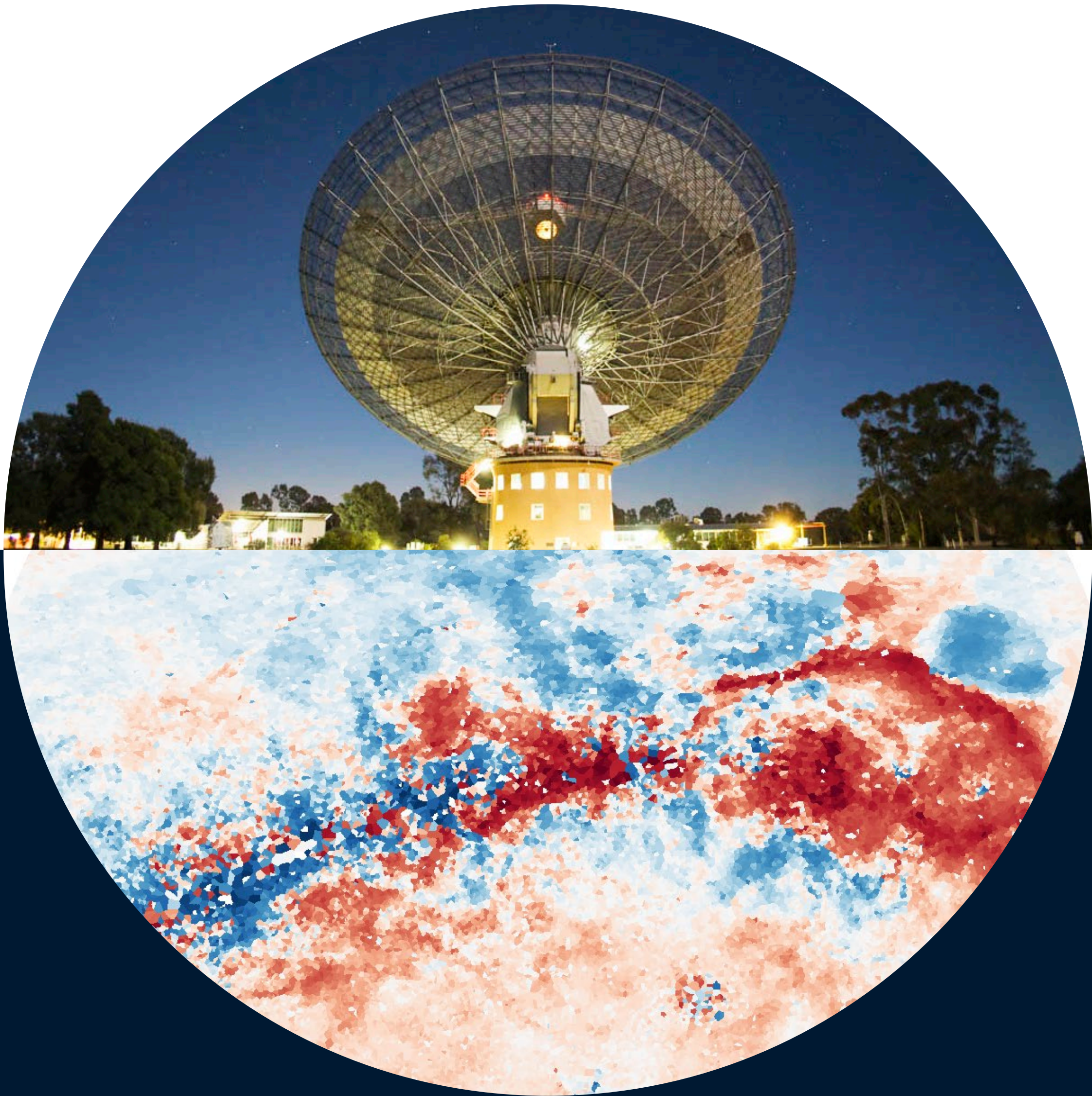
Australia's National Science Agency



Australia Telescope National Facility

Annual Report 2023–24

CSIRO Australia Telescope National Facility
Annual Report 2023–24

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This is the report of the CSIRO Australia Telescope National Facility for the period 1 July 2023 to 30 June 2024 and is endorsed by its Steering Committee. Telescope usage data spans the April to September 2023 and October 2023 to March 2024 observing semesters. Publication data is from the calendar year 2023.

Editors: Dr Marilena Salvo, Rachel Rayner

Cover: (Top) Murriyang, our Parkes radio telescope on Wiradjuri Country. Credit: Shaun Amy/CSIRO. (Bottom) The SPICE-RACS all-sky survey uses ASKAP to map the polarisation patterns in our sky. Blue sections are moving towards us, red sections are moving away. See page 17. Credit: Alec Thomson/CSIRO

Traditional owners

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

The Radiophysics Lab, Marsfield, Wallumattagal

Paul Wild Observatory, Narrabri, Gomeroi People

Parkes Observatory, Parkes, Wiradjuri People

Mopra Observatory, Coonabarabran, Gamilaroi People

ARRC, Kensington, Whadjuk People of the Noongar Nation

WA Observatory Support Facility, Geraldton, Nhanhangardi, Naaguja, Wilunyu and Amangu Peoples

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

Below: Each of ASKAP's survey science projects were presented with a painting by a Wajarri Yamaji artist. This painting by Agnes Boddington, FLASH, was inspired by the ASKAP First Large Absorption Survey in HI (FLASH) project. Agnes Boddington, *FLASH*, 2022, acrylic on canvas.

Contents

About us

On behalf of the Australian Government, we develop and operate several world-class radio astronomy observatories, telescopes, instrumentation and data archives that are collectively known as the Australia Telescope National Facility (ATNF). We are leaders in radio astronomy and are composed of specialists who work across operations, research and technology.

The ATNF includes the Paul Wild Observatory, the Parkes Observatory and the Mopra Observatory in New South Wales, which are home to the Australia Telescope Compact Array (ATCA), Murriyang, our Parkes radio telescope, and the Mopra radio telescope. At Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory in Western Australia, we operate our ASKAP radio telescope.

Our international reputation in radio astronomy has been built on our innovation in instrumentation. Murriyang is more than 60 years old but with advances in receiver technology and signal processing delivered by our engineers, has continued to be state-of-the-art. ATCA is currently undergoing a transformational upgrade of its entire signal processing system crucial to pursuing the science at which it excels, including the burgeoning field of transient sources. ASKAP is equipped with innovative phased array feeds with an unprecedented field-of-view and bespoke digital signal processing systems that process 100 terabits per second of raw data.

The sheer volume of information produced by our new instruments has created a major shift in radio astronomy, with large, centralised archives and high-performance computers replacing the old paradigm of individual astronomers processing data on their own devices. For example, ASKAP includes a supercomputer as part of its system design with astronomers accessing data through our specially designed archive, CASDA. This pathway leads directly towards the SKA project, where data volumes are another order of magnitude greater still.

Data from all our instruments are freely available to researchers. Their importance has been recognised, with the first fast radio bursts discovered in archived Murriyang data. Last year, astronomers published 137 papers using data enabled by our telescopes, specialist instrumentation and data management capabilities. Our three data archives currently hold 12 petabytes of data, and are complemented by our catalogues, databases and software packages used for obtaining and processing data from our facilities.

The ATNF's pivotal role in radio astronomy nationally and internationally makes the facility an important partner in the international SKA project. We, as CSIRO, are partnering with the SKA Observatory (SKAO) to build and operate the SKA-Low telescope in Australia, on behalf of the Australian Government. As such, our long-standing expertise in observatory management, instrumentation and data are supporting the global SKA project.

We manage Australian astronomers' access to NASA's Canberra Deep Space Communication Complex (CDSCC) and we bring together these antennas with ATCA, Murriyang, Mopra, and others in the southern hemisphere, to form the Long Baseline Array (LBA). Through our research and development program we ensure our telescopes remain world class and support development of other facilities around the world.

Astronomers from all over the world can access our telescopes for free, based on the scientific merit of their observing proposal. We receive about 200 unique proposals annually, this year representing more than 700 astronomers. Telescope time can also be purchased.

We also build innovation capacity for Australia and inspire 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 the Paul Wild, Mopra and Parkes Observatories, while a Radio Quiet Zone gives special protection to Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, site of the SKA-Low and ASKAP telescopes.

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 36).

Three of ATCA's six dishes at the Paul Wild Observatory on Gomeroi Country. Image: Emil Lenc/CSIRO

Chair's report

The Australia Telescope National Facility is unique, combining cutting-edge technological development with the operation of major national telescope facilities and conducting scientific research using these instruments. As a result, CSIRO, as the operating organisation of the ATNF, is a key contributor to Australia's acknowledged international success in astrophysics research.

In 2024, the ATNF has seen success in all of these areas. Development has continued on several new instrumentation projects: the CryoPAF for Murriyang; BIGCAT for ATCA; and CRACO for ASKAP. In telescope operations, one of the top priorities has been completing and processing observations for the survey science projects running on ASKAP. And at the same time, construction has continued on the SKA-Low site. Scientifically, we have seen high profile results on topics from neutron stars and fast radio bursts to cosmic magnetic fields, spanning multiple ATNF instruments.

The focus of the Steering Committee in 2024 has again been on the future of the ATNF and the future of the telescopes it operates. There are many external factors that impact funding and hence the capacity to continuing operating the entire suite of telescopes in the SKA telescope era. This brings uncertainty for the future. As such, the focus of the Steering Committee has been in guiding the ATNF to explore different paths and providing advice on possible options.

Throughout these discussions, three important points remain clear:

- Despite the enormous power of the SKA telescopes, each of the major ATNF instruments still has one or more areas in which it will provide substantial value to the user community.
- Technology development is a strategic strength of the ATNF and has been the basis of innovation and discovery for decades; it should remain at the forefront of any future plans.
- The ATNF plays a critical role in supporting the Australian astronomy community, even as the landscape changes and evolves.

After very productive discussions, the Steering Committee endorsed the proposed pathway to implementing the 'ATNF of the Future' strategy.

In May this year, the Steering Committee had the opportunity to visit Murriyang at Parkes. It was a great opportunity to chat with the extremely dedicated site staff and show our international visitors an Australian icon. For many of us, it brought back memories of the observing we have done throughout our careers (and we also had a chance to stock up at the visitors centre!).

This year's annual report summarises the accomplishments across all aspects of ATNF's science and operations. It reflects the dedication of ATNF staff to achieving excellence in scientific research, technological developments, and also service to the national and international astronomy communities.

I would like to thank all staff at the ATNF for this commitment throughout the year (and over many years). I would particularly like to thank the members of the two committees that the ATNF Steering Committee appoints – the ATNF User Committee and the Time Assignment Committee. These committees consist of members of the wider astronomy community, and their advice and input are critical to the smooth operation of the ATNF telescopes. The ATNF Steering Committee is a sub-committee of the CSIRO Board, and we commend this report to it.

Professor Tara Murphy

ASKAP on Wajarri Country.
Image: CSIRO

Director’s report

Since its formation, the ATNF has provided unique facilities and novel instrumentation for astronomers. This approach has not only underpinned the successes of our own facilities, but also allowed us to contribute our cutting-edge technologies, observing systems and software to other facilities, including the SKA project.

Developing instrumentation, software and archives for radio astronomy remained central this year: our unique CryoPAF receiver is set to transform the scientific capability of Murriyang; BIGCAT will enhance the capabilities and productivity of ATCA; the software behind ASKAP’s data pipeline generates science-ready products for the community; and our new fast radio burst detection system, CRACO, is expanding our capabilities in managing huge data rates in real time. These upgrades are driving early SKA-related science, supporting the development of the SKA regional science centres and will ensure our facilities play an important role in the SKA-era.

Our teams have supported the SKA project onsite during construction in Australia and by contributing bespoke software and receiving systems. We continued to work closely with the Wajarri Yamaji to protect and promote their cultural heritage as the Traditional Owners and Native Title Holders of the land. It was another year of milestones for the project. We celebrated the first antennas for the SKA-Low telescope being installed on site in March by SKA-Low (SKAO-CSIRO) collaboration staff. We also hosted the international SKAO Council at Inyarrimanha Ilgari Bundara, our Muchison Radio-astronomy Observatory, where they visited SKA-Low during its construction.

Tracking spacecraft to enable space exploration by our partners remains an important source of revenue. In February, Murriyang was critical in downlinking the data from Intuitive Machines’ (IM) first lunar mission IM-1, the first US mission to land on the Moon since the Apollo era. The lunar lander ended up on its side with none of its antennas pointing to Earth. Within the IM tracking network, Murriyang was the only antenna able to downlink from the lander and its experiments.

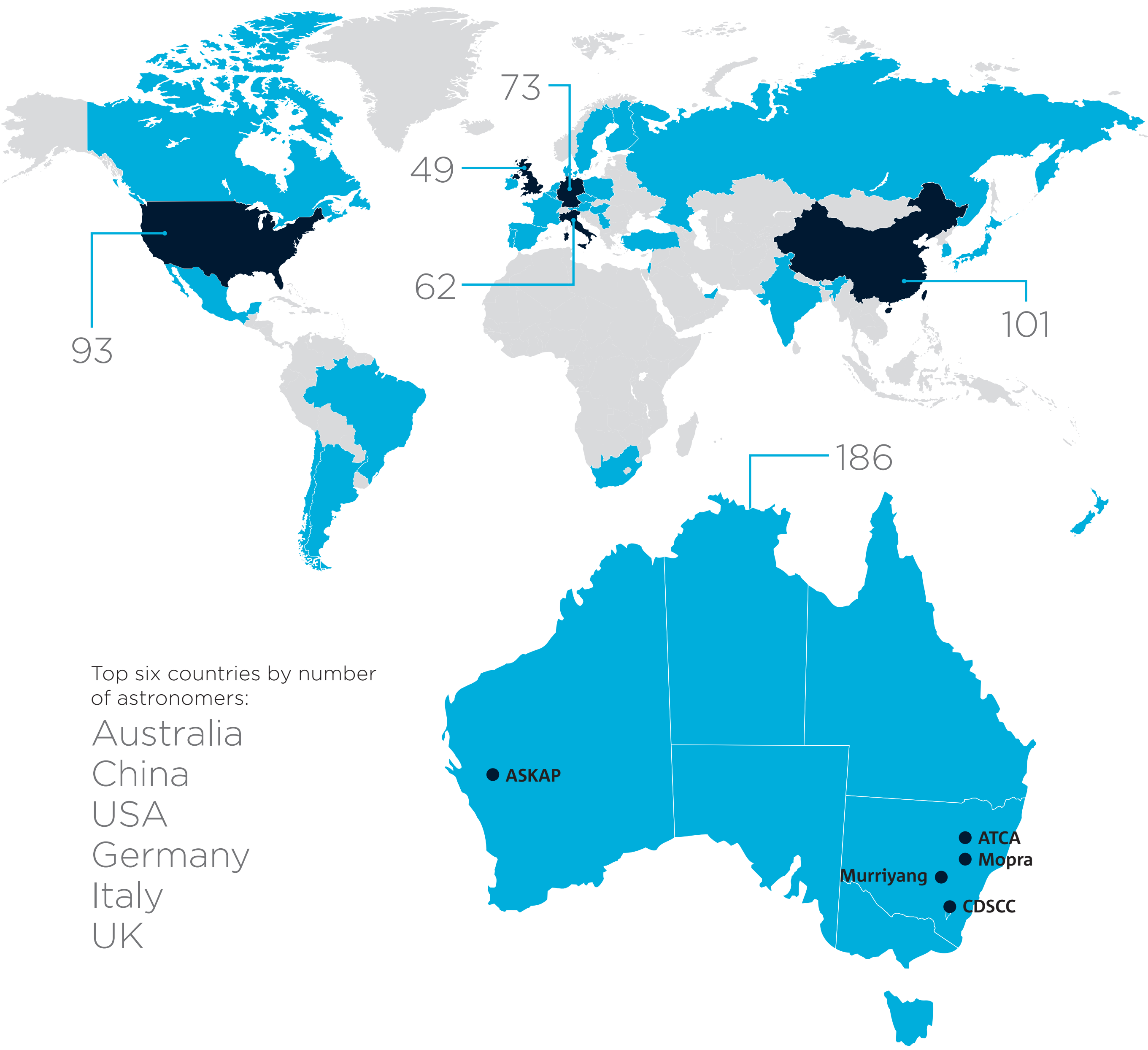
The engagement between our staff and the astronomy community is an important factor in all the work we do. Our staff continue to co-supervise students with our national and international university partners, train the next generation of radio astronomers with our radio schools, take active roles in the decadal plan working groups to ensure our sustained future and drive the next generation of science from our facilities. While I stepped down after six years as chair and vice chair of Commission J of the International Union of Radio Science, I continue the connection as a fellow. In November, our principal engineer in spectrum management, Carol Wilson, became the first woman to chair the Radiocommunication Assembly at the International Telecommunication Union.

I congratulate all ATNF staff on their successes 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 2023–24

323 observing proposals
775 astronomers
from 35 countries



Top six countries by number of astronomers:

Australia
China
USA
Germany
Italy
UK

Time spent observing
65% ATCA
69% Murriyang

12.0
petabytes
in the data archives

191
papers
by our staff

137
papers
cite ATNF data

210
staff

45
postgraduate students

~400
school students
completed PULSE@Parkes

99 316 people
attended our visitors centres

Murriyang, our Parkes radio telescope

Murriyang, our Parkes radio telescope, on Wiradjuri Country, is the only large single dish radio telescope dedicated to science in the southern hemisphere. The majority of observing time in the last year was focused on the transient science at which Murriyang excels. The Parkes Pulsar Timing Array collaboration is a key part of a global network that in effect forms a gravitational wave detector the size of the Milky Way. After two decades of searching, strong evidence has now been found for very low-frequency gravitational waves, spurring our astronomers to continue their efforts in this area of fundamental astrophysics (see page 16).

The reliability of our telescope and the sensitivity and broad bandwidths offered by our ultra wide-bandwidth low (UWL) receiver has proven to be a powerful tool for follow-up of pulsar and transient discoveries made with international telescopes (see pages 16–19). Many science projects utilised the UWL, designed and built by CSIRO, which has become the workhorse of the telescope since its installation in 2018.

One of these science projects is a broadband polarimetric survey of the southern sky in conjunction with ASKAP, capitalising on the unique and complementary capabilities of these two very different telescopes.

The latest development for Murriyang is the new cryogenically cooled phased array feed (CryoPAF) receiver. Engineering work continued throughout the year on this powerful survey instrument, with observation proposals for shared-risk time accepted from the user community (see page 10).

A major program of 20-year maintenance on the telescope began this year with replacement of the telescope's azimuth bearings, which were last replaced in 1994. The telescope has inbuilt hydraulics to support the 1000 tonne weight of the dish allowing the bearings to be extracted and replaced. Operations went smoothly with the work completed ahead of schedule. This refurbishment program by our operations team, together with new instrumentation delivered by our engineering team, secures the reliability and longevity of our iconic telescope well into the future.

Murriyang on Wiradjuri Country.
Image: Shaun Amy/CSIRO

ATCA on Gomeroi Country. Image: Alex Cherney/CSIRO

Australia Telescope Compact Array

The Australia Telescope Compact Array (ATCA) is an array of six precision 22m antennas, forming a versatile and sensitive interferometer telescope situated at our Paul Wild Observatory on Gomeroi Country. A strength of ATCA is its ability to respond to unpredictable astronomical events, in some cases almost instantaneously. This 'rapid response' capability is rare and highly sought after within radio astronomy. This has enhanced ATCA's role in following up transient events, an important and burgeoning research area in astronomy. This role will be further exploited with the advent of a completely new and flexible correlator called BIGCAT (see page 10).

Promising results have already been obtained from in-situ tests of the sophisticated hardware to be installed for BIGCAT, including our specialised Jimble processing boards and wider-bandwidth RF conversion systems. Successful correlations, or 'fringes', were obtained between two antennas equipped with the new BIGCAT hardware, allowing close cross-checking with the existing CABB correlator, for system verification. Upgrades to the frequency conversion systems are being progressively implemented, with some of the local oscillator modules being upgraded to allow entirely independent frequency selection per antenna.

In parallel to BIGCAT, a program of upgrades to improve the reliability and efficiency of the antenna systems commenced this year. The importance of these antenna upgrades was underscored by a recent failure of the backup generator on antenna CA06, leading to the purchase of new generators for all antennas. Antenna CA02 was the first to be fitted with a new travel drive system and modern air conditioners, vital for system stability. The receiver turret machinery on antenna CA06 was replaced, allowing switching to and from the 7mm-band receiver far more efficiently than previously. A completely new azimuth drive system was trialled on antenna CA04. All upgrades are progressing well, with minimal disruption to rapid response requests and the usual program of observations.

ASKAP radio telescope

The ASKAP radio telescope is an array consisting of 36 antennas, each 12m in diameter, situated at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, on Wajarri Yamaji Country in the Murchison region of Western Australia about 800 km north of Perth.

This year, the focus was on sustained survey operations for the Survey Science Projects. ASKAP's pipeline (see page 10) and autonomous scheduling system is performing well with a large pool of survey observations, achieving high observing efficiency. We also offered guest science project time on ASKAP for the first time in the observing semester starting in October 2023, with 10 proposals submitted to date.

Obtaining the necessary data throughput rates on supercomputing infrastructure remained a challenge throughout the year. We worked collaboratively with the Pawsey Supercomputing Research Centre to improve the workflow associated with ASKAP observations.

Even so, in the last 12 months of survey operations, guest science and other observations brought the volume of data products stored in the public science data archive CASDA up to 7 PB. This includes three frequency bands of the Rapid ASKAP Continuum Survey and an early all-sky survey that is now the benchmark for catalogues of radio sources at frequencies between 700 MHz and 1.8 GHz (see page 17).

ASKAP on Wajarri Yamaji Country. Credit: CSIRO

ASKAP's unique capabilities as a sensitive wide-field survey instrument delivering science-ready data products into the publicly accessible CASDA, continue to set the standard for end-to-end delivery of high impact science to astronomers, as we move into the SKA telescopes era.

Long Baseline Array

The Long Baseline Array (LBA) is a partnership between CSIRO, the University of Tasmania, SpaceOps NZ and SARAO. Managed by CSIRO, radio telescopes across the southern hemisphere are combined to perform very long baseline interferometry, or VLBI. The fine angular resolution achieved by having telescopes spread between continents means intergalactic phenomena can be studied in great detail, probing astronomical origins and providing more insight into the physics of our Universe.

The bulk of this year's LBA observations occurred during four VLBI sessions. There were 17 projects involving 35 observations, including participation in Global Millimetre VLBI Array and European VLBI Network observations. Further tests with the Giant Metrewave Radio Telescope in India were also conducted to assess feasibility for extension of the VLBI, showing promise.

Data from LBA observations were correlated at the Pawsey Centre in Perth using Setonix, the most powerful research computer in the southern hemisphere. The DifX correlator software package, which was developed in Australia but is now used world-wide, allows the complex task of correlating the data-streams from each pair of telescopes to be performed on a general purpose computer, rather than using the very specialised VLBI hardware required previously. Time on Setonix is allocated on merit and this year we correlated data from 353 hours of observations and used 200,000 hours of CPU time, producing a total data volume of 353 TB.

The median time from observation to data release was 70 days, an improvement on last year by over 10 per cent. This includes a median 48 days for transferring data from all telescopes to the Pawsey Centre. LBA data are now archived to CASDA. A project migrating past data to CASDA is progressing well, with data from 2020 onwards now available.

WA Observatory Site Entity

CSIRO operates Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, on Wajarri Country on behalf of the nation as the host site for world-class radio astronomy, including our ASKAP radio telescope.

The SKAO's low frequency telescope, SKA-Low, one of two telescopes being built by the SKAO on behalf of the international community, is under construction on the observatory site.

The latter half of 2023 saw the SKAO Council, the governing body of the SKAO, visit Wajarri Yamaji Country and the SKA-Low construction site for the first time. During the visit, Council members participated in an art project with Wajarri artist Susan Merry, organised by the Site Entity team. Susan's resulting artwork, *Our Home*, was gifted to the SKAO by Australia for permanent display at SKAO headquarters in Manchester, UK.

We supported the protection of Wajarri cultural heritage across the observatory, engaging closely with the Wajarri Heritage Service Provider to coordinate heritage monitors who ensure culture is preserved through all construction activities on site. We are also facilitating increased usage of Wajarri language at the observatory, with the name for the SKA-Low construction camp Nyingari Ngurra, meaning zebra finch home, introduced in March. We also work closely with the SKAO and Wajarri community on land care and management, including supporting the protection of threatened species on site and liaising with the Western Australian Government for environmental surveys and permits.

The SKA project

The SKA Observatory (SKAO) is leading an international €2b 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 where the SKA-Low telescope is being built, on behalf of the Australian Government.
- Contributing to construction of the SKA-Low telescope through contracts ranging from overseeing site civil infrastructure to software for the science data processing pipeline (see page 11).
- Australian partner of the SKAO for construction and operation of the SKA-Low telescope
- Partner in the Australian SKA Regional Centre (AusSRC), one in a global network of facilities through which astronomers will access data from the SKA telescopes. The AusSRC has been formed in partnership with The University of Western Australia, Curtin University and the Pawsey Centre with funding from the Australian Government.

Susan Merry, *Our Home*, 2023, acrylic on canvas (detail)

Technology development

A defining feature of the ATNF and a core activity into the future is the development of world class instrumentation for radio astronomy. We are currently 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.

Laying components for the CryoPAF. Image: Karl Schwerdtfeger/CSIRO

CryoPAF

Development of an innovative cryogenically cooled phased array feed (CryoPAF) receiver for Murriyang has continued. The commissioning activities have commenced with the CryoPAF system on the ground, as some rework of this groundbreaking instrument has delayed installation.

The cryogenically cooled radio frequency system, which includes the antenna feed, the low noise amplifiers and the cooling dewar system, has needed rework to mitigate the potential for vacuum leaks to develop, and further work is occurring to mitigate outgassing. Development of the extensive firmware and software has progressed and multiple science use case outputs are ready for testing and commissioning, with further development needed to meet the full system requirements. 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.

Quasar

Quasar Satellite Technologies (Quasar) are repurposing our advanced phased array feed technology for use in space domain awareness, successfully creating a satellite ground station demonstrator capable of tracking five satellites using Quasar's pass booking system. Quasar marked its entry into commercialisation with a prototype ground station that tracks multiple satellites using a single phased array. In February 2024, Quasar was selected as one of seven companies – and the only international organisation – to join the 13th Catalyst Accelerator, backed by the US Air Force Research Laboratory. After a successful program, Quasar was fast-tracked to participate in the U.S. Space Systems Command's SDA TAP Lab Apollo Accelerator Cohort 4.

BIGCAT

BIGCAT is a new system replacing the CABB digital backend for ATCA. It will use a combination of field-programmable gate arrays and graphics processing units to process data at twice the bandwidth of the current system and with much greater flexibility and reliability. In April 2024 a hardware test using the prototype conversion system and digital hardware was completed.

ASKAPsoft

A unique feature of ASKAP is our autonomous, high-performance processing pipeline that rapidly generates science-ready images and catalogues for researchers. These products are made available through our archive, CASDA. The pipeline uses our bespoke radio-astronomy processing suite, ASKAPsoft, developed to handle the demands of huge data. It permits the continual survey operations essential for ASKAP's large-scale Survey Science Projects and prepares us for the SKA telescopes.

ASKAPsoft provides the key tools needed to calibrate, image, and extract sources from ASKAP observations and, from the start, was designed to work efficiently on a high-performance computer. This year, we made numerous improvements in both capacity and efficiency to the pipeline and scaled it up to facilitate the added capacity provided by the Pawsey Centre's Setonix supercomputer.

CRACO

CRACO, a new cluster of computers and accelerators connected to ASKAP, continues to change our understanding of fast radio bursts. CRACO taps ASKAP's correlator to search trillions of pixels per second to find and localise the bursts.

CRACO was installed and commissioned late last year, with an initial version of the correlator and processing pipeline becoming operational. By June, 19 bursts had been found at a rate of approximately one per week, plus around 10 interesting transients. The detection rate is a factor of three times below what is planned. However, development of the second version of the pipeline is underway to achieve the full detection rate.

SKA-Low construction

We are providing project management and contract administration services under a professional services contract for SKA-Low infrastructure. The infrastructure to support installation of the first array assembly was largely completed, along with roads and an emergency airfield. Nyingari Ngurra, the 176-bed SKA-Low construction camp facility, was also completed and camp operations are now the responsibility of SKAO.

The SKAO installed the first antenna for SKA-Low in March and have since progressed at a rapid pace with more than 500 antennas already in place.

Our other construction contracts are also progressing: construction of the beamformer and correlator for SKA-Low, overseeing the testing, integration and verification of the SKA-Low subsystems and developing software for science data handling and processing. The team working towards the central correlator and pulsar search/timing beamformers for SKA-Low has installed production systems in Geraldton and at the Pawsey Centre in Perth, on track to be used with the next SKA-Low array assembly.

RFI management

The ATNF remains engaged in spectrum management at national, regional, and international levels, helping to ensure good outcomes for science services, including radio astronomy, by providing delegates, vice-chairs, and chairs for the International Telecommunication Union's working parties in Propagation and Science Services. The World Radio Conference (WRC) 2023 concluded in December and produced two agenda items for WRC27 for which Working Party 7D (Radio astronomy) is responsible – a workload without precedent. Much work has gone into mitigation measures for our facilities to cope with the unprecedented proliferation of satellites emitting strong radio signals into our receivers, such as SpaceX's Starlink service. Work is ongoing and focusing on the imminent activation of direct-to-handset services at frequencies previously used only for terrestrial-only services.

Contractors work on laying mesh for the SKA-Low antennas. Credit: SKAO

Performance indicators

Telescope usage

The ATNF telescopes, ATCA, Murriyang and ASKAP, had performance indicators across this year of:

- At least 70% of time spent on successful astronomy observations
- No more than 5% of time lost to equipment failures.

The breakdown in time usage for each of these facilities, including the fraction of time in these two categories, is shown in Figure 1.

Successful observing time this year fell short of the 70% target for ATCA and Murriyang. For ATCA, this was attributed in large measure to fewer proposals from the user community in the first proposal period. To address this, a supplementary call for ATCA proposals was issued for the October 2023 Semester, which produced a significant increase in subscription, lifting the figure for successful observing to 71% for the second half of the reporting period. This was a positive indication that underlying demand for observing time is robust and will rebound to former levels in 2024–25 with the greatly enhanced capabilities and reliability of BIGCAT.

Time lost to faults at Murriyang was dominated by an unusually high number of individual equipment failures each resulting in the loss of observing time over an entire weekend. These incidents contributed to 10% of time lost and caused the successful observing time to dip slightly below 70%. Major refurbishments to the telescope's drives and other systems currently underway will improve overall reliability in future, as will continued efforts to bring the technical staffing level up to its full complement after a number of staff retirements over the past 2 years.

For ASKAP, an indicator of 30% was set for successful astronomy in the year 2019–20, increasing by 10% each year to reach the same 70% target as the other two telescopes in 2023–24. Building this indicator for ASKAP incrementally over time recognises the complexity of the telescope, particularly in the automated processing of around 100 TB of data produced per day.

ATCA at the Paul Wild Observatory on Gomeroi Country. Image: Alex Cherney/CSIRO

In 2023–24, ASKAP achieved a figure of 64%, below the 70% target. Time lost to equipment failure was 6%, also slightly outside the target range. ASKAP is perhaps unique in having a supercomputer as an integral part, in the form of Setonix at the Pawsey Centre. Two unscheduled outages at the Pawsey Centre throughout the period were significant contributing factors to the ASKAP result, as were some continuing instabilities with Setonix. The two outages were comprehensively investigated by the Pawsey Centre, and ATNF and Pawsey staff continued to work closely together throughout the year to ensure the full potential of Setonix and other key resources were available on a sustained basis for ASKAP processing.

CDSCC antennas were used for 18 hours in single-dish observing, and contributed to the Long Baseline Array for 35 hours and to the East Asian VLBI Network for 2 hours. The antennas spent a further 72 hours as part of bistatic radar observations of near-Earth objects.

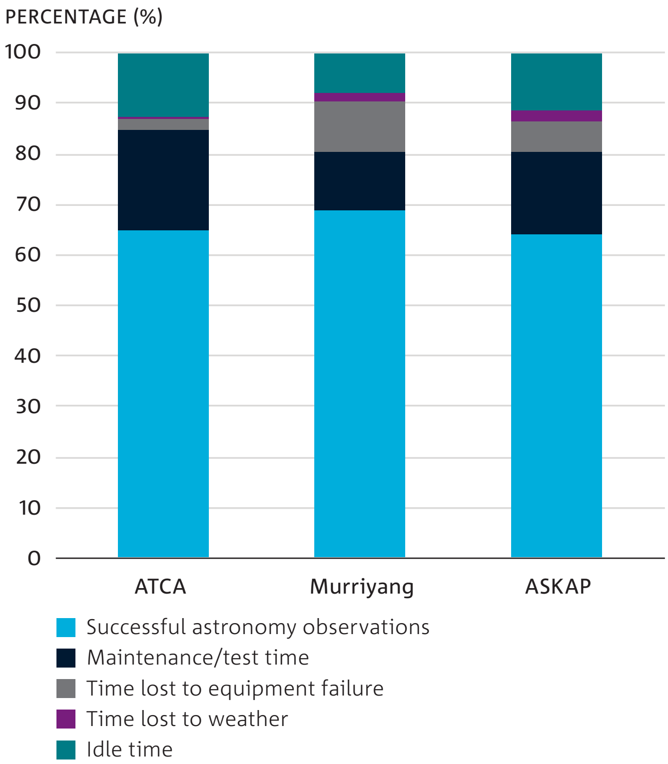


Figure 1: Use of ATCA, Murriyang and ASKAP in this reporting period.

Time allocation

There were 323 observing proposals received for ATCA, Murriyang, LBA, and for CDSCC antennas: 194 of these were unique proposals. CSIRO people led 23 unique proposals, 71 were led by staff of other Australian institutions and 100 by overseas researchers. The telescopes were in demand with an oversubscription rate of 1.7 for Murriyang, 1.75 for ATCA and 1.6 for the LBA. The observing groups included 775 unique investigators from 35 countries. After Australia, most proposers came from the USA, China, Germany, Italy and the UK.

In total 116 proposals were allocated time based on TAC gradings: 61 on ATCA and 55 on Murriyang. A supplementary call for proposals for the 2023OCT semester resulted in a further 33 proposals submitted for ATCA. Time allocation for ATCA and Murriyang is shown in Figures 2 and 3. Observing proposals are listed on page 27.

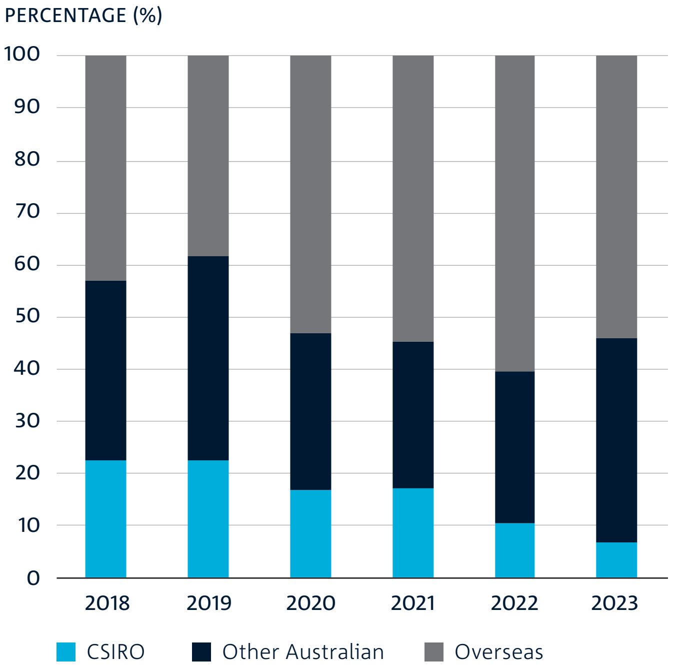


Figure 2: Time allocation on ATCA by affiliation of researcher.

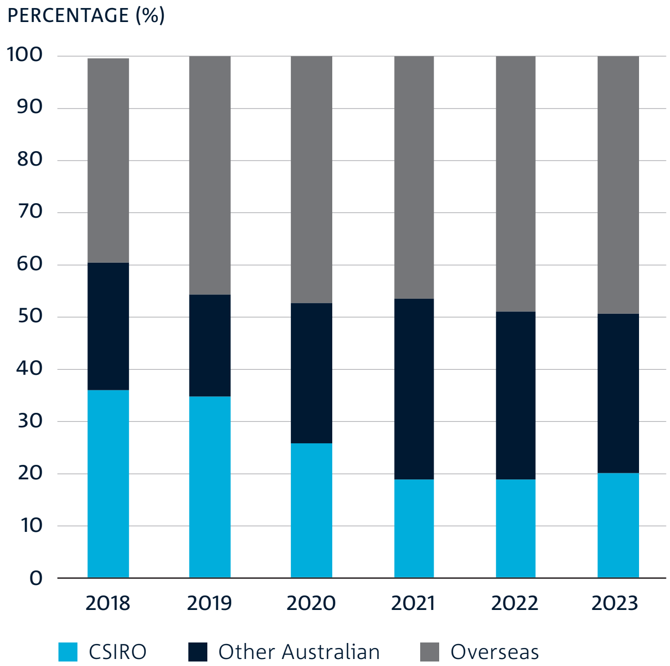


Figure 3: Time allocation on Murriyang by affiliation of researcher.

Data archives

Data processing pipelines and archives are an integral part of the ATNF:

- High-time-resolution datasets from Murriyang are archived in the CSIRO Data Access Portal. Searches of the Parkes pulsar archive on the portal total about 500 per month, with an average of 60 TB of pulsar data downloaded every month.
- Data from ASKAP are processed automatically using online pipelines. Science-ready data products are then made available in the science data archive, CASDA. Every day, CASDA receives about 600 virtual observatory requests and about 10 queries from the web user interface.
- All data from ATCA, as well as spectral line and continuum observations from Murriyang are archived in the Australia Telescope Online Archive (ATOA), which delivers 2 TB of data every month. These are currently being migrated into CASDA.

These data archives are increasing at approximately 4 PB each year, and this growth rate will double in a few years. Our continued upgrade path relates to improved pipeline data processing methods and towards cloud-based processing and access methods.

Publications

In 2023, 137 refereed papers were published that used data from ATNF telescopes: 76 (55%) included a CSIRO author. Our people published 191 refereed papers, including those using data from other facilities. Altogether, there were 232 refereed journal papers and 26 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 consistent with previous years.

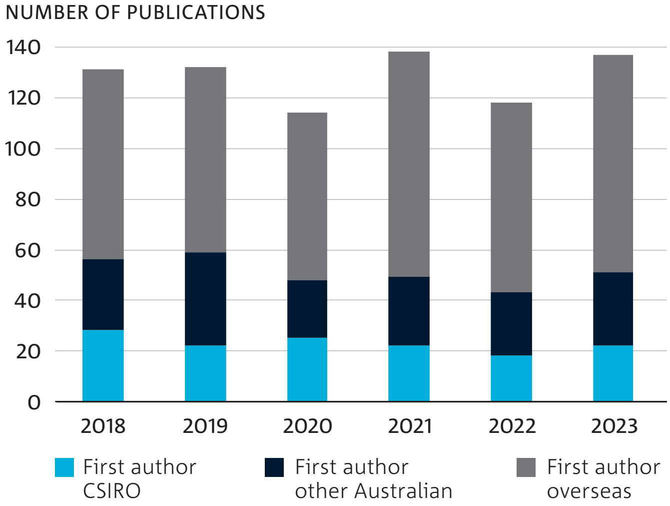


Figure 4: Publications using data from ATNF telescopes.

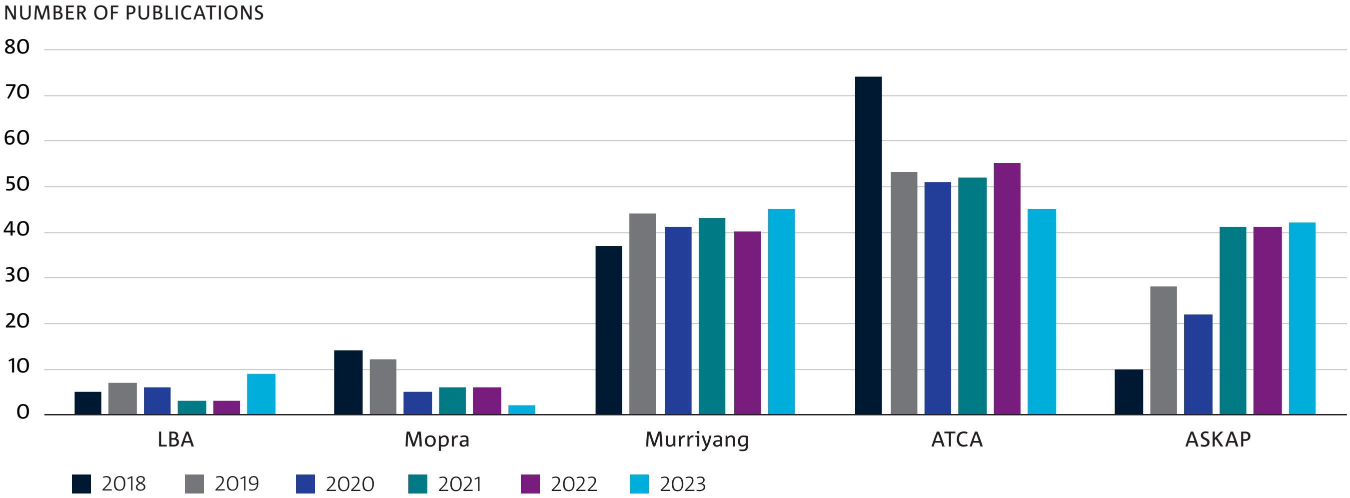


Figure 5: Publications using data from the ATNF, grouped by telescope. A few papers with data from more than one telescope are counted more than once.

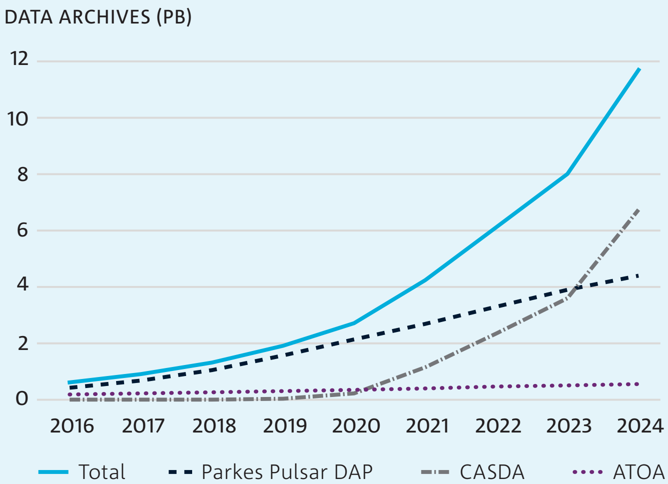


Figure 6: ATNF data archives over time.

Data on display. Credit: CSIRO

Science highlights

Probing the densest stars

What is a neutron star?

Neutron stars are born during supernova explosions of massive stars. Gravitational forces have turned the dense core left behind into a ball of mostly neutrons about 20km in diameter and spinning incredibly quickly. This intense environment produces a beam of radio waves to be emitted from the star's north and south poles. As it spins, these beams of radio waves flash across our sky, allowing us to detect them.

Why do we research them?

A neutron star is an example of physics in the extreme, allowing us to research forces and effects that can't be replicated on Earth. No one neutron star is like another, as they can be rotation-powered pulsars, or accretion-powered pulsars, or magnetars, or even radio-quiet mysteries.

Measuring neutron star jets

For the first time, the super-fast speeds of a neutron star's powerful jets were recorded. Researchers used ATCA and the ESA's Integral observatory for the study, which clocked the jets at 114,000km per second, which is one-third the speed of light!

Russell, T.D. et al. Nature 627, 763–766.

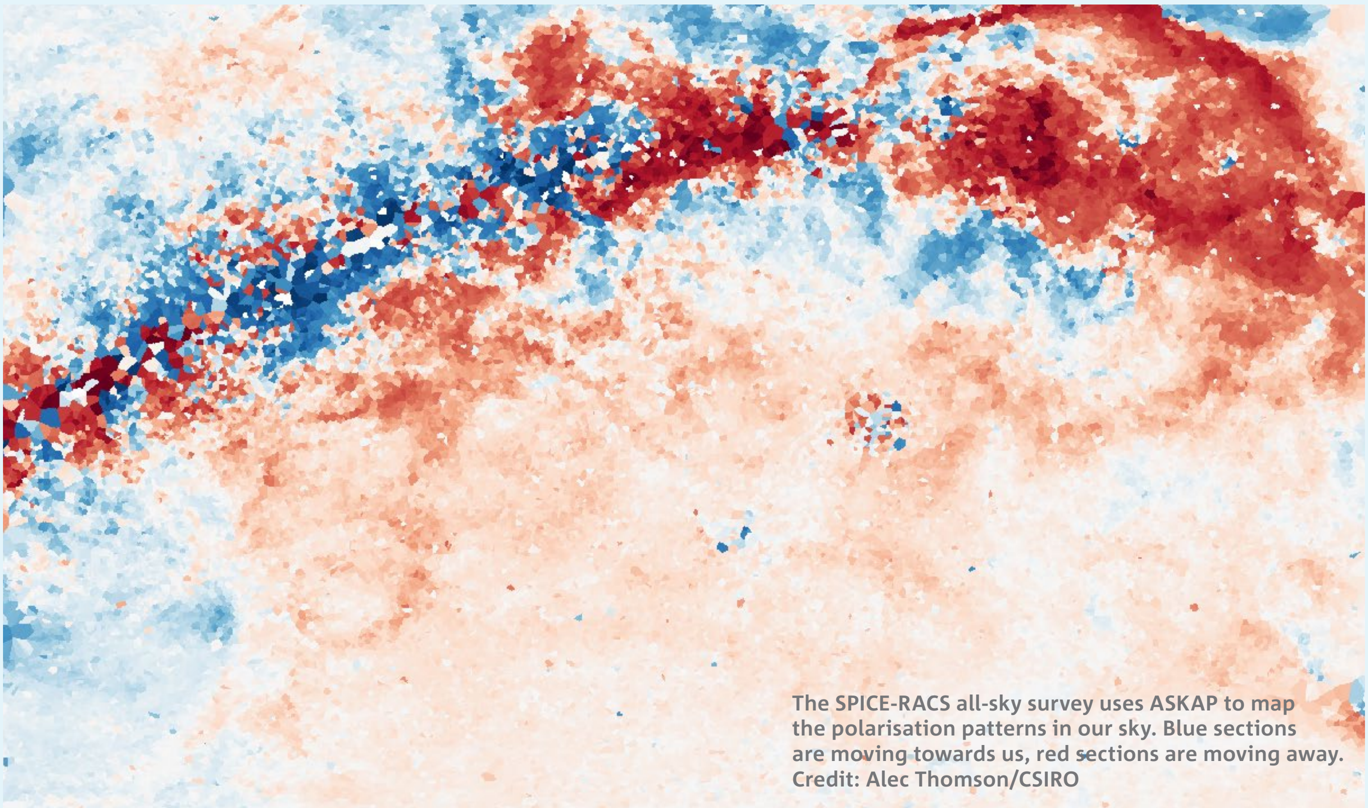
Studying the Universe's most powerful magnets

Researchers using Murriyang studied radio pulses from a previously dormant magnetar and revealed an unexpectedly complex environment. Unlike other magnetars – the Universe's most powerful magnets – this one is emitting enormous amounts of rapidly changing, circularly polarised radio waves.

Lower, M.E. et al. Nat Astron 8, 606–616.

Louise Webster Prize Dr Andrew Zic won the Astronomical Society of Australia's Louise Webster Prize 2024 for leading the third data release of the Parkes Pulsar Timing Array project using Murriyang. The perfect timing of a pulsar's radio beams can be ever so slightly disrupted by gravitational waves from coalescing supermassive black holes, helping us understand these ripples in space-time.

Artist's impression of a nuclear explosion on a neutron star, feeding the jets blasting off from the star's polar regions. Credit: Danielle Futselaar and Nathalie Degenaar, Anton Pannekoek Institute, University of Amsterdam.



The SPICE-RACS all-sky survey uses ASKAP to map the polarisation patterns in our sky. Blue sections are moving towards us, red sections are moving away. Credit: Alec Thomson/CSIRO

Using ASKAP to survey the radio sky

What is a sky survey?

Conducting surveys, in astronomy, is the process of collecting data on everything we can see in the sky. This comprehensive snapshot enables researchers to scan for anomalies, or points of interest, to follow up with other instruments like the future SKA telescopes. They can also be used to compare results from other wavelengths, like optical or gamma waves, to provide a deeper understanding of astronomical objects. Taking regular surveys and comparing results can help researchers find transients and variables, like pulsars. Many telescopes around the world are used to survey the sky and ASKAP is one of the best, capable of collecting the radio signals from many tens of millions of new galaxies.

What are we producing?

Using ASKAP, we are producing many iterations of our all-sky survey, the Rapid ASKAP Continuum Survey (RACS), which are freely available to the national and international astronomy community. First completed in 2020, this year marked a significant milestone with our team completing surveys in low, mid and high radio frequencies. Now available in CASDA, these huge data sets are important resources to be used in studies all around the world.

Duchesne, Grundy, Heald et al., PASA, 41, 2024

Our ASKAP radio telescope. Image: Alex Cherney/CSIRO

Variations on the data

SPICE-RACS is a survey which uses ASKAP's unique capabilities and our researchers' expertise in data processing, to create a revolutionary map of the magnetic fields in space. ASKAP's excellent ability to characterise the polarised emission of radio galaxies allows us to use the Faraday rotation effect to illuminate magnetised plasma in the foreground of these galaxies.

Available to all astronomers via CASDA, the survey is allowing us to probe cosmic magnetic fields and plasma distribution across the entire sky in unprecedented detail.

Artist's depiction of our ASKAP radio telescope with two versions of the mysterious celestial object emitting slow bursts. Is it a neutron star or white dwarf? Credit: Carl Knox/Oz Grav

Bursts in the radio sky

What is a radio burst?

Flashes of radio radiation, or bursts, are detected with our Murriyang, ATCA and ASKAP radio telescopes. These bursts have a variety of characteristics. They can come from distant sources in the depths of space, or from our own galactic plane. They can appear once or repeat frequently. Nearly always, their origin is a complete mystery. Understanding these origins has been a headlining topic in radio astronomy for the past few years.

Why study them?

It's not just trying to discover their origins which make bursts so interesting. Many bursts can be tools to illuminate other features of our Universe. By studying the properties of bursts, researchers can detect their interactions with matter through space, allowing researchers to map its distribution. But there's also studying dark matter or gravitational waves to keep astronomers busy. Bursts will be a focus for the SKA telescopes, built from this work.

Galactic bursts

ASKAP's unique wide-field of view allowed researchers to serendipitously detect an unusual source. While possibly emitted by a neutron star, this source flashes about once each hour: a much longer period than any other neutron star discovered. Another possible candidate is a white dwarf star. Telescopes such as ATCA or SARAO's MeerKAT will further probe its nature.

Caleb, Lenc, Kaplan et al. Nat Astron 8, 1159–1168

Intergalactic bursts

The newest object of radio-astronomy study, the fast radio burst, has been shown to have a range of characteristics, hinting at a variety of sources for the bursts. Using Murriyang's ultra-wide band receiver, researchers produced a multi-epoch monitoring campaign of fast radio bursts to determine common traits amongst different burst populations. Analysing the different radio frequencies as well as the polarisation of the sources has shown that some bursts are from highly dynamic magneto-ionic environments.

Kumar et al. MNAS, 526 3, 2023

Jackson-Gwilt Medal Dr Keith Bannister (CSIRO) and Prof Ryan Shannon (Swinburne University of Technology) received the 2024 Jackson-Gwilt Medal for pinpointing the origin of fast radio bursts with ASKAP. This follows the awarding of the 2023 Shaw Prize to the team who discovered fast radio bursts in Murriyang archival data.

International multiwavelength astronomy

Radio astronomy is one part of the whole spectrum of space. Multiwavelength astronomy is a hugely collaborative endeavour, involving engineers, researchers, and multiple facilities and institutions around the world. We support and enable this work through the availability of our world-class data, our merit-based proposal system, our unique locations, and by supporting our staff to collaborate internationally. This will continue into the SKA era. Our instruments do not work in isolation either, whether producing data at different frequencies for the same projects or connecting into the Long Baseline Array.

We are an integral part in the process of building a global body of knowledge, helping everyone to understand the complexities of our Universe.

Blazing through the galaxies

Blazars are galaxies that have huge active black holes at their centres, emitting powerful jets of fast-moving matter. Studying them allows us to observe matter and forces in the extreme. The best way to do this is to use VLBI alongside data from gamma-ray telescopes.

Using our LBA and NASA's Fermi space telescope, researchers hope the information they've gathered will answer fundamental questions on blazars such as what mechanisms create these jets, how is the jet material collected and accelerated, and what are the origins of the multiwavelength (radio wave and gamma ray) emission?

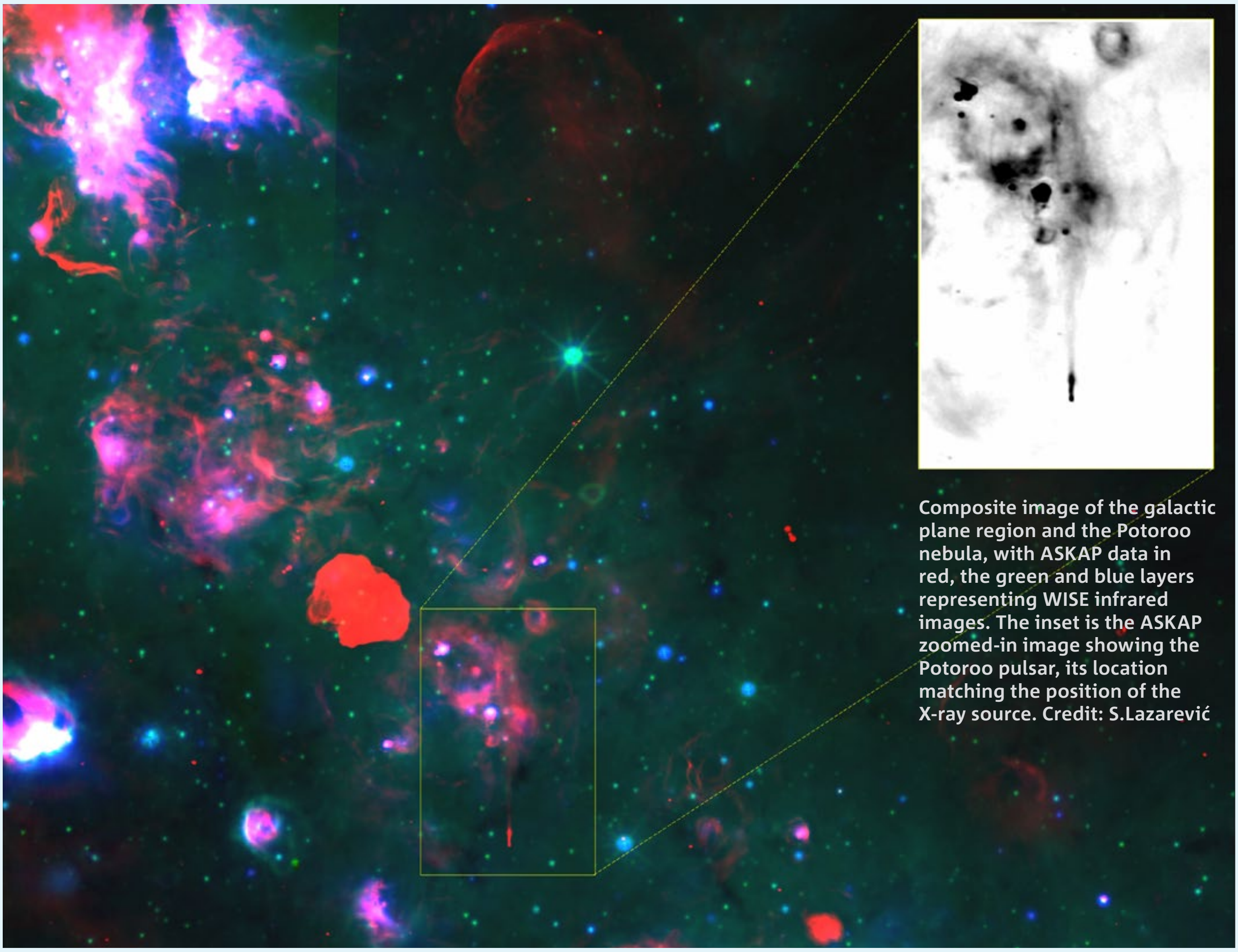
Benke et al., A&A 681 69

Discovering dynamic pulsars

The discovery of a bow-shock pulsar wind nebula, nicknamed Potoroo, and the young pulsar that powers the nebula, was enabled through multi-wavelength astronomy. Researchers used observations from ASKAP, Murriyang, SARAO's MeerKAT, plus NASA's Chandra space telescope and Wide-field Infrared Survey Explorer, to make the discovery.

This unusual pulsar has one of the longest radio tails observed, and is travelling at 2000km/s, generating a shockwave. A possible supernova may be the cause of this dynamic situation but, despite all the data, the tell-tale debris can't be found.

Lazarević et al., 2024 PASA 41 E032



Composite image of the galactic plane region and the Potoroo nebula, with ASKAP data in red, the green and blue layers representing WISE infrared images. The inset is the ASKAP zoomed-in image showing the Potoroo pulsar, its location matching the position of the X-ray source. Credit: S.Lazarević

Students, education and engagement

Postgraduate students

This year we co-supervised 45 postgraduate students who came from 19 universities, including five from overseas. Six PhDs, two Master's and one Honours degree were awarded during the year (see page 26).

Undergraduate students

Our undergraduate vacation student program had 13 students, including one Women in Engineering scholar, from nine universities. These students participated in astrophysics, engineering, computing and science communication research over the summer. Based at our sites around the country, all came together for an observing trip to ATCA in December. This gave students the opportunity to get close to the telescope and learn more about observing and operations. The students presented their work at a symposium in February, attended by CSIRO staff and affiliates.

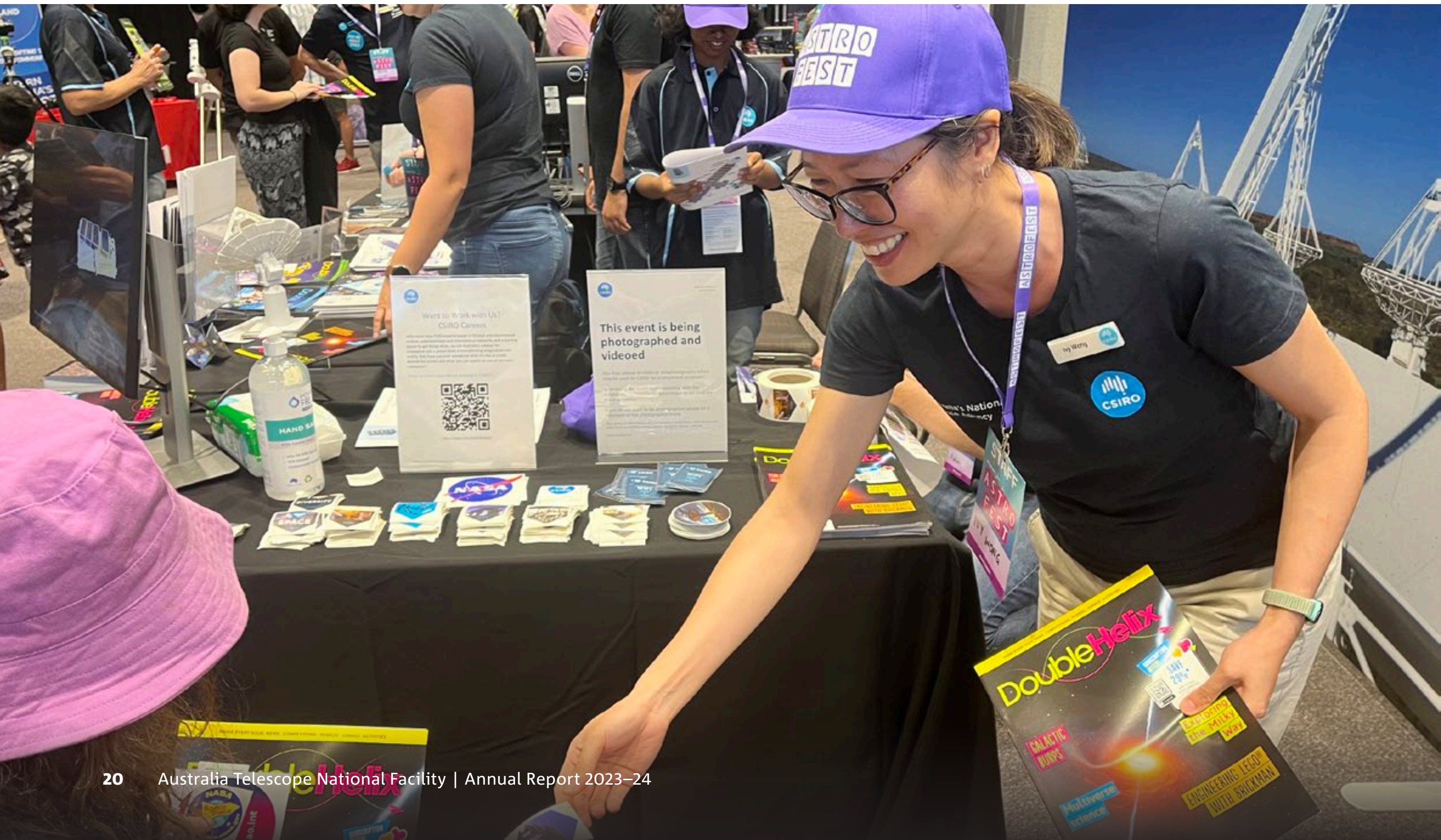
Schools and teachers

The Astronomy from the Ground Up! Teacher workshop was held at the Parkes Observatory in May, the first since 2019. Professional development sessions were held for teachers at science teacher conferences in NSW, Western Australia, Victoria and South Australia. ATNF staff participated in CSIRO's STEM Professionals in Schools and supported CSIRO's Generation STEM program careers expo.

PULSE@Parkes

The PULSE@Parkes program has thrived this year, with about 400 students, 20 schools and 30 teachers across the country participating. We ran a session for students and teachers at the Victorian Space Science Education Centre in March. Sessions are now routinely offered as online or onsite at Marsfield. We have a strong collaboration with the Generation STEM program run by CSIRO Education and Outreach, targeting schools across NSW. We also ran a session for CSIRO's Young Indigenous Women's STEM Academy students. A session ran at the Perth Astrofest in November, attracting many interested members of the public.

Science Leader Dr Ivy Wong connects with visitors at Perth Astrofest. Credit: CSIRO



Communications

This year we shared many research highlights, enabled by our instruments and archives, with domestic and global audiences across online, radio, TV and print media outlets and on social media. Stories that captured public attention included research into neutron stars, magnetars and pulsars, the discovery of a polar ring around a galaxy, and the new Rapid ASKAP Continuum Surveys.

We introduced a regular digital newsletter, ATNF News, to update our user community on recent discoveries, technology upgrades, and the people who make up the ATNF. We engaged the global astronomy community at conferences such as URSI GASS 2023. We developed new designs for the regular Parkes Observatory float in the Parkes Elvis Festival Parade. We also demonstrated research, engineering and collaboration with the ATNF at public events including National Science Week and Perth Astrofest, which attracted nearly 5000 visitors. ATNF scientists and engineers were supported with training and digital assets to present at these events, take part in panel discussions and engage with inspired young people.

Visitors centres

There were significant projects this year at our Parkes Observatory Visitors Centre to support an accessible, inclusive and diverse experience. The accessibility upgrade works were completed in December, with an official opening in February, which was attended by state and local ministers. The upgrades included a disabled-access playground and bathrooms, plus automatic doors to the visitors centre. We also gained agreement and increased the use of the Wiradjuri names gifted to the telescopes at our Parkes Observatory, including Murriyang, our Parkes radio telescope. The names, gifted by the Wiradjuri People, are part of our continuing collaboration with Indigenous communities and our commitment to CSIRO's reconciliation action plan. Work is underway to update billboards and other signs with the new names.

There were many unique engagement opportunities across both visitors centres, with Fizzics Education visiting our Paul Wild Observatory Visitors Centre and Parkes. Parkes hosted a number of other events including the 2024 Teachers' Workshop and the 2023 AstroFest. Winning entries in the 2023 David Malin Awards for astrophotography were put on public display in the Bowen Room, and have become a favourite attraction of Astrofest. The Dish Café closed its doors at the end of January for refurbishments and some reduction in visitor numbers was observed. The visitors centre has set up interim provisions, especially for the school holiday periods. The search for a new tenant for the café is in progress.

Number of visitors to Parkes Observatory and Paul Wild Observatory

	2018–19	2019–20	2020–21	2021–22	2022–2023	2023–2024
Parkes	112 224	100 013	103 185	72 612	93 763	85 818
Paul Wild	10 363	7434	19 659	10 740	13 776	13 498

The official opening of the accessibility upgrade works at Parkes Observatory was held in February 2024.

Our people

As at 30 June 2024, ATNF had 210 staff, including joint appointments. These data exclude honorary fellows, students and those working in the SKA-Low collaboration team.

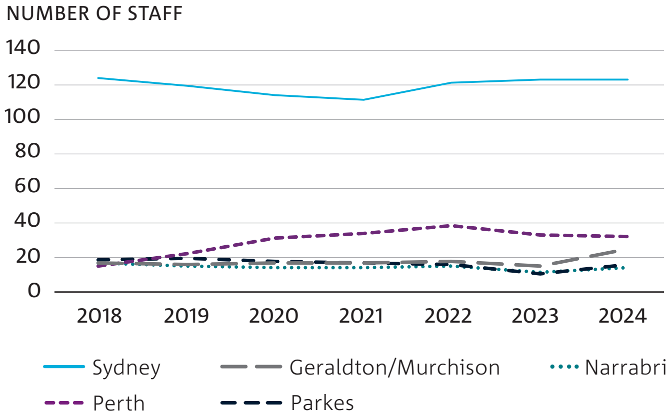


Figure 7: Our staff by site over time. There was an error in our previous report's staff numbers (June 2023). These have been corrected.

Space and Astronomy staff engage in discussion during a National Reconciliation Week event. Image: Joseph Mayers/CSIRO

Diversity

In 2023, CSIRO Space and Astronomy received the Silver Pleiades Award from the Astronomical Society of Australia's Inclusion Diversity Equity in Astronomy Chapter for making significant and positive progress to create a diverse and inclusive workplace.

We undertook a significant review of our impact, including undertaking a comprehensive engagement and consultation exercise with our people to listen, learn and understand how we are making a difference. The results of this informed the development of a Diversity Inclusion and Belonging Action Plan which we will implement over a three-year period focusing on leadership commitment, creating a psychologically safe work environment and increasing the diversity of our workforce.

Since then, we have implemented a greater level of accountability with detailed metrics and are weaving this into our business as usual activities to guide key decisions and activities, such as increasing consultation with our people and embedding changes into our everyday behaviours.

Across our sites we have celebrated key events throughout the year where we engage in important discussions with one another about how and why we show up, listen and learn to further our understanding.

Within the ATNF, increasing the number of women in technical services and research roles has been a focus and will continue to be a priority. We will continue to improve against these results, through targeted, focused and deliberate action to attract, recruit and retain women, especially into technical roles.

While we have made some positive impacts such as increasing the number of Aboriginal and Torres Strait Islander employees and people who identify as gender diverse, we have more work to do.

Diversity of ATNF science, operations and technologies staff

	TOTAL STAFF	ABORIGINAL AND TORRES STRAIT ISLANDER	WOMEN	DISABILITY	GENDER DIVERSE*	NON-ENGLISH-SPEAKING BACKGROUND
June 2021	156	3.20%	21.80%	8.33%	N/A	20.51%
June 2022	183	3.20%	24.59%	7.65%	0.57%	22.95%
June 2023	**194**	**3.09%**	**25.26%**	**9.27%**	**1.03%**	**25.77%**
June 2024	**210**	**6.19%**	**27.62%**	**7.14%**	**1.43%**	**27.62%**

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

Awards and honours

- The Silver Pleiades Award was presented to CSIRO Space and Astronomy from the Astronomical Society of Australia's Inclusion Diversity Equity in Astronomy Chapter.
- The Shaw Prize in Astronomy 2023 went to Prof Matthew Bailes, Swinburne University of Technology, Prof Duncan Lorimer and Prof Maura McLaughlin, both of West Virginia University, for the discovery of fast radio bursts.
- The 2023 CSIRO Medal for Support Excellence went to Lawrence Toomey for improving how users access data collected using Murriyang.
- Dr Ivy Wong was a recipient of the 2023 CSIRO Trusted Medal as a member of the 'CSIRO Presents: Everyday AI' team.
- The 2024 Jackson-Gwilt Medal was awarded by the Royal Astronomical Society to CSIRO's Dr Keith Bannister and Swinburne's Prof Ryan Shannon for pinpointing the origin of fast radio bursts with ASKAP.
- Astronomical Society of Australia's Louise Webster Prize was awarded to Dr Andrew Zic for the paper 'The Parkes Pulsar Timing Array Third Data Release'.
- Carol Wilson was elected as the Chair of the Radiocommunication Assembly 2023 in recognition of her outstanding contributions to the International Telecommunication Union and her expertise. She made history as the first woman to chair the Assembly.
- CSIRO's Dr Balthasar Indermühle and colleagues from Curtin University were the Academic Team of the Year at the Australian Space Awards 2024.

Health, safety and environment

Over the past 12 months we have focussed on enhancing our safety culture with a strong emphasis on safety leadership and management of critical risks. Executive team members continued to take accountability for reviews and control verifications of each critical risk, which are discussed at each monthly meeting. Our approval rate for risk assessment and control records has seen significant improvement, rising from 30% to over 80%, demonstrating our commitment to identifying and documenting risks. The collaboration between the Parkes Observatory team and HSE specialists in relation to high-risk maintenance and construction activities has been strong.

Our recordable injury frequency rates

PERIOD	HAZARDS REPORTED	SLTIFR	LTIFR	MTIFR	TRIFR	COMCARE REPORTABLE
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
2023–24	69	-	-	2.6	2.6	1

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.

The ATNF Steering Committee at Murriyang, our Parkes radio telescope. Image: CSIRO

Inspecting the phased array feed on Diggiedumble, one of ASKAP's 36 dishes. Each dish has a Wajarri Yamaji name. Image: CSIRO

Finance

CSIRO funding to meet ATNF operating costs in the financial year 2023–24 was $44.9m. This was supplemented with $12.7m external revenue from commercialisation activities, sale of telescope time, National Collaborative Research Infrastructure Strategy funding for ASKAP and other external contracts.

Compared with previous financial years, external revenue remained constant as did indirect appropriation. Direct appropriation had a one-off increase in funding to offset higher than anticipated cost of living. Salary costs increased by approximately $2.8m in line with annual salary increase and growth in staffing numbers. Travel costs increased, as interstate and overseas travel returned to pre-COVID levels. ATNF operating costs and overheads remained stable.

OPERATING (A$'000s)	YEAR TO 30 JUNE 2023	YEAR TO 30 JUNE 2024
Revenue		
External	12,525	12,735
CSIRO direct appropriation	22,559	25,013
CSIRO indirect appropriation[1]	19,825	19,908
Total revenue	**54,909**	**57,656**
Proportion of appropriation	77%	78%
Expenditure		
Salaries	22,035	24,884
Travel	923	1,374
Other operating	11,296	11,586
Overheads[2]	13,818	13,782
Depreciation and amortisation	6,007	6,126
Total expenses	**54,079**	**57,752**
Operating result	**830**	**-96**

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. Additional funding of $6m to repair the fibre optic cable between Geraldton and the observatory was provided by CSIRO.

CAPITAL (A$'000s)	YEAR TO 30 JUNE 2023	YEAR TO 30 JUNE 2024
Revenue		
CSIRO funding	1,620	3,194
CSIRO fibre optic cable funding		6,000
ARC LIEF	1,514	1,425
Total revenue	**3,134**	**10,619**
Expenditure		
Total expenditure	**3,134**	**10,619**

Research theses

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

NAME	UNIVERSITY	MONTH AWARDED	THESIS TITLE
Elizabeth Cappellazzo (MRes)	Macquarie University	January 2024	Tracing Interactions between HII Regions and their Natal Molecular Cloud
Saurav Mishra (MRes)	Macquarie University	October 2023	Hunt for millisecond pulsars around the sky region of OJ287 – a supermassive black hole binary
Pascal Keller	University of Cambridge	March 2024	Investigating the Epoch of Cosmic Reionisation with Radio Interferometers
Tomonosuke Kikunaga	Kumamoto University	March 2024	Wideband observation of radio pulsars towards detection of low-frequency gravitational waves
James Leung	University of Sydney	October 2023	A Multi-scale Radio Study of Gamma-ray Burst Afterglows
Joshua Pritchard	University of Sydney	September 2023	Searches for Stellar Radio Activity in Circular Polarisation
Gary Segal	The University of Queensland	November 2023	Detecting the unexpected in astronomical data using complexity based approaches
Susmita Sett	Curtin University of Technology	September 2023	Exploring the Southern Pulsar Population in Image Domain with the Murchison Widefield Array
Asha Wiltshier (Honours)	University of New South Wales, Canberra	October 2023	Space Domain Awareness Automation Processing: Southern Hemisphere Asteroid Radar Program

Murriyang, our Parkes radio telescope on Wiradjuri Country. Credit: CSIRO

Observing programs

Proposals allocated time on ATCA, Murriyang, the LBA and CDSCC over the April 2023 – September 2023 and October 2023 – March 2024 semesters.

ATCA

OBSERVERS	PROGRAM	NO
Stevens, Edwards	ATCA Calibrators	C007
Staveley-Smith, Cendes, Gaensler, Indebetouw, Matsuura, Ng, Tzioumis, Zanardo	Supernova Remnant 1987A	C015
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 high-energy astrophysical 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, Markoff, Lucchini, Miller-Jones, Russell, Sivakoff, Soria, Carotenuto, Tetarenko	The evolving jet properties of transient black hole X-ray binaries	C3057
Anderson, Bell, Miller-Jones, Bahramian, Rowlinson, van der Horst, Ryder, Wijers, Rhodes, Fausey, Chastain	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, Ricci, Wieringa, Ryan, van Eerten, Troja	Late-time emergence of the radio kilonova of GW170817	C3240
Dobie, Murphy, Kaplan, Deller, Gourdji, Lenc, Gulati	Radio follow-up of LIGO gravitational wave events	C3278
Laskar, Alexander, Berger, Bhandari, Chornock, Coppejans, Drout, Fong, Guidorzi, Margutti, Schady, van Eerten	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
Horiuchi, Stevens, Phillips, Edwards, Benner, Giorgini, Slade, Molyneux, Kruzins, Stacy, Savill-Brown, Peters , Molera Calves	Southern Hemisphere Radar Observations of Near-Earth Asteroids (NEAs)	C3319
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
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
Goodwin, Anderson, Miller-Jones, Malyali, Rau, Liu, Merloni	ATCA monitoring observations of eROSITA-detected Tidal Disruption Events	C3334
Carotenuto, Corbel, Tzioumis, Russell	Constraining black hole accretion-ejection coupling at low accretion rate	C3362
Murphy, Kaplan, Dobie, Driessen, Leung, Pritchard, Lenc, Wang, Dykaar, Strain, Gulati, Horesh, Rose, Gaensler, Wang	Follow-up of transients from the ASKAP Variables and Slow Transients survey	C3363
Anderson, Bell, Rowell, Schussler, Taylor, Miller-Jones, van der Horst, Aksulu, Bahramian, Einecke, Hancock, Ohm, Rowlinson, Ryder, Wagner, Wijers, Zhu, Konno, Ashkar, Russell	ATCA Rapid-Response and Monitoring Follow-up of HESS-detected TeV Gamma-ray Bursts	C3374

OBSERVERS	PROGRAM	NO
Dobie, Murphy, Kaplan, Lenc, Stewart, Bell, Hotokezaka, Brown, Wang, D'antonio, Deller, Gourdji	ATCA Follow-up of Neutron Star Mergers	C3395
Dobie, Murphy, Kaplan, Lenc, Stewart, Leung, Wang, Wang	ATCA Monitoring of a Candidate GRB Orphan Afterglow	C3424
Leung, Ghirlanda, Murphy, Lenc, Chandra	Late-time radio monitoring of GRB 171205A	C3447
Izzo, Auchettl, Leung, Murphy, Maeda, De Colle, Wang, Hajela	The jet/cocoon emission in relativistic supernovae at radio frequencies	C3448
Horiuchi, Savill-Brown, Molyneux, Stevens, Phillips, Edwards, Kruzins, Benner, Giorgini, Slade, Stacy, Peters, Molera Calves	Southern Hemisphere Radar Observations of Selected Near-Earth Asteroids (NEAs)	C3463
Leung, Deller, Kaplan, Lenc, Murphy, Wang, Giarratana, Spingola, Giroletti	ATCA Imaging of Gravitationally Lensed GRB Afterglows	C3478
Dobie, Pritchard, Zic	Monitoring the auroral pulses of the slowest-pulsing ultracool dwarf, SCR J1845-6357	C3486
Troja, Ricci, Wieringa, Yang, O'Connor, Ryan, Dichiara, van Eerten, Lien, Sakamoto	Electromagnetic counterparts to gravitational wave events	C3500
Goodwin, Anderson, Miller-Jones, Rau, Malyali, Liu, Merloni	Investigating the origin of late-time radio flares from tidal disruption events	C3513
Kerrison, Sadler, Moss, Yoon, Su, Mahony, JNHS, Glowacki, Weng, Callingham, Gaensler, Mao	Hunting for young radio AGN in gas-rich nurseries	C3515
Schulze, Bauer, de Ugarte Postigo, Hunt, Jonker, Klose, Malesani, Michalowski, Nicastro, Palazzi, Pellizzoni, Possenti, Tanvir, van der Horst, Wieringa, Bufano, Cavallaro, Ingallinera, Brocato, Kann, Lamb, Lekshmi, Lyman, Misra, Pian, Sánchez-Ramírez, De Pasquale, Nicuesa Guelbenzu, Salafia	The properties of compact-object mergers detected by LIGO, VIRGO and KAGRA	C3521
Russell, Carotenuto, van Den Eijnden, Degenaar, Del Santo, Marino	Jet launching in neutron star X-ray binaries	C3524
Ulgiati, Paiano, Russell, Del Santo, Pinto, Pintore, D'Ai, Ambrosi	Unveiling new radio AGN among the 4FGL unidentified gamma ray sources	C3525
Buemi, Leto, Umana, Trigilio, Ingallinera, Cavallaro, Bufano, Loru, Bordiu, Cerrigone, Riggi	Searching for non-thermal radio emission from evolved high mass circumstellar environments	C3526
Arcodia, Goodwin, Rau, Merloni, Anderson, Malyali	ATCA NAPA follow-up of a confirmed QPE source discovered by eROSITA	C3527
Trigilio, Cavallaro, Biswas, Umana, Busa, Leto, Torres, Chandra, Das, Buemi, Bufano, Bordiu, Ingallinera, Loru	Confirming Auroral Radio Emission from an exoplanetary system	C3528
Ng, Liu, Klingler	An Unusual Spectral Turnover of a Pulsar Wind Nebula: Shutoff of Particle Acceleration at Low Energies?	C3529
Taziaux, Mueller, Bomans, Pfrommer, Heesen, Ensslin, Kamphuis, Soida, Dettmar, Chyzy, Wezgowiec, Stein, Tjus	Exploring magnetised galactic winds in the irregular starburst dwarf galaxy NGC 3125	C3531
Aravena, Chapman, Hill, Spilker, Vieira, Murphy, Weiss, Tothill, Stark, Solimano	Identifying the AGN/star-forming activity in a IR hyper-luminous, massive protocluster at z=4.3	C3534
Ighina, Leung, Broderick, Caccianiga, Drouart, Moretti, Seymour	Identifying Blazars in the Primordial Universe	C3535
Su, Gu, Moss, Glowacki, Kerrison	Searching for intervening HI absorption lines towards QSO-galaxy pairs	C3536
Wang, Zic, Leung	Searching for pulsars among Fermi unassociated LAT sources with RACS	C3538
Rajabpour, Filipovic, Alsaberi, Velovic, Koribalski, Rowell, Saponara	Radio Rings in Galaxies: combining ATCA 4-10 GHz with ASKAP/MeerKAT 1 GHz images	C3539

OBSERVERS	PROGRAM	NO
Rose, Murphy, Kaplan, Lenc, Pritchard, Dobie, Wang, Wang, Caleb, Driessen, Duchesne	Radio Emission from a T-type Brown Dwarf – A follow-up campaign	C3540
Anderson, Leung, van der Horst, Ghirlanda, Lenc, Murphy, Rhodes, Rowlinson, Russell, Ryder, Salafia, Starling, Wijers	A Panoptic Radio View of Long Gamma-ray Bursts	C3542
Horesh, Rose, Sfaradi	Exploring the New Phenomenon of Delayed Radio Flares in Tidal Disruption Events	C3543
Jing, Liu, Sun, Wang	Identify the nature of the 'Kookaburra' complex	C3545
Thakur, Piro, Ricci, Bruni, Gianfagna, Wieringa	ATCA observations of high-z Gamma-Ray Bursts	C3546
Dage, Panurach, Plotkin, Saikia, Galvin, Brumback	Radio Observations of Neutron Star Ultra-Luminous X-ray Sources	C3547
Goodwin, Arcodia, von Fellenberg	ATCA observations of the Periodic Nuclear Transient in ESO 253-G003	C3548
Goodwin, Arcodia, von Fellenberg	Characterising the radio emission of a galaxy that shows quasi-periodic X-ray eruptions	C3549
Mahony, Stevens, Phillips	BIGCAT commissioning	C3550
Liu, An, Sun, Heald, Zhang, Guo, Xu	Exploring the polarization properties of high-redshift radio galaxies	C3553
Bignall, Wang, Tuntsov, Murphy, Stevens, Reynolds	Revealing local interstellar plasma structures through annual cycles of rapid scintillators	C3554
Bruni, Gianfagna, Piro, Thakur, Wieringa, Rodi, Natalucci	Radio counterparts of the GW sky with ATCA	C3555
Bloot, Callingham, Vedantham, Kavanagh, Climent, Guirado, Pope	Determining the broadband emission mechanism on AU Micropscopii	C3557
Bloot, Callingham, Vedantham, Kavanagh, Pope	Searching for auroral emission across the M dwarf mass range	C3558
Price, Ma, Seta, Mcclure-Griffiths	Characterising faraday rotation measure in the small magellanic cloud	C3559
Bradbury, Anderson, Ma, Thomson, Mcclure-Griffiths, Heald	Unveiling the structure of radio lobes	C3560
Wenger, Bonne, Emig, Salas	The Kinematics of Bi-polar HII Regions	C3565
Seymour, Broderick, Hedge, Turner, de Breuck	Candidate UHzRGs from Euclid Early Science	C3570
Lazarevic, Dai, Filipovic, Ahmad, Alsaberi, Rowell, Einecke, Hopkins, Kothes, Velovic	New Galactic Pulsar Wind Nebulae (follow-up study from ASKAP discoveries)	C3577
Miller-Jones, Wilms, Weber, Anderson	Determining the accretor type in eROSITA-discovered ULX candidates	C3578

Murriyang

OBSERVERS	PROGRAM	NO
Venkatraman Krishnan, Freire, Kramer, Bailes, Lower, Parthasarathy, Champion, Buchner, Burgay, Possenti, Colom I Bernadich	Timing southern binary pulsar systems	P1032
Dai, Johnston, Kerr, Possenti, Burgay, Ahmad, Keane, Camilo	Long-term timing of millisecond pulsars in Globular Cluster Omega Centauri	P1041
Sengar, Bailes, Balakrishnan, Wongphechauxsorn, Kramer, Champion, Cameron, Johnston, Possenti, Stappers, Burgay, van Straten, Bhat, Petroff, Flynn, Morello, Barr, Ng, Jameson, Bhandari, Colom I Bernadich, Chen	Initial Follow-up of New Pulsar Discoveries from Re-processing of the HTRU-S LowLat Galactic Plane Survey	P1050
Burgay, Stappers, Kramer, Possenti, Breton, Freire, Cognard, Grießmeier, Boettcher, Weltevrede, Ridolfi, Buchner, Barr, Colom I Bernadich, Champion, Thongmeearkom, Sengupta, Voraganti Padmanabh, Venkatraman Krishnan, Carli, Desvignes, Parthasarathy, Balakrishnan, Men, Clark, Keane, Levin, Turner, Vleeschower, Prayag, Berezina, Pillay	Follow-up of pulsar discoveries from MeerKAT searches	P1054
Hafner, Burns, Linz, van Den Heever, Chibueze, MacLeod, Breen, Orosz, Green	Maser Monitoring Parkes Programme: M2P2	P1073
Possenti, Burgay, Esposito, Israel, Rea, Keane, Pilia	Simultaneous radio/X-ray coverage of magnetars and ordinary pulsars following an X-ray activation	P1083
Dai, Niu, Li, Zhu, Feng, Hobbs, Balzan	Monitoring FRB190520 with the Parkes Ultra-Wideband Low receiver	P1101
Lower, Shannon, Johnston, Bailes, Camilo	A movie of a dynamic magnetar magnetosphere	P1102
Hobbs, Lam, Joshi, Jones, Bagchi, Zic, Reardon, Hazboun, Liu, Shannon, Singha, Tiburzi, Mandow, DeCesar, Tarafdar, Spiewak	Monitoring pulse shape changes in the International Pulsar Timing Array pulsar sample	P1122
Carretti, Landecker, Sun, Mcclure-Griffiths, Gaensler, Heald, Hopkins, Thomson, Haverkorn, Dickey, Leahy, Stuardi, Van Eck, Hill, Kothes, West, Filipovic, Crawford, Ma, Akahori, Ingallinera, Trigiglio, Cavallaro, Ordog, Mao, Han, Sobey, Kaczmarek, Reynolds, Macgregor, Davydov	PEGASUS	P1123
Hurley-Walker, Price, Bhat, Anderson, Heald, Galvin, Zic	Parkes triggered follow-up of long-period radio transients	P1139
Uttarkar, Shannon, Kumar, Lower, Deller, Flynn, Bhandari, Keane, Qiu	Probing the enigmatic environment of FRB20201124A with broadband observations	P1158
Liu, Cameron, Hobbs, Wang, Zhu, Hou, Parkinson, Ji, Li, Wang	Timing observations of J1402+13: a bright binary millisecond pulsar and promising candidate for timing arrays	P1162
Bai, Dai, Zhi, Xu, Wang	Timing of millisecond pulsars in binary systems with a massive white dwarf companion	P1165
DeCesar, Dai, Ransom, Kerr	Timing the First Seven Pulsars Discovered in Terzan 1	P1168
Eppel, James, Shannon, Kadler, Bahic, Cruces, Krumpe, Niu, Rau, Spitler, Wilms	Multiwavelength Constraints on the Nature of Fast Radio Bursts with Parkes and XMM-Newton	P1171
Mandow, Zic, Dawson, Hobbs, Gupta, Kapur, Shannon, Curylo, Russell, Reardon, Bhat, Lower	Ongoing Observations of the PSR J1713+0747 Event Recovery – P1172 Extension	P1172
Ahmad, Dai, Lazarevic, Filipovic, Alsaberi	Timing of a Young Pulsar Associated with the Bow-shock PWN CXOU J163802.6-471358	P1176
Ahmad, Dai, Filipovic, Barnes	Timing of a millisecond pulsar identified in binary system at High Galactic Latitude	P1177
Hobbs, Toomey, Johnston, Mandow, Kapur, Cameron, Zic, Kaczmarek	Towards PSRCAT version 2 and an automated online pulsar pipeline	P1178

OBSERVERS	PROGRAM	NO
Bhat, Dai, Grover, Kudale, McSweeney, Meyers, Sett, Xue	Broadband follow-up of PSRs J1357-2530 and J0452-3418	P1180
Zhang, Li, Yang, Dai, Hobbs, Wu, Tang, Chang	Studying the radiation spectrum and polarization of a new energetic FRB 20220529	P1183
Zhang, Li, Yang, Hobbs, Tang, Chang, Geng, Wu, Dai, Russell, Toomey	Studying the radiation spectrum and active periods of FRB 20220529	P1183
Tremblay, Price, Ekers, Siemion	Confirmation of Life in the Galaxy: Re-observation of SETI signals of interest	P1184
Caleb, Bezuidenhout, Stappers, Rajwade, Jankowski, Driessen, Surnis, Kramer, Barr	Monitoring a sample of (long period) magnetar candidates discovered with MeerKAT	P1185
Li, Dang, Xu, Tian, Zhong	The multi-frequency observation of the subpulse drifting of PSR J0934-5249 with Parkers	P1186
Zic, Kaur, Hobbs, Morgan, Ekers, Chhetri, Waszewski, Cheung, Reardon, Kapur	A pulsar-based solar space weather monitoring network	P1189
Wang, Zic, Leung	Searching for pulsars among Fermi unassociated LAT sources with RACS	P1193
Lu, Zhang	Identifying millisecond pulsars among the candidates selected from Fermi LAT	P1194
Kaczmarek, Andersen, Cassanelli, Dong, Hill, Landecker, Lazda, Li, Pearlman, Pleunis, Mckinven, Meyers	CHIME/FRB Observed Repeaters and Follow-up with the UWL (CORFU)	P1195
Sharan, Bhattacharyya, Roy, Johnston, Weltevrede, Stappers	Investigation of spectra and polarization properties for three MSPs discovered using the GMRT	P1196
Mantovanini, Sett, Hurley-Walker, Anderson, Bhat	Searching for pulsars in four supernova remnant	P1197
Lower, Shannon, Uttarkar	Capturing a Galactic fast radio burst analogue	P1198
Hobbs, Li, Zhang, Zhang, Zic, Yang, Dai	Can the cryoPAF find pulsars that were previously missed?	P1206
Xu, Dai, Zhi, Bai, Shang	Timing of new pulsars discovered in the Galactic Bulge	P1207
Ahmad, Dai, Lazarevic, Filipovic, Barnes	A targeted search for Millisecond Pulsars in Galactic Plane towards steep spectrum radio sources	P1211
Zhang, Geng, Wang, Yang, Kaczmarek, Hobbs, Tang, Chang, Wu	Studying the long-term period and microstructure of a peculiar RRAT J1913+1330	P1214
Liu, Li, Heiles, Hobbs, Dawson, Zhi-Yun, Ching, Green, Mcclure-Griffiths, Quan	Exploring Magnetic Field and its Variations in Molecular Clouds with Pulsars	P1219
Qiu, Keane, Gupta, Dai, Zhang	A targeted search for Fast Radio Bursts in dwarf satellite galaxies	P1226
Kerr, Camilo, Clark, Nieder, Ransom, Ray, Smith	Expanding the Gamma-ray Pulsar Timing Array	P1229
Ahmad, Dai, Johnston, Lazarevic, Filipovic, Barnes	Searching for pulsars in new Galactic pulsar wind nebula candidates	P1238
Luo, Dai, Wang, Hobbs, Jiang, Wang	Searching for fast radio bursts from a radio source with likely magnetar origin	P1281
Ghosh, Bhattacharyya, Weltevrede, Kumari, Johnston, Roy	Searching for high frequency eclipses for four spider millisecond pulsars	P1295
Ma, Carretti, Heald, Jung, Kovacs, Mcclure-Griffiths, Seta, Thomson, Van Eck	Polarised radio emission survey of the Small Magellanic Cloud	P1299

OBSERVERS	PROGRAM	NO
Zhou, Liu	Searching for radio pulsations from SGR J1833-0832	P1306
Nguyen, Petzler, Dawson	Parkes Murriyang Telescope Expedition: Hunting for Elusive HI Gas in the Dwarf Galaxies of the Milky Way	P1308
Burgay, Kramer, Manchester, Stairs, Wex, Deller, Coles, Lorimer, Possenti, McLaughlin, Hu, Ferdman	Timing and geodetic precession in the double pulsar	P455
Burgay, Kramer, Manchester, Stairs, Wex, Deller, Coles, Lorimer, Possenti, McLaughlin, Hu, Ferdman	Timing and geodetic precession in the double pulsar	P455
Hobbs, Coles, Manchester, Zhang, Keith, Wang, van Straten, Dempsey, Russell, Bailes, Bhat, Shannon, Zhang, Zhu, Reardon, Kerr, Dai, Oslowski, Curylo, Zic, Spiewak, Sarkissian, Mandow, Kapur, Kaczmarek	A millisecond pulsar timing array	P456
Hobbs, Coles, Manchester, Zhang, Keith, Wang, van Straten, Dempsey, Russell, Bailes, Bhat, Shannon, Zhang, Zhu, Reardon, Kerr, Dai, Oslowski, Curylo, Zic, Spiewak, Sarkissian, Mandow, Kapur, Kaczmarek, Ling	A millisecond pulsar timing array	P456
Lower, Johnston, Sobey, Dai, Kerr, Manchester, Oswald, Parthasarathy, Shannon, Weltevrede	Young Pulsar Timing: Probing the Physics of Pulsars and Neutron Stars	P574
Lower, Johnston, Sobey, Dai, Kerr, Manchester, Oswald, Parthasarathy, Shannon, Weltevrede	Young Pulsar Timing: Probing the Physics of Pulsars and Neutron Stars	P574
Hobbs, Hollow, Lower, Zic, Green, Dai, Mandow, Kaur	PULSE@Parkes (Pulsar Student Exploration online at Parkes)	P595
Hobbs, Hollow, Lower, Zic, Dai, Mandow, Kaur, Ling	PULSE@Parkes (Pulsar Student Exploration online at Parkes)	P595
Hobbs, Manchester, Reynolds, Johnston, Green, van Straten, Jameson, Mader, Shannon, Cameron, Staveley-Smith, Sarkissian, Zic	Instrumental calibration for Parkes	P737
Hobbs, Manchester, Reynolds, Johnston, van Straten, Jameson, Mader, Shannon, Staveley-Smith, Sarkissian, Zic, Dai, Kaczmarek	Instrumental calibration for Parkes	P737
Camilo, Scholz, Lower, Johnston, Sarkissian, Reynolds	Understanding the Remarkable Behaviour of Radio Magnetars	P885
Camilo, Scholz, Lower, Sarkissian, Johnston, Reynolds	Understanding the Remarkable Behaviour of Radio Magnetars	P885
Possenti, Ducci, Mereghetti, Burgay	Catching the first transitional pulsar in an early-type binary system	P945
Possenti, Ducci, Mereghetti, Burgay	Catching the first transitional pulsar in an early-type binary system	P945
Mader	Receiver characterisation	P960
Mader, Kaczmarek	Receiver characterisation	P960
Venkatraman Krishnan, Bailes, van Straten, Bhat, Flynn, Batrakov, Reardon	Orbital dynamics of PSR J1141-6545	P971
Li, Hobbs, Zhang, Toomey, Dempsey, Zhu, Green, Wang, Wang, Yuan, Miao, Wang, Cameron, Dai, Xue	FAST: category 1 purchased time	PX500
Li, Hobbs, Zhang, Toomey, Dempsey, Zhu, Green, Wang, Wang, Yuan, Miao, Wang, Cameron, Dai, Xue, Tedila	FAST: category 1 purchased time	PX500

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OBSERVERS	PROGRAM	NO
Climent, Guirado, Marcaide, Jardine, Brasseur	Characterizing the corona of AB Doradus	V186
Ojha, Edwards, Kadler, and team	Physics of Gamma Ray Emitting AGN	V252
Titov, McCallum, Phillips, Natusch, Reynolds, Horiuchi, Gulyaev, Weston, de Witt, Frey, Shu, McCallum, Lopez, Melnikov, Osetrova	Improving the celestial reference frame through Southern Hemisphere Geodetic VLBI Observations	V515
Dai, Phillips, Hobbs, Zhang, Li, Zhu, Feng, Niu, Jiang	Monitoring VLBI observations of FRB 20190520B and its Persistent Radio Source	V603
Tazaki, McCallum, Phillips, Shen, Stevens, Reynolds, Niinuma, Sugiyama, Horiuchi, An, Honma, Jung, Lee, Sohn, Zhao, Hada, Kino, Lu, Akiyama, Jiang, Jaroenjittichai, Park, Zhang, Kawashima, Yi, Ro, Cui, Mizuno, Fariyanto, Algaba, Cheng, Cho, Hodgson, Lee, Sawada-Satoh, Trippe, Wajima	Probing the Innermost Collimation and Acceleration Regions of the Centaurus A Jet with EAVN+LBA	V604
Park, Edwards, Phillips, Shen, Lobanov, Stevens, Lu, Krichbaum, Gomez, Lee, Hada, Asada, Nakamura, Kim, Tazaki, Jiang, Byun, Kawashima, Pu, Yuan, Hodgson	Probing the Jet Base of M87 in the Time Domain	V610
Janssen, Edwards, Tzioumis, Phillips, Ojha, Kadler, Ros, Stevens, Zensus, Krichbaum, Jung, Fromm, Lee, Asada, Ramakrishnan, Park, Byun, Rottmann, Hodgson	Unraveling the nature of the Cen A jet: From cm to mm on light-day scales	V611
Jiang, Phillips, Shen, Reynolds, Zhang, Cui, Yan, Chen, Zhang, Liu	Investigate the new phase of black hole X-ray binary GRS 1915+105 through high-sensitivity VLBI imaging observations	V612
Deller, Stappers, Caleb, Ding, Rajwade	Pinpointing an ultra-long period magnetar	V615
Hedge, Broderick, Reynolds, Galvin, Seymour, Turner, Ighina, Zhang	Resolving the morphologies of candidate UHzRGs	V620
von Fellenberg, Edwards, Ros, Malyali, Goodwin	Resolving the nuclear radio structure of the periodic nuclear transient in ESO 253-G003	V626
Zic, Wang	Very Long Baseline Interferometry of an eclipsing spider pulsar candidate	V627
Ding, Ren	Probing Gaia parallax zero-points at low Galactic latitudes using VLBI astrometry of radio stars (1)	V628
Radcliffe, Koribalski, Edwards, Phillips, Norris, Hopkins, Prandoni, Kadler, Reynolds, Lonsdale, Rudnick, Vaccari, Galvin, Collier, Shabala, Vernstrom, Riseley, Dai, White, Gupta, Vardoulaki, Leahy, Macgregor, Amarantidis, Faisal ur Rahman, Gordon, Bonnassieux, Anton, Gurkan, Craig, Lazarevic, Delvecchio, Mingo, Tang, Marchetti, Bempong-Manful, McKean, Shetgaonkar	The EMU-VLBI pilot survey – uncovering milliarcsecond radio structures in the Southern sky	V629
Yiu, Marcote, Callingham, Vedantham	Zooming in on a white dwarf around a reignited star	V630
Aditya, Edwards, Sadler, Whiting, Mahony, Moss, Yoon, Su, Weng, Kerrison	Parsec-scale structure of radio sources showing HI-21cm absorption	V631
Molera Calves, Cimo, Gurvits, Frey, Charlot, Fogasy, Desmars, Dirkx, Fayolle-Chambe, Lainey, Said Noor, Pallichadath, Bolton, Witasse	Spacecraft VLBI tracking in support of stellar occultations	V633
Zhang, Titov, Phillips, Reynolds, Zhang, Ding, Shu, Chen, Xu, Mai, Sun, Wen	VLBI Astrometry of Radio Stars to Link Radio and Optical Celestial Reference Frames: Southern Sky	V636

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