CSIRO ASTRONOMY AND SPACE SCIENCE
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CSIRO Australia Telescope National Facility

Annual Report
2012

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This is the report of the CSIRO Australia Telescope National Facility for the calendar year 2012, approved by the Australia Telescope Steering Committee.

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Cover image: One of the majestic antennas of CSIRO's newest radio telescope, the Australian Square Kilometre Array Pathfinder (ASKAP), stands proudly against the night sky in the Mid West region of Western Australia. On 5 October 2012, an official opening ceremony was held to celebrate the construction of ASKAP and the establishment of the Murchison Radio-astronomy Observatory on which ASKAP is sited. Credit: Alex Cherney/terrastro.com.

Inner cover image: A spectacular aerial view over the Murchison Radio-astronomy Observatory in Western Australia; 19 of ASKAP's 36 antennas and the MRO control building are visible. Credit: Dragonfly Media.

Contents

Credit: Wheeler Studios

Director's Report

2012 was certainly an eventful year for CASS and the ATNF. Out of a number of highlights, I'd like to mention two key events. The first was the SKA site decision, which resulted in hosting of the SKA being split between Australia and South Africa. I must pay tribute to the tremendous achievements of the SKA site-bid team, both in CSIRO and in the Federal and WA Governments, and our other partners. The bid process was complex and sometimes difficult, but the bid team was able to secure a very bright future for Australian radio astronomy, and we all look forward to working on this remarkable project.

The second event was the official opening of ASKAP and the MRO, in October. It was really a tremendous year for ASKAP, which saw the completion of infrastructure at the MRO and the installation of all 36 antennas. Three hundred attendees, including the then Minister for Tertiary Education, Skills, Science and Research, Senator Chris Evans, and West Australian Minister for Science and Innovation John Day, spent a memorable day at the MRO to celebrate the availability of this outstanding new facility. The ASKAP team continues to make great progress with the telescope, and in particular with the phased array feed 'radio cameras' that mark ASKAP out as such an innovative instrument.

It was also a year of change at the top of CASS. As many of us had suspected, CASS Chief Phil Diamond was recruited to be Director General of the SKA Organisation in Manchester. Phil was with the ATNF for two short but eventful years, and we wish him all the best in the challenge of leading the SKA internationally. We were also sorry to lose Brian Boyle, who moved to the Department of Innovation as Acting Australian SKA Director. Brian has now been confirmed in this role, and we look forward to working with him on the future of SKA.

Following Phil's departure in October, I acted in the role of CASS Chief while an international recruitment process was under way. We are now delighted to welcome Lewis Ball as CASS Chief. Lewis has returned to CSIRO from his role as ALMA Deputy Director, and will no doubt update you in next year's ATNF report.

Sarah Pearce

ACTING ATNF DIRECTOR

ACTING CHIEF OF CSIRO ASTRONOMY AND SPACE SCIENCE

Chair's Report

Credit: University of Melbourne

The primary focus of the ATNF during 2012 has been on the completion of the ASKAP infrastructure and antennas. The ATNF has delivered a world-class observing site and facility, not only for ASKAP but also successfully to host the MWA and other innovative experimental facilities.

The decision in May 2012 by the Members of the SKA Organisation to build the SKA in both Australia and South Africa was warmly welcomed. In Phase 1, Australia will host a survey instrument that builds on the ASKAP infrastructure, and in particular the innovative development by the ATNF of the phased array feed. In addition, the SKA low-frequency aperture arrays will be hosted in Australia. This decision provides a strong endorsement of the Australian strengths in radio astronomy technology and survey science and the Australian commitment to remain at the forefront of international radio astronomy developments.

In addition to these high profile developments, CASS has continued to support the Australian and international communities with efficient operation of the suite of local radio telescopes. Amongst a variety of conferences and workshops supported, assistance was provided for the community to access ALMA. CASS has continued to support a wide range of programs for the Australian astronomical community, developing priorities in consultation with the community. The open and transparent dialogue between the user community and CASS, with guidance from the ATNF Steering Committee, has been widely appreciated.

CASS has been particularly fortunate to have secured the leadership of Phil Diamond during these stages of the ASKAP project. On many fronts, the period of 2011-2012 has been challenging: financially, technically and organisationally. Phil's leadership during this period has been wise and effective, providing clarity of vision and confidence in the potential of ATNF to deliver a world-class facility. Phil moves to the directorship of SKA with the thanks and best wishes of the entire Australian astronomical community.

Sarah Pearce has taken over the CASS Chief's role after Phil Diamond's departure, and has provided a steady hand until the appointment of the new director. During 2013 CASS is well-placed to commence the commissioning of ASKAP, to continue the fit-out of all the ASKAP antennas and to work towards delivering scientific data to the astronomical community. The Steering Committee is enthusiastic about the appointment of Lewis Ball as CASS Director, and looks forward to a fruitful collaboration over the next few years.

Finally, thanks to members of the Steering Committee who are completing their terms: in particular the Chair, Lister Staveley-Smith; Matthew Colless, who is moving to the directorship at RSSA at ANU; Nigel Poole, Acting Group Executive CSIRO Information Sciences Group; Ian Oppermann, Director CSIRO ICT Centre; Alan Brien of Scitech Discovery Centre; and our international colleagues, Michael Kramer from Germany and Nan Rendong from China.

Rachel Webster

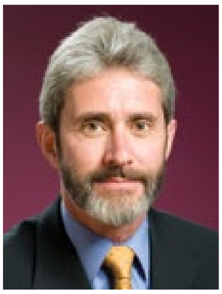
CHAIR, AUSTRALIA TELESCOPE STEERING COMMITTEE

Senior Management

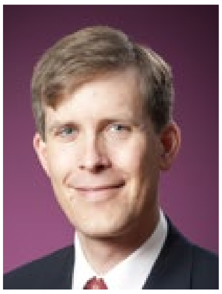
ATNF DIRECTOR AND CHIEF CSIRO ASTRONOMY AND SPACE SCIENCE (TO OCTOBER 2012)
Philip Diamond

CSIRO SKA DIRECTOR
Brian Boyle

DEPUTY CHIEF AND ACTING CHIEF (FROM OCTOBER 2012)
Sarah Pearce

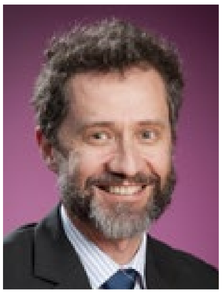


CHIEF SCIENTIST
Robert Braun



ASSISTANT DIRECTOR, OPERATIONS
Douglas Bock

ASSISTANT DIRECTOR, ENGINEERING
Graeme Carrad



ASSISTANT DIRECTOR, ASKAP
Antony Schinckel

ASSISTANT DIRECTOR, ASTROPHYSICS
Simon Johnston

OPERATIONS RESEARCH PROGRAM LEADER
Jessica Chapman

STRATEGIC PLANNING AND MAJOR PROJECT SPECIALIST
Phil Crosby

Credit: Wheeler Studios

1. The ATNF in Brief

Wajarri Yamatji children at the opening of ASKAP and the Murchison Radio-astronomy Observatory (MRO) on 5 October 2012. CSIRO collaborates with the Wajarri Yamatji community, the traditional owners of the MRO site, under the terms of the Indigenous Land Use Agreement for the site. Credit: Colin Murty/News Limited.

The ATNF in Brief

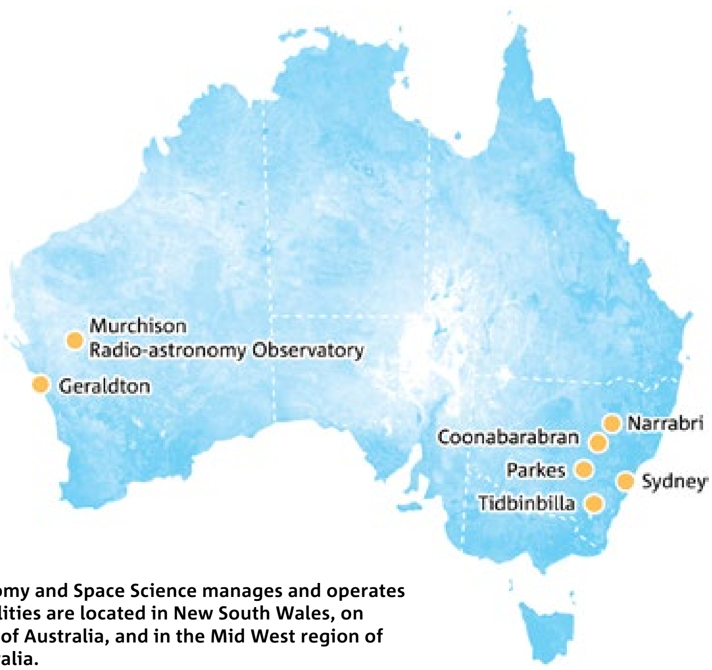
"The primary user base of the Australia Telescope is the university community."

CSIRO's radio astronomy observatories are collectively known as the Australia Telescope National Facility, or ATNF. This set of radio telescopes is operated as a national research facility for use by Australian and international researchers. The ATNF is run by CSIRO's Division of Astronomy and Space Science (CASS), which provides technology and services for radio astronomy, spacecraft tracking and space sciences. CASS has its headquarters at the CSIRO Radiophysics Laboratory in Marsfield, Sydney. This report covers ATNF-related activities of CASS for the 2012 calendar year.

CASS'S MISSION

To develop and operate world-class national facilities for radio astronomy and for spacecraft tracking, by measures that include:

- Development and maintenance of the Australia Telescope (AT) as a national and international research facility
- Advancing national leadership in radio astronomy through positioning Australia for a major role in the Square Kilometre Array
- Delivery of world-class science through exploitation of the AT's unique southern location and technological advantages
- Development and application of innovative technologies and 'big data' processing techniques
- Meeting NASA's need for communication with its spacecraft fleet, and
- Development of a space science capability in support of Government policy.



CSIRO Astronomy and Space Science manages and operates the ATNF. Facilities are located in New South Wales, on the east coast of Australia, and in the Mid West region of Western Australia.

AN OVERVIEW OF THE ATNF

The Australia Telescope currently comprises eight antennas and associated instrumentation located at three geographically separate locations, supported by staff and facilities at the CSIRO Radiophysics Laboratory in Marsfield, Sydney. The three observatories are near the towns of Parkes, Narrabri and Coonabarabran, all in rural NSW.

Parkes Observatory is home to the 64-m Parkes radio telescope, a single, fully steerable antenna equipped with receivers that operate in frequency ranges from 74 MHz to 22 GHz, with bands in the range from 600 MHz to 9 GHz the most commonly used. This telescope has been successfully operated since 1961 and is famous as a national symbol for Australian scientific achievement. Instrumental upgrades, including a 13-beam focal plane array and innovative backend signal-processing instrumentation, have maintained the telescope as a state-of-the-art instrument.

Six identical 22-m antennas make up the Australia Telescope Compact Array, an earth-rotation synthesis telescope located at the Paul Wild Observatory outside Narrabri. The Compact Array is equipped with receivers that operate at frequencies between 1.0 GHz and 110 GHz, with use at the highest frequencies restricted primarily to a 'winter season' by atmospheric stability and transparency considerations.

The Mopra radio telescope is a single 22-m diameter antenna near Coonabarabran, used primarily for large-scale millimetre-wavelength mapping projects and as part of the Long Baseline Array (described below).

CASS also manages the astronomy use of the CSIRO-administered Canberra Deep Space Communication Complex 70-m and 34-m antennas at Tidbinbilla, ACT. NASA/JPL makes approximately 5% of 70-m antenna time available to astronomical research programs.

The eight ATNF radio telescopes can be used together (sometimes in conjunction with antennas operated by the University of Tasmania at Ceduna and Hobart, the CDSCC 70-m antenna, and a new 12-m antenna operated by Auckland University of Technology at Warkworth, NZ) as a Long Baseline Array (LBA) for a technique known as Very Long Baseline Interferometry (VLBI).

CASS is in the process of building a next-generation radio telescope, the Australian Square Kilometre Array Pathfinder (ASKAP), which will become part of the ATNF following its commissioning.

ASKAP will be a wide field-of-view survey telescope made up of 36 antennas, each 12 metres in diameter. It is located at the Murchison Radio-astronomy Observatory, a superbly radio-quiet area in the Mid West region of Western Australia, and will be a key demonstrator instrument for new technologies for the international Square Kilometre Array (SKA) project. The Murchison Support Facility in Geraldton supports the development and operation of the Murchison Radio-astronomy Observatory. Initial commissioning data and images made from this data have been generated during the past year. Additionally, one antenna of ASKAP has been used as part of the VLBI network.

Technical research and development supporting upgrades of the Facility, as well as for the new ASKAP instrument, have traditionally been conducted at CASS headquarters in Marsfield. More recently, Operations staff from Parkes and Narrabri have undertaken work to enable observers using Parkes to conduct their observations from a remote location.

GOVERNANCE

The Australia Telescope is operated as a national facility under guidelines originally established by the Australian Science and Technology Council. Until 30 November 2009 the ATNF undertook this activity as a division of CSIRO in its own right. On 1 December 2009, the ATNF was placed within a new division, CSIRO Astronomy and Space Science (CASS). Through CASS, the ATNF is responsible to the CSIRO Executive and, ultimately, the Minister for Tertiary Education, Skills, Science and Research. The Chief of CASS is also the Director of the ATNF.

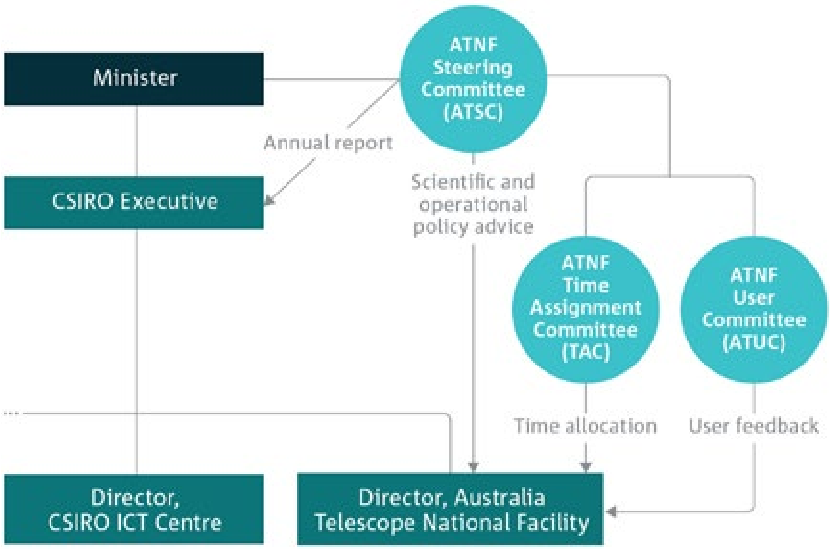
Divisional policy, strategic planning and operational management are the responsibility of the CASS Executive, comprising the Chief (position vacant at the end of 2012), the Deputy Chief (Sarah Pearce, currently in the Acting Chief role), Chief Scientist (Robert Braun), Assistant Directors (Graeme Carrad, Douglas Bock, Simon Johnston, Antony Schinckel), CDSCC Director (Ed Kruzins), Operations Research Program Leader (Jessica Chapman) and Strategic Planning and Major Project Specialist (Phil Crosby).

Divisional plans reflect CSIRO's 2007–2011 Strategic Plan, the new CSIRO Strategic Plan 2012–2015, and the ATNF's mission statement.

ATNF policy is shaped by the Australia Telescope Steering Committee (ATSC), an independent committee appointed by the Minister. The Steering Committee meets at least once a year to advise the Director regarding broad directions of the ATNF's scientific activities and longer-term strategies for the development of the Australia Telescope. The Steering Committee appoints the Australia Telescope Users Committee (ATUC) and the Time Assignment Committee (TAC). ATUC represents the interests of the community of astronomy researchers who use the Australia Telescope. The Committee provides feedback to the ATNF Director, discussing problems with, and suggesting changes to, ATNF operations. It also discusses and provides advice on the scientific merit of future development projects. ATUC meetings are also a forum for informing telescope users of the current status and planned development of ATNF facilities, and recent scientific results. The TAC reviews proposals to use ATNF telescopes on the basis of their scientific merit.

The ATSC, TAC and ATUC members for 2012 are listed in Appendix A.

AUSTRALIA TELESCOPE NATIONAL FACILITY



MANAGEMENT CHANGES IN 2012

In mid-October, after two and a half years in the role, CASS Chief and ATNF Director Phil Diamond resigned to take up the position of Director General of the SKA Organisation based in the UK. Deputy Director Sarah Pearce has undertaken the role of Acting Chief while an international recruitment process for a new Chief is conducted. An appointment is anticipated in early 2013. Graeme Carrad is Acting Deputy Chief and Mark Bowen has taken on Graeme's leadership responsibilities in the Technologies for Radioastronomy Theme.

Tim Cornwell, who led the ASKAP Computing Group for seven years, followed in Phil Diamond's footsteps in mid-November, taking up the position of 'Computing Lead' with the SKA Organisation. An internal search for his replacement is under way.

In May, Ed Kruzins took up the position of Director, Canberra Deep Space Communication Complex, at Tidbinbilla.

FUNDING

In financial year July 2011–June 2012 CSIRO's total expenditure for radio astronomy activities was A$38.2 million; total revenue was A$49.3 million, including a direct appropriation of A$35.6 million from CSIRO. External revenue for the year was impacted by one-off agreements related to funding for the ASKAP project. A summary of finances for the year is given in Appendix B.

THE AUSTRALIA TELESCOPE COMMUNITY

At the end of 2012 the total staff complement of CASS was around 300 research scientists, engineers, and technical and administrative support personnel, of whom 160 were primarily associated with the ATNF. (This number excludes casuals, contractors and students.) CASS resources are distributed across five sites within NSW and the ACT, and Geraldton in Western Australia. A list of all staff who worked for CASS on radio-astronomy-related activities during 2012, including staff from other CSIRO divisions, is given in Appendix C.

The primary user base of the Australia Telescope is the university community, both within Australia and around the world. Approximately 90% of the Australia Telescope's users come from outside CSIRO and 80% are from outside Australia. They gain access to our facilities on the basis of scientific merit and use them without charge. Similarly, Australian astronomers obtain access to overseas facilities operated on the same principle. This 'open skies' policy follows the general practice of the international radio astronomy community.

Observing time on ATNF telescopes is awarded twice a year to astronomers on the basis of the merits of their proposed research programs as judged by the Time Assignment Committee. For 2012, proposals for the Compact Array exceeded the time available by a factor of two, while for Parkes and Mopra proposals this number was closer to 1.3. In total, 138 proposals were received for the 2012 summer semester (October to March) and 257 for the winter semester (April to September). The higher demand for the winter observing months is a reflection of the better weather conditions for higher-frequency 'millimetre' observations with Mopra and the Compact Array.

A 'user-operator' model is used for the Compact Array, the Parkes Telescope, and the Mopra Telescope. Members of each observing team operate the telescope for their allocated time and are supported by CSIRO astronomers and students. For Mopra and the Compact Array, observers enjoy the flexibility of observing remotely from their home institutes and from the new Science Operations Centre at ATNF Headquarters in Marsfield, or from the Compact Array site near Narrabri.

The ATNF headquarters hosts a constant stream of visiting astronomers from around the world who come for periods of between a few days and a few weeks. Some of these visitors are observers passing through on their way to the observatories. Others are part of the Visitor Science Program or Scientific Colloquia series. The Science Operations Centre provides desk space for visitors and a place where staff and visitors can meet and discuss their science. Such interactions are important for the international and collaborative nature of astronomical research carried out by CASS astronomers.

Research scientists and engineers are heavily involved in the training of postgraduate students, and this helps to strengthen the interactions between CASS staff and university colleagues. In September 2012 CASS hosted the regular ATNF Radio Astronomy School at the Compact Array, for 38 students. In 2012 CASS staff co-supervised 33 PhD students, most of whom were undertaking degrees at Australian universities. CSIRO provides direct financial support to most of these students, supplementing the support that they receive through their host universities. Most of the PhD students currently with CASS have an Australian Postgraduate Research Award.

THE WIDER ASTRONOMY COMMUNITY AND OTHER RELATIONSHIPS

The Australia Telescope Steering Committee provides the ATNF Director with strategic advice from the Australian and international research community, and CSIRO provides similar input to other parts of the research community via staff representation on other research community bodies and committees.

CSIRO is a full member of Astronomy Australia Ltd, an organisation established in early 2007 as a company with the principal objective of managing the National Collaborative Research Infrastructure Strategy (NCRIS) funds for astronomy.

CSIRO is also a member of CAASTRO (the ARC Centre of Excellence for All-sky Astrophysics). CAASTRO is a partnership and collaboration between several Australian and international universities and research institutions.

CSIRO is a corporate member of the Astronomical Society of Australia. CSIRO sponsors national events such as the 'Women in Astronomy' workshop and the ASA Annual Science Meeting.

CASS has contracted links with the research and space community, for the provision of both equipment and research outcomes, data, or aspects of ATNF operations to organisations external to CSIRO. Such contracts are few in number, and in the past have generally concerned the delivery of instrumentation for astronomy, and/or spacecraft tracking services. CSIRO has also entered into contracts with Australian university partners for the provision of services that contribute to the operation of the ATNF. Engagement with university partners is seen as increasingly important and will continue to be actively pursued over coming years by CASS as an effective means of broadening the ATNF resource base and ensuring the vitality of the Australian astronomy research community as a whole.

As a component of CSIRO's management of the Murchison Radio-astronomy Observatory (MRO), CSIRO has a Collaboration Agreement with the Western Australian Government, supporting collaboration between CSIRO, ICRAR (the International Centre for Radio Astronomy Research, which comprises Curtin University and the University of Western Australia), and SciTech. CSIRO collaborates with the Wajarri Yamatji community under the terms of the Indigenous Land Use Agreement (ILUA) for the site. A project from the Sustainability Round of the Commonwealth Government Education Investment Fund will see CASS working with CSIRO's Energy Group and several industry partners to improve energy efficiency and provide sustainable power for the MRO and for ASKAP's supercomputing requirements at the iVEC Pawsey Centre in Perth.

International alliances are growing, with a small number of 'formal' links underlined by collaborative agreements supplemented by a larger number of informal community collaborations. CSIRO is a member of RadioNet3, a collaboration to coordinate radio-astronomy facilities to benefit European astronomers. The CASS VLBI team's expertise has led to its inclusion in the (mainly European) 'NEXPReS' consortium to develop e-VLBI which seeks to link observatories across the world by high-speed optical fibre to deliver real time analysis and flexibility in observing that is not currently available in VLBI observing. CASS also works with AUT University (Auckland, New Zealand) on trans-Tasman VLBI observing projects.

CSIRO's relationships with the international astronomical community are increasing in complexity as the SKA project progresses. CSIRO has formal linkages with EU-PrepSKA, NRC-Canada, ASTRON in The Netherlands, the international Office for the SKA Organisation, the Australia – New Zealand SKA Coordination Committee (ANZSCC), INAF in Italy, and research groups in the USA, New Zealand, India, and China. International connections were strengthened in 2012 by a strong CSIRO presence at the International Astronomical Union General Assembly in Beijing.

Finally, as CASS moves through the design, development and construction phases of the ASKAP project, industry will play a crucial role in the delivery and through-life support of the technologies and infrastructure required. The scale of ASKAP and the consequent requirement to produce at scale many of its components continues to draw on the engagement of industry at new levels. Such relationships with industry continued to develop through 2012 with engagement occurring at the research collaboration level and more strategically via the Australasian SKA Industry Consortium (ASKAIC). Organisations with which CSIRO now has connections through ASKAP are noted on pages 61–62.

THEMES

The strategic goals pertaining to the ATNF by CSIRO theme (as at the end of 2012) are as follows:

Astrophysics

Theme goal
To deliver world-class science that directly influences international astronomical research and shapes our understanding of the Universe.

Theme purpose
To conduct world-class research in astrophysics, retaining astronomy's position as Australia's highest-impact fundamental science and furthering our understanding of the Universe through innovative use of CSIRO's telescopes. The primary research deliverables of the theme are refereed papers in high-impact international journals. Current outputs are based, to a large extent, on data obtained with the ATNF telescopes, a hardware investment of about A$200 million made over the past 50 years. About half of theme effort is directed at maximising the scientific return of current and future facilities through the provision of scientific support. This has been directed largely at the ATNF telescopes, but will also extend to the Australian Square Kilometre Array Pathfinder, a A$170 million facility now under construction in Western Australia. The theme is also fully engaged in planning for science outcomes from the €1.5-billion international Square Kilometre Array, which will provide revolutionary science capabilities from about 2018.

Australia Telescope National Facility Operations

Theme goal
To continue to operate the most productive radio astronomy facility in the southern hemisphere in order to serve the Australian and international scientific community.

Theme purpose
This theme operates the National Facility observatories (the Compact Array near Narrabri, the single-dish Mopra telescope, the Parkes radio telescope), the radio-astronomy activities at NASA's Canberra Deep Space Communication Complex, and the Long Baseline Array, to maximise the scientific value of experiments conducted by ATNF users. From 2013, the theme will operate a new telescope — the Australian Square Kilometre Array Pathfinder (ASKAP) — in Western Australia, which is being developed under the ASKAP theme. Operational activities in Western Australia began to move into this theme on 1 July 2011.

The high impact of the ATNF will be sustained by ensuring continuous operation with very high reliability (<5% lost time) and excellent data quality, facilitating astronomical research conducted with our radio telescopes that contributes to the understanding of the Universe. The scientific impact of the theme is measured by the output of CSIRO astronomers (the Astrophysics theme) and the astronomers worldwide who use the facility. A primary measure is the publication record of CSIRO and non-CSIRO facility users.

Technologies for Radio Astronomy

Theme goal
To develop front-line technology for the advancement of radio astronomy in Australia.

Theme purpose
To ensure that CSIRO's existing radio telescopes remain at the leading edge of world technology, securing continued demand from the astronomy research community for CSIRO's radio telescopes, with the effect of maximising the science outcomes from astronomy conducted with the ATNF.

This directly complements the development of a new radio telescope undertaken in the sister theme, the Australian Square Kilometre Array Pathfinder.

These technological developments underpin astronomy's position as the highest-impact field of Australian science and its role in shaping our understanding of the Universe.

In addition, this theme supplies radio astronomy instrumentation to outside organisations and undertakes strategic collaborations with other radio astronomy institutes. These secondary activities allow a broad range of specialist talent to be maintained and developed within CASS, provide significant external revenue for re-investment in the ATNF, and facilitate the international communication necessary to ensure that technological developments at CASS continue to be world-class.

The window of opportunity for success is considered to be medium-term rather than short-term, and is determined by those facilities in the world that might compete in the astronomy field. Timescales for planned work allow sufficient time for front-line science to be conducted before competing facilities come online.

The Australian Square Kilometre Array Pathfinder

Theme goal
To maximise Australia's participation in the Square Kilometre Array (SKA).

Theme purpose
The purpose of the Australian Square Kilometre Array Pathfinder (ASKAP) theme is to develop a world-leading survey radio telescope to explore the history of the Universe, through development and deployment of innovative receiver and data-processing technologies, and establishment of a radio-quiet observatory in Western Australia. Embedding the theme developments in the international SKA program is aimed at maximising Australia's participation in the SKA, to take advantage of the opportunity to be a 'key player' in the SKA domain.

ASKAP will provide impact through:

- Delivering a world-leading instrument to study the southern sky and address the biggest questions regarding our knowledge of the Universe. The complete ASKAP telescope will deliver a roughly 20-fold capability increase in survey speed compared with any radio telescope in the world.
- Establishing a world-class astronomical observatory at the world's best site for metre and centimetre radio astronomy, attracting science engagement and further international investment to Australia, including the SKA.
- Maximising Australia's participation in the SKA — a multi-billion-euro international facility due for full delivery in about 2025, and
- Developing innovative phased array feeds along the SKA development path as well as for other radio telescopes and with broader applications outside radio astronomy.

The ASKAP theme deliverables have achieved their desired aim of influencing site choice and technology choice for the SKA, to promote Australian opportunities.

Capability Development

Theme goal
To build CASS's capability in astronomy, technology, operations and space science.

Theme purpose
This theme focuses on building capability in the following areas:

- Developing capability to participate in the SKA
- Developing innovative 'phased array' technology, in particular looking at manufacturing the technology for the SKA radio telescope
- Developing a space-science strategy for CSIRO.

Telescopes

AUSTRALIA TELESCOPE COMPACT ARRAY
Credit: David Smyth

PARKES RADIO TELESCOPE

MOPRA RADIO TELESCOPE

CANBERRA DEEP SPACE COMMUNICATION COMPLEX 70-M ANTENNA, DSS-43

AUSTRALIAN SQUARE KILOMETRE ARRAY PATHFINDER
Credit: Dragonfly Media

2. Performance Indicators

A phased array feed being installed on an ASKAP antenna at the Murchison Radio-astronomy Observatory in June 2012. In late 2012 successful phase-closure tests were carried out with three phased array feeds on ASKAP antennas — a world first.

Performance Indicators

"Proposals received each semester include approximately 600 authors."

1 SCHEDULED AND SUCCESSFULLY COMPLETED OBSERVING TIME

For the Compact Array and Parkes radio telescope, the ATNF target is that at least 70% of time should be allocated for astronomical observations while the time lost during scheduled observations from equipment failure should be below 5%. For the Compact Array and Parkes, approximately 10% of time is made available as 'Director's time'. This is time that is initially not allocated in the published version of the schedule, but, if not allocated at the discretion of the Director, is later made available for approved observing projects.

For most projects, the proposing astronomers are required to be present at the observatory for their scheduled time. For the Compact Array, remote observing is also possible from other sites. In 2011, 39% of Compact Array observations were taken by observers not present at Narrabri, compared with 32% in 2011 and 2010. The intention is for remote observing to be permitted for experienced observers who require little or no assistance in conducting their observations. All Mopra observations are now taken remotely, the large majority of them from Sydney or further afield.

In 2012 almost all Parkes observations were taken from the observatory. However, work was carried out to develop remote access to the Parkes telescope so that in future observations can be carried out from Marsfield and other locations. (See page 38 for more information on remote observing with the Parkes radio telescope.) The first remote observing with the Parkes telescope from the new Science Operations Centre at Marsfield was carried out in December 2012. These first observations still required someone to be present in the tower at Parkes.

The telescope usage figures are similar to those for recent years. For Mopra, the period 1 April – 30 September corresponds to the period when the majority of observing in the 3-mm band was carried out (the 'millimetre season'). In recent years, Mopra use has extended, at a somewhat lower level, into the 'shoulder season' either side of the 3-mm season for observations in the 7-mm and 12-mm bands.

2 RESPONSE TO RECOMMENDATIONS BY THE USER COMMITTEE

The Australia Telescope User Committee (ATUC) is an advisory group that normally meets twice a year to represent the user community in the ATNF decision-making process. After each meeting the committee presents a list of recommendations to the ATNF Director. ATUC considers matters raised by the user community, current operations, and priorities for future developments. In 2012 three ATUC meetings were held, with a special meeting in February to discuss Parkes instrumentation options.

In most cases ATUC recommendations are accepted and implemented. In 2011, ATUC made 24 recommendations to the ATNF. Of these, 23 were accepted and were completed by June 2012.

The ATUC members are listed in Appendix A.

TABLE 1:
Telescope usage in 2012.

	COMPACT ARRAY	PARKES	MOPRA*
Successful astronomy observations	78%	78%	74%
Maintenance/test time	16%	13%	5%
Time lost due to equipment failure	3%	3%	2%
Time lost due to weather	1%	3%	11%
Idle time	2%	3%	8%

* Mopra statistics are for dates between 1 April and 30 September, corresponding to the 'millimetre season'.

3 TIME ALLOCATION ON AUSTRALIA TELESCOPE FACILITIES

The allocation of time on Australia Telescope facilities is done on the basis of scientific merit. Two six-month observing semesters are scheduled each year, from October to March (OCTS) and from April to September (APRS). For the period from 1 October 2011 to 30 September 2012 a total of 216 proposals were allocated time on ATNF telescopes (each proposal is counted once only per calendar year although some proposals are submitted twice). Of these, 131 were for the Compact Array, 33 were for the Parkes telescope, 30 were for the Mopra telescope and 16 were for the Long Baseline Array. Observing programs allocated time on ATNF facilities are listed in Appendix D.

Proposals requesting service observations with the Canberra Deep Space Communication Complex DSS-43 (70-m) and DSS-34 (34-m) antennas at Tidbinbilla, which are part of the NASA Deep Space Network, are also accepted. Six CDSCC projects were observed during the year.

Figures 1, 2 and 3 show the time allocated to observing teams on the Compact Array, Parkes and Mopra telescopes as a percentage of the total allocated time, determined by affiliation of the team leader.

Figures 4, 5 and 6 show the time allocated to observing teams as a percentage of the total allocated time, determined using the affiliations of all team members. In these plots the time allocated to each proposal has been divided evenly between all authors on the proposal. Including all authors on the proposals, CASS staff were allocated approximately 25% of observing time during the year for the Compact Array, 31% for the Parkes telescope and 9% for Mopra. Mopra continued to be used largely by international investigators, who have been allocated about 70% of observing time in recent years.

ATNF telescopes are able to support a broad range of science areas that include Galactic (ISM, pulsar, X-ray binaries, star formation, stellar evolution, magnetic fields), extragalactic (galaxy formation, ISM, Magellanic Clouds, cosmic magnetism) and cosmological science. The research programs involve astronomers from many institutions in Australia and overseas. Typically, the proposals received each semester include approximately 600 authors. Of these 50 are from CASS, 80 are from other Australian institutions and 470 are from around 175 overseas institutions in 26 countries. The three countries with the largest numbers of proposers are the USA, UK and Germany.

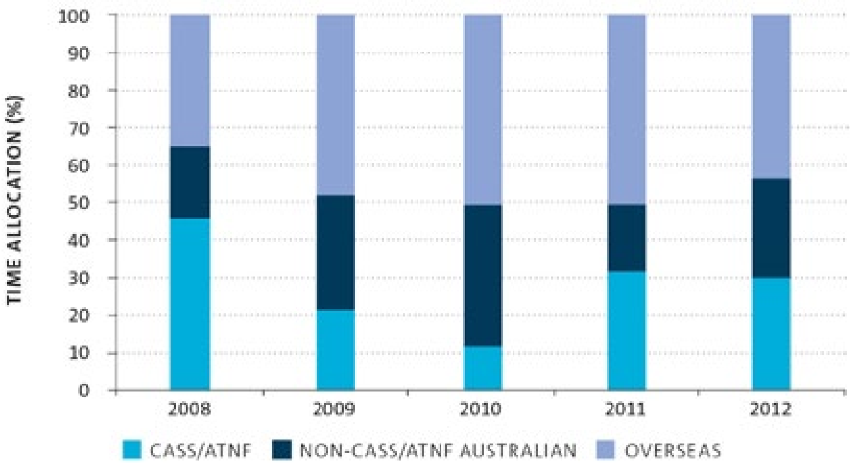


FIGURE 1:
Compact Array time allocation by primary investigator, October 2008 – September 2012. For each year the time allocation is for 12 months from October to September.

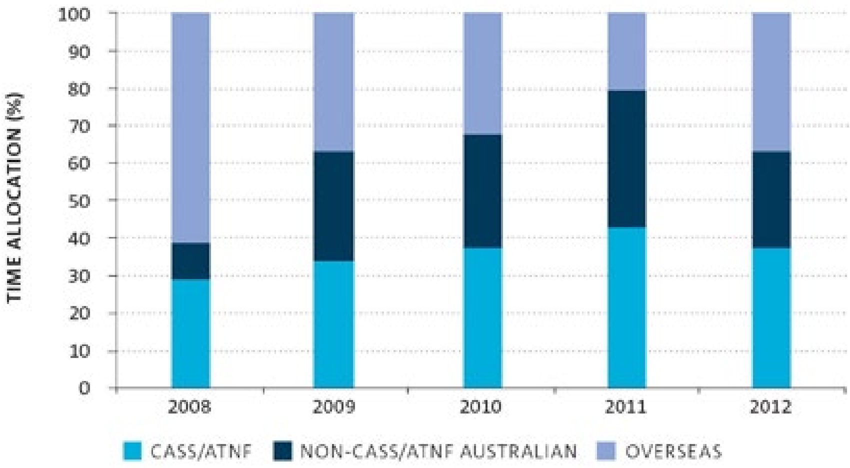


FIGURE 2:
Parkes time allocation by primary investigator, October 2008 – September 2012. For each year the time allocation is for 12 months from October to September.

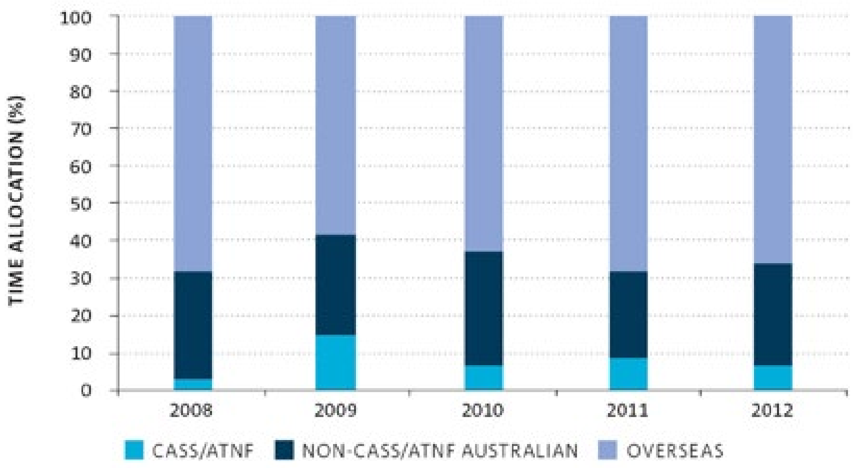


FIGURE 3:
Mopra time allocation by primary investigator, October 2008 – September 2012. For each year the time allocation is for 12 months from October to September.

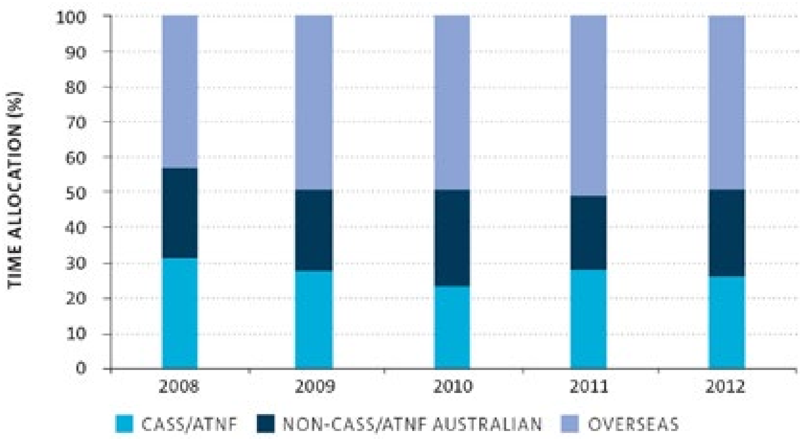


FIGURE 4:
Compact Array time allocation by all investigators.

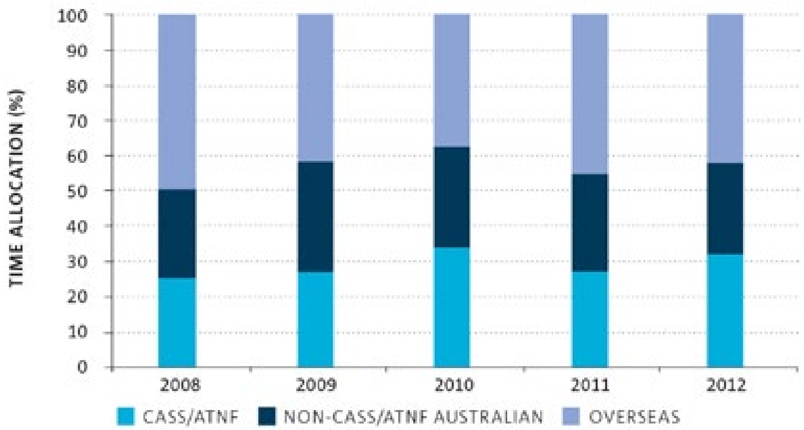


FIGURE 5:
Parkes time allocation by all investigators.

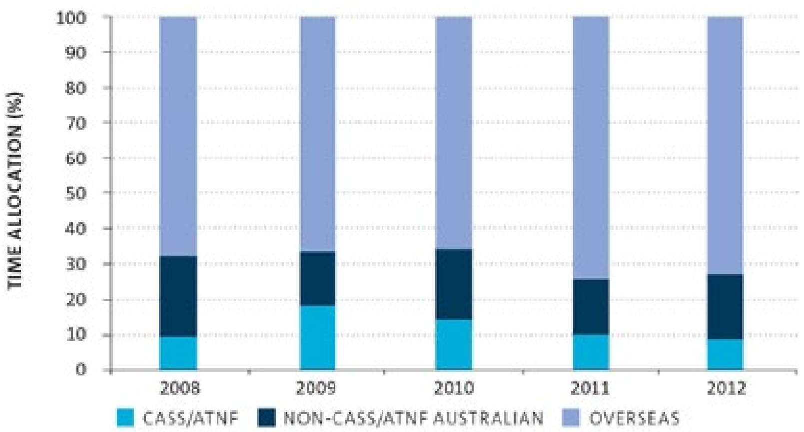


FIGURE 6:
Mopra time allocation by all investigators.

4 TEACHING

In December 2012, CASS staff were co-supervising 33 PhD students. The students' affiliations and thesis titles are given in Appendix E. Seven students were awarded PhDs during the year and their theses are listed in Appendix F.

Figure 7 shows the numbers of PhD students affiliated with CASS. Figure 8 shows the institutions at which CASS-affiliated students were enrolled in 2012. Most students were enrolled in Australian universities, with the majority of these at Swinburne University of Technology, the University of Sydney and the University of Tasmania.

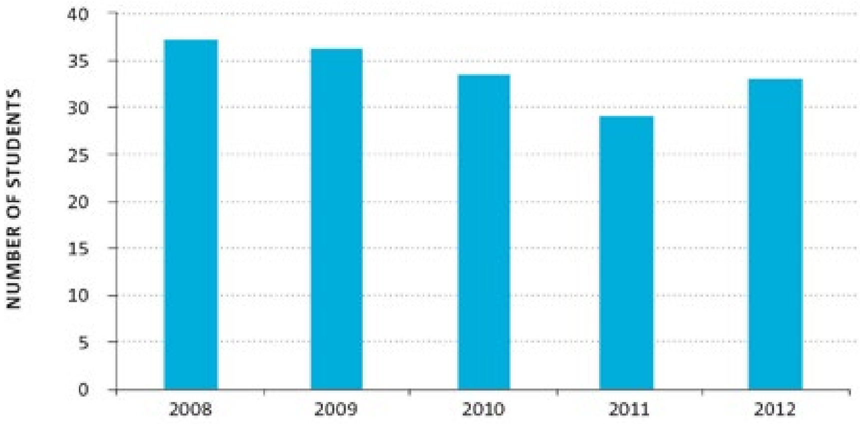


FIGURE 7
Numbers of postgraduate students affiliated with CASS.

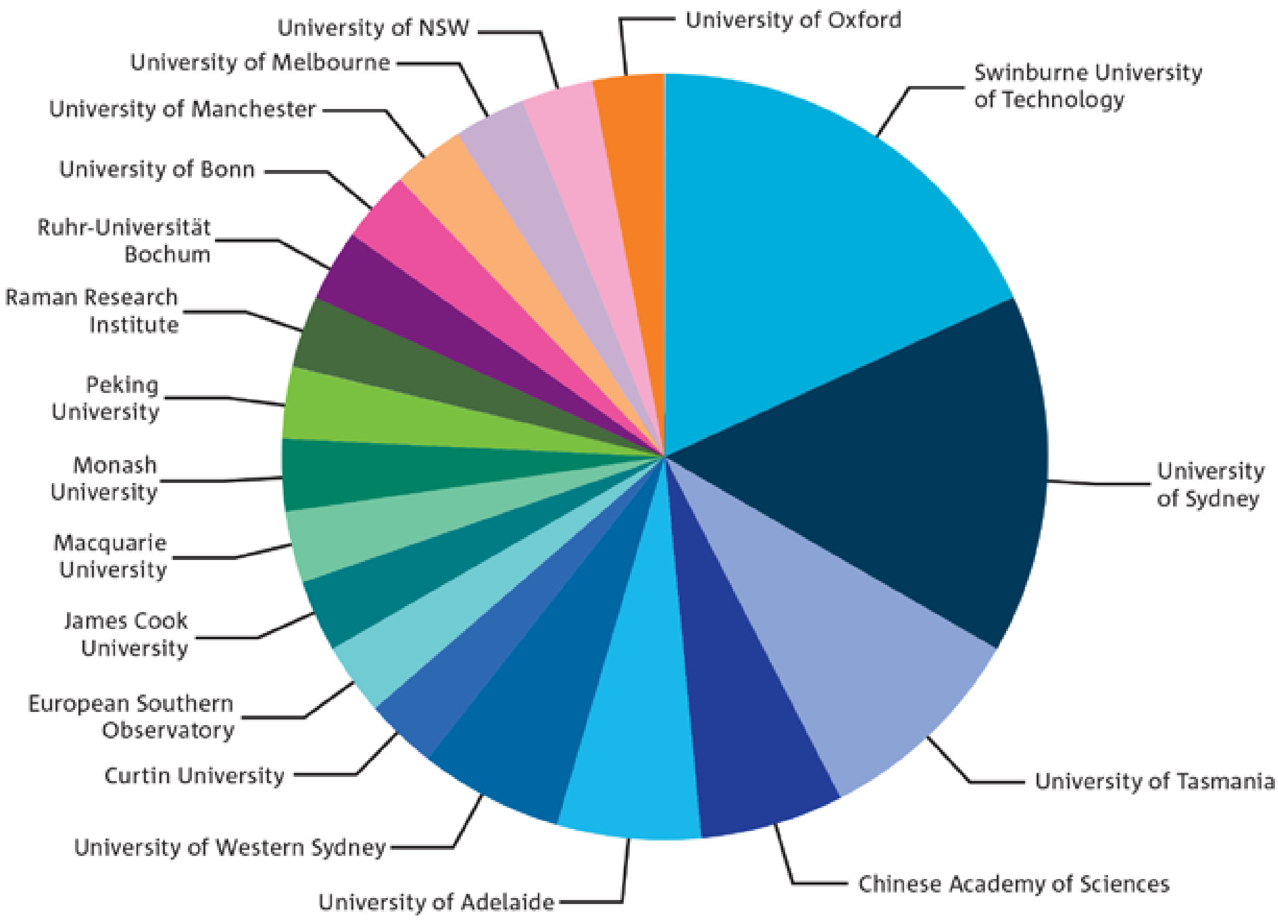


FIGURE 8:
Postgraduate student affiliations 2012.

5 PUBLICATIONS AND CITATIONS

Figure 9 shows the number of publications in refereed journals that include data from, or related to, ATNF facilities — the Compact Array, Mopra, Parkes, VLBI and CDSCC. Publications relating to the scientific goals or development of ASKAP are also included.

The publication counts for refereed journals do not include IAU telegrams, abstracts, reports, historical papers or articles for popular magazines. In 2012, 150 papers were published in refereed journals. The increase over the previous year is largely explained by the larger number of ASKAP-related papers: there were five ASKAP-related papers in 2011 but 18 in 2012. Of the 18 publications, 10 have a first author at another Australian institution. As shown in Figure 9, the number of refereed publications for papers with a first author at other Australian institutions increased significantly, from 35 to 52 papers, reflecting the growth of radio astronomy in Australia.

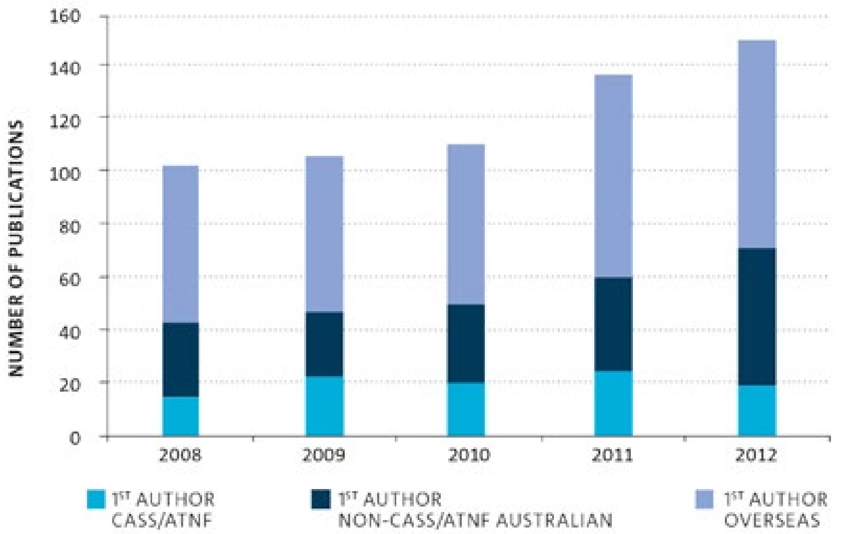


FIGURE 9:
Publications that include data from, or are related to, ATNF facilities (Compact Array, Mopra, Parkes, VLBI, CDSCC and ASKAP), published in refereed journals.*

For consistency, the number of publications listed for the years 2008 to 2011 has been updated to include publications relating to the scientific goals or development of ASKAP; as a result, these numbers differ from those listed in the** ***ATNF Annual Report 2011**.**

CASS staff were included on 60% of the National Facility papers published in refereed journals during the year. Refereed publications by CASS staff, including scientific papers with data from other facilities, have increased strongly in the period 2008 to 2012, from 101 papers in 2008 to 167 papers in 2012, while the number of publishing research staff within CASS has only undergone a modest increase. This increase in research productivity has not come at the expense of a reduction in impact, as the median number of citations per paper remains about three times higher than that of all refereed astrophysics publications tabulated by the Astrophysics Data System.

The refereed papers are listed in Appendix G, which also lists 56 conference papers that either include ATNF facilities or include CASS authors.

Figure 10 shows publication numbers for each facility. A small number of papers with data from more than one facility are counted more than once. For the Compact Array the number of publications (76) is higher than for any previous year of its use. For ASKAP there is a clear growth in the number of papers. In 2012 Mopra showed a sustained number of papers achieved since 2010.

The ATNF is both cost-effective and scientifically productive. Overall the ATNF is ranked second in the world behind the NRAO in terms of total number of refereed publications; the Compact Array and Parkes rank second and third respectively in the world in terms of total number of citations to refereed papers (Trimble and Cega 2008, Astron. Nachr. 329, 632–647). In terms of citations per paper, Parkes is the second most highly cited radio telescope in the world in its class after the Ryle telescope (which has a higher citation/paper ratio but a significantly smaller total number of papers than Parkes).

Astronomy leads Australian science as a discipline of international standing and has a particularly high level of international collaboration.

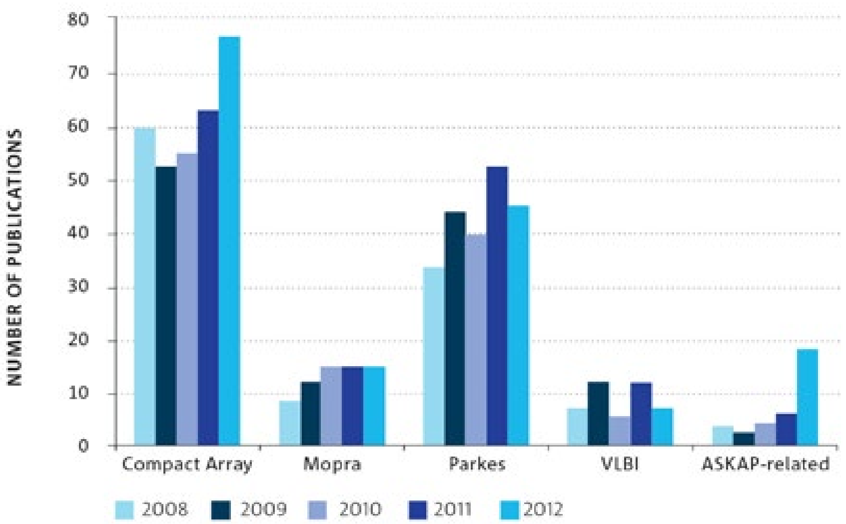


FIGURE 10:
Publications that include data from, or are related to, the Compact Array, Mopra, Parkes, VLBI and ASKAP in 2008–2012.

6 PUBLIC RELATIONS

Figure 11 shows the count of public-relations activities for the years 2008–2012. During 2012 CASS issued five radio astronomy-related media releases (see Appendix H for a full list), and featured in at least 725 print and online articles and 176 television and radio programs. CASS staff delivered at least 151 public lectures during the year to the general-public, education, industry and amateur-astronomy audiences.

The large number of public-relations activities recorded for 2011 was sustained in 2012. This was due to a number of factors:

- The large volume of media coverage was driven by the announcement of the future location of the Square Kilometre Array radio telescope, the official opening of the Australian Square Kilometre Array Pathfinder and Murchison Radio-astronomy Observatory, and several well-targeted media releases related to astronomy research conducted by CASS staff and other researchers using the ATNF.
- Strong public interest in astronomy and an ongoing commitment by CASS staff to delivering talks to school, industry and other groups.

In 2012 there were approximately 927,000 'visits' (38 million 'hits') to the central ATNF website (www.atnf.csiro.au) and approximately 528,000 visits (17.8 million hits) to the outreach and education website. CASS also contributed to the central CSIRO website (www.csiro.au) as well as to CSIRO's Facebook, Twitter and other social-media channels.

Figure 12 shows the number of public visitors to Parkes Observatory and the Australia Telescope Compact Array.

The Parkes radio telescope continues to be a popular attraction in the Central West of NSW. In 2012, 92,547 people visited the Parkes Visitors Centre: this number includes 88 tour groups consisting of 3,083 visitors. Projects completed during the year included the development of a CSIRO display, the unveiling of the Grote Reber monument, creation of the AstroKids scavenger hunt and the launching of the Parkes radio telescope online shop (www.parkesdishshop.com). The Parkes online shop has steadily grown through the year, generating around $10,000 in revenue.

Approximately 13,040 people visited the Compact Array Visitors Centre in 2012, including 16 tour groups. School holidays and public holidays are the most popular time to visit the telescope.

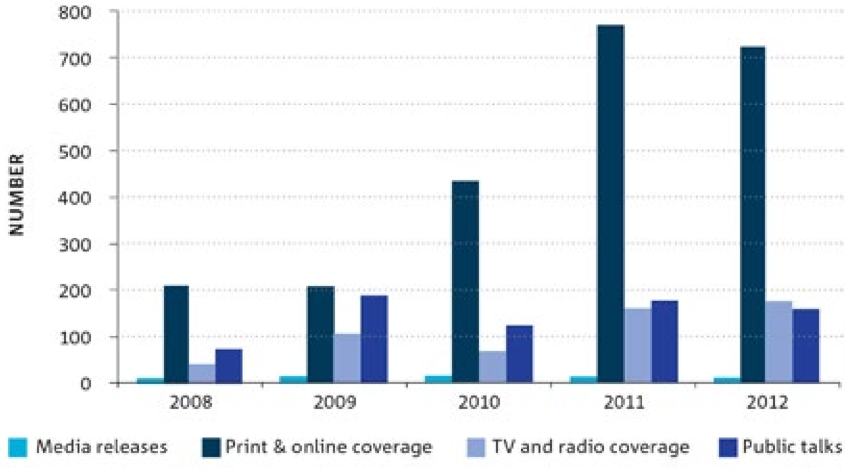


FIGURE 11:
ATNF public relations activities.

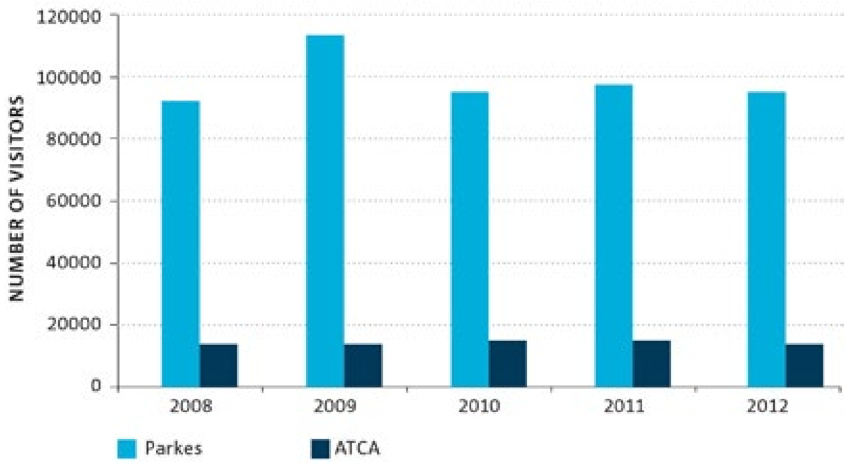


FIGURE 12:
Visitors Centre statistics.

7 USER FEEDBACK

Observers at the Parkes, Compact Array and Mopra telescopes are asked to complete a user-feedback questionnaire with responses given on a scale of 0 (low) to 10 (high).

Figures 13 and 14 show the results of user feedback questionnaires (from 2010 to 2012) for Parkes and the Compact Array, respectively. Table 2 indicates the average user responses for 2010 to 2012.

Feedback from observers at the Parkes telescope was similar or fractionally lower in most categories this year than for 2011. The biggest change was a decrease in the grade for 'Other computing services' a category that includes off-line software, although no specific issues were raised. A decrease in the 'Observer comfort' score is due in part to issues experienced with air conditioning in the control room. Similarly, several observers voiced a view that the observer training sessions were overly long, and is reflected in the decreased grade for this category. Finally, the score for freedom from radio-frequency interference has also decreased, with observing increasingly impacted by signals from satellites or local (but off-site) sources.

Figure 14 shows that in 2012 the feedback from observers using the Compact Array was generally consistent with that given in 2011. The biggest changes were increases in the scores for the Compact Array User Guide and other documentation, which is pleasing to see. There were insufficient responses on the 'Library and journal collection' and 'Offline imaging facilities' to be included.

As in 2011, not enough observers completed the Mopra feedback forms to provide a statistically valid grade in any of the categories. The majority of Mopra observing was conducted remotely, and as a result many of the categories on the form are not relevant. There is, inevitably, also less interaction with Observatory staff, and while this is an indication that the telescopes are operating reliably, it is likely that remote observers feel less obliged to complete feedback forms if, for example, they have completed a couple of shifts on a large project.

With the establishment of the Marsfield Science Operations Centre at the end of 2012, we will be encouraging feedback from observers on the new facilities and will report these in the future.

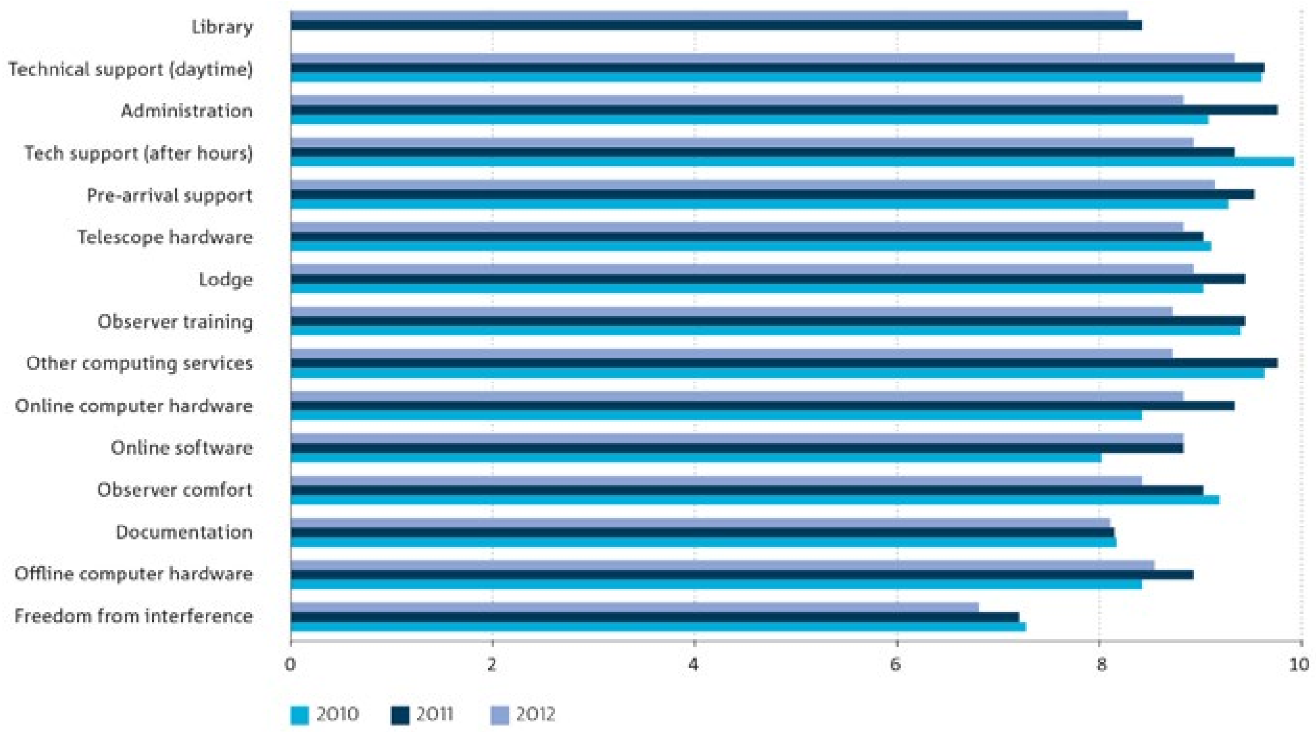


FIGURE 13:
Parkes user feedback on a scale from 1 (poor) to 10 (excellent).

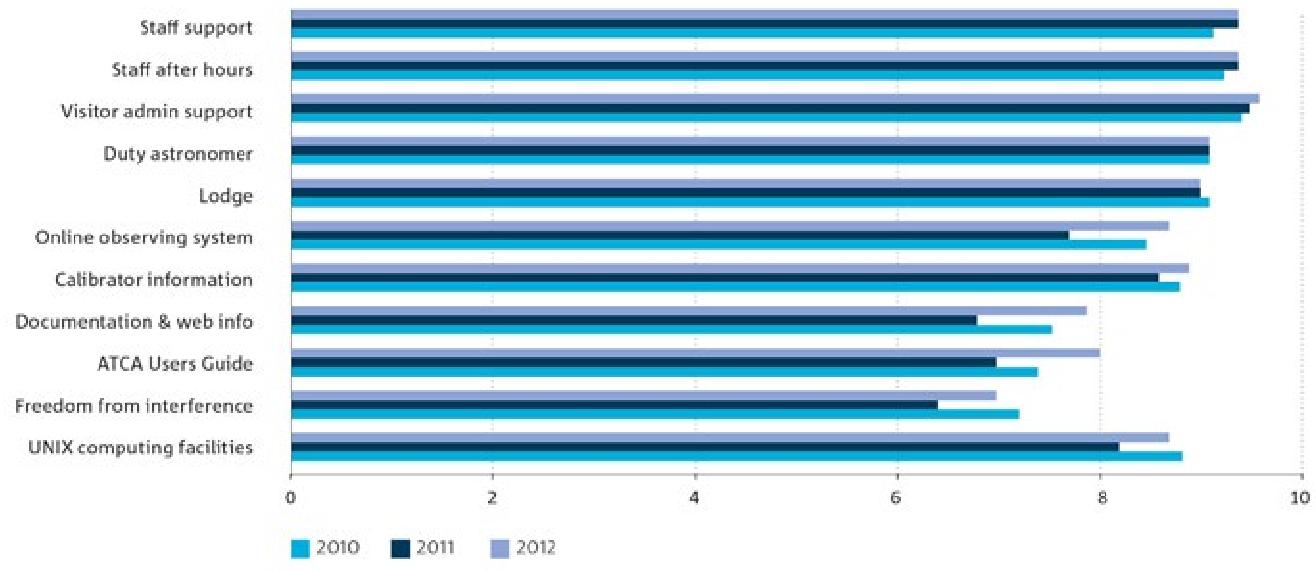


FIGURE 14:
Compact Array user feedback on a scale from 1 (poor) to 10 (excellent).

TABLE 2:
Average telescope user feedback questionnaire satisfaction score on a scale from 1 (poor) to 10 (excellent).

TELESCOPE	2010	2011	2012
Parkes	8.9	9.0	8.6
ATCA (cm)	8.7	8.3	8.7
Mopra	8.8	N/A	N/A

3. Astrophysics

Three antennas of the Compact Array. Upgrades to the telescope's correlator, and its new 4–12 GHz receivers, have enhanced the telescope's capabilities.

Astrophysics

"The staff are global leaders in astrophysical research."

OVERVIEW

The CASS Astrophysics Group is a vibrant research group with a wide range of expertise and technical knowledge in radio astronomy and associated techniques. The group consists of postgraduate students, postdoctoral staff and Australian Research Council (ARC) Fellows, permanent staff and retirees, encompassing a broad range of interests and delivering maximum scientific impact by targeting the highest-priority science questions. This breadth of science is important for ATNF support, given the diversity of the non-CSIRO user community and the range of projects supported on the facilities. A recent Science Review of CASS, conducted in 2011 by an independent panel led by Professor Anne Green (University of Sydney), noted that the staff are global leaders in astrophysical research and have publication and citation rates above benchmark expectations. For more information on CASS staff publications, see page 18 of the 'Performance Indicators' chapter.

During 2012, four new postdoctoral fellows joined the group. CSIRO Office of the Chief Executive Fellows Tim Shimwell (ASKAP commissioning), Peter Kamphuis (gas in galaxies), Yanett Contreras (star formation) and Bolton Fellow Eli Bressert (star formation) have made excellent starts to their post-PhD careers. Meanwhile, Bolton Fellow Shea Brown departed for a faculty position in the USA and Shane O'Sullivan took up a position at the University of Sydney.

Staff received a number of prestigious awards and appointments:

- Bärbel Koribalski became a CSIRO Science Leader in August. The award brings with it significant funds for attracting postdoctoral staff and students to work with Bärbel on studying the gas content of nearby galaxies and the upcoming WALLABY survey on ASKAP.
- George Hobbs obtained an ARC Future Fellowship. George will use the four-year fellowship to further his work on detecting gravitational waves using precision pulsar timing observations with the Parkes telescope.
- Jill Rathborne received a CSIRO Julius Career Award. Jill will use the award to pursue her science of high-mass star formation using Mopra and Australia Telescope Compact Array observations combined with early data obtained with the Atacama Large Millimeter/submillimeter Array.
- Jimi Green and Shari Breen obtained ARC Discovery Early Career Researcher Awards, and will take up their fellowships during 2013.

A number of challenges lie ahead in 2013 and beyond. The Astrophysics Group will play a large part in the scientific commissioning of the Australian Square Kilometre Array Pathfinder (ASKAP) as 2013 sees the deployment of the six-antenna BETA system at the Murchison Radio-astronomy Observatory. This marks an exciting phase for the project and an ideal learning platform for our postdoctoral staff. The upgrades to the correlator capability and the new 4–12 GHz front-ends at the Compact Array will strongly enhance the scientific possibilities with that instrument. The new operational plan for the Parkes radio telescope, and the phasing-in of remote observing, will require a new set of observational strategies. (For more information on operational plans, see page 38 of the 'Operations' chapter.)

GRADUATE STUDENT PROGRAM

Astrophysics staff continued to co-supervise PhD students enrolled at Australian and overseas universities. The program helps strengthen training in radio astronomy science techniques, and furthers collaborations between CSIRO and universities. In December, there were 33 PhD students affiliated with CASS (see Appendix E). In September, the students organised and held a full-day student symposium at Marsfield.

DISTINGUISHED VISITORS PROGRAM

CASS has a distinguished visitors program that provides financial and other support to facilitate visits from leading researchers for extended periods (from several weeks to a year). During 2012 the Astrophysics Group hosted month-long visits from 12 distinguished visitors from around the world.

CONFERENCES AND WORKSHOPS

Astrophysics staff and collaborators organised and hosted a large number of conferences and workshops in 2012. The second Australian ALMA community workshop was held in May to bring the community up to speed with tools and techniques in advance of a further call for proposals. The 'Bolton Symposium', held jointly with the Australian Astronomical Observatory over three days in December, showcased the research of early-career researchers from around the country. The General Assembly of the IAU held in Beijing, China in August was well attended by Astrophysics staff with a number of excellent talks over a range of topics, organisation of symposia and participation in key IAU managerial roles.

In June 2012 we hosted the 5th joint CASS/AAO Southern Cross Conference. The theme of this meeting, 'Multiwavelength Surveys: A Vintage Decade', brought together astronomers across the breadth of the electromagnetic spectrum in the picturesque wine-growing region of the Hunter Valley. The national and international speakers covered the complete range from Galactic scales to simulations of the Universe, and through each wavelength window. The tone of the meeting was set high, beginning with an inspiring overview and reminder of the importance of surveys and survey astronomy by Matthew Colless, Director of the Australian Astronomical Observatory, followed immediately by an update on the SkyMapper survey by recent Nobel Prize winner Brian Schmidt. A highlight was David Malin's public lecture on 'Photography and the Discovery of the Universe', which was as informative as it was entertaining. Even the weather did its bit, with a perfectly timed break in the clouds for the participants to witness the Transit of Venus. The backdrop of the Hunter Valley vineyards made a suitably memorable setting for this special event.

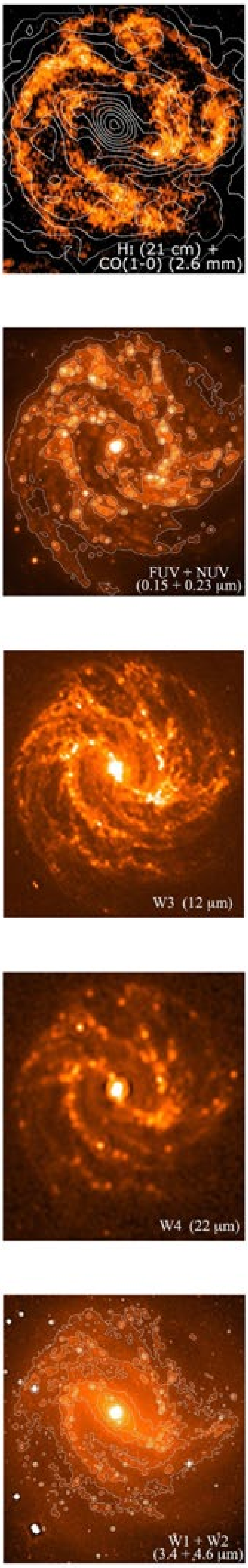
SCIENCE HIGHLIGHTS

The reports on the following pages describe a few of the many projects carried out by CASS staff and other users of ATNF facilities in 2012.

Gas in galaxies: an overview of recent projects

Bärbel Koribalski (CASS)

Dr Bärbel Koribalski is an OCE (Office of the Chief Executive) Science Leader and a recipient of CSIRO's Newton Turner award for 2011-2012. She leads several international research teams.



High-resolution HI observations of many nearby galaxies continue to deliver amazing results, from giant gas disks and enormous HI tails to infalling gas clouds and kiloparsec-scale HI holes in dwarf galaxies, gas accretion and stripping of the outer disk, counter-rotating gas hosts, and gas as fuel for star formation as well as a tracer of dark matter halos. In the following I highlight HI results from recent 21-cm projects under way with radio interferometers such as the Very Large Array (VLA), the Westerbork Synthesis Radio Telescope (WSRT) and the Australia Telescope Compact Array (ATCA). Parkes HI observations also feature strongly, from new high signal-to-noise HI spectra for the study of large-scale peculiar motions (Courtois *et al.* 2011, Hong *et al.* 2013) to source-finding in large spectral-line data cubes (Koribalski 2012a,b; Jurek 2012; Popping *et al.* 2012).

The Local Volume HI Survey (LVHIS), which I lead, is a large HI galaxy project comprising deep (~30 hr on-source) multi-resolution HI data cubes and 20-cm radio continuum data, supplemented by optical, ultraviolet and infrared images. Our emphasis is on measuring the faint and often very extended disks of spiral and dwarf irregular galaxies in the Local Volume (D < 10 Mpc) with the aim of studying their overall structure and morphology, their HI kinematics (including rotation curves), their outer edges and near-field environment. Recent papers include the multi-wavelength study of the dwarf starburst galaxy NGC 5253 (López-Sánchez *et al.* 2012) near M83, the detailed analysis of HI velocity fields (Kirby *et al.* 2012), a comparison of stars and gas in the highly obscured Circinus Galaxy using Spitzer mid-infrared and ATCA HI mosaics (For, Koribalski & Jarrett 2012), and a WISE case study of M83 (Jarrett *et al.* 2012a,b) and other spirals (Figure 1).

FIGURE 1:
The many faces of the galaxy M83, highlighting the evolution from gas to stars. The basic ingredients and processes that drive M83 also determine how other galaxies form and evolve over vast stretches of time. Top to bottom: (a) the neutral (HI greyscale) and molecular hydrogen (CO contours) gas content; (b) massive star formation as viewed by GALEX near ultraviolet (greyscale) and far ultraviolet (white contours), (c) WISE view of 11.3 μm emission from polycyclic aromatic hydrocarbons (PAHs) (W3 band) and (d) re-processed starlight (W4 band), both associated with star formation; and (e) the stellar distribution of the previous generations of star formation, as viewed with the W1 (3.4 μm; greyscale) and W2 (4.6 μm; white contours) bands. From Jarrett *et al.* 2012, AJ 145, 6.

The VLA-ANGST project (Ott *et al.* 2012) complements LVHIS, providing HI data (resolution: 6 arcseconds and 0.6-2.6 km/s) of 35 nearby galaxies (D < 4 Mpc) selected from the ACS Nearby Galaxies Survey Treasury (ANGST) sample (Dalcanton *et al.* 2009). Detailed studies led by PhD students Steven Warren and Adrienne Stilp resulted in a flood of papers. Warren *et al.* (2011, 2012) analysed the HI structure and morphology of dwarf irregular galaxies, as well as the contributions of cold and warm gas to individual HI spectra, showing that the formation of large HI holes in dwarfs requires multiple generations of star formation and suitable ISM conditions. Stilp *et al.* (2013) analysed co-added HI spectra, so-called 'superprofiles', of dwarf galaxies to better understand the possible connections between line widths and star formation.

A VLA HI study by Aeree Chung and collaborators of three early-type galaxies harbouring counter-rotating ionised gas components in their central regions suggests that HI gas is being accreted from their companions and is probably responsible for the kinematically decoupled gas. Using WSRT 21-cm observations, Serra *et al.* (2012) have detected a trail of starless HI clouds near the Hickson Compact Group (HCG) 44, which together with HIPASS data hint at an enormous HI stream towards the distant spiral galaxy NGC 3162 (Koribalski, Wong *et al.* in prep.). And my student Kathrin Wolfinger has published her first paper based on HIJASS data of the Ursa Major region (Wolfinger *et al.* 2012).

Another prominent northern galaxy, M33 — better known to some as the Triangulum Galaxy — was the focus of a Herschel key program known as HERM33ES (Kramer *et al.* 2010). In recent papers we compared its cool and warm dust emission (Xilouris *et al.* 2012) and derived the dust and gas power spectrum (Combes *et al.* 2012). A morphological comparison of star-formation tracers with the molecular and atomic gas in M33, using IRAM CO (2-1) and VLA HI mosaics respectively, was the topic of Pierre Gratier's PhD Thesis (Gratier *et al.* 2010).

The ASKAP HI All-Sky Survey project (known as WALLABY) continues the long path of detailed design studies through dedicated technical and scientific working groups, many of which it has in common with those of the planned WSRT Northern Sky HI Survey (WNSHS). The HI survey parameters, science goals and source-finding challenges for WALLABY and WNSHS are briefly outlined in Koribalski (2012b). The latter also includes a comparison with the HI Parkes All-Sky

FIGURE 2:
Figure 2: A multi-wavelength image of the southern spiral galaxy Messier 83. This image combines data taken in the ultraviolet, optical, infrared and radio regions of the spectrum by several instruments, including the Compact Array. The radio data, shown in pale blue, show the neutral hydrogen gas in the galaxy; the optical data reveal the stars; and the ultraviolet highlights star-forming regions. Image by Ángel López-Sánchez (AAO/Macquarie University) and Bärbel Koribalski (CASS).

Survey as well as new HIPASS detections, both in emission and absorption. A key WALLABY paper was published in 2012 by Alan Duffy and collaborators: this used sophisticated numerical simulations to estimate the expected source counts and source sizes as a function of signal-to-noise and array configuration. Assuming an rms noise of 1.6 mJy/beam per 4 km/s channel, WALLABY (led by B. Koribalski & L. Staveley-Smith) and WNSHS (led by G. Józsa) together will detect ~830,000 galaxies with a median redshift of 0.054. The respective sky coverage is 30,940 deg^2 for WALLABY and 10,313 deg^2 for WNSHS over a redshift range of z = 0–0.26. A Special Issue on 'Source Finding and Visualisation' was published in PASA (Koribalski 2012a).

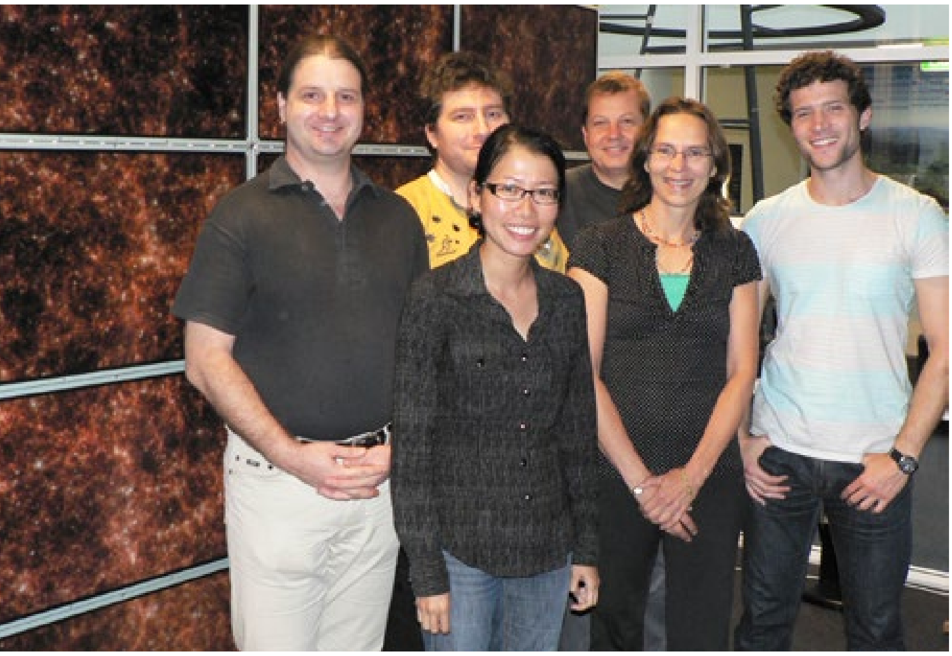
In August 2012 I started my 5-year appointment as OCE Science Leader. This CSIRO fellowship provides funding for two postdocs and top-up scholarships for PhD students working with me on 'Current and Future HI Surveys'. The appointment process has now concluded. I am pleased to announce that Paolo Serra (currently based at ASTRON) has accepted the advertised 5-year HI research position. He will relocate with his family to Sydney and commence his research position in September 2013. The three-year HI postdoctoral position was accepted by Megan Johnson (currently based at NRAO), who is set to arrive in Sydney with her family in August 2013.

Newton Turner Award — 3D Visualisation of Galaxies

To explore nearby galaxies in a novel way I have established an international collaboration with experts in the field of 3D visualisation, simulations and modelling. The two key people are Klaus Dolag from the Universitäts-Sternwarte München (USM) and the Max-Planck-Institut für Astrophysik (MPA) in Garching, Germany, and Claudio Gheller from the Swiss National Supercomputing Centre (CSCS) in Lugano, Switzerland. Our aim is to create realistic 3D data visualisations — including stereoscopic movies — of the gaseous and stellar distributions of many nearby galaxies, informed by multi-wavelength data sets (including 21-cm HI data from the Compact Array). To this effect we are using and expanding the capabilities of the software package Splotch (Dolag *et al.* 2008), an open-source ray-tracing code, to visualise numerical simulations as well as real data.

In November of last year I organised the *2011 Simulations Fest* in Sydney, inviting key people from around Australia and overseas to give presentations and to experiment with a range of visualisation equipment: among them were colleagues from the 3D Applied Laboratory for Immersive Visualisation Environments (3D ALIVE) at Monash University. We had access to the Marsfield OptiPortal, a stereographic viewer borrowed from CSIRO's Advanced Scientific Computing Group in Melbourne (courtesy of Justin Baker and Peter Tyson), and a Linux-operated three-screen tiled display. Other experts in the field — Klaus Dolag, Gyula Józsa and Claudio Gheller (Figure 3) — visited in November and December 2011. Together we created our first 3D movie showing a fly-through of the spiral galaxy M83 (with music); a few weeks later we added in two dwarf irregular galaxies and made a stereo movie of this small group.

In April 2012 I spent two weeks working with Klaus Dolag and Claudio Gheller in Europe. With help from TiRiFiC creator Gyula Józsa (ASTRON, The Netherlands) and my postdoctoral fellow Peter Kamphuis, we were able to include the warped 3D shape of galaxy disks in our visualisation, informed by tilted-ring models of the gas kinematics of each galaxy. The 3D visualisation project has raised a number of important questions regarding the gas kinematics and distribution of galaxies. It allows us to check our best models (derived from the data), improve our understanding of the overall structure and scale-heights of galaxy disks and halos, and communicate the results widely.



(L-R) Gyula Józsa (ASTRON), Russell Jurek (CASS), Ivy Wong (CASS), Klaus Dolag (USM/MPA), Bärbel Koribalski (CASS) and Alan Duffy (ICRAR)

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Periodic structure in the megaparsec-scale jet of PKS 0637–752 provides new insights into the physics of AGN jets

Leith E.H. Godfrey (ICRAR/Curtin) on behalf of the extended Chandra Quasar Jet Survey team

Radio galaxies are a class of active galaxy. They produce highly collimated jets of relativistic plasma that emit strongly at radio wavelengths and give rise to a feedback loop between supermassive black holes and their environment known as radio-mode feedback. This feedback loop is thought to be responsible for the co-evolution of galaxies and supermassive black holes, the inhibition of cooling flows in massive clusters, and 'cosmic downsizing' — the shifting of star-formation activity from larger to smaller galaxies over cosmic time.

Despite decades of dedicated observational and theoretical study, the understanding of radio galaxies remains relatively superficial. The general paradigm, that jet production in radio galaxies is linked to accretion onto a super-massive black hole, is widely accepted, and jets are known to contain relativistic electrons that emit synchrotron radiation. However, many details more specific than these remain under debate, even fundamental issues such as: "What is the composition of radio galaxy jets?", "How exactly are the jets produced?", and "How fast are the jets on kiloparsec scales?" Radio galaxies are a fascinating phenomenon worth studying in their own right, but a detailed understanding of radio-galaxy physics is also of vital importance if we are to understand their influence on the cosmic structure we observe today.

The jets of high power radio galaxies and quasars often exhibit peaks and troughs of emission, with the peaks commonly referred to as 'knots'. In some sources, trains of bright knots with a regular or quasi-periodic pattern are observed. Understanding the physical processes that are responsible for the periodic structure seen in extragalactic jets can provide new insight into their physical conditions and dynamics.

As part of a campaign to study kiloparsec-scale quasar jets with strong X-ray emission, we observed a sample of 14 flat-spectrum radio quasars at 20 GHz with the Compact Array in the 6-km configuration, which provided 0.5-arcsecond angular resolution. These observations enabled detailed mapping of the jet structure, and in one of our targets, PKS 0637-752, they revealed a spectacular train of quasi-periodic knots extending 11 arcseconds along the jet (see Figure 1). The periodic nature of the knots in PKS 0637–752 is striking, and in a recent article based on the 20-GHz Compact Array image (Godfrey *et al.* 2012) we pose the question: what physical process is responsible for the periodic knot structure? Are the knots a static pattern through which the flow travels or a real variation within the flow, caused by a variable jet engine?

If the knots are a static pattern, the most obvious possibility is that they are due to re-confinement or 'pinching' shocks, produced as the jet expands and contracts periodically along its length in an attempt to match the pressure of the surrounding material, and repeatedly overshooting the equilibrium position. Because the jet is supersonic, this expansion and contraction of the jet boundaries would result in a network of criss-crossed shock waves, or 'shock diamonds', which would cause a brightening of the jet emission (the knots). Re-confinement shocks are commonly observed in laboratory jets, as well as in supersonic outflows on Earth such as the afterburner exhaust of reconnaissance

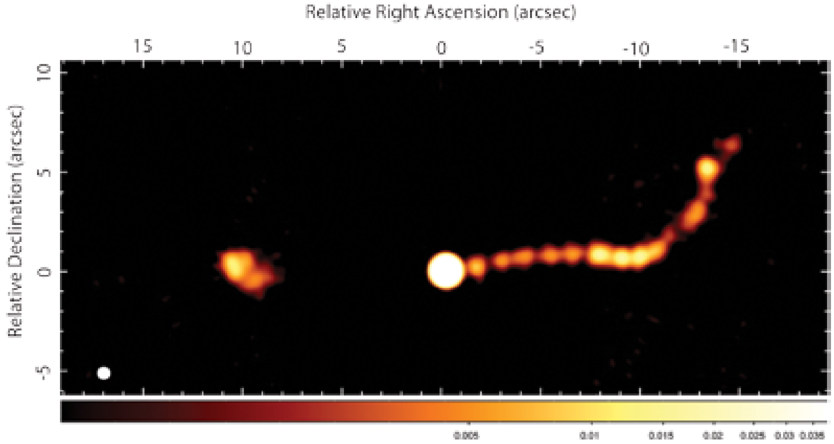

FIGURE 1:
An 18-GHz image of the large-scale jet of PKS 0637-752, made with the Compact Array. Note the regularly spaced peaks of emission that occur along the jet.

FIGURE 2:
A Blackbird reconnaissance aircraft, with afterburners on. Note the regularly spaced peaks of emission in the outflow from the afterburners. These peaks of emission correspond to 'diamond shocks' in the supersonic outflow, and bear a striking resemblance to the regularly spaced peaks of emission in the extragalactic jet of PKS 0637-752.

jets (see Figure 2), and in hydrodynamic simulations of AGN jets. Interpreting the knots in PKS 0637-752 as re-confinement shocks provides an estimate of the jet kinetic power Q_{jet} ~ 10^{46} ergs per second. However, if the knots are indeed due to re-confinement shocks, and the jet is expanding into a realistic external medium with radially decreasing density profile, we would not expect the knot spacing to remain constant all along the jet (Saxton *et al.* 2010).

How might the knots be produced by modulation of the jet engine? In this class of model, the knots are associated with periods of heightened output from the central engine. We find that the modulation period implied by the observed periodic structure is 2,000 yr < T < 300,000 yr, with the lower end of this range applicable if the jet remains highly relativistic on kiloparsec scales, as implied by models of the jet's X-ray emission. We suggest that the periodic structure in PKS 0637–752 may be analogous to the quasi-periodic modulation seen in the jet of the microquasar GRS 1915+105 on a timescale of 30 minutes, which is believed to result from limit-cycle behaviour in an unstable accretion disk (see, for example, Fender & Belloni, 2004). Accretion disk instabilities are expected to produce quasi-periodic modulation of the jet output due to modulation of the accretion rate. The physical timescales are expected to scale linearly with the mass of the black hole, and therefore, the T ~ 30 minute oscillations in the jet of GRS 1915+105 (MBH ~ 14 $M_\odot$) extrapolate to T ~ 2,000 yr for PKS 0637–752 (MBH ~ 5 × 10^8 $M_\odot$), consistent with the modulation timescale inferred from the periodic jet structure.

Finally, the variations in the accretion rate might be driven by a binary black hole. In this case, the predicted orbital radius is 0.7 pc < a < 30 pc, which corresponds to a maximum angular separation of 0.1–5 milli-arcseconds.

Other mechanisms, such as Kelvin-Helmholtz instabilities, may be possible. Follow-up observations of this object at higher angular resolution with the Compact Array, and observations of other objects showing quasi-periodic jet structure (such as those in Figure 3), will enable us to discriminate better between the various models of periodic knot production, providing an additional clue to the nature of radio galaxies — the powerful instruments of radio-mode feedback.

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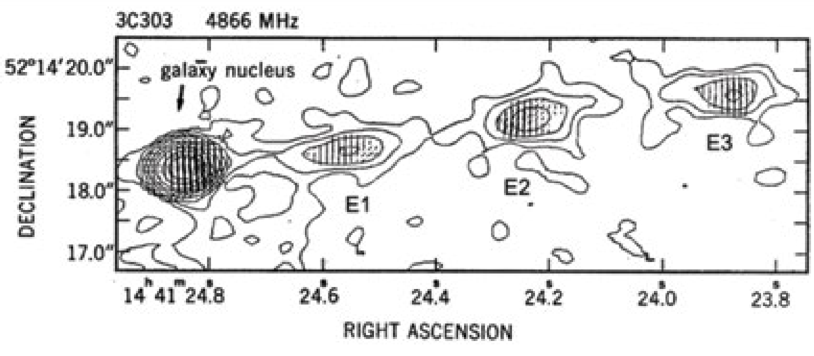


FIGURE 3:
Two more examples of radio galaxy jets showing periodic structure on kiloparsec scales. Top: VLA image of 1919+479 at 6 cm from Burns et al. (1986). Bottom: VLA image of 3C 303 at 4.9 GHz from Kronberg (1986).

ATLAS: Spectroscopic catalogue and radio luminosity functions

Minnie Y. Mao (NRAO) on behalf of the extended ATLAS team

Using data from the Australia Telescope Large Area Survey (ATLAS), combined with optical spectroscopy data from AAOmega on the Anglo-Australian Telescope (AAT), we have found that low-luminosity Active Galactic Nuclei (AGNs) are about three times more common than previously thought.

ATLAS used the Compact Array to survey seven square degrees of the sky at 1.4 GHz to study the formation and evolution of galaxies since the Big Bang. ATLAS aims to reach a uniform rms sensitivity of 10 μJy/beam over the entire region, making it the widest deep-field radio survey attempted to date. The first data release (DR1) reached an rms of ~30 μJy/beam and contains 2,018 radio sources (Norris *et al.* 2012, Middelberg *et al.* 2008). The latest data release (Banfield *et al.*, in preparation) reaches ~15 μJy/beam rms and contains about 5,000 sources.

In order to study the evolution of galaxies, we observed our radio sources with the multi-object spectrograph AAOmega on the AAT. We obtained redshifts for 466 ATLAS radio sources, achieving ~30% completeness at an R-band magnitude of ~20. The sources for which we were able to determine redshifts had spectra good enough for us to spectroscopically classify them as either star-forming (SF) or active galactic nuclei (AGN). Figure 1 shows examples of AAOmega spectra for each of our classifications.

These data were used to compute the radio luminosity function (RLF) for both star-forming galaxies and AGNs. The RLF allows direct insight into the evolutionary history of galaxies. While both star-forming galaxies and high-luminosity AGNs are known to evolve positively with redshift (i.e. they were more common in the past), the evolution of low-luminosity AGNs is less well understood. Best & Heckman (2012) suggest that the luminosity dependence of the evolution of AGNs may be attributed to the varying fractions of ‘hot’ and ‘cold’ mode sources with redshift.

Figure 2 shows the RLF we computed for star-forming galaxies. Comparing this with previous work by Afonso *et al.* (2005) and Mauch & Sadler (2007), and taking cosmic evolution into account (dashed lines), we find our RLF for star-forming galaxies

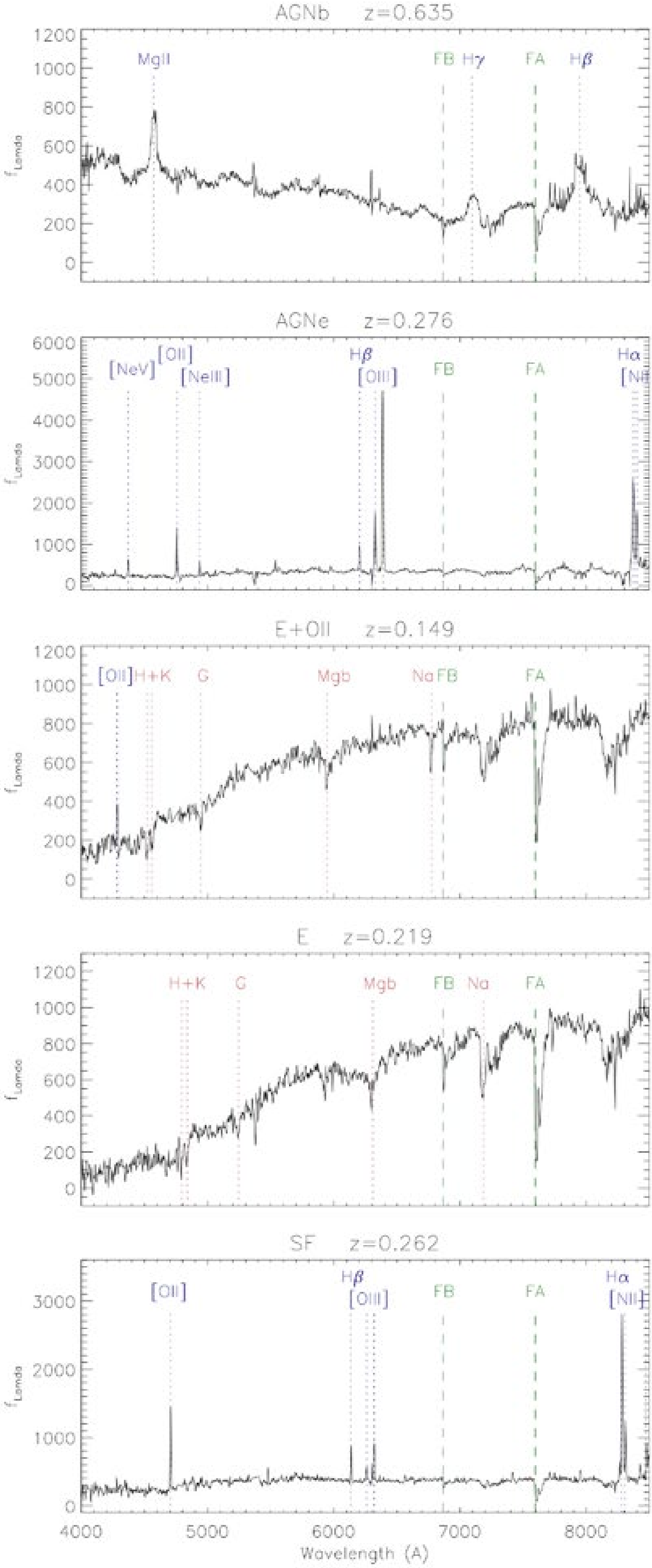
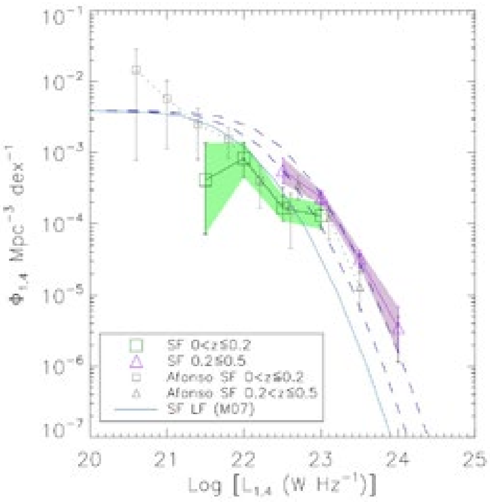


FIGURE 1:
Examples of each spectroscopic classification from the ATLAS data. The red dotted lines indicate absorption features and the blue dotted lines indicate emission features. The green dashed lines indicate the Fraunhofer A+B atmospheric absorption bands from O_2. Top to bottom: two AGN; two early-type galaxies; a star-forming galaxy.



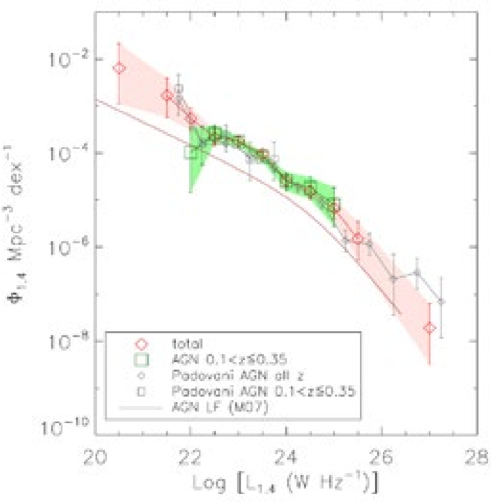


FIGURE 2:
The radio luminosity function for SF galaxies. We have split our data into two redshift bins to make possible a direct comparison with Afonso *et al.* (2005) (grey data points). The parametric fit to the SF RLF from Mauch & Sadler (2007) is also shown, both in its original form and after applying luminosity evolution in the form $L \propto (1+z)^Q$, with Q = 2.7 ± 0.6 (Hopkins 2004) and z = 0.2 and 0.5.

FIGURE 3:
The radio luminosity function for AGNs with data from Padovani *et al.* (2011) overplotted. Both the total AGN RLF and the RLF for the redshift range $0.1 < z \leq 0.35$ are plotted to allow direct comparison with Padovani *et al.* (2011). The pink line is the local AGN RLF from Mauch & Sadler (2007).

agrees well with these previous studies, giving us confidence in our spectroscopic classifications.

Figure 3 shows the RLF we computed for AGNs. When we compare it to previous work by Padovani *et al.* (2011) and Mauch & Sadler (2007), we find our RLF is a factor of 3–4 higher than that of Mauch & Sadler, but similar to that of Padovani *et al.*

Could cosmic variance explain this apparent discrepancy? For example, large-scale structures could inflate the RLF because only relatively small volumes are being probed. For instance, Mao *et al.* (2010) detected a large overdensity at z ~ 0.2 associated with a wide-angle tail galaxy in ELAIS. However, removing galaxies in the overdensity did not lower the AGN RLF significantly and so we conclude that cosmic variance is not enough to explain the 'high' RLF.

Mauch & Sadler (2007) present RLFs for both star-forming galaxies and AGN in the local Universe and the mean redshift of their sample is z ~ 0.043, which is markedly lower than the mean redshift of the ATLAS sample at z ~ 0.316. Similarly, the AGN RLF computed by Padovani *et al.* (2011) was for a deep, radio-selected survey.

We conclude that the increased number density of AGNs, specifically at the low-luminosity end, may be attributed to low-luminosity AGNs being more readily detected by deep, wide radio surveys such as ATLAS.

ATLAS is the pathfinder for the forthcoming Evolutionary Map of the Universe Survey (EMU, Norris *et al.* 2011), which will survey 75% of the sky to an rms of 10 μJy/beam using the Australian Square Kilometre Array Pathfinder (ASKAP). The results obtained in this study and others based on the ATLAS survey are now being used to guide EMU survey design.

For a detailed description of this work, see Mao *et al.* 2012.

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Searching for neutral hydrogen gas in young radio galaxies

James Allison and Elaine Sadler (University of Sydney)

Cold neutral gas plays a crucial role in the co-evolution of galaxies and their super-massive black holes, both in the formation of stars and in the feeding of active galactic nuclei (AGN). Radio-loud AGN contain powerful jets of plasma, which plough into the surrounding medium and accelerate charged particles to high energies, thereby emitting synchrotron radiation. By directly observing cold gas in the host galaxies of radio sources, we can study the complex feedback that exists between the AGN, the stellar population and the radio jets. In particular, by studying the most compact (and potentially youngest) radio sources, we can directly probe the initial stages of this brief and important stage of the galactic evolutionary cycle.

Neutral atomic hydrogen (HI), seen as 21-cm absorption of the background radio flux, provides an excellent tracer of the cold gas in and around AGN. The advantage of absorption-line observations is that their sensitivity does not decrease with distance (it depends only on the brightness of the background continuum source), so we can detect relatively small amounts of gas even in very distant galaxies.

To date there have been a number of efforts to survey the 21-cm absorption line associated with the hosts of compact radio sources, with typical sample sizes around 20–30 objects and detection rates ranging from 10% to 30%. Morganti *et al.* (2001) used the Compact Array to carry out a pioneering study of 23 nearby radio galaxies, and detected HI absorption in five of them. They also found (Morganti *et al.* 2005) that HI absorption studies can reveal very fast (~1,000 kilometres per second), massive outflows of neutral gas driven by the interaction between the expanding radio jets and the surrounding interstellar medium enshrouding the central regions. These jet-driven neutral outflows are likely to have a strong feedback effect on their parent galaxy.

Next generation wide-field surveys on the Square Kilometre Array (SKA) precursor and pathfinder telescopes will provide order-of-magnitude increases in the number of galaxies that can be surveyed for 21-cm absorption. Even the early BETA stages of the Australian SKA Pathfinder (ASKAP) will allow us to carry out a blind search for cold HI gas in the redshift range $0.5 < z < 1$, something no other radio interferometer can currently do.

To expand our knowledge of the gas content of these compact radio galaxies, and to provide real data for testing the line-finding algorithms we have developed for ASKAP, we began an observing campaign with the Compact Array Broadband Backend (CABB). We selected our targets from the Australia Telescope 20-GHz survey (AT20G; Murphy *et al.* 2010), which contains the most complete sample of young and newly triggered radio galaxies in the local universe, and chose objects with compact radio sources brighter than 50 mJy for which the 21-cm HI line fell within the 1.4-GHz CABB band.

Our observations of 29 of these galaxies have so far yielded three detections of 21-cm absorption, two of which are new (Allison *et al.* 2012a). Figure 1 shows the spectra for each of these detections, highlighting the excellent band-pass stability provided by the Compact Array Broadband Backend (CABB). We automated the detection of absorption-lines using the Bayesian inference method developed by Allison *et al.* (2012b) for use on ASKAP data. This technique assumes that the process of detection is equivalent to comparing two competing hypotheses given the data. We assign detection significance by comparing the marginal likelihood of a spectral-line and continuum model (the detection) with that of a continuum-only model (the non-detection). Furthermore, differing complexities of spectral-line model can be compared and selected based on their marginal likelihood ratios, intrinsically incorporating Occam's Razor (that is, choosing the simplest available hypothesis).

Our new detection of HI absorption toward PKS B0013-240, with a deep narrow line and broad red-shifted wing, is consistent with the optical classification of the host as an edge-on disk galaxy. This absorption is similar to the deep absorption towards the active nucleus of another disk galaxy, PKS B1814-637 (Morganti *et al.* 2011), which we also re-detected in our program.

The absorption-line profile towards PMN J2054-4242 (hosted by a massive elliptical galaxy) is far more unusual. Firstly, on visual inspection of the spectrum the absorption line could easily be mistaken for a continuum artefact in the CABB baseline. Secondly, the line is very broad (approximately 500 km/s) and lacks the deeper narrow component that is usually seen in associated HI absorption. Several factors prompted us to class this as a real detection and re-observe the source for verification. The 21-cm line velocity is consistent with the optical redshift, and the best-fitting depth and width of the line are quite different from those of the low-level

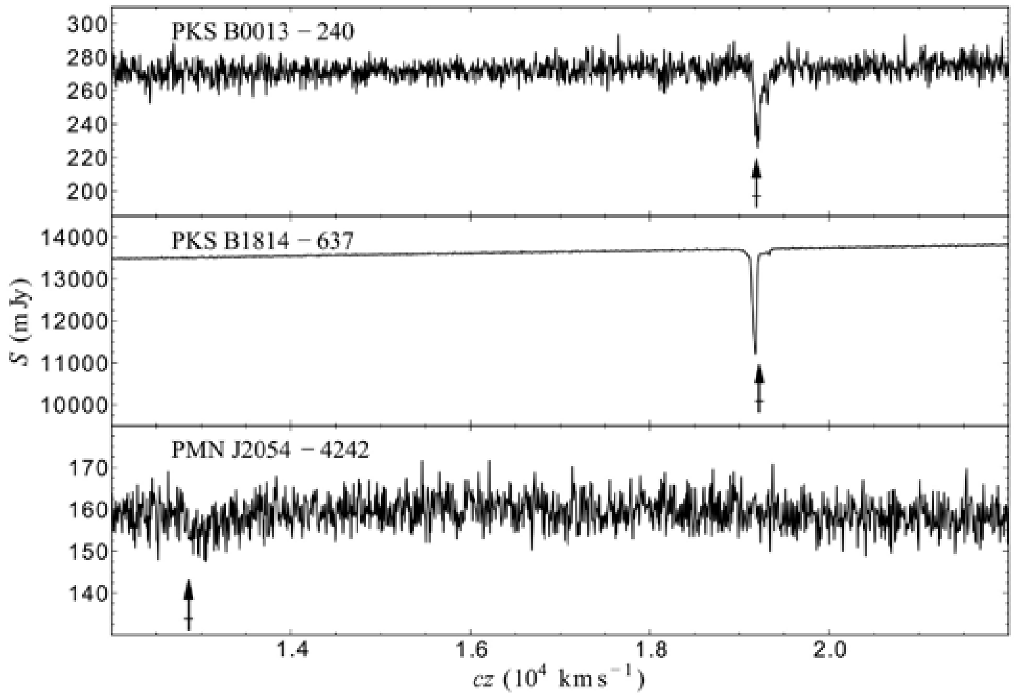

FIGURE 1:
Wideband spectra from our CABB observations of three compact radio sources in which we have detected 21-cm absorption. The arrow and horizontal line show the mean and uncertainty in the optical spectroscopic redshift respectively.

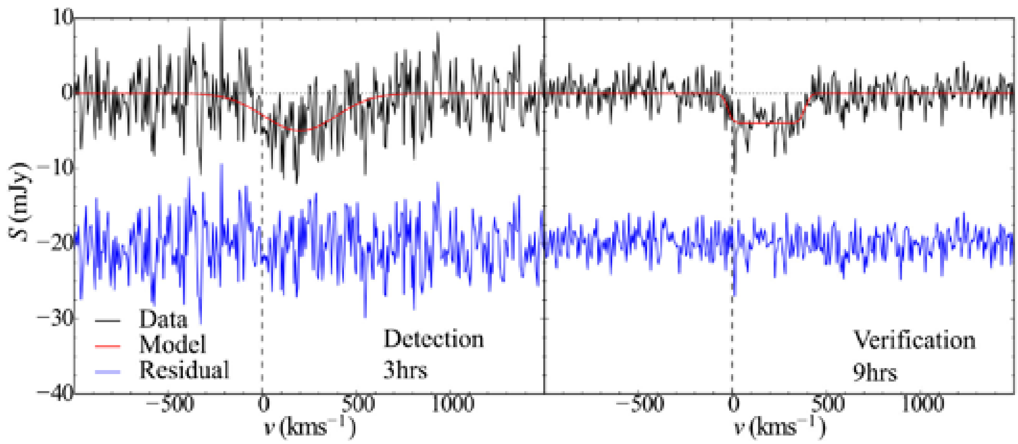

FIGURE 2:
Detection and verification of HI 21-cm absorption towards PMN J2054-4242 (adapted from Allison *et al.* 2013). The black line represents the data following subtraction of the best-fitting continuum model, the red line the best-fitting spectral line model and the blue line the residual. The velocity axis is given with respect to the rest frame defined by the optical spectroscopic redshift.

continuum artefacts in our data. Figure 2 compares our original detection from three hours of observation with CABB, and the subsequent verification from a further nine hours (Allison *et al.* 2013).

Such a broad absorption-line, seen towards a point source, is difficult to interpret without further spatial and multi-wavelength information. It could plausibly be the signature of cold gas infalling towards the nucleus, perhaps as a series of blended HI clouds. We are carrying out follow-up observations of both our new detections using the Australian Long Baseline Array (LBA), as well as making new observations at optical and millimetre wavelengths to image the ionised and molecular gas.

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Recent highlights from the Parkes Pulsar Timing Array project

Ryan Shannon (CASS) for the PPTA Team

With the Higgs boson now identified, the most exciting prospect for early twenty-first century physics is the direct detection of gravitational waves. Produced by accelerating masses, gravitational waves are propagating distortions of space-time predicted by Einstein's general theory of relativity. While there is strong evidence for the existence of gravitational waves (most notably from orbital decay in a handful of binary pulsar systems), none have yet been directly detected.

One method for detecting gravitational waves uses the exquisite spin stability of millisecond pulsars — radio-bright neutron stars that rotate at nearly a thousand times per second. Gravitational waves travelling across the line-of-sight from the pulsar to Earth distort the intervening space-time, resulting in variations in the light-travel time from the pulsar to the Earth, and hence in the arrival times of the pulsed radio emission. By monitoring the pulse arrival times from a set of millisecond pulsars (referred to as a Pulsar Timing Array, PTA), we can discriminate gravitational waves from 'noise' sources.

The sources of gravitational waves to which PTAs have greatest sensitivity are binary super-massive black holes. When galaxies merge, their gargantuan (10^6–10^{11} $M_\odot$) black holes are dragged to the centre of the remnant galaxy. At this point, the pair of black holes becomes a strong emitter of gravitational waves. The combined signature from millions of binary black holes systems from the nearby universe (redshift < 1) is a stochastic gravitational-wave background that we are trying to detect and constrain using pulsar timing. Conversely, by studying this gravitational-wave background, we can understand the evolution of black holes across cosmic time, which is a difficult task for the 'electromagnetic' astronomer.

The Parkes Pulsar Timing Array (PPTA) project (ongoing since the mid-2000s) is longest-running of the timing-array projects and utilises the Parkes telescope to monitor 20 millisecond pulsars. This year has been especially productive for the PPTA. We have published the first PPTA data release, placed a new limit on the strength of the gravitational-wave background, and found startling implications for the limit.

The paper containing the first data release provides an extensive discussion of the ins and outs of deploying a pulsar-timing array, something that was hitherto lacking in the literature. Importantly, the data release reports both regular PPTA observations that commenced in early 2005 (displayed in Figure 1) and observations from earlier observing programmes that extend back to the mid 1990s. These earlier data are particularly useful when placing limits on the gravitational-wave background, discussed below. We have shared this dataset with our international colleagues and will soon publish it on the PPTA website.

To produce these datasets, which are the most sensitive in the world, we needed to correct for dispersive effects of the interstellar medium that contribute time-varying frequency-dependent variations in pulse arrival times, referred to as dispersion measure (DM) variations. We have developed a technique to optimally correct for DM variations and applied it to our datasets. Importantly, we have shown that our correction technique (unlike previous methods) doesn't attenuate the gravitational-wave signal. We have also shown the utility of our datasets for studying the interstellar medium on size scales unaccessible to other techniques.

Armed with the datasets, we have set a revised limit on the strength of the gravitational-wave background. To do so, we developed a technique to limit the strength of the background in datasets that have varying length and sensitivities to gravitational waves (Shannon *et al.*, submitted). When this technique was applied to our dataset, we set a limit that is a factor of six better than previously published limits, as shown in Figure 1.

In 2012 we also produced an improved model for the expected GW signal from super-massive black hole binaries. We used the 'Millennium' dark-matter simulations and an accompanying semi-analytic model for galaxy and black hole co-evolution to calculate the expected strength of gravitational-wave background. This model is the most self-consistent one for the gravitational-wave background, because (unlike previous models) it explicitly incorporates many other cosmological observables, such as the quasar luminosity function. We found that the background is less Gaussian than previously thought, meaning that it probably shows large cosmic variance. Despite this large cosmic variance we found that the model is highly inconsistent with our observations (Figure 2), suggesting that there is something wrong with the cosmology of galaxy and black-hole evolution in the commonly accepted 'Millennium paradigm'.

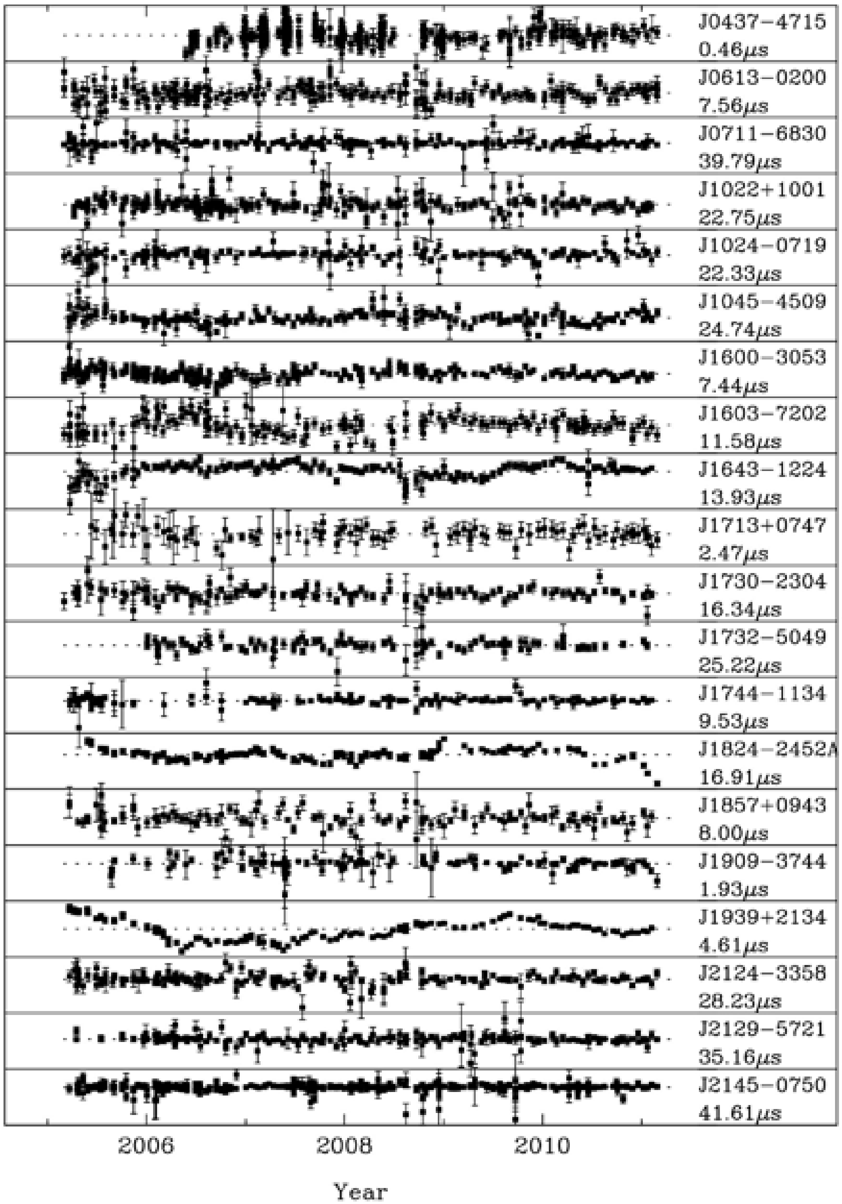

FIGURE 1:
Residual times of arrival for PPTA pulsars. These datasets have been optimally corrected for variations in dispersion measure variations. To the right of each residual is the pulsar name and the peak-to-peak variation in the residual arrival time.

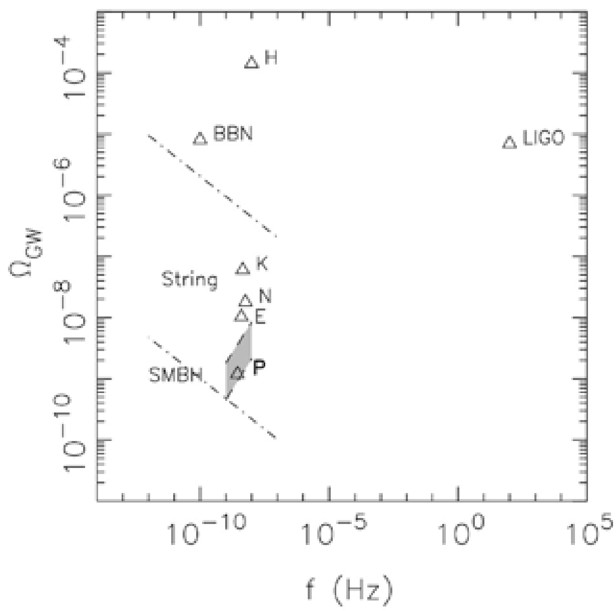

FIGURE 2:
Limits on the gravitational-wave background energy density Ω versus gravitational-wave frequency f. We show limits on the strength of the gravitational-wave background derived from pulsar timing measurements and LIGO (Abbott *et al.* 2009). The triangle labelled H is the limit derived from JPL pulsar timing in the 1970s (Hellings *et al.* 1983); K, from early Arecibo MSP observations in the 1980s (Kaspi *et al.* 1994); N, from the North American Nanohertz Observatory for Gravitational Waves (Demorst *et al.* 2013); E, from the European Pulsar Timing Array (van Haasteren *et al.* 2011); and P, from the Parkes Pulsar Timing Array (Shannon *et al.*, submitted). We also show the predicted range of strengths for backgrounds originating from super-massive black hole binaries as the grey shaded region, and range of backgrounds produced by cosmic strings bounded by the dash-dotted lines. The PPTA limit strongly rules out the gravitational-wave background predicted by the Millennium simulations and accompanying semi-analytic models.

Of course we have also searched our dataset for evidence of a gravitational-wave background. Given the large variations in timing precision between the pulsars and the stringent limit that we have set, we haven't yet detected gravitational waves (if we had, you would have heard about it by now!). However, prospects for detection are good. By observing for longer, making higher-precision measurements (for example, by deploying a wide-bandwidth feed and receiver on Parkes), and combining our data with that of colleagues at other observatories around the world, we will increase our sensitivity and — we expect — detect gravitational waves. In the meantime, our recent results have demonstrated that limits on the strength of the gravitational-wave background (which until detection is achieved, will only get better) have profound implications for cosmology.

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4. Operations

The Parkes radio telescope tracking Mars on 31 July 2012, during a test for the Mars Science Laboratory 'Curiosity' track the following week. Parkes support for this project is described on page 38.

Operations

"Remote access to the Parkes telescope was a significant focus."

Late in 2011, CSIRO announced its strategy for shaping operations at the Compact Array, Parkes radio telescope and Mopra radio telescope, to prepare for ASKAP operations. Implementation began in earnest in 2012.

At Parkes, this meant comprehensive renewal of power infrastructure, new remote-observing capabilities, a decrease in the level of user support, and a decrease in the number of receiver changes and other instrument reconfigurations. Consequently during 2012 the RAPT project (Remote Access to the Parkes Telescope) was a significant focus at Parkes. The project aimed to make the final telescope system changes necessary to enable safe and unattended operation of the telescope by remotely located observers. The major part of this project was to design, construct and install a telescope protection system — the TPS — that would detect any conditions threatening safe operation, issue alarms and put the telescope into a safe state. The TPS was installed with its first firmware version late in the year and the first remote observations were conducted from the Marsfield SOC on 6 December. Testing of the TPS and other systems will continue for the first months of 2013 with a gradual increase in the fraction of observing conducted remotely. (For more details of the TPS, see page 42.)

An in-principle agreement to operate the Mopra Telescope with funding from two consortia — the National Astronomy Observatory of Japan, and the University of New South Wales and the University of Adelaide — was reached during the year, and will be formalised in 2013. The agreement provides for approximately one-quarter of winter observing time to remain available to ATNF users, and allows Mopra to continue within the LBA.

The Australia Telescope Compact Array underwent the next phase of its multi-year upgrade with the provision of the first antennas with new '4-cm' (formerly 3- and 6-cm) receivers. These receivers complement the Compact Array Broadband Backend in providing up to 4 GHz of bandwidth instantaneously in the 4–12 GHz band for unprecedented sensitivity at these frequencies. At the completion of this upgrade in 2013, the Compact Array will be outfitted with state-of-the-art instrumentation in all its frequency ranges. (For more details, see the 'Technology' chapter.)

To position CASS to operate ASKAP jointly with the other facilities, and support SKA pre-construction phase work, a new capability group, 'Software and Computing' was formed late in the year. The new group is led by Juan Carlos Guzman and encompasses the activities that had belonged to the Science Computing and Archive Project (ATNF Operations) and the ASKAP Computing Group. In Western Australia, the Geraldton group led by MRO Site Manager Barry Turner came under ATNF Operations late in the year, following the official opening of ASKAP and the MRO.

In the second half of the year the new Science Operations Centre (SOC) took shape at Marsfield.

The SOC is intended to support the astronomical operations of all ATNF facilities, including ASKAP, with facilities for both staff and visitors. As well as providing observing facilities for the four telescopes, an important goal for the SOC is to facilitate interactions between local staff and visiting scientists in support of high impact science.

The observing rooms are linked to the four telescopes — ASKAP, Parkes, Compact Array, and Mopra. ASKAP commissioning will use one of the larger observing rooms. The two larger rooms can be joined into one large space for group observing sessions such as LBA observing, ASKAP 'busy weeks', and 'PULSE@Parkes'. Next to the observing rooms is an open space ('interaction space') to encourage interactions between observers and other visitors and local staff, with comfortable seating, whiteboards, and tables for discussions and small informal meetings. The area immediately behind the lecture theatre is used for workspaces for visitors and the librarian's desk. The office for the Visitors Services Group is now located at the end closest to the main reception area, in a location much easier for visitors to the site to find. Finally, in the old compactus area of the library there is now a quiet reading area, with shelving accommodating the collection of theses and other reference material.

The first tests of observing from the SOC were made with Mopra and the Compact Array, with the first phase of Parkes remote observing (still requiring the presence of someone in the tower at Parkes) beginning in December 2012.

A highlight of the year was the excitement of NASA's Mars Science Lander mission that landed the Curiosity rover on Mars in August. The Parkes Telescope provided the unique capability of monitoring the UHF signal from the spacecraft during the final minutes of the landing sequence, as a backup against the failure of higher-frequency links that relied on relay via missions orbiting Mars.

Science Operations

The Science Operations Group consists of four projects: Telescope Operations and Science Services, Scientific Computing and Archives, Computing Infrastructure, and the Visitors Services Group.

TELESCOPE OPERATIONS AND SCIENCE SERVICES

Telescope Operations and Science Services provides the main interface to observers, from handling proposals to training observers and keeping documentation up to date. Several changes were announced to users this year.

Observers were advised in the call for proposals that the 2012 April semester might be the last in which Mopra was made available as part of the National Facility, as alternative funding sources were being sought for the ongoing operation of the telescope. The deadline for Mopra proposals was extended by a month, to 15 January 2012, so that proposers could be advised of any changes to this understanding. An additional member of the international millimetre-wave community was added to the TAC to aid in deliberations in prioritising the ongoing large projects, in particular, for the April semester. Ultimately, as mentioned above, two consortia have been able to provide funding to ensure the continued operation of Mopra, in return for guaranteed observing time on the facility. This will ensure that a fraction of Mopra time remains available to the broader astronomy community through the ATNF.

In the call for proposals for the October semester, Parkes observers were advised that reduced resources at the observatory would result in a limited number of receiver changes during the semester. It was noted that the 20-cm multibeam receiver, 10/50-cm receiver, and H-OH receiver were expected to be scheduled, but the availability of other receivers would be driven by proposal pressure. Further, highly graded proposals requesting a receiver that was not installed in the focus cabin in the 2012 October semester would be reconsidered for scheduling in the 2013 April semester with the same grade, without the need to resubmit the proposal. As it turned out, this did not eventuate.

A leap second was added to Coordinated Universal Time on 1 July, and as there had been some issues with the implementation of the most recent leap second (1 January 2008) careful planning and preparations were undertaken … and everything went according to plan.

A series of flux-density calibration checks were undertaken between the Compact Array, the EVLA and the WMAP satellite, indicating that the flux-density scales were in good agreement. Further checks were planned.

The ATNF continues to have access to telescope time at the Canberra Deep Space Communication Complex (CDSCC) under the host-country agreement. Observations with the CDSCC are carried out in service mode by Shinji Horiuchi, a CDSCC staff member. Over the 2011 October and 2012 April semesters, 487 hours of observing were conducted, corresponding to 5.6% of the time. Of these, 425 hours were single-dish observations using the 70-m dish, and 62 hours were used in support of LBA observations, using either the 70-m or one of the 34-m antennas. The 70-m antenna was taken off-line in November 2012 for an expected 7-month down time in order to re-grout the azimuth track.

Time Assignment Committee

Increasing demand for observing time using ATNF facilities has increased the load on the eight members of the Time Assignment Committee (TAC), with a team of international 'readers' now supporting the TAC members. The readers supply grades and comments on a number of proposals within their area of expertise but do not attend meetings or have full access to all proposals. The TAC readers (listed in Appendix A) are appointed by the ATNF Director for a term of three years.

The TAC convened at Marsfield over three days in early February to consider the 257 proposals for the 2012 April semester, and met again over two days in late July to review and grade the 142 proposals received for the 2012 October semester.

Long Baseline Array

The Long Baseline Array (LBA) uses the technique of Very Long Baseline Interferometry (VLBI) to image radio sources with milli-arcsecond-scale angular resolution. The LBA includes the Parkes, Mopra, and Compact Array telescopes, the Hobart and Ceduna antennas of the University of Tasmania, and, on occasions, antennas at the Canberra Deep Space Communication Complex (CDSCC). In 2012, the LBA also included on occasions the Hartebeesthoek 26-m and 15-m antennas (South Africa), TIGO (Chile), Warkworth (New Zealand), and the Katherine and Yarragadee antennas of the AuScope geodetic array, operated by the University of Tasmania. A single ASKAP antenna is also sometimes available at 20-cm or 3-cm wavelength bands.

Hobart and Ceduna VLBI operations continued to be supported under a contract between CASS and the University of Tasmania. Correlation of most LBA observations recorded is performed under contract by Curtin University in Western Australia. Most data is transferred electronically to the correlator.

During 2012 there were four major LBA sessions, in March, April–May, September and November. 'Out of session' participation with a subset of antennas was made in support of RadioAstron space VLBI observations. Observations in 2012 were made in all LBA wavelength bands (20-cm, 13-cm, 6-cm, 3-cm and 1-cm), with the 3-cm band again being the most popular, accounting for about 40% of the observing time. A total of 25 days' observing, which included time for testing and development, was carried out. Successful electronic Very Long Baseline Interferometry (e-VLBI) tests were carried out between the Compact Array, Mopra, Hobart and dishes of the Korean VLBI Network in March, and attracted some media attention.

CASS is participating in NEXPReS (Novel Explorations Pushing Robust e-VLBI Services), a three-year project funded by the European Community that commenced in July 2010. NEXPReS will build upon the successes of the EXPReS project, which ran from 2006 to 2009, and will continue to develop the next generation of e-VLBI tools and processes.

In 2012 the LBA achieved a 95% success rate, with the success rates of most ATNF telescopes greater than 95%. (The figures do not include the ASKAP or Warkworth antennas, which participated on a best-efforts basis in the early part of the year while their systems were still being developed.) The largest contribution to lost time was from Ceduna, and was caused mainly by wind stows. A summary of ATNF antenna observation time and success rates is given in Table 1. The hours scheduled include all test observations, fringe checks, and scheduled observations. The success rate is determined for the data subsequently correlated at the Curtin correlator.

Scientific Computing and Archives

The Science Computing and Archives (SCA) project has responsibility for the maintenance and development of the software packages that are used to operate and monitor the telescopes, and to reduce and archive the data taken by the telescopes. At Narrabri, a long-standing issue with the main observing program (CAOBS) being reliant on an old compiler was resolved with the latest Intel compiler now being useable. Attenuator control was added to CAOBS for the new 16-cm and 4-cm receivers on the array. Miriad has been enhanced with support for large (> 8 GB) scratch files and the larger image cubes that CABB produces. Among other improvements to Miriad: the task *uvaflag* now supports pulsar-binning observations; the LOFAR *AOFlagger* (SumThreshold) algorithm was incorporated in the task *pgflag* to improve automated RFI flagging in continuum datasets; and an *fsystemp* option was added to the task invert to enable the use of weights based on auto-correlation spectra. Other issues raised in the review of data-reduction packages undertaken in 2011 were also addressed. The online 'ATCA Forum' continues to be a successful means of encouraging and documenting debate on approaches for handling CABB data.

At Mopra, MoniCA was upgraded to replace the *mopra_protect* script, which automatically started the generator when weather conditions advocated this action. Continuous data cycling was implemented, removing the previous (small) gaps in data stream due to local-oscillator setting. Fixes were made to *Gridzilla* to account for correlator dropouts in fast-binning On-The-Fly mapping mode, and to *Livedata* to fix a bias in the baseline when stacking spectra.

At Parkes, the Remote Access to the Parkes Telescope project required a number of changes to existing software to accommodate the new methods of observing. An internal workshop was held during the year to discuss the increasing use of web-based interfaces, with good participation from the Science Operations and ASKAP groups. The meeting was very productive and enabled efforts to be focused on development paths.

The Australia Telescope On-line Archive (ATOA) continues to add data from the Compact Array, Mopra, and non-pulsar data from Parkes. The MALT-90 team made the data cubes from their 2011 Mopra observations available through ATOA.

TABLE 1:
Observation time and success rate of core LBA antennas.

TELESCOPE	PARKES	COMPACT ARRAY	MOPRA	HOBART	CEDUNA	CDSCC	LBA
Hours scheduled	492	530	455	533	436	62	556
% success	98%	97%	99%	96%	94%	73%	95%

Computing Infrastructure

The Computing Infrastructure (CI) group provides general account, security and password related computing activities in support of observers, and maintains computer infrastructure and networking at, and between, the sites. The AARNet fibre that runs from the Narrabri Observatory to AARNet's trunk line along the Newell Highway started developing problems several years ago as the highly reactive soil dried out during a long dry spell. Temporary fibre repair work carried out in 2011 has enabled the continued provision of network services to the Observatory. Although it had been intended to do the full repair in early 2012, with the cost shared between CSIRO IM&T and CASS, advice received from a CSIRO soil scientist suggested that the proposed method would only provide a short-term fix. Subsequently, a more detailed survey was undertaken, which recommended a more significant (and expensive) repair to ensure the long-term future of the link. This may need to be staged in order to manage costs.

The CI group is implementing a Linux High-Availability, two-server cluster to replace our on-line observing servers. This is a much more advanced version of having a spare and a standby machine in case of failure and will allow for the live migration of processes from one host to the other should the first host alert us to problems (such as failure of a disk or power supply). The first of these servers was installed at Parkes late in the year in readiness for the move to remote observing.

There has been significant CI involvement in planning for the SOC, from the layout of the control rooms, to cabling requirements for the visitor desks, to planning a 'feature wall' in the interaction area comprising four large screens showing telescope status, webcam images and other information. Two 'smartboard' systems have been purchased to support ASKAP commissioning, with one installed at the SOC and the other at the MRO. These are interactive whiteboards, with a PC attached to each and an additional Windows server installed to manage the collaboration.

ASKAP has required an increasing amount of CI time, with a much-improved network realised early in the year. There was also significant CI involvement in the ASKAP Opening Ceremony on 5 October, both with on-site preparations and in providing the video stream that was webcast during the ceremony.

Visitors Services Group

The Visitors Services Group (VSG) takes care of the lodging and catering for observers, staff and other visitors to the Parkes and Narrabri observatories and the Marsfield site. In 2012, the Marsfield Lodge underwent a series of upgrades and improvements in readiness for the Science Operations Centre (SOC). In the past the Lodge has mainly been used by visitors working regular work hours, but with the advent of observing from the SOC, and nighttime observers needing to sleep during the day, the sound- and light-proofing of the rooms has been improved. VSG staff at Marsfield moved into their new office in the SOC area in October, with their new location making it easier for them to interact with visitors.

Ahead of the expected drop in the number of observers visiting Parkes, changes were made to the operations of the VSG at Parkes from the beginning of the 2012 October semester. The Parkes Quarters continue to provide accommodation, breakfast and evening meals; lunches for observatory staff, observers and other visitors are available from the Dish Café.

Engineering Operations

Engineering Operations has continued to deliver support for the day-to-day operations of the Compact Array, Mopra and Parkes Radio telescopes. This support has involved planning, scheduling and performing maintenance on the telescope systems, and routine activities such as receiver changes, to meet the operational objectives of the telescopes. This year the telescopes have continued to operate with high reliability and minimal downtime, in line with the CASS key performance indicators.

In addition to the routine activities, Engineering Operations contributes to the development of the telescopes and the capabilities of the systems at each site. A number of site development projects have been completed in the year and assistance has also been provided to the improvements and activities planned by staff of the Technologies theme. The objective is to deliver operational efficiencies and reliability improvements that will enable the support of ASKAP Operations into the future.

Safety and environmental aspects are important factors at the telescope sites. Following recommendations from an electrical safety audit, the Narrabri, Parkes and Mopra sites have improved safety for the maintenance staff working on the telescope drive systems. Clear covers have been installed into the electrical drive-system cabinets that provide isolation from dangerous voltages while allowing maintenance on the extra-low-voltage control circuits. We aim to implement isolation or lower-voltage control circuits into other systems. Electrical safety signage has also been improved, but more work is planned in this area, along with making sure all electrical diagrams are up to date.

As a result of new CSIRO HSE procedures, we have revised site and project safety documentation. For the operational sites new risk management plans were developed and many new 'safe work instructions' have been written; more are being developed. Staff have undertaken various training modules such as Driver, Height Safety, Health Safety Representative, Electrical Safety, High Voltage and First Aid. The training is to ensure continuous improvement and/or maintain proficiencies.

The environmental impact of operations is always a consideration. When systems are replaced or updated there is often the opportunity to implement more efficient ones. In the case of electricity, reduced usage not only benefits the environment but also cuts operating costs. An example of this is the maser hut replacement described below. In other moves to reduce environmental impact, the use of electric buggies and bikes on site has been expanded, and material from the older systems being decommissioned is recycled as much as possible.

CROSS-SITE DEVELOPMENTS

Wherever possible improvements are undertaken to ensure equipment and systems installed at the telescopes can work across sites, to streamline efficiencies regarding support, spare parts and inventories. Staff have investigated, for instance, modifying the hardware that sends out clock and timing information for the telescopes, so that the same hardware can be utilised across the sites without specific modifications to the hardware for each site.

Radio Frequency Interference (RFI) work continues across a number of areas in order to reduce the impact of RFI on the telescope operations. Staff have evaluated commercial systems for their ability to detect and identify site RFI. This is very important for the MRO, but it could also be very useful at the Narrabri and Parkes sites. Staff continue to monitor potential off-site developments that could have an impact on RFI at the sites.

PARKES RADIO TELESCOPE

Staff have worked to modify several systems at Parkes to make it possible to operate the telescope remotely in the future, under the Remote Access to the Parkes Telescope Project (RAPT) project.

One deliverable is a Telescope Protection System (TPS), to capture issues that would have a major impact if not acted on in a timely manner. In the past, many of these issues have been left to the observer(s) to deal with. The TPS is a standalone controller that communicates with systems such as power, weather, vibration monitoring, cryogenics and other equipment. It has been developed and was installed in the telescope tower late in the year. The TPS will require testing and further development, but progress has been good, and it should be fully operational in the next year.

To allow remote operations, staff have also installed and commissioned an Uninterruptible Power Supply for the drive system. This will provide a backup to both the site mains power and the generator if both should fail, and allow the telescope to be stowed safely. In the past, when power was lost completely, the telescope had to be stowed manually, with two staff operating brakes simultaneously — a very difficult procedure to perform safely.

The Parkes Equipment Control and Monitor Project was completed this year, and has delivered a number of systems and hardware improvements to improve control and monitoring of the telescope systems via software. This was a project of the Technologies theme, but used some staff from Engineering Operations. Following formal project completion, there has been a regular and ongoing effort to add further control and monitoring improvements, such as refined monitoring points for the Parkes conversion system and new monitoring of the power system. The latter will help make the most efficient use of the supplied power.

Following a risk report on the site power infrastructure, significant effort has been put into improving the power systems to increase their reliability and to ensure a continued power supply to the telescope. Most power infrastructure at Parkes is more than 50 years old, dating back to when the telescope was built. It is expensive to replace, and isn't built to modern safety standards.

The work for the year involved:

- installing and commissioning a generator with new control system, outside the old power house
- decommissioning and removing the existing generator
- replacing fuel tanks, and
- installing and commissioning new high-voltage infrastructure.

The new generator was fitted out with a new control system at Narrabri before being transported to the Parkes site. At Parkes it was installed and integrated into the existing power control system, but located outside the existing power house. The old generator and fuel tanks were removed as planned and a new fuel tank installed, away from the underground high-voltage cables.

Late in the year, the old high-voltage infrastructure (the original high-voltage 11-kV circuit breaker, regulator and transformer) was turned off and decommissioned. The original underground cable into the site remains, but it has been cut and joined to new cable to supply power to the new high-voltage infrastructure. The new high-voltage equipment comprises a switch-gear cabinet with incoming circuit breaker, meter and monitoring; a three-phase regulator; and a 750-kVA transformer.

The high-voltage cutover required much planning and preparation to have the actual power outage and changeover occur all within one day. New high-voltage agreements had to be made with the supply utility for the connection to take place. New monitoring was installed on the incoming high-voltage supply: this now feeds data into the monitoring system, MoniCA. The new three-phase regulator also has a monitoring capability built in, and this will be interfaced into MoniCA in the future.

The year also saw the installation of a new environmental container, purpose-designed to house the on-site hydrogen maser. The previous maser hut was aged and its air-conditioning plant overdue for attention. The new container has an environmental control system that maintains the maser at a near-constant temperature, for timing stability: this uses reservoirs of cool and warm water to regulate and generate an air supply at a precisely controlled temperature. The container is also well-insulated. The complete system should perform better and be more energy-efficient than the system it replaces, reducing running costs.

COMPACT ARRAY

Operations staff have been involved in a number of upgrades of the Compact Array. These are described in the 'Technology' chapter of this report, and include the installation of the new 4-cm (old C/X band) system and further developments on the Compact Array Broadband Backend (CABB). Operations staff also replaced noise couplers for the 16-cm (old L/S band) receiver to provide better polarisation characteristics, and made further cooling enhancements to the 3/7/12-mm receiver.

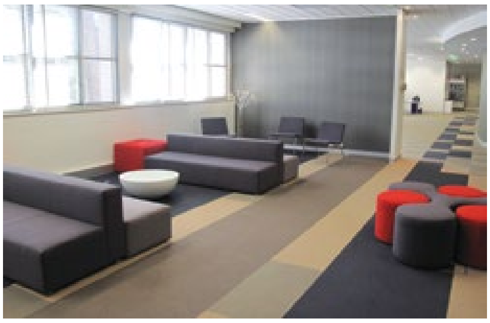
Testing of the water vapour radiometers continued. New firmware has been installed that increases the size of the data sample collected and integrated within a given time period, and improves the sychronisation of data collection between the radiometers. Testing has suggested it would be worthwhile to make a further improvement by using the existing hardware synchronisation within the telescopes to also synchronise the radiometers, and so planning has commenced for a small modification to enable this.

MURCHISON RADIO-ASTRONOMY OBSERVATORY

The ASKAP Telescope, located at the Murchison Radio-astronomy Observatory, was and still is in a transition phase. Engineering Operations staff have been providing support to the project to allow ASKAP systems to be tested, installed and commissioned. Staff located in Western Australia have been moved into Engineering Operations, where they will be fulfilling an ongoing support role for ASKAP. (See page 56 for further information on ASKAP.)

MOPRA RADIO TELESCOPE

No significant engineering developments were undertaken at Mopra, but routine maintenance and support activities continued to keep the telescope at a high operational availability. Some small improvements were made to control and monitoring. The 6/3-cm (C/X band) receiver was removed during the year to be used as part of a rotation of receivers at Narrabri as the Compact Array Broadband project upgrade was rolled out. (For more information on the telescope site development projects, see page 52 of the 'Technology' chapter.)



The new Science Operations Centre at Marsfield has an open meeting or 'interaction' space, seen here in the foreground; the visitors' area can be seen in the background.

Other activities

SPECTRUM MANAGEMENT

Spectrum management relating to the protection of radio astronomy has been an important activity for CSIRO since the 1970s. CASS has continued to support such activities and was involved in the following areas in 2012:

- Participation in national spectrum planning and protection activities through the Australian Communications and Media Authority (ACMA). This involved not only national spectrum planning issues, but also participation in ITU (International Telecommunications Union) study groups and the World Radio Conference (WRC-12).
- Participation in regional and international meetings under the auspices of the ITU. The primary activity is the regular meetings of ITU Working Party 7D (Radio Astronomy) in Study Group 7 (Science Services). This group is responsible for all technical studies and ITU Recommendations and Reports for the protection of Radio Astronomy; the current chairman is from CSIRO.

- Participation in IUCAF (Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Sciences), an inter-union committee of the IAU, URSI and COSPAR. IUCAF has been very active in ITU meetings and has had a significant impact on Study Group and WRC deliberations.
- Participation in the Radio Astronomy Frequency Committee in the Asia Pacific region (RAFCAP), which promotes awareness of radio astronomy and protection of the radio spectrum in the Asia Pacific. RAFCAP works closely with the regional spectrum management group, the Asia Pacific Telecommunity (APT). The current RAFCAP chairman is from CSIRO.

A World Radiocommunications Conference (WRC-12) was held in January-February 2012. Many WRC Agenda Items impacted on radio astronomy, but favourable outcomes were achieved for all items. The issue of most interest was Agenda Item 1.6, on ‘Spectrum usage by passive services between 275 and 3000 GHZ, and procedures for free-space optical communications links’. Broad international consensus on Agenda Item 1.6 was reached, satisfactory for all science services.

The new ITU-R Report on ‘Characteristics of Radio Quiet Zones’ (RQZ) was adopted by Study Group 7 in its May 2012 meeting and is published as Report ITU-R RA.2259. This report is very important for the protection of new radio-astronomy instruments such as the SKA. CSIRO participants played a key role in its development.

The September 2012 ITU-R Working Party 7D (WP7D) meeting was held in Manta, Ecuador. The program for the 2012-15 ITU-R study cycle was established and studies were commenced. A revision of the ITU-R Radio Astronomy review was initiated and a firm timetable established.

This WP7D meeting was preceded by the first ITU Seminar for the Americas Region on ‘Science services: regulatory, technical and practical implications’, with a significant component on radio astronomy and participation by CSIRO. This seminar was extremely well received and supported by the Ecuador science ministry.

Spectrum management activities were also well represented at the IAU General Assembly in Beijing in August 2012. IUCAF held an official public meeting where it reported on its work for the past triennium and its plans for the future. RAFCAP also took advantage of the IAU gathering and held a successful annual regional meeting.

OUTREACH AND EDUCATION

This year our outreach and education activities have continued to build on our strong history of engaging with students, teachers and the public on the important science conducted with the ATNF and CSIRO’s radio astronomy activities, and developing public interest in astronomy.

Visitors centres

The education program offered at the Parkes radio telescope was bolstered in 2012 with the development of a range of pre-visit educational resources for teachers, the ‘AstroKids’ scavenger hunt and a new school booking procedure. Feedback from primary school teachers on these initiatives has been very positive.

Parkes Observatory’s new ‘AstroKids’ scavenger hunt and activity booklet have been a success with family visitors with 7–14 year-olds, and with primary school groups.

The Parkes radio telescope was visited by 88 pre-arranged tour groups, totalling 3,083 visitors. ‘Seniors’ dominated the groups category (56 groups), while school-group numbers were still strong (32 groups).

The Parkes Observatory Visitors Centre expanded its retail operations with the launch of an online shop in 2012. The new online shop makes some of the most popular items from the Parkes Observatory Visitors Centre shop — including books, DVDs, science kits, posters, toys, puzzles and souvenirs — available to budding scientists, amateur astronomers and ‘Dish’ enthusiasts around Australia. Sales through the online shop grew through the year and rose very high in the pre-Christmas period.

Seven high-school work-experience students each spent a week living and working at Parkes Observatory. The students — from New South Wales, Victoria and Queensland — engaged in a range of activities that gave them insight into the operation of a world-leading astronomical research facility, and a taste of what it would be like to work at a radio observatory.

A new school-holiday program was developed and implemented in the four school-holiday periods in 2012. Twenty-two workshops were run, engaging more than 500 school-age children in a range of fun activities. Workshops included a water-bottle rocket challenge, t-shirt chromatography, 'physics fun' and a liquid nitrogen show, solar telescope viewing, and a 'marble run' challenge. The workshops were free and aimed at local and regional families.

A variety of new displays and exhibitions were installed at the Parkes Observatory Visitors Centre in 2012. These included:

- The development of a display showcasing CSIRO as a diverse research and development organisation and focusing on some of CSIRO's major developments.
- The construction of a monument to Grote Reber. A small sculpture of Grote Reber's original dish was made and mounted atop a sandstone plinth in honour of the 'Father of radio astronomy'. A portion of Grote Reber's ashes were interred in the metal framework during a small ceremony on the 10th anniversary of his death (20 December).
- The development of a Parkes radio telescope display at Parkes Shire Council's tourism office. The display gives an overview of Parkes Observatory and the world-leading research conducted at the facility.
- Hosting the David Malin Awards, an amateur astrophotography competition run by the Central West Astronomical Society, and 'The Big Think' exhibition, an art exhibition that explains the 'Big Bang' theory through forty black and white hand-drawn illustrations.

Education activities

The popular three-day 'Astronomy from the Ground Up' teacher workshop again ran at Parkes Observatory in May. Participating teachers made the most of the opportunity to learn about some of the latest developments in astronomy as well as exciting educational programs and activities. With the Transit of Venus (6 June) and solar eclipse (13 November) coming up, the workshop included a special session exploring ways to observe the Sun safely. Subsequent reports from participants revealed that many were able to run successful transit and eclipse viewings at their schools.

Participants in the three-day 'Astronomy from the Ground Up' teacher workshop held at Parkes Observatory in May enjoyed taking a look around the recently upgraded displays at the Visitors Centre.

The solar eclipse in November captured national and international interest. Queensland Education arranged for CASS Education Officer Rob Hollow to visit Cairns in April to prepare schools for the eclipse: he ran a two-day workshop for teachers from across far-north Queensland and visited several schools to talk with students about the transit and the eclipse. In November, Rob supported a solar-eclipse viewing for 100 students from northern Queensland participating in the 'Under a Darkened Star' student astronomy-education conference organised by Atherton State High School.

An eclipsed Sun rises over a ridge at Maitland Downs, Queensland.

Participants in the 'Under a Darkened Star' student astronomy education conference were treated to a spectacular solar eclipse viewing on 13 November.

Other astronomy education activities that took place during the year included:

- Delivery of teacher development workshop sessions at several state and national science teacher conferences in Sydney, Canberra, Melbourne and Brisbane.
- Presentation of six workshops (in four cities and towns) on a teacher professional development tour of Tasmania coordinated by the Science Teachers' Association of Tasmania and the Tasmanian Education Department. The workshops were well attended and reached a large number of Tasmanian primary and science teachers.
- CASS staff participation in CSIRO's 'Scientists in Schools' program, which links scientists, engineers and mathematicians with a school.

Many CASS staff gave public talks to a diverse range of audiences in 2012, often related to the Square Kilometre Array (SKA) and Australian Square Kilometre Array Pathfinder (ASKAP). To celebrate the official opening of ASKAP, Lisa Harvey-Smith delivered an evening presentation and Rob Hollow ran a daytime astronomy activity session at the Western Australian Museum Geraldton.

PULSE@Parkes

Science is put directly into students' hands through a program called 'PULSE@Parkes' that allows students to remotely control the Parkes radio telescope and observe pulsars over the Internet. In 2012, ten PULSE@ Parkes school sessions were held reaching approximately 160 students. In addition to the sessions run from Marsfield for senior high school students, PULSE@Parkes sessions were held:

- interstate , at the Victorian Space Science Education Centre in Melbourne and at SPICE at the University of Western Australia in Perth, and
- in Sydney , as part of CSIRO Education's January school holiday program for Double Helix club members.

The International Pulsar Timing Array Winter School for pulsar and gravitational-wave graduate students was held at the University of Sydney in June. Students took part in a PULSE@Parkes session early in the workshop. For many it was their first observing session with a radio telescope. It was also a 'master class', with an international panel of expert pulsar astronomers discussing techniques with the students.

In 2012, PULSE@ Parkes was awarded a grant from the Australia-Japan Foundation to take the program to Japan to foster educational and scientific collaborations. The tour, scheduled for 2013, will further expand the program's reach.

CASS Undergraduate Vacation Scholarship Program

In 2012–2013 students participating in the program were based at Marsfield, Parkes and Narrabri and worked on a diverse range of astrophysics, engineering, operations and outreach projects. As in past years, students visited the observatories to carry out research projects with the telescopes. This year, however, half the group visited Narrabri while the other half visited Parkes, which allowed enough time for the students to do individual observing projects rather than group projects. Astrophysics staff gave the students valuable background talks on aspects of radio astronomy and prepared them for their observing trip. Each of the students will give a talk about their main research project at CSIRO Information Sciences Group's 'Big Day In' to be held at Macquarie University in early 2013.

An encouraging sign of the value of the program is the number of students keen to continue their contact with CASS as co-supervised Honours or PhD students.

HEALTH, SAFETY AND ENVIRONMENT

CASS continued to improve in the area of health, safety and environment (HSE) and is in line with the CSIRO HSE Strategy 2011–2015. Throughout 2012, the CASS Executive focused on health and safety areas identified in the division's HSE risk profile as presenting a high or significant potential risk of serious injury: vehicle and driving safety, electrical safety, health and wellbeing, and emergency preparedness.

HSE training continued with excellent uptake by divisional line management of 'HSE for Leaders' training, which focused on improved leadership behaviours and risk-management principles.

Positive performance indicators remained in the 'excellent' range until May 2012, when a CSIRO-wide review of the indicators commenced and formal reporting ceased. Internal tracking of indicators showed that we continued to maintain the same excellent rates for the rest of the year.

Incidents and injuries

During the year reporting of incidents, including hazards and near-miss incidents, continued to be encouraged. CASS, excluding Canberra Deep Space Communication Complex staff, reported a total of 28 HSE incidents (hazards, near misses, injuries and environmental) in 2012. The main causes of incidents were being hit by or against objects, animal strikes during open-road driving, slips and falls, bites and stings, electrical hazards and manual handling.

CASS had five internally reportable 'serious HSE incidents' in 2012 that resulted in two lost-time injuries and one workers' compensation claim:

- The two lost-time injuries were related to (i) a slip and fall on the surface of a Compact Array antenna dish, and (ii) a wrist strain from carrying metal sheets and plastic tubs that aggravated an underlying non-work-related medical condition. The first injury resulted in a week away from work covered by a workers' compensation claim, and the second resulted in a single day away from work: both staff members recovered with physiotherapy intervention. In both cases, the tasks leading to the incidents were reviewed and corrective actions were implemented.
- Two of the serious HSE incidents were classified as 'high potential' incidents, a new classification in CSIRO's incident reporting criteria that is defined as an incident that did not result in an injury, but had the potential to do so in accordance with the HSE risk matrix. Both incidents related to vehicle and driving safety: (i) a vehicle travelling from the MRO to Geraldton carrying three CSIRO staff and an affiliate veered off the road as the front right-hand wheel went through a deep puddle of water, and (ii) a vehicle towing a trailer skidded and turned 180 degrees while travelling around a sweeping bend in the road between Geraldton and the Murchison Radio-astronomy Observatory (MRO). Neither incident resulted in any injuries; only minimal vehicle damage occurred (a flat tyre in the first incident). These incidents were taken extremely seriously by CASS and the CSIRO Executive, who identified the Geraldton–MRO journey as the number-one potential risk of a work-related fatality occurring within CSIRO. Measures that have now been put in place to manage the risk are listed on page 48.
- The fifth serious HSE incident related to the unexpected opening of the emergency door of a charter plane hired to transport staff and visitors between Perth airport and the MRO; the door fell in on the laps of two passengers when the plane landed at Perth airport. No-one was injured, the charter company grounded the plane until its investigation was complete, and the CSIRO Aviation Safety Procedure had been followed when contracting the charter company.

CASS made one 'dangerous incident' notification to Comcare in 2012:

- A staff member suffered a minor electric shock (tingle) when he was handed an in-line filter (capacitor) that still held a charge several hours after it had been removed from equipment in the Parkes control room. The staff member was taken to hospital for observation and an electro-cardiogram (consistent with the CSIRO Electrical Safety Procedure); he was reviewed and released with no injury. As a result of the incident a number of local procedural changes were implemented and the incident was shared across CSIRO.

Health and wellbeing programs

CASS continued its health and wellbeing program in 2012. This included:

- resilience training workshops at Marsfield, Parkes and Narrabri to support staff with developing professional and personal resilience plans
- regional site visits by psychologists at Parkes and Narrabri to provide staff with on-site counselling services
- continuation of the 'Sun Safety and Work Outdoors' campaign that commenced in late 2011. A heat stress information package was developed by one of the site HSE Officers and shared across CASS sites to remind staff to take care of themselves and their colleagues when working outdoors, and during periods of hot and humid weather
- flu vaccination clinics, and/or local access to flu vaccinations, across all sites (with an excellent uptake by staff)
- 'Health and Wellbeing' days and a 'Ride to Work Day' at the Marsfield site.

In addition, 7% of CASS staff completed a personalised health risk assessment via a new CSIRO web portal called 'Your Total Wellbeing' that was launched in August.

Environment and sustainability programs

As a result of on-site sustainability reviews, several environment and sustainability program initiatives were conducted at CASS sites during the year:

- CASS funded the clean-up of the McCreedy's Hill tip site at Parkes, an area to the southeast of the observatory that has historically been used as a general rubbish dump, mainly for excavated soil but also for industrial and building materials (bricks and concrete), large vegetation (tree stumps), old (oil-based) tarmac, and metals. The area had become unsightly, a haven for weeds and feral animals, and unacceptable in terms of modern sustainable landscape management practice. The area is now free of rubbish and smoothed, ready for vegetative cover.
- The Compact Array Visitors Centre opened a new a public amenities building — a self-composting toilet. As well as demonstrating the environmental benefits of a waterless and odourless composting toilet, the building has been designed to showcase the basic elements of passive solar design. Local cypress pine was used as far as possible in the building's construction and 'seconds' bricks from a nearby brickyard were used

in the reverse-brick-veneer construction. Control and monitoring technology normally used to operate the Compact Array and Parkes telescope has been used to help control a natural ventilation system for maintaining a comfortable temperature inside the building; landscaping around the building will be used to assist with heating and cooling; and educational and interpretive signs will be installed to explain the building to visitors.

- CASS funded an external survey of the Compact Array control building's air-conditioning efficiency with the aim of identifying opportunities to reduce electricity usage on site. Subsequently, new heating, ventilation and cooling units were purchased to replace the old and inefficient units; the units were delivered and waiting to be installed at the end of the year.
- Staff worked with CSIRO's corporate environment and sustainability team to develop innovative strategies for waste collection and removal at the Murchison Radio-astronomy Observatory (MRO). A glass crusher was purchased to reduce the volume of waste requiring disposal; the largest cost associated with the MRO's waste disposal is transportation. In addition, scrap electrical cabling, scrap metal and aluminium cans continued to be collected and recycled from the MRO and Boolardy accommodation facility.
- Staff were offered opportunities for e-waste recycling, and
- Staff participated in the CSIRO-wide 'C-Greens' work program, assisting with the implementation of new site waste-disposal practices, including self-management of office waste and a major recycling initiative.

HSE for Murchison Radio-astronomy Observatory

Commitment to HSE at the MRO remained high and consistent throughout 2012:

Marsfield 'C-Greens' volunteers Phil Crosby (CASS) and Kim DaCosta (ICT Centre) assisted with the implementation of new site waste disposal practices that included removing personal rubbish bins from under desks and replacing them with central waste hubs for general waste, recycling and paper.

- The CASS HSE Leader conducted two site visits during the year to review site practices as the MRO changed from being a construction site to an operational site.
- On-site incidents have required nothing more than minor first aid, a significant achievement given the level and type of activity that occurred at the MRO during the year.
- In late 2012 a management review team was established to systematically review the MRO HSE practices and ensure they meet regulatory and organisational procedural requirements as well as being practical and sustainable for the MRO.

In addition, there was a strong emphasis on HSE during planning for the Australian Square Kilometre Array Pathfinder and MRO opening ceremony, which saw CASS transport approximately 300 people to the MRO by car, bus or plane. Only two incidents occurred: (i) a plane's emergency door fell in on landing at Perth airport (reported as a 'serious HSE incident', and (ii) an animal was struck by a 4WD, resulting in some minor vehicle panel damage.

Continuous review and improvement initiatives

A major review of vehicle and driving safety identified that CASS staff (excluding CDSCC) drive an average of 60,000 kilometres per month; the largest portion of this being between Geraldton and the MRO, and in and around the MRO site. The existing safety controls were reviewed with representatives from each site to seek opportunities for improvements from existing local practices, and also with other CSIRO divisions that undertake significant open-road and 4WD driving activities.

An external investigator was engaged to review the investigation into a 'high potential' vehicle incident in which a vehicle veered off the road between Geraldton and the MRO. Several layers were added to the existing control measures as a result of this review, including:

- site-specific 4WD training at the MRO in recognition of the fact that most vehicle incidents are occurring because staff are not adjusting their driving to the local road conditions
- a vehicle 'Take-5' pre-risk assessment
- a mandated rest stop between Geraldton and the MRO
- a specific operating instruction to clarify all driving and vehicle-related safety requirements
- a personal discussion between staff and the CSIRO Chief Executive on the need to drive to the local conditions and consequences of a serious injury on family and colleagues.

By the end of 2012, the review of site emergency management plans that had started in late 2011 had been completed, and all site plans had been updated and practiced. A review of the CASS business continuity plan, and the establishment of a divisional emergency management plan, had also commenced.

Significant effort regarding the review of electrical safety practices and compliance with the Work Health Safety Act 2011 and Work Health Safety Regulations 2012 commenced in early 2012, but halted due to changing regulatory expectations. The final Electrical Code of Practice was issued in November 2012; once CSIRO completes a review and update of the CSIRO Electrical Safety Procedure (which is expected to be available in early 2013) CASS will resume the review of site electrical-safety practices and compliance. Regardless of the changing regulatory environment, a number of improvements were implemented at the sites, including the installation of Perspex sheeting across the drive cabinets in the Compact Array antennas that will prevent electronics technicians and non-licensed electricians from coming into contact with low-voltage (50–1000 V AC or 120–1500 V DC) hard-wired currents.

HUMAN RESOURCES

Staffing levels

CASS ATNF staffing levels declined by 7.5% in 2012 as a result of structural and business changes. The staffing reductions are most notable in the Engineering Group and are largely due to redundancy and term ends. Project Support and ASKAP/Project Specialists were the only groups to experience an increase in staffing levels in 2012. Communication staff were transferred to the CSIRO Information Sciences Communication Group in July 2011 and will no longer be reported in the ATNF Annual Report.

There were a number of key changes to the CASS Executive team during the year. In October, CSIRO farewelled CASS Chief Phil Diamond who returned to the UK to take up the position of Director General, Square Kilometre Array Organisation. Sarah Pearce (Deputy Chief) subsequently stepped into the role of Acting Chief while an international search for a new Chief was under way . Graeme Carrad (Assistant Director – Engineering) then filled the role of Acting Deputy Chief.

During 2012 recruitment activity remained almost parallel with the previous year, with 16 new appointments in 2012 compared with 17 in 2011. However, recruitment activity in 2012 was once again largely offset by staff cessations. A total of 25 staff ceased employment during 2012 due to resignation (10), retirement (3), term employment ending (4), redundancy (7) and other reasons (1).

CASS is pleased to have appointed its first Indigenous Cadet, Kobi Zamora-Pullin. Kobi is enrolled to study physics at the Australian National University. Throughout his course, he will spend 12 weeks each year working on a research project with CASS staff.

Staff awards

The expertise of staff has once again been recognised through internal and external awards.

In January, Square Kilometre Array (SKA) Executive Officer Michelle Storey was awarded a Public Service Medal in this year's Australia Day Honours list. The Medal was awarded for her exceptional and tireless efforts in supporting CSIRO's radio astronomy objectives and, more specifically, in working with the Australian, Western Australian and New Zealand Governments in their bid to host the future €1.5 billion SKA radio telescope project.

The Compact Array centimetre-receiver upgrade project managed by Mark Bowen received a highly commended award in the research and development category of Engineers Australia's Engineering Excellence Awards (Sydney Division), announced in September. Mark led a team of engineers that designed new receivers for the 25-year-old telescope. The upgrade enabled the full capability of the Compact Array Broadband Backend

TABLE 2:
Staff levels.

GROUP	TOTAL STAFF 2010*	TOTAL STAFF 2011*	TOTAL STAFF 2012*
ASKAP/Project Specialists	15	15	17
Astrophysics	25	27	24
Engineering	63	59	46
Management	9	9	9
Operations	58	58	55
Support	4	5	8
Total	174	173	160

*Total staff at December excluding casuals, contractors and students.

upgrade at centimetre wavelengths to be used, doubling the telescope's sensitivity and keeping the facility at the forefront of international radio astronomy research. The project was also a finalist in the 'manufacturing and high-tech design' category of The Australian Innovation Challenge 2012, announced in December.

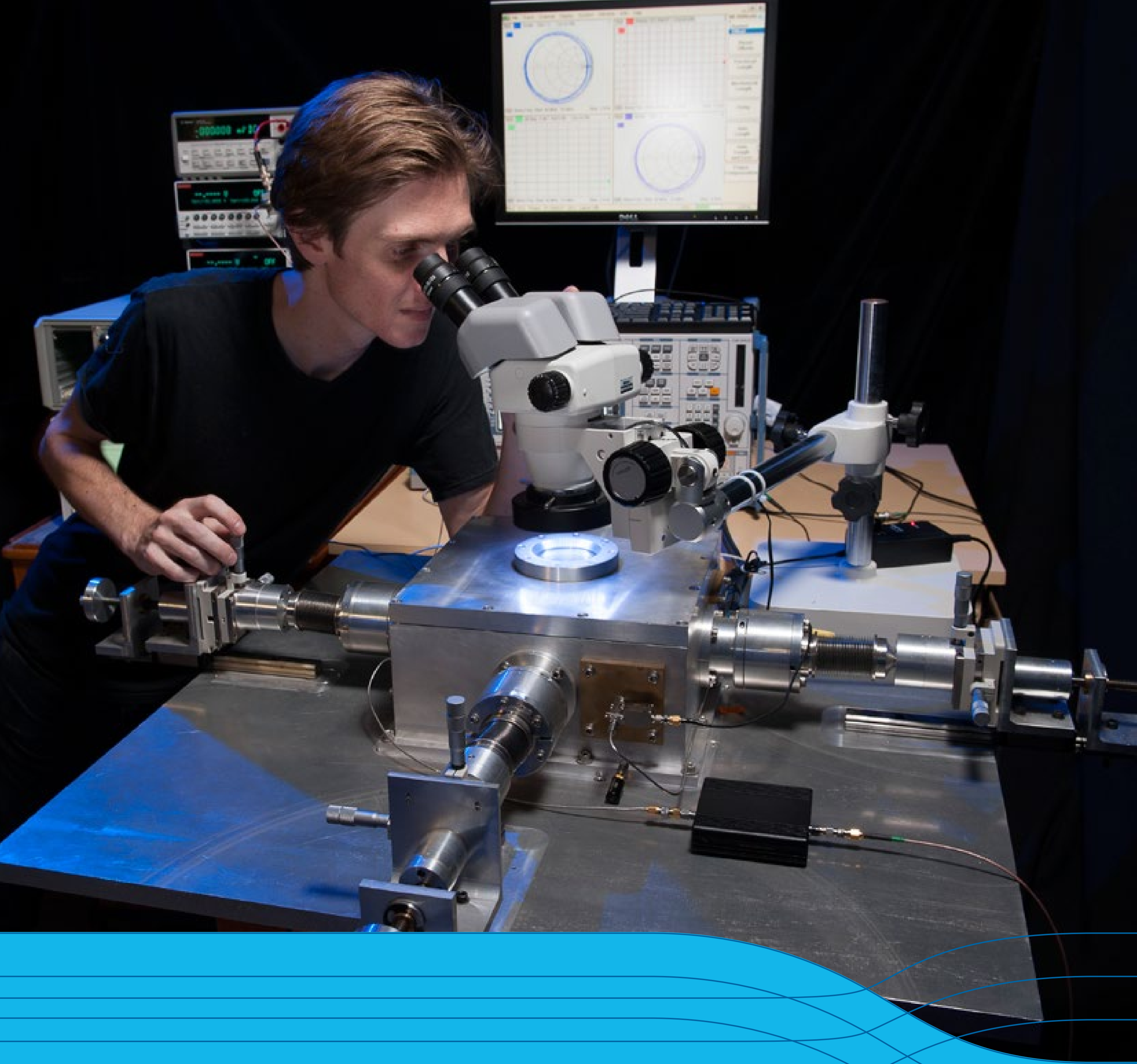
Astrophysics staff received significant awards: Bärbel Koribalski was awarded an Office of the Chief Executive Science Leader position, Jill Rathborne received a Julius Career Award, and George Hobbs won an Australian Research Council Future Fellowship; Jimi Green and Shari Breen obtained ARC Discovery Early Career Researcher Awards.

In September, Phil Crosby was joint recipient of the BAE SYSTEMS Chairman's Award, with the citation 'Capturing the Imagination'. This award recognised his contribution to industry engagement for the SKA while posted to the SKA Program Development Office in the UK.

Diversity and inclusion

Following a 'Women in Astronomy' workshop, hosted by CASS in May 2011, a working group was established to explore issues faced by both male and female staff in relation to career development and managing family responsibilities. The working group had several meetings to discuss potential issues and solutions. Following CASS Executive support, the group extended its scope to include other diversity matters and became the CASS Diversity Group; in this form, the group held its first meeting in December 2012.

Face-to-face anti-discrimination, bullying and harassment training was conducted in Marsfield, Narrabri and Parkes in the second half of 2012.



5. Technology

CSIRO engineer Alex Dunning conducting measurements on a low-noise amplifier stage. Credit: Tim Wheeler.

Technology

“This has been a most exciting year for the Technologies theme.”

This has been a most exciting year for the Technologies theme. The 1–3 GHz receiver systems on the Compact Array have proved their worth: in concert with the Array’s broadband backend, they have provided data leading to scientific results that challenge accepted theoretical models. The 4–12 GHz systems being fabricated to replace the Compact Array’s 24-year-old 6/3-cm receiver systems promise to boost performance at higher frequencies, just as the 1–3 GHz systems have. The quality of the engineering and its impact led to the receiver upgrade project being a finalist in two engineering and innovation competitions. The provision of an extra ‘zoom’ mode for the Compact Array Broadband Backend (CABB) has been a welcome increase in capability that will serve astronomers well in conjunction with the new receivers.

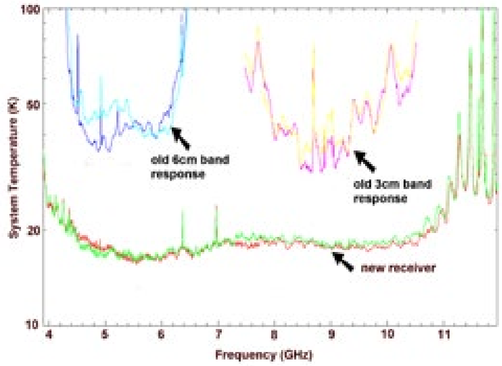
COMPACT ARRAY 20/13- AND 6/3-CM RECEIVER UPGRADE

Astronomers will now be able to use the full capability of the Compact Array Broadband Backend (CABB) at centimetre wavelengths, thanks to the installation of new broadband receivers. This upgrade has been funded by grant money made available through Astronomy Australia Limited.

The installation in 2011 of a complete suite of ‘16-cm’ receivers covering the 1–3 GHz band had dramatic results. With next to no time needed for commissioning, astronomers were able to use the system almost immediately. The first observations with the new system generated an impressive result: a paper calling into question traditional methods of measuring cosmic magnetic fields (O’Sullivan *et al.* 2012, *Complex Faraday depth structure of active galactic nuclei as revealed by broad-band radio polarimetry*. MNRAS, 421, 3300–3315). This work was made possible only by the increased bandwidth and sensitivity of the new 1–3 GHz receivers.

Hopes were high for a similarly superb performance from the replacements for the Compact Array’s original 6/3-cm receivers, given the pleasing performance of a ‘proof of concept’ 4–12 GHz receiver late in 2011. And those hopes have been fulfilled: the four production receivers installed on the Compact Array to the end of 2012 have replicated the performance of the ‘proof

(From left) CASS staff Mark Bowen, Alex Dunning and Henry Kanoniuk collected the Compact Array centimetre-receiver upgrade project’s Highly Commended award in the research and development category at Engineers Australia’s Engineering Excellence Awards (Sydney Division).



Sensitivity and bandwidth of the old and new Compact Array receivers for 4–12 GHz. The degradation in performance above 11 GHz is due to the limitations of the Array's old feeds.

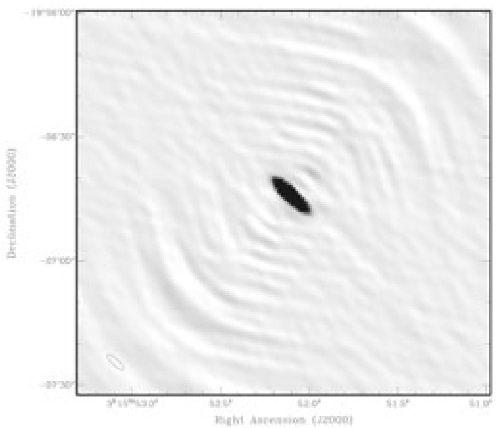
of concept' instrument. This performance is testimony to the innovative low-noise amplifier (LNA) circuit design and a new, more rigorous design path we have now adopted. Each of the three stages of a low-noise amplifier is designed, fabricated and tested in the cryogenic environment in which it will eventually operate.

Technologies staff have also developed a new orthomode transducer. This is a device that separates the two different polarisations of the incoming signal, and allows them to pass from waveguide to coaxial cable, following their conversion from incoming radio waves to electrical currents by the antenna feed. The new orthomode transducer was developed using computer-aided design techniques, including three-dimensional electromagnetic simulation, and exceeds specifications. The Compact Array's old 6/3-cm feeds, still in use, operate to only 11 GHz: preliminary tests have shown that (if funding were available) they could be replaced with ones that use the new orthomode transducer to cover the full 4–12 GHz band.

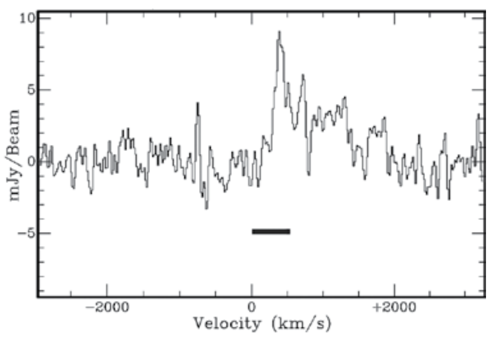
The success of the Compact Array receiver upgrade project prompted CASS to enter it into the Engineering Excellence Awards (Sydney Division) and the Australian Innovation Awards. It received a *Highly Commended* award in the former, and was a finalist in the latter.

COMPACT ARRAY BROADBAND BACKEND UPGRADE

The power of the Compact Array Broadband Backend (CABB) is being enhanced through the implementation of a number of fixed bandwidth modes with zoom capability. The 'zoom' allows a finer frequency resolution within the band. This year all 16 zooms for the 64-MHz mode have been implemented to complement the continuum mode (available since commissioning in 2009) and the 1-MHz mode with its full complement of 16 zooms (available since December 2010). Future effort will be focused on providing modes for the 16-MHz and 4-MHz CABB bandwidths with associated 'zooms'. There are some technical problems inherent in the system, which we have been investigating. Despite this, astronomers are exploiting the capabilities of CABB. The paper that describes the system (Wilson *et al.* 2011, MNRAS 416, 832) is well cited by astronomers around the world. CABB is now used for a diverse range of studies: 21-cm HI absorption measurements, 7-mm Galactic Plane surveys (MALT-45), the detections of supernovae and measurements of their light curves, deep surveys such as ATLAS, and polarisation measurements; and studies of nearby galaxies, distant black holes, molecular gas in high-redshift galaxies, Galactic masers, brown dwarfs, quasars, and grain growth in proto-planetary disks.



The first image taken with the new 4–12 GHz receivers on the Compact Array. This observation was made just hours after all the receivers were installed. The object is a rare example of a spiral galaxy that harbours a super-massive black hole. In the local Universe, nearly all supermassive black holes are associated with elliptical galaxies — galaxies that have exhausted most of their gas in star formation. Studies of objects like this one will help us to understand how super-massive black holes regulate the host galaxies that surround them. Observation: M. Mao



The power of the Compact Array Broadband Backend (CABB): the spectrum of the (1-0) transition of CO obtained with the Compact Array towards the galaxy 00183, showing an 8-σ detection obtained near the galaxy's rest frequency (86.8 GHz). This image, obtained soon after CABB commissioning, shows that there is an enormous amount of CO in this galaxy, which appears to be a quasar in the process of switching on. The old Compact Array correlator, with a total bandwidth shown by the bar in the figure, could not reveal the spectral line. Observation by R. Norris *et al.*

For more information related to CABB, see pages 40 and 43 of the 'Operations' chapter.

TELESCOPE SITE DEVELOPMENT PROJECTS

The development projects (most of which are for Parkes) are designed to facilitate remote observing through changes to control and monitoring systems, and receiver rationalisation.

The Parkes Equipment Control and Monitor Project was one of the measures taken to make Parkes' operations more efficient, in preparation for the Australian Square Kilometre Array Pathfinder coming on-stream. Although falling within the Technologies theme, this project was managed and undertaken by personnel from the Operations theme. Attention this year focused on focus-cabin remote power switching, focus-cabin temperature monitoring, and the power backup diesel/ UPS control and monitoring. The project has been completed, and has brought the remote operation of Parkes another step closer.

For more information on telescope site development projects, see page 38 of the 'Operations' chapter.

WATER-VAPOUR RADIOMETERS

Water-vapour radiometers (WVRs) are instruments that sample the atmosphere above the antennas of the Compact Array and generate corrections that are applied to observational data to improve the integrity of the astronomical signal degraded by the effects of water vapour. A project to equip the Compact Array antennas with such devices was primarily funded by the University of New South Wales and was completed in 2012. Characterisation of these units installed on each antenna of the Compact Array was completed mid year and calibrator scans, even during stable periods of weather, showed they could improve the signal phase by up to 30%. The system looks likely to prove a useful addition to high-frequency observing.

THE FAST MULTIBEAM PROJECT

Staff of CASS and CSIRO's ICT Centre have been engaging with engineers from the National Astronomical Observatory Chinese Academy of Sciences to realise a 19-pixel receiver operating in the 1–1.5 GHz band for the Five-hundred-meter Aperture Spherical Telescope (FAST), now under construction in Guizhou, China. In 2012 CASS staff began a feasibility study, and designs for all elements of the receiver are at an advanced stage. The determination by the FAST team of their desired frequency band will finalise the design parameters and allow CASS to complete a single-pixel-input waveguide (feed, orthomode transducer, gap guide and waveguide window) and amplifier to be fabricated and tested in a purpose-built cryostat. Members of the FAST team will visit the CASS laboratories to assist with measurements and become familiar with the receiver components.

6. The SKA and the Australian SKA Pathfinder

The Australian SKA Pathfinder.
Credit: Dragonfly Media.

The SKA and the Australian SKA Pathfinder

"Development of ASKAP and participation in the SKA continued to be strategic priorities."

Development of the Australian Square Kilometre Array Pathfinder (ASKAP), and participation in the international Square Kilometre Array (SKA) program, continued to be strategic priorities for CASS during 2012. The ASKAP project has four principal goals:

- establishing the Murchison Radioastronomy Observatory (MRO) as a unique new radio-quiet observatory to ultimately host the SKA
- developing new technology to advance radio astronomy and to demonstrate its viability for the SKA
- delivering high-quality science, in particular to establish and explore science themes that will be fully exploited by the SKA
- fostering the next generation of astronomers and engineers who will become the users and builders of the SKA.

To achieve these goals the ASKAP project will deliver:

- chequerboard phased array feed (PAF) receivers and associated technology for radio astronomy
- 36 antennas with advanced receiver systems (PAFs) and signal processing
- the geothermally cooled MRO Control Building and all support infrastructure
- an on-site power plant with a significant renewable component
- the MRO Support Facility (in Geraldton)
- an SKA-capable fibre-optic network linking the MRO to the MRO Support Facility and continuing on to Perth.

Construction of all 36 ASKAP antennas was completed in 2012.

In 2012 the ASKAP project team successfully delivered a number of major components and passed many key milestones:

- completion of the assembly of all 36 ASKAP antennas on site at the MRO, with initial holographic tests showing exceptional accuracy
- completion of major MRO infrastructure
  - the new geothermally cooled, heavily EMC-shielded, RFI-compliant MRO Control Building
  - 36 kilometres of access roads and tracks
  - power and data reticulation
  - antenna foundations
  - a high-speed optical-fibre connection to Geraldton
- the start of construction of the new MRO Support Facility (MSF) in Geraldton
- advances in the ASKAP Design Enhancement program, which is to improve efficiency and performance of the telescope
- development of the new digital signal-processing card set using the latest developments in field-programmable gate arrays. This represents technology one-and-a-half generations ahead of that which is commercially available.
- installation and testing of bespoke ASKAP telescope operating system software on all MRO computers, which allows the antennas to be controlled and monitored from the CASS headquarters in Marsfield
- validation of chequerboard phased array feed receivers and digital beamformers for radio astronomy, through successful phase-closure tests between three PAFs installed on ASKAP antennas
- memorable celebrations for the opening ceremony of ASKAP and the MRO, marking the end of the construction phase.

These achievements show ASKAP's potential to become a world-leading survey radio telescope, and are testament to the dedication of the project staff.

The ASKAP team was also involved in:

- ensuring a strict legislative framework for radio-spectrum management in the Mid West Radio Quiet Zone
- providing input to iVEC on the design of the integrated supercomputer at the iVEC Pawsey Centre in Perth, now under construction
- a number of Australia–New Zealand strategy discussions to prepare for the formation of consortia to complete the Project Execution Plan (PEP) work led by the international SKA Office.

SKA ACTIVITIES

SKA site announcement

On 25 May the international SKA Organisation announced that the SKA radio telescope will be deployed in Australia and New Zealand, as well as in southern Africa. The organisation noted that a dual-site implementation model for the SKA had been agreed upon by the majority of its members. Construction of the SKA Phase 1 is planned to start in 2016, with sets of antennas with complementary frequencies to be placed on each continent and then networked together. In Phase 1, Australia will build 60 mid-frequency SKA dishes equipped with phased array feeds (PAFs), and an array of low-frequency antennas.

Critically, the impact of the dual-site implementation does not change the fundamental assumption that as much technology and infrastructure as possible should be common to all SKA systems. The expectation is that consortia of institutes, companies and other stakeholders will respond to a Request for Proposals (RfP) from the SKA Office early in 2013.

The international SKA project became a new legal entity at the end of 2011 — the SKA Organisation, an independent, not-for-profit UK company limited by guarantee. The founding members were the UK, the Netherlands, Italy, China, Australia, New Zealand and South Africa; Canada, Sweden and Germany have since joined as members, bringing the total to ten. India is an associate member.

SKA pre-construction involvement

The Office of the SKA Organisation will manage the next phase of the SKA, the four-year pre-construction phase (2012–2016) outlined in the Project Execution Plan (PEP). The PEP sets out the major work packages, building on the exploratory technology of the European PrepSKA Work Package 2 (WP2) program.

CSIRO has contributed to a number of the PrepSKA WP2 technology tasks, including digital-systems design, computing, dish and receivers, and signal transport, and is well placed to continue significant involvement in PEP phase. The latter stages of this phase will involve development and validation of prototype SKA elements, ready to be built as Phase 1 of the SKA (from 2016).

The SKA Project Office has led the development of a full work breakdown structure (WBS) covering all aspects of the first year of the pre-construction phase, to culminate with the Systems Requirements Reviews.

The Australian Department of Innovation, Industry, Science, Research and Tertiary Education (DIISRTE) has also run open briefings to industry to encourage interest in participating in the pre-construction work. CSIRO assisted with these briefings, setting out the scope of pre-construction work for participants. Within CSIRO we have identified which of the consortia we wish to participate in, allocated some preliminary resources and begun more detailed discussions with national and international partners. Current priorities are towards consortia for Dish Array work (with an emphasis on receiver systems — for all feed types — and PAF systems), Computing, and Site & Infrastructure, with lower levels of engagement in a number of other work packages.

Australia–New Zealand SKA Coordination Committee

CSIRO is an active member of the Australia–New Zealand SKA Coordination Committee (ANZSCC), the intergovernmental body overseeing Australia and New Zealand SKA strategy and policy. The ANZSCC advises the relevant Ministers of the Commonwealth, Western Australian and New Zealand governments. The Chief of CASS represents CSIRO on the ANZSCC, and the CSIRO SKA Executive Officer attends meetings as a supporting official.

The ANZSCC was involved with key decisions made in the lead-up to the SKA site announcement and many of the milestones met in the international SKA project in 2012: among these were the SKA site decision, the appointment of a new SKA Director General and the formal acceptance of new members of the international SKA Organisation. The ANZSCC was also engaged in the official openings of both Australian SKA pathfinder facilities sited at the MRO, CSIRO's ASKAP telescope and the Murchison Widefield Array (MWA).

Work began in 2012 to develop the mechanisms by which the SKA will be built and operated in each of the host nations. The ANZSCC, assisted by a Hosting Agreement Working Group chaired by a CSIRO senior officer, is working closely with the international SKA Organisation to develop an agreement.

Guests begin to arrive for the ASKAP and MRO opening ceremony. Credit: Dragonfly Media.

MURCHISON RADIO-ASTRONOMY OBSERVATORY ACTIVITIES

ASKAP celebrates official opening

To celebrate the construction of ASKAP, and the establishment of the MRO on which ASKAP is sited, CSIRO hosted an official opening ceremony and affiliated events in October 2012.

The then Minister for Tertiary Education, Skills, Science and Research, Senator Chris Evans, officially opened ASKAP and the MRO, supported by CSIRO Chief Executive Megan Clark, the then CASS Chief Phil Diamond, West Australian Minister for Science and Innovation John Day, and Murchison Shire President Simon Broad.

Highlights of the ceremony included a 'Welcome to Country', traditional dancing by members of the local Wajarri Yamatji community, and bestowing of traditional Wajarri names on 30 ASKAP antennas. (The first six antennas had already received traditional names in a community event in 2011).

Guests who travelled to the remote site for the day included Board members of the SKA Organisation, senior government representatives, ambassadors of SKA countries, neighbouring pastoralists, and the traditional owners of the MRO site, the Wajarri Yamatji.

Senator Evans concluded proceedings with the push of a button, initiating the slewing of the ASKAP antennas towards radio source Virgo A as test data began to stream in.

Local celebrations were also held at the CASS sites at Marsfield, Parkes, Narrabri, and Tidbinbilla. These events included viewing the live webcast of proceedings that was streamed in 'real time' from the MRO and seen by viewers around the world.

Minister John Day, Western Australian Minister for Science and Innovation (left), Minister Chris Evans, Australian Minister for Tertiary Education, Skills, Science and Research (centre), and CSIRO's Chief Executive Dr Megan Clark (right) at the official opening of ASKAP and the MRO. Credit: Dragonfly Media.

Wajarri Yamatji dancers (both male and female) performed at the opening ceremony.
Credit: Dragonfly Media.

The audience at the official opening of ASKAP and the MRO on Friday 5 October 2012. Credit: Dragonfly Media.

Senator the Hon. Chris Evans, Minister for Tertiary Education, Skills, Science and Research, officially opened ASKAP and the MRO. Credit: Dragonfly Media.

MRO infrastructure

The MRO Control Building is a unique facility that houses power-distribution, networking and communications equipment, telescope control computers, and the complex digital processing, beamforming and correlator equipment to be used by ASKAP and other major instruments under development at the MRO.

Construction was completed in mid-2012, and the facility was officially handed over to the ASKAP team for occupation.

The building is the distribution hub for power and data cables that connect the site to the outside world. It required unique construction solutions for the challenges associated with the remote location, the stringent RFI protection requirements of the MRO, and efficient energy management.

Occupation and commissioning of the building involved relocating peripheral, ‘temporarily installed’ devices, such as beamformers, computing and networking equipment, and a correlator for the first ASKAP antennas already installed with PAF receiver systems. This equipment was previously housed in a modified 20-foot shipping container, known as the ‘BETA Box’, near the core of the ASKAP array.

Other infrastructure finalised in 2012 included antenna foundations, and bores and plumbing for the MRO Control Building’s geothermal cooling system. Main access roads and antenna access tracks were completed, the MRO airstrip was upgraded, and power transmission cabling was installed.

This infrastructure, constructed by McConnell Dowell Constructors (Australia) Pty Ltd, supports all projects at the MRO: ASKAP, the Murchison Widefield Array (MWA) and the Experiment to Detect the Global Epoch of Reionization Signature (EDGES).

MRO Support Facility

Construction began this year on CSIRO’s new MRO Support Facility (MSF) in Geraldton, Western Australia. The MSF is located within the Geraldton Universities Centre. It will provide remote operations services for ASKAP and other projects at the MRO, and office space for technical, maintenance and research staff. It will also feature a dedicated room for Geraldton-based researchers who have been awarded computing time on iVEC’s Pawsey Centre supercomputers. Following a public tender process, CSIRO awarded the contract for construction of the MSF to Merym Pty Ltd (trading as EMCO Building).

The high-speed optical-fibre connection between the MSF and the MRO (a distance of 370 km) was completed this year. A link between the MSF and the iVEC Pawsey Centre in Perth was also installed as part of the National Broadband Network. AARNet is playing a key role in providing data communication from the MRO to the Pawsey Centre.

AUSTRALIAN SKA PATHFINDER (ASKAP)

Antennas

In May 2012, the assembly of all 36 of CSIRO’s ASKAP antennas at the MRO was completed. The antennas were constructed by their manufacturer, the 54th Research Institute of China Electronics Technology Group Corporation (known as CETC54), with the assistance of CSIRO’s ASKAP team and local contractors.

To celebrate this milestone, CSIRO hosted a special dinner for the CETC54 team at the MRO to mark the ‘end of build’.

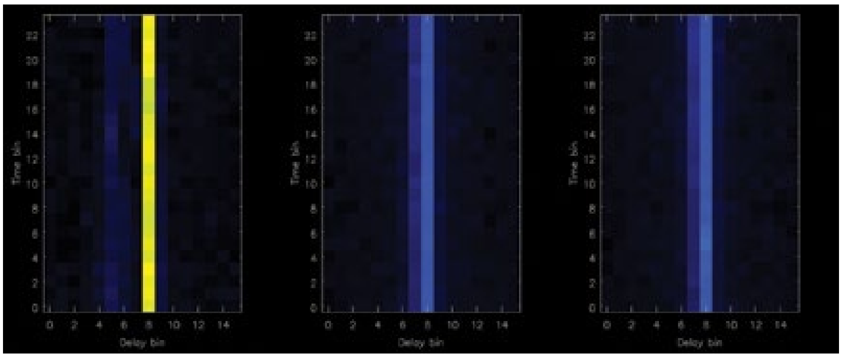
Final site-acceptance tests have shown that the antenna surfaces are a factor of two better than the required ASKAP specification. The surface accuracy actually achieved on all 36 delivered antennas was close to, or better than, 0.5 mm, effectively doubling the range of astronomy-capable operation up to 20 GHz.

Members of the CETC54 and ASKAP teams celebrate assembly of all 36 ASKAP antennas in May 2012. Final site acceptance tests have since confirmed reflector accuracy better than ASKAP specification, meaning that the antennas will be able to operate at up to 20 GHz.

ASKAP Design Enhancements (ADE)

Since August 2011, development of a second-generation (MkII) receiver and data-processing chain for ASKAP has been under way through a work package known as the ASKAP Design Enhancement (ADE).

The main focus of the package is the design optimisation and enhancement of the chequerboard PAF receiver to improve the performance, reduce total system costs (by



First fringes achieved as part of system-verification tests using three of CSIRO's PAF receivers installed on ASKAP antennas at the MRO.

using new cost-effective technologies) and enhance manufacturability and testability. These improvements have resulted in a design that will meet all the science requirements.

By creating a highly reliable and modular design, the ADE system will also provide ASKAP with a high degree of availability, provide significant benefits in system performance, simplify manufacturing, and increase maintainability.

Such improvements will be achieved by a number of design changes and upgrades, including improvement of the chequerboard geometry of the PAF, upgrading to signal transmission using 'RF-over-fibre' technology, direct sampling of the radio-frequency signal at the MRO Control Building, and new digital signal-processing (DSP) hardware that uses the latest in field-programmable gate array devices.

The proposed ADE work package included a phase of design and validation running through most of 2012, followed by a phase of prototyping and initial production from late 2012 through 2013.

A Critical Design Review was held in June 2012 to examine the completeness and stability of the system, module validation, design decisions, test planning and initial results, design for manufacturability and telescope integration, management, and system engineering processes.

The team also successfully completed the Integration Readiness Review in December 2012, which will allow for manufacture of the prototypes and, after further review, the first set of ASKAP receiver systems in 2013.

Systems commissioning

The Boolardy Engineering Test Array, BETA, is an engineering testbed array of the first six PAFs to be installed on ASKAP antennas at the MRO. The substantial commissioning required to prepare BETA (and ultimately ASKAP) for scientific observation can be broken down into three, partially overlapping, phases:

- **Engineering, Integration and Functionality:** the engineering and integration plan will be executed by the System Commissioning Team, SCOM-1, and driven by ASKAP's Systems Engineering, Integration and Commissioning project team.
- **Science and User Readiness:** when BETA is capable of producing useful observations, commissioning will be executed by SCOM-2, the Science Commissioning Team, driven by ASKAP's Science and User Policy team.
- **SST-Specific Readiness:** once BETA can provide scientifically useful data, the ASKAP team will work closely with the ten ASKAP Survey Science Teams to test and debug BETA for science-survey readiness.

In August 2012, we achieved a major milestone in ASKAP commissioning: the first-ever successful demonstration of phase closure between three phased array feed (PAF) receivers (installed on ASKAP antennas at the MRO).

Phase-closure tests are an important systems-verification step in calibrating the antennas in preparation for interferometry, as they demonstrate the proper functioning of the antennas and their electronic systems. The August demonstration was the first time correlation has ever been shown using a closed-loop, three-PAF system.

The Systems Commissioning team used the strong compact astronomical source Virgo A to perform the correlations at the MRO, with data captured simultaneously from the three beamformers and processed in real time. The three baselines were then combined to form the closure phase, the results of which were encouragingly close to zero degrees.

The correlation between antennas was achieved using a software correlator developed by the Computing Infrastructure group to process signals from multiple ASKAP PAFs in 'real time' and allow end-to-end system tests. This is a vital diagnostic verification tool for full system implementation and crucial for the end-to-end system testing in this configuration, and an interim step prior to the commissioning of a full BETA hardware correlator in 2013.

Further system verification success was achieved by demonstrating simple multibeam imaging on three PAF-equipped ASKAP antennas. Several hours' worth of observation data was used to construct a rudimentary image, effectively demonstrating the full data-reduction path from the software correlator to imaging in ASKAP's purpose-built software package, *ASKAPsoft*.

This is one of the biggest single events in the ASKAP project to date, validating the chequerboard PAF technology CSIRO has developed for radio astronomy.

ASKAP SCIENCE

Throughout 2012, cooperation continued between CASS and members of the ten large ASKAP Survey Science Projects announced during 2009.

During the first five years of ASKAP operation, at least 75 per cent of observing time will be dedicated to the ten Survey Science Teams. Each Survey Science project requires more than 1,500 hours to complete and is designed to make use of ASKAP's unique capabilities.

Dr Lisa Harvey-Smith was appointed Project Scientist for ASKAP to provide critical input and leadership in the areas of ASKAP performance, Survey Science Team management, commissioning, and international SKA developments.

A special issue of PASA (Publications of the Astronomical Society of Australia) was released in September, dedicated to 'Source Finding and Visualisation' (PASA, 29 (3), 2012).

Three editions of a new publication, ASKAP Update, were produced to keep the science community, industry and other interested stakeholders informed about the progress being made on technical, science and commissioning aspects of ASKAP. This publication merged two previous publications, ASKAP Science Update and ASKAP Technical Update.

Science commissioning

During the year the SCOM (Systems Commissioning) and Science and User Policy teams finalised the Engineering Commissioning plan for BETA, which is now being implemented by the SCOM team.

The broad strategy for the next phase — BETA science verification — is being developed by the team in conjunction with the Survey Science Teams and the CASS operations team. 'Test case' science-verification experiments are being designed that will let the Survey Science Teams verify the quality of the data products that will be produced by their surveys, and modify their survey strategies if necessary.

The main focus of BETA remains as a test array for both optimising beam-forming methods and for detailed system testing. Engineering experiments and science verification will take priority on BETA, but when the array is not being used for these purposes, some limited-scope science experiments may be possible. The ASKAP Project Scientist is taking part in discussions with Survey Science Teams about early science experiments that it may be possible to carry out with BETA on a shared-risk basis. The team continues to welcome approaches from scientists who have an interest in exploring science with BETA.

Beyond BETA, the next important step in science commissioning is to determine twelve- and eighteen-antenna configurations. The Science and User Policy team has been working closely with the Survey Science Teams through meetings of ASKAP Working Group 4b (Commissioning) to explore the requirements for these interim configurations. A decision on the configurations, based on both scientific and operational considerations, will be made in mid 2013, when preparatory work on the relevant antenna pedestals is expected to begin.

INDUSTRY AND OTHER STAKEHOLDER INVOLVEMENT

CSIRO's ASKAP and SKA industry engagement activity continued to strengthen through an ongoing program of briefings, publications and tender updates, and early-phase research and development collaborations.

The ASKAP team's engagement with industry representatives in Western Australia's Mid West region continued this year through regular participation in industry events organised by the Mid West Chamber of Commerce and Industry and the City of Geraldton-Greenough, as well as regular meetings with the WARAG (Western Australia Regional Advisory Group) committee, chaired by the Mid West Development Commission.

CSIRO also provided assistance to companies in the Mid West region of WA to help them comply with Radio Quiet Zone requirements. This included modelling potential interference from new radio transmitters, providing advice on measures that would reduce interference, and providing advice to the Australian Communications and Media Authority (ACMA) regarding agreed solutions. CSIRO assessed Radio Emission Management Plans for some proposed mining activities within the Radio Telescope Mineral Resource Management Area, assisted in improving these plans as necessary, and provided supporting advice to the WA Government.

CSIRO continued to be an active member of the Australasian SKA Industry Consortium (ASKAIC), a self-funded group of companies with a strong interest in ASKAP and the SKA. ASKAIC offers both practical help and excellent guidance in shaping plans for industry involvement.

Through the ASKAP project, CSIRO has strategic engagements with many and varied industry partners and other stakeholders:

- **AARNet**, and major sub-contractors **CCTS** and **North Coast Holdings**: these companies are providing high-speed data communication services from the MRO to Geraldton and through to the iVEC Pawsey Supercomputer Centre in Perth .

- **Aurecon** and **Merym Pty Ltd** (trading as EMCO Building): these companies were responsible for, respectively, the design and construction of the Murchison Support Facility (MSF) in Geraldton. Aurecon was also a partner in the development of the MRO Control Building.
- **Australian Government — Department of Broadband, Communications and the Digital Economy**; **NextGen** and **NBN Co**: CSIRO has worked closely with these organisations, and with AARNet, on the installation of the National Broadband Network link from Geraldton to Perth.
- **Cray**: Cray is providing the Cray Cascade supercomputer for the ASKAP Central Processor.
- **Geraldton Universities Centre** (GUC): CSIRO meets regularly with staff of GUC, the location of the Murchison Support Facility .
- **Horizon Power**: CSIRO is working with Horizon Power on the development of hybrid solar–diesel power generation for the MRO.
- **Intel**: Intel is providing developer support and has lent CSIRO pre-release software development platforms.
- **iVEC**: iVEC operates the Pawsey Supercomputer Centre in Perth, including the platform that hosts the ASKAP Central Processor and Science Data Archive.
- **McConnell Dowell Constructors (Aust) Pty Ltd**: this firm has been responsible for the MRO infrastructure. In particular, CSIRO collaborated with McDonnell Dowell, Aurecon and Adelaide-based business **Robin Johnson Engineering** (RJE) on the successful development and completion of the MRO Control Building.
- **Mid West Development Commission** (MWDC) and the **WA Regional Advisory Group** (WARAG) of the Australia – New Zealand SKA Coordination Committee: CSIRO liaises regularly with the MWDC and participates in WARAG.
- **Murchison Shire Council**: CSIRO participates in regular Council meetings and discussions .
- **Puzzle Precision**, a supplier of high-end digital systems: this firm has delivered major components of the ASKAP digital systems, such as signal-processor boards.
- **SGI**: SGI is providing the disk-based storage and hierarchical storage management software for the ASKAP Science Data Archive.
- **Xilinx**: CSIRO has worked with Xilinx to develop field-programmable gate arrays (FPGAs) to meet ASKAP requirements of approximately two peta-operations per second with 100 Terabit per second communications. The FPGAs provide an economical solution for both power consumption and capital cost compared with other alternatives, such as high-performance computing.
- **WA Local Government Association** (WALGA): CSIRO provides regular briefings to the biannual meetings of the Murchison Country Zone of WALGA (known locally as the Cue Parliament), which are attended by representatives of Local, State and Commonwealth Government and industry groups in the area.

COLLABORATOR PROJECTS

In 2012, two radio-astronomy experiments other than ASKAP made use of the superbly radio-quiet environment at the MRO: the Murchison Widefield Array (MWA) and the Experiment to Detect the Global Epoch of Reionization Signature (EDGES).

The MWA is an international collaboration between US, Indian and Australian institutions, including CSIRO, to build a wide-field dipole array at the low-frequency range (80–300 MHz) of the SKA specification. The MWA was formally launched at ceremonies at the MRO and in Geraldton on 30 November 2012. An Announcement of Opportunity was released in December 2012, to ready the MWA for the operation phase from July 2013.

The EDGES project was deployed at the MRO in 2009. It is a collaboration between Arizona State University and MIT/Haystack Observatory, and is funded by the US National Science Foundation. In 2012, EDGES continued to collect data between 80 and 200 MHz to provide a long-term baseline measurement of low-level RFI and ionospheric conditions. In parallel with the operation of the existing instrument, the EDGES team also prepared a new instrument (EDGES-2) that aims to improve on performance of the existing experiment by a factor of ten. The first deployment of the new system is expected in September 2013.

The MRO and EDGES infrastructure was also used in 2012 to support testing of a prototype receiver and antenna for the Dark Ages Radio Explorer (DARE), a NASA mission concept, to characterize the hardware and test absorption models of the ionosphere. DARE mirrors the goals and techniques of EDGES and is being developed as a collaboration between the EDGES group and a team led by the University of Colorado.

In 2012 a small number of CSIRO staff continued their collaboration with the University of Sydney on the Square Kilometre Array Molonglo Prototype (SKAMP) project, which aims to develop new technology for the SKA by producing a completely new digital-signal pathway on the existing mechanical superstructure of the Molonglo Observatory Synthesis Telescope.

7. Appendices

After the ASKAP opening ceremony, guests toured the MRO Control Building, a unique facility that will house the complex digital systems of ASKAP, termination points for approximately 7600 high-bandwidth optical-fibre links from projects on the site, and the fibre link to Geraldton. Credit: Dragonfly Media.

A: Committee membership

ATNF Steering Committee in 2012

CHAIR

Professor Lister Staveley-Smith, International Centre for Radio Astronomy Research*

MEMBERS

Ex-officio

Dr Matthew Colless, Director, Australian Astronomical Observatory

Dr Ian Oppermann, Director, CSIRO ICT Centre*

Mr Nigel Poole, acting Group Executive, CSIRO Information Sciences Group*

Astronomers

Professor Brian Schmidt, Research School of Astronomy and Astrophysics, Australian National University

Professor Rachel Webster, University of Melbourne (Chair from November 2012)

International advisers

Professor Jacqueline Hewitt, Director, MIT Kavli Institute for Astrophysics and Space Research, USA

Professor Michael Kramer, Director, Max-Planck-Institut für Radioastronomie, Germany*

Professor Nan Rendong, National Astronomical Observatories, China*

Broader community

Mr Alan Brien, Chief Executive Officer, Scitech Discovery Centre*

Mr Jim Noble, Australian Government Department of Defence (retired)

NEW MEMBERS FROM NOVEMBER 2012

Ex-officio

Dr Michael Brünig , Director, CSIRO ICT Centre

Dr David Williams, Group Executive, CSIRO Information Sciences Group

Astronomers

Professor Steven Tingay, Curtin Institute of Radio Astronomy/ICRAR

International advisers

Dr Di Li, National Astronomical Observatories, Chinese Academy of Sciences, China

Professor Raffaella Morganti, Netherlands Foundation for Research in Astronomy, The Netherlands

Broader community

Mr Noel Wainwright, Lockheed Martin

* Members whose term ended during the year.

Australia Telescope User Committee in 2012

CHAIR

Professor John Dickey, University of Tasmania (2012 – 2014)

SECRETARY

Dr Chris Phillips, CSIRO Astronomy and Space Science (October 2010 – June 2013)

MEMBERS

Dr Hayley Bignall, Curtin University (October 2008 – May 2012)

Dr Chris Springob, Australian Astronomical Observatory (October 2009 – May 2012)

Dr James Allison, University of Sydney (October 2011 – May 2014)

Dr Virginia Kilborn, Swinburne University of Technology (October 2011 – May 2014)

Dr Stephen Ord, Curtin University (October 2011 – May 2014)

Dr Ryan Shannon, CSIRO Astronomy and Space Science (October 2011 – May 2014)

Dr Minh Huynh, University of Western Australia (October 2012 – May 2015)

Dr Tobias Westmeier, University of Western Australia (October 2012 – May 2015)

STUDENT MEMBERS

Kathrin Wolfinger, Swinburne University of Technology (October 2011 – May 2012)

Giovanna Zanardo, University of Western Australia (October 2011 – May 2012)

Vikram Ravi, University of Melbourne (October 2012 – June 2013)

Sarah Reeves, University of Sydney (October 2012 – June 2013)

The Australia Telescope Steering Committee appoints members to the Australia Telescope User Committee. New members usually start their three-year term with the October/November meeting in their first year and finish their term after the May/June meeting in their last year. Students are appointed for one year (two meetings). Dates of the first and last meetings are given.

Australia Telescope Time Assignment Committee in 2012

CHAIR

Professor Michael Drinkwater, University of Queensland

MEMBERS

Ex-officio

Dr Douglas Bock, CSIRO Astronomy and Space Science

Dr Jessica Chapman, CSIRO Astronomy and Space Science

Dr Philip Edwards, CSIRO Astronomy and Space Science

TAC members

Dr John Carpenter, California Institute of Technology, US

Dr James Green, CSIRO Astronomy and Space Science

Dr Helen Johnston, University of Sydney

Dr Emil Lenc, CSIRO Astronomy and Space Science

Dr Jim Lovell, University of Tasmania

Dr Martin Meyer, International Centre for Radio Astronomy Research

Dr Shane O'Sullivan, CSIRO Astronomy and Space Science

Dr Jill Rathborne, CSIRO Astronomy and Space Science

Dr Willem van Straten, Swinburne University of Technology

Dr Andrew Walsh, James Cook University

Readers

Dr Ettore Carretti, CSIRO Astronomy and Space Science

Dr Simon Ellingsen, University of Tasmania

Dr Gary Fuller, University of Manchester, UK

Dr Jose Gomez, Instituto de Astrofisica de Andalucia, Spain

Dr Mareki Honma, National Astronomical Observatory of Japan, Japan

Dr Richard Hunstead, University of Sydney

Dr Minh Huynh, International Centre for Radio Astronomy Research

Dr Virginia Kilborn, Swinburne University of Technology

Dr Maura McLaughlin, West Virginia University, USA

Dr Vincent Minier, University of Paris, CEA Saclay, France

Professor Raffaella Morganti, Netherlands Foundation for Research in Astronomy, The Netherlands

Dr Erik Muller, East Asian ALMA Regional Centre, Japan

Professor Ray Norris, CSIRO Astronomy and Space Science

Dr Juergen Ott, National Radio Astronomy Observatory, USA

Dr Gavin Rowell, University of Adelaide

Dr Snezena Stanimirovic, University of Wisconsin, USA

B: Financial summary

The table below summarises the revenue and expenditure applied to CSIRO's radio astronomy activities, also including related activities resourced from the CSIRO ICT Centre.

	Year ending 30 June 2010 (A$'000)	Year ending 30 June 2011 (A$'000)	Year ending 30 June 2012 (A$'000)
Revenue			
External	966	7,181	13,726
Appropriation	33,031	36,419	35,623
Total revenue	33,997	43,600	49,349
Expenses			
Salaries	12,500	14,046	14,884
Travel	976	1,080	1,093
Other operating	5,091	5,028	5,081
Overheads*	10,282	12,914	13,055
Corporate support services	0	0	0
Depreciation and amortisation	3,925	3,953	4,081
Doubtful debt expense	0	0	0
Total expenses	32,773	37,021	38,194
Profit/(Loss) on sale of assets	0	0	0
Operating result	1,223	6,579	11,155

CSIRO has a 'matrix' operating structure. This financial summary refers to the 'output' side of the CSIRO matrix: outputs are CSIRO portfolios and themes.

External revenue for the years ending 30 June 2011 and 30 June 2012 was impacted by one-off agreements related to funding for the ASKAP project.

*Overheads include corporate support services and business-unit support services.

C: Staff list

ALL STAFF WHO WORKED FOR CASS ON RADIO ASTRONOMY RELATED ACTIVITIES IN 2012

MARSFIELD		
Allen	Graham	Engineering
Amy	Shaun	Operations
Ardern	Kerry	Project Specialist
Axtens	Peter	Engineering
Banfield	Julie	Astrophysics
Bannister	Keith	Astrophysics
Bateman	Tim	Engineering
Beresford	Ron	Engineering
Bock	Douglas	Operations
Bolton	Russell	Engineering
Bourne	Michael	Engineering
Bowen	Mark	Engineering
Boyle	Brian	Portfolio Leader SKA
Braun	Robert	Astrophysics
Breen	Shari	Astrophysics
Bressert	Eli	Astrophysics
Broadhurst	Steven	Operations
Brooks	Kate	Project Specialist
Brown	Andrew	Engineering
Brown	Shea	Astrophysics
Calabretta	Mark	Operations
Carrad	Graeme	Engineering
Castillo	Santiago	Engineering
Caswell	James	Astrophysics
Chapman	Jessica	Operations
Chaudhary	Ankur	Operations
Chekkala	Raji	Engineering
Cheng	Wanxiang	Engineering
Chippendale	Aaron	Engineering
Chung	Yoon	Engineering
Cook	Alan	Engineering
Cook	Geoffrey	Engineering
Cooper	Paul	Engineering
Cornwell	Tim	Software Development
Crosby	Phil	Business Strategy
Davis	Evan	Engineering
Death	Michael	Engineering
Diamond	Philip	CASS Chief and ATNF Director
Dixon	John	Engineering
Doherty	Paul	Engineering
Drazenovic	Vicki	Operations
Dunning	Alexander	Engineering
Edwards	Leanne	Operations
Edwards	Philip	Operations
Ekers	Ron	Astrophysics

Emonts	Bjorn	Astrophysics
Feain	Ilana	Business Strategy
Ferris	Richard	Engineering
Forsyth	Ross	Engineering
Franzen	Thomas	Astrophysics
Fraser	Vicki	Project Specialist
Frost	Gabriella	Project Specialist
Gonidakis	Yiannis	Astrophysics
Gough	Russell	Engineering
Gough	Sarah	Engineering
Green	James	Astrophysics
Guzman	Juan Carlos	Software Development
Haan	Sebastian	Astrophysics
Hakvoort	Eliane	Engineering
Hampson	Grant	Engineering
Harvey-Smith	Lisa	Astrophysics
Haskins	Craig	Software Development
Hassan	Amr	Software Development
Hill	Alex	Astrophysics
Hobbs	George	Astrophysics
Hotan	Aidan	Project Specialists
Humphreys	Ben	Software Development
Huynh	Minh	Engineering
Indermuehle	Balthasar	Operations
Jackson	Carole	Project Specialist
Jackson	Suzy	Operations
Jeganathan	Kanapathippillai	Engineering
Johnston	Simon	Astrophysics
Jurek	Russell	Astrophysics
Kamphuis	Peter	Astrophysics
Kanoniuk	Henry	Engineering
Keith	Michael	Astrophysics
Kesteven	Michael	Engineering
Khoo	Jonathan	Astrophysics
Kiraly	Dezso	Engineering
Koenig	Ron	Engineering
Koribalski	Bärbel	Astrophysics
Kosmynin	Arkadi	Operations
Lauter	Benjamin	Engineering
Leach	Mark	Engineering
Lie	Jennifer	Engineering
Mackay	Simon	Engineering
Macleod	Adam	Project Specialists
Maher	Tony	Software Development
Manchester	Dick	Astrophysics
Marquarding	Malte	Software Development
Marston	Michiko	Project Specialist
Marston	Neil	Business Development
McClure-Griffiths	Naomi	Astrophysics
McConnell	David	Operations
McIntyre	Vincent	Operations
Mickle	Samantha	Engineering
Moncay	Ray	Engineering

Morison	Neale	Software Development
Neuhold	Stephan	Engineering
Ng	Alan	Project Specialist
Ng	Andrew	Engineering
Norris	Ray	Astrophysics
O'Sullivan	John	Engineering
O'Sullivan	Shane	Astrophysics
O'Toole	Sally	Engineering
Pearce	Sarah	CASS Deputy Chief
Petroff	Emily	Astrophysics
Phillips	Chris	Operations
Pope	Nathan	Operations
Rathborne	Jill	Astrophysics
Reilly	Les	Engineering
Reynolds	John	Project Specialist
Roberts	Paul	Engineering
Sanders	Aaron	Engineering
Schinckel	Antony	Project Specialist
Seymour	Nicholas	Astrophysics
Shannon	Ryan	Astrophysics
Shields	Matthew	Engineering
Shimwell	Timothy	Astrophysics
Sloman	Michael	Engineering
Storey	Michelle	Policy Strategy
Tam	Kam	Operations
Troup	Euan	Operations
Tuthill	John	Engineering
Tzioumis	Tasso	Operations
Vera	Jeffrey	Engineering
Voronkov	Maxim	Software Development
Whiting	Matthew	Software Development
Wilson	Warwick	Engineering
Wong	Ivy	Astrophysics
Wormnes	Kjetil	Engineering
Wright	Adrian	Engineering
Wu	Xinyu	Software Development
MARSFIELD RESEARCH SUPPORT		
Barends	Anne	Executive Secretary
Broadhurst	Sue	Reception
Clampett	Keith	Stores
Conway-Derley	Flornes	Communications and Outreach
Crawshaw	Tony	Communications and Outreach
D'Amico	Andy	Stores
Fraser	Kylie	Health, Safety and Environment
Gray	Amanda	Administration
Hartmann	Carmel	Administration
Hollow	Robert	Communications and Outreach
Joos	Ariana	Library
Kachwalla	Elsa	Reception
Khilji	Vickie	Reception
Kucic	Anita	Human Resources
Levers	Helen	Human Resources
Looi	Chee Kong	Health, Safety and Environment

Manefield	Gwenyth	Administration
Mather	Pat	Human Resources
Merrick	Sarah	Finance
Mok	Rebecca	Finance
O'Loughlin	Vicki	Administration
Poshoglian	Meg	Reception
Randell	Sandra	Finance
Russell	Gabby	Communications and Outreach
Sim	Helen	Communications and Outreach
Tesoriero	Julie	Administration
Wilson	Briony	Finance
NARRABRI		
Bateman	John	Operations
Brem	Christoph	Operations
Brodrick	David	Operations
Dodd	Susan	Operations
Forbes	Kylee	Operations
Hill	Michael	Operations
Hiscock	Brett	Operations
Hiscock	Jennifer	Operations
Houldsworth	Joanne	Operations
Kelly	Pamela	Operations
Lennon	Brett	Operations
Madden	Brian	Operations
McAllister	Kelly	Operations
McFee	John	Operations
McFee	Margaret	Operations
McPherson	Liza-Jane	Operations
Mirtschin	Peter	Operations
Munting	Scott	Operations
Prestage	Joslin	Operations
Rees	Margaret	Operations
Stevens	Jamie	Operations
Sunderland	Graeme	Operations
Tough	Bruce	Operations
Wark	Robin	Operations
Webster	Norman	Operations
Wieringa	Mark	Operations
Wilson	Christine	Operations
Wilson	John	Operations
Wilson	Tim	Operations
NARRABRI RESEARCH SUPPORT		
Johnson	Brian	Property Services
Leven	Clarence	Property Services
Parkes		
Armstrong	Brett	Operations
Carretti	Ettore	Operations
Craig	Daniel	Operations
Crocker	Jonathan	Operations
D'Mello	Glen	Operations
Evans	Anne	Operations
Hockings	Julia	Operations

Hoyle	Simon	Operations
Hunt	Andrew	Operations
Ingram	Shirley	Operations
Kaletsch	Robert	Operations
Lees	Tom	Operations
Lensson	Erik	Operations
Mader	Stacy	Operations
Marshall	Margaret	Operations
McFarland	Matthew	Operations
McRobert	Ian	Operations
Pieroz	Allan	Operations
Preisig	Brett	Operations
Reeves	Ken	Operations
Ruckley	Timothy	Operations
Sarkissian	John	Operations
Smith	Malcolm	Operations
Spratt	Gina	Operations
PARKES RESEARCH SUPPORT		
Dean	Andrew	Communications and Outreach
Hollingdrake	Chris	Communications and Outreach
Lampe	Nathanael	Communications and Outreach
Milgate	Lynette	Communications and Outreach
Trim	Tricia	Communications and Outreach
Unger	Karin	Communications and Outreach
Veale	Roxanne	Communications and Outreach
Wilson	Beverley	Communications and Outreach
GERALDTON		
Boddington	Robin	Project Specialist
Briggs	Brayden	Health, Safety and Environment
Clayton	Priscilla	Project Specialist
Harding	Alex	Operations
Morris	John	Operations
Pena	Wilfredo	Health, Safety and Environment
Puls	Lou	Operations
Reay	Michael	Operations
Simpson	Godfrey	Project Specialist
Turner	Barry	Operations
Whiting	Gemma	Operations
CANBERRA		
Zamora-Pullin	Kobi	Astrophysics

The staff list includes staff from CSIRO Astronomy and Space Science (CASS) and other divisions who worked for CASS on radio-astronomy related activities in the period January to December 2012.

D: Observing programs

The observations listed are those that were allocated time through the Time Assignment Committee's processes. A small number of 'Target of Opportunity' observations are not listed. Proposal cover sheets are available online through the ATNF proposal application system, OPAL (http://opal.atnf.csiro.au/searchProposals.do).

OBSERVATIONS MADE WITH THE AUSTRALIA TELESCOPE COMPACT ARRAY

October 2011 to September 2012

OBSERVERS	PROGRAM	NO.
Stevens, Edwards, Wark, Wieringa	ATCA calibrators	C007
Staveley-Smith, Gaensler, Tzioumis, Kesteven, Ng, Zanardo, Potter	Supernova remnant 1987A	C015
Bozzetto, Filipovic, Crawford, De Horta, Haberl, Sasaki	SNRs and SNR candidates in the Magellanc Clouds: Part V - new class of senile and large supernovae remnants	C634
Dodson, Mcconnell, Rioja, Deshpande, Raja	CABB observations of the Vela PWN with ATCA	C946
Coriat, Tzioumis, Corbel, Fender, Brocksopp	Radio jets in recurrent and new black hole X-ray transients	C989
Maud, Voronkov, Hoare, Urquhart, Lumsden, Purcell	High resolution continuum observations of massive YSOs	C1176
Corbel, Tzioumis, Fender, Kaaret, Tomsick, Orosz	Large scale radio/X-ray jets in microquasars	C1199
Feain, Sadler, Ekers, Hunstead, Kanekar, Emonts, Wagg	Confirming the mass of extended, cold molecular gas in a radio galaxy at z = 5.2	C1214
Lundqvist, Ryder, Hancock, Bjornsson, Fransson, Schmidt, Perez Torres	Probing the radio emission from a young Type Ia supernova	C1303
Ryder, Weiler, Stockdale, Van Dyk, Panagia, Amy, Mahony, Immler	NAPA observations of core-collapse supernovae	C1473
Prandoni, Ricci, Parma, De Ruiter	Assessing the AGN component in the faint radio population	C1661
Johnston-Hollitt, Finoguenov, Bahringer, Shakouri, Pratt, Croston	Radio imaging of an X-ray luminosity selected galaxy cluster sample	C1683
Breen, Lopez-Sanchez, Hollow, Schnitzeler	ATNF summer vacation programme 2011/2012	C1726
Edwards, Macquart, Lovell, Ojha, Kadler, Hungwe, Stevens, Blanchard, Mueller, Wilms, Boeck	ATCA monitoring of gamma-ray loud AGN	C1730
Delhaize, Gaensler, -Smith, Sadler, Kesteven, Subrahmanyan, Meyer, Boyle, Popping, Driver	Galaxy evolution — a pathfinder study	C1805
Eckart, Sjouwerman, Baganoff, Straubmeier, Kunneriath, Garcia-Marin, Valencia-S., Moser, Bursa, Karas	2012 coordinated run on SgrA*	C1825
Benaglia, Koribalski, Dougherty, Marti, Sanchez-Sutil, Peri	A mosaic of Westerlund 2: the key to HESS J1023-575?	C1847
Lumsden, Voronkov, Brooks, Hoare, Garay, Urquhart, Purcell, Guzman, Maud, Strom	Ionised winds and jets from massive young stellar objects	C1862
Voronkov, Caswell, Green, Sobolev, Ostrovskii, Ellingsen, Goedhart, Gaylard, van der Walt	Understanding periodic flares of the methanol masers	C1929
Moin, Wang, Wang	Search for the radio counterparts of newly discovered X-ray binary transients	C1971
Agliozzo, Trigilio, Buemi, Umana, Noriega-Crespo, Leto	The radio morphology of three Luminous Blue Variables in the Large Magellanic Cloud	C1973
Hoare, Rathborne, Burton, Brooks, Green, Fuller, Fender, Ellingsen, Moore, Green, Cesaroni, Urquhart, Dougherty, Churchwell, Lumsden, Walsh, Thompson, Zijlstra, Kurtz, Purcell, Paladini, Umana, Pandian, Molinari, Wieringa, Marti, Jackson, Cotton, O'Brien, Paredes, Diamond	The Co-Ordinated Radio 'N' Infrared Survey for High-mass star formation — CORNISH-South	C1977
Jordan, Bains, Voronkov, Lo, Jones, Muller, Cunningham, Burton, Brooks, Green, Fuller, Barnes, Ellingsen, Urquhart, Morgan, Rowell, Walsh, Loenen, Baan, Hill, Purcell, Breen, Peretto, Jackson, Lowe, Longmore	The MALT-45 survey	C2029

OBSERVERS	PROGRAM	NO.
Corbel, Edwards, Sadler, Thompson, Gehrels, Tingay, Wieringa, Grenier, Chaty, Dubus, Cameron, Abraham	ATCA follow-up of unidentified flaring Fermi gamma-ray sources	C2051
Emonts, Sadler, Morganti, Norris, Tadhunter, Ekers, Feain, Oosterloo, Miley, Chow, Stevens, Mao, Carilli, Villar-Martin, Mahony, Saikia, Rottgering, Van moorsel, Berciano	CO content of protocluster radio-galaxies in the early Universe: a CABB study	C2052
Walsh, Voronkov, Lo, Jones, Cunningham, Burton, Brooks, Hoare, Phillips, Green, Urquhart, Thompson, Purcell, Breen, Harvey-Smith, Indermuehle, Hindson, Britton, Lowe, Jordan, Longmore	Accurate water maser positions for HOPS	C2148
Reynoso, Wardle, Walsh, Lazendic-Galloway	A high-resolution HI and OH study of the SNR Puppis A.	C2290
Green, Caswell, Mcclure-Griffiths, Harvey-Smith, Robishaw	MAGMO: Mapping the Galactic magnetic field through OH masers	C2291
Ott, Koribalski, Henkel, Edwards, Norris, Meier, Feain, Curran, Martin-Pintado, Beelen, Aalto, Combes, Israel, Muller, Espada, Guelin, Black, V-Trung, Impellizzeri, Persson	The ATCA CABB line survey on Centaurus A: properties of the molecular gas from the dust lanes to the central engine	C2298
Jones, Lo, Cunningham, Burton, Thorwirth, Menten, Schilke, Walsh, Bronfman, Purcell, Cordiner, Remijan, Lowe, Charnley, Qin, Balnozan	The spatial distribution of complex molecules in Sagittarius B2: a line survey at 7 mm with CABB	C2318
Malarecki, Staveley-Smith, Subrahmanyan, Saripalli, Jones	Large scale structure, the warm-hot IGM and giant radio galaxies	C2340
Webb, Lenc, Corbel, Fender, Heywood, Farrell, Cseh, Godet, Barret	Understanding the radio jets of the intermediate mass black hole ESO 243-49 HLX-1	C2361
Brown, Rudnick, Pfrommer, Jones	Unveiling the synchrotron cosmic web: a pilot study	C2364
Lumsden, Croom	Star formation in dusty quasars	C2365
Marriage, Hughes, Partridge, Marsden, Gralla, Scott	ACT-ATCA study of 148 and 218 GHz selected sources	C2424
Sadler, Morganti, Zwaan, Whiting, Curran, Bland-Hawthorn, Oosterloo, Allison, Emonts, Reeves	A search for HI absorption in young compact radio galaxies	C2434
Greve, De Breuck, König, Ivison, Papadopoulos, Kovacs	Probing the cold molecular gas reservoir in a proto-cluster at z=4.11, continued	C2450
Possenti, Burgay, Israel, Wieringa, Rea, Esposito	Continuum radio emission from magnetars in outburst	C2456
Baker, Hughes, Marriage, Aguirre, Braglia, Das, Hernandez-Monteagudo, Infante, Lima, Lindner, Menanteau, Sehgal, Schmitt, Sifon	ATCA mapping of eight galaxy clusters in a mass-selected sample	C2457
Brooks, Gaensler, Voronkov, Rathborne, Burton, Garay, Green, Breen, Robishaw, Smith, Reiter	CARPARC — Carina Parkes-ATCA Radio Continuum Survey	C2489
Emonts, Sadler, Norris, Ekers, Feain, Miley, Mao, Villar-Martin, Rottgering	Mapping the wide-spread molecular gas in the z~2 radio galaxy MRC0152-209	C2498
Murphy, Stark, Marrone, Mcintyre, Vieira, Carlstrom, Chapman, Malkan	Radio spectral indices and accurate positions for high redshift strongly lensed dusty star-forming galaxies discovered with the South Pole Telescope	C2507
Cunningham, Mcclure-Griffiths, Jones, Dickey, Ford, Walsh, van Loon, Hennebelle, Gibson, Kerton, Jones, Arce	Testing theories of molecular cloud formation using observations of OH and HI in the G333 region	C2508
Schnitzeler, Gaensler, Staveley-Smith, Carretti, Haverkorn, Kesteven, Poppi, Stevens, Bernardi	Unveiling the Galactic magnetic field in the Southern Sky	C2511
Malu, Kale	ATCA study of the X-ray brightest and hottest southern MACS clusters	C2512
Motogi, Sorai	Thermal counterpart of highly variable water maser site G353.27+0.6	C2513
Miller-Jones, Migliari, Diaz Trigo	Probing the disc wind-jet connection in black hole transients	C2514
Umana, Norris, Massardi, Trigilio, Buemi, Leto, Ingallinera, Agliozzo, Franzen	Stellar radio emission in the SKA era: the SCORPIO project	C2515
Dehghan, Johnston-Hollitt, Shakouri	A systematic study of head-tail galaxies as barometers and anemometers of cluster weather	C2516
van Loon, Gomez, Green, Imai, Lakicevic	Finding truly metal-poor OH masers	C2521
Miller-Jones, Tzioumis, Maccarone, Jonker, Nelemans, Sivakoff	Constraining black hole formation with triggered LBA astrometry	C2538

OBSERVERS	PROGRAM	NO.
Miller-Jones, Tzioumis, Phillips, Nicolson, Tingay, Moin, Reynolds	Triggered LBA imaging of the relativistic jets in Circinus X-1	C2540
Coriat, Corbel, Fender, Belloni, Miller-Jones, Soleri	Following the decay of the black hole candidate X-ray binary SWIFT J1753.5-0127	C2541
Zechlin, Voronkov, Lobanov, Horns	Dark Fermi sources: a different AGN population or first signals from dark matter?	C2551
Burke-Spolaor, Johnston	The search for a supernova remnant Around PSR J0824-2454	C2560
Huynh, Norris, Emonts, Mao, Coppin, Smolcic	Tracing molecular gas in high-redshift (z > 4) submillimeter galaxies	C2561
Smolcic, Bertoldi, Huynh, Schinnerer, Strom	Molecular gas in high-redshift (z>4) submillimeter galaxies	C2565
Shannon, Johnston	CAPES: The Compact Array Pulsar Emission Survey	C2566
Uscanga, Gomez, Miranda, Torrelles, Gomez, Anglada, Tafoya, Suarez, Boumis	Confirmation of the association of water masers with the planetary nebulae IRAS 12405-6219 and IRAS 16333-4807	C2567
Burke-Spolaor, Hobbs, Ekers, Godfrey	PKS 0637–752: Supermassive binary black hole or jet shocks?	C2568
Anderson, Gaensler, Feain	RM synthesis as a probe of active galactic nuclei	C2570
Robbins, Gaensler, Murphy, Moss, Reeves, Miller	Multi-wavelength imaging of the newly discovered young supernova remnant G306.3-0.9	C2572
Reeves, Murphy, Koribalski, Sadler, Allison, Emonts	A search for HI absorption in gas-rich galaxies from HIPASS	C2573
Feain, Gaensler, Norris, Nulsen, O'Sullivan, Hardcastle, Croston, Anderson, Jiraskova, Kraft	Energies and acceleration mechanisms in parts of Centaurus A's lobes	C2575
Macquart, Edwards, Bock, Madejksi, Nalewajko, Sikora	The origin of the strong gamma-ray emission in the Fermi blazars PKS 1510-089 and AO0235+164	C2576
Chitsazzadeh, Friesen, Bourke, Di Francesco, Schnee	Ammonia observations of a super-Jeans starless core in L1689	C2578
Ng, Gaensler, Slane	Anatomy of the 'cosmic hand'	C2579
Norris, Lenc, Feain, Chow, Emonts, Mao	CO in the ultraluminous infrared galaxy IRAS F00183-7111	C2580
Edwards, Stevens, Cheung, Dubus, Corbet	ATCA monitoring of the new gamma-ray binary 1FGL J1018.6-5856	C2581
Hunstead, Green, Saripalli, Schaefer	Giant radio galaxies from SUMSS	C2583
Ravi, Hobbs, Keith, van Straten, Stevens, Khoo	Baseband pulsar timing with the ATCA	C2584
Kale, Paul	ATCA 2-GHz survey of extreme galaxy clusters from the SPT sample	C2585
Dawson, Mcclure-Griffiths, Jones, Dickey, Cunningham, Jones	The atomic-to-molecular transition: Anatomy of a forming molecular cloud	C2586
Wolfinger, Kilborn, Koribalski	Studying the HI content of the NGC 4930 group	C2587
Cseh, Corbel, Kaaret, Miller, Mushotzky, Lang, Grise	Radio nebulae around ultraluminous X-ray sources	C2588
Horiuchi, Green, Young	Imaging star forming sites in the Carina molecular complex	C2589
Paul, Bagchi, Datta, Iapichino	Probing phases of major galaxy cluster mergers with ATCA	C2590
Koerding, Tzioumis, Miller-Jones, Woudt, Strom, De Bude	Radio emission from the dwarf nova VW Hyi in super outburst	C2593
Carrasco-Gonzalez, Gomez, Torrelles, Anglada, Rodriguez, Marti	Mapping the magnetic field in massive protostellar jets	C2594
Mezcua, Lopez-Sanchez	HI observations of X-shaped and double-double radio galaxies: traces of merging and gas outflows	C2595
Polychroni, Pestalozzi, Busquet, Molinari, Elia, Schisano, Rygl	Ammonia observations towards Herschel cores in Orion A	C2596
Calvelo, Tzioumis, Broderick, Fender	Revealing the twisted outflows of Circinus X-1: a twin of SS 433	C2597
Malu, Rottgering	ATCA SZ Effect survey of southern radio relic Clusters	C2599
Sugiyama, Dodson, Ellingsen, Fujisawa, Rioja, Hachisuka	Overall spatial distribution and magnetic field direction of the 6.7 GHz methanol masers	C2600
Malu, Kale	The peculiar radio halo cluster MACS J0417-1154	C2602
Wilcots, Kaczmarek	Interactions and bars in Magellanic spiral galaxies	C2603
Nesvadba, Bryant, De Breuck, Hunstead, Johnston, Lehnert, Collet	Jets and AGN feedback at high-z: the role of radio power	C2604
Stierwalt, Cluver, Howell, Privon, Armus, Evans	The coupling of gas reservoirs and star formation in local LIRGs	C2605
Villar Martin, Perez Torres, Emonts, Rodriguez, Humphrey	The molecular gas content of 3 SDSS type 2 quasars at z~0.3	C2607
Bray, Hobbs, Ravi, Lo	Wideband observations of CU Virginis	C2610

OBSERVERS	PROGRAM	NO.
Perez-Sanchez, Chapman, Vlemmings	Probing the magnetic field structure of the water fountain IRAS 15445-5449	C2617
Toala , Guerrero, Sanchez-Monge, Cappa	Studying the interestellar medium around Wolf-Rayet 40	C2618
Mahony, Sadler, Morganti, Ekers, Curran, Allison, Chow, Emonts	First systematic deep search for high-z CO absorption	C2620
Petrov, Murphy, Mcconnell, Edwards, Sadler, Taylor, Mahony, Ferrara, Kovalev, Schinzel	ATCA observations of Fermi unassociated sources	C2624
Smolcic, Bremer, Birkinshaw, Raychaudhury, Horellou, Rottgering, Pacaud, Mcgee, Lidman, Pierre, Chiara, Comastri	ATCA-XXL pilot project: constraining black hole growth and feedback processes through cosmic times	C2627
Loinard, Menten, Rodriguez, Zapata, Kaminski	Molecules in Eta Carinae	C2634
Hoq, Rathborne, Jackson, Foster, Sanhueza	Chemical oddballs in the late stages of star formation	C2635
Rathborne, Walsh, Alves, Testi, Jackson, Foster, Longmore, Bally, Bastian, Bressert	Initial conditions within a massive, arches-like protocluster	C2639
Muller, Henkel, Menten, Curran, Beelen, Aalto, Combes, Guelin, Black, Horellou, Longmore, Ubachs, Bagdonaite, Murphy, Wiklind	Constraining the cosmological variations of the proton-to-electron mass ratio using methanol	C2642
Johnston, Keto, Beuther, Wood, Linz, Boley, Robitaille, van Boekel	Probing the effect of ionization on the circumstellar structure of the massive embedded star AFGL 4176	C2646
Fender, Tzioumis, Calvelo, Munoz Darias, Gallo	Black hole jet production at the lowest luminosities: a new nearby candidate in SWIFT J1357.2-0933	C2647
Mao, Mcclure-Griffiths, Dawson, Zweibel, Hill	The magnetic field of the supergiant shell LMC 5 in the Large Magellanic Cloud	C2648
Jones, Dickey, Anderson, Bania	Recombination lines from two distant HII Regions	C2650
De Breuck, Weiss, Marrone, Mcintyre, Vieira, Greve, Aravena, Chapman, Aguirre, Bothwell	Unveiling the cold molecular gas emission in two highly magnified star forming galaxies at z~2.7	C2655
Wang, Beuther, Zhang, Henning, Bik, Jiang	Evolutionary processes in high-mass star formation: the very luminous region G10.3	C2660
Salter, Bock, Chandler, Mundy	Evolution of the synchrotron spectrum from colliding magnetospheres	C2662
Tobin, Bourke, Mader, Arce, Chen	Probing binary star formation in its earliest phase: high-resolution observations of dense gas kinematics in BHR71	C2665
Hill, Gaensler, Mcclure-Griffiths, Sun	Breakup of a magnetised high velocity cloud	C2666
Norris, Wall, Mao, Kellermann, Condon, Seymour, Vernstrom	Are diffuse sources responsible for the ARCADE excess emission?	C2669
Bell, Gaensler, Murphy, Trott, Hancock	A blind survey for variable radio sources at 5 GHz	C2670
Haan, Hibbard, Braun, Cluver, Stierwalt, Privon, Armus, Evans, Rich, Diaz-Santos, Frayer, Sanders, Surace	GOALS-3D: ATCA HI survey of interacting local LIRGs	C2671
Hatsukade, Kohno, Ohta, Nakanishi, Tamura, Hashimoto	Unveiling hidden star formation in host galaxies of dark gamma-ray bursts	C2672
Massardi, Ricci, De Zotti, White, Michalowski, Ivison, Baes, Lapi, Temi, Lopez-Caniego, Herranz, Seymour, Gonzalez-Nuevo, Bonavera, Negrello	ATCA follow-up of blazar candidates in the H-ATLAS fields	C2673
Purcell, Gaensler, Mcclure-Griffiths, Sun, Hill, Burkhart, Lazarian	Measuring the turbulent ISM via polarised radio-emission	C2676
Franzen, Murphy, Sadler, Chhetri, Mahony	Multi-frequency follow-up of extragalactic sources from the AT20G-deep pilot survey	C2677
Rathborne, Jackson, Foster, Freeland	Imaging outflows associated with Green Fuzzies	C2678
Macario, Johnston-Hollitt, Venturi, Brunetti, Dallacasa, Brown, Pratt, Ferrari, Cassano, Giacintucci, Arnaud	Searching for radio halos in the Macs-Planck X-ray luminous cluster sample	C2679
Webb, Lenc, Corbel, Fender, Heywood, Farrell, Cseh, Godet, Barret	Understanding the radio jets of the intermediate mass black hole ESO 243-49 HLX-1: NAPA observations	C2683
Hancock, Gaensler, Murphy, Bell, Burlon, De Ugarte Postigo	ATCA observations of the brightest, shortest and highest redshift GRBs	C2689
Prinz, Becker	Radio follow-up observations of X-ray selected supernova remnant candidates	C2690
Gomez, Green, Miranda, Suarez, Bendjoya, Uscanga	Polarisation properties of planetary nebulae with OH maser emission	C2691

OBSERVERS	PROGRAM	NO.
Ricci, Maddison, Wilner, Testi, Carpenter	Constraining the collisional models of planetesimals through an ATCA survey of debris disks	C2694
Stanway, Davies	Local analogues for the z>4 Lyman Break Galaxy population	C2695
Seymour, Norris, Braun, Emonts, Huynh, Symeonidis	Characterising radio emission from z=0.2-0.5 ULIRGs	C2696
Ryder, Gaensler, Murphy, Stockdale, Hancock, Burlon	Late-time radio observations of core-collapse supernovae	C2697
Sun, Gaensler, Mcclure-Griffiths, Purcell, Hill, Burkhart, Lazarian	The energy spectrum and geometrical structure of Galactic turbulent magnetic field	C2698
Michalowski, Van Der Werf, Hjorth, Castro Ceran, Malesani, Xu, Rossi, Savaglio, Stephane, D'Elia, Palazzi, Hunt	The first insight into the atomic gas properties of the host galaxy of gamma-ray burst 980425	C2700
Farrell, Lenc, Koribalski, Webb, Barret, Jurek	Investigating the origin of the intermediate mass black hole ESO 243-49 HLX-1 through HI mapping	C2703
Kilborn, Koribalski, Wong, Wolfinger, Jurek, Jozsa, Denes, Kauffmann, Catinella	Gas accretion in nearby spiral galaxies	C2705
Hancock, Gaensler, Murphy, Kulkarni, Schmidt	The GRB-SNe central engines as revealed by relativistic SNe	C2707
Carretti, Staveley-Smith, Brown	Deep imaging of Abell 3667	C2708

OBSERVATIONS MADE WITH THE PARKES RADIO TELESCOPE

October 2011 to September 2012

OBSERVERS	PROGRAM	NO.
Bailes, Verbiest, Bhat, van Straten	Studies of relativistic binary pulsars	P361
D'amico, Possenti, Manchester, Johnston, Kramer, Sarkissian, Lyne, Burgay, Corongiu, Camilo, Bailes, van Straten	Timing of millisecond pulsars in globular clusters	P427
Burgay, Possenti, Manchester, Kramer, Lyne, Mclaughlin, D'Amico, Camilo, Stairs, Lorimer, Ferdman, Yuen	Timing and geodetic precession in the double pulsar	P455
Hobbs, Manchester, Verbiest, Sarkissian, Bailes, Bhat, Jenet, Keith, Burke-Spolaor, van Straten, Yardley, Ravi, Oslowski, Hotan, Champion, Khoo, Shannon, Chaudhary	A millisecond pulsar timing array	P456
Titov, Lovell, Dickey, Edwards, Jauncey, Ellingsen, Reynolds, Fey, Tingay, Hase, Shabala, Stanford, Dawson, Johnston	Improving the terrestrial and celestial reference frame through southern hemisphere geodetic VLBI observations	P483
Hong, Koribalski, Staveley-Smith, Masters, Macri, Jarrett, Jones, Springob	Mapping mass in the local Universe with 2MASS	P561
Shannon, Possenti, Manchester, Johnston, Hobbs, Keith, Romani, Thompson, Thorsett, Roberts, Weltevrede	Pulsar timing and the Fermi and AGILE missions	P574
Camilo, Johnston, Sarkissian, Reynolds, Ransom, Halpern, Andrews	The remarkably active radio magnetar 1E 1547.0-5408	P602
Wolleben, Gaensler, Mcconnell, Mcclure-Griffiths, Dickey, Carretti, Haverkorn, Han, Fletcher, Leahy, Reich, Taylor, Schnitzeler, Landecker	Parkes 300 to 900 MHz rotation measure survey	P617
Burgay, Possenti, Sarkissian, Israel, Rea, Esposito	Searching for radio pulsations triggered by the X-ray outburst of magnetars	P626
Champion, Possenti, Johnston, Kramer, Burgay, D'amico, Bailes, Bhat, Keith, van Straten, Stappers, Bates, Levin, Milia, Ng, Thornton, Coster	The high time resolution universe	P630
Delhaize, Staveley-Smith, Lopez-Sanchez, Kesteven, Bailes, Hopkins, Meyer, Boyle, van Straten, Bauer, Driver, Robotham	Galaxy evolution — a pathfinder study	P669
Andersson, Carretti, Bhat, Crutcher, Vaillancourt	The magnetic field in Tapia's Globule 2	P736
Hobbs, Manchester, Carretti, Johnston, Sarkissian, Reynolds, Bailes, Keith, van Straten, Oslowski, Jameson, Khoo, Shannon	Instrumental calibration for pulsar observing at Parkes	P737
White	Switched on water masers	P745

OBSERVERS	PROGRAM	NO.
Possenti, Manchester, Johnston, Kramer, Sarkissian, Lyne, Burgay, Corongiu, D'Amico, Camilo, Bailes, van Straten, Milia	A new deep search for millisecond pulsars in globular clusters	P778
Mclaughlin, Johnston, Kramer, Lyne, Burke-Spolaor, Eatough, Stappers, Keane, Miller, Palliyaguru, Young	Transient radio neutron stars	P786
Keith, Possenti, Manchester, Johnston, Verbiest, Kramer, Hobbs, Burgay, Camilo, Stairs, Bailes, Burke-Spolaor, Ferdman, Eatough, Lorimer, van Straten, Stappers, Levin, Champion, Ng	Timing of binary and millisecond pulsars discovered at Parkes	P789
Camilo	Monitoring known X-ray magnetars for intermittent radio emission	P791
Verbiest, Kramer, Antoniadis, Tauris	The mass of PSR J1933-6211	P794
Malu, Carretti, Subrahmanyan, Wieringa, Narasimha	Catching the 'Bullet' with Parkes: a pilot study for large-scale galaxy cluster observations	P804
Ravi, Hobbs, Keith, van Straten, Stevens, Khoo	Baseband pulsar timing with the ATCA	P805
Dawson, Mcclure-Griffiths, Jones, Dickey, Cunningham, Jones	The atomic-to-molecular transition: anatomy of a forming molecular cloud. (Part II: diffuse OH with Parkes)	P806
Breen, Caswell, Green, Ellingsen	Polarisation properties of 6.7- and 12.2-GHz methanol masers in high-mass star formation regions	P807
Xu, Manchester, Hobbs, Han, Han	Parkes search for radio pulsars from unidentified Fermi sources at 50 cm	P809
Knispel, Kramer, Eatough, Keane, Ng, Allen	New pulsars from Einstein@Home	P813
Camilo, Johnston, Ransom, Keith, Ray, Kerr, Ferrara, Shannon	Millisecond pulsar searches in unidentified Fermi sources at high Galactic latitudes	P814
Kerr, Johnston, Bailes, Shannon, Buchner, Den hartog	High-sensivity baseband observations of the Vela Pulsar: a rich dataset for rich science	P816
Dawson, Caswell, Gomez, Mcclure-Griffiths, Jones, Dickey, Cunningham, Green, Carretti, Ellingsen, Walsh, Breen, Hennebelle, Gibson, Jones	SPLASH: a Southern Parkes Large Area Survey in Hydroxyl	P817
Staveley-Smith, Carretti, Bernardi	Mapping the cosmic web	P819
Peters, Allen	Detecting thermal OH emission in the LMC	P820
Tobin, Bourke, Mader, Arce, Chen	Probing binary star formation in its earliest phase: kinematic mapping of the circumbinary core BHR71	P825
Leurini, Jones, Cunningham, Wyrowski, Pillai, Schuller, Testi, Stanke	Temperature distribution in the infrared dark cloud G351.77-00.51	P826

OBSERVATIONS MADE WITH THE MOPRA RADIO TELESCOPE

October 2011 to September 2012

OBSERVERS	PROGRAM	NO.
Barnes, Fukui, Caselli, Molinari, Hernandez, Tan, Yonekura, O'Dougherty, Ma, Butler, Zhang	CHAMP-111 dynamics and chemistry of molecular clump envelopes	M161
Lowe, Bains, Lo, Rathborne, Jones, Cunningham, Minier, Urquhart, Hill, Zavagno, Bontemps, Motte, Fissel	Characterising star formation in the Vela molecular ridge	M401
Indermuehle, Edwards	Maser and flux monitoring at 3 mm, 7 mm and 12 mm	M426
Burton, Rathborne, Simon, Urquhart, Stark, Rowell, Tothill, Pineda, Storey, Langer, Martin, Walker, Kulesa, Stutzki, Hollenbach, Au, Glueck	The Mopra–STO–Nanten2 atomic and molecular gas survey: the formation of giant molecular clouds	M446
Jackson, Lo, Rathborne, Jones, Muller, Cunningham, Brooks, Fuller, Barnes, Menten, Schilke, Garay, Mardones, Minier, Longmore, Wyrowski, Herpin, Hill, Bronfman, Deharveng, Schuller, Motte, Peretto, Bontemps, Wienen, Contreras, Lenfestey, Foster, Sanhueza, Claysmith, Hoq	Millimetre Astronomy Legacy Team 90-GHz survey (MALT 90)	M516
Barnes, Lo, Muller, Cunningham, Fuller, Longmore, Brogan, Indermuehle, Caselli, Molinari, Tan, Lowe, Crutcher, O'Dougherty, Bania	ThrUMMS (MALT110): the Three-mm Ultimate Mopra Milky Way Survey	M566
Fukui, Yamamoto, Kawamura, Torii, Furukawa, Akio, Okuda, Enokiya, Nakamura, Furuhashi, Hanaoka	Molecular gas toward the Trifid Nebula M20 and its ionizing star: a scrutiny of formation of the very young star cluster	M609

OBSERVERS	PROGRAM	NO.
Burton, Jones, Cunningham, Walsh, Tothill, Jones, Crocker, Sultmann	The central molecular one in carbon monoxide	M611
Britton, Voronkov, Linz, Vasyunina	Searching for masers in infra-red dark clouds	M612
Dawson, Mcclure-griffiths, Jones, Dickey, Cunningham, Jones, Jachym, Palouš, Sidorin	The atomic-to-molecular transition: anatomy of a forming molecular cloud. (Part III: CO (J = 1 – 0) with Mopra)	M614
Fukui, Yamamoto, Dawson, Kawamura, Torii, Furukawa, Akio, Okuda, Enokiya, Nakamura, Furuhashi, Hanaoka	A high density molecular line study in the Trifid Nebula M20	M615
Hawkes, Fukui, Burton, Rowell, Walsh, Hayakawa, Maxted, Aharonian, De Wilt	Probing for jet/ISM interactions in the microblazar Circinus X-1	M616
Torii, Fukui, Morris, Enokiya, Nakamura, Furuhashi	A molecular line study of the Double Helix Nebula in the Galactic Center	M617
Baes, Gentile, Allaert, Kuno, Verstappen	Mapping the gas-to-dust ratio in the edge-on spiral galaxy IC2531	M622
Roman-Duval, Hughes, Bolatto, Bernard, Israel, Pineda, Gordon	CO observations of molecular regions not observed by MAGMA in the Large Magellanic Cloud	M624
Belloche, Parise, Tsitali	Will Chamaeleon III ever produce stars?	M627
Benedettini, Burton, Busquet, Caselli, Pezzuto, Viti	Dense cores in Ophiuchus and Chamaeleon molecular clouds: detection and evolutionary trends	M628
Wong, Hughes, Ott, Henkel, Muller, Fukui, Maddison, Kawamura, Looney, Bernard, Paradis, Chu, Gruendl, Pineda, Seale	MAGMITA: An extension of the MAGMA survey to faint clouds	M633
Hawkes, Fukui, Burton, Rowell, Walsh, Djannati-Atai, De Naurois, Gallant, De Ona Wilhelmi, Wagner	HESSJ1808-204 – Extreme particle acceleration from a Magnetar and/or massive stellar cluster?	M634
Fissel, Lo, Jones, Cunningham, Fukui, Ward-Thompson, Minier, Olmi, Schneider, Lowe, Goodman, Devlin, Netterfield, Novak, Pascale, Podevin	Characterising the importance of magnetic fields in star formation in the Vela molecular ridge	M635
Smith, Gomez, Eales, Davies	Mopra Fornax Cluster CO-line legacy survey	M639
Fukui, Torii, Akio, Soga	Molecular gas toward the bright-rimmed cloud BRC 82 illuminated by NGC6231: triggered star formation associated with HII regions	M640
Fuller, Peretto, Lenfestey, Lackington	The kinematics of filamentary molecular clouds	M643
Anderson, Hughes, Ott, Meier	Deep imaging of 30Doradus: structure, UV impact and shocks of the star forming gas	M644
Jones, Fukui, Burton, Rowell, Walsh, Aharonian, De Wilt, Hofverberg, De Ona Wilhelmi	G318.2+0.1: The first unambiguous evidence of a hadronic pevatron?	M645
Torii, Fukui, Furukawa, Akio, Keisuke	Molecular emission towards RCW38 and RCW120: possible candidates of the star formation via cloud-cloud collision	M646
Jones, Fukui, Burton, Rowell, Walsh, Aharonian, De Wilt, Hofverberg	Unveiling the nature of the TeV emitting SNR G15.4+0.1	M647
De wilt, Rathborne, Fukui, Burton, Brooks, Rowell, Walsh, Aharonian, Dawson, Hawkes, Au, Voisin	7-mm survey of dense gas towards Galactic TeV gamma-ray sources	M648
Mizuno, Muller, Onishi, Kawamura, Minamidani, Fujii	Dense molecular clumps associated with the LMC supergiant shell 4	M653
Fujita, Muller, Saito, Kobayashi, Yasui	The origin of gamma rays from young open clusters	M655

VLBI OBSERVATIONS

October 2011 to September 2012

OBSERVERS	PROGRAM	NO.
Ojha, Lovell, Edwards, Kadler	Physics of gamma-ray-emitting AGN	V252
Ellingsen, Caswell, Voronkov, Dodson, Phillips, Green, Dawson, Menten, Shen, Reid, Hachisuka, Goedhart, Walsh, Brunthaler, Chen, Fujisawa, Rioja, Zhang, Xu, Zheng, Honma, Krishnan	Astrometric observation of methanol masers: determining Galactic structure and investigating high-mass star formation	V255
Bhat, Verbiest, Deller, Bailes, Tingay	Measuring the proper motion of the relativistic binary PSR J1141–6545	V256
Petrov, Murphy, Tzioumis, Phillips, Sadler, Kim, Burke-Spolaor, Bietenholz, Pogrebenko, Bertarini, Booth, Fomalont, De witt	LBA calibrator survey 5	V271
Deller, Loinard, Forbrich	The distance to the Coronet Cluster in Corona Australis	V329

OBSERVERS	PROGRAM	NO.
Reines, Deller	Confirming the AGN in the dwarf starburst galaxy Henize 2-10 with the LBA	V429
Kovalev, Phillips, Petrov	2FGL AGNs at parsec scales in the southern sky	V441
Deller, Johnston, Burke-spolaor, Romani, Kerr	LBA parallaxes to probe gamma-ray pulsar physics	V444
Green, Caswell, Hutawarakorn Kramer	Magnetic field properties at the highest resolution	V452
Edwards, Deller, Stevens, Cheung, Dubus, Corbet	A first epoch LBA observation of a new gamma-ray binary	V454
Tzioumis, Bignall, Lovell, Edwards, Phillips, Jauncey, Reynolds, Ekers, Nicolson, Quick, Natusch, Tingay, Reynolds, Kellermann, Gulyaev	High resolution imaging of PKS1934-638	V465
Reeves, Tzioumis, Phillips, Sadler, Braun	The influence of background source size on HI absorption profiles	V466
Shabala, Lovell, Titov, Mccallum, Jauncey, Ellingsen, Godfrey, Stanford	Core shifts in geodetic quasars	V469
Kovalev, Bignall, Edwards, Tzioumis, Phillips, Jauncey, Baan, Lobanov, Gurvits, Giroletti, Giovannini, Zensus, Horiuchi, Kellermann, Sokolovsky, Kardashev	RadioAstron-LBA Space VLBI survey of AGN at the largest angular resolutions	V475
Alakoz, Voronkov, Henkel, Mccallum, Sobolev, Menten, Ellingsen, Baan, Imai, Kostenko, Matveyenko	RadioAstron-LBA maser observations with ultra-high resolution	V477
Gwinn, Tzioumis, Phillips, Kramer, Jauncey, Gupta, Bartel, Buchner, Johnson, Popov, Smirnova, Shishov, Soglasnov	RadioAstron-LBA observations of the Vela pulsar	V479

CDSCC OBSERVATIONS

October 2011 to September 2012

OBSERVERS	PROGRAM	NO.
Tothill, Burton, Green, Horiuchi, Wong	The physical conditions of the Lupus clouds	T199
Lowe, Lo, Jones, Cunningham, Burton, Urquhart, Hill, Redman, Horiuchi, Tothill	Temperatures of dense cores in the G333 giant molecular cloud	T200
Tarchi, Horiuchi, Panessa, Castangia, Braatz, Columbano	NLSy1 galaxies vs. H_2O masers: a prolific sample for new detections	T201
Bendjoya, Gomez, Rizzo, Suarez, Chesneau, Niccolini, Abe, Rivet, Stee	Water maser survey in young debris disks for exoplanet detection	T202
Hagiwara, Horiuchi	H_2O maser survey of narrow-line Seyfert 1 galaxies	T203
Engels, Green, Menten, Maercker, Nyman, Horiuchi,	H_2O maser observations of bright southern late-type stars	T207

E: Postgraduate students

PHD STUDENTS CO-SUPERVISED BY CASS STAFF IN 2012

NAME	UNIVERSITY	PROJECT TITLE
Craig Anderson	University of Sydney	Radio polarimetry and rotation measure synthesis as probes of inner AGN structure
Jay Blanchard	University of Tasmania	Linking the radio and gamma-ray properties of blazars
Justin Bray	University of Adelaide	Ultrahigh energy neutrinos and their detection with the lunar Cherenkov technique
Tui Britton	Macquarie University	Methanol masers in star-forming regions
Paul Brook	University of Oxford, UK	Variability in pulsars
Jordan Collier	University of Western Sydney	The history of supermassive black holes in the Universe
Paul Coster	Swinburne University of Technology	Accelerated searches for the most relativistic binary pulsars using next-generation instrumentation
Helga Denes	Swinburne University of Technology	Global HI properties of galaxies in the southern sky
Xinping Deng	Chinese Academy of Sciences, China	Pulsar timing and its application in spacecraft navigation
Phoebe de Wilt	University of Adelaide	Investigating the connection between star forming regions and unidentified TeV gamma-ray sources
Guillaume Drouart	European Southern Observatory, Germany	AGN and stellar components in HzRGs
Christopher Hales	University of Sydney	Deep imaging of the radio sky in total intensity and linear polarisation
Christopher Jordan	James Cook University	CS(1-0) observations with MALT-45: a 7-mm survey of the southern Galaxy
Dane Kleiner	Monash University	The large-scale structure's effect on the HI content of galaxies
Vasaant Krishnan	University of Tasmania	Astrometric observation of methanol masers
Vicki Lowe	University of New South Wales	The environments of massive star formation
Vanessa Moss	University of Sydney	Low and intermediate velocity HI clouds in the Milky Way
Stefan Oslowski	Swinburne University of Technology	The highest precision pulsar timing
Nipanjana Patra	Raman Research Institute, India	Measurement of spectral features in the cosmic radio background
Emily Petroff	Swinburne University of Technology	Our dynamic galaxy
Hayden Rampadarath	Curtin University	Application of wide-field VLBI
Vikram Ravi	University of Melbourne	Evincing the history of massive black hole and galaxy populations with gravitational waves
Sarah Reeves	University of Sydney	HI and OH absorption line studies of nearby galaxies
Dan Thornton	University of Manchester, UK	Pulsar and transient searching with GPUs
Anita Titmarsh	University of Tasmania	Investigating the earliest stages of massive star formation
Catarina Ubach	Swinburne University of Technology	A multi-wavelength study of grain growth in protoplanetary discs
Jingbo Wang	Chinese Academy of Sciences, China	Pulsar glitches and the gravitational-wave memory effect
Marion Wienen	University of Bonn, Germany	Multi-wavelength follow-ups to the APEX Telescope Large Area Survey: the Galaxy
Kathrin Wolfinger	Swinburne University of Technology	The effect of environment on the evolution of nearby gas-rich spiral galaxies
Graeme Wong	University of Western Sydney	Physics and chemistry of molecular gas in the Milky Way Galaxy
Meng Yu	Peking University, China	Pulsar X-ray thermal emission in a solid quark star model and glitches in southern radio pulsars
Rai Yuen	University of Sydney	Investigation on pulsar magnetosphere
Peter-Christian Zinn	Ruhr University Bochum, Germany	New avenues in galaxy evolution studies: large-scale magnetic fields and properties of high-redshift radio emitters

F: PhD theses

PHD THESES OF STUDENTS CO-SUPERVISED BY CASS STAFF IN 2012

Chhetri, Rajan (University of New South Wales, June 2012). "Quasars, radio galaxies and gravitational lenses in the high radio frequency Universe".

Contreras, Yanett (University of Chile, May 2012). "The nature of filamentary structures of dense molecular gas in the Galactic plane".

Chow, Kate (née Randall) (University of Sydney, March 2012). "The evolution of young radio sources and the milliJansky radio source population".

Guzman, Andreas (University of Chile, January 2012). "Ionized jets and molecular outflows in high-mass young stellar objects".

Hindson, Luke (Hertfordshire University, June 2012). "The G305 star forming complex: A panoramic view of the environment and star formation".

Levin, Lina (Swinburne University of Technology, June 2012). "A search for radio pulsars: From millisecond pulsars to magnetars".

Mao, Minnie (University of Tasmania, May 2012). "Cosmic evolution of radio sources in ATLAS".

G: Publications

PAPERS PUBLISHED IN REFEREED PUBLICATIONS

This list includes refereed papers with data from, or related to, ATNF facilities and other staff papers.

* Indicates publication with CASS staff (not including CASS staff based at CDSCC)

C = Compact Array, M = Mopra, P = Parkes, V = VLBI, A = ASKAP, S = SKA, O = other staff paper

*Abramowski, A.; Acero, F.; Aharonian, F.; Akhperjanian, A. G.; Anton, G.; Balzer, A.; Barnacka, A.; Barres de Almeida, U.; Becherini, Y.; Becker, J. and 201 coauthors. “A multiwavelength view of the flaring state of PKS 2155-304 in 2006”. A&A, 539, 149 (2012). (C)

*Ackermann, M.; Ajello, J.; Ballet, G.; Barbiellini, D.; Bastieri, A.; Belfiore; Bellazzini, B.; Berenji, R.D. and 57 coauthors. “Periodic emission from the Gamma-Ray Binary 1FGL J1018.6–5856”. Science, 335, 189-193 (2012). (O)

*Agliozzo, C.; Umana, G.; Trigilio, C.; Buemi, C.; Leto, P.; Ingallinera, A.; Franzen, T.; Noriega-Crespo, A. “Radio detection of nebulae around four luminous blue variable stars in the Large Magellanic Cloud”. MNRAS, 426, 181-186 (2012). (C)

*Ainsworth, R.E.; Scaife, A.M.M.; Ray, T.P.; Buckle, J.V.; Davies, M.; Franzen, T.M.O.; Grainge, K.J.B.; Hobson, M.P.; Shimwell, T. and 12 coauthors. “AMI radio continuum observations of young stellar objects with known outflows”. MNRAS, 423, 1089-1108 (2012). (O)

*Allison, J.R.; Curran, S.J.; Emonts, B H.C.; Geréb, K.; Mahony, E.K.; Reeves, S.; Sadler, E.M.; Tanna, A.; Whiting, M.T.; Zwaan, M.A. “A search for 21 cm HI absorption in AT20G compact radio galaxies”. MNRAS, 423, 2601-2616 (2012). (C)

*Allison, J R.; Sadler, E.M.; Whiting, M.T. “Application of a bayesian method to absorption spectral-line finding in simulated ASKAP data”. PASA, 29, 221-228 (2012). (A)

*Alves, M.I.R.; Davies, R.D.; Dickinson, C.; Calabretta, M.; Davis, R.; Staveley-Smith, L. “A derivation of the free-free emission on the Galactic plane between l= 20° and 44°”. MNRAS, 422, 2429-2443 (2012). (P)

*Anderson, G.E.; Gaensler, B.M.; Slane, P.O.; Rea, N.; Kaplan, D.L.; Posselt, B.; Levin, L.; Johnston, S.; Murray, S.S.; Brogan, C.L. and 22 coauthors. “Multi-wavelength observations of the radio magnetar PSR J1622-4950 and discovery of its possibly associated supernova remnant”. ApJ, 751, 53 (2012). (C)

*Argo, M.; Hollow, R. “Astronomy outreach in the remote mid west region of Western Australia”. CAPJ, 12, 16 (2012). (O)

Auld, R.; Smith, M.W.L.; Bendo, G.; Pohlen, M.; Wilson, C.; Gomez, H.; Cortese, L.; Morganti, R.; Baes, M.; Boselli, A. and 11 coauthors. “Herschel observations of Cen A: stellar heating of two extragalactic dust clouds”. MNRAS, 420, 1882-1896 (2012). (C)

Bagchi, M.; Nieves, A.C.; McLaughlin, M. “A search for dispersed radio bursts in archival Parkes Multibeam Pulsar Survey data”. MNRAS, 425, 2501-2506 (2012). (P)

*Bannister, K.W.; Murphy, T.; Gaensler, B.M.; Reynolds, J.E. “Limits on prompt, dispersed radio pulses from gamma-ray bursts”. ApJ, 757, 38 (2012). (P)

*Barger, K.A.; Haffner, L.M.; Wakker, B.P.; Hill, A.S.; Madsen, G.J.; Duncan, A.K. “Present-day galactic evolution: Low-metallicity, warm, ionized gas inflow associated with high-velocity Cloud Complex A”. ApJ, 761, 145 (2012). (O)

*Batejat, F.; Conway, J.E.; Rushton, A.; Parra, R.; Diamond, P.J.; Lonsdale, C.J.; Lonsdale, C.J. “Rapid variability of the compact radio sources in Arp220. Evidence for a population of microblazars?”. A&A, 542, L24 (2012). (O)

*Bates, S.D.; Bailes, M.; Barsdell, B.R.; Bhat, N.D.R.; Burgay, M.; Burke-Spolaor, S.; Champion, D.J.; Coster, P.; D’Amico, N.; Jameson, A. and 12 coauthors. “The high time resolution universe pulsar survey - VI. An artificial neural network and timing of 75 pulsars”. MNRAS, 427, 1052-1065 (2012). (P)

*Battistelli, E.S.; Carretti, E.; de Bernardis, P.; Masi, S. “Large radio telescopes for anomalous microwave emission observations”. AdAst., 2012, id 607384 (2012). (P)

*Beardsley, A.P.; Hazelton, B.J.; Morales, M.F.; Capallo, R.J.; Goeke, R.; Emrich, D.; Lonsdale, C.J.; Arcus, W.; Barnes, D.; Bernardi, G.; Stevens, J. and 38 coauthors. “A new layout optimization technique for interferometric arrays, applied to the Murchison Widefield Array”. MNRAS, 425, 1781-1788 (2012). (O)

Benedettini, M.; Pezzuto, S.; Burton, M.G.; Viti, S.; Molinari, S.; Caselli, P.; Testi, L. “Multiline spectral imaging of dense cores in the Lupus molecular cloud”. MNRAS, 419, 238-250 (2012). (M)

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*Blake, C.; Brough, S.; Colless, M.; Contreras, C.; Couch, W.; Croom, S.; Croton, D.; Davis, T.M.; Drinkwater, M.J.; Jurek, R.J. and 16 coauthors. “The WiggleZ Dark Energy Survey: joint measurements of the expansion and growth history at z < 1”. MNRAS, 425, 405-414 (2012). (O)

*Blanchard, J.M.; Lovell, J.E.J.; Ojha, R.; Kadler, M.; Dickey, J.M.; Edwards, P.G. “High resolution rapid response observations of compact radio sources with the Ceduna Hobart Interferometer (CHI)”. A&A, 538, 150 (2012). (C)

Bozzetto, L.M.; Filipovic, M.D.; Crawford, E.J.; De Horta, A.Y.; Stupar, M. “Multifrequency radio observations of SNR J0536-6735 (N 59B) with associated pulsar”. Serb.Astron., 184, 69-76 (2012). (C)

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Bozzetto, L.M.; Filipovic, M.D.; Crawford, E.J.; Payne, J.L.; de Horta, A.Y.; Stupar, M. “Radio continuum observations of LMC SNR J0550-6823”. RevMexAA, 48, 41-46 (2012). (C)

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*Breen, S.L.; Ellingsen, S.P.; Caswell, J.L.; Green, J.A.; Voronkov, M.A.; Fuller, G.A.; Quinn, L.J.; Avison, A. “12.2-GHz methanol maser MMB follow-up catalogue. I. Longitude range 330° to 10°”. MNRAS, 421, 1703-1735 (2012). (P)

*Breen, S.L.; Ellingsen, S.P.; Caswell, J.L.; Green, J.A.; Voronkov, M.A.; Fuller, G.A.; Quinn, L.J.; Avison, A. “12.2-GHz methanol maser Methanol Multibeam follow-up catalogue. II. Longitude range 186-330”. MNRAS, 426, 2189-2207 (2012). (P)

*Brunetti, G.; Blasi, P.; Reimer, O.; Rudnick, L.; Bonafede, A.; Brown, S. “Probing the origin of giant radio haloes through radio and gamma-ray data: the case of the Coma cluster”. MNRAS, 426, 956-968 (2012). (O)

*Burke-Spolaor, S.; Johnston, S.; Bailes, M.; Bates, S.D.; Bhat, N.D.R.; Burgay, M.; Champion, D.J.; D’Amico, N.; Keith, M.J.; Kramer, M. and 5 coauthors. “The High Time Resolution Universe Pulsar Survey - V. Single-pulse energetics and modulation properties of 315 pulsars”. MNRAS, 423, 1351-1367 (2012). (P)

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*Camera, S.; Santos, M.G.; Bacon, D.J.; Jarvis, M.J.; McAlpine, K.; Norris, R.P.; Raccanelli, A.; Röttgering, H. “Impact of redshift information on cosmological applications with next-generation radio surveys”. MNRAS, 427, 2079-2088 (2012). (A)

*Camilo, F.; Kerr, M.; Ray, P.S.; Ransom, S. M.; Johnston, S.; Romani, R.W.; Parent, D.; DeCesar, M.E.; Harding, A.K.; Donato, D. and 7 coauthors. “PSR J2030+3641: Radio discovery and gamma-ray study of a middle-aged pulsar in the now identified fermi-LAT source 1FGL J2030.0+3641”. ApJ, 746, 39 (2012). (O)

*Camilo, F.; Ransom, S.M.; Chatterjee, S.; Johnston, S.; Demorest, P. “PSR J1841-0500: A radio pulsar that mostly is not there”. ApJ, 746, 63 (2012). (P)

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*Casey, C.M.; Berta, S.; Béthermin, M.; Bock, J.; Bridge, C.; Burgarella, D.; Chapin, E.; Chapman, S.C.; Clements, D.L.; Conley, A.; Seymour, N. and 21 coauthors. “A population of z > 2 far-infrared Herschel-SPIRE-selected starbursts”. ApJ, 761, 139 (2012). (O)

*Cassano, R.; Brunetti, G.; Norris, R.P.; Röttgering, H.J.A.; Johnston-Hollitt, M.; Trasatti, M. “Radio halos in future surveys in the radio continuum”. A&A, 548, A100 (2012). (A)

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H: Media releases

CASS/ATNF MEDIA RELEASES ISSUED IN 2012

Cosmic magnetism attracts student (2 February 2012)

A CSIRO summer student has been tackling one of the most challenging problems in astrophysics: the relationship between galaxies and their magnetic fields.

http://www.csiro.au/Portals/Media/Cosmic-magnetism-summer-student.aspx

Korean connection makes an 8000-km telescope (15 March 2012)

Australian and Korean radio telescopes have been linked for the first time, forming a system that acts as a telescope 8,000 km across.

http://www.csiro.au/en/Portals/Media/Korean-connection-makes-an-8000-km-telescope.aspx

Dual SKA site welcomed by CSIRO (26 May 2012)

The A$2.5 billion Square Kilometre Array radio telescope will be deployed in Australia-New Zealand, as well as South Africa, the international SKA Organisation in Manchester, UK, announced yesterday.

http://www.csiro.au/en/Portals/Media/Dual-SKA-site-welcomed-by-CSIRO.aspx

There's more star-stuff out there but it's not Dark Matter (30 May 2012)

More atomic hydrogen gas — the ultimate fuel for stars — is lurking in today's Universe than we thought.

http://www.csiro.au/en/Portals/Media/Atomic-hydrogen-gas.aspx

Belching black hole proves a biggie (5 July 2012)

Observations with CSIRO's Australia Telescope Compact Array have confirmed that astronomers have found the first known 'middleweight' black hole.

http://www.csiro.au/en/Portals/Media/Belching-black-hole-proves-a-biggie.aspx

I: Abbreviations

AAL	Astronomy Australia Ltd
AAO	Australian Astronomical Observatory
AARNet	Australia's Academic and Research Network
ACMA	Australian Communications and Media Authority
ADASS	Astronomical Data and Software Systems
AGN	Active Galactic Nuclei
AIPS	Astronomical Image Processing System
ALFA	Arecibo L-band Feed Array
ALMA	Atacama Large Millimetre Array
ANZSCC	Australia – New Zealand SKA Coordination Committee
APSR	ATNF Parkes Swinburne Pulsar Recorder
ARC	Australian Research Council
ASCC	Australian SKA Coordination Committee
ASDAF	ASKAP Science Data Archive Facility
ASKAIC	Australasian SKA Industry Consortium
ASKAP	Australian Square Kilometre Array Pathfinder
ATCA	Australia Telescope Compact Array
ATLAS	Australia Telescope Large Area Survey
ATNF	Australia Telescope National Facility
ATSC	Australia Telescope Steering Committee
ATUC	Australia Telescope User Committee
BETA	Boolardy Engineering Test Array
CABB	Compact Array Broadband Backend
CALOSIS	Centaurus A Synthesis Imaging Survey
CASS	CSIRO Astronomy and Space Science
CDSCC	Canberra Deep Space Communication Complex
CDF-S	Chandra Deep Field South
CMIS	CSIRO Mathematical and Information Sciences
CSOF	CSIRO Officer
CONRAD	Convergent Radio Astronomy Demonstrator
CoRE	Cosmological Reionization Experiment
COSMOS	Cosmological Evolution Survey
COSPAR	Committee on Space Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAS	Data Acquisition Systems
DFB	Digital Filterbank
DBCDE	Department of Broadband, Communications and the Digital Economy
DIISRTE	Department of Innovation, Industry, Science, Research and Tertiary Education
DSN	Deep Space Network
EIF	Education Investment Fund
EDGES	Experiment to Detect the Global Epoch of Reionization Signature
ELAIS	European Large Area ISO Survey
e-MERLIN	Extended Multi-Element Radio Linked Interferometer
EPICS	Experimental Physics and Industrial Control System
ESO	European Southern Observatory
EU SKADS	European SKA Design Study
FARADAY	Focal-plane Arrays for Radio Astronomy: Design, Access and Yield
FIR	Far Infrared
FITS	Flexible Image Transport System
FPA	Focal Plane Array
FPGA	Field Programmable Gate Arrays
FTE	Full Time Equivalent
GASS	Galactic All Sky Atomic Hydrogen Survey
GW	Gravitational Wave
HEMT	High Electron Mobility Transistor
HI	Neutral Hydrogen
HIPASS	HI Parkes All Sky Survey
HIZOA	HI Zone of Avoidance
HPC	High Performance Computing
HSE	Health, Safety and Environment
HVC	High Velocity Clouds
IAU	International Astronomical Union
ICIP	Industry Cooperative Innovation Programme
ICRAR	International Centre for Radio Astronomy Research
ICTC	Information and Communications Technology Centre
IEEE	Institute of Electrical and Electronics Engineers
IFRS	Infrared Faint Radio Sources
InP	Indium Phosphide
ISM	Interstellar Medium
ISSC	International SKA Steering Committee
IT	Information Technology
ITU	International Telecommunications Union
IUCAF	Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Sciences
IVS	International VLBI Service
JIVE	Joint Institute for VLBI in Europe
JPL	Jet Propulsion Laboratory
KAT	Karoo Array Telescope
LBA	Long Baseline Array, used for Australian VLBI observations
LFD	Low Frequency Demonstrator
LNA	Low Noise Amplifier
LO	Local Oscillator
LOFAR	Low Frequency Array
LOFAR DMT	Low Frequency Array Dark Matter Telescope
LVHIS	Local Volume HI Survey
MASIV	Micro-Arcsecond Scintillation-Induced Variability
MIRIAD	Multichannel Image Reconstruction Image Analysis and Display
MIT	Massachusetts Institute of Technology
MMBS	Methanol Multibeam Survey
MMIC	Monolithic Microwave Integrated Circuit

MNRAS	Monthly Notices of the Royal Astronomical Society
MNRF	Major National Research Facilities
MOPS	Mopra Spectrometer
MRO	Murchison Radio-astronomy Observatory
MSF	Murchison Radio-astronomy Observatory Support Facility
MSP	Millisecond Pulsar
MWA	Murchison Widefield Array
NASA	National Aeronautics and Space Administration
NCRIS	National Collaborative Research Infrastructure Strategy
NRAO	National Radio Astronomy Observatory
NRC-HIA	National Research Council Canada – Herzberg Institute of Astrophysics
NOT	Nordic Optical Telescope, Spain
NSF	National Science Foundation
OCE	CSIRO's Office of the Chief Executive
PAF	Phased Array Feed
PAPER	Precision Array to Probe Epoch of Reionization
PDFB	Pulsar Digital Filterbank
PMPS	Parkes Multibeam Pulsar Survey
PPTA	Parkes Pulsar Timing Array
PrepSKA	Preparatory Phase Studies for the Square Kilometre Array
PTF	Parkes Testbed Facility
RAFCAP	Radio Astronomy Frequency Committee in the Asia Pacific
RFI	Radio Frequency Interference
RSAA	Research School of Astronomy and Astrophysics
SCG	Southern Compact Group
SEST	Swedish-ESO Submillimetre Telescope
SINGS	Spitzer Infrared Nearby Galaxies Survey
SKA	Square Kilometre Array
SKAMP	SKA Molonglo Prototype
TAC	Time Assignment Committee
THEA	Thousand Element Array
TIGO	Transportable Integrated Geodetic Observatory
UCSD	University of California, San Diego
UNSW	University of New South Wales
URSI	International Union of Radio Science
USNO	United States Naval Observatory
VLA	Very Large Array
VLBI	Very Long Baseline Interferometry
VO	Virtual Observatory
VSOP	VLBI Space Observatory Program
WDM	Wavelength Division Multiplexed
WLAN	Wireless Local Area Network
WRC	World Radio Conferences

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