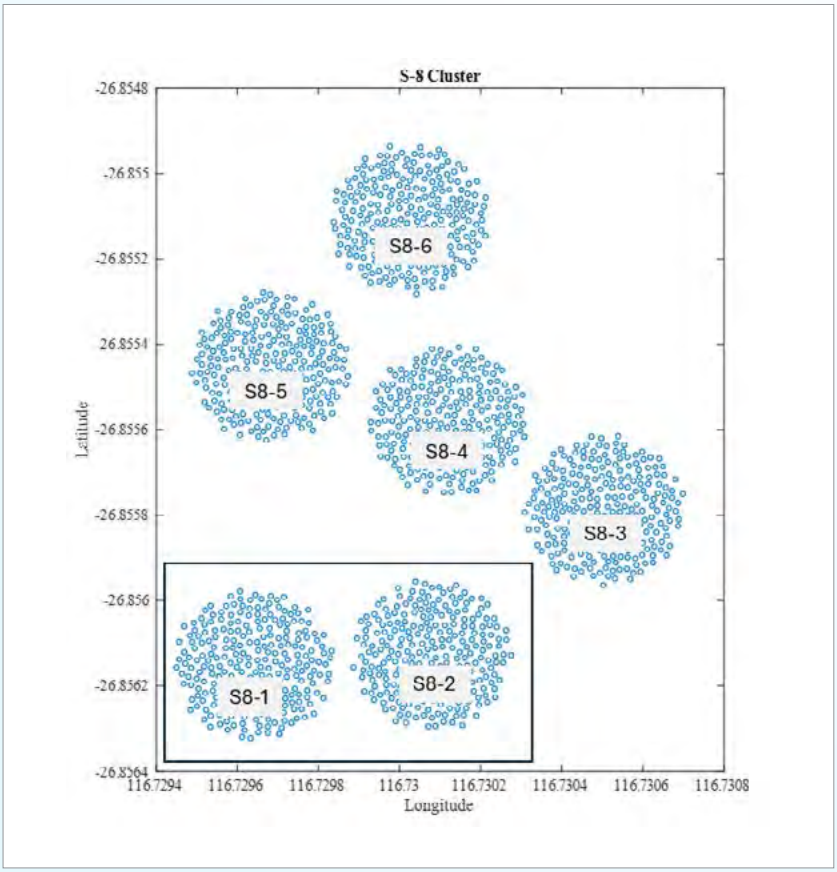


Figure 2. S8 cluster of six AAVS3P stations.

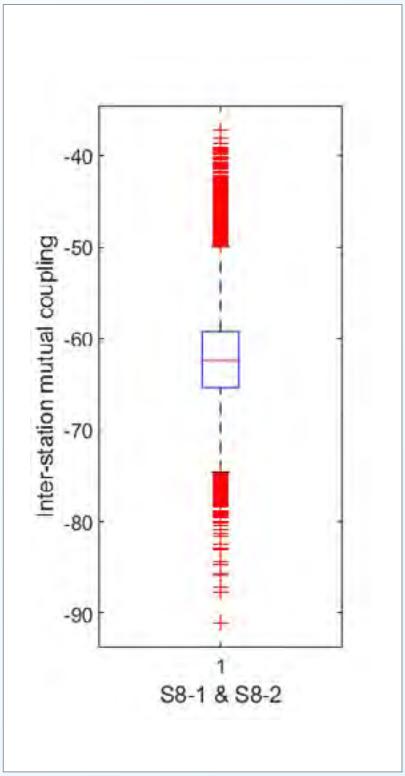


Figure 3. All pairs of coupling coefficients in an array of two SKA-Low AAVS3P stations. Figures of merit such as the maximum coupling level (-37 dB) and the mean coupling (-62 dB) are particularly of interest.

Night Sky to Night Life: Translating Fireball Tracking Expertise to Wildlife-Disturbing Artificial Light Monitoring

HADRIEN DEVILLEPOIX
ELLIOTT CHARLTON
BEN HARTIG

The Desert Fireball Network (DFN) partnered with Nocterra Pty Ltd. to accelerate the development of the company's Small-Sky Camera (SSC), applying our experience in all-sky fireball tracking to all-sky light monitoring that can better support wildlife protection under Australia's National Light Pollution Guidelines for Wildlife (DCCEEW 2024). Together, we developed calibration methods to accurately measure sky brightness at any point in the sky. Recognition of the impacts of artificial light pollution has grown significantly both internationally and within Australia in recent years. This growing awareness has led to the release of DCCEEW 2024, which sets a precedent for addressing the risks of artificial light exposure to sensitive wildlife. In accordance with these guidelines, industry projects are required to undertake artificial-light impact and risk assessments when threatened wildlife are present. A critical aspect of these assessments is the ability to capture and measure biologically relevant artificial light. Such measurements are vital for establishing baseline data, understanding spatial and temporal variations in light exposure, and evaluating potential impacts of project sites on wildlife.

Nocterra has developed two specialised solutions: an All-Sky Camera (ASC) system and continuous-logging sensors. The ASC follows the industry-standard setup of a DSLR camera with a fisheye lens to capture wide-angle imagery of the night sky at the relevant habitat. This is similar to the approach used by the DFN to monitor for fireballs. This imagery provides detailed spatial data and quantifiable measurements, making it ideal for assessing visible-light emissions across the sky. However, it requires regular maintenance (battery charging and manual data download), and is costly to build.

To address these limitations, Nocterra has begun developing a Small-Sky Camera (SSC) that accounts for the distinct strengths



Figure 1. Nocterra's Small-Sky Camera prototype.

and limitations of its existing systems. By integrating a high-sensitivity camera with onboard processing, power management, and wireless connectivity, the SSC could enable autonomous deployment in remote locations with reduced maintenance requirements. The system is intended to provide spatially resolved measurements of artificial light across the sky while maintaining a smaller physical footprint and lower power demand than the conventional ASC setup.



Figure 2. An example all-sky image with a combination of artificial and natural light sources.

Accurately measuring biologically relevant artificial light using wide-field imaging systems presents several technical challenges. Fisheye lenses allow all-sky cameras to capture the full sky dome in a single image; however, they introduce substantial optical distortion, vignetting, and spatial variation in light transmission across the field of view. These effects make it difficult to directly translate pixel values into reliable, comparable measurements of sky brightness or artificial light intensity. Calibration methods for commercial all-sky cameras are not readily transferable to the specialised components needed for a compact monitoring system. Similar challenges were previously addressed by the DFN in the context of fireball monitoring.

Our research collaboration with Nocterra explored an approach that uses in-field calibration techniques based on stellar photometry and astrometry. By referencing the known brightness and positions of stars captured within the camera's field of view, the optical characteristics of the lens and sensor system can be characterised under operational conditions. This approach provides a practical pathway to account for distortion and sensitivity variations across the image, enabling more reliable interpretation of wide-field imagery for the quantitative assessment of artificial light in the night environment.

DFN's long-term experience in wide-field fireball tracking – where accurate calibration under real operating conditions is essential – has translated directly to the challenges of environmental light monitoring. By applying those methods to Nocterra's Small-Sky Camera development, we are helping deliver more reliable, scalable measurements of artificial light, supporting better decisions and stronger protections for sensitive wildlife.

DFN Phase II Prototype Delivers a Fresh Meteorite with a New Search Strategy

DALE GIANCONO

In 2025, the Desert Fireball Network team began developing a new prototype camera system, which I had the pleasure of leading. The vision was a high frame rate system that could capture fireballs through our atmosphere with unprecedented photometry data. The prototype system was installed in April 2025 at Forrest Airport in the middle of the Nullarbor for long-term testing. As this was in the middle of the core DFN, it would be surrounded by existing systems for comparison, as well as spectral systems from collaborators in Comenius University, Slovakia.

In July 2025, a fireball streaked across the skies of central Western Australia during the Meteoroids 2025 conference in Perth. This was the first meteorite-dropping fireball successfully captured by my new high frame rate photometry prototype, with the rock falling deep in the outback approximately 400 km northeast of Kalgoorlie on Upurli Upurli Nguratja land. Initial processing of the imagery indicated a small final mass of around 50 g, which initially made a recovery mission seem unlikely given the thick bush terrain. However, the high frame rate prototype enabled us to acquire a high-fidelity light curve, enabling a detailed fragmentation model to be run.

This model revised the estimated final mass to 600 g or greater, and alongside spectral analysis suggesting an atypical composition. This prompted a dedicated ground expedition in November 2025.

I led a three-person field team, travelling to the remote fall site to conduct a systematic drone survey of a 3 km by 0.5 km area. Before commencing the main survey, our field crew trained the drone's machine learning model on site by placing meteorite analogues (black painted rocks) among the

Figure 1. Phase II prototype system with 5 astrometric cameras and one photometric camera, installed at Forrest, WA.



red dirt and local vegetation to help it identify small dark objects. The image processing utilised a dedicated online platform developed by Hadrien Devillepoix with support from Astronomy Australia Limited's ADACS program. This allowed a fully remote image processing pipeline, starting with uploading images directly to the Pawsey Supercomputing Facility, inference and manual sorting done by the team based in Perth, with target candidates reported back to the remote team within a couple of hours. We then used the web app to assist in real-time geolocation of the targets.

During the survey, the drone captured imagery identifying 31,153 initial surface candidates. Our field team and researchers at base control sorted these detections to identify 728 high-priority targets for physical inspection, though most candidates turned out to be terrestrial objects like gumnuts and spider holes. On the final day of the expedition, I went to check out candidate site 727, and it was our meteorite!

The recovered rock represents the 11th meteorite with a known orbit successfully retrieved by the Desert Fireball Network in Australia, the potential of the prototype systems for the future of the DFN, and the first recovery using the novel crowd-sourced image processing pipeline developed in partnership with the ADACS team.



Figure 2. Drone imagery of the meteorite.



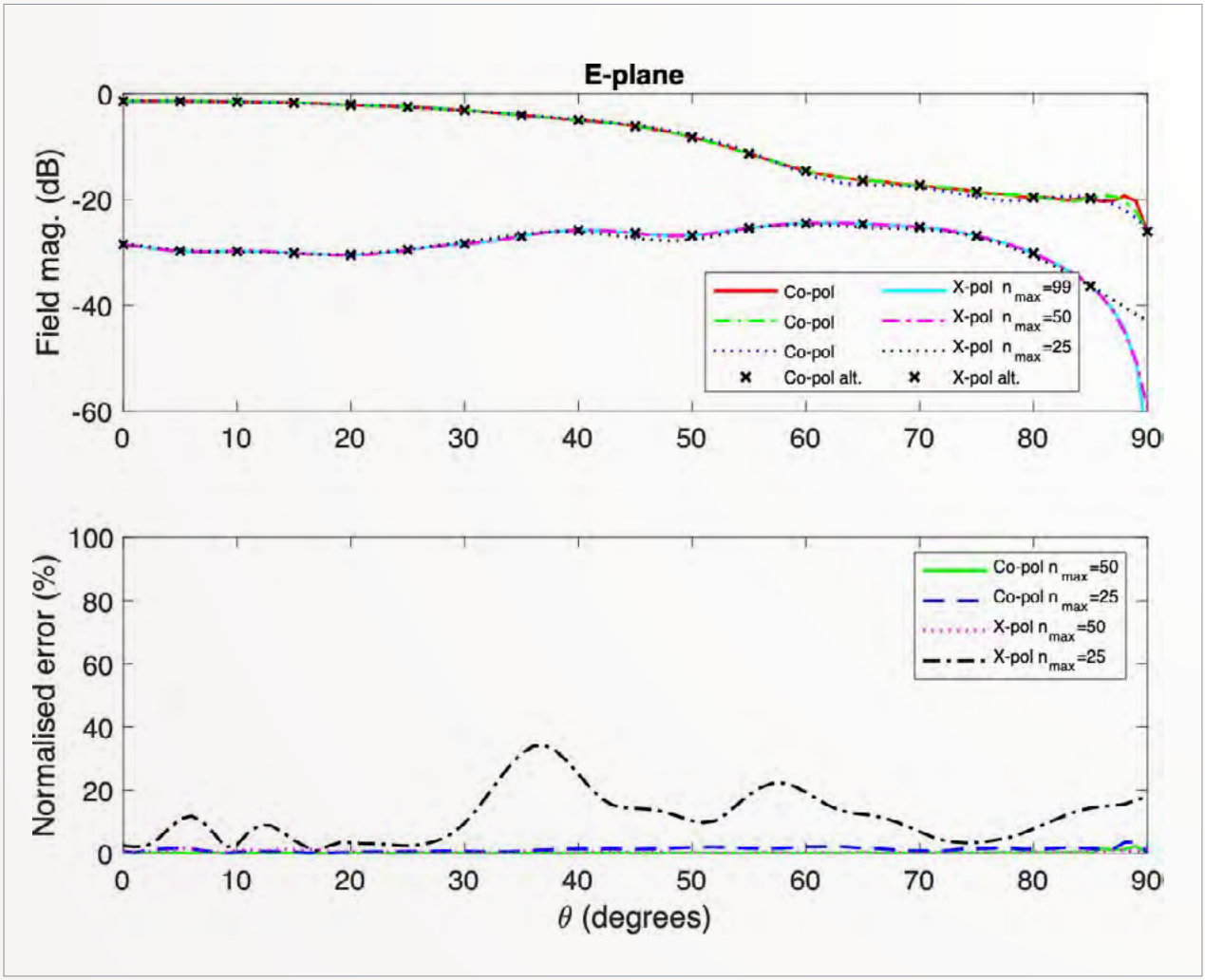
Figure 3. Michael Frazer, Iona Clement and Dale Giancono from the DFN team with the meteorite.

Efficient Storage of Embedded Element Patterns for SKA-Low

DAVID DAVIDSON
ADRIAN SUTINJO

Electromagnetic modelling of the Square Kilometre Array-Low telescope has been a major focus at CIRA throughout most of the ICRAR-III programme. This instrument, currently under construction in Western Australia, operates from 50–350 MHz, and consists of large stations made up of many closely spaced antennas. Because these antennas interact strongly, each element's response depends on its neighbours. This behaviour is captured through embedded element patterns (EEPs), which describe the angular sensitivity of each antenna across the sky. Accurate EEPs are essential for station calibration and high fidelity beamforming. CIRA has been closely involved with this work and contributed extensively to the simulation of several prototype systems.

Figure 1. The reconstructed electric fields for the EEP of antenna 1 of the AAVS3 SKA-Low prototype station. This is the E-plane pattern for the EW polarisation, dB scale; frequency: 90 MHz. Also shown is the impact of decreasing the number of modes included in the analysis. The upper figure shows field magnitude, the lower figure shows the error normalised to the co- or cross-polar field at zenith (Image: Davidson & Sutinjo, 2024)



Traditionally, EEPs are stored as finely sampled angular grids. For realistic sampling in both angle and frequency, a single station configuration can require more than half a terabyte of storage. Since each unique station layout requires its own set, reducing this burden is critical.

Spherical mode representations offer a powerful solution. By expressing the angular structure of each EEP using associated Legendre special functions, the data can be compressed by around three orders of magnitude without sacrificing accuracy. Electromagnetic tools such as FEKO already support storing fields in spherical mode form, and this approach has been used for smoother beams in earlier instruments like the MWA. However, implementing a robust general method for SKA-Low is complicated by inconsistent notation across the literature, differing normalisation conventions for associated Legendre functions, and mismatches between physics and engineering phasor sign conventions.

The work described here consolidates these disparate formulations into a consistent, self contained framework compatible with MATLAB's highly efficient implementation of Legendre functions and aligned with conventions used in computational electromagnetics. The framework also addresses practical issues such as handling derivatives, avoiding apparent singularities, and ensuring numerical stability. Validation tests confirm correctness, followed by demonstrations on a SKALA4 antenna and a full 256 element prototype station. The resulting compression—roughly a thousand fold reduction—makes spherical mode storage a compelling option for large scale arrays. Another useful feature of this approach is that, depending on the accuracy required, not all the stored modes need be used for field reconstruction (see Figure 1).

Beyond calibration, spherical modes are increasingly relevant across radio astronomy, including in simulators such as OSKAR and in m-mode imaging, which requires spherical mode representations of baseline dependent beam products. A unified and efficient formulation therefore supports not only SKA-Low calibration but a broader ecosystem of emerging analysis tools. The MATLAB code has been made available on the Curtin Research Data Collection, along with selected test cases, at https://doi.org/10.25917/n05j-th75.

RECENT PUBLICATIONS

Bolli, P, Davidson, DB, et al. 2022, "Computational electromagnetics for the SKA-Low prototype station AAVS2", *Journal of Astronomical Telescopes, Instruments, and Systems*, vol. 8, no. 1, article 011017, https://doi.org/10.1117/1.JATIS.8.1.011017.

Davidson, DB & Sutinjo, AT 2024, "Efficient storage of embedded element patterns for low-frequency radio telescopes", *Radio Science*, vol. 59, https://doi.org/10.1029/2024RS008080.

Meteoroids 2025 Conference

MICHAEL FRAZER

In July 2025, Curtin University and the Desert Fireball Network (DFN) hosted the 12th triennial Meteoroids conference. Curtin welcomed nearly 100 international researchers to discuss the full life cycle of meteoroids – covering their origins in the Solar System, their passage through the Earth's atmosphere as meteors and fireballs, and the recovery of meteorites on the ground.

The sessions on meteoroid origins explored their orbital dynamics, parent populations and physical properties across the Solar System. Topics included new models of the Near Earth Object population, association of meteors with parent bodies, targeted investigations of comets and asteroids, and predictions of future meteor showers.

Meteor sessions focused on the objects during their passage through the atmosphere, investigating their composition, physical properties, and the effect of the atmosphere on their flight. Work presented in these sessions made use of established, repurposed, and newly developed observational techniques, ranging from infrasound, seismic and hydroacoustic detections to high frame rate and event-based cameras, radar-optical comparisons, space-based lighting and nuclear-test monitoring systems, and observations of lunar impact flashes.

Recovery-focused sessions explored techniques used to identify and recover meteorites in the field. This session highlighted real-time drone-assisted meteorite recovery being developed by the DFN at Curtin University, and fireball networks from Australia, New Zealand, Morocco, France, Russia, Tajikistan, Oman, the UK and the US also presented updates on recent operations, meteorite recoveries and lessons learned.

In addition to natural meteoroids, there was also a strong focus on human-generated events, including observations of controlled (and uncontrolled) re-entries, space debris and rocket launches, and the role of the community in space situational awareness and planetary defence.

Outside of the official sessions, conversations continued over a welcome BBQ on the first night and a gala dinner among one of the world's largest meteorite collections at the WA Museum Boola Bardip. Participants also headed out for an afternoon of semi-competitive sailing on the Swan River. The LOC was also able to offer eight grants to support student travel and attendance at the conference, and presenters were also invited to submit their work to a special issue of Icarus.

Meteoroids 2025 brought the global research community together to identify gaps in the field and spark new ideas, and has already led to numerous new collaborations and projects. We look forward to the next iteration of the conference in 2028!

Figure 1. Delegates of the Meteoroids 2025 conference outside T.L. Robertson Library, Curtin.



Exercise Western Dawn

SCOTT HAYDON
ADRIAN SUTINJO
JACOB YEO

To the global scientific community, CIRA is synonymous with looking towards the stars and developing the technology required to deeply explore the early universe. Yet within the institute, the Engineering team has long been evolving new strands of innovation. By applying their expertise to complex terrestrial challenges, they are translating the high-precision techniques of radio astronomy into sovereign applications for defence and national security.

In 2025, the Translation and Impact (T&I) function identified an opportunity to guide this expertise into the spotlight by encouraging the institute's participation in Exercise Western Dawn 2025, to showcase CIRA's engineering capabilities. Delivered through a strategic partnership between the Australian Army's 13th Brigade and Curtin University, Western Dawn is a high-intensity innovation activity designed to bridge the gap between Defence, Academia and Industry.

The participating CIRA representatives were scattered across different teams comprising diverse skill sets and backgrounds to collaborate within the Academia-Industry-Defence nexus to solve complex operational problems. This required a collective commitment to a complex technical concept; diverse members had to be convinced of its value, master the narrative, and ultimately sell it to a judging panel of experts. This process highlights a core merit of the T&I activity which demands that researchers translate established theory into a compelling operational narrative.

For CIRA engineering participant Scott Haydon, the exercise arrived at a professional crossroads. His recently completed Master's thesis, which was deeply rooted in previous research funded by the Defence Science and Technology Group (DSTG), was coming to an end. While considering his career options, Scott entered Western Dawn with an open mind, viewing it as an opportunity even though it entailed an intensive exercise timeline that demanded a significant level of engagement, in addition to Scott's full-time duties as a Research Officer.

Amidst these competing demands, he developed four distinct concepts for his team to consider. These were not existing projects, but conceptual solutions inspired by CIRA's potential capability that could be realised with targeted funding. One of these options was 'Project WeakPoint', a framework derived directly from his Master's research that hit a specific Defence priority. The team unanimously rallied behind this concept, recognising it as a potential winning idea if they could successfully showcase its utility. Scott was inspired by the team's decision to back the concept derived from his personal research and felt a renewed commitment to deliver the best outcome despite his limited availability.

The result justified the intense effort. 'Project WeakPoint' secured the Excellence in Defence Innovation award, the sole prize of the exercise. Beyond the accolade, the win serves as a powerful validation of CIRA's engineering capability. It demonstrated to Defence that the Institute possesses formidable expertise to deliver sovereign capability that warrants investment, extending



Figure 1. Scott Haydon with Exercise Western Dawn 'Excellence in Defence Innovation' Award. (Image: Jacob Yeo)

well beyond the domain of radio astronomy. For Scott, this success turned a period of professional uncertainty into a clear strategy. The victory is now a strong indicator for future success as the team leverages this momentum to pursue a Defence and Research Teaming (DaRT) grant and a Collaborative Research Grant (CRG) to breathe new life into the project.

This turnaround directly challenges a common misconception in academia: that innovation activities are reserved for fully funded, mature projects. Instead, this initiative demonstrated that engaging with T&I can be a catalyst that takes established research, narrows its focus to specific real-world problems, and propels toward new funding streams.

The Western Dawn experience serves as a proof point for one of the many ways to engage in a T&I activity. It demonstrates that there is a robust pipeline from grassroots talent to national impact through Curtin University and proves that CIRA's engineering expertise has significant value beyond the stars.

Transponders for Ionospheric Measurement

JACOB YEO
ADRIAN SUTINJO

Conventional radar is limited to line-of-sight distances, in the range of tens to hundreds of kilometres—whereas over-the-horizon radar (OTHR) extends the range to thousands of kilometres. Achieving this extended range relies on reflecting high frequency (HF) radio waves (3–30 MHz) off the ionosphere, allowing operators to monitor a much wider expanse. For example, Australia's vast northern approaches are monitored by a world-class OTHR, the Jindalee Operation Radar Network (JORN).

OTHR operation is supported by infrastructure which provides real-time knowledge of the ionosphere's characteristics—an ionospheric sounder (ionosonde) measures the bottom-side ionosphere frequency reflections which informs understanding of ionospheric variability, while transponders validate radar accuracy and ranging by transmitting test targets with simulated distance and velocity achieved by a programmable delay and Doppler shift.

CIRA has expertise in understanding and measuring ionospheric effects in the context of radio astronomy. We leveraged that knowledge to embark on a US-funded contract to design and deliver Transponders for Ionospheric Measurement (TIM) —a program that aims to improve understanding of ionospheric propagation by developing and deploying a dense sensor network of TIM instrumentation, which serves as calibration infrastructure for OTHR.

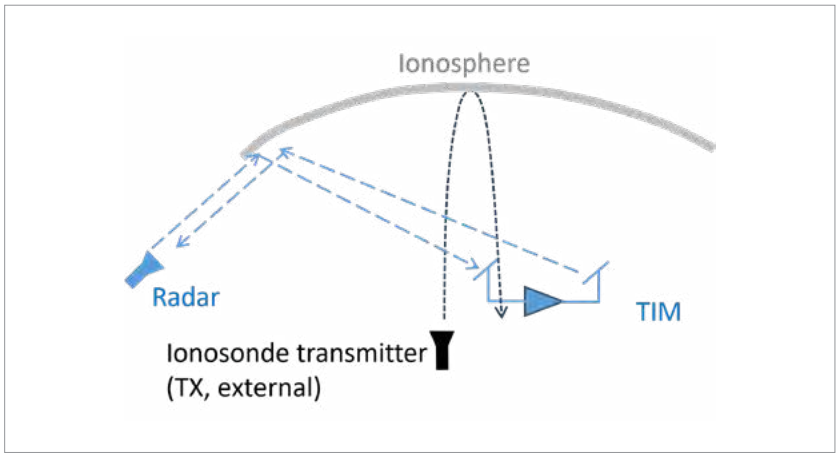


Figure 1. OTHR support infrastructure schematic. (Image: Adrian Sutinjo)

Commencing in July 2024, the team embarked on realising a design brief of a low size, weight, power and cost (SWAP-C), commercial-off-the-shelf (COTS) prototype transponder, with each team member bringing a distinct skill set to the task of developing a solution to a complex set of competing parameters.

Led by A/Prof. Adrian Sutinjo, an industry-level engineering process design framework was put in place to convert the design brief requirements into a set of unambiguous specifications with a quantifiable validation.

CIRA alumnus, Dr. Ferry Lanter, took the lead in exploring the trade-offs between transmit power, reception sensitivity and costs to develop an RF front-end and antenna solution that was COTS available, one-person deployable and low cost.

Following completion of the CIRA Graduate Intern Program, Maxwell Morris was offered a staff position on this project. Max took on the responsibility of software development, utilising a COTS Software Defined Radio (SDR) platform, selected specifically for its feature-rich industry-level development tools – features which offset its relatively high cost and allowed for rapid development.

T&I provided support across the various non-technical aspects, bringing together a diverse skill set to support the project with industry best-practice project management including navigating contract and legal obligations, procurement, budgeting, scheduling, logistics and shipping – including Defence Export Controls considerations.

As the prototype transponder design neared completion, the core team was ably supported by the CIRA Operations team – leveraging their experience over 15 years maintaining the Murchison Widefield Array to assist with the prototype transponder node mechanical and electrical design, assembly and pre-shipment testing.

2025 saw the conclusion of the nine-month program – culminating in field testing in Florida, USA.

CIRA's prototype transponder nodes (named TIM 1.0) were deployed on site alongside two other US companies who received funding under this program and put through a series of tests. We demonstrated that TIM 1.0 could successfully receive quasi-vertical and oblique soundings from up to 1600km away, transpond test targets at power levels observable by US-based radar operators, and capture ionospheric data of equivalent sensitivity and stability as results achieved by much more sophisticated and costly equipment currently used to support the same purpose. A highlight of the week-long testing was not only the accolades from the US funder, but also recognition from the other US performers on a job well done.

Following the successful performance of CIRA's TIM 1.0 nodes during field testing, a contract was secured to continue funding the program for an additional two years, commencing in June 2025. This next phase of funding aims to convert the TIM 1.0 prototypes to a scalable and fieldable solution (TIM 2.0). TIM 2.0 iterations aim to feature enhanced functionality, environmental hardening, remote operation capabilities and a solar power supply.

The increased scope of work necessitated the inclusion of additional personnel: Dr Martin Blake joined the team to provide support for RF and digital design and testing; and CIRA alumnus Dr Tyrone O'Doherty brings an astronomy-based skill set, focusing on using signal processing techniques to explore RF propagation in the ionosphere.

As 2025 draws to a close, the program is well positioned with critical design milestones being met, and assembly and integration testing of the first TIM 2.0 node underway.

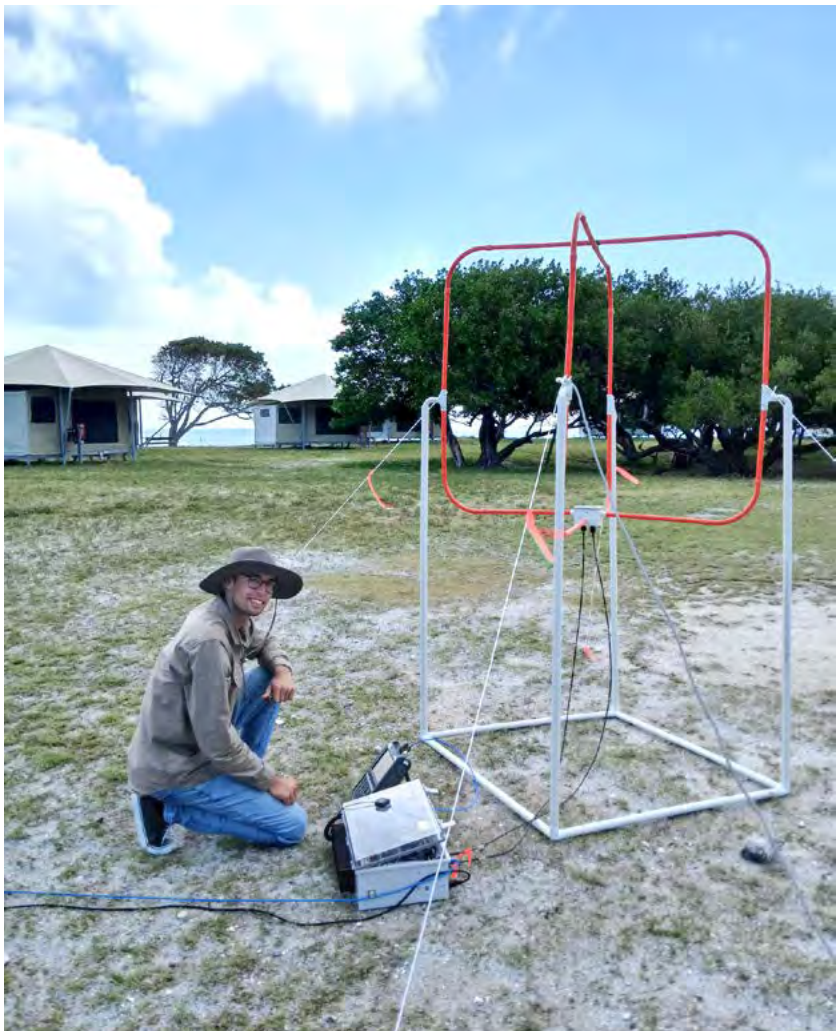


Figure 2. Ferry Lanter and TIM node. (Image: Jacob Yeo)



Figure 3. CIRA team on location, Florida, USA. L-R: Ferry Lanter, Maxwell Morris, Jacob Yeo, Adrian Sutinjo. (Image: Jacob Yeo)

The MWA's Security Odyssey

JAMIE PIERCE



Figure 1. Microsoft Copilot's interpretation of this article.

Building a safer observatory network in a noisy Universe

For much of the MWA's life, the operating principle was refreshingly direct: "just make it work." That approach delivered extraordinary science—but, like an early spacecraft design, it also meant a few "temporary" hatches were left a little too easy to open. Over the past two years, CIRA has been closing the airlocks: turning an organically grown environment into one with clearer boundaries, better visibility, and more repeatable operational discipline.

The first step was knowing what we are defending. A formal asset inventory was completed and documentation practices improved using netTerrain and maintained registers, giving us a much clearer map of the systems that keep the telescope observing. In parallel, network protection moved to CIRA-managed firewalls, with a re-architecture and segmentation under way. Importantly, the MRO site was disconnected from the CSIRO-provided network, with internet access now via Curtin and CIRA-managed firewalls.

Operationally, we introduced a predictable maintenance rhythm: telescope servers, networking equipment, and AWS compute services are now patched on a monthly patching cycle, with more frequent patching in designated test environments to reduce risk before the scheduled window. A major hardware refresh has replaced end-of-life systems across MWA infrastructure and key components, with encryption at rest used where supported, and encryption in transit in place between the MRO and Curtin, and onwards to Pawsey.

While we monitored the telescope's health via tools like Icinga, Grafana, and Observium, we lacked centralised security event monitoring. 2025 changed that: all MWA servers (physical and virtual) and firewalls were successfully onboarded into Curtin University's Microsoft Sentinel SIEM. Now, every log entry – from user login attempts to network traffic – is funnelled into a 24×7 Security Operations Centre (operated by Curtin's security partner, LevelBlue). This gives us automated threat detection, alerting, and threat-hunting capabilities.

The MWA's approach to user access also saw a stellar overhaul. Now, remote access to critical systems requires Curtin-managed credentials with multi-factor authentication (MFA) for an extra layer of verification. For the isolated telescope control network, the team eliminated password logins entirely—shutting the door on password-guessing attacks. While a fully federated identity solution for all MWA systems is still on the horizon, current practices ensure that no one gains access without proving their identity.

We are not claiming a finished destination—but the MWA has materially improved its baselines, boundaries, and operational cadence, so that unexpected events stand out less like background noise and more like a detectable transient. This journey ensures that the MWA's groundbreaking cosmic observations are protected, allowing astronomers to focus on the stars while our cyber defences handle the dark matter of cyberspace.

Microsoft Copilot was used in the production of this article. Thank you, AI overlords—I know you are listening.

‘Calvins & Hobbes’ and Replacement Servers for the MWA

GREG SLEAP

In late 2024, CIRA made an application to Curtin’s Strategic Research Infrastructure (SRI) fund to replace some of the MWA’s ageing ‘mwacache’ servers and to procure new servers to provide a near-real-time calibration pipeline in preparation for the future MWA real-time beamformer project. CIRA was awarded the funding and, with some additional funding from Astronomy Australia Limited (AAL), a procurement was carried out in a successful partnership with Curtin’s Strategic Procurement team.

The ‘mwacache’ servers reside in Curtin’s B206.206 data centre and receive the data files from new observations taken by the MWA, store them temporarily on large disk volumes, and when Pawsey is online, upload them to the MWA’s 57 PB archive. The ‘mwacache’ servers provide a vital function: ensuring that MWA observations can continue at the MRO, even if data is unable to be ingested into the Pawsey archive.

The existing ten ‘mwacache’ servers, purchased in 2017, were well out of warranty and had started to show signs of increased failure rates. The procurement, led by the MWA Operations team, selected Dell to supply ten replacement servers, each with 260 TB of usable storage. Eight of the ten servers are in use at any time (each receiving a data stream from three of the twenty-four MWA correlator servers), with two serving as ‘warm spares’.

The MWA real-time beamformer is an important future development for the MWA. The new beamformer will be mainly used for coherent tied-array beamforming which allows astronomers to make very sensitive measurements of pulsars and transients. This requires the calibration of the telescope to be completed before the beamforming operation. A ‘calibrator’ observation of a well-modelled radio source is taken, then the data is processed to produce calibration solution–the corrections needed to ensure all the antennas are synchronised in time and their power levels are corrected. These corrections will then be fed ‘just in time’ to beamformer observations as required.

The MWA Operations team selected Xenon Systems to supply seven powerful Lenovo servers, to be co-located with the MWA, and each has a powerful graphical processing unit (GPU), 1 TB of memory and fast local disk. These were named ‘Calvin’ servers, with six in regular use and one spare. Another server, named ‘Hobbes’ was provisioned in MWA’s virtual server infrastructure to serve as the job manager of the seven Calvin servers, running common job scheduling software called ‘Slurm’. Hobbes monitors the MWA schedule and, when a new calibrator observation is complete, assigns a calibration job to one of the Calvin nodes. This involves retrieving the calibrator observation’s data files, running Birli to preprocess the data, running Hyperdrive to produce a calibration solution and then inserting it into the MWA’s calibration database as well as storing the solution files on a central server called ‘Vulcan’. The future beamformer will retrieve the solution files from ‘Vulcan’ and apply them to the data stream before beamforming is performed.

In April 2025, the ‘Calvins & Hobbes’ and ‘mwacache’ servers were installed and commissioned. They are performing well. The successful funding, procurement and deployment of these servers ensure the MWA continues to provide high-quality data to the radio astronomy community and highlights the effectiveness of collaboration between CIRA, Curtin Strategic Procurement, AAL and Curtin’s Research Infrastructure office.



Figure 1. Calvins servers installed at the MRO.



Figure 2. Mwacaches servers installed at the Curtin data centre.

Electrostatic Discharge (ESD) Mitigation and Testing

CARY WINTLE
DAVE EMRICH

Today's electronic products are constructed with miniature components that are often individually quite sensitive to electrostatic discharges from various sources. As the density of features on integrated circuit silicon wafers has increased, the size of those features has shrunk, making them more susceptible to damage from ESD. Without appropriate design techniques to manage this, a product can suffer anything from temporary "glitches" in behaviour, to complete failures that may involve heat and magic smoke!

Typical real-world sources of electrostatic discharge (or ESD) include:

- Charges induced by moving thunderclouds, even in the absence of lightning
- Charges built up on people from movement over carpets, clothing brushing against plastic furniture, etc.
- Gradual build-up on metal surfaces exposed to wind in dry conditions
- Products subject to friction against insulating materials, or containing rotating belts etc.

These discharges can enter through connectors, attached cables, power supplies, or even indirectly by contact with metal parts of the outer case. They can also vary widely in the level of energy transferred to the product, and the resulting pulse shape.

It is therefore critical to design in, test, and verify mitigation measures to divert these potentially harmful discharges away from sensitive internal parts. Surge diversion/suppression devices are chosen, and carefully placed, to provide alternate pathways for discharge currents to flow and/or limit voltage transients at sensitive points within circuits.

During prototyping, the completed product should be tested to prove that these measures are effective.

International standards exist that describe standard measurement techniques and environments, so that tests conducted anywhere in the world are repeatable in any suitable laboratory. In Australia, we refer to AS/NZS IEC 61000–4–2:2025.

This standard describes the test environment and test equipment setup required to test a 'device under test' (DUT) consistently. There are several levels of discharge designed to mimic different situations to which a DUT may be subjected in normal use.

It is important to note that the standard does not prescribe the level of discharge to select or exactly how a given DUT is permitted to respond after being subjected to an ESD event. Some DUTs are allowed to 'glitch' or temporarily operate at a reduced capacity in response to the event but recover either automatically or after a 'user reset' operation or



Figure 1. Standards compliant test table and reference ground (the shiny metal on the floor).

similar. Other DUTs must continue to operate perfectly as if the discharge event never occurred. However, under no circumstances should a DUT permanently or unrecoverably change functionality after an ESD event. The exact pass/fail criteria and level of discharge are normally established by the manufacturer and communicated to the testing authority, with consideration of the device's intended operating environment and the consequences of its failure.

In the commercial world, standardised testing is usually a subcontracted product qualification step which is either 'pass' or 'fail', and any analysis of failure(s) comes at an additional cost, often requiring resources beyond the scope of a purely qualification-focused testing laboratory.

However, in a research environment, additional test capabilities such as internal probing for surge voltage/current measurements, electric-field simulations, etc., can be used to ascertain why a product responds poorly to a given ESD event and inform design options to suitably “harden” the product.

CIRA has developed both a measurement and analysis capability in this space as a result of work on the TIMS project, which will see battery-powered products operating unattended in potentially remote outdoor locations, subject to various sources of ESD including nearby lightning strikes.

Our first step was to establish a standards-compliant testing setup, required to verify a product against the simple pass/fail criteria above. This was initially done by hiring a standard-compliant ESD simulator and developing suitable working areas and procedures to conduct standard tests.

We have also produced a high-voltage / high-speed attenuator system designed so that the actual pulse shape and amplitude can be directly measured from the ESD simulator probe tip using a typical lab oscilloscope. This can be used to verify that the simulator remains in calibration. This attenuator also permits measurement of the shape and amplitude of any remnant pulse on the other side of ESD protection circuitry, to assess whether remnant pulses fall within the input capabilities of the next component in line.

Lastly, we are constructing a standards-compliant ESD target which gives a second means of verification of the pulse shape and energy delivered by the ESD simulator.

With these capabilities and instrumentation CIRA can now test any of the devices we design in a repeatable way to determine how they perform in harsh electrostatic environments to which they may be subjected.



Figure 2. Close up of the ESD simulator operator's screen.

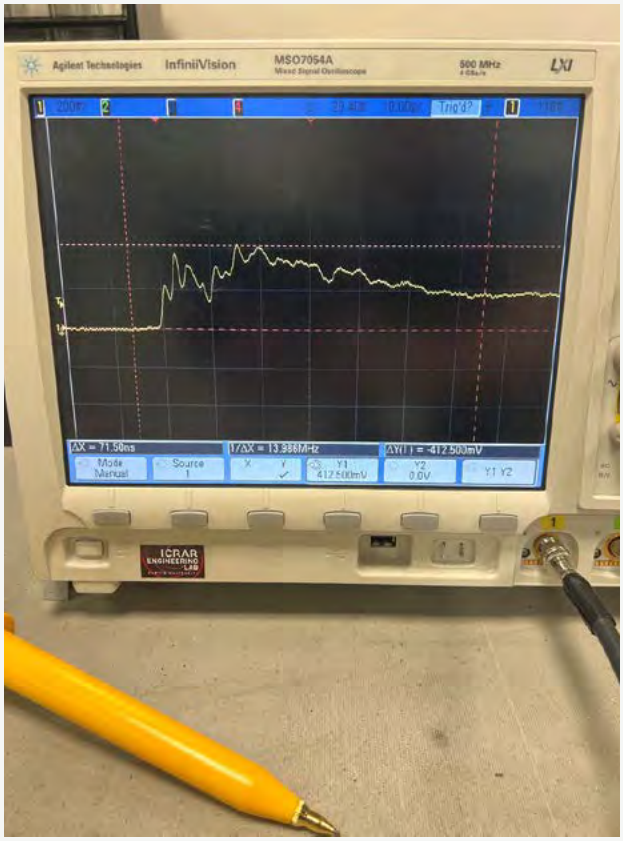
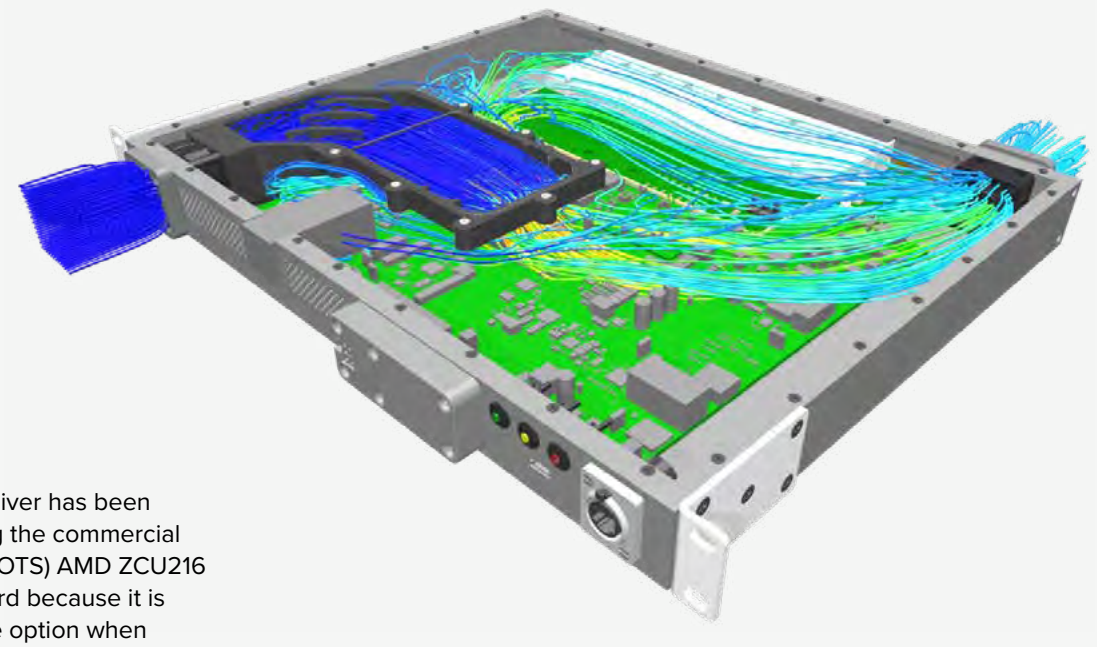


Figure 3. Example of a remnant pulse after ESD mitigation.

Going with the Flow

LUKE VERDUYN



The CIRA Receiver has been designed using the commercial off-the-shelf (COTS) AMD ZCU216 evaluation board because it is a cost-effective option when compared to existing hardware.

The evaluation board is supplied with a heatsink on the radio frequency System-on-chip integrated circuit (RFSoC) and a 50 mm × 10 mm fan mounted to top of the heatsink.

The primary challenge involved routing cooling air from the front panel to a centrally located heatsink within highly constrained internal volume. Through iterative CAD design and Computational Fluid Dynamics (CFD) analysis, the final cooling solution was developed to manage a 100 W thermal load, successfully reducing peak component temperatures from 73°C to 56°C under worst-case ambient conditions.



↗ **Figure 1.** View of the fan on the heatsink.

The 1 U form factor (44.45 mm height) presents a significant challenge to manage airflow. To maximize efficiency, a dedicated duct was designed to bridge the gap between the front intake and the primary heat source.

To ensure computational efficiency and mesh stability, the following steps were taken:

- Model Simplification: Non-critical PCB components were suppressed to reduce the overall mesh count while maintaining the primary flow path.
- Domain Extension: The air volume was modelled beyond the front and rear exhaust vents. This allows for a fully developed flow profile, ensuring that back-pressure calculations at the fan interface are physically accurate.

The first phase of simulation focused purely on fluid dynamics. Various duct geometries were tested to minimize static pressure losses. For each duct iteration, the fan operating points defined the actual flow rate and static pressure that the fans could achieve within the duct geometry.

Once the operating points were established and the flow parameters determined, thermal boundary conditions were applied to the model.

Ambient temperature: 32°C (Simulating a worst-case field cabinet environment).

Thermal Load: 100W constant dissipation on the primary chip.

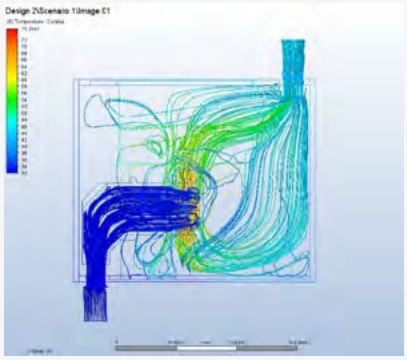
Max chip temperature: 85°C (Maximum working temperature).

The simulation compared two distinct fan configurations to evaluate their impact on the 100W load:

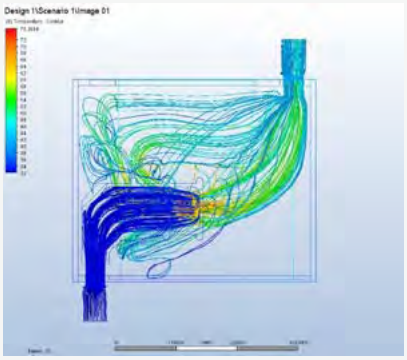
- 20 mm fan configuration: Using a standard axial fan, the chip reached 73°C. While this is below the 85°C limit, the 12°C margin was deemed insufficient for long-term reliability.
- 28 mm deep fan configuration: A higher-flow rate axial fan was integrated with the refined duct shape. This increased the mass flow rate across the heatsink fins, dropping the peak temperature to 56°C.

After we purchased two boards, we found that the heatsinks were rotated 90 degrees out from each other. The variation in temperature and static pressure between the two heatsinks is negligible. This is because the duct directs the air to the top of the heatsink where it is forced downwards.

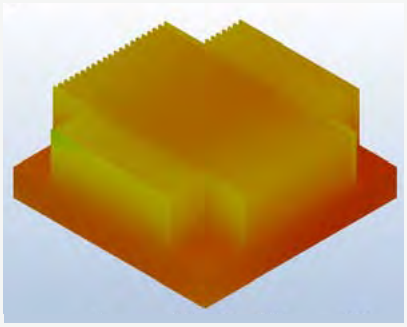
To address space constraints in a 1U enclosure, a custom duct was developed to channel air from the front panel to a 100W chip. Through CFD iterations and fan curve analysis, an optimized high-flow fan configuration was selected. This reduced peak operating temperatures from 73°C to 56°C, ensuring a robust safety margin.



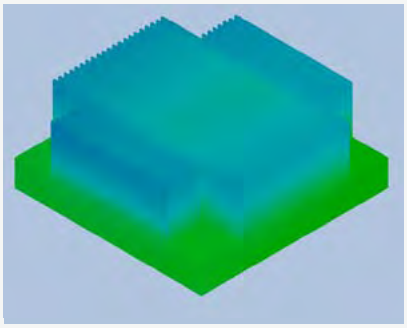
↗ **Figure 2.** Flow with heatsink parallel to fan.



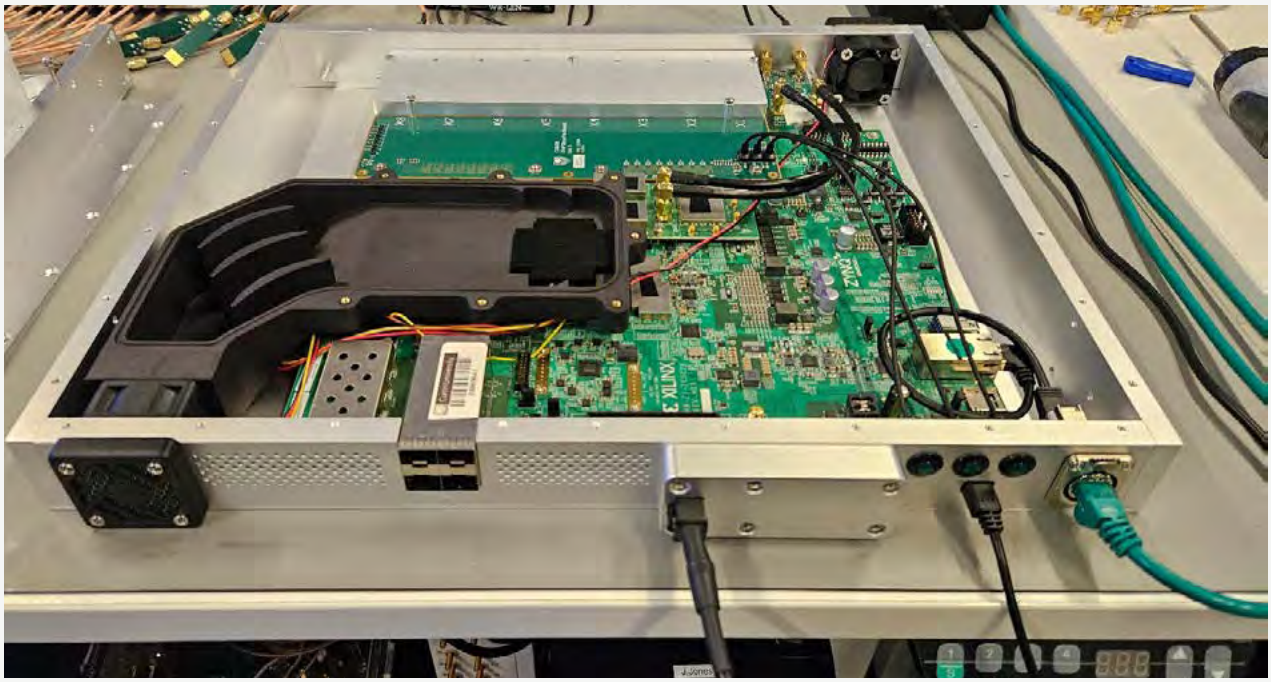
↗ **Figure 3.** Flow with heatsink perpendicular to fan.



↗ **Figure 4.** Heatsink and chip with 20mm fan. Temperature gradient of 32°C to 80°C.



↗ **Figure 5.** Heatsink and chip with 28 mm fan. Temperature gradient of 32°C to 80°C.



↗ **Figure 6.** Assembled CIRA receiver ready to be tested.

CIRA's New Outdoor Test Environment

VENUS CHICO
RUVINDU KALUARACHCHI

Over the past year, CIRA commissioned a purpose-built outdoor testing facility. The development was a joint project between CIRA and Curtin University Properties. The outdoor test facility will support the conduct of engineering research by providing a secure 24-hour outdoor test location. This facility enables fully remote outdoor testing and control of physical devices, giving researchers and students the flexibility to experiment, iterate, and collect data.

Located north of Building 610, the testing facility can be reached from the building's northeast exit near the bike shelter. Alternatively, it can be accessed via Brodie Hall Drive through the adjacent building's parking area. The facility sits on an elevated location, and both the perimeter fence and control enclosure are locked for security. Keys are maintained by the laboratory officers.

The outdoor test environment brings together remote network access, network-controlled power, reliable secure connectivity, and physical protection in a single, real-world deployment space. Students and researchers can install hardware on site, then manage, monitor, and modify their systems remotely over extended periods without needing to travel to the facility. This is especially valuable for academic projects, collaborative research teams, and time-sensitive experiments.

Outdoor Testing System Design and Setup

Each hosted device has full network connectivity via a DTSmanaged switch, allowing authorised users to log in remotely and access their systems as if they were physically present. By making the network the primary interface for control, the facility enables all project users to collaborate from any location.

A defining feature of the environment is its network-controlled power management. Users can remotely power devices on or off, perform controlled reboots, and manage charging cycles without manual intervention using the Power Distribution Unit (PDU) component of the outdoor testing system. For research projects and experiments, this capability enables convenient testing of boot processes, failure recovery, energy consumption, and long-term system reliability. Devices can operate continuously for days, supporting data collection while minimising downtime.

Unlike indoor labs, the outdoor facility exposes devices to real environmental conditions, including temperature changes, weather, and ambient interference. This makes it ideal for students and researchers developing telecommunications equipment, sensors, antennas, and other technologies intended for real-world outdoor deployment. Experiments can move beyond simulation and into practical, field-based validation.



Figure 1. The new CIRA outdoor testing facility.



Figure 2. (1) Secured protective enclosure housing the network switch and PDU. (2) The enclosure contains racks for the network switch, PDU, and other electronics. (3) Fibre patch module with blue inbound fibre and yellow patch leading to the switch. (4) Mains power distribution box feeding the cabinet outlets.

Security is built into both the physical and digital layers of the environment. A secured perimeter, reinforced fencing, and a locked network cabinet protect equipment from unauthorised access or disruption. On the network side, authentication and Curtin DTS monitoring ensure that only authorised users can access devices, preserving the integrity of experiments and research data.

The combined capabilities of CIRA's outdoor test environment provide a reliable platform for experimentation and development. Looking ahead, CIRA plans to install a weather station at the facility to monitor environmental conditions. The outdoor testing facility will support this project while enabling further research and testing in the future.



Figure 3. Power Delivery Unit (PDU) inside the enclosure.



Figure 4. Antenna installed within the outdoor test environment.

A Showcase of the CIRA Operations Team's Evolving Capacity to Produce Bespoke Hardware

PHILLIP GIERSCH
JAKE JONES

In recent years, the CIRA Operations team have contributed to several major projects, providing technical and operational expertise in addition to developing bespoke hardware solutions. Over time the team has evolved and developed new capabilities that we'd like to showcase in this article through our recent development of the MWA Tile Tester. Collectively, we have a wide range of skills and capabilities including:

- Printed Circuit Board (PCB) design and layout
- Analog RF electronic design
- Digital electronics & embedded system design
- Software development
- FPGA firmware development
- Mechanical design & manufacture
- Signal processing
- Networking infrastructure
- Logistics



Figure 1. The MWA Tile Tester.

The MWA Tile Tester

In 2025, the operations team was tasked with rapidly developing a new piece of portable test equipment for the MWA called the MWA Tile Tester with the purpose of testing and identifying faults in both the analog beamformer and individual dipoles within an MWA Tile; while the technician is physically located at the Tile. The overall goal was to design a device that could provide the following key functions:

- Test and validate a beamformer by supplying power, measuring current, sending pointing commands and measuring the resulting RF spectrum.
- Test and validate an MWA dipole by supplying power, measuring the current and measuring the resulting RF spectrum.
- Test and validate RFoF Tiles by measuring the RF spectrum that is transmitted over an RFoF fiber.

In addition to these core features, the device had the following practical requirements:

- Have sufficiently low radiated EMI as to not to interfere with our own measurement of the spectrum.
- Be powered by off-the-shelf Dewalt 18V power-tool batteries as these are widely used at the MWA.
- Have both copper and fibre Ethernet interfaces that enable network communications while located at the remote long baseline tiles.
- Have a sufficiently bright display that is readable in bright daylight.
- Be user friendly such that it could be used by contractors and laypeople.

Building on existing knowledge and experience

The operations team have been building bespoke radio astronomy hardware for several years at this point and some past projects have a significant functional overlap with the Tile Tester project. The previous knowledge and experience obtained from these projects was invaluable for the rapid development of the Tile Tester.

For example:

- The front-end RF module was based on previous Analogue Signal Conditioner designs used in the MWA receivers, resulting in a very rapid turnaround for this module.
- The re-use of circuit designs used in the MWA long baseline RFoF tiles, once again allowed for very rapid development time of this RF circuitry.
- The EMC compliant design principles learned as part of our involvement in the SKA Power and Signal Distribution and the development of the new MWA Phase III receiver cabinets also allowed us to meet the EMC requirements with little to no extra design revisions.
- Additionally, our extensive experience developing Raspberry Pi based monitoring and control systems made for the relatively seamless and rapid development of the control system.

Hardware Development

The final design of the Tile Tester consists of a portable briefcase design with several internal components, both custom and off-the-shelf. Some of the off-the-shelf components selected for this design include:

- External low-noise E-Ink panel for displaying data during test sequences while the briefcase lid is closed.
- Internal OLED Touch screen display embedded in the lid of the briefcase.
- Step-up power supply for converting the 18V power supplied from the DeWalt batteries to the 48V required to power and test a beamformer.
- USB to Gigabit optical Fiber media converter for connecting into the on-site network.
- Two RF-Explorer spectrum analysers which form the basis of our signal analysis system.

Battery control and integration

Hardware designed by Cary Wintle. This system allows for continuous operation and battery hot swapping. It is capable or supplying power to a full MWA Tile, communicating with the internal battery monitoring system, tracking discharge and preventing the Dewalt batteries from fully self-discharging. It also provides sufficient 5V power to run all the other systems in the enclosure.

Analogue Interface PCB

Hardware designed by Dave Emrich, Jake Jones, Cary Wintle. The Analogue front end supports testing of an entire Beamformer, a single Dipole-antenna, and Astron Optical Module enabled subsystems. Software automatically adjusts input levels to fit the input range of the RF Explorer devices.

Main Board PCB

Hardware Designed by Phillip Giersch. This is the first time that the CM5 (the industrial variant of the Raspberry-Pi 5) has been integrated into a CIRA Operations Team Project. This module allows for much more flexibility in the design with fewer cables, more parts built into the PCB, and improved part layout and positioning than would otherwise be possible with the standard Raspberry Pi. It also allowed for the integration of fully switchable USB ports as well as a wide range of input/output options.

Control and Signal Processing

Software/system design by Jake Jones. The software has the responsibility for integrating multiple disparate devices using multiple different API interfaces and busses from USB, RS232, SPI, I2C to the Raspberry Pi's onboard GPIO that are required to make this device function. Packaging this all into an easily usable and intuitive Graphical User Interface that anyone could use to troubleshoot faults with minimal training is a testament to the skills available.

Mechanical Design and Construction

With our in-house Mechanical Engineer Luke Verduyn able to build EMC tight enclosures around both off the shelf components that were never intended to be integrated into a design, as well as providing guidance and multiple options to the team on shape and mechanical properties that fed into the PCB design process and a consistent simulation and advanced CAD focused approach allowed for a rapid design iteration and the finding of issues early in the process.

With the hard work of the CIRA Operations Team, we were able to get a low-volume design available for testing and ready for production in a very compact time schedule with four Tile Testers now ready to support the expanded operations of the now 256 Tile MWA.

Western Australia is at the Unique Intersection of Radio Astronomy and Translatable Defence Capability

STEVEN TINGAY
ELEANOR SANSOM

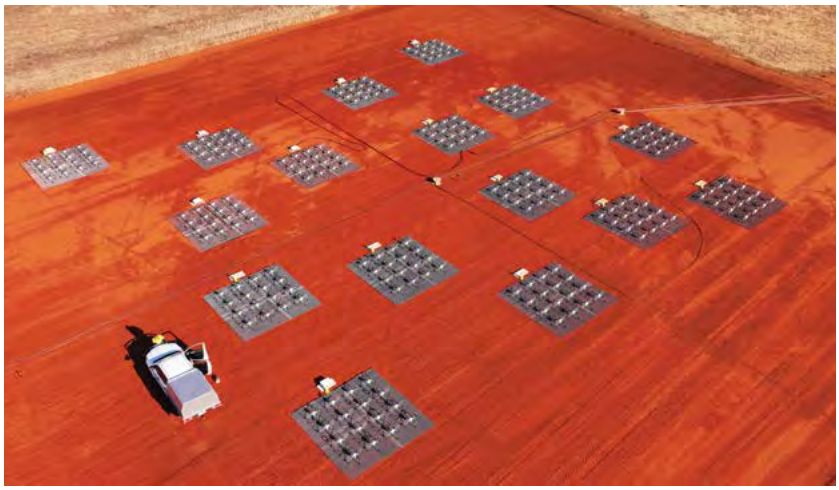


Figure 1. In partnership with Australian company Nova Systems, ICRAR-Curtin has established a multi-function Space Situational Awareness (SSA) facility at Nova's Space Precinct near Peterborough in South Australia. An array of passive radar nodes creates a 24/7, all-sky system to measure transmissions from Resident Space Objects, as well as space weather. Source: ICRAR-Curtin. Supplied.

Radio astronomy is a curiosity-led, fundamental science that seeks to understand our universe and its constitution over its 13.8-billion-year history. It is a challenge that requires radio telescopes of massive scale and high performance to be realised with modest budgets that, in turn, drive innovation and efficiency. At the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR–Curtin), we translate the technologies and techniques of radio astronomy to harness these innovation benefits for immediate practical impact in other sectors.

Transferable Experience

One such sector is Defence, a sector heavily reliant on radio frequency technologies, including communications and surveillance, and the emergence of space as an important new contested domain. The ICRAR–Curtin team has translated its experience in transforming low-cost, commercial off-the-shelf technologies into high-performance systems for a range of defence applications of relevance to the space domain.



Figure 2. ICRAR researchers from its Curtin University node have developed low-cost passive radar antennas, which can detect satellites, aircraft and space junk. Passive radar uses third-party transmissions such as broadcast radio and TV signals to locate objects, without revealing its own existence. Source: ICRAR–Curtin. Supplied.

The transition between the Earth's atmosphere and space is the ionosphere, the uppermost layer of the Earth's atmosphere that is bombarded by radiation from the Sun. The ionosphere experiences space weather, which impacts radio frequency communications and GPS measurements, and can drag satellites out of orbit.

ICRAR-Curtin, supported by two rounds of U.S. Defense Advanced Research Projects Agency (DARPA) funding, has developed and demonstrated an integrated ionospheric sounding and characterisation system, based on a commercial-off-the-shelf Software Defined Radio platform and ICRAR–Curtin's deep experience in the design of low-cost performant antennas and signal processing algorithms.

Our approach to this program of work aims to lower the price point of such systems by up to a factor of 100, allowing cost-effective, at-scale, wide-area deployments of hundreds or thousands of devices to characterise the ionosphere in support of Over-The-Horizon Radar (OTHR) facilities, such as the Jindalee Operational Radar Network (JORN). The development of this system continues, with scaled production scheduled to commence this year.

Space Domain Awareness

Beyond the ionosphere, the orbital domain is rapidly becoming congested and contested, with tracking and pattern-of-life characterisation of Resident Space Objects (RSOs) increasingly important. ICRAR–Curtin, in a

commercially focused partnership with Australian company Nova Systems, has established a dedicated multi-function Space Situational Awareness (SSA) facility at Nova's Space Precinct near Peterborough, in South Australia.

Inspired by Curtin's leadership of the Murchison Widefield Array (MWA) project, the SSA facility adapts MWA technologies and radio astronomy data processing techniques to realise a 24/7, all-weather, all-sky system capable of passive radar measurements of RSOs, passive radio frequency measurements (measurements of direct transmissions from RSOs), and space weather measurements for both the ionosphere and the huge volume between the Earth and the Sun.

The ICRAR–Curtin team, also drawing on its leadership of the Desert Fireball Network (which uses optical cameras to detect objects entering the Earth's atmosphere from space), is bringing together optical and radio sensors and data-fusion techniques at the Nova Space Precinct.

The synthesis and joint analysis of data from optical and radio sensors offer new dimensions for SSA, in particular to support the detection and characterisation of re-entry events. With ever more objects in space, the frequency of objects falling back to Earth and potentially threatening populated areas is also rising. Large-area, passive surveys like ours are, therefore, also ideal for capturing uncontrolled and unplanned events.

In all cases, the capabilities described here generate massive volumes of information-rich data, requiring secure and reliable large-scale, high-performance computing and advanced data processing algorithms, again drawing upon parallels from radio astronomy techniques. Our Western Australian industry partners, such as DUG Technology, play an important role in this regard.

These three brief examples illustrate the rich crossover between the pursuit of fundamental science and translation into high-value practical applications.



Figure 3. Field testing of prototypes, such as this ionospheric sounding transponder system, provides real-time data about the ionospheric layers of the Earth's upper atmosphere. Source: ICRAR-Curtin. Supplied.

Western Australia is at the unique intersection of radio astronomy, with the multi-billion-dollar Square Kilometre Array under construction, and several areas of translatable defence capability, including space. The long-standing WA Government support of ICRAR has fostered this multi-dimensional work.

Figure 4. Established in 2005, Curtin University's Desert Fireball Network (DFN) is an inter-disciplinary research group studying meteorites and fireballs and their pre-Earth orbits. DFN camera systems are deployed across the Nullarbor and have been installed at the Nova Space precinct, bringing together both optical and radio sensors. Source: ICRAR-Curtin. Supplied.



Translation & Impact Events

EMMALINE YEASLEY

2025 marked a significant transition for CIRA with the commencement of ICRAR IV. The Translation and Impact (T&I) team played a key role in supporting this shift, helping to embed a renewed focus on translation and impact through externally engaged activities across CIRA and ICRAR. This included the delivery of a dedicated workshop at **'ICRARcon'**, which introduced the new KPIs and facilitated constructive discussion on strategies for achieving these objectives.

A core function of the T&I team is to support grant applications, awards, and submissions for both external and Curtin funding initiatives. In 2025, the team supported more than ten applications spanning **international collaborations, creative projects, fellowships, staff awards, and industry-led initiatives**. The team also contributed to early-stage **navigation of international contracting and strategic planning for prospective projects and partnerships in the Singapore region**.

The following section highlights a selection of more outward-facing activities delivered or enabled by the T&I team during the year.



Undergraduate Engineering and Physics Scholarship recipients L-R: Sophie Tse, Tehya Conroy, Natalie Langford.

WOMEN AND NON-BINARY UNDERGRADUATE SCHOLARSHIPS

This scholarship initiative aimed to support pathways into astronomy and advance gender diversity at CIRA by providing financial assistance and community support to female and non-binary students. Funded by the ICRAR-Curtin Science and Engineering teams, the Astrophysics and Electrical Engineering Scholarships were awarded to Sophie Tse, Tehya Conroy, and Natalie Langford in recognition of their academic excellence and leadership potential. Natalie has since commenced a HDR at CIRA.



NEW CIRA WEBSITE LIVE

With months of quiet behind-the-scenes work, CIRA's website underwent a transformation that would enable it to better connect with relevant audiences and act as a portal to engagement. Kirsty Snadden worked through content and page navigation and liaised with marketing teams and DTS to support the successful launch of the new site. You can take a look here https://research.curtin.edu.au/cira/



GLEAM X Scarf as worn by Silvia Mantovanini. (GLEAM X image: Silvia Mantovanini, Natasha Hurley-Walker, Kat Ross, Stefan Duchesne, Gemma Anderson, and Tim Galvin)

GLEAM-X SCARF

The GLEAM-X scarf was officially launched at the MWA project meeting (August 2025), marking the start of an exciting merchandise initiative that celebrates CIRA's connection to the radio sky. The T&I team handled the administration of this initiative, navigating bulk ordering, pricing, and initial sales, enabling impact into the wider community. The GLEAM-X scarf can now be found on the Guild website.

EXERCISE WESTERN DAWN

The T&I team provided support for CIRA staff participation in Exercise Western Dawn (EWD) by Scott Haydon, Dr Martin Blake, and Maxwell Morris. EWD provided an opportunity to showcase CIRA's engineering capabilities and for engagement with WA defence industry, leading to new projects being scoped with new clients. Scott and Jacob's article on page 55 provides a more detailed account of EWD and Scott's team's winning pitch!

IAES INTERNSHIP

As part of our engagement with the IAES program, we welcome returning IAES alumni who are looking for additional hands-on experience in the radio astronomy field. Caleb Langan, a former IAES participant and current undergraduate student at the University of Melbourne, undertook an internship at CIRA focused on this pathway.

Caleb's internship project was primarily supervised by Arash Bahramian, Andrew Williams, and Dev Null and aimed to prototype a machine learning (or other novel) approach to analysing the calibration and health data, and identifying faults with the telescope in near real-time. The faults can then be provided to the MWA Operations and Fieldwork teams to rapidly diagnose and repair any faults, improving data quality for all researchers using data from the MWA telescope.



TAFE ENGAGEMENT

This year we initiated relationships with local TAFEs to explore pipelines for students into radio astronomy domains and areas for staff development.

We facilitated a staff exchange with North Metro TAFE for one of their senior programming lecturer within their Artificial Intelligence and Computing domain (see the AusSRC highlights for more information). This has opened future collaborations with North Metro TAFE and provided insights into their industry links and applications.

Towards the end of the year we invited engineering students from South Metro TAFE for a Lab tour to demonstrate how the skills they are learning translate into radio astronomy research.

INDIGENOUS AUSTRALIAN ENGINEERING SCHOOL (IAES)

Curtin University partners with Engineering Aid Australia to run the Indigenous Australian Engineering School (IAES) program, which seeks to provide First Nations youth with increased education and career opportunities in engineering and technology. As a sponsor of the IAES program, ICRAR-Curtin hosted the students for an afternoon, demonstrating astronomy engineering. The students' visit to CIRA included presentations by Maxwell Morris and Kristen Dage and our popular dipole-building competition that got the students racing against the clock to build their own MWA dipole.

IAES visit to CIRA.



PROJECT HIGHLIGHT – TRANSPONDERS FOR IONOSPHERIC MEASUREMENT (TIM)

Jacob Yeo

The TIM project exemplifies a clear translation of the mature RF engineering skillset developed over many years at CIRA in service of radio astronomy and its application into a real-world domain.

Demonstrating this capability has enabled a number of key engagements including US government and respected research groups (DSTG, ONR) which T&I are fostering to explore opportunities beyond the funded program.

The field testing offered a unique opportunity for our research engineers to perform alongside two professional US engineering teams – to say we performed admirably would be an understatement!

We can comfortably say T&I was the cornerstone of the non-academic elements of this project. With Aoife's contract/legal review, and shepherding through Research Office, Kirsty's input into Risk management, Defence Export Control administration, and Jacob's Project Management, budgeting, and supplier negotiations. For a detailed walkthrough and technical background of the TIM project, see pages 56-57.

MWA PHASE PROJECT MEETING AND PHASE III LAUNCH 2025



The team with Zaneta Mascarenhas MP.

The T&I team supported the planning, organisation and delivery of the annual MWA Project Meeting and the Phase III Launch Event in August.

Our involvement was primarily in the minute-by-minute planning and delivery of these events, as well as VIP invitations, responses, and providing tailored briefing notes to VIPs.

T&I at the Australian SKA Regional Centre

COURTNEY CARR (Industry and External Engagement Lead for the AusSRC)



Conversations at the AusSRC Meetup.

AUSSRC COLLABORATORS MEET-UP

In May, we hosted guests from CSIRO, the Pawsey Supercomputing Research Centre, and both the UWA and Curtin nodes of ICRAR, for a collaborators meet-up. Participants heard updates on AusSRC's software development projects and T&I activities and had the opportunity to explore the diverse capabilities across the AusSRC collaborator ecosystem and discuss crossovers and mutual interests.

AUSSRC INDUSTRY ENGAGEMENT

In 2025, the T&I focus was on establishing relationships outside astronomy and exploring diverse opportunities for translation. This included connecting with Perth-based healthcare providers to explore the link between remote patient monitoring and radio astronomy. The team also developed proof-of-concept initiatives with key players in the astro-tourism sector to use astronomical concepts for improving community wellbeing and mental health outcomes (in discussion with local councils and support service providers). We also built relationships with the Australian Research Data Commons and Research Data Alliance (RDA) and discussed possible synergies between the international data sharing platforms that RDA uses for sectors such as agriculture and ecology and the SRCs.

We engaged with global leaders in collaboration, by participating in both the international University Industry Innovation Network (UIIN) conference and the UIIN Forum in Perth. Taking learnings from across Europe, the United States, and Asia around the value of cluster models and innovation hubs, market-driven research collaboration best practices, and strategies for fostering entrepreneurial mindsets, measuring impact, and strengthening governance in collaborative projects. From networking with fellow UIIN participants, a relationship was developed with local bushfire research organisations and the link between time-series analysis expertise in radio astronomy and fire science is now being explored.

Locally, other multidisciplinary engagement activities included participating in the Machine Learning in Earth Science think tank event, the IAU 399: Indigenous Astronomy in the Space Age symposium, and the Australian Computer Society (ACS) WA Tech summit.



STAFF EXCHANGE WITH NORTH METROPOLITAN TAFE

In April, we hosted North Metropolitan TAFE advanced programming lecturer, Rafael Avigad, for a staff exchange. Rafael spent 10 weeks working with the AusSRC Software Development team at CIRA on a project focused on compute memory optimisation and benchmarking.

As a result of their time with AusSRC, Rafael reported gaining fresh insights, strengthened technical skills in areas such as command line and containerisation, and being inspired to explore integrating new languages such as Rust into future curricula. In turn, the AusSRC team benefited from Rafael's up-to-date industry expertise. The Software Development Team was able to explore new programming best practices in areas such as dependency management and object-oriented design, as well as produce benchmarking results comparing Rust and Python programming languages. These results are now informing future memory optimisation projects.

"It was an absolute honour to spend a couple of months at the Curtin Institute of Radio Astronomy. The subject matter is incredible and getting to see early glimpses of new visions of the universe and the galaxy — WOW!" Rafael Avigad, North Metropolitan TAFE senior programming lecturer

CIRA Teaching 2025

DAVID DAVIDSON
JAMES MILLER-JONES

Our staff taught into multiple areas across the School of Electrical Engineering, Computing and Mathematical Sciences (EECMS) in 2025, with CIRA staff engaged in 19 different undergraduate units. These had a **combined total enrolment of almost eight hundred students**. While most of our effort has traditionally gone into the delivery of units in the Physics & Astronomy and Electrical Engineering (EE) disciplines (the latter also delivered at two of Curtin's offshore campuses), CIRA staff also have a teaching footprint in the Mathematics & Statistics discipline. With the new Space Domain Awareness and Planetary Defence project in the Engineering program including staff from the School of Earth and Planetary Sciences (EPS), we are now also teaching into units delivered by the Faculty of Science and Engineering, as well as assisting with EPS units.

In 2025, the following staff acted as unit coordinators in addition to their roles in teaching delivery: Ramesh Bhat, David Davidson, Natasha Hurley-Walker, James Miller-Jones, Maria Kovaleva, Adrian Sutinjo, Nick Seymour, and Jishnu Thekkeppattu; and the following taught into various units in 2025: Gemma Anderson, Arash Bahramian, Kristen Dage, Hadrien Devillepoix, Adelle Goodwin, Scott Haydon, Natasha Hurley-Walker, Clancy James, Bradley Meyers, Kat Ross, Sam McSweeney, and Ellie Sansom. **In addition, a number of our HDR students acted as teaching assistants.** Several guest lecturers, including SKAO staff, who also contributed to the delivery.

Beyond our delivery of coursework units, our staff supervised multiple student projects over the course of the year, from summer projects to third-year (7) and Honours (5) projects in the Physics major, as well as final-year and taught Master's engineering projects (9).

2025 saw a major accreditation visit from Engineers Australia (EA) as part of the regular five-year cycle. The accreditation team reviewed all the engineering majors at the undergraduate level. This included working through samples of teaching material and evaluation products (exams, major assignments, etc.) and conducting extensive interviews with staff and students. The process was primarily driven by the Faculty, but required regular input from staff, especially in engineering. EA made a number of recommendations and commendations following the visit.

It has been great to see CIRA engaging more broadly across the faculty, leveraging new opportunities, building new collaborations, and exposing new groups of talented students to the exciting work that we do.

The strength of our undergraduate teaching programs directly impacts HDR enrolments, with high-quality teaching both inspiring students to continue their engagement with CIRA and giving them the fundamental knowledge to underpin their future research work.

The strong and highly competitive RTP cohorts of the past few years attest to the excellent work which our staff continue to do in the teaching space.

Stronger Together WA for Women in STEM

Creating Space to Belong through Mentorship

ZSA ZSA KARTIKA

On one afternoon at the CIRA campus, a group of students gathered around a table scattered with neon Post-it® notes. Each note bears short, yet honest words that carry heavy emotion: “unheard.” “unsafe.” “ideas dismissed.” These are the feelings many young women and gender-diverse students carry with them into their academic journey in STEM.

This exercise is part of the Stronger Together STEM mentorship program. It represents a vulnerable yet hopeful moment, and a step toward empowering participants of all genders and backgrounds to take ownership of their journeys in STEM.

An Initiative to Build Confidence and a Sense of Belonging

Stronger Together: Women in STEM is a longitudinal mentorship and professional development initiative created to empower women+ (or anyone who identifies as a woman, including transgender, non-binary, and gender-diverse individuals) in their academic journey in STEM. Initiated by Dr. Kristen Dage and supported by CIRA and the Department of Communities WA, the program is a collaborative effort made possible by the passion and dedication of Dr. Susmita Sett, Dr. Kat Ross, and the Translation & Impact (T&I) team.



Figure 1. Second workshop—Building confidence in STEM Career.

Its core vision is simple yet essential for the communities: to help underrepresented students build confidence in themselves and form genuine connections with peers and mentors. The program connects students across universities in Perth with experienced mentors, women leaders, and allies in various fields in STEM, such as engineering, IT, and life sciences.

Stronger Together offers a layered structure of support: curated mentor-mentee pairings, group mentoring circles, and a series of skill-building workshops open to all participants. In practice, this meant that over the course of the year, students are encouraged to meet regularly with an assigned mentor for personal guidance and gather in workshops and networking sessions with the entire cohort.

Workshops Tackling Challenges from Impostor Syndrome to Career Clarity

Our very first workshop talked about Impostor Syndrome, a syndrome that is dangerously more common and closer to us than we realised. In that workshop, our very own Dr. Kat Ross, as the key speaker, openly discussed the nagging feeling that she was not “smart enough” or did not truly belong, despite frequent evidence showing otherwise. Together, the participants were then divided into groups to get to know each other and brainstorm strategies to quiet their inner critics. By the session’s end, mentors and mentees discovered that they shared the same secret anxieties and could also share the tools to overcome them.

The second workshop, led by Julianne Sullivan of Forefront Wellbeing and Curtin University’s Diversity & Equity Senior Advisor Sheldon Smith, invited participants to slow down and reflect on where they are going in STEM and how they want to show up along the way. One of the activities at the workshop was assembling pieces to form a face in a fun, Picasso-style painting. It became a playful yet strong metaphor for identity and the experiences we carry throughout our lives. It was a different kind of learning, the kind that was less about ticking skill boxes and more about expanding awareness.

The third workshop was a candid panel discussion held at Engineers Australia’s building, featuring five



Figure 2. Third workshop—Panel Discussion.

brilliant women working across STEM sectors as our panellists. The panellists include professionals from CSIRO, Rio Tinto, Woodside Energy, WiTWA, and Murdoch University, some of whom were mentors in our program. The panellists shared stories about their professional journey, which included many unexpected pivots. However, the most important part was how the panellists collectively agreed on the importance of being resilient and trusting your instincts, even when the map is unclear. even when the map is unclear.

From Exclusion to Empowerment: A New Supportive Community in STEM

As the Stronger Together Program ends, we have already seen the impact on inclusion and visibility in the STEM community. Meaningful connections were made. Positive supports were exchanged. What began as a pilot initiative has blossomed into a supportive community that aims to lift each other up.

This kind of impact is exactly what the program hoped to achieve. It sends a message to incoming (and current) students and institutional leaders that STEM does not have to be a lonely or intimidating place anymore, not when we show up for each other and move forward, stronger together. Inclusion in STEM is not just a buzzword here in Perth, it is a lived reality boosted by programs like this.

Huge thank you to the CIRA community for the support of making this program happen!

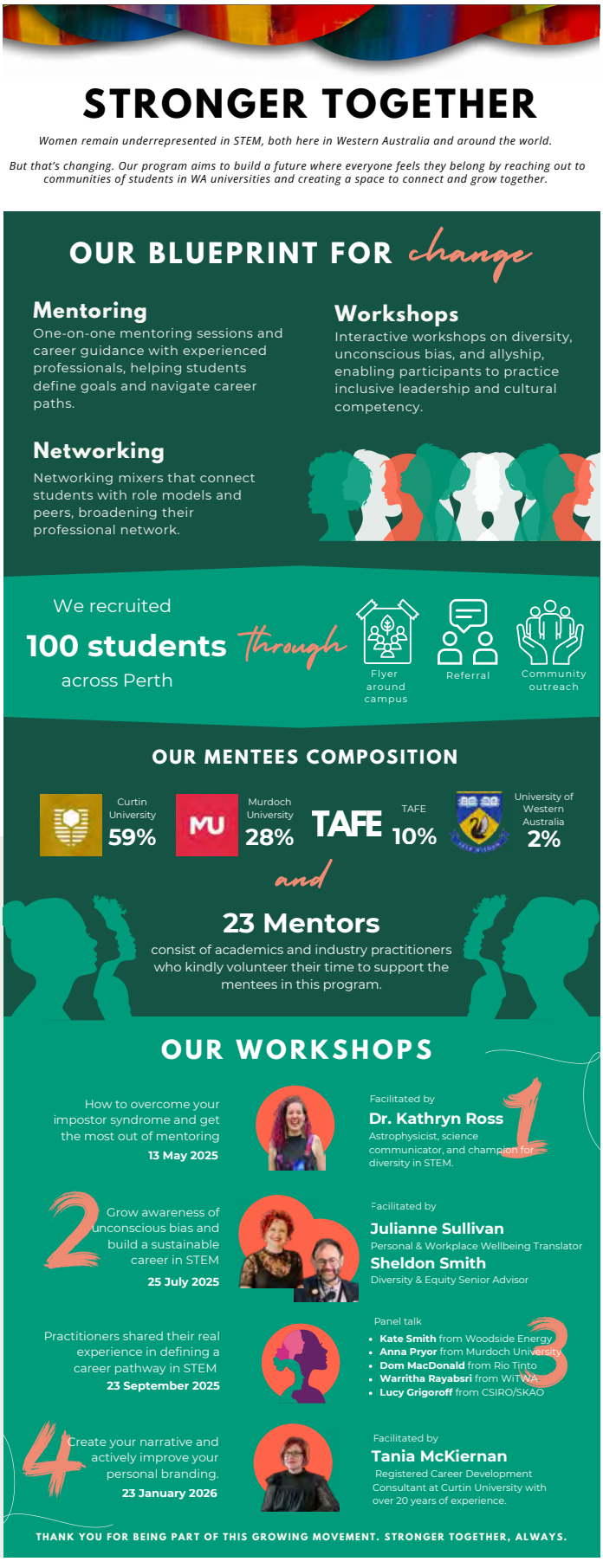


Figure 3. Stronger Together Infographic.

Media, Awards & Acknowledgements

Media

April

CARBONACEOUS METEOROIDS



Hadrien Devillepoix and Patrick Shober
Curtin News Interview about publication in *Nature Astronomy*.
https://www.curtin.edu.au/news/media-release/scientists-may-have-solved-a-puzzling-space-rock-mystery/



Natasha Hurley Walker
On the Record Interview with Fiona Bartholomaeus about the AAS Nancy Millis Medal.
https://rtrfm.com.au/story/associate-professor-natasha-hurley-walker-named-the-2025-recipient-of-the-nancy-millis-medal/

May

MOTHER'S DAY MAY METEOR



Desert Fireball Network
Channel 9: Mother's Day Meteorite.
https://www.9news.com.au/national/wa-shooting-star-mothers-day-meteor-tracked-down-seven-hours-east-of-perth/a7f92acc-43b0-4d19-b7d1-8fc853eb91a9

ICRAR



Media release: 'Discovery of X-ray Pulsations from a Long-period Transient'.
https://www.icrar.org/xray-transient/

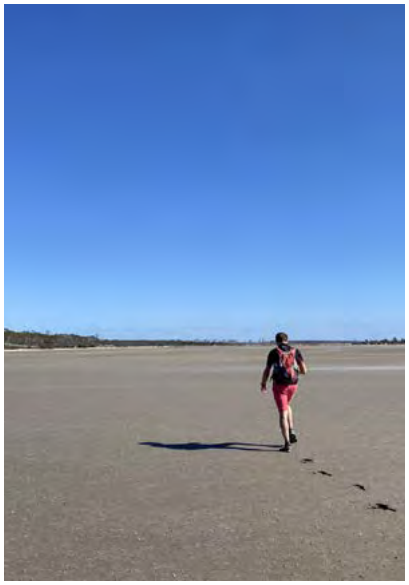
MWA



Natasha Hurley Walker
3CR Community Radio *Lost in Space* Podcast interview on her research using the MWA.

July

MOTHER'S DAY MAY METEOR



Desert Fireball Network Team
Curtin News Interview: Mother's Day May meteor.
https://www.curtin.edu.au/news/media-release/epic-outback-trip-leads-to-out-of-this-world-space-rock-discovery/

October

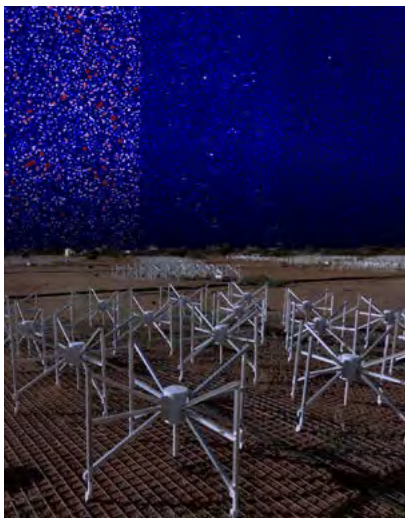
GLEAM-X



Silvia Mantovanini
Natasha Hurley-Walker
ABC Perth, yahoo News, Science News, RTRFM – On the Road, Channel 10, The Conversation: Interviews and articles about the new GLEAM-X view of the Galactic Plane.
https://theconversation.com/new-images-reveal-the-milky-ways-stunning-galactic-plane-in-more-detail-than-ever-before-264688

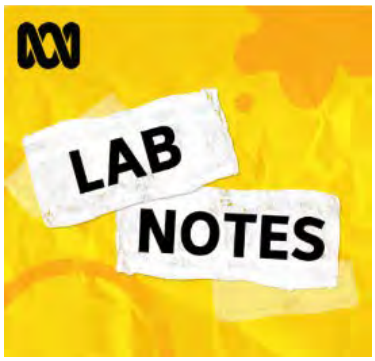
September

ICRAR



Ridhima Nunhokee
Cath Trott
Media release: 'The Universe 'warmed-up' before it 'lit up'.
https://www.icrar.org/eor-limit/

ABC RADIO NATIONAL



Ben Hartig
ABC Radio National Lab Notes podcast: 'Move over, NASA—Australia's heading back into space'.
https://www.abc.net.au/listen/programs/lab-notes/lab-notes-move-over-nasa-australia-heading-back-into-space/104824122

December

UNIVERSE TODAY



Angira Mahida
Universe Today: No evidence for Accretion Around the Intermediate-mass Black Hole in Omega Centauri.
https://www.universetoday.com/articles/radio-observations-find-nothing-at-omega-centauris-heart

Awards & Recognition



Maxwell Morris
Finalist at Australian Space Awards 2025 – Graduate of the Year.

SatPing Team
Finalist at Australian Space Awards 2025- Space Situational Awareness Program of the Year.



Shih Ching Fu
Awarded PhD Top-up Scholarship from The Statistical Society of Australia.

Winner at EECMS HDR Forum for Best Presentation.



Natasha Hurley-Walker
Awarded AAS Nancy Millis Medal. Awarded David Syme Research Prize for her work titled *Radio Astronomy*.



Aman Chokshi
Forrest Fellowship Award.



Kirsty Snadden
Curtin Values Award at the Science and Engineering Staff Excellence Awards.



Dr Ziteng (Andy) Wang (not pictured)
Dr Apurba Bera
A/Prof Natasha Hurley-Walker
Dr Sam McSweeney
Dr Kristen Dage (not pictured)
A/Prof Clancy James
Dr Ramesh Bhat
Curtin University 2025 Research Excellence and Impact Award for the media release 'Cosmic mystery deepens as astronomers find object flashing in both radio waves and X-rays' associated with the article 'Detection of X-ray Emission from a Bright Long-Period Radio Transient', published as Z. Wang et al., *Nature* 642, pages 583–586 (2025).

Kristen Dage
Australian Research Council Discovery Early Career Researcher Award (ARC DECRA).

Curtin 2030 Future Fund Grant.

Sophie Deam
Best poster at the Space Domain Awareness Conference.

Dylan Grigg
Winner of the 2025 Ken and Julie Michael Prize for the Curtin node.



James Miller-Jones
Steven Tingay
Arash Bahramian
Australian Research Council Discovery Project.



Cath Trott
Finalist in Mid-career Scientist of the Year at WA Premier's Science Awards.

DFN Team
Ellie Sansom
Ben Hartig
Hadrien Devillepoix
Martin Cupak
Jennifer Hardwick
Sophie Deam
Dale Giancono
Iona Clemente
Thomas Stevenson
Michael Frazer
Mia Walker
Inaugural Media Collaboration Champions at Curtin Research and Engagement Awards.

Hadrien Devillepoix & DFN Team
Finalist at the INCITE Technology Awards for their innovation of Real-time Drone-Assisted Meteorite Recovery using Machine Learning.

Scott Hayden
Excellence in Defence Innovation Award at Exercise Western Dawn.

Ellie Sansom
Selected to participate in the 2025 Young Leadership Dialogue, a two-year program as part of the Australian American Leadership Dialogue.

AuScope Opportunity Fund Grant.

Publications

Science

Abac, A. G., "Search for Continuous Gravitational Waves from Known Pulsars in the First Part of the Fourth LIGO-Virgo-KAGRA Observing Run", *The Astrophysical Journal*, vol. 983, no. 2, Art. no. 99, IOP, 2025. doi:10.3847/1538-4357/adb3a0.

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Staff and students are pictured alphabetically by given name.



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PhD Candidate



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Andrew McPhail
Program Manager



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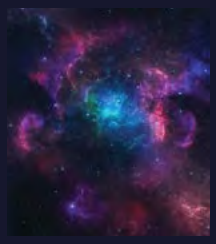

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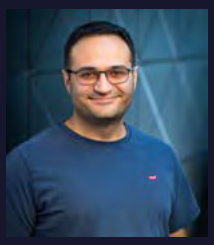

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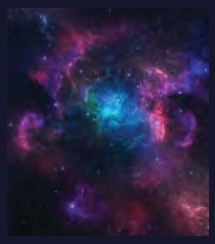

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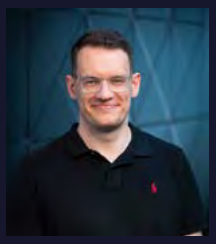

Benjamin Burridge
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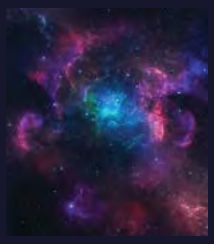

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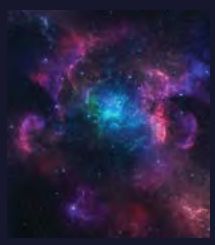

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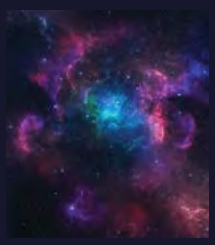
Professor



Cathy Hardy
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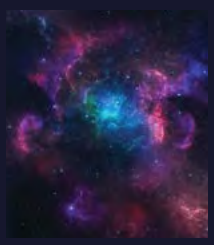

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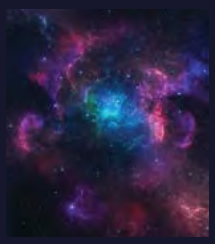

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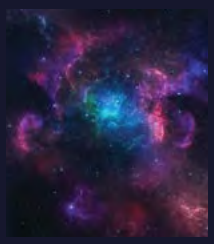

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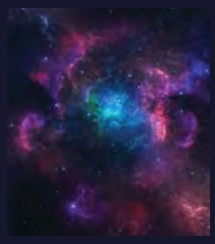

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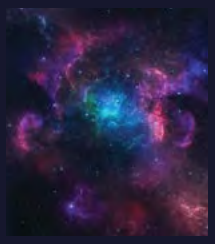

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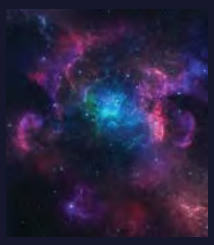

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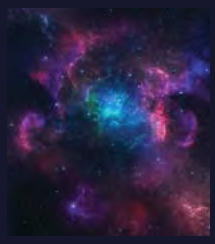

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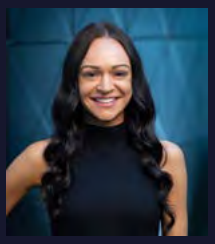

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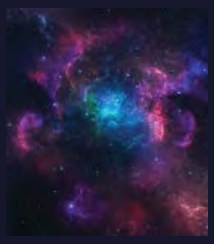

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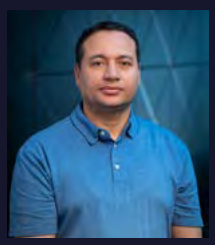

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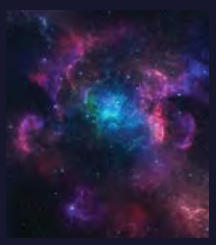

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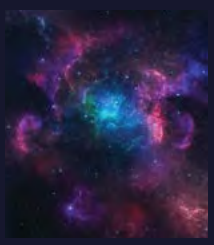

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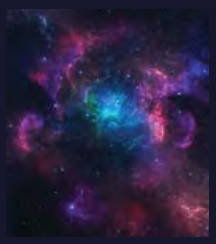

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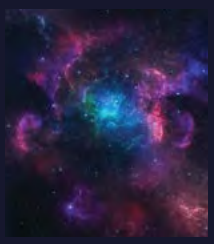

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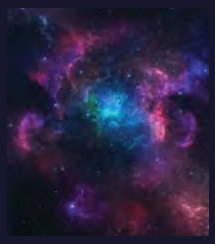

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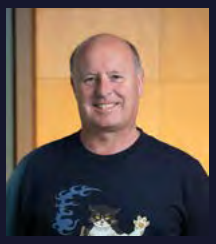

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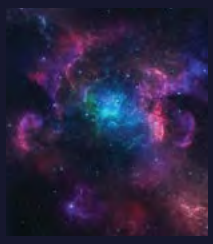

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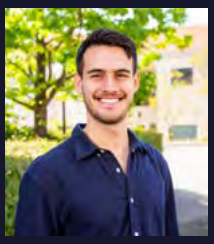

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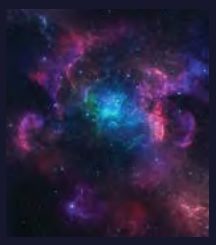

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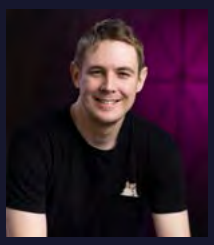

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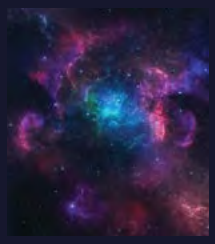

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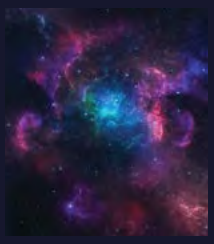

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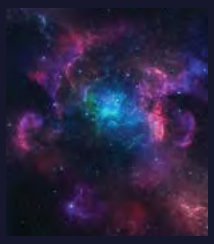

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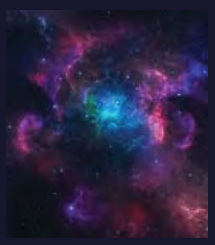

Dr Kristen Dage
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Mechanical Design



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Dr Maria Kovaleva
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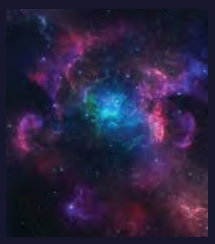

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Mel Santos
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Mouriyan Rajendran
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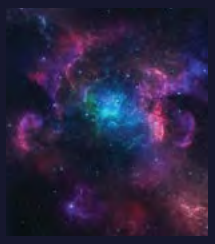

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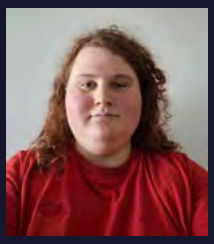

Olivia Walters
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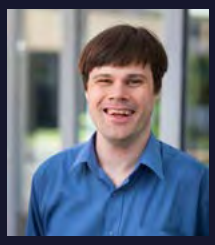

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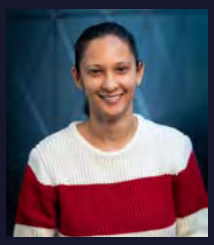

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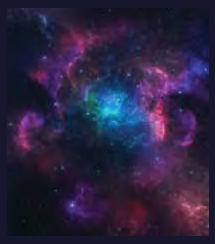

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Senior Developer



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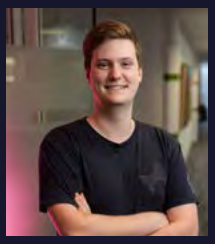

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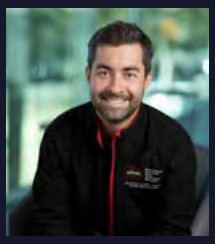
PhD Candidate



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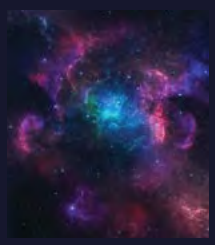

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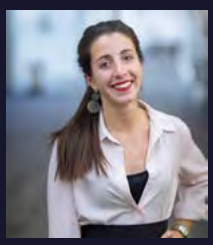

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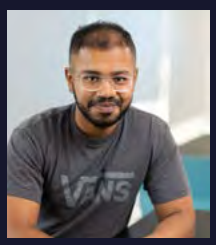

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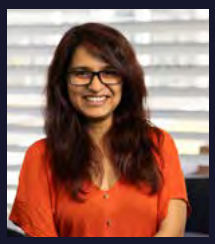
Associate Lecturer



Prof Steven Tingay
Executive Director



Dr Susmita Sett
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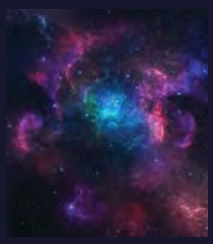
Casual Research Assistant
PhD Candidate



Tina Salisbury
Business Manager



Tom Booler
Director Engineering



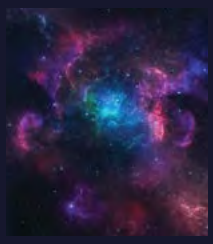
Tyrone O'Doherty
Senior Research Officer



Venus Chico
Project Officer/Technician



Wayne Arcus
PhD Candidate



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