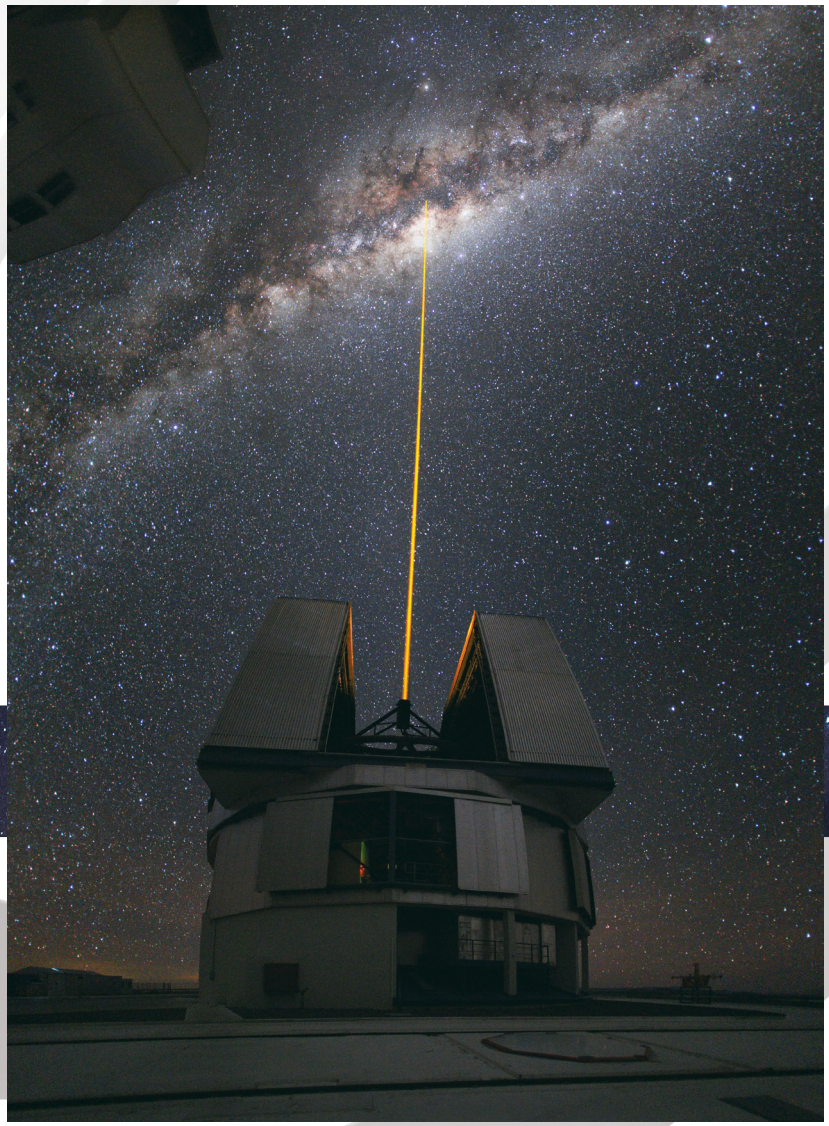
Astronomy Australia Ltd.

2016 / 17 Annual Report



Astronomy Australia Limited

Vision

Australian-based astronomers will have access to the best astronomical research infrastructure.

Mission

Astronomy Australia Limited (AAL) will achieve its vision by engaging with astronomers in support of the national research infrastructure priorities of the Australian astronomy Decadal Plan, and advising the Australian Government on the investments necessary to realise those priorities.

Principles

1. Access to major astronomical research infrastructure should be available to any Australian-based astronomer purely on scientific merit.
2. The concept of national astronomical research infrastructure includes participation in international facilities.
3. AAL recognises the roles of other organisations in Australia that manage components of the national astronomical research infrastructure.

Who we are

AAL is a non-profit organisation whose members are all the Australian universities and research organisations with a significant astronomical research capability. AAL works with Australia's national observatories, relevant infrastructure providers, astronomers at Australian universities, and the Australian Government to advance the infrastructure goals in the Australian Astronomy Decadal Plan 2016–2025, "Australia in the era of global astronomy".

What we do

Since its incorporation in 2007, AAL has coordinated the Australian astronomy response to, and managed the funding for, a number of national schemes and projects, including the Australian Government's investments in astronomy infrastructure through the National Collaborative Research Infrastructure Strategy (NCRIS). AAL-administered funding has enabled construction, instrumentation development, upgrades, maintenance and operations across a portfolio of world-class astronomy facilities and projects. In this era of global astronomy, AAL also plays a key role representing Australia's interests in a number of major international projects and partnerships.

Values

AAL is committed to equity and diversity and endeavours to create an environment in which every individual is treated with dignity and respect.

Front cover image: Laser guide star facility at Yepun, a Unit Telescope of the Very Large Telescope. Credit: ESO/Y. Beletsky, licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/legalcode), cropped and resized from original (http://eso.org/public/images/potw1036a/).
First page image: Close planetary encounter seen above Mauna Kea. Credit: Dr. Hideaki Fujiwara, Subaru Telescope, NAOJ.

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Australian Government | NCRIS National Research Infrastructure for Australia

Part of the NCRIS network

Astronomy Australia Ltd.

A message from the Chair

This year has been one that has seen the initiation of significant change within the Australian astronomical community. The Australian Government announcement of funding for a strategic partnership with the European Southern Observatory (ESO) is a very significant investment in Australian astronomy over the next ten years. The Australian astronomical community has been seeking access to the world-leading ESO facilities for over two decades, and I am delighted to see this strategic partnership come to fruition. I would like to extend special thanks, on behalf of the Board, to AAL CEO Mark McAuley for his leadership and efforts in supporting the Government to realise the Australia-ESO strategic partnership. The AAL Board are proud to have played a part in supporting the Government's pursuit of the strategic partnership, and made a commitment of $5 million per annum of the astronomy National Collaborative Research Infrastructure Strategy (NCRIS) grant towards supporting the necessary change in Australian domestic arrangements that result from the ESO decision. Specifically these funds will support the establishment of a national optical instrumentation capability.

To effectively support the major activity of the transition of the Australian Astronomical Observatory (AAO) instrumentation capability to a new Sydney-based group by mid-2018, as well as assist with the other changes associated with the ESO investment, the AAL Board approved the establishment of an AAL Sydney office. The Sydney office was opened on the 31st July 2017 and we are grateful to Macquarie University, who kindly agreed to host that office for an initial period of one year. The new office will primarily focus on optical astronomy matters in the coming year, but will also serve as a contact point for the six AAL members based in Sydney.

In Dec 2016, the Australian Research Council (ARC) announced a new $31.3 million ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) to be led by Professor Matthew Bailes, Swinburne University of Technology (SUT). OzGrav will capitalise on the first detections of gravitational waves to understand the extreme physics of black holes and warped spacetime. In addition, $30.3 million was awarded to the ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D), to use 3D technology to help unlock the secrets of the early universe and the development of elements that make up the periodic table. Led by Professor Lisa Kewley from the Australian National University (ANU) Research School of Astronomy and Astrophysics (RSAA), Astro-3D will ensure Australian astronomers, astrophysicists and engineers play a central role in the exploration of the formation of the universe over the next decade. Centres of Excellence are significant collaborative research programs in areas of national importance. I would like to congratulate Matthew and Lisa, and their collaborators, on their significant achievements for Australian astronomy.

Image: AAL Chair, Prof Rachel Webster (left), receiving the Bronze Pleiades Award from Sarah Brough, Chair of the Inclusion, Diversity and Equity in Astronomy chapter, ASA. Credit: CAASTRO.

I am delighted that AAL's commitment to improving equity and diversity within our company structures has been recognised with a Bronze Pleiades Award for 2017–2019 from the Astronomical Society of Australia's Inclusion, Diversity and Equity in Astronomy Chapter. AAL was commended for the positive steps taken towards gender balance on its Board and committees and its flexible working arrangements.

I was honoured to be appointed as Chair of the AAL Board in Feb 2017. I offer my thanks to outgoing Chair, Anne Green, who retired from the Board at the Nov 2016 AGM, for her invaluable contributions to AAL over her six years on the Board, and particularly as Chair in 2016. I would also like to thank the other three AAL Directors who retired from the Board at the Nov 2016 AGM for their significant contributions to AAL: Ian Chessell, Lisa Kewley and Ron Ekers. At the 2016 AGM we also welcomed new Board members Karl Glazebrook, Chris Tinney and Naomi McClure-Griffiths, all astronomers of high standing within the national and international astronomical community, and who bring a wide range of scientific, technical and academic management expertise to the Board. Director Ben Greene was also appointed at the 2016 AGM, but unfortunately had to step down in May 2017 due to other commitments. I thank Ben for the contributions he made during his time on the Board.

The coming year will be one of excitement and opportunity for the Australian astronomical community, but also will see us face a number of challenges, particularly in developing new domestic arrangements around the Anglo-Australian Telescope (AAT) and the AAO optical instrumentation capability. I am confident of the ability of the AAL team to navigate the coming year and to work together with AAL members to deliver excellent outcomes for the community.

Professor Rachel Webster, Chair

A message from the CEO

AAL celebrated its tenth birthday on 18th April 2017; three weeks later the Australian Government announced funding for a 10-year strategic partnership with ESO. AAL's role in establishing this ESO partnership is possibly the most important contribution AAL has made to Australian astronomy. The opportunities enabled by the ESO partnership will greatly enhance the ability of Australian-based astronomers to continue their world-leading research to extend our understanding of the universe.

The potential benefits from engaging with ESO had been consistently communicated to the Australian Government over many years, including in the most recent Decadal Plan. During 2016/17 I worked with leading astronomers, ESO, and the Department of Industry, Innovation and Science (DIIS), to advance the case for an Australia-ESO strategic partnership. The strength of the ESO proposal, combined with the astronomy community's consistent endorsement of ESO engagement, enabled AAL to strongly recommend the ESO partnership to the Australian Government. I would like to take this opportunity to thank Professor Brian Schmidt, Vice-Chancellor ANU, for the critical role he played in enabling ESO partnership, and Minister Sinodinos for the support of the Australian Government.

In July 2016 significant access to ESO facilities was still just an aspiration, and AAL had to ensure that Australian-based astronomers maintained access to large optical telescopes. With the support of senior Australian astronomers, I engaged with the leadership of the Subaru Telescope to negotiate Australian access to ten nights on that telescope in 2018. While the ESO partnership will become the dominant source of access to large optical telescopes, I hope the scientific and technical collaborations that have been triggered by the Subaru arrangements will continue to benefit Australian astronomy for many years.

AAL's support for computing and data research infrastructure took another step forward during 2016/17. Following a competitive tender process, AAL engaged the SUT, Curtin University, and Pawsey Supercomputing Centre to jointly deliver Astronomy Data and Computing Services (ADACS). ADACS provides astronomy-focused training, support and expertise to assist astronomers to maximise the scientific return from data and computing infrastructure. The ADACS initiative, combined with AAL's ongoing investments in the All-Sky Virtual Observatory and GPU Supercomputer for Theoretical Astrophysics Research (gSTAR), are intended to complement the peak computing infrastructure offered by the National Computational Infrastructure (NCI) and Pawsey. During 2018, AAL will continue to work with the NCI and Pawsey to ensure those facilities meet the needs of Australian astronomers.

Image: AAL CEO Mark McAuley at the Rosse 72-inch telescope, Ireland (first light 1845).

Research infrastructure requires significant, preferably long-term, investment. I was delighted when the Department of Education and Training announced two-year NCRIS allocations for NCRIS capabilities, an improvement on the recent yearly NCRIS allocations. AAL received an $18 million grant for the period July 2017 until June 2019.

In May 2017 the Department of Education and Training released the Research Infrastructure Roadmap. AAL, in partnership with the National Committee for Astronomy (NCA), had spent the previous twelve months working through the Department's consultation process, with the objective that the Roadmap would reflect the research infrastructure priorities of the Decadal Plan. We achieved that objective: the Roadmap appropriately acknowledged the importance of the Giant Magellan Telescope (GMT), Square Kilometre Array (SKA) and 8-metre-class optical telescopes. The recommendations in the Roadmap provide a platform from which AAL will continue to seek long-term support for the research infrastructure priorities of the Decadal Plan.

Mr Mark McAuley, Chief Executive Officer

Image: The European Southern Observatory's Very Large Telescope (VLT) during observations. Credit: ESO/S. Brunier, licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/legalcode), cropped and resized from original (http://www.eso.org/public/images/vlt-brunier-nuit/).

The Year in Highlights

The Australian Astronomy Infrastructure Portfolio

The Australian Government's release of the 2016 National Research Infrastructure Roadmap aligns with the priorities of the Australian Astronomy Decadal Plan 2016–2025 - "Australia in the era of global astronomy".

In March 2016, the Australian Government commissioned an Expert Working Group led by the Chief Scientist, Dr Alan Finkel, to produce a national 10 year plan to underpin Australian research and identify future national research infrastructure priorities and areas for investment. Over the following nine months AAL worked closely with other astronomy representatives to present astronomy priorities to the working group and advocate for the key elements of the Australian Astronomy Decadal Plan. As a result, when the National Research Infrastructure Roadmap was released in May 2017, it closely reflected the astronomy plan.

Maintaining and strengthening Australia's position at the front-line of astronomical research requires access to world-class facilities. The next generation of these facilities, needed to make the next major discoveries about our universe, are of such scale and complexity that they require multinational partnerships to fund and build. Australian astronomy has already begun the transition from a national research infrastructure portfolio of mid-scale, Australian-owned facilities, to partnership in multinational, billion-dollar, landmark facilities.

When the decadal plan for Australian astronomy was written in 2015, the country was at a critical early stage in the transition. A key challenge was to get the goals of the astronomy discipline recognised in Federal Government strategic documents. The announcement of the National Infrastructure Roadmap in March 2016 presented the ideal opportunity to do just that.

Australia is playing a critical role in two of the world's biggest billion-dollar astronomy projects: the SKA, which will be partly built in Australia with local industry and regional engagement; and the GMT, which will be the first in a new class of extremely large telescopes (ELTs) and for which Australia is building key instrumentation. The GMT and SKA present an extreme leap in telescope size; the last time a size-leap of this scale happened, we discovered planets around other stars, the supermassive black hole in the centre of our galaxy, and that the universe is accelerating (which resulted in a Nobel Prize for Australian astrophysicist Professor Brian Schmidt). On the path to these next generation optical and radio telescopes, the Decadal Plan highlighted the importance of the "pathfinders" for the SKA and GMT, namely the Australian SKA Pathfinder (ASKAP)

and Murchison Widefield Array (MWA) for the SKA; and 8-metre-class optical telescopes for the GMT.

To complement optical and radio astronomy facilities, the Decadal Plan also recommended exploiting Australian capabilities to gain access to, or partnership in, large international projects in emerging areas of high energy astrophysics, which will allow us to see the universe in entirely new ways, and probe some of the most energetic cosmological events. In addition, the Decadal Plan emphasised that a strong foundation of eResearch infrastructure is vital if astronomers are to effectively store, share, reuse, combine and analyse the big data volumes generated by next generation facilities, and to run sufficiently high-resolution theoretical simulations to interpret the data.

In collaboration with other key Australian astronomical representatives, AAL presented the requirements of the astronomical community to the Expert Working Group responsible for the National Roadmap, and provided community feedback on the draft document. The final roadmap lists the following priority areas for astronomy infrastructure:

1. Enhance capability in optical astronomy and associated technologies by establishing a formal partnership in an 8-metre-class optical telescope, to maximise return on our investment in the GMT.

2. Maintain priority through full utilisation of the SKA precursor telescopes (ASKAP and the MWA) to maximise the Australian benefit via technology development and scientific discovery during the construction of the SKA.

In addition, the report recognised the importance of national scale high performance computing (HPC) to astronomy and made a key recommendation that Australia's tier-1 HPC computing facilities be refreshed as a top priority.

A key achievement for AAL in 2016/17 has been the inclusion of the astronomy decadal plan priorities into the national strategic infrastructure roadmap.

Image left: Artist's conception of the GMT facility during laser tomography adaptive optics observations. Credit: GMTO Corporation.

Image above: Artist's impression of the SKA low frequency dipole antennas deployed at the Murchison Radio-astronomy Observatory (MRO). Credit: SKA Organisation.

The Australia-ESO Strategic Partnership

Australian Government signs strategic partnership agreement with the European Southern Observatory, fulfilling key goal of decadal plan.

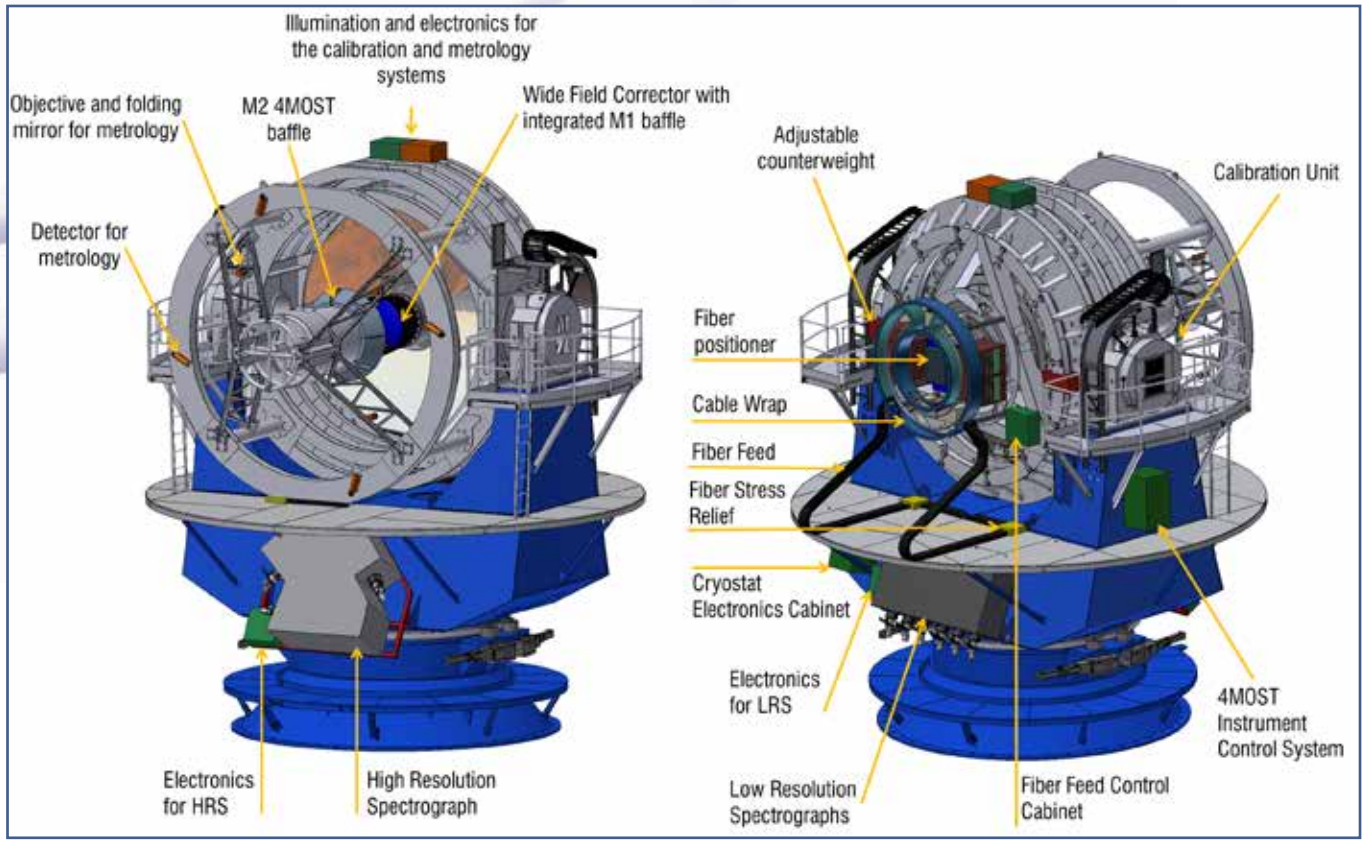
In May 2017, the Australian Government announced its decision to enter into a 10-year Strategic Partnership with the European Southern Observatory (ESO), starting in 2018. ESO is an international astronomy consortium which operates the world's most comprehensive suite of optical telescope facilities located in the Atacama Desert in Chile, one of the premier global sites for optical astronomy.

Access through partnership in a leading international optical and infrared (IR), 8-metre-class observatory, is the highest unmet need of the Australian astronomical community. This $26.1 million investment over the next four years, with ~$12 million/year for the following six years, is a pathway to full ESO membership for Australia and immediately satisfies the proposed goal of 30% access to an optical and IR 8-metre-class telescope, as stated in the Decadal Plan.

ESO provides 8-metre-class optical and IR telescopes, with the broadest available world-class instrument suite, that best meet Australian scientific goals. A strategic partnership with ESO also allows Australian instrument builders to maintain their world-leading capabilities in instrumentation development and provide opportunities for industry engagement in large construction projects. Long-term partnership is critical both to maintain scientific leadership within 8-metre-class telescopes, and also for continued development of Australian astronomy in the ELT era, specifically within areas of demonstrated Australian strength including astrophotonics, astrorobotics and all-sky surveys.

AAL, as a consortium of the Australian universities and research institutions involved in astronomical research, strongly supports the Government's announcement. "Access to ESO is a really high priority for AAL, and we will be making a substantial commitment in support of that effort." – Professor Rachel Webster, AAL Chair, in response to the Australian Government's announcement to enter into a Strategic Partnership with ESO.

Image: Senator the Hon Arthur Sinodinos AO, the Minister for Industry, Innovation and Science, and Professor Tim de Zeeuw, the Director-General of the European Southern Observatory, signed the arrangement to allow Australia to partner with ESO. The event was officiated by the Vice-Chancellor of the ANU and Nobel Laureate Professor Brian Schmidt and the President of the Astronomical Society of Australia, Professor Virginia Kilborn, at the Astronomical Society of Australia's 2017 Annual Scientific Meeting.
Credit: Australian Government.



Instrumentation Collaborations with ESO

Massively multi-object spectroscopy system funded for VISTA

A key capability that Australia brings to the strategic partnership with ESO, is the strong instrumentation and innovation capacity of the Australian astronomical community. Australia has in fact been collaborating on ESO instrumentation projects for a number of years prior to the new Australia-ESO Strategic Partnership. The latest example being involvement in ESO's current $55 million upgrade to the Visible and Infrared Survey Telescope for Astronomy (VISTA) with a new facility, the 4-metre Multi-Object Spectrograph Telescope (4MOST). The Australian ESO Positioner is a critical element of the new facility, based on technology patented by the AAO that cannot be sourced from anywhere else in the world. The AAO will construct over two thousand high-precision, rapid positioning optical fibres, which will crucially allow 4MOST to cut the time of undertaking large-scale surveys of stars and galaxies from decades to years.

Through the AAO's collaboration with ESO and the 4MOST collaboration, Australian astronomers have access to the science surveys undertaken by the facility. In particular, Australia is entitled to lead one 4MOST Consortium Survey, the Wide Area VISTA Extragalactic Survey, which will study two million galaxies to better understand dark matter and galaxy formation. At the commencement of collaboration on 4MOST, Australia was the only one of the thirteen international partners in the consortium that was not an ESO member; the AAO's involvement in the project was a consequence of their international reputation in cutting-edge technology development.

Image: The 4-metre Multi-Object Spectrograph Telescope. Credit: 4MOST Consortium.

Subaru Telescope

Australian astronomers gain 10 nights on the 8-metre Subaru Telescope in 2018

AAL has been actively investigating options to address the Australian astronomy Decadal Plan priority for 8-metre-class optical telescope access. In 2016/17 AAL engaged with the National Astronomical Observatory of Japan (NAOJ) to discuss collaboration that would see Australian access to the 8.2-metre Subaru Telescope in Hawaii. In May 2017, AAL entered into an agreement with the NAOJ, which will see Australian astronomers have access to ten nights on Subaru in 2018.

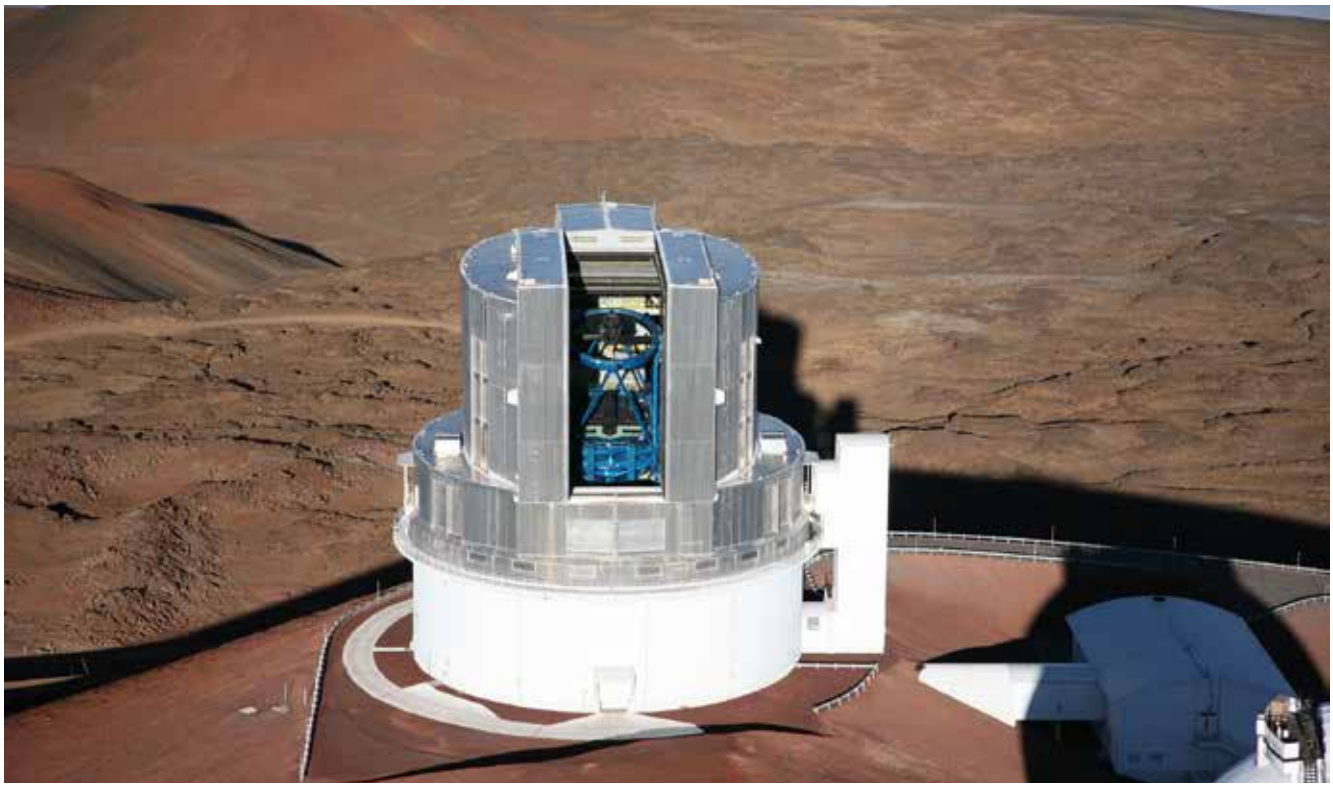
In return, Australia will provide financial support, technical contributions and four nights on the AAT to the Japanese astronomical community. The technical contributions to the telescope will include a conceptual design study, undertaken by the ANU, in collaboration with the NAOJ, of a Ground Layer Adaptive Optics (GLAO) system for the Subaru Telescope, as part of the ULTIMATE-Subaru project. The goals of the program are to conduct performance simulations of the Subaru GLAO system, and conceptual designs of the Wavefront Sensor and Laser Guide Star systems. In addition, the AAO will lead a design study for a Nasmyth beam-switcher for the Subaru Telescope.

In November 2016, AAL's CEO Mark McAuley and AAO's Director, Professor Warrick Couch met with Director General of the NAOJ, Masahiko Hayashi and the Subaru Advisory Committee in Tokyo to reach an agreement on terms for a short-term arrangement for Australian access to Subaru in 2018. Following this meeting, the AAO hosted a joint Australia-Japan workshop at the AAO offices in North Ryde on 15 December 2016. The workshop was an opportunity for astronomers in the two communities to discuss science, form collaborative links and establish joint projects using instruments on the Subaru Telescope and facilities in Australia.

In March 2017, Warrick Couch and Professor Matthew Colless (Director of RSAA, ANU) attended the Subaru international science workshop that included a business session for the Australia-Subaru collaboration, laying the foundations for Australia's technical contributions to the Subaru Telescope.

Throughout the year, AAL has continuously engaged with Subaru management. Sustaining communication with the NAOJ will strengthen the foundations for continued scientific and technical collaborations between Australia and Japan.

Image: Subaru Telescope on the summit of Mauna Kea. Credit: NAOJ.



Astronomy and Data Computing Services

Consortium formed to provide eResearch support to Australian astronomers

Astronomers are increasingly challenged by the size, dimension and complexity of astronomical data and related simulations. To address these challenges, AAL set up the Astronomy and Data Computing Services (ADACS) to provide discipline-specific training, support and expertise to allow astronomers to maximise the scientific return from data and computing infrastructure. ADACS resources will be used to aid Australian-based astronomers to generate, process, store, curate, analyse and visualise data to enable new scientific discovery.

There are many computational bottlenecks for astronomers that are a barrier to scientific discovery. In some cases, astronomers cannot even unload their data, others are under continual pressure to process and delete files to free up resources for others, some struggle to find adequate computational cycles to process their data or perform their simulations, and others require help to construct the necessary code and pipelines for data processing. Once the data are processed, curation and presentation to the outside world requires suitable databases, media and portals.

On the other hand, astronomy facilities can now generate raw data at over 100 TB per day, and their intermediate data products often tally to several petabytes per year. It will be increasingly essential for astronomers to have skills and resources across a wide range of areas.

To better address these needs, AAL has invested NCRIS funds in the establishment of the ADACS initiative, to provide eResearch support services for the astronomy research community. A two-stage tender process was initiated to identify appropriate eResearch subcontractors, resulting in two service providers engaged to deliver ADACS-related services: (1) Swinburne University of Technology (led by Prof. Jarrod Hurley); (2) Curtin University (led by Prof. Andrew Rohl) and Pawsey Supercomputing Centre (Dr. Jenni Harrison).

ADACS aims to provide astronomy-focused training, support and expertise to allow astronomers to maximise the scientific return from data and computing infrastructure. In 2017, ADACS is focusing on delivering the following three service components:

1. Provide astronomy-focused training, using workshops, hackathons, webinars and online documentation, in the following areas: (1) advanced statistical analysis, informatics and machine learning/artificial intelligence techniques; (2) advanced visualisation of data and simulations; (3) programming and software development (including HPC-related programming); (4) use of virtual observatory (VO) tools and data portals; and (5) data management.

2. Collaborate with relevant astronomy experts to create/enhance astronomy data portals to facilitate the management, sharing and reuse of data. This includes: (1) managing the All-Sky Virtual Observatory (ASVO) project (which comprises a growing network of distributed data hubs that are owned and operated by a range of subcontractors); (2) seeking funding for future VO/data portal integration and better connectivity developments; and (3) coordination with the Australian and international VO communities and projects.

3. Collaborate/partner with national eResearch providers to help coordinate and maximise the computing and storage resources available to astronomers. This includes: (1) coordinating an HPC time allocation process on AAL's behalf; (2) providing expert services which could be allocated to individuals and projects to develop data pipelines, algorithms and other software to deal with big data challenges; (3) setting up a national computing help desk for the astronomy community; and (4) engaging with Amazon and Microsoft to offer commercial data and computing resources to the astronomy community.

Ancient Dead Galaxy Challenges Theories

Significant Australian-led discovery using the 10-metre Keck telescope

A recent spectroscopic study of an ancient, dead galaxy is challenging established galaxy formation theories. The galaxy, ZF-COSMOS-20115, entered a quiescent state after its internal star formation process was quenched – over 12 billion years ago (Glazebrook, K. et al., 2017, Nature, 544, 71). Bereft of short-lived, hot, blue stars, only its cooler, redder stars persist; it's now... "red and dead".

The galaxy is massive but compact; several times the mass of our Milky Way are condensed into a dense region many times smaller. According to hitherto prevailing galaxy formation theories, such rapidly formed, massive, compact galaxies shouldn't exist at ancient epochs.

As might be expected, the study is spurring reexamination of theoretical galaxy formation models (e.g. cold dark matter halo assembly) and a search for physical mechanisms (e.g. merger events) to reconcile the quandary of its existence.

The moribund galaxy was examined with the Multi-Object Spectrograph for Infrared Exploration instrument on the 10-metre Keck I telescope. Subsequent data analysis was performed by an international team, with strong representation from Australian institutions. Other Australian researchers are amongst those releasing refined galaxy formation simulations.

AAL maintained Australian community access to the Keck Observatory in 2016/17 through support from the Australian Government's NCRIS, via the Department of Education and Training, and an Australian Government astronomy research infrastructure grant, via the Department of Industry, Innovation and Science. The ANU and SUT provided additional institutional access.

Image: Artist's impression of ZF-COSMOS-20115, an ancient galaxy in which significant star formation has long since ended. The existence of such an old, massive, compact system conflicts with previous galaxy formation theories. Credit: Leonard Doublet, SUT.

Murchison Widefield Array GLEAMs

First results from three-year radio survey of the southern sky with the SKA pathfinder telescope

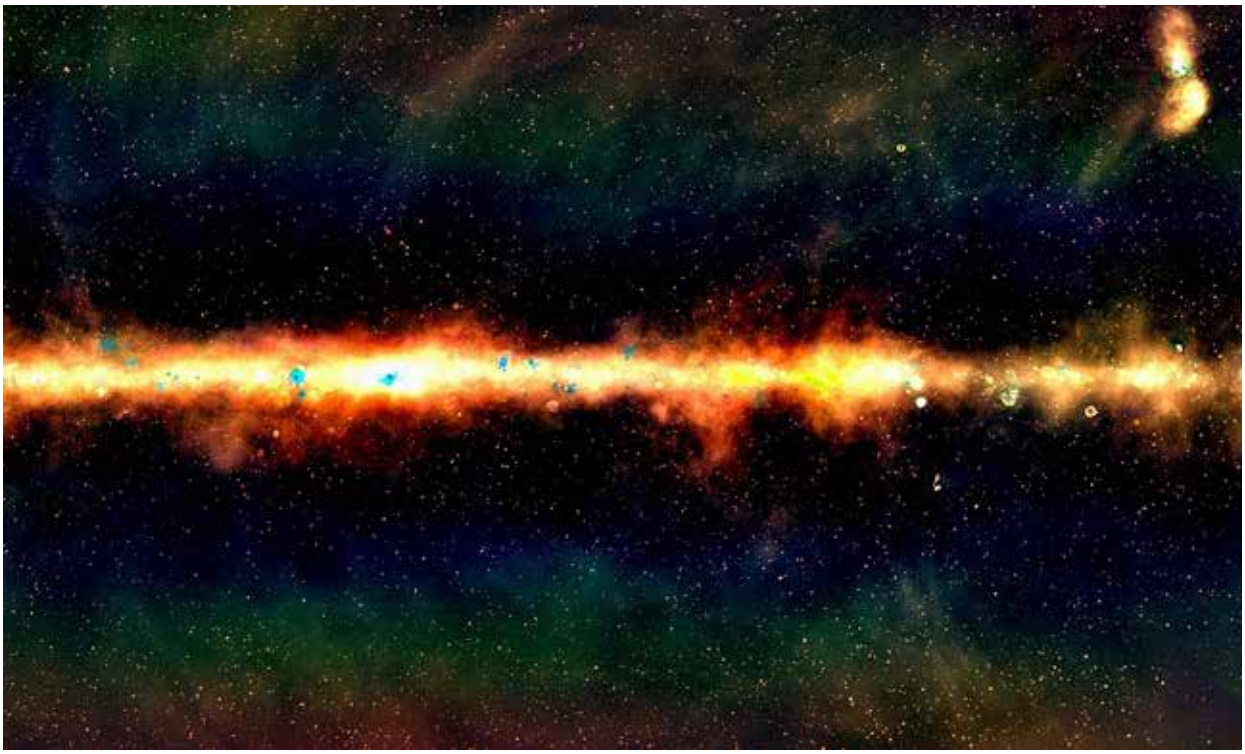
A three-year observing campaign with the Murchison Widefield Array (MWA) has led to the largest and most accurate radio survey that has ever been produced of the southern sky. The first results from the GaLactic and Extragalactic All-sky MWA (GLEAM) survey were published in Monthly Notices of the Royal Astronomical Society in October 2016 by a team led by Dr Natasha Hurley-Walker (Curtin/ICRAR). The paper presents a catalogue of over 300,000 radio galaxies; data to be used initially to investigate the collisions of entire galaxy clusters. These results are to be followed by maps of sources of radio waves that lie within the Galaxy. The GLEAM survey team hope to find the remnants of many more supernovae than we currently know of. These "missing" supernovae are thought to be the cause of the Galaxy's background synchrotron glow.

A "radio colour" image of GLEAM survey data was named one of the best science images of 2016 by Nature. To create the image, low frequency emission was coloured red, mid-range emission green and the highest frequency emission blue.

The GLEAM survey has been made available to the public in a variety of ways, including a mobile phone app available on Google Play, the online GLEAMoscope, and a TEDx talk in Perth in October 2016 by Dr Natasha Hurley-Walker.

AAL provided funding for MWA in 2016/17 through support from the Australian Government's NCRIS, via the Department of Education and Training.

Image: FIRST GLEAMING. The Milky Way flows through this image, which encompasses more than 300,000 galaxies. Credit: Natasha Hurley-Walker (Curtin/ICRAR), GLEAM survey team.



Detecting the Fastest Radio Bursts in the Universe

Six-day multi-wavelength observational campaign detects supernovae and transient phenomena

From a control room at Swinburne University of Technology's (SUT) Hawthorn campus, a massive collaboration of about 20 telescopes from around the world, and in space, has been searching for fast radio burst (FRBs).

The SUT's supercomputer enables real-time data processing and analysis for the Deeper, Wider, Faster program. The program detects the fastest radio bursts in the universe by coordinating over 20 telescopes of all wavelengths from around the world and in space from this room at the SUT. The bursts last only fractions of a second to hours. The data must be processed and analysed quickly (in seconds to minutes) to identify the events while they are still in outburst to trigger other telescopes to get more detailed observations.

Over the course of six days of observing, the astronomers discovered more than a dozen supernovae very early in their explosions, one in a very peculiar host galaxy, several mysterious exploding events, thousands of rapid pulsating events, asteroids and flaring stars. But sadly, no FRBs.

"We didn't detect an elusive FRB, but the odds are low because they are so rare, hence we need a number of these observing runs to detect one," says program leader Dr Jeff Cooke.

"We process and search the data in real-time using the Swinburne supercomputers and are essentially making very sensitive and detailed movies of the active universe. We were happy with the outcome," Dr Cooke says. "We have ongoing follow-up observations that are equally important with an array of telescopes all over the world, including gravitational wave detectors, and both the data and discoveries are still forthcoming."

The telescopes involved in this experiment included the Australian Telescope Compact Array (ATCA), MWA and ANU's SkyMapper. AAL has provided funding to these telescopes under NCRIS in 2016/17.

Images: The Deeper, Wider, Faster program searches for the fastest bursts in the universe and incorporates over 20 telescopes worldwide and in space. The program is based at the SUT and nearly 100 researchers, including students and young potential researchers, are involved in the program. Credit: Carl Knox, SUT/OzGrav.

ASKAP Fast Tracks Bright FRB Discovery

Short survey yields immediate results and demonstrates telescope's capability

FRBs are powerful, millisecond radio pulses. These enigmatic phenomena are thought to come from extragalactic sources, though given their highly transient nature, are very difficult to pinpoint with precision. FRBs are rare, of unknown physical origin and a hot topic of astrophysical research. Australian astronomers, with ASKAP, have proven themselves up to the challenge of detecting these rare, transient phenomena, recently adding a new, bright member to the census of known FRBs (Bannister, K. W. et al., 2017, Astrophys. J. Lett., 841, L12).

The discovery is made remarkable by the fact that the FRB, designated FRB 170107, was detected after a modest ASKAP survey of less than four days. To put that in perspective, only about 30 have ever been detected, anywhere, including those found by inspection of archival radio data. This new FRB is a vindication of the dedication put into the ASKAP project and demonstration of the utility of its large field of view. If the results of this modest survey are anything to go by, ASKAP is set to dramatically increase the census of known FRBs (see too the article elsewhere in this report about the concerted efforts to catch a FRB in real-time, "Detecting the Fastest Radio Bursts in the Universe").

The bright, new FRB 170107, or Bannister Burst (named after Dr. Keith Bannister, Commonwealth Scientific and Industrial Research Organisation (CSIRO), shown opposite), helps bridge the gap between the high number of theorised FRB events, ~2500 per sky per day (above a 1.4 GHz fluence of ~2 Jy ms), and the low numbers actually detected. Furthermore, it suggests the existence of a distinct, very high brightness class of FRBs within the general FRB population.

As the search for new FRBs at ASKAP and other facilities continues, we are left to ponder their origins. Repeating, though non-periodic, FRBs have been detected from, ostensibly, the same location in space. This suggests they don't arise from single cataclysmic events. Origins hypotheses are varied, but a leading candidate is hyperflares from young magnetars (such as the one pictured here).

AAL provided funding for ASKAP and the associated CSIRO ASKAP Science Data Archive (CASDA) under NCRIS in 2016/17.

Image: Artist's impression of a magnetar, a type of neutron star with an ultra-powerful magnetic field. Though the source of FRBs is unknown, magnetar hyperflares are one hypothesis. Credit: ESO/L. Calçada, licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/legalcode), resized from original (http://www.eso.org/public/images/eso1415a/).

Image: Dr. Keith Bannister, lead author on the FRB discovery paper. © Copyright CSIRO Australia, 23 May 2017.

Stargazing Live

Australian astronomy showcased on live television broadcast from the AAT

April 2017 saw the premiere of the ABC's Stargazing Live, featuring popular TV science personality Professor Brian Cox. Broadcast live from in front of the Anglo-Australian Telescope (AAT), it ran consecutive nights, interacting with home viewers. One segment explained how viewers could participate in citizen science efforts to find new exoplanets. A young mechanic and amateur astronomer from Darwin, Andrew Grey (shown), took part in earnest, contributing to discovery of a candidate four-exoplanet system.

Image: Andrew Grey, Darwin mechanic who found a candidate four-exoplanet system. Credit: Helen Orr. Andrew is interviewed on the SPUN Stories Podcast (www.spunstories.net/andrew-grey).

AAL funded AAT instrumentation (the Two-degree Field (2dF) and High Efficiency and Resolution Multi-Element Spectrograph (HERMES) upgrades) under NCRIS in 2016/17. When not appearing in Stargazing Live, or performing other tasks, the AAT uses the 2dF and HERMES to collect spectra to catalog Kepler Second Light exoplanet hosts and constrain exoplanet sizes.

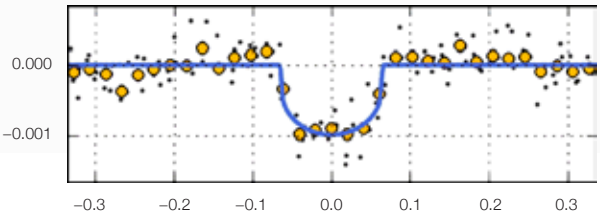


Image: relative stellar flux versus phase (days), showing a characteristic lightcurve dip caused by one of Andrew's exoplanet candidates. Credit: Zooniverse.org platform, development of which is funded by generous support, including a Global Impact Award from Google, and by a grant from the Alfred P. Sloan Foundation.

GCo Electrical

MWA industry partner provides key project documentation for the SKA

GCo Electrical won the tender in 2012 to manage installation of site infrastructure for the Murchison Widefield Array (MWA) radio telescope. Thus began a science-industry partnership that has strengthened over the years, with GCo regularly supporting MWA and CSIRO activities at the Murchison Radio-astronomy Observatory (MRO). Along the way, GCo has developed a deep understanding of the demands of the remote MRO site, and of the unique considerations of radio astronomy projects. That insight led to GCo being engaged to compile and cost a deployment plan for the 130,000 low frequency antennas for the initial phase of the SKA. The high quality of the resulting report is a reflection of the time and effort both the MWA team and the company have put into a partnership which has resulted in a Geraldton based enterprise developing the capability to contribute meaningfully to a once in a generation science project.

The most significant returns to local industry from the SKA will come through the operation and maintenance of the facility over its 50-year life. GCo is developing exactly that expertise, having provided the majority of the effort required to complete the recent doubling in size of the MWA, and subsequently taking over responsibility for the routine operational maintenance of the array.

Image: Aerial photograph of the core region of the MWA. Credit: MWA Corporation/Curtin University.

Visualising the Universe

Multicolour southern sky picture named one of Nature's top images of 2016

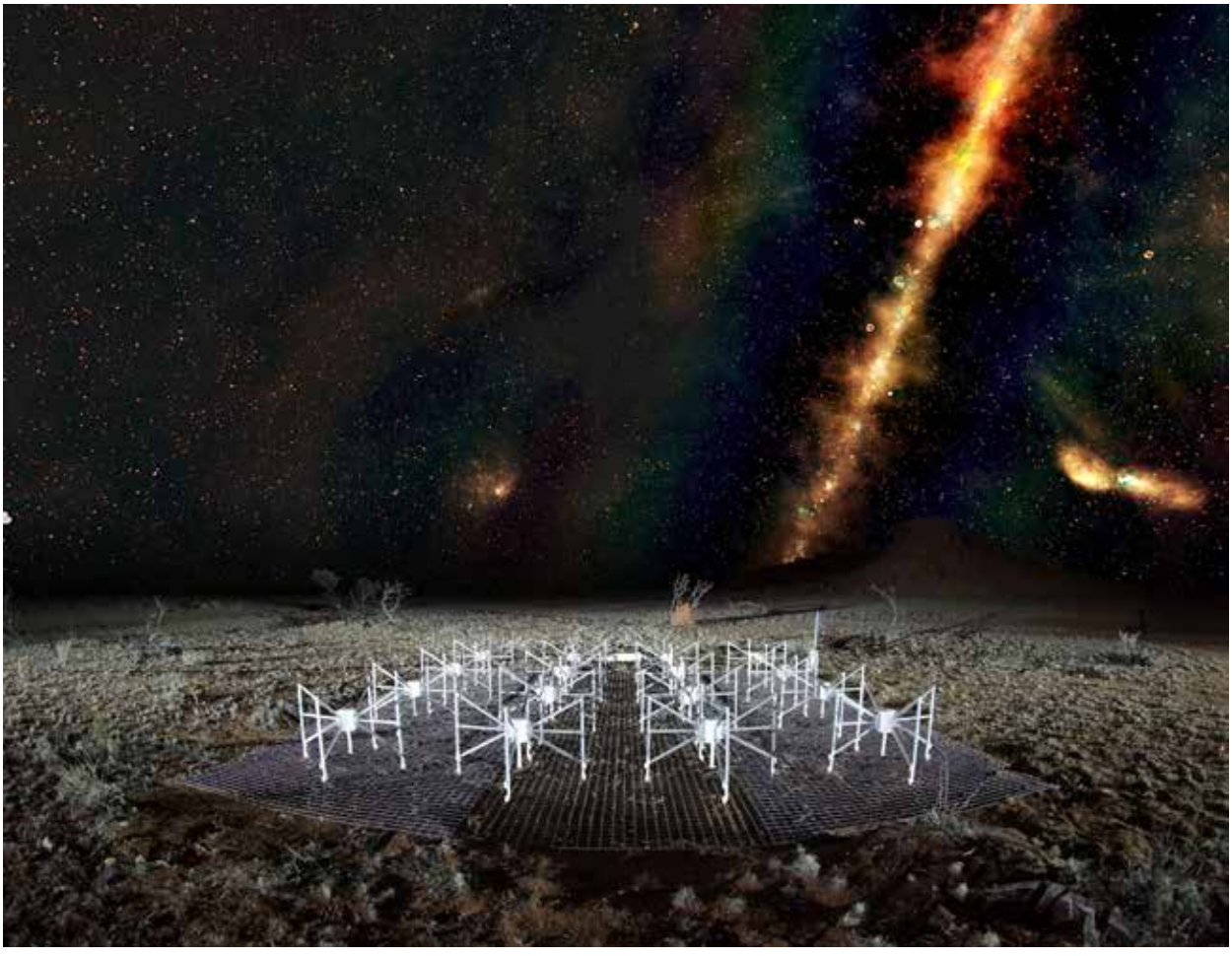
Australian astronomers are very active in public outreach, undertaking a wide variety of activities aimed at a range of audiences, from primary, secondary and tertiary students to members of the general public. Outreach engages the community in the exciting research being undertaken at NCRIS-supported facilities and helps inspire the next generation of scientists. In 2016/17, NCRIS-supported facilities undertook a large number of science outreach activities.

A highlight was the release of the GLEAM survey, accompanied by a variety of multimedia resources aimed at engaging the public in radio astronomy. These resources have had thousands of 'hits' since going online with the release of the GLEAM survey paper. A GLEAM survey view of the centre of the Milky Way, in radio colour, was selected in Nature's best science images of 2016.

At Astrofest 2017, Dr John Goldsmith (Celestial Visions), Dr Natasha Hurley-Walker (Curtin/ICRAR) and the GLEAM Team were jointly awarded the "Best Timelapse Video" award for the GLEAM/Visible timelapse. The judges said they loved how it showed how astrophotography and science could sometimes be one and the same.

This is a unique timelapse movie showing the sky above a tile of the MWA radio telescope, located in outback Western Australia. The normal optical sky transitions to a view of the sky at radio wavelengths. The Milky Way is visible as a band across the sky, and the dots beyond are some of the 300,000 galaxies observed by the telescope for the GLEAM survey.

Image credit: Radio image by Dr Natasha Hurley-Walker (Curtin/ICRAR) and the GLEAM Team. MWA tile and landscape by Dr John Goldsmith / Celestial Visions. See the time-lapse video: https://vimeo.com/188100116



Astronomy Infrastructure Portfolio

AAL receives funding from the Australian Government via programs such as the National Collaborative Research Infrastructure Scheme (NCRIS), via the Department of Education and Training, and an Australian Government astronomy research infrastructure grant, via the Department of Industry, Innovation and Science. This funding supports Australian-based astronomers to access a range of world-class national and international astronomical facilities. AAL also supports various development projects to upgrade or develop future national and international astronomical infrastructure. AAL manages, represents and supports the interests of Australian astronomers in a number of international projects and facilities. These activities align with the national research infrastructure priorities of the Australian Astronomy Decadal Plan. The following pages outline facilities and projects to which AAL committed funding in 2016/17:

- **Optical Astronomy;**
- **Radio Astronomy;**
- **Data and Computing Infrastructure; and**
- **High Energy Astrophysics.**

Image: Tiles of the MWA.
Credit: MWA Corporation/Curtin University.

Optical Telescopes:
Giant Magellan Telescope

The Giant Magellan Telescope (GMT) is a next generation optical and IR, giant, ground-based telescope that promises to revolutionise our view and understanding of the universe. It will be constructed at Las Campanas Observatory in Chile, which is owned by the Carnegie Institution for Science. Perched at an elevation of over 2,400 m (8,000 ft) in the Andes mountain range, the site is known for clear weather and is well-isolated from the light pollution that poses a major obstacle to ground-based optical astronomical research.

The GMT has a unique design with seven segmented 8.4-metre mirrors that will form a single optical surface of 24.5 metres in diameter, with a total collecting area of 368 m^2. The GMT will have a resolving power 10 times greater than the Hubble Space Telescope. Poised to be the first Extremely Large Telescope (ELT) to begin operations, and designed to have an operational lifespan of 50 years or more, the GMT will provide unprecedented clarity and sensitivity for the observation of astronomical phenomena. First light and commissioning for the telescope is expected by 2023, with the GMT becoming fully operational by 2025. The GMT will be critical in enabling Australian-based astronomers to tackle many of the key science questions identified in the 2016–2025 Decadal Plan for Australian astronomy.

Image: Artist's impression of the GMT.
Credit: GMTO Corporation.

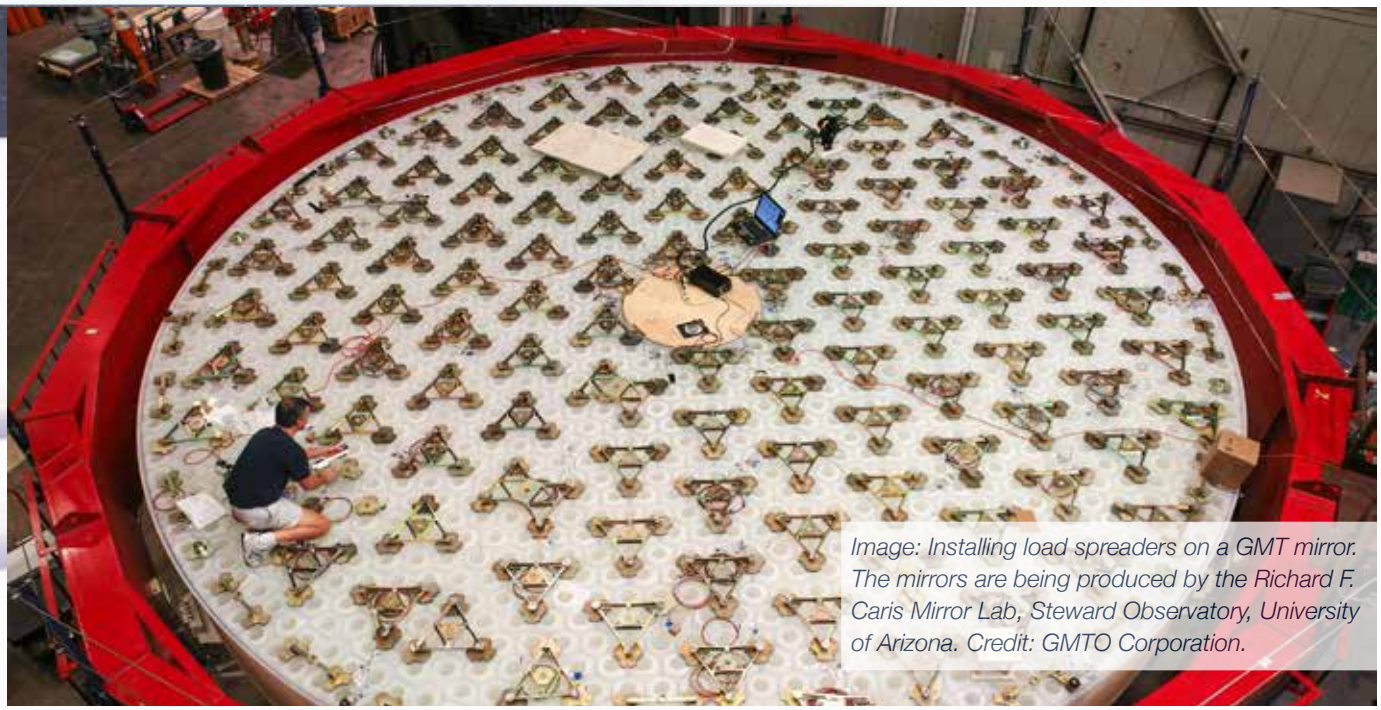


Image: Installing load spreaders on a GMT mirror. The mirrors are being produced by the Richard F. Caris Mirror Lab, Steward Observatory, University of Arizona. Credit: GMTO Corporation.

The GMT Organisation

The GMT Organisation (GMTO) is an independent organisation created by an international consortium of leading academic and research institutions, with the mission of funding, engineering, constructing and operating the world's largest optical telescope. Australia is a 10% partner in the GMT, via the ANU and AAL, which are both 5% partners. The Australian Government has invested ~$93 million of Commonwealth funding in the billion-dollar GMT project, which has positioned Australia to play a leadership role in GMT science and instrumentation. During 2016/17, AAL funding supported continued engagement in GMT governance, including representation on the GMTO Board as the project progresses through the first phase of construction and actively seeks new funding and partners to realise the full budget.

Progress and highlights

In January 2017, the GMTO announced the appointment of physicist Robert N. Shelton, PhD, to the position of President. Dr. Shelton will work closely with the GMTO Board of Directors, the leadership at the partner institutions, and the GMT team to move the project forward. Dr Shelton has already had an impact on managing the project's leadership, external relationships and fundraising activities.

The project to build an ELT in Chile has progressed steadily in 2017 including construction of accommodation at the Las Campanas site, agreement to cast mirror segment five, and growth in project staff. The second major contract (telescope mount) is in the later stages of the procurement process.

Associate Professor Sarah Brough from the University of New South Wales (UNSW) was appointed as an observer to the GMTO Science Advisory Committee (SAC) for two years.

"The GMT will be an incredible asset to the future of scientific discovery and our understanding of the universe," Robert N. Shelton, PhD, President, GMTO. "I am delighted to join the organisation behind this historic project and look forward to working with the Board and our partner institutions to ensure the successful completion of the telescope."

Australian instrumentation

Australia has a strong international reputation for optical and IR technology and innovation, which has resulted in Australian instrumentation groups such as the AAO and ANU's Advanced Instrumentation and Technology Centre (AITC) winning instrumentation contracts from overseas observatories. This includes instrumentation for the GMT which has brought in onshore revenue and provided opportunities to partner with local industry.

Over 2016/17, the AITC continued developing the GMT Integral Field Spectrometer, a near-IR imager and integral-field spectrograph. The total value for the design and build of this instrument to Australia is expected to be ~$25 million. The AITC is also designing the GMT Laser Tomography Adaptive Optics subsystem.

A third Australian contract for GMT instrumentation is for the AAO to develop the Many-Instrument Fibre System, a fibre positioner designed to feed all the natural-seeing spectrographs of the GMT.

Optical Telescopes:
8-Metre-Class Telescopes

Enhancing our capability in optical astronomy and associated technologies by establishing a formal partnership in an 8-metre-class optical telescope, is identified as a priority in the Australian Astronomy Decadal Plan 2016–2025. During 2016/17 AAL continued engaging with 8-metre-class facilities including ESO, Keck, Magellan and Subaru to explore options for future Australian partnership.

In 2016/17, AAL purchased time on the world-class Gemini, Keck, Magellan and Subaru telescopes, via $1.8 million of NCRIS and Department funds. Approximately $32 million of Commonwealth funds have purchased time on 8-metre telescopes since 2006.

Access to 8-metre-class telescopes was highly competitive with subscription rates averaging 240% for time on Magellan, Keck and Gemini in 2016/17. Australian based researchers from 14 institutions continued to be very scientifically productive co-authoring 118 papers in 2016/17. 97% of these publications involved Australian and international collaborations and 25% of the co-authors were students.

Australia-ESO Partnership

The Australian Government has committed $26.1 million to enable Australia to enter into a 10-year strategic partnership with ESO, starting in 2018. The Strategic Partnership will give Australian astronomers access to facilities at the La Silla Paranal Observatory, including the four 8.2-metre telescopes of the Very Large Telescope (VLT).

Subaru Telescope

The National Astronomical Observatory of Japan (NAOJ) manages Hawaii's 8.2-metre Subaru Telescope. A 2017 AAL-NAOJ agreement secures 10 nights for Australian astronomers in 2018. Australia's contribution includes technical work ($600,000 from the AAO and/or ANU) and four nights on the AAT. *Image credit: Tom Kerr, UK IR Telescope.*

Magellan Telescopes

The 6.5-metre Baade and Clay telescopes were built at the Las Campanas Observatory in Chile for the Magellan Project, a collaboration between the Carnegie Institution of Washington, Univ. Arizona, Harvard Univ., Univ. Michigan, and Massachusetts Institute of Technology. Since 2007, AAL has negotiated 15 nights per year of Australian community access to the Magellan telescopes. This access is available to all Australian astronomers to the end of 2020.

International Telescopes Support Office

The International Telescopes Support Office (ITSO) has been hosted by the AAO since 2008, and operates as a division of the DIIS. ITSO coordinates Australian use of international telescopes for which AAL has negotiated access agreements for the Australian community. In 2016/17 this included time on the Gemini telescopes (seven nights in each of 2016 and 2017); 15 nights per year on the Magellan telescopes; and a pooling of AAL's 15 nights per year on the Keck telescopes with similar amounts of time secured by the ANU and SUT through a joint Keck Time Allocation Committee (KTAC).

Image: ITSO "roadshow" of all AAL member institutions. Credit: AAO.

Gemini Telescopes

The Gemini Telescopes are twin 8.1-metre optical and IR telescopes. Collectively, Gemini North (Hawaii) and Gemini South (Chile) can access the entire sky. Gemini is operated by a partnership between Argentina, Brazil, Canada, Chile and the USA. Australia will remain a limited-term Gemini partner in 2017, with a seven-night observing allocation.
Image credit: Image Capture 2013 © 2017 Google.

Keck Telescopes

The W. M. Keck Observatory operates two of the world's largest telescopes on the summit of Mauna Kea, Hawaii. Each Keck telescope has a mirror 10 metres in diameter, made up from 36 hexagonal segments, and is equipped with state-of-the-art instrumentation. Australian astronomers have access to 15 nights/year on these telescopes in 2016 and 2017. AAL also has an agreement with the ANU and SUT, who each have 15 nights/year in 2017, to pool the time and make it available via KTAC. KTAC provides a single interface for Australian-based astronomers who wish to request access to the total of 45 Keck-nights available per year in 2016 and 2017. This model is designed to facilitate larger programmes and broader collaborations to maximise the scientific return from Australia's engagement with the Keck telescopes. All Australian-based astronomers are eligible for AAL time on Keck in 2016 and 2017. AAL has engaged ITSO to manage and support this programme within Australia.

Optical Telescopes:
Anglo-Australian Telescope

The Anglo-Australian Telescope (AAT) is Australia's top ranked national optical and IR facility producing leading science. Located at Siding Spring Observatory, in Coonabarabran, NSW, the telescope is operated by the Australian Astronomical Observatory (AAO), a division of the Department of Industry, Innovation and Science (DIIS). The AAT is an exceptionally high-quality 4-metre telescope equipped with a suite of state-of-the-art instrumentation to explore in detail some of the most exciting regions of the Southern Sky including the centre of our own Milky Way galaxy and the Magellanic Clouds.

AAT instrument upgrade

In 2016/17, AAL supported critical major maintenance of the Two-degree Field (2dF) fibre cable system that channels light into the two most heavily used AAT spectrographs, HERMES and AAOmega. The 2dF system is critical to the operation and scientific productivity of the AAT. The 2dF is over 20 years old and this maintenance was required to extend its life to support HERMES and AAOmega. Any significant downtime of the 2dF would result in a massive drop in the research productivity of the AAT.

AAT Survey highlights

Australian Dark Energy Survey
The Australian Dark Energy Survey (OzDES) is a large survey at the AAT, using the 2dF fibre positioner and AAOmega to measure the redshifts of tens of thousands of galaxies and obtain spectra of supernovae and other transients. The galaxy redshifts will be used to make the most detailed measurement of the universe's expansion history, leading to a better understanding of the physics behind the acceleration of the universe. The realisation that the expansion of the universe is not slowing down but actually speeding up was one of the most significant scientific discoveries of the last century. The discovery led to the 2011 Nobel Prize in physics.

OzDES Data Release 1 is the first data release from the six year duration of OzDES. At the end of three years, and over 52 observing nights on the AAT, OzDES has spectroscopically confirmed almost 100 supernovae, and has measured redshifts for 17,000 objects, including the redshifts of 2,566 supernova hosts.

SAMI Survey
Data for the SAMI Galaxy Observatory is collected with the Sydney-AAO Multi-object Integral-Field Spectrograph (SAMI) on the AAT. Integral-field spectroscopy allows a unique view of how stars and gas zoom around inside distant galaxies because we collect dozens of spectra across the entire face of each galaxy. The survey began in March 2013, with the intention of creating a large survey of ~3400 galaxies across a large range of environments. Galaxies included in the SAMI Data Release 1 are drawn from all galaxies observed in the Galaxy And Mass Assembly (GAMA) regions as of June, 2015. The SAMI team announced their data public release in July 2017, hosted on AAO Data Central (ADC).

GALAH Survey
The GALactic Archaeology with HERMES (GALAH) survey is a Large Observing Program using HERMES to survey one million galactic stars measuring elemental abundances and stellar kinematics to understand the formation history of our Milky Way galaxy. GALAH has been observing since late 2013, and has collected spectra for over 500,000 Milky Way stars to date in an observing program that uses 70 nights per year on the AAT. The first public data release was in September 2016.

Image: Inside the AAT Dome. Credit: AAO.

Optical Telescopes: Antarctic PLATeau Observatory

The PLATeau Observatories (PLATOs) are self-contained automated platforms for conducting year-round experiments completely robotically from the Antarctic plateau. PLATOs are deployed to several locations on the high Antarctic plateau (Dome A, Dome Fuji, Ridge A) in collaboration with institutes and Antarctic logistics agencies of China, Japan and the USA. This is one of the best sites in the world to undertake optical and IR astronomy, due to the cold, dry and stable atmospheric conditions and is the only ground-based site from where effective terahertz observations can be made.

Progress and highlights

Annual PLATO for Dome A (PLATO-A) servicing was completed during the first three weeks of January 2016. Four Chinese engineers/astronomers on the traverse worked on the Antarctic Survey Telescopes × 3 #2 (AST3-2), PLATO-A, Chinese Small Telescope Array, meteorological tower, and a new all-sky camera. PLATO-A operated perfectly before and after the service mission, under diesel power during the winter months and under combined solar power and diesel engines for the rest of the year.

The AST3-2 telescope functioned successfully during 2016/17. Data disks from the 2016 winter season, holding over 15 TB of telescope data, were returned via the Xuelong icebreaker in January and are now being worked on at the UNSW. The raw image data was released to the Australian astronomical community on 27 July 2017, and will be followed with the release of a data pipeline to turn the raw images into calibrated images. A Chinese/Australian team was awarded five AAT nights to follow up AST3-2 observations in September 2016. Additionally, the ANU 2.3-metre telescope at Siding Spring Observatory has been used to obtain spectra of supernovae discovered by the AST3-2.

The AST3-3 project also progressed over the year. This is a strong international Antarctic astronomy partnership with a consortium of Australian institutes who are developing a near-IR K band camera for a telescope built by the Nanjing Institute of Astronomical Optics and Technology.

International collaborations were strengthened over the year via many joint activities. The 2nd Australia-China Workshop on Astrophysics was held in Suzhou China in Dec 2016. This conference involved over 90 attendees discussing topics from radio astronomy science and the SKA, Antarctic astronomy science, big data challenges, and large optical and IR facilities. Project personnel met with scientists and engineers of the British Antarctic Survey in May 2017, about running their Halley Station remotely in 2018, and the relevance of PLATO technology. Project personnel also visited the Nanjing Institute for Astronomical Optics and Technology in June 2017, along with a delegation from the AITC, to discuss possible Australia-China collaborations to develop instrumentation for the Chinese 12-metre Large Optical Telescope and Antarctic Kunlun Dark Universe Survey Telescope. Chinese collaborators from the Beijing Astronomical Observatory and the National Astronomical Observatory of China visited the UNSW for extended periods throughout the year to work on PLATO servicing.

UNSW (in collaboration with the AAO, ANU, SUT and U. Sydney) successfully obtained a four year $120,000 grant from the Australian Antarctic Division to assist with logistical expenses to support the PLATO project.

Image: Chinese traverse team members with the 0.5-metre AST3-2 optical telescope at Dome A, 12 Jan 2017. Credit: Polar Research Institute of China.

Radio Telescopes:
SKA Pathfinders

The Square Kilometre Array (SKA) is a global, next generation radio telescope project involving institutions from over 20 countries. The SKA will be the largest and most capable radio telescope ever constructed. During its 50+ year lifetime, it will expand our understanding of the universe and drive technological development worldwide. Australia and southern Africa will each host different SKA components that will develop Australia's local industry and regional engagement. The Decadal Plan also highlighted the importance of the two official SKA precursor telescopes, ASKAP (capital value $188 million) and the MWA (value $50 million). Australia has invested heavily in these precursors, which are acting as testbeds for advanced technology solutions for the SKA and demonstrating the exceptional conditions in outback Western Australia for radio astronomy. In addition, they are scientifically powerful instruments in their own right, making data available to more than a quarter of Australian astronomers and hundreds of international collaborators.

2016/17 NCRIS funds enabled ongoing operation of the two Australian SKA precursors, the Australian SKA Pathfinder and the Murchison Widefield Array.

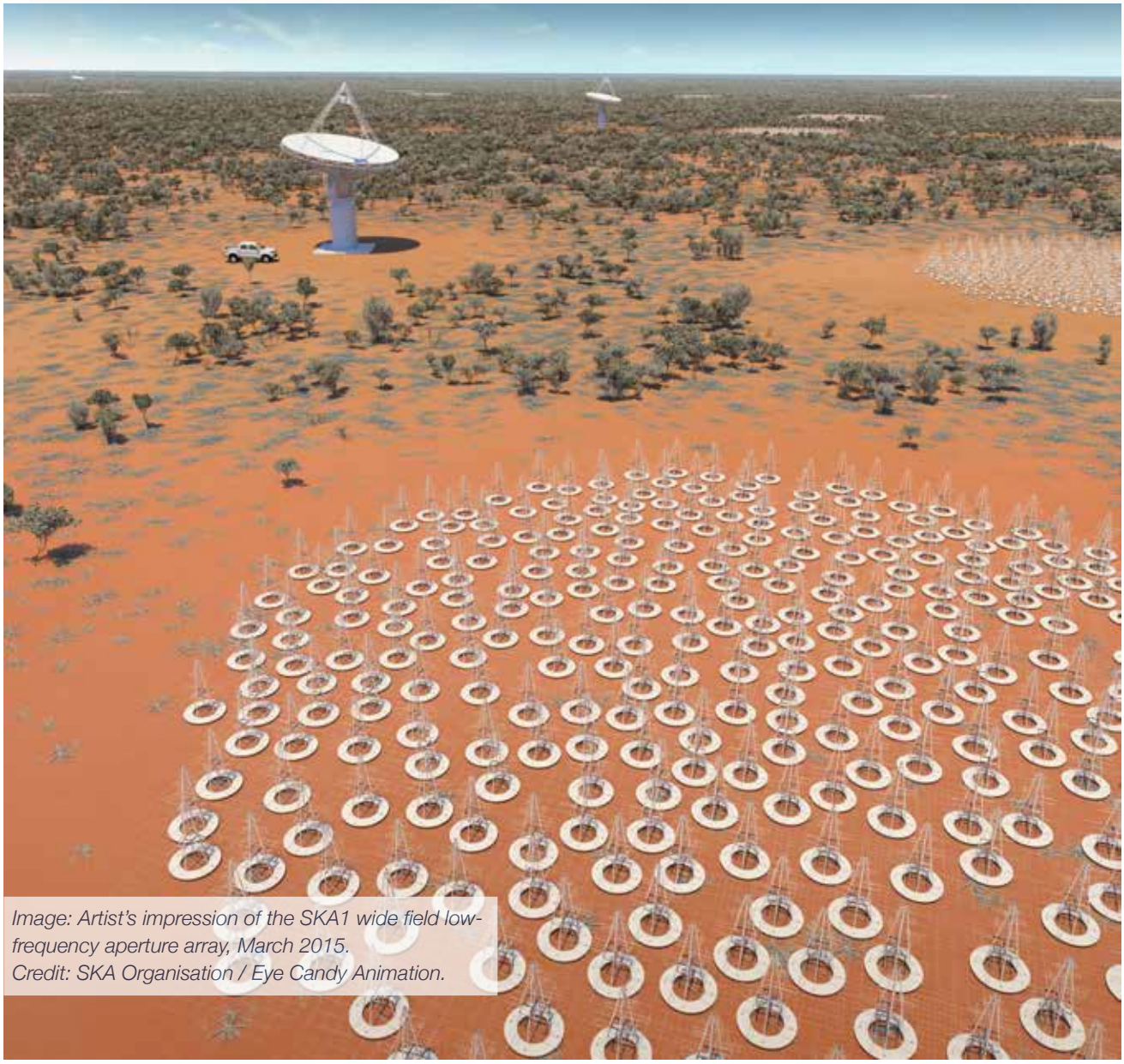


Image: Artist's impression of the SKA1 wide field low-frequency aperture array, March 2015.
Credit: SKA Organisation / Eye Candy Animation.

Radio Telescopes: Murchison Widefield Array

The Murchison Widefield Array (MWA) is a low-frequency radio telescope located at the Murchison Radio-astronomy Observatory (MRO) in Western Australia, the planned site of the future SKA low-band telescope, and is one of three telescopes designated as a precursor for the SKA. The MWA is an international collaboration, including partners from Australia, Canada, China, Japan, New Zealand and the USA.

The MWA is performing large surveys of the entire Southern Sky and acquiring deep observations on targeted regions. It enables astronomers to pursue four key science objectives. The primary endeavour is the hunt for intergalactic hydrogen gas that surrounded early galaxies during the cosmological epoch of reionisation (EoR). The MWA will also provide new insights into our Milky Way galaxy and its magnetic field, pulsing and exploding stellar objects, and the science of space weather that connects our Sun to the environment here on Earth.

The telescope collects radio waves with low frequencies between 80 and 300 MHz via 8192 antennas, split up into 256 groups of 32 called 'tiles' that are spread as far as 5 km apart. It is designed to have a wide field of view on the sky and to be highly versatile and adaptable through signal processing rather than through moving parts.

During 2016/17, AAL supported MWA operations through $1.32 million of NCRIS funding. AAL has previously provided over $11.7 million to enable MWA construction and early operations, using Commonwealth funding under NCRIS and other infrastructure programs.

Progress and highlights

The MWA completed its seventh and eighth six-month operational observing campaigns. Despite these campaigns being significantly impacted by the Phase 2 expansion program, a total of 2480 hours of observing were completed, with 4088 TB of data collected in support of more than 19 projects. Since commencing operations in July 2013, the MWA has completed more than 13,000 hours of observing in support of 59 different projects. More than 15 PB of MWA data is archived at the Pawsey Centre, 6 PB of which is now publicly available.

FY2016/17 saw the successful deployment, commissioning and initial observing with the Phase 2 'compact' configuration with improved sensitivity for EoR science; and substantial progress in the deployment of the new long-baseline tiles required for the Phase 2 'extended' configuration that will enhance the MWA's survey capability. Much of this work was completed by Geraldton based companies, as the MWA continued to fulfil its role as an SKA precursor by helping to prepare local industry to make a meaningful contribution to SKA construction and operations.

The MWA collaboration produced 25 refereed journal articles in 2016/17 including almost 70 international collaborators and over 70 Australian co-authors.

One of the highlights was the release of the GLEAM survey which was accompanied by a variety of multimedia resources aimed at engaging the public in radio astronomy. These resources have had thousands of 'hits' since going online with the release of the GLEAM survey paper. A GLEAM survey view of the centre of the Milky Way, in radio colour, was selected in Nature's best science images of 2016.

Image: MWA tiles at the MRO.
Credit: Curtin University/MWA Corporation.

Radio Telescopes:
Australian SKA Pathfinder

The CSIRO's Australian SKA Pathfinder (ASKAP), located at the remote radio-quiet MRO in Western Australia, is designed to be one of the world's fastest and most powerful radio telescopes.

ASKAP's wide field-of-view, generous spectral bandwidth, rapid survey speed, excellent uv-plane coverage, southern hemisphere location and radio-quiet site will make it an unprecedented synoptic telescope. ASKAP comprises an array of 36 dish antennas, each 12 metres in diameter and fitted with state-of-the-art phased array feeds (PAFs), that work together as a single instrument. ASKAP is both a demonstrator for the award-winning Australian PAF technology and a world-class instrument in its own right. Approximately one in four Australian-based astronomers are investigators on ASKAP science projects. These unique features will allow ASKAP to make substantial advances in key areas of SKA science, including:

- galaxy formation and gas evolution in the nearby universe through extragalactic HI (neutral hydrogen) surveys;
- galactic evolution, formation and populations across cosmic time via high resolution, confusion limited, continuum surveys;
- characterisation of the radio transient sky through detection and monitoring, including very-long-baseline interferometry, of transient and variable sources; and
- evolution of magnetic fields in galaxies over cosmic time through polarization surveys.

In 2016/17, AAL invested $2.6 million of NCRIS funds through the CSIRO towards the costs of operating ASKAP and supporting user engagement to ensure that the community has the capability to exploit the full potential of ASKAP. AAL support for ASKAP assists the CSIRO in developing the MRO site for the SKA, and in hosting other world-class instruments including the MWA and Experiment to Detect the Global Era of Reionisation Signature. AAL has provided over $28 million in Commonwealth funds to support ASKAP construction and operations.

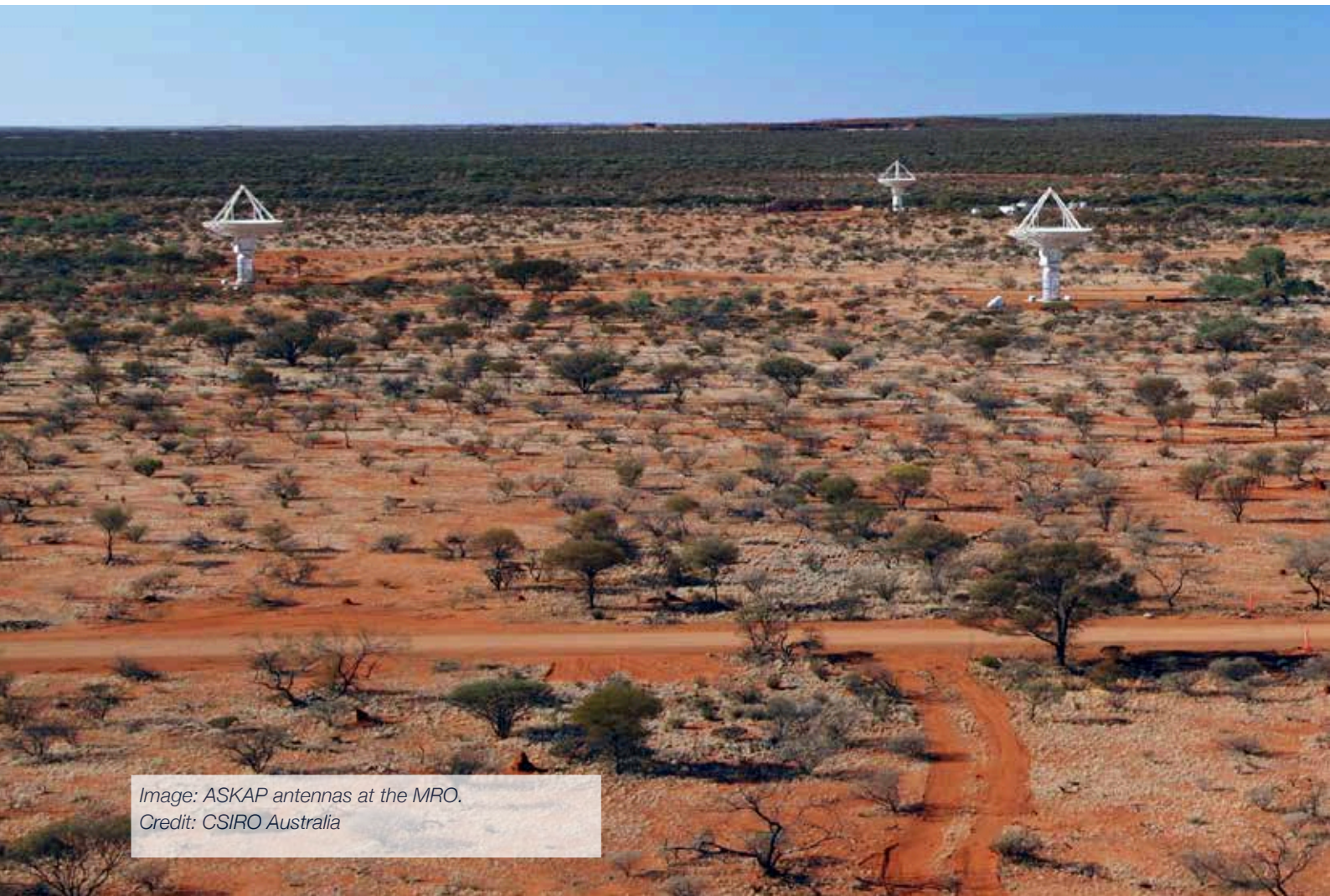


Image: ASKAP antennas at the MRO.
Credit: CSIRO Australia

Progress and highlights

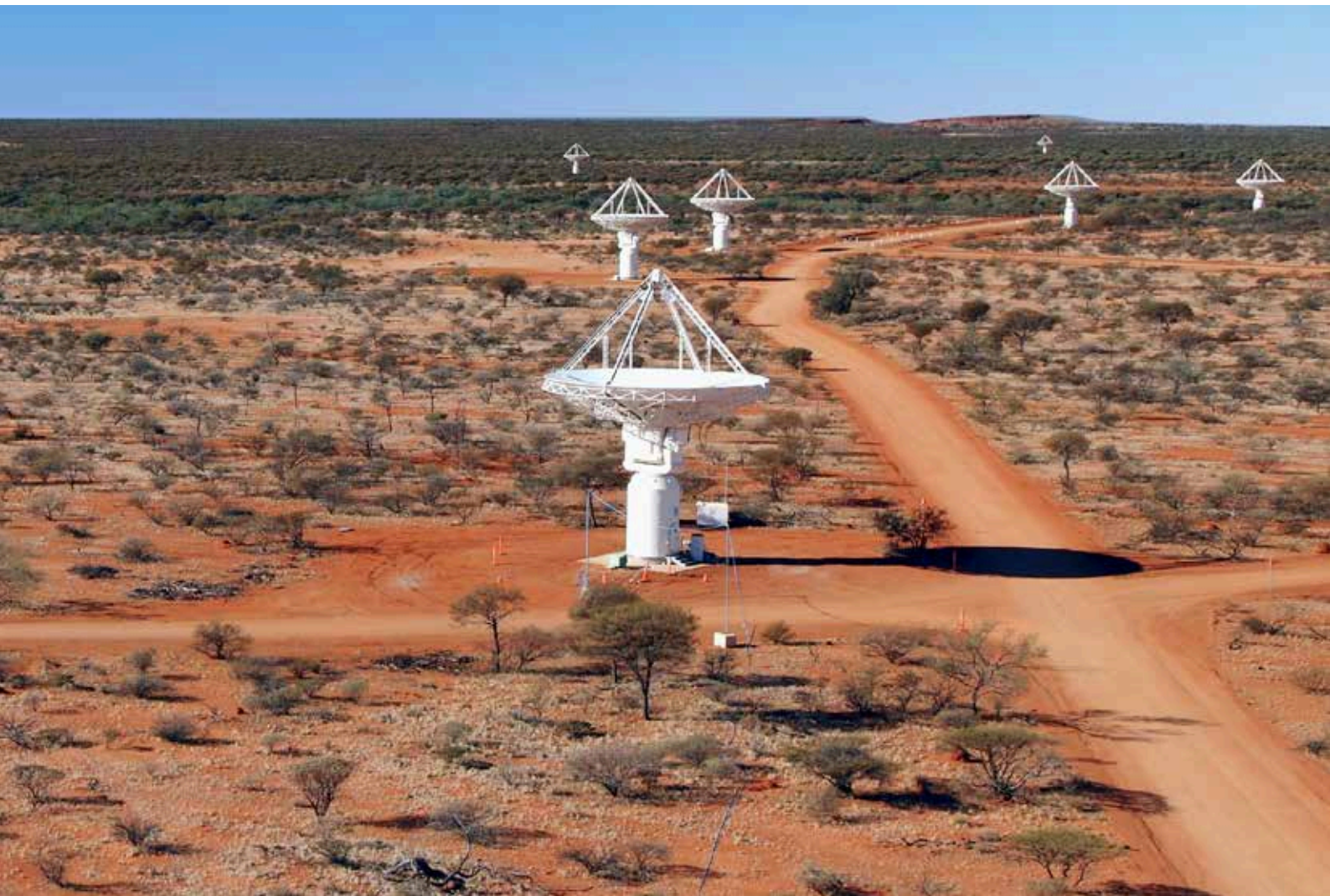
The last twelve months have seen continued strong progress with the ASKAP telescope. In October 2016 observations for the ASKAP 'Early Science' program commenced, using an array comprising the first twelve antennas to be equipped with the Mark-II PAF receivers. Thirty of the thirty-six receiver systems required for full ASKAP have now been installed, with the final six systems to be rolled out during 2017. Science papers from Boolardy Engineering Test Array continue to flow, demonstrating not only the great potential of PAFs for radio astronomy, but also the unique radio-quiet environment of the MRO.

Over 500 hours of Early Science time has been devoted to the ASKAP HI All-Sky Survey, Wallaby. Wallaby is proposed to become the largest, most homogeneous HI sample of galaxies to date. The survey volume is so large that observations are expected to put new constraints on several cosmological parameters.

Early Science Time has also been used to capture data for the CRAFT (Commensal Real-time ASKAP Fast Transients) Survey, a high time resolution survey for fast radio transients. A particular focus for CRAFT will be the newly discovered, highly luminous FRBs. Four new FRBs were discovered using Early Science Time. Work is proceeding on an automated, near real-time, FRB detection pipeline which will greatly help the search for the source of the FRBs.

CSIRO ASKAP Science Data Archive

AAL provided funding for CASDA, to enable researchers to gain access to research data, software and other digital assets published by the CSIRO across a range of disciplines. The portal is maintained by CSIRO Information Management and Technology. The first CASDA public data release, of six ASKAP Early Science Data sets, occurred on 10 July 2017.



High Energy Astrophysics:
Pierre Auger Observatory

Many of the key science questions to be addressed by astronomy in the next decade will require researchers to combine electromagnetic radiation (from radio to x-ray energies), cosmic rays, neutrinos and gravitational waves. This multi messenger approach to astronomy will probe some of the most energetic phenomena in the universe, including black hole mergers, the interiors of pulsars, FRBs, and the production of cosmic rays. Investments in high-energy astrophysics projects enable Australian astronomers to gain access to cutting edge facilities such as the Pierre Auger Observatory and Cherenkov Telescope Array.

The Pierre Auger Observatory operates as a hybrid observatory to study the highest energy particles in nature. It has two major components, a ground-based system of 1660 large-area radiation detectors, plus a system of 27 large telescopes which track cosmic ray cascades as they pass through the atmosphere at distances of up to 40 km. This project supports the latter facility in providing detailed cloud cover information over the 3000 km^2 area of the observatory.

The project is carried out through the use of AAL-funded long-wave IR cloud cameras which scan the telescopes' fields of view every five minutes and the full sky at 15 minute intervals, to provide observers with real-time information on cloud conditions, and to fill the observatory cloud database which is used as part of the analysis stream for all users of data from the 27 ultraviolet telescopes. Four cameras operate on each shift night (after sunset and at times of low moon illumination), one supporting each telescope site. Those sites are located with spacings of the order of 60 km.

Progress and highlights

In the past year, four optical and IR cameras have been added to the system to provide independent checks of cloud analyses when there is sufficient dawn and dusk light. These cameras have proved to be excellent with generally good reliability. However the software and factory calibrations have proved to be inadequate. Rewriting the code to interpret raw pixel analog-to-digital converter data, and writing our own sky mapping and analysis code has been successful.

The data from the Large Telescopes are being used to determine the composition of cosmic rays that are detected at the highest energies. This is a major success for the observatory and depends on reliable atmospheric monitoring, including cloud. It had not been expected to be possible at these energies, where the composition of nuclei at distances of tens of kilometres may be required. These data are now being used to interpret the directional properties of the cosmic ray beams which results from the structure of galactic and intergalactic magnetic fields, combined with the composition properties of the beams. In 2017, major results on cosmic ray arrival directions have been obtained, enabling broad-scale measurement of cosmic ray arrival direction properties at significant statistical levels, allowing serious correlations with possible cosmic ray source directions.

Further composition studies will develop as the Pierre Auger Observatory implements upgrades over the next two years. The upgrade is in its engineering phase, with the new systems performing above specification. This will increase the composition data rate by over 6×.

Image: Parked cloud camera and an optical camera at the Auger Coihueco fluorescence site. This site is on a hill overlooking the Pampa Amarilla in western Argentina which is the 3000 km^2 site of the Pierre Auger Observatory. These cameras, plus three others at other sides of the observatory, are used to locate clouds at night over the full sensitive area of the observatory.

High Energy Astrophysics: Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) is a €300 million multinational, next generation project to construct and operate the world's largest and most sensitive high energy gamma ray observatory. With more than 100 telescopes located in the northern and southern hemispheres, the CTA will be the world's largest and most sensitive high energy gamma ray observatory. The CTA is driven by our desire to understand extreme processes in nature such as those associated with black holes, massive stars, neutron stars, supernovae and the quest to understand dark matter.

Over 1000 scientists and engineers from over 32 countries participate in the CTA Consortium. The CTA-Australia component consists of six institutions, led by the University of Adelaide.

NCRIS 2016/17 funds of almost $160,000 supported Australia's role in commissioning the CTA's highest energy telescope cameras, running of two CTA-Australia workshops, attendance at several meetings including the CTA General Meetings, and attendance at major domestic and international conferences.

Progress and highlights

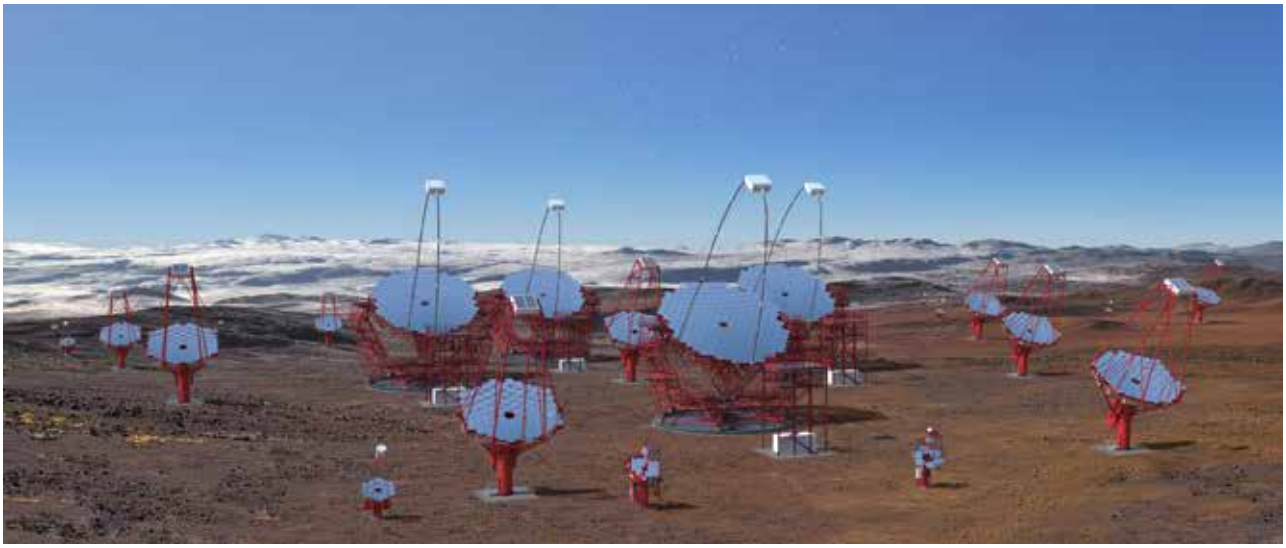
The CTA is in its pre-production phase which will see the initial telescopes installed. A highlight of the year was the approval of Australia's membership of the CTA Observatory (CTAO) governing Council.

The CTA-Australia consortium held two meetings, first at Adelaide (Sep 2016) and then the Western Sydney University (WSU, Apr 2017). Invited speakers from radio, optical and neutrino astronomy enabled further discussions concerning linkages with the CTA. Areas of particular interest were transients (the MWA, CRAFT, SkyMapper, UTMOST), the interstellar medium (ASKAP-Galactic ASKAP, ATCA, Mopra), radio continuum surveys (the MWA, ASKAP-Evolutionary Map of the Universe) and optical interferometry.

CTA-Australian members played active roles in developing the science case documents for some of the key science projects. This included projects devoted to the Large Magellanic Cloud, dark matter searches and Galactic plane surveys.

The CTA General Meetings were held in Bologna (Oct 2016) and Rio de Janeiro (May 2017). CTA-Australia members presented updates on Australia's radio astronomy programs relevant to the CTA.

Image: CTA Telescopes in the southern hemisphere. This image illustrates all three classes of the 99 telescopes planned for the southern hemisphere as viewed from the centre of the array. While not an accurate representation of the final array layout (the smallest telescopes will be spread just beyond the centre), this rendering illustrates the enormous scale of the CTA telescopes and the array, itself. Credit: Gabriel Pérez Diaz, Instituto de Astrofísica de Canarias (IAC).



Data and Computing Infrastructure:
High Performance Computing

AAL has historically invested in astronomy-specific eResearch resources designed to build on, and complement, the significant investments the Government has made in national computing, storage and networking infrastructure. However, the continued transition towards large-scale data-rich telescopes and associated high-resolution simulations has seen the size of theoretical and computational astrophysics community grow from ~10% to ~30% of the overall Australian astronomy community in the past decade. This is placing increasing demands on the national eResearch infrastructure and creating a need for specialised data archives and software, and support and training to help users fully exploit the available infrastructure.

The Decadal Plan for Australian Astronomy 2016–2025 emphasises that a strong foundation of eResearch infrastructure is vital if astronomers are to effectively store, share, reuse, combine and analyse the big data volumes generated by these facilities, and to run sufficiently high-resolution theoretical simulations to interpret the data.

To better support this priority, AAL invested in three key areas of eResearch infrastructure:

- GPU Supercomputing for Theoretical Astrophysics Research (gSTAR)
- Astronomy Data and Computing Services (ADACS)
- All-Sky Virtual Observatory (ASVO)

Data and Computing Infrastructure: gSTAR/OzSTAR

The gSTAR provides the Australian astronomy community with a next generation computing cluster based on graphics processing unit (GPU) technology. Theoretical astrophysics represents a major research effort in Australia, with a growing reliance on High Performance Computing (HPC) to solve some of the most complex problems in astrophysics. Within the HPC landscape, the emerging technology of GPUs offered an affordable path to a massive boost in processing power.

The objectives of gSTAR are: i) to provide national access to a large-scale GPU based supercomputer, ii) to keep Australian astronomers at the cutting-edge of theoretical research, iii) enhance the capacity of the national astronomy community to undertake world-leading research and provide scientific innovation, and iv) facilitate training to graduate students in this important new area of computation.

AAL has previously supported the construction and operations of gSTAR, with a total of $2 million of Commonwealth funding.

Progress and highlights

During 2016/17, AAL provided $850,000 of NCRIS funding to support ongoing operations of gSTAR including funding to develop the gSTAR Data Management and Collaboration Platform and the SUT supercomputer refresh project which will see new OzSTAR hardware installed in late 2017. The OzSTAR powered by Dell EMC will be used to help the new ARC Centre of Excellence for Gravitational Wave Discovery's (OzGrav) search for gravitational waves.

The gSTAR supercomputing system provides the equivalent of ~7,500,000 CPU hours per year for the dedicated use of the national astronomy community. Throughout 2016/17, the facility uptime was greater than 95% and usage grew by 70 new astronomy researchers to 320 unique users. gSTAR related research produced almost 80 refereed publications.

Image: The Green II Supercomputer, SUT.
Credit: Carl Knox, SUT.

Data and Computing Infrastructure:

Astronomy Data and Computing Services

The Decadal Plan for Australian Astronomy 2016–2025 identified five top-level science infrastructure priorities, including "world-class HPC and software capability for large theoretical simulations, and resources to enable processing and delivery of large data sets from these facilities".

To better address this priority, AAL's eResearch advisory committee commissioned a working group and released a final "computing infrastructure planning working group report" in October 2016, which gave an in-depth review of existing astronomy related computing infrastructures and advised AAL on investments over the next five years in data and computing infrastructure areas. In accordance with the recommendations in this report, AAL has invested in the establishment of the Astronomy Data and Computing Services (ADACS) initiative, to provide eResearch support services for the astronomical research community.

A two-stage tender process was initiated to identify appropriate eResearch subcontractors, resulting in two service providers engaged to deliver ADACS-related services:

(1) Swinburne University of Technology, with four collaborators (1a) eScience Institute, University of Washington, (1b) Institute for Data Intensive Engineering and Science, Johns Hopkins University, (1c) Microsoft Azure, and (1d) NVIDIA; and,

(2) Curtin University and Pawsey Supercomputing Centre with two collaborators (2a) Cray Inc., and (2b) Cisco.

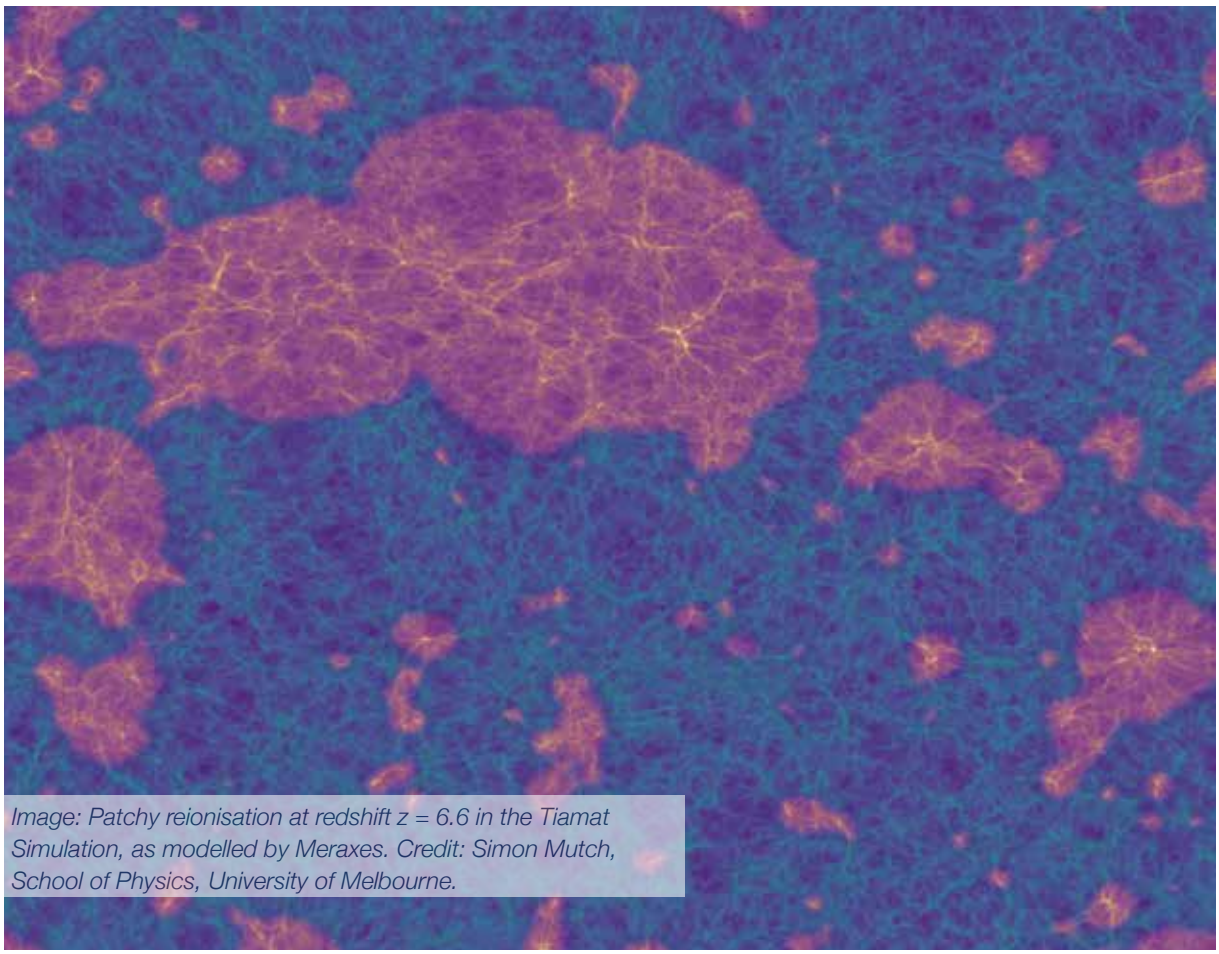


Image: Patchy reionisation at redshift z = 6.6 in the Tiamat Simulation, as modelled by Meraxes. Credit: Simon Mutch, School of Physics, University of Melbourne.

Progress and highlights

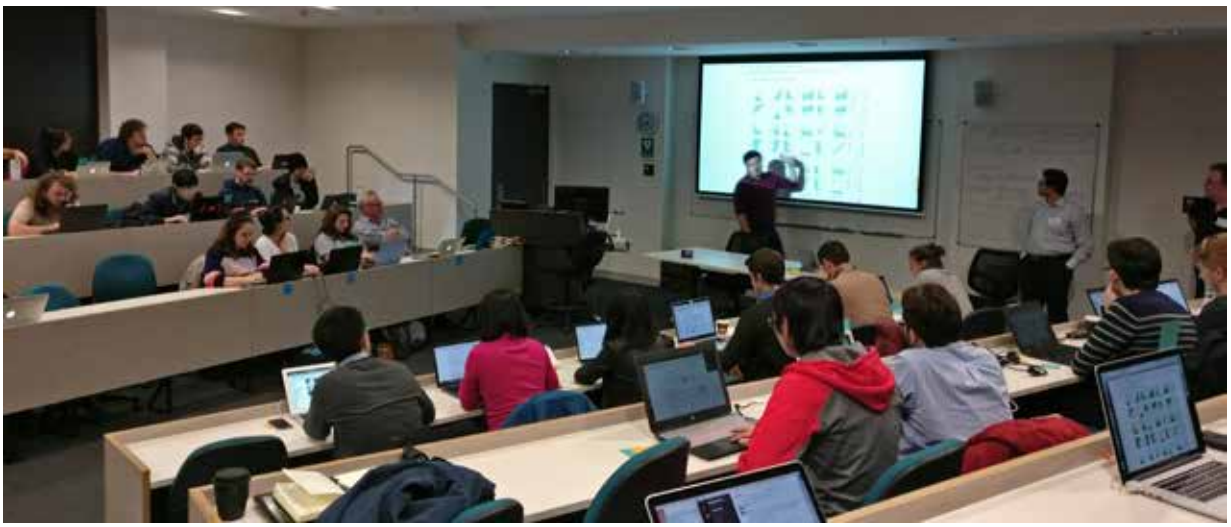
ADACS was officially launched in early 2017, to provide astronomy-focused training, support and expertise to allow astronomers to maximise the scientific return from data and computing infrastructure. ADACS currently focuses on delivering the following three service components:

• Provide astronomy-focused training, using workshops, hackathons, webinars and online documentation.
• Collaborate with relevant astronomy experts to create/enhance astronomy data portals to facilitate the management, sharing and reuse of data.
• Collaborate/partner with national eResearch providers to help coordinate and maximise the computing and storage resources available to astronomers.

In its first full year of operation ADACS' services have been used by 97 astronomers, including 50 students, from 19 Australian institutions.

For more details, please see: *https://adacs.org.au*

Images: ADACS workshop participants. Introduction to Machine Learning workshop – Canberra July 2017. The three-day workshop was aimed at postgraduate students and early career researchers who have not had formal computational training and would like to get up to speed. Credit: Dr. Rebecca Lange, ADACS.



Data and Computing Infrastructure:
All-Sky Virtual Observatory

New telescopes and facilities coming online in the next three to five years will produce data in volumes never previously experienced in Australian astronomy. To gain maximum scientific benefit from this data flood, the federation of datasets from all types of astronomical facilities in Australia will be needed. This will involve creating the hardware, tools and services to bring together data from radio telescopes, optical telescopes and supercomputers, covering all parts of the Southern Sky, under a virtual observatory.

The ASVO project involves the AAO, ANU, NCI, SUT and AAL. ASVO has received funding from the Commonwealth though the National eResearch Collaboration Tools and Resources (NeCTAR) Project, Australian National Data Service (ANDS) and NCRIS.

In 2016/17, AAL invested $439,000 of funding to ASVO development and operations. A total of $3.6 million of Commonwealth funding has been provided to ASVO.

Progress and highlights

ASVO supports a growing collection of theoretical and observational datasets, via a distributed network of "Nodes".

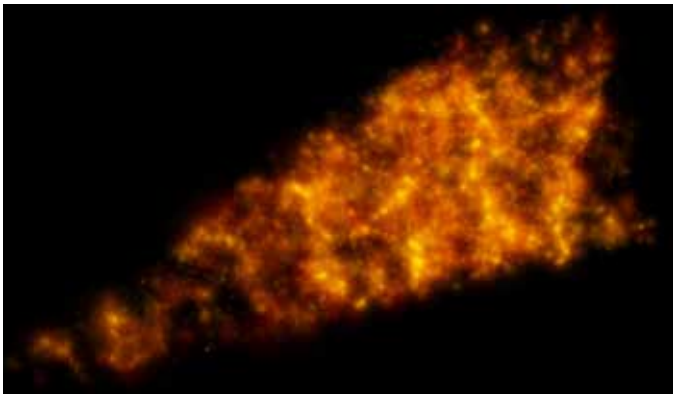
ASVO-TAO Node: The Theoretical Astrophysical Observatory (TAO) Node, developed at the SUT and launched in March 2014, houses a growing ensemble of theory data sets and galaxy formation models, primarily focused on survey science. Mock catalogues can be built from the database without the need for any coding. Results can be funnelled through higher-level modules to build custom light-cones and images. TAO is accessible from anywhere you can access the Internet.

During 2016/17, TAO v4.0 was successfully released to production that allows for major enhancements to the infrastructure, accommodating hydrodynamical simulations that open up TAO for new science questions, including the survey science projects of the Australian radio facilities MWA and ASKAP.

ASVO-AAT Node: The AAO Data Central (ADC) forms the AAT Node of ASVO. The ADC is developing an archive infrastructure and interface that is extensible and scalable, designed to meet the current and future needs of the Australian astronomical community. This will be demonstrated by the deployment of two exemplar datasets (SAMI and GAMA survey data) that span the range of capabilities to be provided. The extensibility requirement ensures that, at the conclusion of the project, the AAO is capable of ingestion and deployment of all AAT surveys of major national significance through the AAT Node.

The AAO team successfully delivered the ADC (AAT Node) with the two exemplar data sets GAMA and SAMI. The ADC also delivered SAMI survey public release 1 data to the public in July 2017. Additional GALAH and AAT Legacy data sets were added to the ADC.

Image: 3D visualisation of a 20° × 20° light-cone generated from the Millennium Simulation. Galactic radii and intensities are scaled by their total stellar masses. The colouring map represents the Sloan Digital Sky Survey absolute G band. Credit: Tim Dykes.



ASVO-SkyMapper Node: Deployed at the ANU, the SkyMapper Node provides Australians with priority access to a world-leading digital atlas of the Southern Sky. The SkyMapper telescope at Siding Spring Observatory takes images in a unique set of optical filters, and is building catalogues of the one billion objects it detects. Astronomers can use ASVO tools to inspect and download the images and measurements.

During 2016/17, the NCI delivered an upgrade to the production Table Access Protocol (TAP) service that enables the ASVO-SkyMapper services to query the databases containing millions of stars, galaxies and other astronomical objects. The upgrade ensures the system can handle the expected increase in traffic following the release of SkyMapper data. The TAP service upgrade and deployment was based on the implementation developed by the CASDA team.

The survey had a limited-area Early Data Release of bright stars in May 2016, with the first all-sky data release of 318 million objects and 2.3 billion detections in June 2017. Regular updates will continue over the next three years, with the final release of the full five-year data set around 2020.

ASVO-MWA Node: AAL previously funded a feasibility study to determine requirements for building the first radio astronomy node of ASVO, which would support access to complex data from the AAL-supported MWA telescope. Partial ADACS funding has now been used to extend the feasibility and design study. A pilot ASVO MWA Node will be finished by the end of 2017, providing public MWA data visibility.

Image: The SkyMapper telescope under the Milky Way. Credit: James Gilbert.

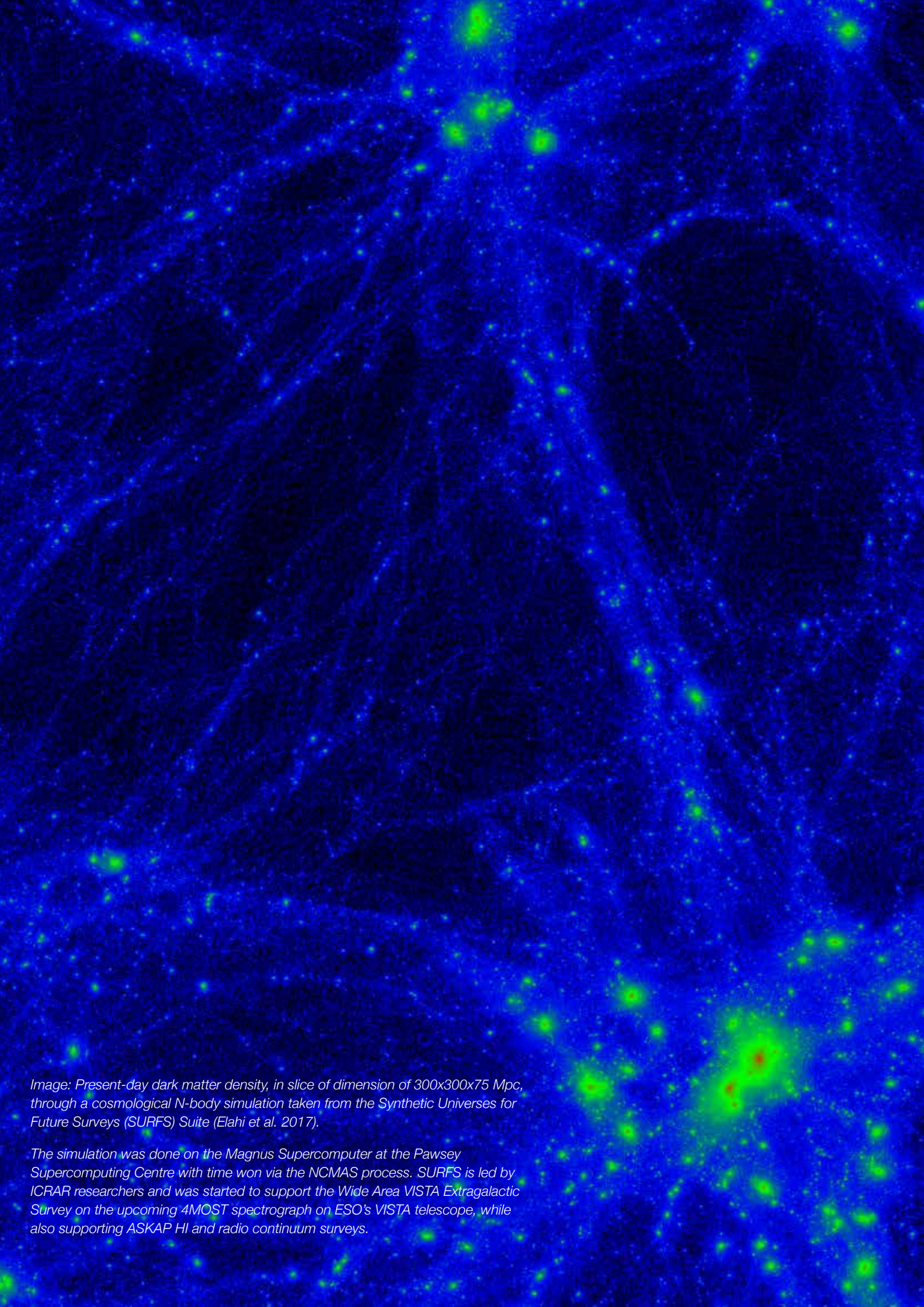
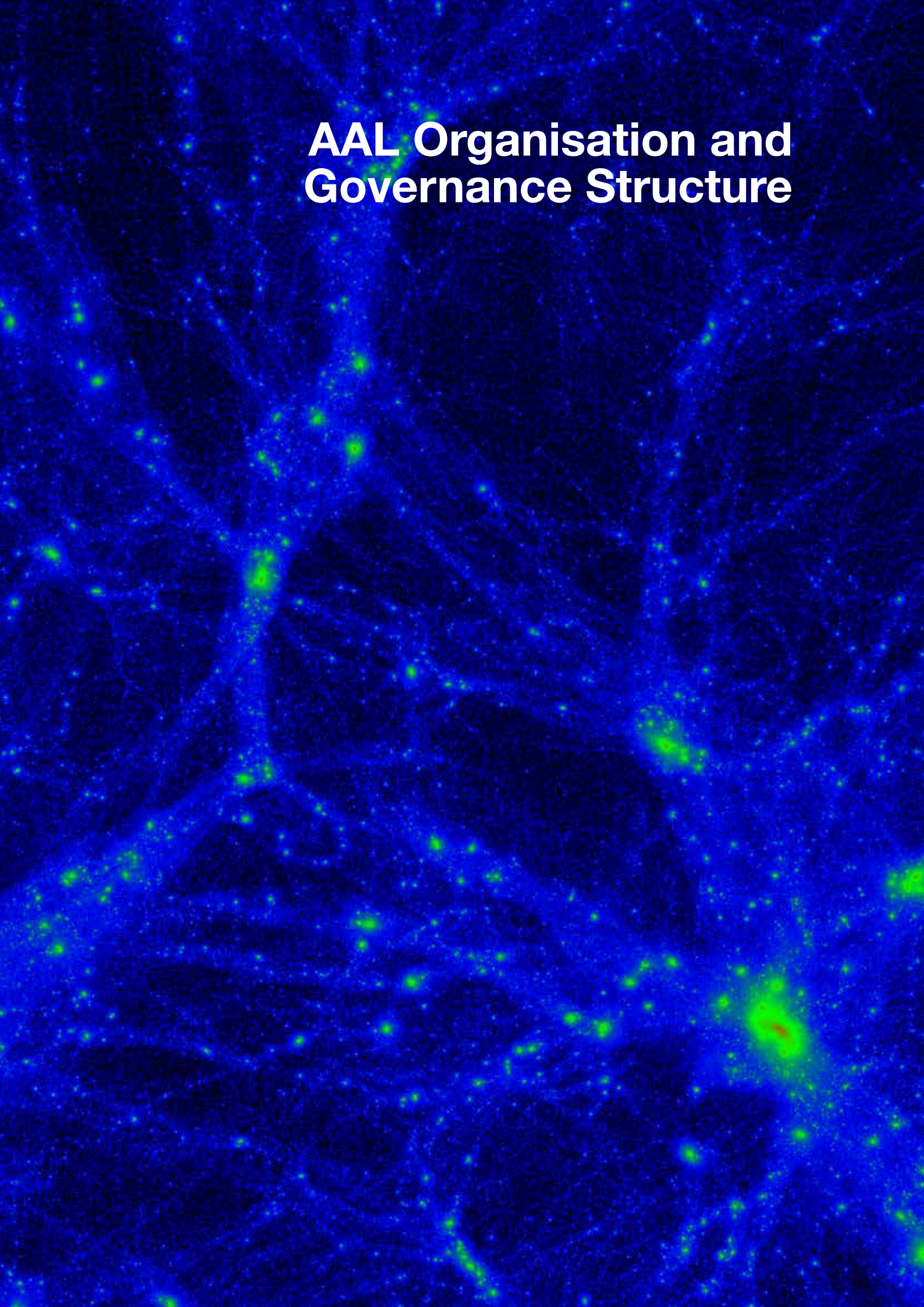


Image: Present-day dark matter density, in slice of dimension of 300x300x75 Mpc, through a cosmological N-body simulation taken from the Synthetic Universes for Future Surveys (SURFS) Suite (Elahi et al. 2017).

The simulation was done on the Magnus Supercomputer at the Pawsey Supercomputing Centre with time won via the NCMAS process. SURFS is led by ICRAR researchers and was started to support the Wide Area VISTA Extragalactic Survey on the upcoming 4MOST spectrograph on ESO's VISTA telescope, while also supporting ASKAP HI and radio continuum surveys.

AAL Organisation and Governance Structure



Information about Directors

Prof. Rachel Webster, Chair
BSc(Hons), PhD
Special responsibilities: Member of the Radio Telescope Advisory Committee and a member of the Audit and Risk Management Committee and Executive Remuneration Committee.

Prof. Rachel Webster is a Professor at the University of Melbourne in the School of Physics where she leads the Astrophysics research group. She has had a stellar career teaching and researching astronomy for over 20 years. Originally gaining a PhD at Cambridge University, she spent productive years honing her skills in Canada at the University of Toronto, both teaching and doing research. Her work has been internationally recognised with internationally prestigious scholarships. She was also the inaugural Australian Institute of Physics Woman in Physics Lecturer. She is a key member of an international consortium involving Australian, American, Indian and New Zealand astrophysicists to help design and build a new low frequency radio telescope (Widefield Array) at Mileura in Western Australia aiming to detect the first luminous sources in the universe. Dr Webster is a member of the International Astronomical Union, and an Honorary Fellow of the Astronomical Society of Australia, the Royal Society of Victoria, and the American Astronomical Society. Dr Webster is a member of innumerable committees, including The University of Melbourne Council and the University College Council.

Dr. Rosalind Dubs, Deputy Chair
BSc(Hons), Dr ès Sc, FTSE, FAICD
Special responsibilities: Chair of the Audit and Risk Management Committee.

Dr. Rosalind (Ros) Dubs is a professional company director, currently serving on the boards of ASX100 company Aristocrat Leisure Limited, government shipbuilder ASC Pty Ltd, the Australian Academy of Technology and Engineering (ATSE) and ANU Enterprise Pty Ltd. Her diverse business career spans a range of industries in publicly listed, private and government companies in Germany, France and Australia. For Thales SA, she was managing director delivering state-of-the-art-navigational aids to 65% of the global aviation market, served as the COO of the world's largest exporter of air traffic management systems, and sold mission-critical software and communications systems to the Australian Defence Force. At Airservices Australia, as director of operations support, she was responsible for all engineering operations across Australia. Dr Dubs was appointed to the CSIRO's senior executive service in 1983. Within universities, she was Registrar of the Australian National University (1985–91), and Deputy Vice Chancellor (External Relations) at University of Technology Sydney (2007–09). Dr Dubs chaired the Australian Space Industry Innovation Council (2010–12), served on the Australian Astronomical Observatory Advisory Committee (2011–15), and was elected a Fellow of the ATSE in 2014.

Prof. Karl Glazebrook
BSc(Hons), PhD, FASA, FAA
Special responsibilities: Member of the of the Optical Telescope Advisory Committee.

Prof. Karl Glazebrook is a Distinguished Professor at Swinburne University of Technology and Director of the Centre for Astrophysics and Supercomputing. His career has spanned the UK, USA and Australia, including professorships at Johns Hopkins University and Swinburne, and the award of a prestigious Packard Fellowship. His most notable scientific accomplishments are the development of the 'nod and shuffle' spectroscopic technique, characterising the bimodal colour and environmental distributions of local galaxies, the study of the morphological and spectroscopic evolution of galaxies across cosmic time using Gemini, Hubble and Keck telescopes, and the development of innovative cosmological techniques such as 'Baryonic Acoustic Oscillations'. He is an official ISI "Highly Cited Researcher" and has won the Muhlmann Award for his work on instrumentation. His most notable current service roles are Chair of the International Facilities Working Group of the Australian Astronomy Decadal 2016–2025 Plan and member of the ARC College of Experts. He has also served on the Keck Scientific Steering Committee, the Gemini Science and Technology Advisory Committee and the GMT Instrument Development Advisory Committee.

Prof. Matthew Bailes
BSc(Hons), PhD
Special responsibilities:
Member of the Multi Messenger Astronomy Working Group and Executive Remuneration committee.

Prof. Matthew Bailes is an ARC Laureate Fellow at Swinburne University of Technology and leads the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav). His main scientific interests concern the discovery and high precision timing of millisecond radio pulsars and the discovery of extragalactic fast radio bursts (FRBs). He is the chair of the advisory board for the Collaboration for Astronomical Signal Processing and Electronics Research (CASPER) and serves on the Steering Committee for the Australia Telescope National Facility. He collaborates extensively with the Max Planck Institute for Radio Astronomy (MPIfR), the University of Manchester, the Cagliari Radio Observatory, Caltech and the CSIRO. He is leading the redevelopment of the Molonglo Radio Observatory's correlator so that it can time pulsars and search for FRBs. He is the Australian lead of the Breakthrough Listen project to search for alien transmissions with the Parkes radio telescope and leading the MeerTime pulsar timing project on the South African Square Kilometre Array pathfinder MeerKAT.

Prof. Naomi McClure-Griffiths
BA(Hons), PhD
Special responsibilities:
Member of the Radio Telescope Advisory Committee.

Prof. Naomi McClure-Griffiths is a Professor and ARC Future Fellow at the Research School of Astronomy and Astrophysics (RSAA) at the Australian National University. She spent 13 years at the CSIRO, holding various roles including OCE Science Leader and Head of National Facility Science for the Australian Telescope National Facility. Her research is in the structure and evolution of gas and magnetic fields in our own Milky Way and the nearby Magellanic System. Her research group uses radio telescopes, including the Australian Telescope Compact Array, Parkes Radio telescope and Green Bank telescope. She co-leads the Galactic ASKAP survey, and the Polarisation survey and has roles in Square Kilometre Array (SKA) science planning, including membership on the SKA Science & Engineering Advisory Committee, Australia New Zealand SKA Coordination Committee and Science Advisory Committee. She received the 2006 Prime Minister's Malcolm McIntosh Prize for Physical Scientist of the Year and the 2015 Pawsey Medal from the Australian Academy of Science.

Prof. Chris Tinney
BSc(Hons), PhD, GAICD
Special responsibilities:
Member of the Astronomy eResearch Advisory Committee.

Prof. Chris Tinney is a Professor at the University of New South Wales (UNSW) in the School of Physics. He is Associate Dean (Research) for the UNSW's Faculty of Science and heads the Exoplanetary Science at UNSW research group. He obtained his PhD from the California Institute of Technology, and has been an active researcher in the field of exoplanets and brown dwarfs for over 20 years. He has worked in both the research infrastructure and University sectors, spending almost 12 years with the Anlgo-Australian Observatory as a Research Astronomer (where he headed the IRIS2 instrument project) and then as Head of Astronomy, before moving to the UNSW as a Professorial Fellow.

Retired Directors

Dr. Ian Chessell
BSc(Hons), PhD (Physics), FTSE
Special responsibilities – until 18 November 2016
Chair of the Audit and Risk Management Committee and a member of the Executive Remuneration Committee.

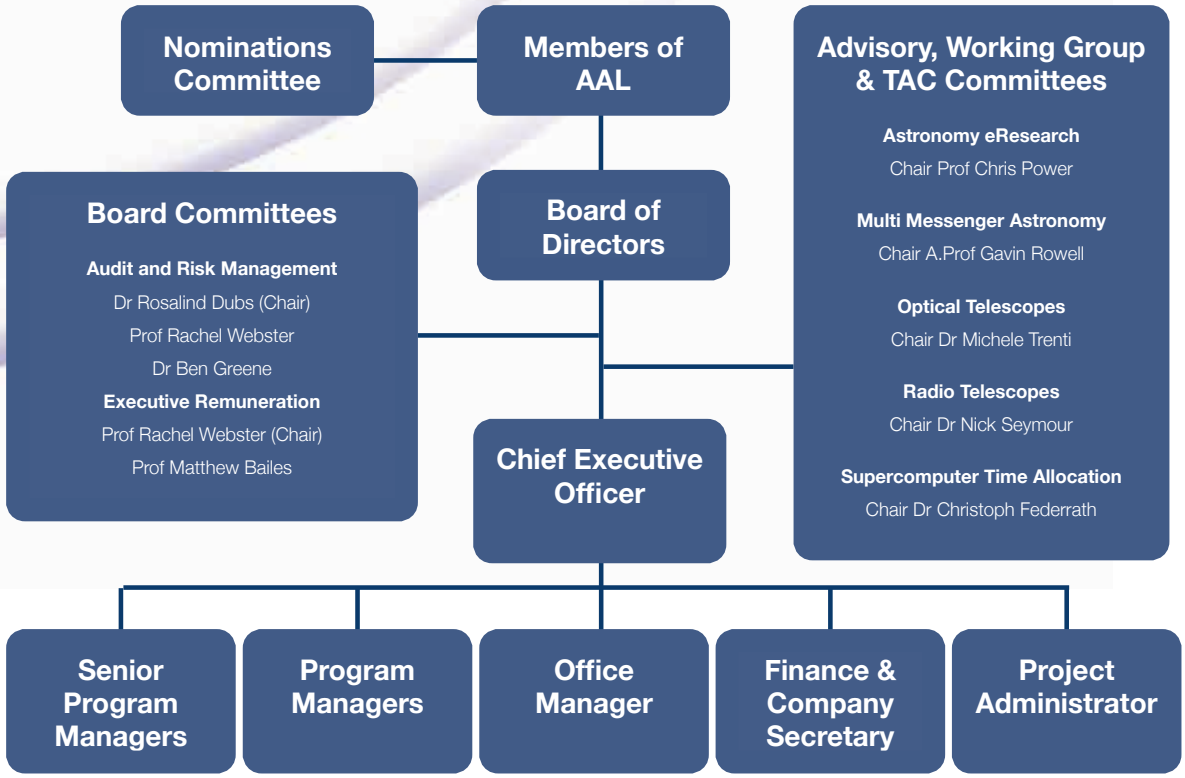
Prof. Anne Green
BSc(Hons), PhD, FTSE, FASA, FAIP
Special responsibilities - until 18 November 2016
Board Chair and a member of Audit and Risk Management Committee and Executive Remuneration Committee.

Prof. Lisa Kewley
BSc(Hons), PhD (Astrophysics), FAA
Special responsibilities- until 18 November 2016
Member of the Optical Telescope Advisory Committee and an observer on the Keck Science Steering Committee.

Prof. Ronald Ekers
BSc(Hons), PhD (Astronomy), FAA, FRS
Special responsibilities – until 18 November 2016
Member of the Multi Messenger Astronomy Working Group.

Dr Ben Greene
BEng(Hons), PhD
Special responsibilities – until May 2017
Member of the Audit and Risk Management Committee.

Organisational and Governance
Structure



Members

AAL is very proud that its membership comprises all institutions in Australia with a significant astronomy research program. There are currently 16 institutional members of AAL and each member has a nominated representative who attends the Annual General Meeting to elect Board Directors. Member representatives are also consulted throughout the year on key astronomy infrastructure and investment decisions.

Committees

AAL has four advisory committees and a supercomputer time allocation committee, whose members are appointed to provide the relevant breadth of expertise, and an appropriate mix of gender, seniority and institutional diversity. AAL committee members meet quarterly and are encouraged to engage with their colleagues in order to understand and reflect the views of the wider astronomy community. AAL relies on its committee members to monitor and assess the progress of all projects and sub-projects, evaluate key performance indicators, and advise on opportunities for collaboration and improving project outcomes.

Board

The independent, skills-based Board of Directors comprises seven individuals with an appropriate breadth of expertise in astronomy, management and finance. The Board meets quarterly to review progress of programs under AAL's contractual arrangements, set strategic goals, and approve financial allocations. The AAL Board makes key decisions about projects based on the committees' recommendations, the Board's own considerable and diverse expertise, and in consideration of the priorities and recommendations in the Australian Astronomy Decadal Plan.

Staff

AAL executive and staff have responsibility for financial management, oversight of the programs under AAL's contractual arrangements, reporting to the AAL Board on the status of projects, and liaising with the AAL Board, advisory committees, project leaders, members, Government departments and other key stakeholders.

These governance and management arrangements have led to very successful outcomes from AAL-managed Education Investment Fund, NCRIS and other Commonwealth Government infrastructure programs projects since 2007.

AAL

Members and Committees

Committees

Astronomy eResearch Advisory Committee (AeRAC)

Chris Power (Chair), University of Western Australia
Ben Evans, National Computational Infrastructure (NCI)*
Jenni Harrison, Pawsey Supercomputing Centre*
Alex Heger, Monash University
Jarrod Hurley, Swinburne University of Technology*
Arna Karick, Swinburne University of Technology
Mark Krumholz, Australian National University
Greg Poole, University of Melbourne
Katrina Sealey, Australian Astronomical Observatory
Chris Tinney, AAL Board representative*
Matthew Whiting, CSIRO
Andreas Wicenec, University of Western Australia

Astronomy Supercomputer Time Allocation Committee (ASTAC)

Christoph Federrath (Chair), Australian National University
Weiguang Cui, University of Western Australia
Roger Edberg, National Computational Infrastructure (NCI) representative*
Magda Guglielmo, University of Sydney
Chris Harris, Pawsey Supercomputing Centre representative*
Jarrod Hurley, Swinburne University of Technology*
Anne Hutter, Swinburne University of Technology
Daniel Mitchell, CSIRO
Simon Mutch, University of Melbourne

Advisor and secretary:
Amr Hassan, Swinburne University of Technology

Multi Messenger Astronomy Advisory Committee (MMAAC)

Gavin Rowell (Chair), University of Adelaide
Matthew Bailes, AAL Board representative*
Miroslav Filipovic, Western Sydney University
Anne Green, University of Sydney
Gary Hill, University of Adelaide
Susan Scott, Australian National University, OzGrav representative*
Bram Slagmolen, Australian National University

Optical Telescopes Advisory Committee (OTAC)

Michele Trenti (Chair), University of Melbourne
Michael Ashley, University of New South Wales
Martin Asplund, Australian National University
Julia Bryant, University of Sydney
Warrick Couch, Australian Astronomical Observatory*
Karl Glazebrook, AAL Board representative*
Juan Madrid, CSIRO
Richard McDermid, Magellan SAC representative*
Stuart Ryder, Australian Astronomical Observatory*
Lee Spitler, Macquarie University

Radio Telescopes Advisory Committee (RTAC)

Nick Seymour (Chair), Curtin University
Adam Deller, Swinburne University of Technology
Simon Ellingsen, University of Tasmania
Natasha Hurley-Walker, Curtin University
Minh Huynh, University of Western Australia
Naomi McClure-Griffiths, AAL Board representative*
Attila Popping, University of Western Australia
John Reynolds, CSIRO*

* Ex-officio.

Members

Member

Australian Astronomical Observatory
Australian National University
CSIRO
Curtin University
Macquarie University
Monash University
Swinburne University of Technology
University of Adelaide
University of Melbourne
University of New South Wales
University of Queensland
University of Southern Queensland
University of Sydney
University of Tasmania
University of Western Australia
Western Sydney University

Representative

Prof Warrick Couch
Prof Matthew Colless
Dr Douglas Bock
Prof Steven Tingay
Prof Mark Wardle
Prof Alexander Heger
Prof Michael Murphy
Prof Bruce Dawson
Dr Christian Reichardt
Prof Jeremy Bailey
Prof Michael Drinkwater
Prof Brad Carter
Prof Joss Bland-Hawthorn
Prof John Dickey
Prof Peter Quinn
Prof Miroslav Filipovic

Telescopes Representatives

Cherenkov Telescope Array

CTAO Board: Gavin Rowell, University of Adelaide

Giant Magellan Telescope

Board: Nigel Poole, University of New South Wales
GMTO Founder Representative: Mark McAuley, AAL
GMT SAC: Sarah Brough, University of New South Wales

Keck Telescopes

California Association for Research in Astronomy (CARA) Board: Lisa Kewley (ANU appointment)

Magellan Telescopes

Magellan Council: Mita Brierley, AAL (observer)
Magellan SAC: Richard McDermid, Macquarie University (observer)

Murchison Widefield Array

MWA Board: Andrew Hopkins, Australian Astronomical Observatory (observer)

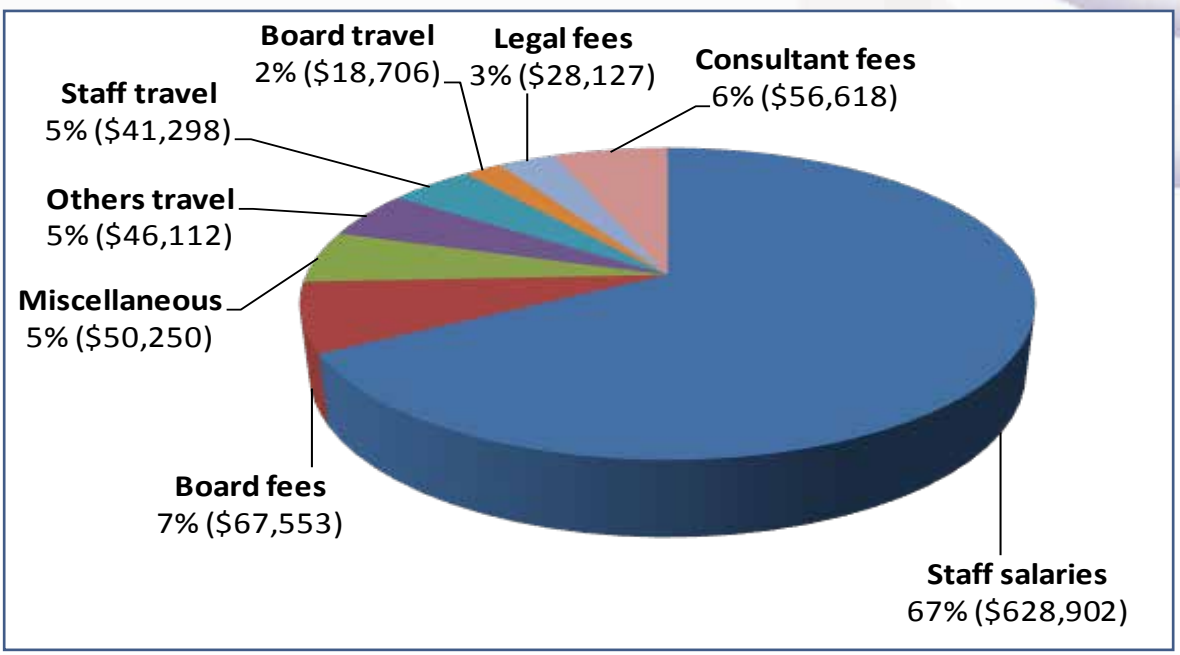
All Members, their representatives and committee members are accurate as of 30th June 2017.

Financial Summary

The following summary highlights the key financial transactions (exclusive of Goods and Services Tax) for the 2016/17 financial year. The audited financial accounts are available on the AAL website at: http://www.astronomyaustralia.org.au/publications

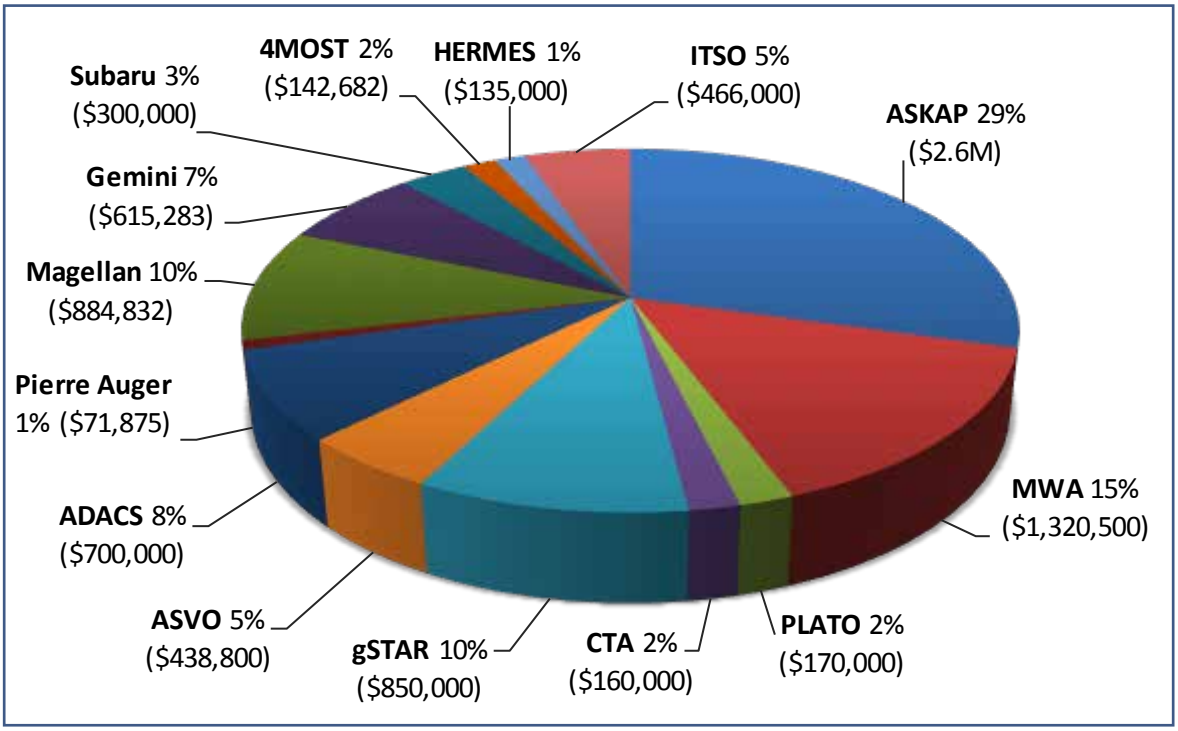
AAL Operating Expenses

Actual operating expenses for 2016/17 were $937,566.



Grants Paid to Projects during 2016/17

Total grants paid in 2016/17 were $8,854,972.



Grants Received and Balance of Grants held as at 30 June 2017

Grant	Grants Received	Closing Balance
NCRIS 2013 Grant	-	$348,044
AAO 2014 Grant	-	$60,000
ANDS Grant	$100,000	$60,000
NeCTAR NCRIS Grant	$112,500	-
NeCTAR NCRIS 2016 Grant	$141,600	$12,800
DIIS 2015 Grant	-	$764,654
NCRIS 2015 Grant	-	$485,000
DIIS 2016 Grant	-	$1,680,000
NCRIS 2016 Grant	$7,405,673	$1,920,000
DIIS 2017 Grant	$350,000	$350,000
	$8,109,773	**$5,680,498**

Reserves

During 2016/17 AAL maintained two reserves with the net interest earned to be used for projects associated with the relevant funding agreement. There were the following transfers to and from Reserves:

Reserve	Net Interest	Transfer from Reserve	Purpose of Funds	Closing Balance
Overseas Optical Reserve*	$38,963	$52,172	AAL management fee	$2,595,370
NCRIS 2013-17 Reserve	$77,744	$99,266	CASDA	$88,399
		$33,748	gSTAR Data Platform project	

*The Overseas Optical Reserve is primarily used to cover shortfalls in payments to overseas optical telescope facilities. $673,304 of this reserve is committed to future Magellan and Subaru payments.

Statement of profit or loss and other comprehensive income for the year ended 30 June 2017

	2017 $	2016 $
Revenue including Government Grants	9,834,043	11,577,784
Expenses		
Depreciation	(3,384)	(2,581)
Grants paid	(8,816,290)	(10,633,681)
Direct grant project expenses	(38,942)	(29,265)
Employee benefits expenses	(696,455)	(601,494)
Other expenses	(237,727)	(220,216)
Surplus (Deficit) before income tax attributable to members of the entity	**41,245**	**90,547**
Income tax	-	-
Surplus (Deficit) after income tax attributable to members of Astronomy Australia Ltd	**41,245**	**90,547**
Other comprehensive income	-	-
Total comprehensive income for the year attributable to members of Astronomy Australia Ltd	**41,245**	**90,547**

The Company is an income tax exempt charitable institution.

Statement of changes in equity for the year ended 30 June 2017

	Retained Surpluses	Overseas Optical Reserve Account	NCRIS2013–2017 Reserve Account	Total Equity
	$	$	$	$
Balance at 30 June 2015	**329,989**	**2,656,874**	**36,287**	**3,023,150**
Surplus attributable to equity members	90,547	-	-	90,547
Allocated to Reserves	(170,296)	62,914	107,382	-
Transfers from Reserves	111,209	(111,209)	-	-
Balance at 30 June 2016	**361,449**	**2,608,579**	**143,669**	**3,113,697**
Surplus attributable to equity members	41,245	-	-	41,245
Transfer to Reserves	(116,707)	38,963	77,744	-
Allocation from Reserves	185,186	(52,172)	(133,014)	-
Balance at 30 June 2017	**471,173**	**2,595,370**	**88,399**	**3,154,942**

Statement of Financial Position as at 30 June 2017

	2017 $	2016 $
Current Assets		
Cash and cash equivalents	8,756,602	10,990,676
Trade and other receivables	209,442	-
Total Current Assets	8,966,044	10,990,676
Non-Current Assets		
Property, plant and equipment	5,942	6,904
Total Non-Current Assets	5,942	6,904
Total Assets	**8,971,986**	**10,997,580**
Current Liabilities		
Trade and other payables	5,761,765	7,833,054
Employee benefits	49,609	48,289
Total Current Liabilities	**5,811,374**	**7,881,343**
Non-Current Liabilities		
Employee Benefits	5,670	2,540
Total Non-Current Liabilities	5,670	2,540
Total Liabilities	**5,817,044**	**7,883,883**
Net Assets	**3,154,942**	**3,113,697**
Equity		
Reserves	2,683,769	2,752,248
Retained surpluses	471,173	361,449
Total Equity	**3,154,942**	**3,113,697**

The complete audited financial accounts are available on the AAL website at: http://astronomyaustralia.org.au/publications.

Acronyms

2dF	Two-degree Field
4MOST	4-metre Multi-Object Spectrograph Telescope
AAL	Astronomy Australia Limited
AAO	Australian Astronomical Observatory
AAT	Anglo-Australian Telescope
ADACS	Astronomy Data and Computing Services
ADC	AAO Data Central
AeRAC	Astronomy eResearch Advisory Committee
AITC	Advanced Instrumentation and Technology Centre
ANDS	Australian National Data Service
ANU	Australian National University
ARC	Australian Research Council
ASA	Astronomical Society of Australia
ASKAP	Australian Square Kilometre Array Pathfinder
AST3	Antarctic Survey Telescopes × 3
ASTAC	Astronomy Supercomputing Time Allocation Committee
ASTRO 3D	ARC Centre of Excellence for All-Sky Astrophysics in 3D
ASVO	All-Sky Virtual Observatory
ATCA	Australia Telescope Compact Array
ATNF	Australia Telescope National Facility
ATSE	Australian Academy of Technology and Engineering
CAASTRO	ARC Centre of Excellence for All-Sky Astrophysics
CASDA	CSIRO ASKAP Science Data Archive
CASPER	Collaboration for Astronomical Signal Processing and Electronics Research
CC	Creative Commons
CRAFT	Commensal Real-time ASKAP Fast Transients
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTA	Cherenkov Telescope Array
CTAO	CTA Observatory
DIIS	Department of Industry, Innovation and Science
ELT	Extremely large telescope
EoR	Epoch of Reionisation
ESO	European Southern Observatory
FAA	Fellow of the Australian Academy of Science
FAICD	Fellow of the Australian Institute of Company Directors
FAIP	Fellow of the Australian Institute of Physics
FASA	Fellow of the Astronomical Society of Australia
FRB	Fast Radio Burst
FRS	Fellow of the Royal Society
FTSE	Fellow of the Australian Academy of Technological and Engineering Sciences
GAICD	Graduate of the Australian Institute of Company Directors
GALAH	GALactic Archaeology with HERMES
GAMA	Galaxy And Mass Assembly
GLEAM	GaLactic and Extragalactic All-sky MWA (survey)
GMT	Giant Magellan Telescope
GMTO	GMT Organisation
GPU	Graphics Processing Unit
gSTAR	GPU Supercomputer for Theoretical Astrophysics Research
HERMES	High Efficiency and Resolution Multi-Element Spectrograph
HPC	High Performance Computing
IAC	Instituto de Astrofísica de Canarias
ICRAR	International Centre for Radio Astronomy Research
IR	Infrared
IRIS2	Infrared Imager and Spectrograph 2
ISI	Institute for Scientific Information
ITSO	International Telescope Support Office
KTAC	Keck Time Allocation Committee
M1	Mirror 1 (primary mirror)
M2	Mirror 2 (secondary mirror)
MMAAC	Multi Messenger Astronomy Advisory Committee
MPIfR	Max Planck Institute for Radio Astronomy
MRO	Murchison Radio-astronomy Observatory
MWA	Murchison Widefield Array
NAOJ	National Astronomical Observatory of Japan
NCA	National Committee for Astronomy
NCI	National Computational Infrastructure
NCRIS	National Collaborative Research Infrastructure Strategy
NeCTAR	National eResearch Collaboration Tools and Resources
OTAC	Optical Telscopes Advisory Committee
OzDES	Australian Dark Energy Survey
OzGrav	ARC Centre of Excellence for Gravitational Wave Discovery
PAF	Phased Array Feed
PLATO	PLATeau Observatory
PLATO-A	PLATO for Dome A
RSAA	Research School of Astronomy and Astrophysics (ANU)
RTAC	Radio Astronomy Advisory Committee
SAC	Science Advisory Committee
SAMI	Sydney-AAO Multi-object Integral-field spectrograph
SKA	Square Kilometre Array
SUT	Swinburne University of Technology
TAC	Time Allocation Committee
TAO	Theoretical Astrophysical Observatory
TAP	Table Access Protocol
UNSW	University of New South Wales
UWA	University of Western Australia
VISTA	Visible and Infrared Survey Telescope for Astronomy
VLT	Very Large Telescope
WSU	Western Sydney University

Astronomy Australia Ltd.

Part of the NCRIS network

Astronomy Australia Ltd

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