Australia's National
Science Agency

Australia Telescope National Facility

Annual Report 2022–23

CSIRO Australia Telescope National Facility
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ISSN 1038-9954

This is the report of the CSIRO Australia Telescope National Facility for the period 1 July 2022 to 30 June 2023 and is endorsed by its Steering Committee. Telescope usage data spans the April to September 2022 and October 2022 to March 2023 observing semesters. Publication data is from the calendar year 2022.

Editor: Marilena Salvo

Cover: (Top) A part of the Galactic Plane as seen by our ASKAP radio telescope and Murriyang, our Parkes radio telescope, showing supernova remnants and the space between the stars (see page 11). Image: R. Kothes (NRC) and the PEGASUS team. (Bottom) ASKAP radio telescope at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory. Image: CSIRO/ Alex Cherney.

Traditional owners

We acknowledge the Traditional Owners of the lands of all our sites and pay respect to their Elders past and present.

Marsfield, Sydney, Wallumattagal People

Paul Wild Observatory, Narrabri, Gomeroi People

Parkes Observatory, Wiradjuri People

Mopra, Coonabarabran, Gamilaroi People

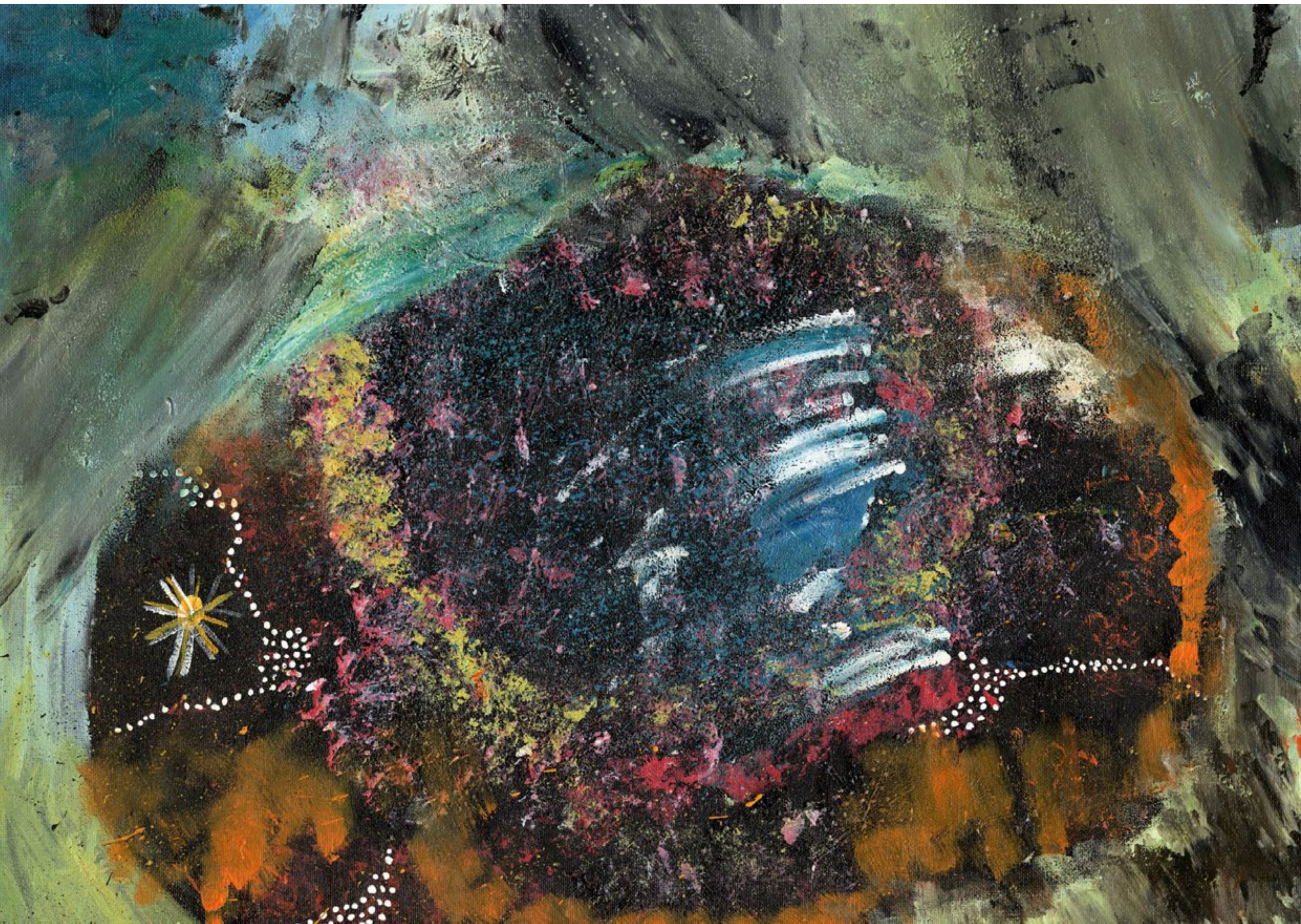
CDSCC, Ngunnawal People

Kensington, Perth, Whadjuk People of the Noongar Nation

Geraldton, Nhanhangardi, Naaguja, Wilunyu and Amangu Peoples

Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, Wajarri Yamaji People

Below: Each of ASKAP's survey science projects were presented with a painting by a Wajarri Yamaji artist. This painting by Tenille Taylor, *VAST,* was inspired by the ASKAP Variables and Slow Transients (VAST) project. During its pilot survey, VAST discovered the brightest ever pulsar and a mysterious signal from the centre of the galaxy. Tenille Taylor, *VAST*, 2019, acrylic on canvas.



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About us

On behalf of the Australian Government we develop and operate world-class radio astronomy facilities for researchers from across Australia and around the world. We attract and retain the best staff and are leaders in technology and research.

The Australia Telescope National Facility (ATNF) comprises the Australia Telescope Compact Array (ATCA) near Narrabri, the Australian Square Kilometre Array Pathfinder (ASKAP) telescope, and Murriyang – our 64-m Parkes telescope. We manage Australian astronomers' access to NASA's Canberra Deep Space Communication Complex (CDSCC) and we manage the combination of these antennas with ATCA, Murriyang, our Mopra telescope, and others in the southern hemisphere, as the Long Baseline Array (LBA). Through our research and development program we ensure our telescopes remain world class and support development of facilities around the world.

Astronomers from all over the world can access our telescopes free of charge based on the scientific merit of their observing proposal. We receive about 200 unique proposals annually, this year representing more than 1000 astronomers. Telescope time can also be purchased.

The primary output from the ATNF is scientific research. In 2022, astronomers published 118 papers using data enabled by our telescopes and specialist instrumentation. Our impact is realised by building innovation capacity for Australia and by inspiring the next generation. We achieve this through our programs for students and teachers, and the stories of our people, infrastructure, and the excellent science we enable and how this delivers benefit for Australia.

Protecting our telescopes, and others around the world, from increasing levels of radio frequency interference is more important than ever before. Our experts in this field are deeply involved with the international regulatory bodies that manage uses of the radio spectrum. In Australia there are Radio Notification Zones around ATCA and Murriyang while a Radio Quiet Zone gives special protection to Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, home to ASKAP and soon the SKA-Low telescope.

The ATNF Steering Committee (ATSC) is an advisory body appointed by the CSIRO Board to provide advice to the ATNF Director on CSIRO's ongoing delivery of radio astronomy capabilities for the nation. The ATSC appoints the ATNF Users Committee (ATUC), which represents the interests of astronomers using our telescopes, and the Time Assignment Committee (TAC), which reviews observing proposals (see page 26).

Murriyang, our 64-m Parkes radio telescope on Wiradjuri Country, and the Milky Way. Image: CSIRO/Alex Cherney.

Chair's report

The Australia Telescope National Facility is one of a handful of places in the world that brings together expertise in technology development, radio telescope operations, and scientific research. The success of this distinctive combination is why CSIRO is recognised as a world leader in radio astronomy and space science.

This area of science is undergoing a revolution, and it is critical that ATNF continues to lead the way and remain responsive to changing trends in Australia and internationally. Over the coming years, a combination of medium and long-term factors will create a phase change in our community:

- Both SKA telescopes, SKA-Low in Australia and SKA-Mid in South Africa, will come online at the end of this decade, raising questions about the future of all other low-to mid-frequency radio astronomy facilities including those in Australia.
- New facilities will lead to new research outcomes and approaches, including a stronger emphasis on multi-wavelength and multi-messenger synergies (for example, optical and radio astronomy; detection and follow-up of gravitational wave detections).
- Provision of data, algorithms and computation via shared facilities will be a vital part of any national facility's offering, as demonstrated by the 2023 Shaw Prize, awarded for the discovery of fast radio bursts using archival data from the Murriyang telescope at Parkes.

The ATNF Steering Committee and staff have assessed the current state and future opportunities for ATNF's facilities, in consultation with our community. It is clear that even in the SKA era, each facility offers some unique advantages: for example ASKAP's wide field of view for survey science; Murriyang's status as the only large single-dish astronomy telescope in the southern hemisphere; and ATCA's wide frequency coverage and flexibility which make it an ideal platform for teaching and technology experimentation. Of course, there are significant challenges in sustaining a full suite of operating telescopes. However, there are also opportunities to increase revenue through the sale of telescope time to external partners: this will be a focus in the coming years.

In May this year the Steering Committee had the opportunity to visit the Compact Array near Narrabri, NSW. It was great to meet the on-site team who has been supporting observations and upgrading instrumentation in challenging circumstances over the past year, including being isolated due to floods. Chatting with them over lunch brought back many memories of observing at ATCA in my early career. With the installation of BIGCAT, ATCA will have access to more bandwidth and processing power, with fewer necessary modes of operation and greater overall reliability.

This annual report presents an outstanding range of accomplishments in all aspects of ATNF's operations and science. I would like to thank the management and staff of the ATNF and the two committees that the ATNF Steering Committee appoints – the ATNF User Committee and the Time Assignment Committee – whose advice and diligence is critical to the smooth operation of the ATNF. The ATNF Steering Committee is a sub-committee of the CSIRO Board and we commend this report to it.

Professor Tara Murphy

Our Australia Telescope Compact Array (ATCA) is a set of six 22-metre diameter antennas near Narrabri on Gomeroi Country. Image: CSIRO/Alex Cherney.

Director's report

For more than 25 years, the ATNF team has been developing technology and preparing for the next generation of global radio facilities that now make up the international SKA Observatory. This year has marked a culmination of our efforts. In November we celebrated with our partners the signing of a new Indigenous Land Use Agreement to build the SKA-Low telescope on the land of the Wajarri Yamaji, the Traditional Owners and native title holders of Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory. Then, in December, four years after the convention establishing the SKA Observatory was signed in Rome, we helped mark the official start of construction of the SKA telescopes in Australia and South Africa. This year we also formalised our collaboration with the SKA Observatory to operate the SKA-Low telescope in Australia. This new team of predominantly CSIRO radio astronomy staff will eventually more than double our presence in Western Australia.

For our teams operating and upgrading the existing ATNF telescopes, 2022–23 was a year of bringing new capabilities to life and solving challenges raised by residual pandemic supply chain impacts. After several years of design and development our cryogenically cooled phased array feed receiver for Murriyang, our 64-m telescope, was tested at our Parkes site. We also continued to develop a replacement correlator for the ATCA. These capabilities will ensure the ATCA and Murriyang remain at the forefront of discovery while supporting cost-effective operating models.

In a major milestone, ASKAP surveys commenced this year following successful pilot programs and the installation of a new supercomputer at the Pawsey Supercomputing Research Centre. All the data from our precursor Rapid ASKAP Continuum Survey have now been released to the research community through our archive.

As Australia and the world shift focus from national to international astronomy facilities, we have been working to realign our national radio astronomy capacity around maximising impact from Australia's participation in the SKA project. This is not just about how we operate telescopes: the instrumentation and technology development capability of the ATNF has been recognised as one of our core strengths. This capability and research enabled by telescopes from Murriyang to SKA-Low will continue to inspire young Australians to turn their talents and energy towards STEM careers.

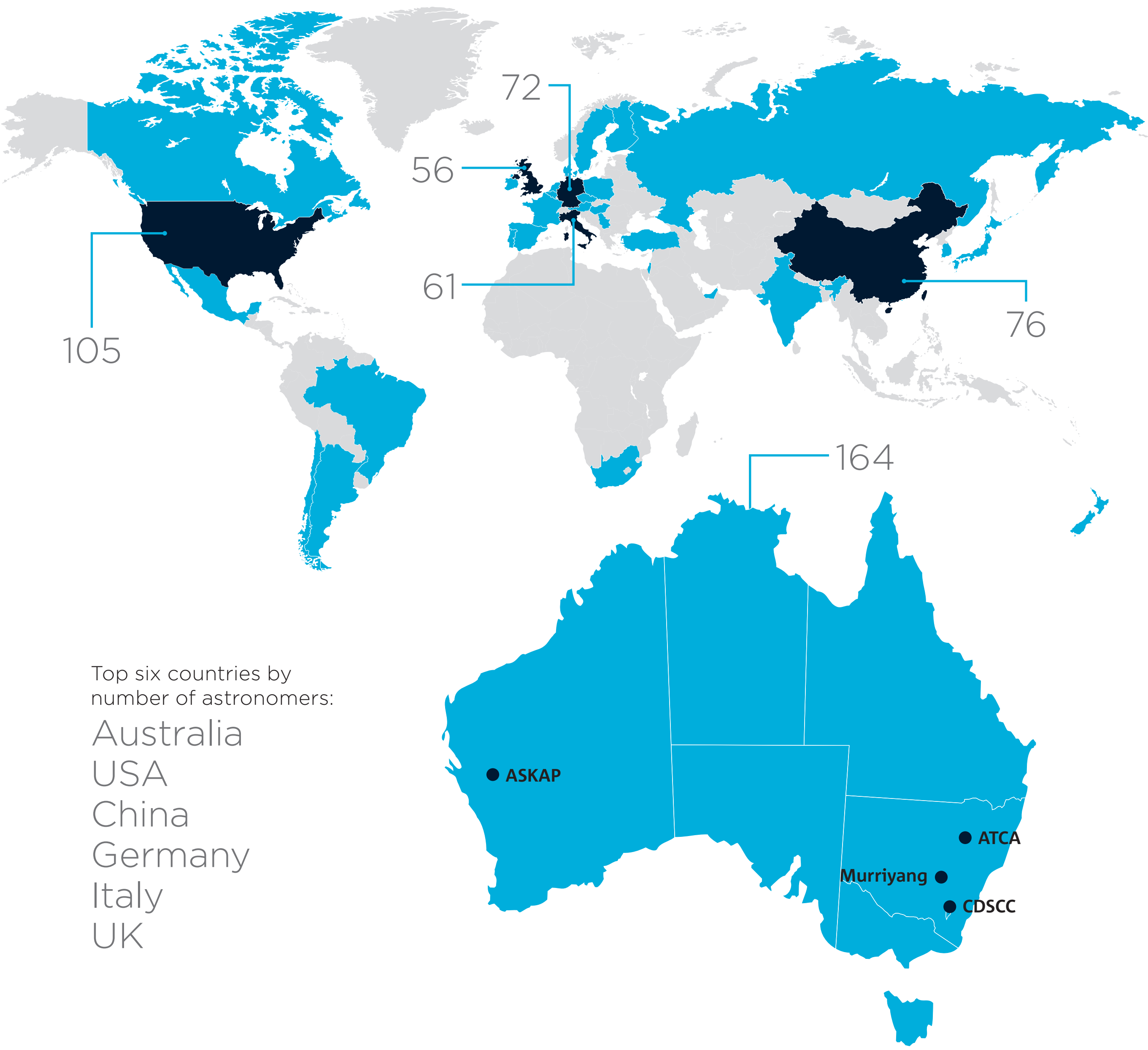
Our facilities also support commercial outcomes. Quasar Satellite Technologies is taking our phased array feed technology, originally developed for ASKAP, and applying it to the dual problems of tracking objects in space and communicating efficiently with many satellites at once. We recently signed a five-year agreement with SpaceX to provide ground station downlink services using Murriyang and other telescopes. This is the second contract of its type. Revenue raised by selling telescope time helps keep all the ATNF instruments operational, state-of-the-art and available for science.

People are central to our success. We have continued to strive for best practices in recruitment and an inclusive work environment. I thank and applaud the staff of the ATNF for their efforts and achievements this year. Finally, I thank the ATNF Steering Committee, Users Committee and Time Assignment Committee for their advice and guidance.

Dr Douglas Bock

Snapshot of 2022–23

234 observing proposals
1437 astronomers
from 33 countries



Top six countries by number of astronomers:

Australia
USA
China
Germany
Italy
UK

Time spent observing
60.5% ATCA
74.5% Murriyang

8.0
petabytes
in the data archives

173
papers
by our staff

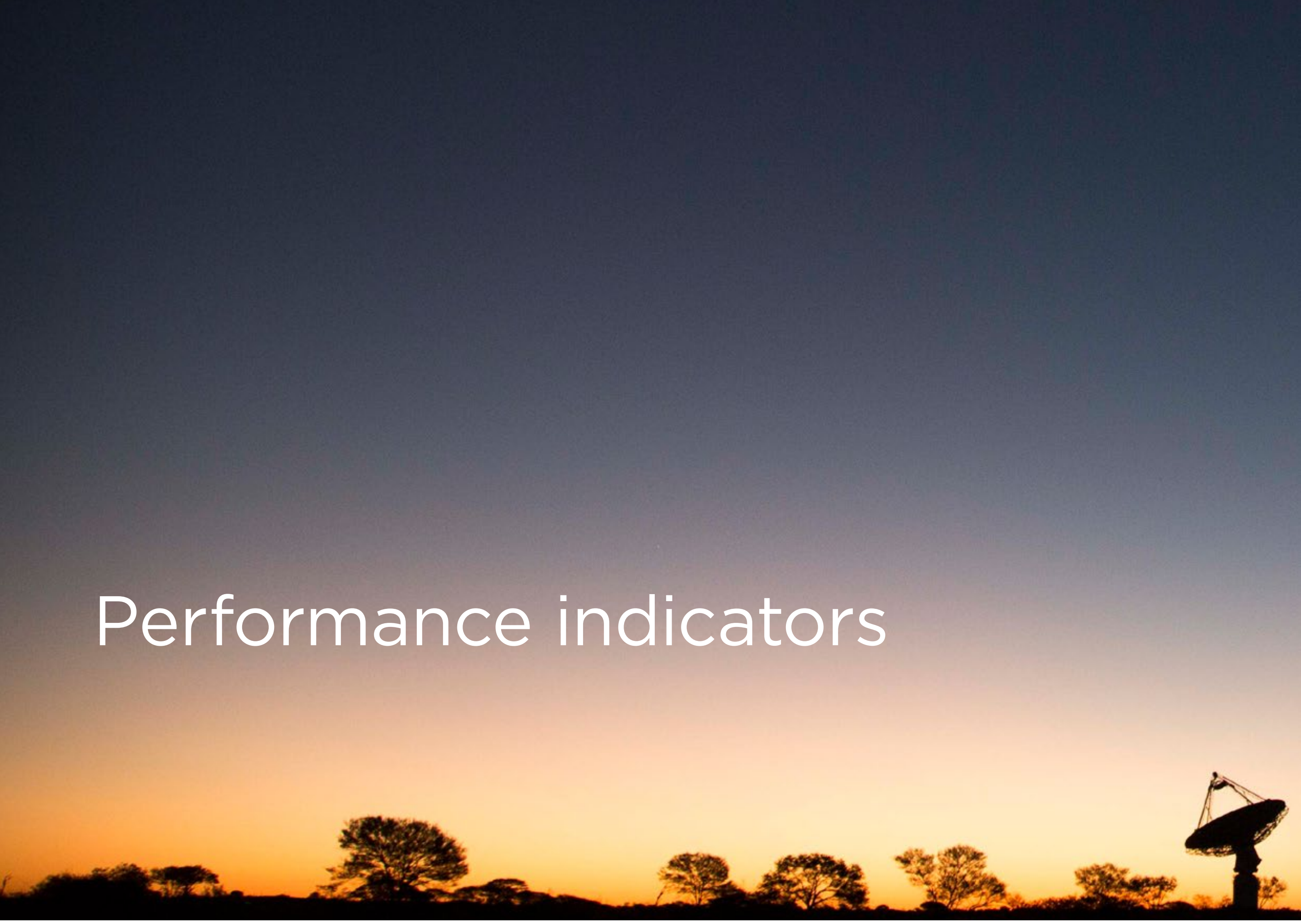
118
papers
cite ATNF data

243
staff

35
research
students

~400
school students
did PULSE@Parkes

107 539 people
attended our visitors centres



Performance indicators

Telescope usage

Our KPIs for ATCA and Murriyang are:

- At least 70% of telescope time successfully used for observing.
- No more than 5% of time lost during scheduled observations due to equipment failure.

Murriyang continues to meet its performance targets. Time allocated for maintenance has dropped back to typical levels following extensive infrastructure upgrades last year (Figure 1).

ATCA fell below its KPI, with only 60.5% of telescope time successfully used for observing. This arose through several one-off factors. Completion of the StarFISH Legacy project created unused ‘Green time’ not usable for other projects. Lack of flexibility in the ageing CABB correlator impeded efficient scheduling of rapid response observations, at which the ATCA excels. This will be addressed by the delivery of the new correlator BIGCAT (see page 19). Some failures of electrical infrastructure, since rectified, also contributed to a loss of scheduling efficiency (see page 15). An increase in the fraction of time lost to equipment failure was partly due to the sudden failure of the cable management system in one of the antennas, which took two months to repair. This was a one-off failure caused by a long-standing and undetected defect in installation.

ASKAP is incrementally building towards these KPIs and nearly achieved its 2022–23 target of 60%, achieving 59% observing time. In this period, 4.1% of scheduled observing time was lost due to equipment failure. Additional delays were the result of commissioning challenges for the new Setonix supercomputer, which have been addressed by the Pawsey Supercomputing Research Centre in close collaboration with the supplier of the system.

CDSCC antennas were used for 13.5 hours in single dish observing, contributed to the Long Baseline Array for 57 hours and to the East Asian VLBI Network for 21 hours, and spent a further 149.5 hours as part of bistatic radar observations of near-Earth objects.

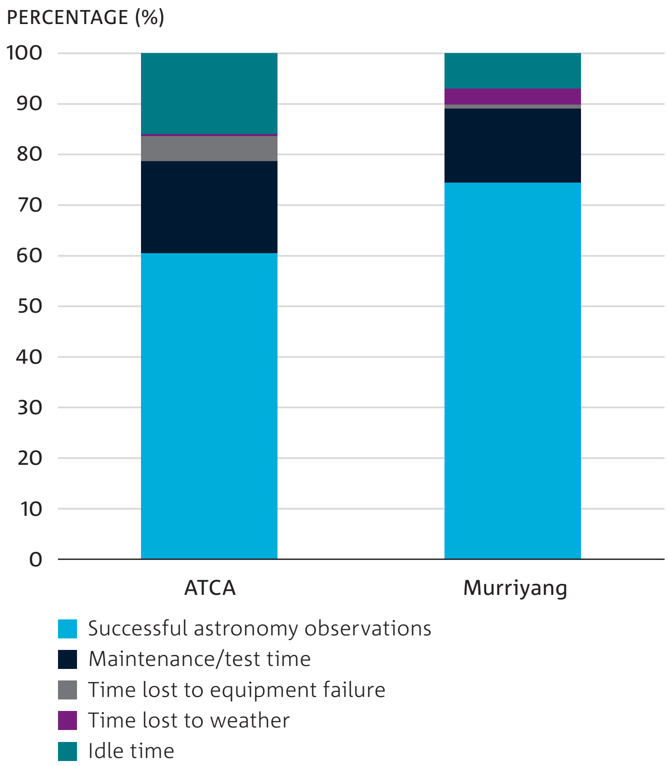


Figure 1: Use of ATCA and Murriyang in this reporting period.

Our ASKAP radio telescope at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, on Wajarri Country in Western Australia. Image: CSIRO/Red Empire Media.

Time allocation

There were 234 observing proposals received for ATCA, Murriyang, the LBA, and for CDSCC antennas: 179 of these were unique proposals. The telescopes were in demand with an oversubscription rate of 1.0 for Murriyang, 1.5 for ATCA (after excluding legacy projects) and 1.3 for the LBA. The observing teams consisted of 1437 researchers from 33 countries. After Australia, most proposers came from the USA, China, Germany, Italy and the UK. CSIRO people led 11% of unique proposals, 29% were led by staff of other Australian institutions and 60% by overseas researchers.

In total 154 proposals were allocated time based on TAC gradings: 84 on ATCA, 51 on Murriyang, 17 on the LBA and two on CDSCC antennas. Time allocation for ATCA and Murriyang is shown in Figures 2 and 3. There were 44 other proposals allocated Director's discretionary time, most on a 'target of opportunity' basis in response to observations made with other telescopes: 21 on Murriyang, 23 on ATCA (see page 29).

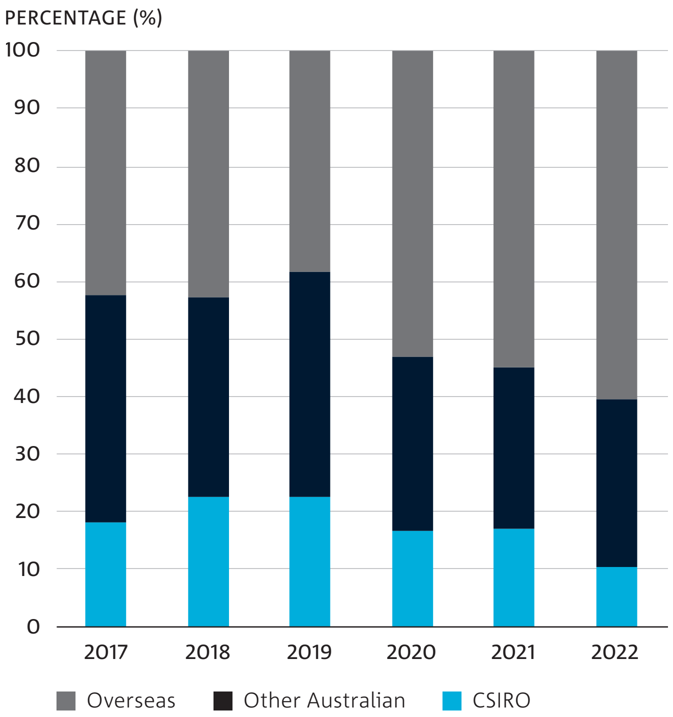


Figure 2: Time allocation on ATCA by affiliation of researcher.

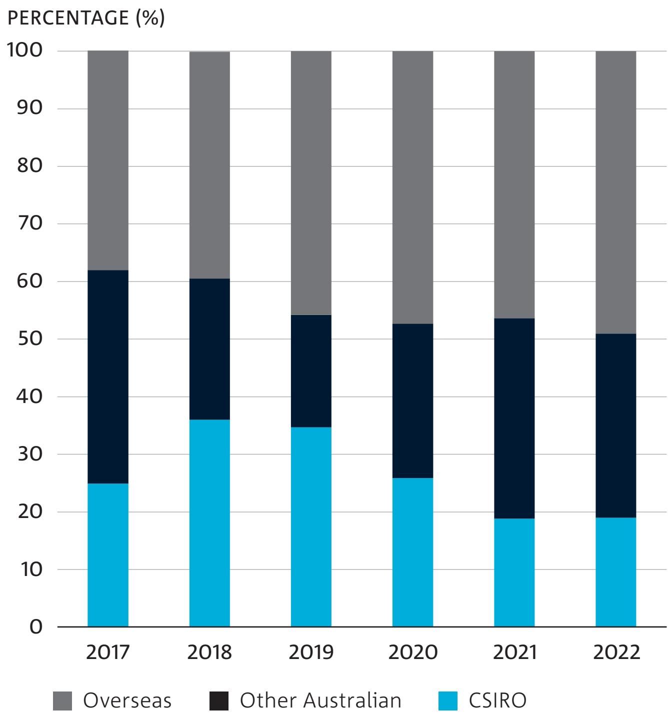


Figure 3: Time allocation on Murriyang by affiliation of researcher.

Publications

In 2022, 118 refereed papers were published that used data from ATNF telescopes: 67 (57%) included a CSIRO author. Our people published 173 refereed papers, including those using data from other facilities. Altogether, there were 225 refereed journal papers and 18 conference papers that used ATNF data and/or had ATNF authors, listed at www.atnf.csiro.au/research/publications.

ASKAP, ATCA and Murriyang publication numbers remain steady compared with previous years.

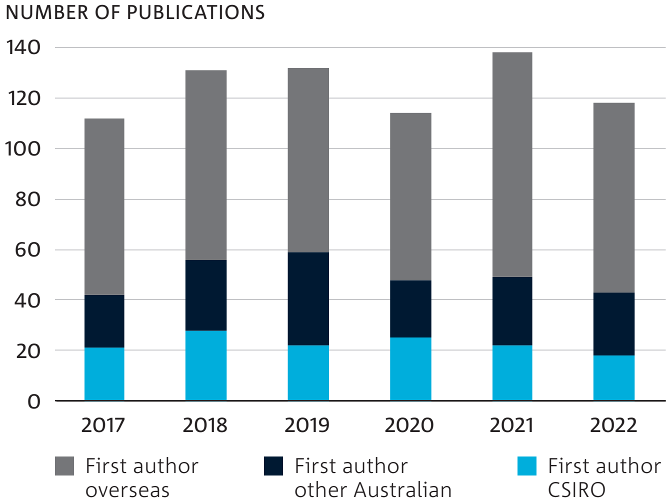


Figure 4: Publications using data from ATNF telescopes.

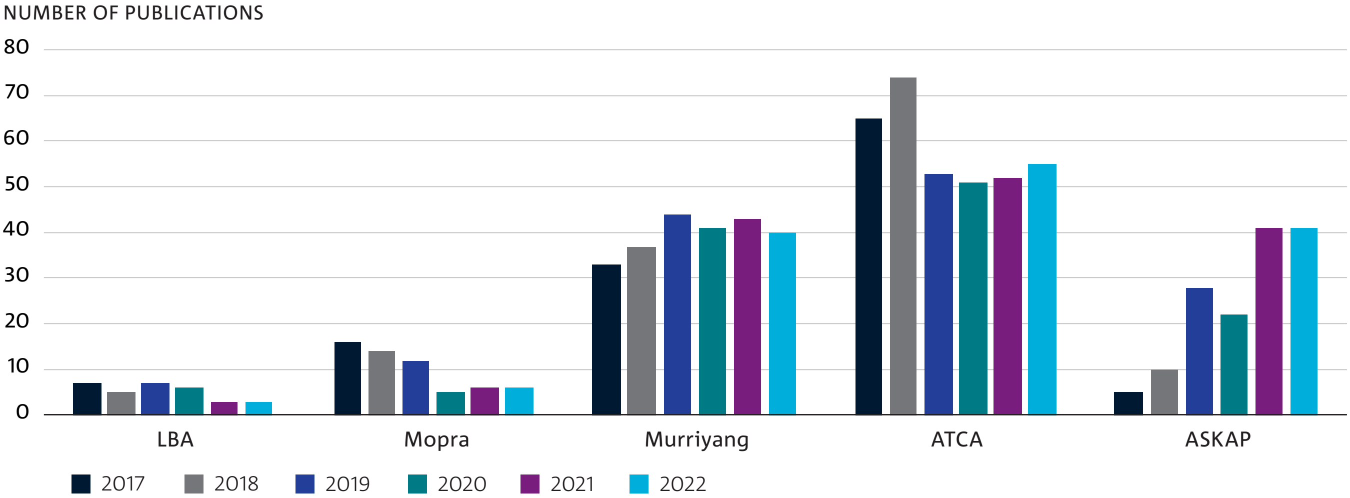


Figure 5: Publications using data from the ATNF, grouped by telescope. A few papers with data from more than one telescope are counted more than once.

Data archives

Our data archives, currently totalling around 8.0 PB, play an important part in the research work of our astronomer user community. Every day, the CSIRO ASKAP Science Data Archive (CASDA) receives about 2000 virtual observatory requests and more than 10 queries from the web user interface on the CSIRO Data Access Portal.

Searches of the Parkes Pulsar Archive on the Data Access Portal total about 400 per month, with an average of 20 TB of pulsar data downloaded every month. The Australia Telescope Online Archive (ATOA) delivers 1.5 TB of data every month. CASDA has now completed the move to new infrastructure at the Pawsey Supercomputing Research Centre, with deposit modules running on a dedicated node of the Setonix supercomputer.

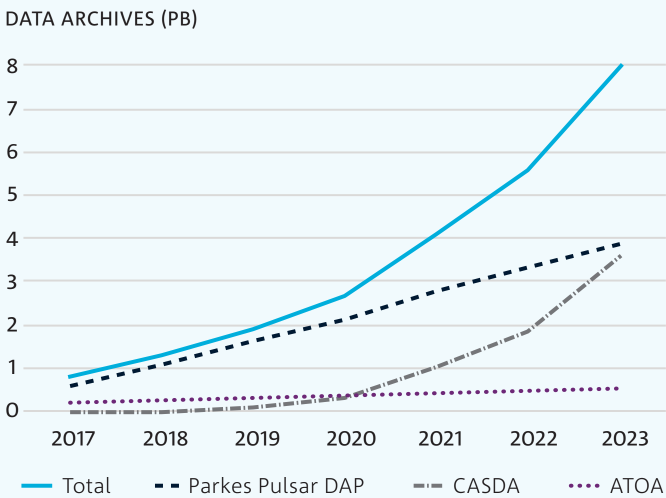


Figure 6: ATNF data archives over time.

ASKAP radio telescope

ASKAP has now commenced its five-year survey program for six of nine international survey teams, with two more in the final stages of preparation and another assessing technical requirements based on emerging capabilities.

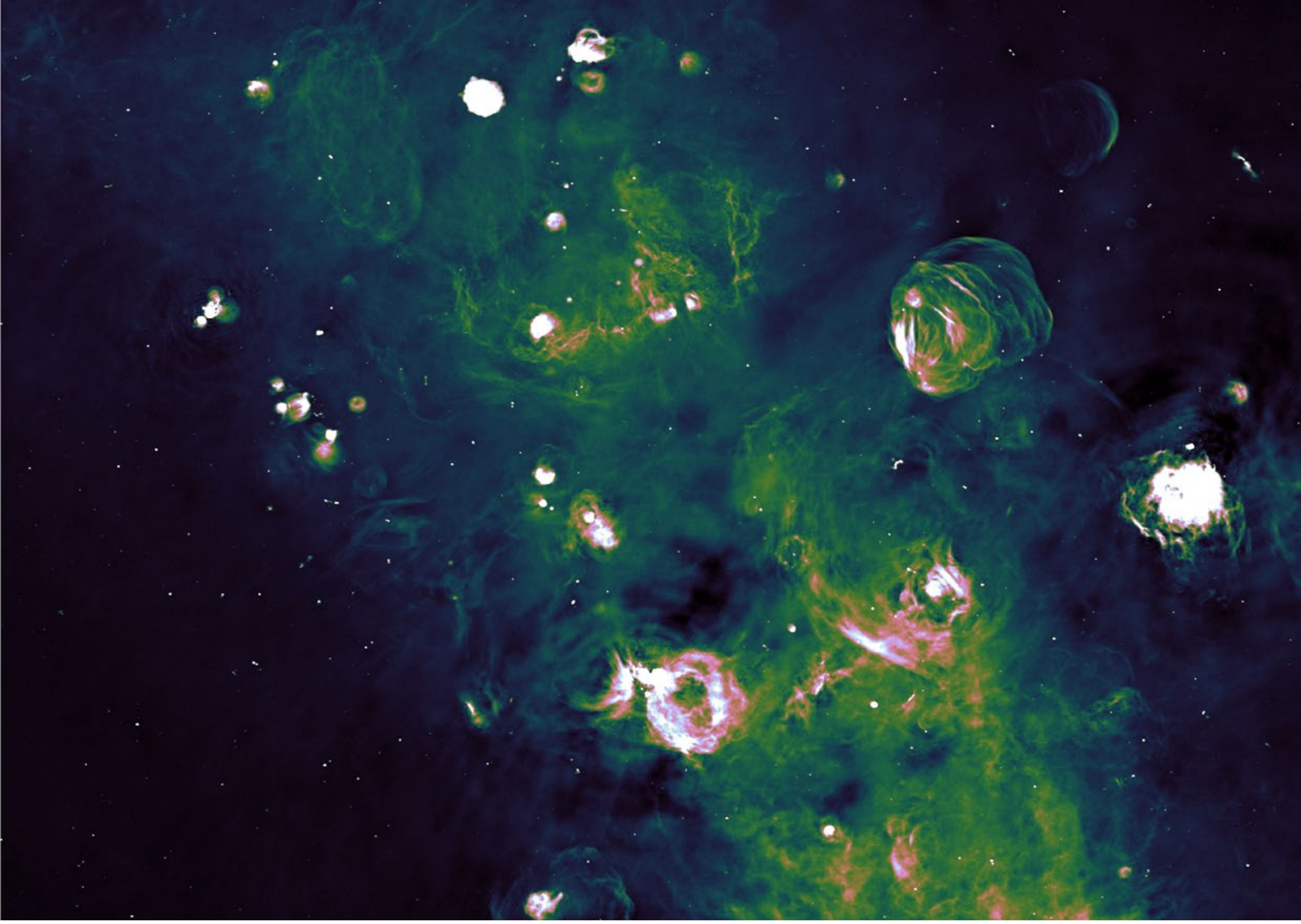
This is an historic milestone for ASKAP, which has been preparing for survey operations through science commissioning, an early science observing campaign, two rounds of pilot surveys and four surveys of the entire observable sky as part of the Rapid ASKAP Continuum Survey over the past few years.

In order to keep survey data flowing smoothly into the hands of the international astronomy community, we have developed autonomous scheduling and workflow management software and a processing pipeline that uses the latest supercomputing technology provided by the Pawsey Supercomputing Research Centre.

Ongoing optimisation will ensure that ASKAP operates with the highest possible observing efficiency as the first national research facility to provide science-ready data products. Outputs from the pipeline have been flowing into the CSIRO ASKAP Science Data Archive with a peak measured rate of up to 125 TB per week in 2023.

We are also gathering options for upgrades to ASKAP so that it remains at the forefront of astronomical research into the SKA era, providing a unique wide-field survey capability.

Our ASKAP telescope on Wajarri Yamaji Country. Image: CSIRO/Red Empire Media.



SCIENCE HIGHLIGHT

This image of the Milky Way was created using data collected with our ASKAP telescope and Murriyang, our Parkes radio telescope. It is the most detailed radio image of this region of the Milky Way ever made and may help answer long-standing questions about our Galaxy and its history. It reveals extended emission associated with magnetised material filling the space between stars, and supernova remnants.

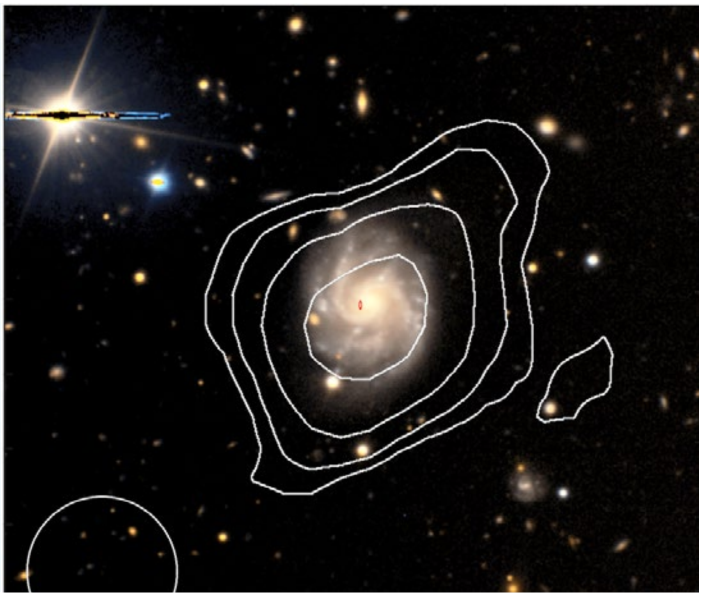
Image: R. Kothes (NRC) and the PEGASUS team.

SCIENCE HIGHLIGHT

Astronomers using ASKAP's powerful receiver technology detected a fast radio burst (FRB) and pinpointed its host galaxy. This is the first simultaneous detection of the two occurrences.

The radio burst's surprisingly calm environment shines new light on the puzzle of FRBs. Previous studies suggested colliding galaxies could create massive stars that may cause fast radio bursts, a picture that is challenged by this research. Key to this ongoing study is ASKAP's unmatched ability to analyse gas distribution in galaxies, while also hunting for the signatures that can help astronomers better understand the cosmic flashes.

M. Glowacki et al. 2023 ApJ 949 25



Murriyang, our 64-m Parkes radio telescope, during preparations for the new CryoPAF receiver. Image: CSIRO/John Sarkissian.

Murriyang radio telescope

Murriyang, our Parkes 64-m telescope, continued to produce high quality science throughout the year. The majority of observing time was again focused on the pulsar and fast radio burst science at which it excels. Other important observations were also undertaken including a new broadband polarimetric survey of the sky to complement ASKAP surveys, demonstrating the unique capabilities of these two very different telescopes. The new survey uses the Ultra-Wideband Low receiver, designed and built by CSIRO, which has become the workhorse of the telescope since its installation in 2018.

The Parkes Pulsar Timing Array, a major project utilising the telescope for almost two decades, has played a critical role in the announcement of the strongest evidence yet for low frequency gravitational waves (see more at right).

The latest receiver for Murriyang, the new cryogenically cooled phase array feed (CryoPAF), arrived at the observatory in October 2022 for a series of ground tests, a trial installation and early on-sky measurements using an interim narrow-bandwidth backend. The receiver spent some time on the ground looking upwards in the new 'hotbox' test rig before being installed on the telescope for a period of 10 days. The on-sky tests proved very encouraging, confirming the new receiver will provide a very high efficiency across its two square-degree field-of-view, promising again to transform the ability of the telescope to conduct fast and deep surveys of the sky.

After several retirements and departures of long-serving staff over the previous two years, key positions were filled during the year to help rebuild staff numbers and capability. Preparations for the delivery of the CryoPAF and other essential maintenance work continue to be supported by technical staff from Marsfield and Narrabri.

SCIENCE HIGHLIGHT

A research team using Murriyang discovered something unusual from a fast radio burst (FRB). For the first time, they observed a reversible magnetic field around an FRB. Scrutinised over 17 months, the field was highly magnetised and incredibly turbulent, changing direction twice during this period. The findings help bring us closer to solving the enigma of FRBs and uncover new insights into some of the most extreme environments in the Universe.

Anna-Thomas et al. 2023 Science 380 6645

SCIENCE HIGHLIGHT

In 1916, Albert Einstein's general theory of relativity described the Universe as a four-dimensional 'fabric' called spacetime that can stretch, squeeze, bend and twist. According to Einstein, massive objects could produce ripples, called gravitational waves. This year, astronomers using Murriyang found their strongest evidence yet for low-frequency gravitational waves.

Astronomers from the Parkes Pulsar Timing Array collaboration (part of the International Pulsar Timing Array collaboration) monitored a set of rapidly spinning stars that pulse like a lighthouse, called pulsars. By carefully analysing the pulses over 20 years, looking for nanosecond timing delays, the researchers found a remarkable signal: a hint of the fingerprint of these gravitational waves.

Zic et al. 2023 PASA 40 E049

An artist's impression of a pulsar timing array. Image: OzGrav/Swinburne, Carl Knox.

Our Australia Telescope Compact Array on Gomeroi Country. Image: CSIRO/Red Empire Media.

Australia Telescope Compact Array

An important niche of the ATCA continues to be its agility to respond to unpredictable astronomical events, in some cases almost instantaneously. This 'rapid response' capability is completely novel within the ATNF and probably within radio astronomy. The capability has enhanced the ATCA's role in following up transient events, which is an important and growing area within astronomy. This role will be further expanded when the existing correlator system is replaced by BIGCAT.

Development of the replacement digital backend BIGCAT continued this year, as noted under Technology development (see page 19). Local activity was focused on rewriting the main user control program, simplifying the control for a software-based processor, and including a general library to support the new output data format.

The site's power transformers are now decades old, and over the past year substations 1, 4 and 9 failed and several others are at risk of failure. Substation 9, which powers the stations at the western end of the antenna track, failed first. While we waited for a replacement transformer to arrive, which took almost a year, we purchased hundred-metre power extension leads to use for the antennas. We also replaced the transformer for substation 10, which powers the main control building. We now have three more transformers on order, and all the transformers are scheduled to be replaced over the next few years.

As part of the wider plan to upgrade the antenna systems we have engaged the services of an engineering firm to design a new travel-drive system. This includes the drives that move the antennas along the track during reconfiguration, and associated electronics. We anticipate that the new travel system will allow us to conduct our reconfigurations more safely, reliably and with a much higher level of automation.

SCIENCE HIGHLIGHT

Astronomers using ATCA to study in detail the properties of 24 ring galaxies found significantly low amounts of neutral atomic hydrogen when a strong central 'bar' structure is also present. The findings reinforce research suggesting these structures play an important role in redistributing both gas and regions of active star formation. The researchers benefitted from the telescope's sensitivity for accurate modelling of the sample galaxies.

Murugeshan et al. 2023 PASA 40 e018

SCIENCE HIGHLIGHT

Astronomers used ATCA to analyse the nearby radio galaxy NGC 3100 and a loose group of galaxies in its proximity, learning important information about the formation and evolution of massive galaxies and the role of black holes in their growth. They found interactions between the galaxies in the group are causing cold gas clouds to be pulled towards the centre of NGC 3100, which has led to the formation of a cold disk that is feeding a hungry supermassive black hole at the centre of the galaxy.

Maccagni et al. 2023 A&A 675 59

Long Baseline Array

The Long Baseline Array (LBA) is a partnership between CSIRO, the University of Tasmania and Auckland University of Technology. We manage the LBA as a national facility by joining ATNF instruments with radio telescopes across the southern hemisphere to perform very long baseline interferometry, or VLBI. The fine angular resolution achieved by having telescopes spread between continents means astronomical phenomena can be studied in such detail that the physics behind their origin can be probed.

The bulk of this year's LBA observations occurred during four VLBI sessions. There were 16 projects involving 26 observations, including participation in Global Millimetre VLBI Array and European VLBI Network observations. Tests with the Giant Metrewave Radio Telescope in India, and the East Asian VLBI Network, were also conducted.

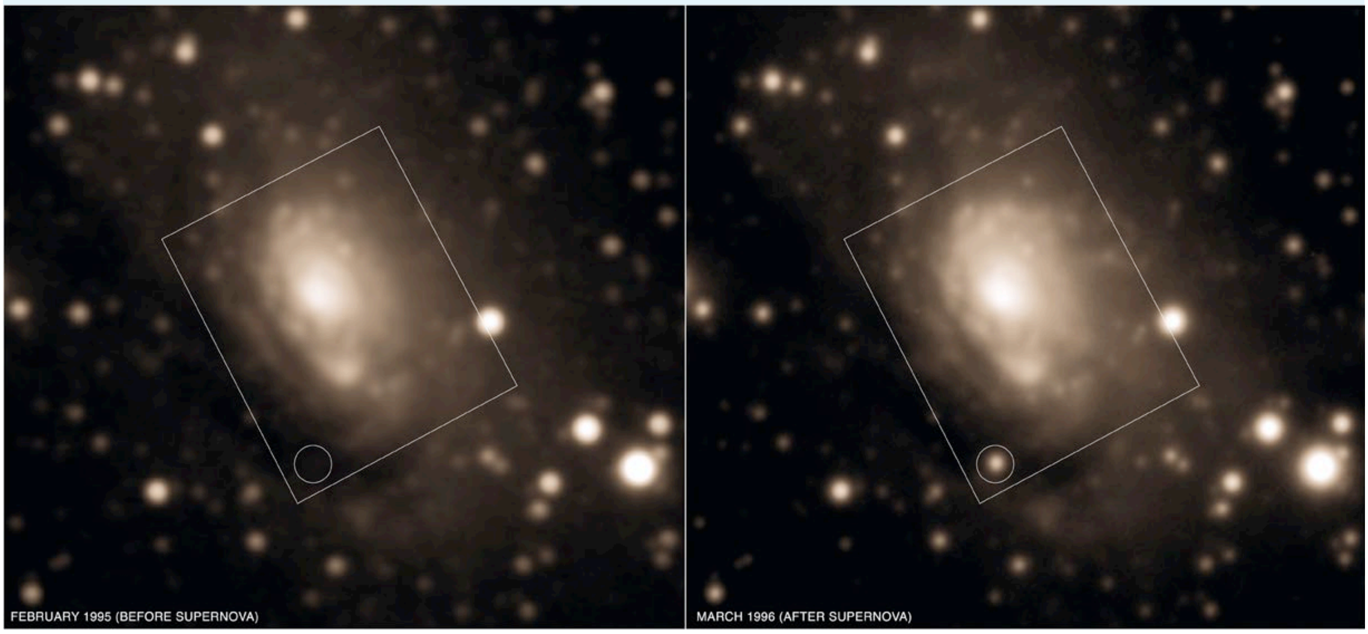
Data from LBA observations were correlated using the distributed FX (DiFX) software correlator. During this year operations successfully transitioned to the Setonix supercomputer at the Pawsey Supercomputing Research Centre in Perth. This year we correlated data from 339 hours of observations and used 95000 hours of CPU time, with a total data volume of 560 TB.

The median time from observation to data release was 80 days. This is down from 118 days last year and includes 30 days for transferring data from all telescopes to the Pawsey Supercomputing Research Centre. A project is now underway to migrate the LBA archive from ATOA to CASDA, and is expected to be complete in the first quarter of 2024.

SCIENCE HIGHLIGHT

Astronomers using the Long Baseline Array to observe supernova SN 1996cr detected the highest known radio flux density for an optically identified radio supernova. The supernova, in the Circinus galaxy, is one of only a handful of supernovae which can still be observed at radio frequencies more than 20 years after the explosion. SN 1996cr was observed at 2.3 GHz on 17 February 2020 and at 4.8 GHz on 3 March 2020 using telescopes in Australia, South Africa and New Zealand.

Bietenholz et al. 2023 MNRAS 521 2239



Optical images from the Anglo-Australian Telescope show the Circinus galaxy before (February 1995) and after (March 1996) the supernova explosion of SN 1996cr was visible. The field of view of the Chandra/Hubble Space Telescope composite is shown with a rectangle, along with the position of SN 1996cr. Images: Anglo-Australian Observatory.

WA Observatory Site Entity

CSIRO operates Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, on behalf of the nation through our Site Entity team.

The latter half of 2022 saw the execution of several interconnected agreements between CSIRO, SKAO, the Government of Western Australia, the Australian Government and the Wajarri Yamaji that enabled the start of construction of the SKA-Low telescope. One of these was a new Indigenous Land Use Agreement (ILUA) for the extended observatory site.

The ILUA ensures Wajarri culture, heritage and Country are protected and supported for generations to come, with ongoing education and employment opportunities for the Wajarri Yamaji. The first outcome was the observatory's dual name. Inyarrimanha ilgari bundara means 'sharing the sky and stars' in the Wajarri language. We are humbled that the Wajarri Yamaji, Traditional Owners and native title holders of the site, chose a name connecting the rich heritage of the region's first astronomers with the international scientific research occurring on the site.

On 5 December 2022, the SKAO hosted an event at the observatory and in Perth alongside events in South Africa and at SKAO Headquarters in the UK to mark the official start of construction on the two SKA telescopes.

The SKA project

The SKA project is a €2b international project to build the world's most advanced radio telescopes in Australia (SKA-Low) and South Africa (SKA-Mid). CSIRO is involved in several aspects of the SKA project:

- Operation of the observatory site on behalf of the Australian Government (the observatory's Site Entity)
- Construction of SKA-Low through several contracts ranging from overseeing site civil infrastructure to software for the science data processing pipeline (see page 19).
- Operation of SKA-Low in partnership with the SKA Observatory
- Establishment of the Australian SKA Regional Centre (AusSRC), one in a global network of facilities through which astronomers will access data from SKA-Low. The AusSRC is being formed in partnership with The University of Western Australia, Curtin University and the Pawsey Supercomputing Research Centre with funding from the Australian Government.

Aunty Julie Ryan, a member of the Minangu Land Committee, and Site Entity Leader Rebecca Wheadon at the Wajarri Yamaji Aboriginal Corporation celebration for the new ILUA on 5 November 2022. Image: CSIRO/Rachel Rayner.

Technology development

We are developing several new receivers and backend processing systems in collaboration with our partners at Australian universities, and with financial support from the Australian Research Council.

CryoPAF

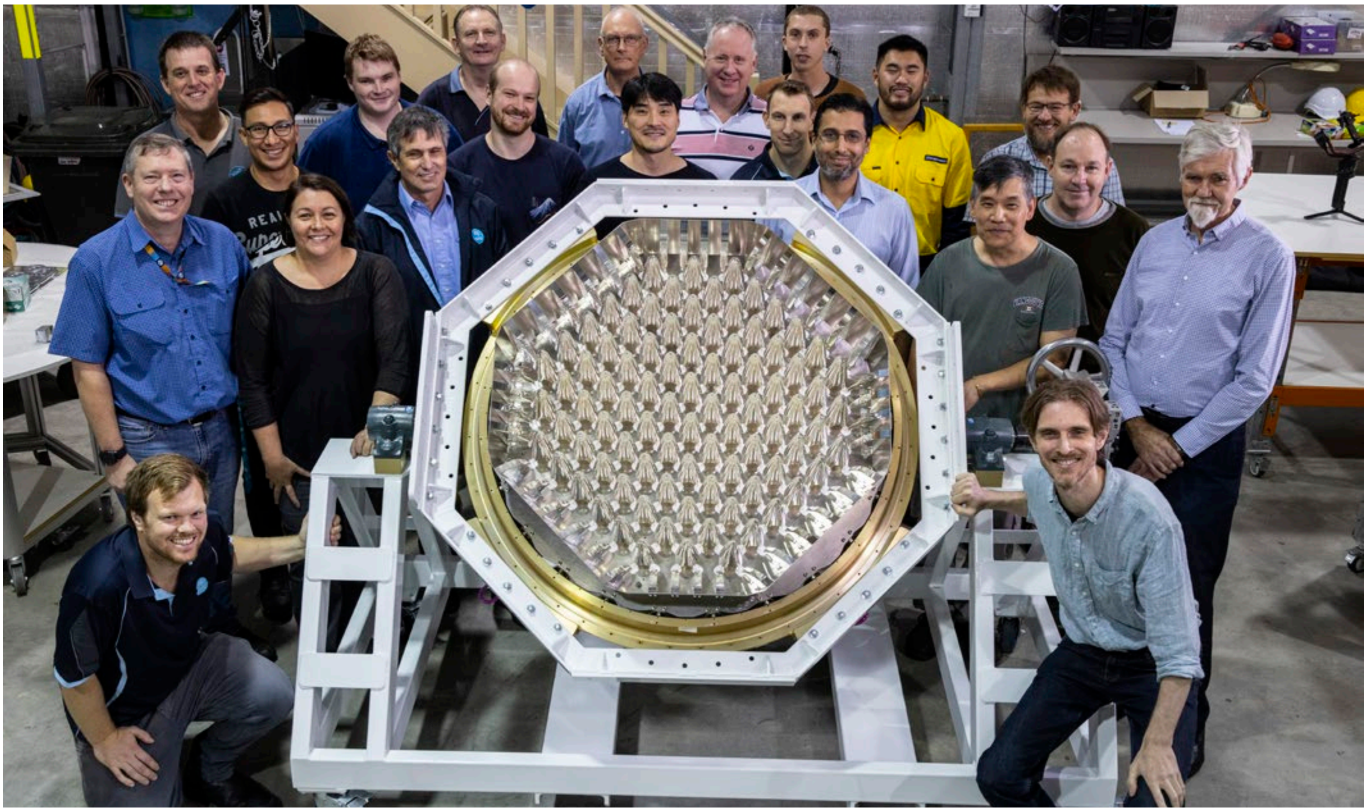
Development of an innovative cryogenically cooled phased array feed (CryoPAF) receiver for Murriyang continued. The design of all aspects of the CryoPAF system has been finalised and hardware construction is almost complete.

The cryogenically cooled radio frequency (RF) system, which includes the antenna feed, the low noise amplifiers and the cooling dewar system, has been built and tested. The warm RF electronics boards have been manufactured and installed. The digitisation boards based on RF-system-on-chip technology were produced and installed on the back of the dewar. The digital beamforming hardware based on Xilinx's Alveo field-programmable gate array technology has been procured and installed.

Development of the extensive firmware and software required has progressed sufficiently to test the system end-to-end, with further development needed for the full system.

We're planning installation and key 'on telescope' testing of the receiver and its science commissioning in 2023–24. Once complete, the CryoPAF will bring significant improvements in several key areas that, taken together, will help astronomers see fainter objects, survey more of the sky, and study a wider range of cosmic phenomena.

The CryoPAF technologies are being commercialised by start-up company Quasar Satellite Technologies, who are looking to solve two space industry challenges: tracking objects in space and communicating with multiple satellites at once. The Quasar demonstrator system has been built in parallel with the CryoPAF and construction of its sub-systems are nearing completion.



Our Technologies team with the CryoPAF receiver in our Sydney workshop. Image: CSIRO/Karl Schwerdtfeger.

BIGCAT

BIGCAT is a new system that will replace the CABB digital backend for ATCA. It will use a combination of field-programmable gate arrays and graphics processing units (GPUs) to process data at twice the bandwidth of the current system.

This year, our comparison of several different GPUs found the correlator performance scaled proportionally with the memory bandwidth of the GPU. This information informed the choice of correlator server computers, each with dual NVIDIA L40 GPUs. These servers arrived in June and matched our expected performance. Integration testing is scheduled to begin in the first half of 2023–24, and full installation in the second half of 2023–2024.

CRACO

ASKAP revolutionised our understanding of fast radio bursts (FRBs) and our new CRACO system promises to have ASKAP changing the scientific landscape once again. CRACO's FRB trigger is five times more sensitive than the existing system. CRACO will 'tap' ASKAP's correlator, rather than the beamformers, to search trillions of pixels per second to find and localise FRBs.

The correlator firmware is now complete and the final CRACO cluster has been delivered and is being installed. The team is commissioning the search pipeline using the existing pilot cluster and working to find the first FRB using the new system.

SKA-Low construction

We are providing project management and contract administration services under a Professional Services Contract for SKA-Low infrastructure. Construction activity at the observatory site commenced in February under the site management of SKAO. Since then, preliminary construction activity has included site surveying and outlining of heritage areas, construction of two large water access points and establishment of water bores, and clearing works for temporary and future accommodation facilities.

There has also been progress in our four other SKA construction contracts: construction of the correlator and beamformer for SKA-Low; the testing, integration and verification of SKA-Low subsystems; developing software for science data handling and processing; and the initial contract to define the scope and management for the construction and integration of the SKA-Low antenna stations at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory.

SCIENCE HIGHLIGHT

The phased array feed technology at the heart of our ASKAP telescope's receivers enables excellent survey speed. We've previously released data from two full surveys of the entire southern sky via the Rapid ASKAP Continuum Survey (RACS). This year we released the third RACS data set, RACS-mid, which is significantly deeper and has better spatial resolution than previous radio surveys at similar wavelengths. In future we will be providing the community with yet more frequency coverage, increased data quality, and multiple passes to find variable and transient sources.

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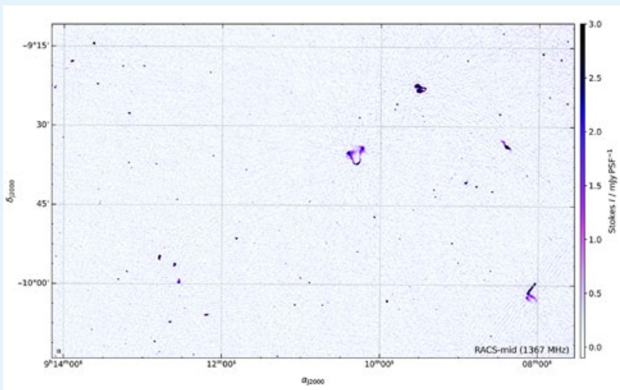

Students, education and engagement

Research students

This year we co-supervised 30 PhD students, four Masters and one Honours student. The students came from 16 universities including four overseas. Ten PhDs, three Masters and two Honours degrees were awarded during the year (see page 28).

Undergraduate students

Our undergraduate vacation student program had 16 students, including two Women in Engineering scholars, from ten universities. The students undertook astrophysics, engineering, computing and science communication projects over the summer, and were based in Kensington, Tidbinbilla, Parkes and Marsfield. The observing trip to ATCA ran for the first time in three years, having been suspended during COVID, giving the students the opportunity to visit an observatory and learn more about observing and operations. The students presented their work at a symposium in February.

Schools and teachers

Professional development sessions were held for teachers at science teacher conferences in NSW, ACT, Victoria, Tasmania and South Australia. ATNF staff participated in CSIRO's STEM Professionals in Schools. ATNF astronomers and educators visited the Pia Wadjarri Remote Community School in late 2022, running a series of astronomy education activities prior to hosting the school students and teacher at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, which hosts ASKAP.

PULSE@Parkes

The PULSE@Parkes program has thrived this year, with almost 400 students and 70 teachers across the country participating. We ran special sessions for students and teacher workshops at the Victorian Space Science Education Centre and the Australian Space Discovery Centre in Adelaide plus one for the National Youth Science Forum. More recently we have resumed on-site sessions at Marsfield and plan on offering both on-site and online sessions as standard in the future. We have a strong collaboration with the Generation STEM program run by CSIRO Education and Outreach, targeting schools across NSW. We also ran a week for the Virtual Work Experience Program and a session for CSIRO's Young Indigenous Women's STEM Academy students.

Our 2022–23 undergraduate vacation students enjoyed their visit to ATCA on Gomeroi Country. Image: CSIRO/Anita Hafner.

Communications

We collaborated with other Australian and international astronomy organisations to share the latest discoveries enabled by the ATNF instruments with a wide audience.

The solar eclipse visible across Australia on 20 April was an opportunity to promote our work in solar physics, space weather and radio astronomy. We secured prominent media coverage featuring our spokespeople and engaged directly with many Australians via CSIRO's social media channels. We sponsored Astrotourism WA's Eclipse Discovery Tours, which included our radio astronomy stories in 27 community stargazing events – four of these featuring a CSIRO speaker – in regional Western Australia.

We again participated in Astronomy WA's Perth Astrofest, which this year attracted more than 2,500 attendees. Beyond the Milky Way – the augmented reality feature on Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, and SKA precursor instruments including ASKAP – continued its national tour in Canberra and Geraldton. We shared the work we do in the Murchison region with the local community and visitors at the inaugural Ancient Lands Under Brilliant Skies festival, highlighting the importance of the region to international radio astronomy.

For National Science Week we created and ran 'ASKAP Recap', an online panel event on the telescope's unique capabilities and latest research results. Popular YouTube creator Tom Scott visited Murriyang and his video has been watched more than three million times. We also shared our experience of science communication with other practitioners at the International Astronomical Union's biannual 'Communicating Astronomy with the Public' conference hosted by Macquarie University in Sydney.

Visitors centres

The new space-themed playground at Parkes Observatory has received positive feedback from visitors including local families who bring their children to enjoy the new facility.

Astronomy talks were held during school holidays throughout the year. Visitors could sit, listen and ask questions of guest speakers on all topics relating to the telescope, astronomy and the work of the observatory.

Astrofest at Parkes was once again a very successful event, and we continued to host the popular David Malin Astrophotography Awards exhibition.

A milestone was the 20th birthday of the Dish Café. Opened in April 2003, the café has been a valuable adjunct to the centre.

The Parkes Observatory Visitors Centre playground with its new shade sail. Image: CSIRO/John Sarkissian.

Number of visitors to Parkes Observatory and ATCA.

	2017–18	2018–19	2019–20	2020–21	2021–22	2022–2023
Parkes	105 085	112 224	100 013	103 185	72 612	93 763
ATCA	12 081	10 363	7434	19 659	10 740	13 776

Our people

As of 30 June 2023, there were 243 staff receiving financial support from CSIRO, including joint appointees and those employed under contractor or labour hire arrangements. These data exclude honorary fellows, students and those working in the SKA-Low collaboration team.

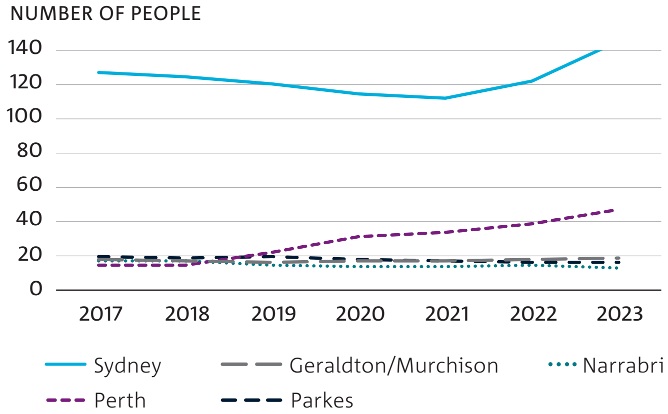

Figure 7: Our people by site over time.

Diversity and inclusion

The Space and Astronomy's Diversity and Inclusion (D&I) Committee was established in 2014 and has demonstrated a sustained commitment to change. Now supported by a newly established full-time Diversity and Inclusion Manager to co-ordinate and lead change across the business unit, the Committee has evolved to a dedicated team representing diverse genders, ages and levels of seniority, and our many locations across Australia.

We have reached our targets of achieving gender balance on the Space and Astronomy Executive, Space and Astronomy Rewards Committee, ATNF Steering Committee and ATNF User Committee. Additionally, there has been a 22% increase in the number of women group leaders.

We have been making a positive impact through engaging with the community, such as participating alongside CSIRO colleagues in the 2023 World Pride and Sydney Mardi Gras Fair Day and Parade, contributing to CSIRO's 'Impossible without Diversity' campaign, and being represented on the Astronomical Society of Australia's Diversity and Equity in Astronomy (IDEA) Chapter Committee.

Focus areas for Space and Astronomy in the year ahead include working towards a Silver Pleiades Award, refreshing our Diversity and Inclusion Action Plan to make sure it is aligned to the CSIRO Diversity, Inclusion and Belonging Strategy and to ensuring we are accountable through robust monitoring and reporting. We will continue to make impact through an engaged and committed leadership team, and increasing the number of Indigenous people and women in technical roles.

The table below shows the Space and Astronomy diversity profile at 30 June 2023; ATNF staff are 71% of the total business unit staff.

Space and Astronomy diversity profile.

	TOTAL S&A STAFF	ABORIGINAL AND TORRES STRAIT ISLANDER	WOMEN	DISABILITY	GENDER DIVERSE*
2017–18	266	3.76%	21.1%	4.89%	N/A
2018–19	283	2.83%	23.3%	4.95%	N/A
2019–20	266	2.63%	21.1%	5.64%	N/A
2020–21	270	1.85%	23.0%	5.56%	N/A
2021–22	314	1.59%	24.2%	5.73%	0.3%
2022–23	341	1.76%	24.6%	7.04%	1.2%

* Recorded as unspecified in CSIRO HR records. CSIRO does not report on this at an organisational level.

Awards and honours

Our award winners this year included:

- The Boolardy Services Team, who received the 2022 CSIRO Aboriginal and Torres Strait Islander Engagement Impact Excellence Medal for significant contribution to the formation of a joint venture between two Indigenous-owned companies to operate the Boolardy Accommodation Facility.
- Dr Vanessa Moss and Dr Laura Driessen, who received the Superstars of STEM Award from Science & Technology Australia.

Our team participated in Mardi Gras Fair Day in Sydney, February 2023. Pictured (left to right) are Communication Advisor Mikayla Keen, CSIRO Brand Manager Kirsten Lea, and ATNF Science Group Leader Dr Minh Huynh. Image: CSIRO/Katherine Appleby.

Health, safety and environment

Safety culture has been an ongoing focus for S&A in 2022–23 with particular attention applied to safety leadership on site and addressing critical risks. Our critical risk review program was rolled out and involves sharing the risk ownership among executive team members to take accountability for reviews and control verifications of each critical risk. Hazard reports have increased indicating a strong safety culture.

Our recordable injury frequency rates.

PERIOD	HAZARDS REPORTED	SLTIFR	LTIFR	MTIFR	TRIFR	COMCARE REPORTABLE
2017–18	1	-	3.6	-	3.6	-
2018–19	3	-	3.6	-	3.6	1
2019–20	8	-	2.9	-	2.9	1
2020–21	6	-	2.8	2.8	5.5	-
2021–22	35	-	-	-	-	1
2022–23	84	-	3.0	-	3.0	2

Frequency rate is per million hours worked by employees. SLTFR Serious Lost Time Injury Frequency Rate. LTIFR Lost Time Injury Frequency Rate. MTIFR Medical Treatment Injury Frequency Rate. TRIFR Total Reportable Injury Frequency Rate.

Our Australia Telescope Compact Array on Gomeroi Country. Image: CSIRO/Alex Cherney.

Finance

A change to the ATNF financial model was made between 2021–22 and 2022–23. Previous ATNF annual reports included external revenue and associated costs associated with the SKA project. They have now been removed to enable a more accurate financial picture of the ATNF that includes the ATNF Science, ATNF Operations and Technologies for Radio Astronomy programs, plus management costs only.

CSIRO funding to meet ATNF operating costs in financial year 2022–23 was $42.4m. This was supplemented with $12.5m external funding for commercialisation activities, sale of telescope time, National Collaborative Research Infrastructure Strategy funding for ASKAP and other external contracts.

Compared with the previous financial year, external revenue increased by approximately $3.8m and we received a modest increase in indirect appropriation. Salary costs increased by approximately $2m in line with the annual salary increase and growth in staffing numbers, and travel costs increased as COVID restrictions eased. ATNF operating costs decreased by approximately $0.9m as most one-off costs for Quasar Satellite Technologies occurred in the previous year. Overheads increased in line with salary cost increases in CSIRO's enterprise services area.

OPERATING (A$'000s)	YEAR TO 30 JUNE 2022	YEAR TO 30 JUNE 2023
Revenue		
External	8,740	12,525
CSIRO direct appropriation	22,256	22,559
CSIRO indirect appropriation[1]	18,939	19,825
Total revenue	49,935	54,909
Proportion of appropriation	82%	77%
Expenditure		
Salaries	20,057	22,035
Travel	379	923
Other operating	12,152	11,296
Overheads[2]	12,940	13,818
Depreciation and amortisation	5,999	6,007
Total expenses	51,527	54,079
Operating result	**-1,592**	**830**

1. CSIRO indirect appropriation is funding for overheads and depreciation.
2. Overheads include support services such as human resources, health and safety, IT, finance and property services.

The table below shows capital revenue and expenditure for the ATNF. This includes CSIRO capital and funding through the Australian Research Council Linkage Infrastructure, Equipment and Facilities grant to contribute to telescope infrastructure upgrades. Capital funding from CSIRO over the past five years has averaged $1.9m per year.

CAPITAL (A$'000s)	YEAR TO 30 JUNE 2022	YEAR TO 30 JUNE 2023
Revenue		
CSIRO funding	1,807	1,620
ARC LIEF	284	1,514
Total revenue	**2,091**	**3,134**
Expenditure		
Total expenditure	**2,091**	**3,134**

ATNF management team

Director, Dr Douglas Bock

Deputy Director, Dr Mark Cheung (commenced August 2022)

Program Director ATNF Science, Dr George Heald

Program Director Technologies for Radio Astronomy, Dr Tasso Tzioumis

Program Director ATNF Operations, Dr John Reynolds

SKA Program Leader, Dr Mita Brierley

Chief Operating Officer, Ms Kate Callaghan

Committee membership

ATNF Steering Committee

Chair

Prof Tara Murphy, University of Sydney
(1 May 2022 to 31 March 2025)

Australian astronomy community

Prof Sarah Brough, University of NSW
(1 April 2020 to 31 March 2025)

Prof David Davidson, Curtin University
(1 April 2020 to 31 March 2023)

Prof Steven Tingay, Curtin University
(1 April 2023 to 31 March 2026)

Prof Naomi McClure-Griffiths, Australian National University
(1 April 2019 to 31 March 2024)

Prof Tara Murphy, University of Sydney
(1 April 2020 to 31 March 2025)

International astronomy community

Prof Jayaram Chengalur, National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, India
(1 April 2021 to 31 March 2024)

Prof Scott Ransom, National Radio Astronomy Observatory, USA
(1 April 2020 to 31 March 2025)

Prof Michael Wise, Netherlands Institute of Space Research
(1 April 2019 to 31 March 2024)

Australian stakeholder communities

Ms Catherine Livingstone AO
(1 January 2019 to 31 March 2024)

Ms Rosie Hicks, Australian Research Data Commons
(1 April 2022 to 31 March 2025)

Ex-officio

Mr Brendan Dalton, Chief Information Officer, CSIRO

Prof Elanor Huntington, Executive Director, Digital, National Facilities and Collections, CSIRO

Secretariat

Dr Marilena Salvo, Executive Officer, CSIRO

ATNF User Committee

Chair

Dr Ramesh Bhat, ICRAR/Curtin University
(April 2020 to May 2023)

Dr Stanislav Shabala, University of Tasmania
(May 2023 to May 2026)

Members

Dr Craig Anderson, NRAO
(October 2022 to May 2025)

Dr Hayley Bignall, Manly Astrophysics
(October 2022 to May 2025)

Dr Michelle Cluver, Swinburne University of Technology
(May 2020 to October 2022)

Dr Adelle Goodwin, Curtin University
(October 2022 to May 2025)

Dr Yik Ki Ma, Australian National University
(October 2022 to May 2025)

Dr Emil Lenc, CSIRO
(October 2020 to May 2023)

Dr Nickolas Pingel, Australian National University
(October 2020 to May 2023)

Dr Ryan Shannon, Swinburne University of Technology
(October 2020 to May 2023)

Dr Ivy Wong, CSIRO
(October 2021 to May 2024)

Student members

Mr James Kwanyin Leung, University of Sydney
(October 2021 to May 2022)

Mr Emily Kerrison, University of Sydney
(October 2022 to May 2023)

Mr Peter Macgregor, University of Sydney
(October 2022 to May 2023)

Ms Yuanming Wang, University of Sydney
(October 2020 to May 2022)

Executive Officer

Dr Vanessa Moss, CSIRO

ATNF Time Assignment Committee

Chair

Dr Adam Deller, Swinburne University of Technology
(February 2021 to July 2023)

Voting members

Prof Geoff Bicknell, Australian National University
(February 2020 to July 2022)

Dr Jess Broderick, ICRAR/Curtin University
(February 2021 to February 2023)

Dr Manisha Caleb, University of Sydney
(February 2022 to July 2024)

Dr Shi Dai, Western Sydney University
(February 2022 to July 2024)

Dr Kathryn Grasha, Australian National University
(February 2022 to July 2024)

Dr Kelly Gourdji, Swinburne University of Technology
(February 2023 to July 2025)

Prof Karl Glazebrook, Swinburne University of Technology
(February 2023 to February 2024)

Dr Katie Jameson, CSIRO
(February 2020 to July 2022)

Dr Jongwhan Rhee, ICRAR/University of Western Australia
(February 2021 to July 2023)

Dr Tessa Vernstrom, ICRAR/University of Western Australia
(February 2022 to July 2024)

Ex-officio

Dr Douglas Bock, CSIRO

Dr Jamie Stevens, CSIRO

Dr George Heald, CSIRO

Secretariat

Dr Elizabeth Mahony, CSIRO

Research theses

Theses awarded to co-supervised students (PhD, unless marked otherwise).

NAME	UNIVERSITY	MONTH AWARDED	THESIS TITLE
Albany Asher (MRes)	Western Sydney University	July 2022	A Novel Approach to Relativistic Ray-tracing Technique in N-body Simulation
Mark Edwards (Masters)	University of Sydney	June 2022	A volume-limited survey for radio-loud M-dwarfs with the Australian Square Kilometre Array Pathfinder
Daniele d'Antonio	University of Technology Sydney	December 2022	Radio afterglows of Gravitational Waves
Samuel Darwell (Hons)	University of New South Wales Canberra	October 2022	Polarimetric and Spectral Analysis of Near-Earth Asteroids Observed by the Southern Hemisphere Asteroid Radar Program
Rami Mandow (MRes)	Macquarie University	November 2022	Evaluating New Millisecond Pulsars from the Parkes Pulsar Timing Array Observing Program
Perica Manojlovic	Western Sydney University	June 2022	Searching for Clusters using Large ASKAP and ATCA Surveys
Shannon Melrose	University of New South Wales	August 2022	A column density probability distribution function analysis of the Vela Molecular Ridge Cloud C and G333 giant molecular clouds
Blake Molyneux (Hons)	Australian National University	December 2021	Characterizing Near Earth Asteroids using the Southern Hemisphere's novel Planetary Radar System
Steve Prabu	Curtin University of Technology	August 2021	Advantages and Limitations of using the Murchison Widefield Array for Space Surveillance: A Feasibility Study
Renzhi Su	Shanghai Astronomical Observatory, CAS	March 2023	The Observational Studies of HI 21-cm Absorption
Jishnu Thekkeppattu	Curtin University	July 2022	Towards Detection of Redshifted 21-cm Signal form Cosmic Dawn and Epoch of Reionisation
Miranda Yew	Western Sydney University	June 2023	Classification and Alignment of DRAGNs
Yuanming Wang	University of Sydney	June 2023	Image-Plane Radio Transients on Short Timescales with ASKAP
Ziteng Wang	University of Sydney	March 2023	Exploring the Transient Radio Sky with ASKAP

Observing programs

Proposals allocated time on ATCA, Murriyang and the LBA over the April 2022 – September 2022 and October 2022 – March 2023 semesters.

ATCA

OBSERVERS	PROGRAM	NO
Stevens, Edwards, Wieringa, Moss	ATCA Calibrators	C007
Lundqvist, Perez Torres, Ryder, Bjornsson, Fransson, Filipovic, Venkattu	Probing Type Ia Supernova progenitors with ATCA	C1303
Ryder, Marnoch, Kundu,Filipovic, Alsaberi, Anderson, Stockdale, Maeda, Renaud, Kotak	NAPA Observations of Core-Collapse Supernovae	C1473
Edwards, Stevens, Ojha, Kadler, Wilms, Rowell, Einecke	ATCA monitoring of Fermi gamma-ray sources	C1730
Possenti, Wieringa, Esposito, Israel, Rea, Burgay	Continuum radio emission from magnetars in outburst	C2456
Russell, Miller-Jones, Sivakoff, Altamirano, Soria, Krimm, Tetarenko	Jet-disc coupling in black hole X-ray binary outbursts	C2601
Russell, Altamirano, Ceccobello, Lucchini, Markoff, Miller-Jones, Russell, Sivakoff, Soria, Tetarenko	The evolving jet properties of transient black hole X-ray binaries	C3057
Breen, Walsh, Rowell, Ellingsen, Cunningham, Jones, Burton, Contreras, Voronkov, Ott, De wilt, Green, Longmore, Indermuehle, Fuller, Smith, Bronfman, Novak, Toth, Jordan, Hyland, McCarthy, Phillips, Federrath, Jackson, Fissel, Kainulainen, Dawson, Schneider, Avison	StarFISH	C3145
van Velzen, Miller-Jones, Anderson, Goodwin, Shappee, Jonker, Arcavi, Holoien, Gezari	Radio emission from stellar tidal disruption flares	C3148
Perez-Torres, Peña-Moñino, Gomez, Ortiz, Leto, Anglada, Trigilio, Amado, Alberdi, Osorio, Umana	Probing star-planet interaction in Proxima with the ATCA	C3180
Anderson, Bell,Hancock, Miller-Jones, Bahramian, Rowlinson, Aksulu, Bannister, van der Horst, Macquart, Ryder, Plotkin, Wijers	ATCA rapid-response triggering on Swift detected short gamma-ray bursts: Exploring the link with gravitational wave events	C3204
Plotkin, Miller-Jones, Gallo, Jonker, Russell, Homan, Tomsick, Kaaret, Shaw	The Disk/Jet Connection for Hard State Black Holes	C3219
Piro, Troja, Ricci, Wieringa, Ryan, van Eerten	Late-time emergence of the radio kilonova of GW170817	C3240
Dobie, Murphy, Kaplan, Lenc, Brown, Stewart, Hotokezaka, Bannister	Long term radio follow-up of GW170817	C3251
Laskar, Alexander, Berger, Bhandari, Chornock, Coppejans, Drout, van Eerten, Fong, Guidorzi, Margutti, Mundell, Schady, Schroeder	GRB Physics with ATCA: Direct Implications for the Explosions and Progenitors	C3289
van Den Eijnden, Degenaar, Russell, Miller-Jones, Wijnands, Sivakoff, Hernandez Santisteban, Rouco Escorial	Observing evolving jets during a Be/X-ray binary outburst	C3299
Pineda, Villadsen, Moss, Zic	ATCA Search for Planet-Induced Radio Emissions	C3303
Horiuchi, Benner, Benson, Edwards, Stevens, Phillips, Stacy, Giorgini, Molyneux, Cashman, Slade, Kruzins, Molera Calves	Southern Hemisphere Radar Observations of Near-Earth Asteroids (NEAs)	C3319
McCarthy, Ellingsen, Voronkov, Burns, Orosz, Hyland, Green, Breen	ATCA follow-ups of maser flares	C3321
Laskar, Alexander, Berger, Bhandari, Blanchard, Cendes, Chornock, Coppejans, Cowperthwaite, Duffell, Eftekhari, Fong, Gomez, Hajela, Hosseinzadeh, MacFadyen, Margutti, Metzger, Mundell, Nicholl, Paterson, Schady, Schroeder, van Eerten, Villar, Terreran, Williams, Xie	ATCA Follow-Up of NS mergers from LIGO/Virgo in O4	C3322

OBSERVERS	PROGRAM	NO
Alexander, Wieringa, Berger, Blanchard, Bright, Cendes, Chornock, Coppejans, Cowperthwaite, Eftekhari, Fong, Gomez, Hajela, Hosseinzadeh, Komossa, Laskar, Margutti, Nicholl, Saxton, Terreran, Williams	Exploring Mass Ejection in SMBHs via Radio Observations of TDEs	C3325
Anderson, Miller-Jones, Rau, Wilms, Goodwin, Kawka, Malyali, Liu, Grotova	ATCA follow-up of eROSITA-detected Tidal Disruption Events	C3334
Tothill, Rowell, Cunningham, Filipovic, Jordan, Voronkov, Crocker, Krumholz, Breen	Mapping the ionisation tracer HCO near the W28 SNR	C3348
Uscanga, Imai, Orosz, Gomez, Tafoya, McCarthy, Villafranca	Southern sky monitoring and imaging of water fountains with FLASHING program	C3361
Carotenuto, Corbel, Tzioumis	Constraining black hole accretion-ejection coupling at low accretion rate	C3362
Anderson, Bell, Rowell, Schussler, Taylor, Miller-Jones, van der Horst, D'antonio, Aksulu, Bahramian, Einecke, Hancock, Ohm, Plotkin, Rowlinson, Ryder, Wagner, Wijers, Zhu	ATCA Rapid-Response and Monitoring Follow-up of HESS-detected TeV Gamma-ray Bursts	C3374
Miller-Jones, Anderson, Wilms, Schmidt, Goodwin, Middleton, Rau	Jet-disc coupling at the Eddington limit: transient ultraluminous X-ray sources with eROSITA	C3375
Dobie, Murphy, Kaplan, Lenc, Stewart, Bell, Hotokezaka, Brown, Wang, D'antonio	ATCA Follow-up of Neutron Star Mergers	C3395
Ho, Dobie, O'Brien, Kaplan, Margalit, Perley	A New Class of Engine-Driven Stellar Explosions	C3409
Matthews, Margutti, Coppejans, Terreran, Bright, Laskar, Wieringa	The Radio Hunt for the Power Source in Superluminous Supernovae	C3417
Bright, Wieringa, Coppejans, Margutti, Laskar, Alexander, Matthews, DeMarchi	Radio Observations of a Fast Blue Optical Transient	C3419
Dobie, Murphy, Kaplan, Lenc, Stewart, Leung, Wang, Wang	ATCA Monitoring of a Candidate GRB Orphan Afterglow	C3424
Paduano, Bahramian, Miller-Jones, Kawka, Strader, Chomiuk, Heinke, Maccarone, Rivera Sandoval, Kamann, Dreizler, Husser, Göttgens, Willer	The Black Hole Population in 47 Tucanae	C3427
Urquhart, Patel, Yang, Thompson, Moore, Menten	Systematic Search for Hyper Compact HII regions	C3446
Leung, Ghirlanda, Murphy, Lenc	Late-time radio monitoring of GRB 171205A	C3447
Izzo, Auchettl, Leung, Murphy, Maeda, De Colle	The jet/cocoon emission in relativistic supernovae at radio frequencies	C3448
Hurley-Walker, Anderson, Galvin, Heald	ATCA triggered follow-up of an ultra-long period magnetar	C3451
Dannerbauer, Bakx, Bendo, Chen, Hagimoto, Imamura, Harrington, Satoya, Serjeant, Urquhart	Fuel for Star Formation: Molecular gas in the most intensely star-forming galaxies at the peak of cosmic evolution	C3452
Russell, van Den Eijnden, Degenaar, Altamirano, Beri, Del Santo, Marino, Segreto, Pinto, Ambrosi, Pintore, D'Ai'	Disk-jet coupling in the neutron star X-ray binary 4U 1820-30	C3456
Chen, Ellingsen, McCarthy, Mao, Breen, Yang	Extragalactic class I methanol masers related to shocks induced by rotational galactic bars?	C3457
De Becker, Benaglia, Marcote	Search for particle accelerators among a sample of Wolf-Rayet stars: insight into the synchrotron/binarity correlation	C3458
De Becker, Benaglia, Marcote	Search for particle accelerators among southern massive binaries with known absolute orbits	C3459
Curran, Darling, Edwards, Pihlstrom, Athreya	Ultra-Rare Redshifted OH Absorption in a Newly Detected CO Absorber	C3460
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Kurahara, Akahori, Ohmura	Broadband Full-Polarization Observation of Newly Found Head-Tail Galaxy in Abell 3322 with ATCA	C3494
Damato, Massardi, Lapi, Behiri, Giulietti, Galluzzi	The 2.1 GHz H-ATLAS survey: a new window on SMBH evolution	C3495
Troja, Ricci, Wieringa, Yang, O'Connor, Dichiara, Sakamoto, van Eerten, Ryan, Lien, Julakanti, Yang	Electromagnetic counterparts to gravitational wave events	C3500

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Behiri, Massardi, Lapi, Damato, Giulietti	Tuning into the Radio Emission of SFGs at z>1.5 with a Serendipitous 2GHz Survey	C3502
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Stevens	Observations of SPT-S J000056-6049.0 flare	CX505
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Galvin, Hurley-Walker	Observations of transient seen in MWA archival data	CX509
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This artwork by Wajarri Yamaji artist Judith Anaru represents an ASKAP survey science project called Commensal Real-time ASKAP Fast Transients (CRAFT). CRAFT surveys all the data coming in from ASKAP to find fast radio bursts. It also searches for other fast transients, which are radio signals that last for less than five seconds.

Judith Anaru, CRAFT, 2019, acrylic on canvas.

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