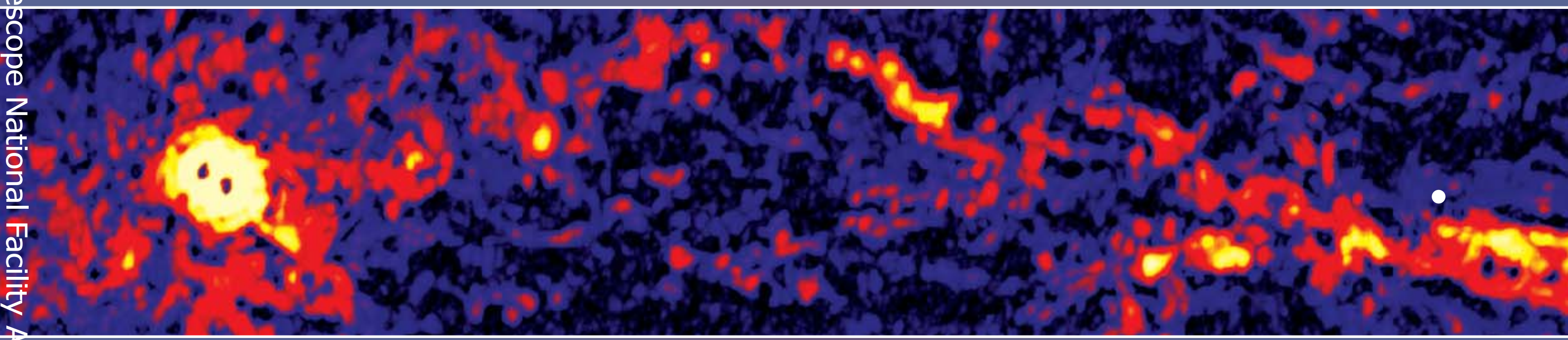
# CSIRO Australia Telescope National Facility



# Annual Report 2005

Australia Telescope National Facility Annual Report 2005


Annual Report 2005
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This is the report of the Steering Committee of the CSIRO Australia Telescope National Facility for the calendar year 2005.

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Cover image

This image shows the distribution of dense molecular gas close to the centre of the Milky Way. The image was made from a mosaic of 840 individual positions observed with the Australia Telescope Compact Array for an area of one degree by 0.2 degrees near the Galactic Centre. The colours represent the strength of ammonia emission from the (1,1) transition. The image has an angular resolution of 19 arcsec and shows the distribution of the molecular clouds across the Galactic Centre region in more detail than has previously been obtained.

The actual centre of the Milky Way, Sagittarius A* is marked by the white circle to the right. The prominent emission toward the left of the map is Sagittarius B2, a very active region in the Galaxy where stars currently form in great number. The "fuel" for star formation is the molecular gas depicted in the map. In turn, the violent processes associated with the formation and early death of stars influence the properties of the molecular gas and the formation of subsequent generations of stars.

Image credit: Jürgen Ott, Lister Staveley-Smith (ATNF), Axel Weiß, Christian Henkel (Max-Planck-Institut für Radioastronomie, Bonn, Germany)

Sunrise at the Compact Array
Photo: © Shaun Amy, CSIRO

# Contents

# Chairman's report

Professor Matthew Bailes,
Chair AT Steering Committee

Photo: © Swinburne University of Technology

2005 has been another great year for the Australia Telescope National Facility as outlined in this beautifully presented report. Independent citation analyses demonstrate that Australian radio astronomy facilities are resulting in publications that are well-cited, with Parkes and the Compact Array ranked only behind the VLA in terms of radio facilities (page 15). The total Australian use of the National facilities has continued to climb (page 13), although it should be noted that University access continues to decline as a lack of investment in the higher education sector continues to bite into senior researchers' time for observing. Today, the role of the National Facility is more imperative than ever before in supporting research in the higher education sector. At a time when Universities are struggling to retain research infrastructure we are very fortunate to have world-class instruments to use free of charge, run on behalf of Australian astronomers by the CSIRO. User satisfaction with these instruments is extremely high as demonstrated by user feedback surveys (pages 18 – 19). The true international nature of the astronomical research undertaken by our astronomers will soon be made obvious to the hierarchy within the higher education sector as we enter the realm of the Research Quality Framework (RQF) exercises. What these will reveal about astronomy and Australian astronomers is that they operate in an internationally-competitive marketplace, and perform extremely well. Whilst many might fear the RQF, I believe it will be an opportunity for Universities to realise the true worth of our nation's astronomers and the excellent research infrastructure they exploit.

In my last report I outlined the inevitable move to large-number small-diameter radio telescope arrays such as the Square Kilometre Array (SKA). The biggest challenge facing the ATNF over the coming decade will be the balance between maintaining our existing facilities such as Parkes and the Compact Array, and investing in new technologies that promise to deliver more science, but not immediately. Australia continues to play a leading role internationally in the SKA project with the ATNF Director now also the Australian SKA Director. The development of a realistic demonstrator in WA can only further the cause. The Steering Committee has been very supportive of moves for Australia to take a leadership role by increasing the scale of the demonstrator to be built in WA.

The ATNF has had spectacular success at breathing new life into its oldest instrument, the Parkes 64-m radio telescope through innovative instrumentation and partnerships with international collaborators like Jodrell Bank as detailed in Dick Manchester's report on the multibeam surveys. Once again, the multibeam collaboration has unveiled a discovery worthy of publication in Nature, the RRATs, Rotating Radio Transients. Also in this report Jessica Chapman and her collaborators outline the discovery of a planetary nebula around an OH/IR star (page 30), while Jurgen Ott and his collaborators used the Mopra millimetre facility to identify 150 individual molecular clouds (page 32). The VLBI team demonstrated the future of VLBI with a spectacular effort to monitor the descent of the Huygen's probe by flying disks of data in the wee hours of the morning across the outback and using international network links to transmit it to the JIVE correlator in Europe (page 36)! New links between the major telescopes on the Eastern seaboard will soon make e-VLBI a normal part of Australian LBA operations. Finally, Kate Brooks and Tony Wong highlight how the new millimetre receivers are yielding new science at the Compact Array (page 38).

I want to spend the last paragraph in my final report as ATNF Steering Committee Chair singing the praises of what I would term the "unsung heroes" of the ATNF, its everyday people. The professionalism and cheerfulness of the staff ranging from the engineers who grease the dish, to the cooks or staff who pick us up from the airport when we come to observe, to the support staff at the ATNF who produce reports such as this are the foundation of this great institution that I have been proud to serve as the Steering Committee Chair.

Matthew Bailes
Chair, ATNF Steering Committee

# Director's report

Professor Brian Boyle, Director of the ATNF

In November 2005 Australian astronomy's Decadal Plan for 2006 – 2015 was published. Compiled with contributions from over 150 astronomers at 20 separate astronomical institutions, it reaffirmed the importance of radio astronomy and the continued operation of the ATNF facilities to the strength of Australian astronomy. It was particularly encouraging to note that the facilities provided by the ATNF (the Parkes radio telescope, Compact Array, Mopra radio telescopes and the Long Baseline Array) accounted for over one quarter of all citations produced by Australian astronomers over the past Decade. The Decadal Plan also identified the Square Kilometre Array and the phased development of world-leading facilities towards this goal, as the high priority radio astronomy project for the next decade. The Decadal Plan remarked on the challenge of operating existing infrastructure while planning for the future:

> *Continued operational support for the existing ATNF telescopes (Parkes, Mopra and Compact Array) is seen as important throughout the next decade. Nevertheless, over this period, resources from these telescopes will increasingly have to be reprioritised into the development and operation of infrastructure on the roadmap to the SKA if Australia is to maintain its world-leading position in radio astronomy. This will ultimately restrict the range of operational modes offered by the ATCA and Parkes to a smaller number of areas where they can still offer world-class performance by the end of the decade.*

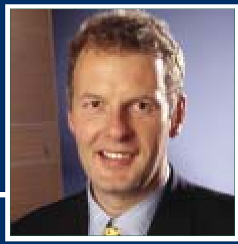
These issues were echoed in CSIRO's 2005 Broad Direction Setting document that acknowledged the importance of Radio Astronomy as a leading science initiative in Australia. As part of the Broad Direction Setting, CSIRO not only expressed its ongoing support for the Australian Telescope National Facility (ATNF) as a research facility for the broader community, but also for the world-class research conducted by ATNF scientists. The Square Kilometre Array (SKA), and its forerunner the extended New Technology Demonstrator (xNTD), were seen as key planks of Australia's determination to remain at the forefront of radio astronomy.

Delivering in the present while planning for the future is a significant challenge. In this Annual Report, you will find plenty of evidence that the ATNF is responding to this challenge in an exemplarily fashion. The ATNF continues to deliver on science (from RRATs to Huygens) on engineering (the delivery of 6-GHz multibeam and 3-mm MMIC receiver in 2005 were each ground-breaking in their own right) and the continued leadership in the SKA domain via engineering programs such as the Compact Array Broadband Backend, the New Technology Demonstrator and the recent submission of a comprehensive proposal for siting the SKA in Australia. Continued success in each of these areas points the way forward for the ATNF, CSIRO and Australian radio astronomy.

Finally, I would like to acknowledge the contribution made to the ATNF by the Steering Committee, User Committee, Time Assignment Committee and Australasian SKA Consortium committee. The advice and insight provided by the members of these committees is highly valued and plays a key role in the continuing success of the ATNF. I would particularly like to acknowledge Matthew Bailes' contribution as Chair of the ATNF Steering Committee for the past three years. He has made a significant contribution to the development of the ATNF's strategy and I look forward to continuing to work with Matthew as the ATNF moves forward.

Brian Boyle
Director, CSIRO ATNF

# ATNF Senior Management Group and Federation Fellows in July 2005



Director
**Brian Boyle**
Photo: © Kristen Clarke

Executive Secretary
**Anne Barends**
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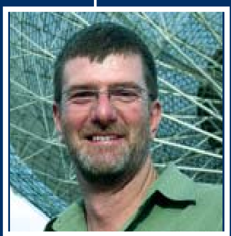
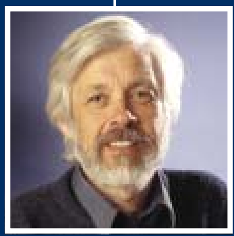
Executive Officer
**Mark McAuley**
Photo: © Mark McAuley

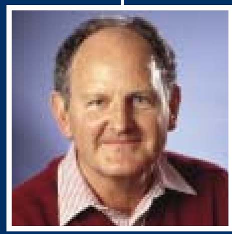


Deputy Director
**Lewis Ball**
Photo: © John Sarkissian



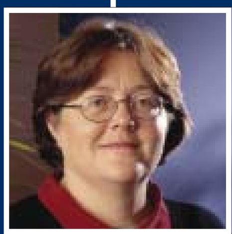
Assitant Director: Operations
**Dave McConnell**
Photo: © Kristen Clarke

Assistant Director: Astrophysics
**Lister Staveley-Smith**
Photo: © Kristen Clarke



Assistant Director: Engineering
**Warwick Wilson**
Photo: © Kristen Clarke

OIC Narrabri
**Bob Sault**
Photo: © David Smyth

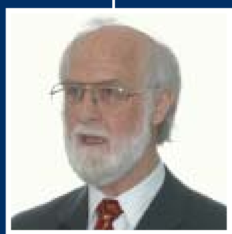


Head, National Facility Support
**Jessica Chapman**
Photo: © Kristen Clarke

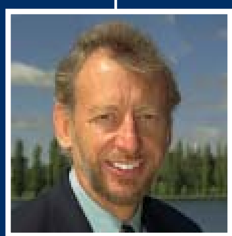
OIC Parkes
**John Reynolds**
Photo: © CSIRO

VLBI Operations and Development
**Tasso Tzioumis**
Photo: © CSIRO

Deputy OIC Narrabri
**Brett Hiscock**
Photo: © CSIRO



Federation Fellow
**Ron Ekers**
Photo: © David Smyth



Federation Fellow
**Dick Manchester**
Photo: © Australian Research Council

# The ATNF in brief

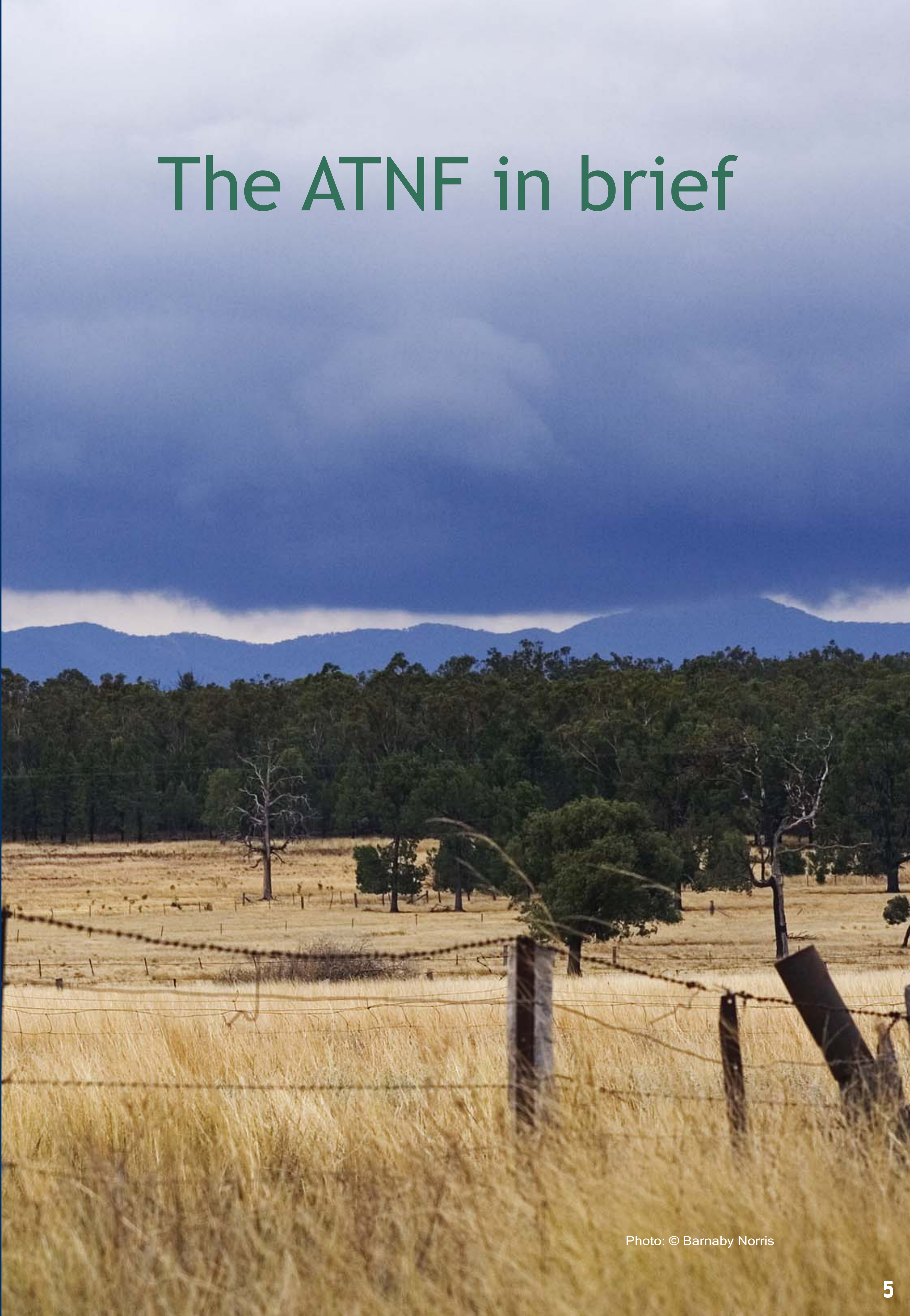


Photo: © Barnaby Norris

The ATNF supports Australia's research in radio astronomy, one of the major fields of modern observational astrophysics. It operates the Australia Telescope, comprising the Compact Array at Narrabri, the Mopra 22-m antenna near Coonabarabran, and the Parkes 64-m radio relescope at Parkes in New South Wales.

## Mission

- To operate and develop the Australia Telescope as a national research facility for use by Australian and international researchers;
- To exploit the telescope's unique southern location and technological advantages to maintain its position as a world-class radio astronomy observatory;
- To further the advancement of knowledge.

## Size and funding

The ATNF employs approximately 180 staff. In 2004 – 2005 the organisation's total expenditure was AUD 28.4M. The total revenue was AUD 25.5M, including a direct appropriation of AUD 22.3M from CSIRO.

## Status within CSIRO

The ATNF is managed as a National Facility by Australia's largest national research institution, CSIRO. Formerly part of the CSIRO Division of Radiophysics, it became a separate division in January 1989.

## Status as a National Facility

The ATNF became a National Facility in April 1990. As a National Facility, the Australia Telescope provides world-class observing facilities in radio astronomy for astronomers at Australian and overseas institutions. The Australia Telescope is operated as a National Facility under guidelines originally established by the Australian Science and Technology Council.

## Users of ATNF telescopes

Observing time on the ATNF's telescopes is awarded to researchers on the basis of the merits of their proposed research programs by a Time Assignment Committee appointed by the Steering Committee. Approximately 90% of the telescopes' users come from outside the ATNF.

## The ATNF in the Australian context

The ATNF is the largest single astronomical institution in Australia. Approximately 90% of Australian radio astronomy is carried out through the ATNF. The organisation has strong links with its primary user base, the university community. The interests of telescope users are represented by the Australia Telescope Users Committee.

The ATNF's Sydney headquarters are co-located with those of the Anglo-Australian Observatory, an independent bi-National Facility that provides world-class optical and infrared facilities. This close association is unique, in world terms, and promotes valuable collaboration between the two organisations.

## The ATNF in the global context

Of the fields of modern astronomy—X-ray, ultraviolet, optical, infrared and radio—Australia makes one of the most significant contributions to world astronomy through radio astronomy. This is a result of Australia's early lead in the field, continuous technological advances, and southern hemisphere location. The Australia Telescope is the only major radio telescope of its kind in the southern hemisphere, and thus can view part of the sky which is out of reach of northern hemisphere telescopes. It provides one of the most powerful radio astronomy facilities in the world.

Australian and international observers use the Australia Telescope without access charges. This is in accordance with a general practice of the worldwide astronomical community, in which telescope users from different countries gain reciprocal access to facilities on the basis of scientific merit. This allows Australian scientists to use telescopes in other countries as well as space-based instruments and other international facilities such as particle accelerators. Such access provides Australian scientists with a diversity of instruments and leads to a rich network of international collaborations.

## The ATNF's observatories

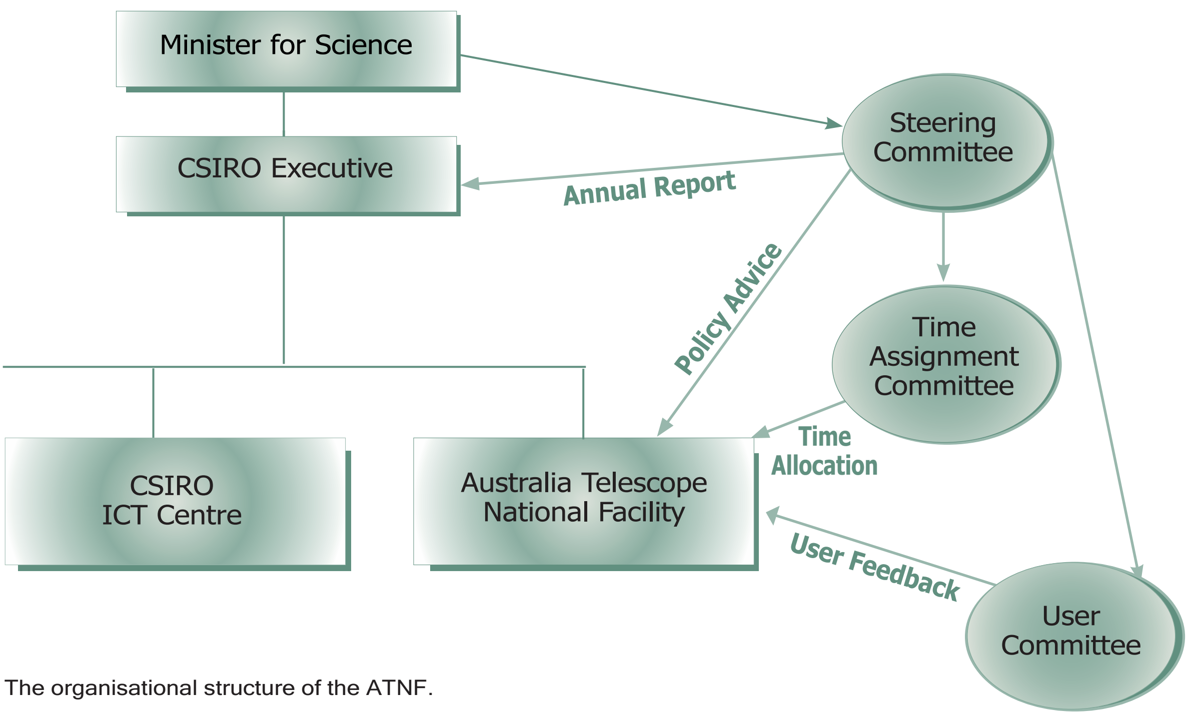
The Australia Telescope consists of eight radio-receiving antennas, located at three sites in New South Wales. Six of them make up the Australia Telescope Compact Array, located at the Paul Wild Observatory near the town of Narrabri. Five of these antennas sit on a 3-km stretch of rail track running east–west, or on a 200-m spur running north of the main track; they can be moved to different points along the track to build up detailed images of the sky. A sixth antenna lies 3 km to the west of the main group. Each of these antennas has a reflecting surface 22 metres in diameter. After the radio signals from space are "collected" by the antennas' surfaces they are transformed into electrical signals, brought together at a central location, and then processed. The end result is usually a picture or a spectrum of the object being studied—a picture equivalent to a photograph, but made from radio waves instead of visible light.

A further 22-m antenna, known as the Mopra telescope, is located near Mopra Rock in the Warrumbungle Mountains near Coonabarabran, New South Wales.

The other key component of the Australia Telescope is the Parkes 64-m radio telescope, located near the town of Parkes. 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, have maintained the telescope as a state-of-the-art instrument.

The eight ATNF telescopes can be used together as the Long Baseline Array (LBA) for a technique known as very long baseline interferometry (VLBI) which is used to obtain high resolution images of small areas of sky.

The LBA is used as part of a larger Australian network of radio telescopes which includes the NASA satellite tracking antennas at Tidbinbilla, near Canberra, and radio antennas in Tasmania, South Australia and Western Australia. The LBA is sometimes also used as part of the Asia-Pacific Telescope which links radio telescopes in Australia, Japan, China, Hawaii and India.




The organisational structure of the ATNF.

## Engineering and technology development

The advance of radio astronomy depends crucially on exploiting the latest technological developments in a range of areas which include electronics, receiver technology, signal detection and processing, control systems, data processing and information technology. The ATNF provides a platform for the development of cutting-edge technology in Australia, and is one of the leaders in the international effort to design, build and operate the next generation of radio-astronomy facilities through its involvement with the Square Kilometre Array (SKA). The SKA is a billion-dollar global project that will provide a radio telescope with a collecting area of about one square kilometre, making it a hundred times more sensitive than any existing radio telescope.

## ATNF Steering Committee

ATNF policy is determined by the ATNF Steering Committee, an independent committee appointed by the Minister for Science. The Committee helps the ATNF develop long-term strategies. The inaugural meeting of the ATNF Steering Committee was held in May 1989. Since then it has met at least once a year, to define the broad directions of the ATNF's scientific activities and the development of the Australia Telescope. It is also responsible for promoting the use of the Facility and, indirectly, for allocating observing time.

The Steering Committee appoints the Australia Telescope Users Committee (ATUC) to provide feedback and advice from the user community, and the Time Assignment Committee (TAC) to review proposals and allocate observing time. The committee members for 2005 are listed in Appendix C.

## Australia Telescope Users Committee

ATUC represents the interests of the Australia Telescope's users. The committee provides feedback to the ATNF Director, discussing problems with, and suggesting changes to, ATNF operations; it also discusses and ranks by scientific merit 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. ATUC reports can be found on the web at www.atnf.csiro.au/management/atuc.

## Time Assignment Committee

The ATNF receives more applications for observing time than it can accommodate: proposals for time on both the Parkes and Narrabri telescopes exceed the time available by a factor of approximately two. The proposals are assessed, and time allocated to them, by the TAC. The TAC reviews typically 130 telescope applications at each meeting.

## Strategic Objectives

In 2005, CSIRO restructured its major activities and funding under "themes", with some themes including work across two or more of the Divisions. Following the changes within CSIRO, the ATNF re-aligned its activities under four separate themes. The strategic objectives of the ATNF by theme (as at end-2005) are:

### National Facility Operations

To continue to operate the world's most productive radio astronomy facility in the Southern Hemisphere in order to serve the Australian and international scientific community.

The ATNF will provide access to its facilities to satisfy the needs of Australian and overseas users. At least 70% of time on the Parkes and Narrabri telescopes will be used for astronomy. Time lost during scheduled observing periods will be kept to below 5%.

### Technologies for radio astronomy

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

Leading edge technology development is an essential component of the ATNF's determination to continue to operate a world-class National Facility for radio astronomy, maintaining the scientific productivity of what is currently the second most productive radio astronomy facility in the world. Contracts and collaborations of a strategic nature with other radio astronomy institutes are also undertaken. These support a broad range of specialist talent within the ATNF, maintain the international communication links necessary to ensure that technological developments at ATNF continue to be state-of-the-art, and recoup some of the development costs.

### Astrophysics

To conduct world-class research in astrophysics, retaining astronomy's position as Australia's highest impact science and furthering our understanding of the Universe through innovative use of CSIRO's telescopes.

The ATNF Astrophysics Group undertakes major observational research projects, many of which involve sizable national and international collaborations. The success of these projects is underpinned by a deep understanding and technical knowledge of the telescope systems. In turn, the knowledge gained is used to provide the scientific case and the technical requirements for new generations of telescopes and instrumentation, ensuring that they deliver maximum scientific impact by targeting the highest priority science questions.

### The xNTD and SKA Phase 1

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

This is an emerging theme that is closely connected to the theme of technologies for radio astronomy. It encompasses activities that are primarily aligned with the SKA development path, concentrating on developing the next generation of radio telescopes at the world's best site for radio astronomy – Mileura in Western Australia. Current work centres on fundamental engineering research through the New Technology Demonstrator project and its development into a scientific instrument – the extended New Technology Demonstrator (xNTD). For low frequency (below 3 GHz) surveys the xNTD will deliver a 20-fold increase in speed over the Australia Telescope Compact Array. The SKA Phase 1 will deliver fundamentally new science, with 10% of the collecting area of the SKA and a uniquely quiet radio environment allowing detailed studies of much fainter features of the radio universe than are possible at present.

## ATNF management changes in 2005

In February 2005 Neil Killeen, the leader of the Marsfield Scientific Computing Group, took leave of absence. Vincent McIntyre took over as group leader.

In May 2005 Baerbel Koribalski was appointed as the Deputy Leader for the Astrophysics Group. Mark McAuley, the ATNF Executive Officer, joined the senior management group with responsibility for finance, business development and project management.

In July 2005 Phil Howson, the ATNF Divisional Secretary, left after 35 years of service in CSIRO. Phil commenced with CSIRO in 1970 in the regional Administrative Office and joined the CSIRO Division of Radiophysics (the precursor to the ATNF) in 1983. Shortly after joining Radiophysics Phil became a member of the Australia Telescope Project team and was strongly involved with the transition to a National Facility.

In July 2005 the ATNF changed to a new management structure, with each of the three themes of the ATNF's activities headed by an Assistant Director. David McConnell took on the new role of Assistant Director: Operations, with responsibility for the Parkes and Narrabri Observatories, the VLBI operations and the National Facility Support group. Warwick Wilson and Lister Staveley-Smith continued to lead the Engineering and Astrophysics themes respectively, with the new titles of Assistant Director: Engineering and Assistant Director: Astrophysics. Lewis Ball replaced Ray Norris as the ATNF Deputy Director. Lewis has specific responsibility for ATNF relationships internal to CSIRO, including coordination of ATNF's input to the Science Investment Process, the new mechanism for distributing funding within CSIRO by research theme rather than by Division.

The new structure also allowed for changes to the governance of Australia's SKA efforts and the ATNF Director, Brian Boyle took on the role of Australian SKA Director with CSIRO assuming the role of contracting body for the SKA.

# Performance indicators

Photo: © Shaun Amy, CSIRO

This chapter describes indicators that are used to assess the performance of the ATNF.

## 1 Scheduled and successfully completed observing time

For the Parkes radio telescope and the Compact Array the ATNF sets a target 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 Parkes and Narrabri, approximately 10% of time is made available in each semester as "Director's time". This is time that is initially reserved in the initial published version of the schedule, but which is later made available for approved observing projects.

### Telescope usage in 2005

| | Compact Array | Parkes | Mopra* |
|---|---|---|---|
| Successful astronomy observations | 83.7% | 82.2% | 62.5% |
| Maintenance/test time | 13.2% | 10.7% | 19.8% |
| Time lost due to equipment | 1.5% | 1.1% | 2.0% |
| Time lost due to weather | 0.9% | 2.4% | 10.6% |
| Idle time | 0.6% | 3.6% | 5.0% |

*Mopra statistics are for dates between 12 May – 11 November, corresponding to the "millimetre season". Following significant improvements to the Mopra radio telescope (page 50) the Mopra downtime due to equipment failure of 2% was considerably less than in 2004 (11.5%).

For most observing programs, observers are required to be present at the Observatory for their observations. For the Compact Array, remote observing is also possible from other sites. In 2005 10.3% of Compact Array scheduled observations were taken remotely.

## 2 Response of the ATNF to recommendations by the Users Committee

The ATNF Users Committee (ATUC) is an advisory group that 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 Director. ATUC considers matters raised by the user community, current operations and priorities for future developments.

In most cases the ATNF accepts and implements ATUC recommendations. In 2004 ATUC made 44 recommendations to the ATNF. Of these, 35 were accepted and completed by December 2005. The other nine recommendations were not adopted by the ATNF.

The ATUC members are listed in Appendix C.

## 3 Time allocation on ATNF facilities

The allocation of time on ATNF facilities is done on the basis of scientific merit. Two six-month observing semesters are held each year, from October to March (OCTS), and from April to September (APRS). For the period from 01 October 2004 to 30 September 2005 a total of 190 proposals were allocated time on ATNF facilities (each proposal is counted once only per calendar year although some proposals are submitted twice). Of these, 114 were for the Australia Telescope Compact Array, 42 were for the Parkes telescope, 23 were for the Mopra telescope and 11 were for the Long Baseline Array.

The ATNF also accepts proposals requesting service observations with the Tidbinbilla DSS43 70-m antenna which is operated by the Canberra Deep Space Communication Complex, as part of the NASA Deep Space Network. During the 2004 OCTS and 2005 APRS semesters service observations were taken for nine programs.

In 2005 the proposals allocated time by the ATNF included at least 400 authors. Of these, approximately

40 authors were from the ATNF, 80 were from 14 other institutions in Australia, and 280 authors were from around 120 overseas institutions in 20 countries.

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

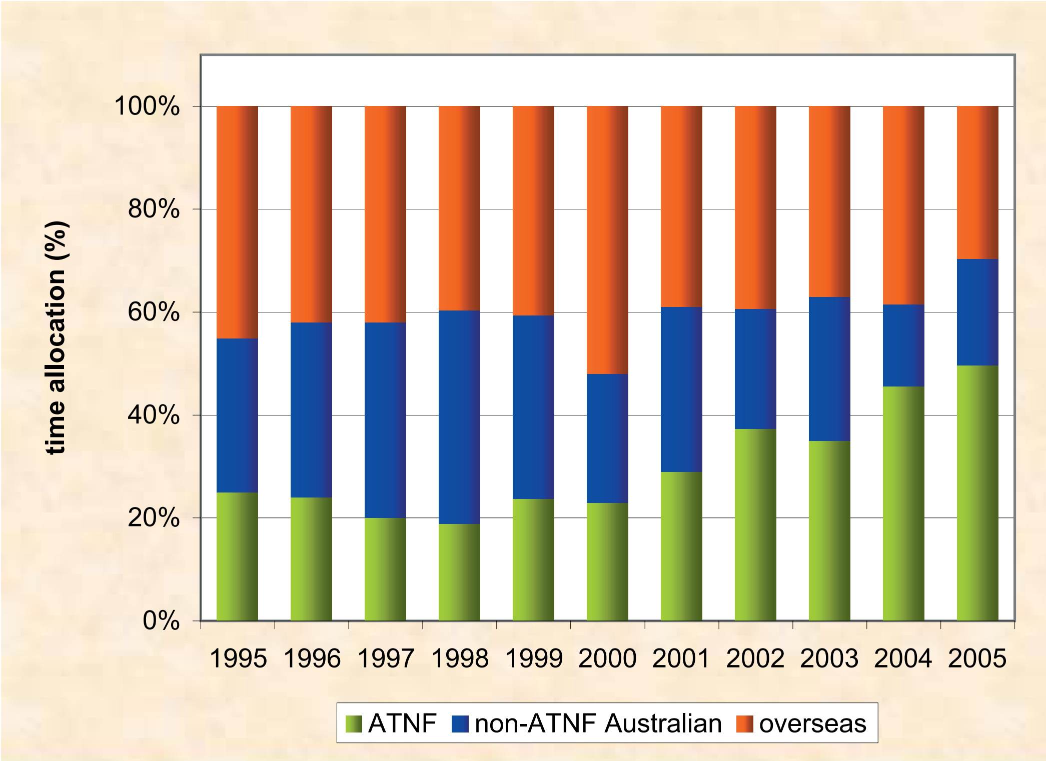



Figure 1 Compact Array time allocation, 1995 – 2005.

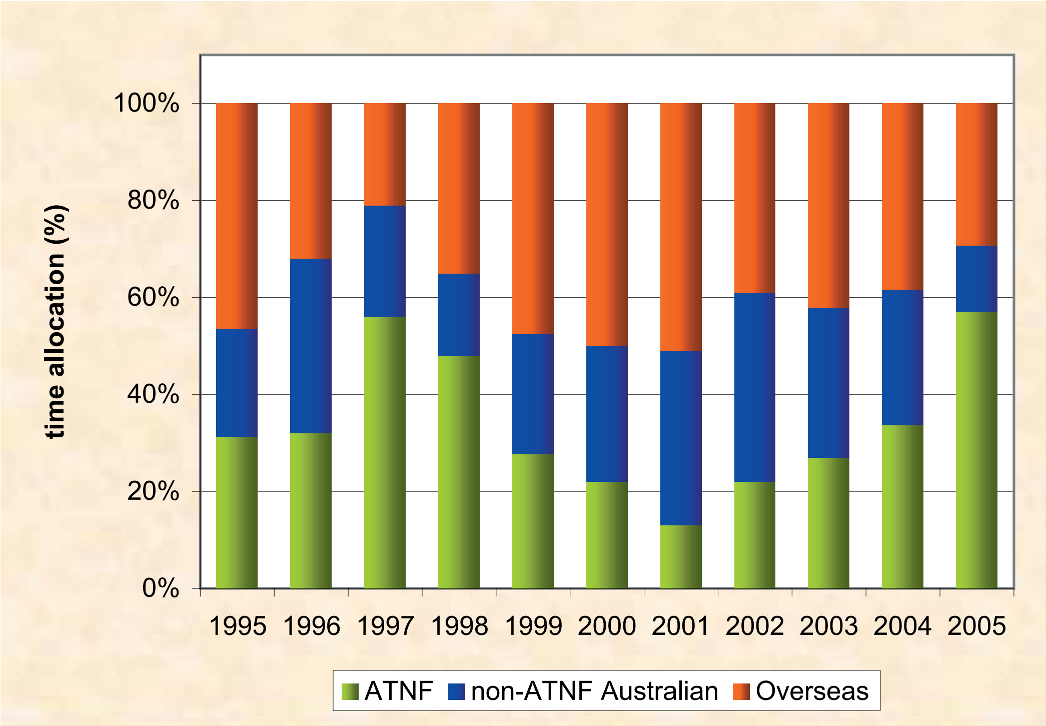



Figure 2 Parkes time allocation, 1995 – 2005.

## 4 Teaching, measured by the number of postgraduate students supervised by ATNF staff

In December 2005 there were 30 PhD students affiliated with the ATNF as well as an Australian or overseas university. Their affiliations and thesis titles are given in Appendix H. Three students were awarded PhDs during the year. Their theses are listed in Appendix G.

## 5 Publications and citations

### Publications

Figure 3 shows the number of publications in refereed journals which include data obtained with the Australia Telescope. The publication counts include papers dealing with operations or data reduction but do not include IAU telegrams, abstracts, reports, historical papers, articles for popular magazines, or other papers by ATNF authors. In 2005, 119 papers with ATNF data were published in refereed journals. These are listed in Appendix G, which also lists 46 conference papers with ATNF data and 46 other papers by ATNF staff. The publication counts for 2005 are similar to those for 2004. In 2005 ATNF staff were included as authors on 70% of papers, while 64% of papers have a first author at an overseas institution.

Figure 4 shows ATNF publication numbers for papers that include Compact Array, Parkes, VLBI and Mopra data. A small number of papers with data from more than one facility are counted more than once. For Mopra, the number of publications was the highest recorded, with eight refereed publications in 2005.

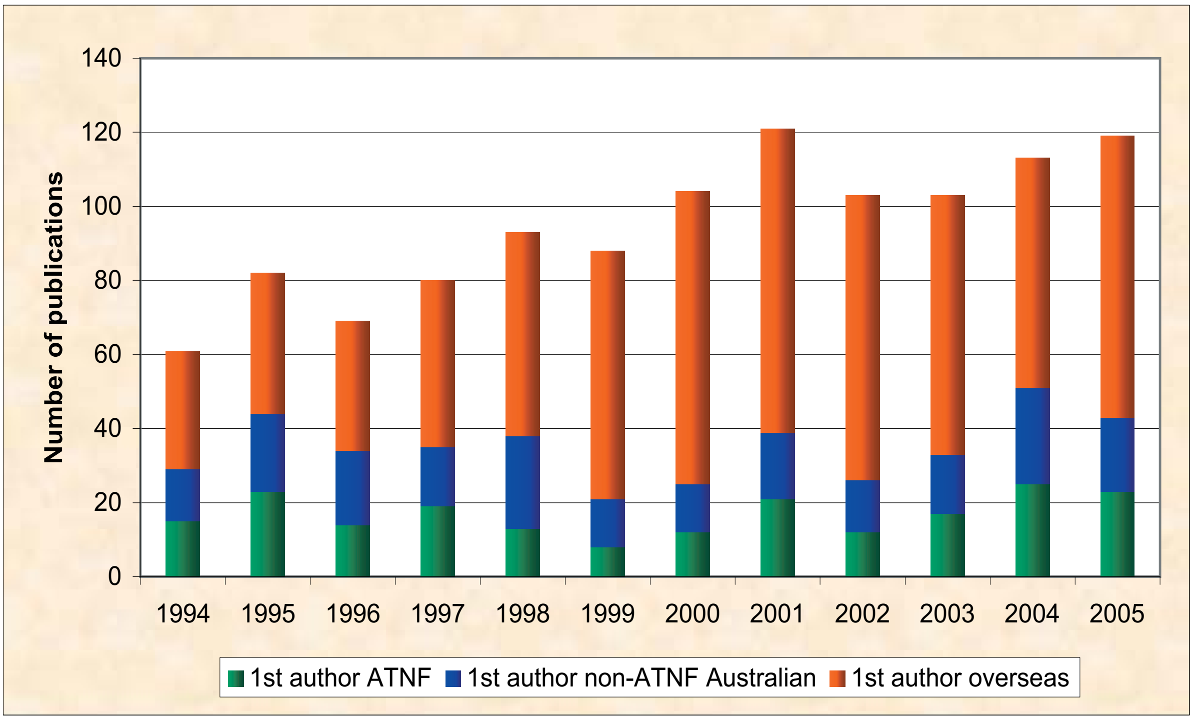



Figure 3 Publications from data obtained with the Australia Telescope, published in refereed journals.

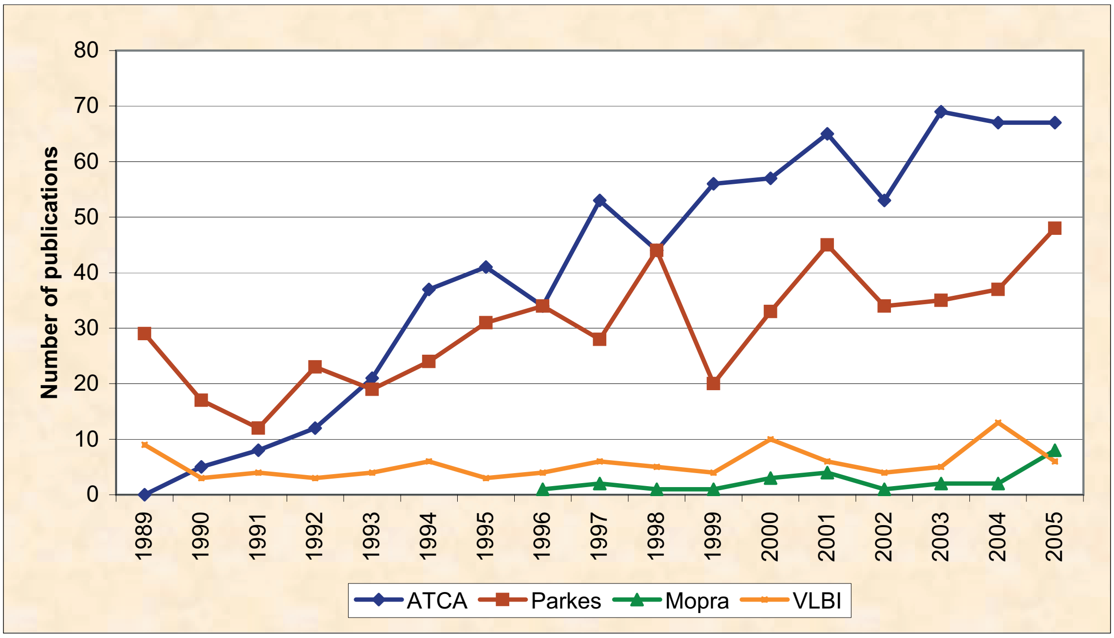



Figure 4 Publications from data obtained with the ATCA, Parkes, VLBI and Mopra, 1989 – 2005.

## Citation analyses

A recent citation analysis of radio facilities by Virginia Trimble (University of California, Irvine) and collaborators, reports that, amongst radio telescopes worldwide, the Parkes telescope is second only behind the VLA in terms of total citations to papers published in refereed journals while the Compact Array ranks third. A further outstanding finding is that the Parkes radio telescope leads the world in "impact", defined as the number of citations per paper. This study (an extract of which will be published in Nature in January 2006), is based on citations in the years 2002 – 2004 to papers published in the year 2001 with 25 radio institutions included in the study.

A separate study on *A bibliometric study of astronomical sciences publications* by Biglia and Butler, was commissioned as part of the *New Horizons, A decadal plan for Australian Astronomy 2006 – 2015*, prepared by the National Committee of Astronomy of the Australian Academy of Science and published in November 2005. This study looks at the publications and citations performance of Australian astronomy institutions.

The Butler and Biglia study shows that for the years 1981 – 2003, Australian institutions produced approximately 4% of world astronomy publications and 5.5% of citations. This compares with 2% of publications, and 3.4% of citations for the years 1981 – 1985. As with other Australian institutions, the ATNF publishes in high impact journals, with an average citation rate that is well above a world benchmark. For the years 1998 – 2002, the ATNF had 386 publications included in this study (which counts only papers that include ATNF staff). Of these, 16 papers were included in the top 5% of most highly cited publications.

Australian publications were also discussed in the report *Australian Astronomy Publication and Facilities Survey*, prepared by the Decadal Plan Working Group 3.1. This study was incomplete in terms of including all publications, but included 2063 publications for the years 1996 – 2004. Publication and citation data were obtained for 57 Australian facilities covering all branches of observational and theoretical astronomy. From a performance measure based on the number of publications, with a weighting factor for the fraction of Australian authors on the paper (case 2), the Compact Array and Parkes ranked first and second respectively. From a second performance measure, for the total impact of facilities based on weighted citation rates (case 6), the Compact Array and Parkes were ranked second and third respectively, with the optical Anglo-Australian Telescope ranked highest.

## 6 Public relations

Figure 5 shows counts for media activities for the years 2000 – 2005. During the year the ATNF issued 10 media releases (Appendix F) and featured in at least 170 newspaper reports. ATNF staff gave approximately 140 TV and radio interviews and 50 public talks.

A major tool for communication with professional astronomers and the public is the web. Approximately two million hits are received each month on the central ATNF website at www.atnf.csiro.au. In May 2004, a new website was released for outreach and education. This received approximately 2.5 million hits in 2005. The ATNF also contributed to the new central CSIRO website at www.csiro.au.

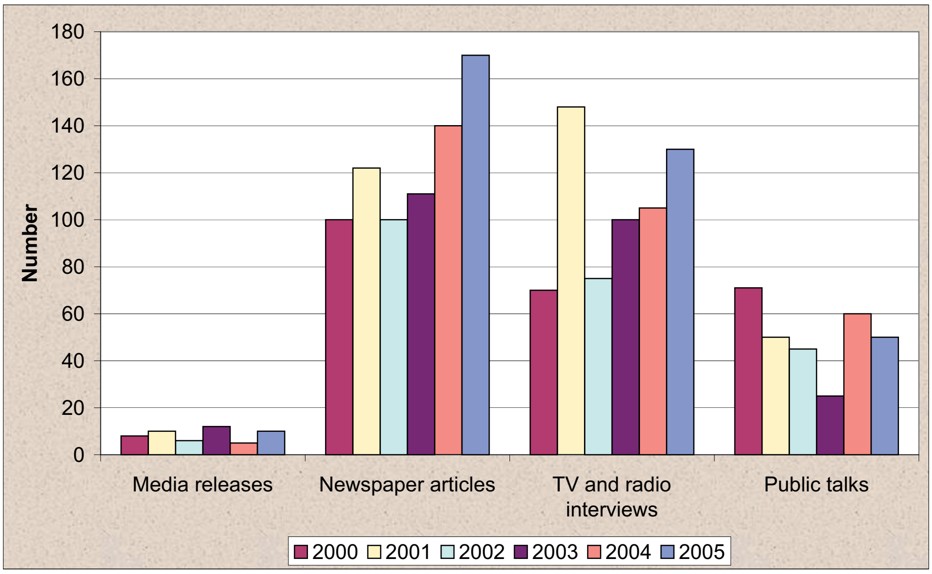



Figure 5 ATNF media activities.

Figure 6 shows the number of visitors to the Parkes Visitors Centre. The strong increase in visitor numbers in 2001 followed the release of the movie *The Dish*. The number of visitors has remained high since then, with approximately 110,000 visitors in 2005, slightly lower than for the previous year.

The number of visitors to the Narrabri Visitors Centre has been fairly constant for some years, with approximately 11,000 visitors in 2005.

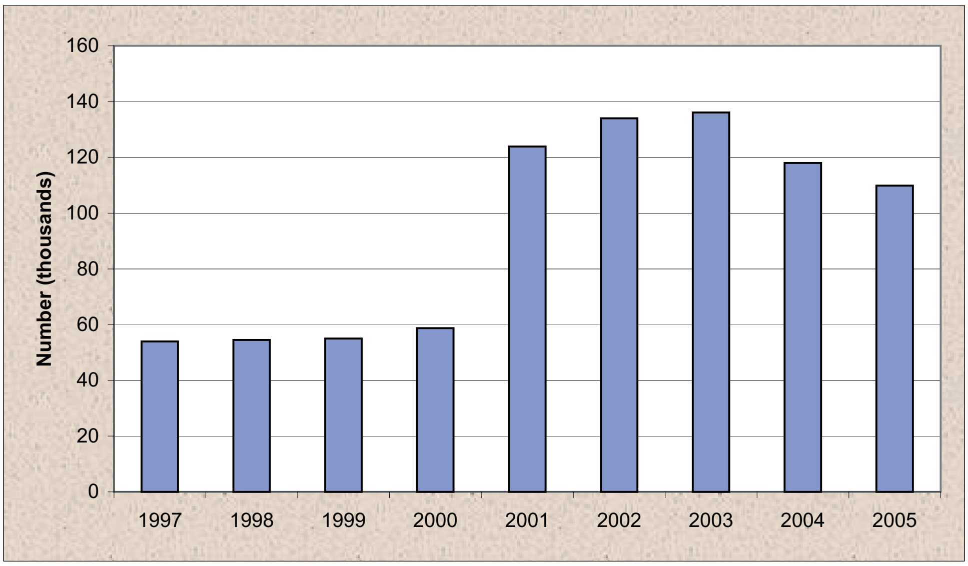



Figure 6 Number of visitors to the Parkes Visitors Centre.

Photo: © Barnaby Norris

# Performance indicators

## 7 User feedback at Narrabri and Parkes

Observers at the Parkes, Narrabri and Mopra observatories are asked to complete a user feedback questionnaire. Figure 7 shows the user responses for 2003 – 2005 for the Parkes Observatory. The user feedback is consistent over the three years, with an averaged response for 2005, of 86%.

Figures 8 and 9 show the user feedback for Compact Array observations taken with the centimetre and millimetre systems. The averaged responses were 86% for centimetre observing and 76% for millimetre observing.

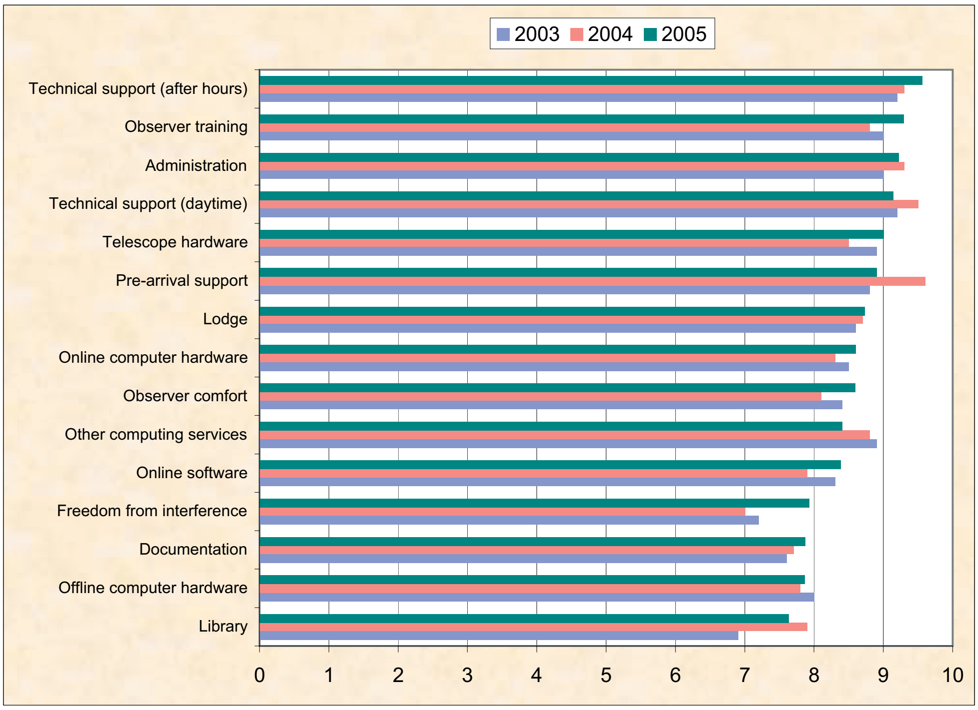



Figure 7 Parkes user feedback on a scale of 1 (poor) to 10 (excellent).

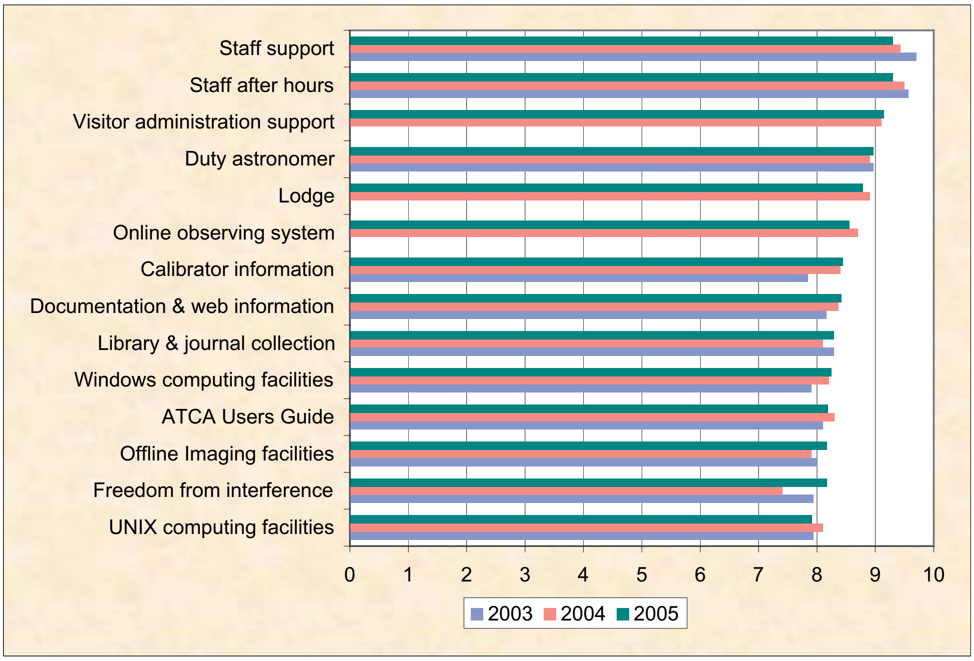



Figure 8 Narrabri user feedback for centimetre observations, on a scale of 1 (poor) to 10 (excellent).

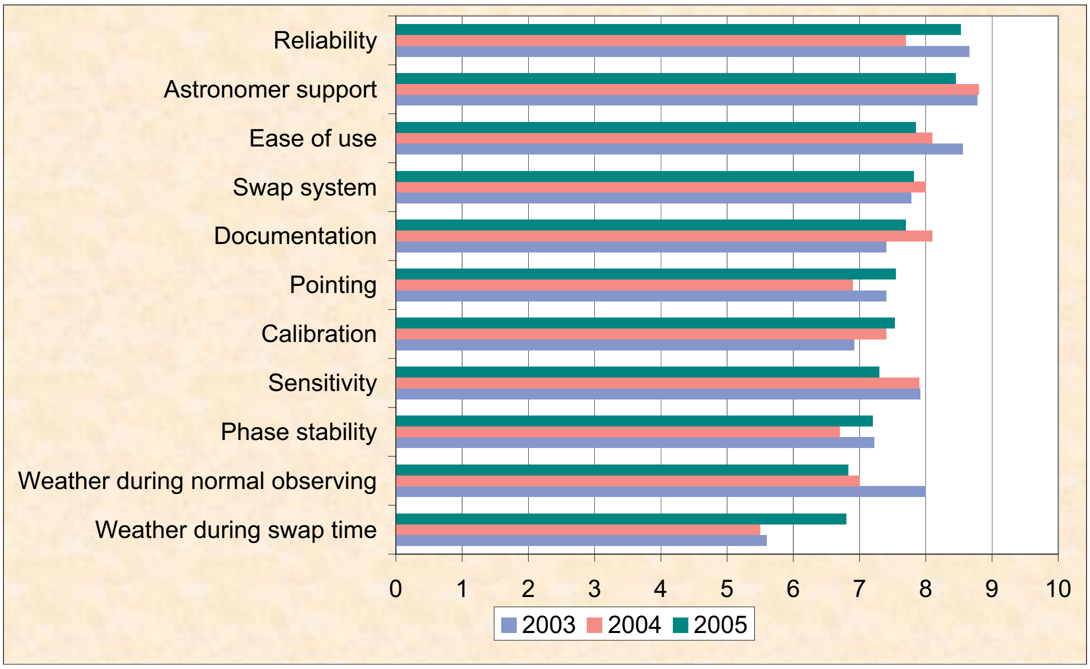



Figure 9 Narrabri user feedback for millimetre observations, on a scale of 1 (poor) to 10 (excellent).

Figure 10 shows the user feedback in 2004 and 2005 for the Mopra telescope. The averaged response for 2005 was 80%. Three items showed relatively poor responses in 2004: the on-line observing system, documentation and web information and offline data processing software. The responses for 2005 indicate that these were improved although further work is planned.

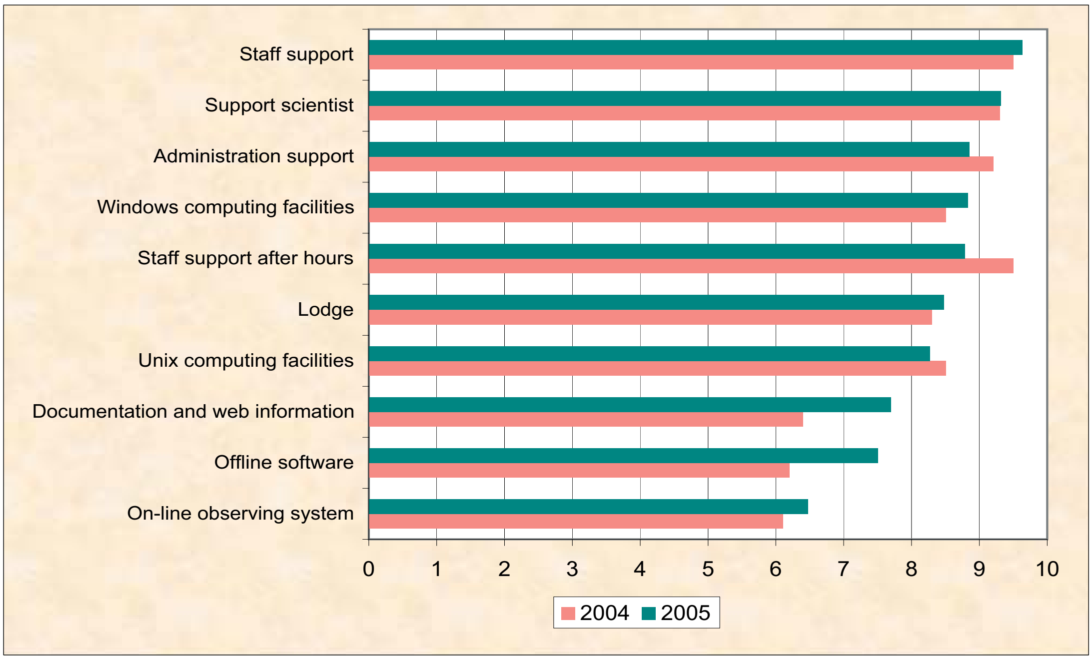



Figure 10 Mopra user feedback on a scale of 1 (poor) to 10 (excellent).

4
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# Astronomy reports

Photo: © Shaun Amy, CSIRO

# Multibeam pulsar surveys at Parkes

Dick Manchester (ATNF)

The 20-cm multibeam receiver at Parkes was originally conceived with the aim of detecting galaxies through their 21-cm HI emission and has been very successful in that endeavour. However, it did not take pulsar astronomers long to realise the potential of the instrument for pulsar surveys. The outstanding success of pulsar surveys using this receiver has made Parkes the premier telescope world-wide for pulsar discoveries. Counting earlier surveys, Parkes has discovered about two-thirds of the 1750 or so known pulsars or, put another way, *Parkes has discovered twice as many pulsars as the rest of the world's telescopes put together!* More than three-quarters of these pulsars, or more than half the total number of pulsars known, have been discovered in the past eight or nine years using the multibeam receiver.

What are the principal reasons for this outstanding success? There are three. Firstly, the location of Parkes is ideal for Galactic surveys, with the Galactic Centre passing almost overhead. The spatial density of pulsars increases greatly toward the Galactic Centre and so searches of the inner parts of our Galaxy are generally more productive. Secondly, thanks to the foresight and skill of our engineers and scientists, the receivers and back-end systems installed at Parkes are at the forefront in development of innovative technologies. In particular, the multibeam receiver was years ahead of the competition. With its 13 beams and extremely good sensitivity, this receiver is a highly effective instrument for pulsar (and HI) surveys, increasing the effectiveness of such surveys by more than an order of magnitude. Finally, the international team responsible for the major multibeam pulsar surveys is highly experienced in developing the equipment and signal-processing techniques needed for pulsar surveys.

## The Parkes 20-cm multibeam pulsar system

The 20-cm multibeam system has 13 beams arranged in a double hexagon about a central beam (Figure 1). The beams are spaced on the sky by approximately two beamwidths, but by combining four interleaved pointings, essentially complete sky coverage can be obtained. Each of the 26 receiver channels (two orthogonal linear polarisations per beam) has a bandwidth of nearly 300 MHz centred at about 1375 MHz. As well as having very wide bandwidths, the first-stage amplifiers (designed and constructed at Jodrell Bank Observatory, University of Manchester) have exceptionally good noise figures, with system temperatures of about 21 K. The 26 signals are amplified and down-converted to feed a massive filterbank/digitiser system which was designed at the Jodrell Bank Observatory, and constructed there and at the Astronomical Observatory, Bologna. Each filterbank has 96 channels, each 3 MHz wide. Corresponding channels from the two polarisations are summed to give 1248 data streams which are one-bit digitised with a sample interval typically of 125 or 250 microseconds and written to tape for subsequent analysis.

Several different pulsar surveys have been undertaken with the multibeam system and all used basically the same analysis procedure. Data from each beam are "dedispersed", that is, data from different frequency channels are delayed to compensate for the effects of interstellar dispersion and then summed, for a range of dispersion measures. Each dedispersed data stream is then Fourier-transformed to give the modulation spectrum of the signal. Peaks in this spectrum may result from various forms of interference or may represent a pulsar. Real pulsar signals can generally be distinguished from interference by their dependence on frequency, time and dispersion. After rejecting those thought to be due to interference, details of strong signals are saved as pulsar candidates. These are re-observed at the telescope to show whether or not they are real pulsars. Confirmed pulsars are then observed at intervals of a few weeks over a year or 18 months to determine the precise pulsar period and other parameters, including binary parameters if the pulsar is a member of a binary system.

## Multibeam pulsar surveys

The most extensive survey is the Parkes Multibeam Pulsar Survey (PMPS), a search of a 150- by 10-degree strip along the southern Galactic Plane. A large international team with members from the UK (Jodrell Bank Observatory), Italy (Bologna Astronomical Observatory/Cagliari Astronomical Observatory), USA (Columbia University, Massachusetts Institute of Technology, Haverford College), Canada (University of British Columbia, McGill University) and the ATNF was responsible for this survey which commenced in mid-1997 and took six years to complete. A total of 2670 pointings, each of 35 minutes duration, was needed to cover the survey region and more than three terabytes of data were recorded. The data were processed using computer clusters at the collaborating institutions. Recently, all of the data have been reprocessed using the COBRA


Figure 1: The 20-cm multibeam receiver being hoisted into the Parkes focus cabin on 21 January 1997, its first installation. With a diameter of 1.3 metres and weight of 650 kg, the receiver is the heaviest and one of the largest ever installed at Parkes.

cluster at Jodrell Bank Observatory to give improved rejection of interference, improved sensitivity to long-period pulsars and pulsars in short-period binary orbits and to search for isolated dispersed pulses. Overall, the survey has been extremely successful, finding more than 750 pulsars, by itself nearly doubling the number of known pulsars.

A more limited survey at higher Galactic latitudes was carried out by a team from Swinburne University with an extension done in collaboration with Caltech. This survey was optimised for discovery of millisecond pulsars (MSPs) and found 15 such pulsars among a total of 95 discoveries. The PMPS collaboration also carried out a high-latitude survey with parameters similar to that of the Swinburne survey. This survey found 17 pulsars, including the now-famous "double pulsar", PSR J0737–3039A/B, voted by Science magazine to be one of the top ten scientific breakthroughs of 2004. The high efficiency of the multibeam system was also exploited in a survey of the Magellanic Clouds which discovered 14 very weak pulsars, 12 of which are believed to be associated with the Clouds. With the eight previously known pulsars, two of which were discovered at X-ray wavelengths, this brings the total number of Magellanic Cloud pulsars known to 20. So far, these are the only known pulsars outside of our Galaxy.

Figure 2 shows the distribution in Galactic coordinates of all known radio pulsars (excepting those in globular clusters) with pulsars discovered in the principal multibeam surveys marked. Although this distribution is strongly affected by observational selection, there is a clear concentration of pulsars along the Galactic equator and in the inner Galactic quadrants. Because of their high density on the sky, most of the PMPS pulsars are unresolved in this plot.

## Pulsars and Magnetars

Pulsars are renowned as highly precise celestial clocks. But their periods are not constant – all pulsars slow down as a result of loss of energy and angular momentum to "magnetic-dipole" radiation (electromagnetic radiation at the pulsar frequency) and charged-particle winds. The rate of period increase is tiny, typically a fraction of a microsecond a year, and it varies considerably from pulsar to pulsar. The plot of rate of period increase, that is, the first period time-derivative, versus pulsar period (the "$P - \dot{P}$ diagram") is a basic tool of pulsar astrophysics. Figure 3 shows this plot for all known pulsars except those in globular clusters. (The observed period derivative for globular cluster pulsars is often affected by acceleration of the pulsar in the cluster gravitational potential and so it doesn't represent the intrinsic spindown of the pulsar.) This figure clearly shows the huge number of pulsars discovered in the PMPS!

Pulsars in the top-right of Figure 3, marked with an open star are the AXPs, Anomalous X-ray Pulsars, which are evidently rotating neutron stars just like pulsars, but with enormous magnetic fields, greater than $10^{15}$ G in some cases, and relatively long periods, between 5 and 12 seconds. They are only detectable at hard X-ray and γ-ray wavelengths. Despite their rapid spindown, the integrated X-ray and γ-ray luminosity exceeds the power available from the loss of rotational kinetic energy and it is believed that they are powered by decay of the super-strong magnetic fields. Because of this, they are often known as "magnetars".

As well as greatly increasing the available sample for studies of the evolution and Galactic distribution of pulsars and the interstellar medium studies, the multibeam surveys have uncovered new populations of pulsars and many interesting individual objects. A whole new population of young, highly magnetised and relatively long-period radio pulsars has been found by the PMPS. These pulsars have magnetic fields of $10^{13}$ Gauss or more and periods as long as 7.7 seconds, which puts some of them at least in the same part of Figure 3 as the AXPs. Yet these are radio pulsars with very different properties to the AXPs, a difference which is not currently understood. The large $\dot{P}$ of these pulsars means that they evolve very quickly and, despite their relatively small numbers, they account for a large fraction of the total pulsar birthrate.

## Rotating radio transients

Another completely new and very interesting population of pulsars, the so-called Rotating Radio Transients, or RRATs for short, was revealed by the single-pulse analysis of the PMPS data. Like the AXPs, these objects have very different emission properties to normal pulsars and are believed to be rotating neutron stars with relatively long periods. RRATs are distinguished by the fact that just single pulses of emission are seen at

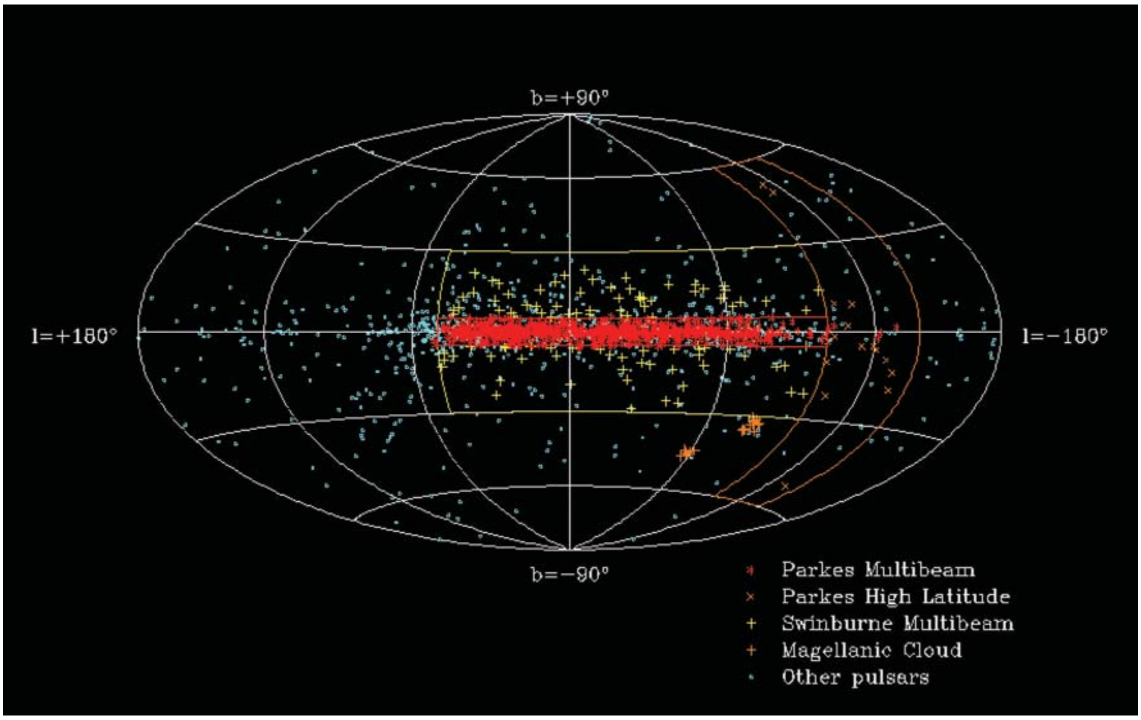


Figure 2: Galactic distribution of all known radio pulsars excepting those in globular clusters. The Milky Way runs along the horizontal axis with the Galactic Centre at the centre of the plot. Pulsars discovered in the principal multibeam surveys and the boundaries of those surveys are marked.

intervals which range from several minutes to several hours. Eleven of these sources were found in the reanalysis of the PMPS data. Figure 4 shows an individual dispersed pulse from two of the sources. A careful analysis of the intervals between the pulses from a given source showed that there was a common factor, much shorter than the intervals between the pulses and typically a few seconds. This common factor is identified as the rotation period of the under-lying neutron star. The observed periods range from 0.44 to 6.9 seconds.

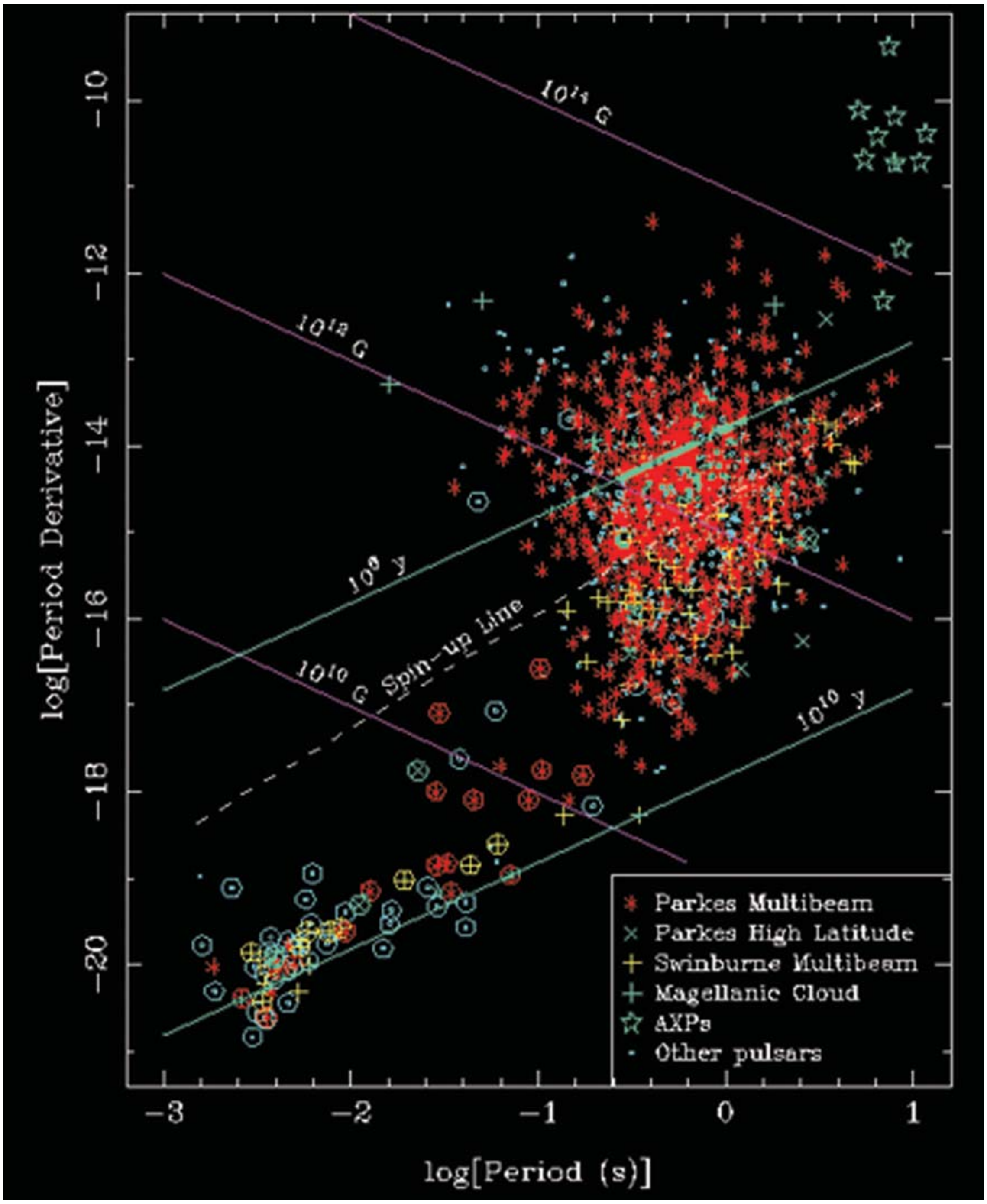


Figure 3: Plot of spin-down rate or period derivative ($\dot{P}$) versus pulsar period for all known pulsars with measured $\dot{P}$ except those in globular clusters. Pulsars discovered in the principal multibeam surveys and AXPs are indicated and binary pulsars are marked with a circle around the symbol. Lines of constant characteristic age, $\tau_C = P/(2\dot{P})$, and surface magnetic-dipole field strength, $\propto (P\,\dot{P})^{1/2}$, are shown along with the spin-up line which represents the minimum period that a pulsar can attain through “recycling” or accretion of matter from a companion star.

This identification of RRATs as rotating neutron stars was confirmed by long-term timing of three of the most frequently pulsing objects, which showed the slow period increase typical of pulsars. In fact, for one of the objects at least, the implied magnetic field is greater than $10^{13}$ G, putting the RRATs among the long-period high-magnetic field pulsars discovered by the PMPS. The emission from RRATs must be beamed as for normal pulsars, otherwise there would be no periodicity. However, unlike other pulsars, the emission process is extremely intermittent, being active for only a small fraction of the neutron-star rotation period – in no case have two consecutive pulses ever been seen. It is not known why the emission process is so different. RRATs have a similar Galactic distribution to normal pulsars. They could be relatively young neutron stars born with different properties to normal pulsars or maybe they represent a terminal stage in the life of a normal pulsar. At least in the former case, their discovery means that the population of neutron stars in the Galaxy is much greater than previously realised. Their extremely intermittent nature means that many have been missed by pulsar surveys and so the underlying population must be large, maybe more than that of normal pulsars. If true, this would have significant implications for our understanding of mechanisms for formation of neutron stars. Finding more of these enigmatic objects will help to solve these mysteries but unfortunately it will not be easy.

## Binary pulsars and tests of gravitational theories

In total, the Parkes multibeam surveys have discovered 40 binary pulsars, nearly half of the 87 known in the Galactic disk. Many interesting systems have been discovered. For example, PSR J1909–3744 is a 2.95-millisecond pulsar in a 1.53-day orbit around a white dwarf companion discovered in the Swinburne mid-latitude survey. The main interest of this pulsar comes from its very narrow (half-power width 42 microseconds) and relatively strong pulse which leads to very precise timing of the pulsar and hence detection of a number of interesting effects. Daily averages for this pulsar yield an rms timing residual of only 74 nanoseconds, the most accurate so far obtained. As well as determining a very precise position and proper motion for the system, timing measurements have given an accurate measurement of the annual parallax (0.88 ± 0.03 milliarcseconds) and hence the distance to the system (1.14 ± 0.04 kpc). They have also allowed measurement of the Shapiro delay, that is, the delay due to the ray path passing through curved space-time close to the companion star (Figure 5). The shape and amplitude of this curve give both the inclination angle of the orbit and the mass of the companion white dwarf. Fortuitously, the orbit of this system is viewed almost edge-on (inclination angle $i$ = 86.8 degrees) and hence the Shapiro delay is large, giving an accurate value for the companion mass, 0.2038 ± 0.0022 solar masses. This, combined with the mass function, a relation between the masses and orbital parameters derived from Kepler's third law, gives a value for the pulsar mass, 1.438 ± 0.024 solar masses, very similar to neutron-star masses derived from observations of double-neutron-star systems. This value is interesting as it shows that a pulsar can become highly recycled with the accretion of only a relatively modest amount of mass.

As Figure 3 shows, the PMPS has been especially successful in filling in what was something of a gap between MSPs and normal pulsars. Binary pulsars with these intermediate periods are very interesting as they are

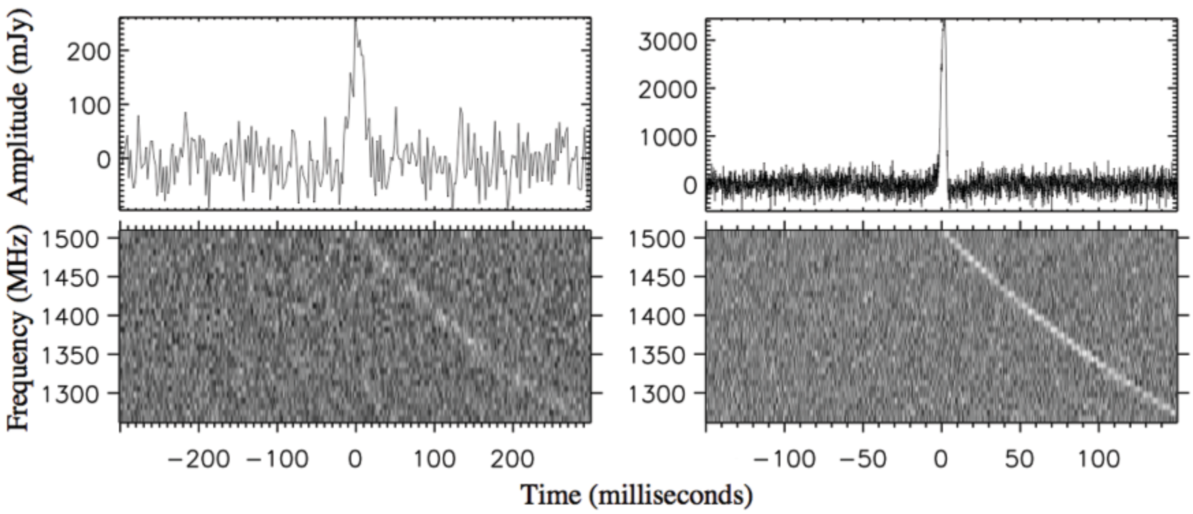


Figure 4: Single dispersed pulses from two RRATs, PSR J1443–60 and PSR J1819–1458. The lower part of each plot shows the dispersion of the pulse resulting from the frequency-dependent group delay in the interstellar medium. The upper plot shows the dedispersed pulse profile.
Image credit: M. McLaughlin (JBO)

mainly double-neutron-star systems, formed from binary systems containing massive stars. These stars evolve quickly and there is insufficient time for the recycling process to spin up the first-born neutron star to short millisecond periods before the second supernova explosion and formation of the second neutron star. Two of the eight double-neutron-star systems currently known were found in the PMPS and another, the double pulsar, was discovered in the High-Latitude multibeam survey. These systems are important for a number of reasons. Because of the large system masses and compact orbits (most have orbital periods of less than one day), relativistic perturbations to the orbits are readily detectable, allowing a variety of tests of the gravitational theories used to interpret these effects. Furthermore, because of the highly compact nature of neutron stars ($GM/Rc^2 \sim 0.1$), gravitational theories can be tested under strong-field conditions that are inaccessible elsewhere. Another significant property of these systems is that their orbits decay relatively rapidly due to loss of orbital energy to gravitational radiation. This ultimately leads to a violent coalescence of the two neutron stars to form a black hole. These coalescence events are the principal astrophysical target of ground-based gravitational-wave detectors such as LIGO and VIRGO.

## The double pulsar

Without doubt, the most exciting of these discoveries is the double pulsar, PSR J0737–3039A/B. This unique system consists of a 22-millisecond recycled pulsar (A) in a mildly eccentric orbit with a much slower but younger 2.7-second pulsar (B). The orbital period is just 2.4 hours, making it the most highly relativistic binary system known. For example, the rate of precession of periastron is 16.9 degrees per year, nearly four times larger than that of PSR B1913+16, the Hulse-Taylor binary pulsar. The detection of the second neutron star as a pulsar provided a spectacular confirmation of the ideas behind the recycling mechanism for formation of MSPs. It also makes the system a "double-line" binary, giving a direct measurement of the mass ratio of the two stars and providing an important constraint on gravitational theories. This system has by far the shortest coalescence time of all the double-neutron-star systems, about 85 million years, leading to a greatly increased estimated rate for the detection of these events by gravitational-wave detectors such as LIGO. As if all this was not enough, fascinating interactions between the winds and magnetospheres of the two pulsars have been observed, opening up a new window on magnetospheric physics and the pulse emission process.

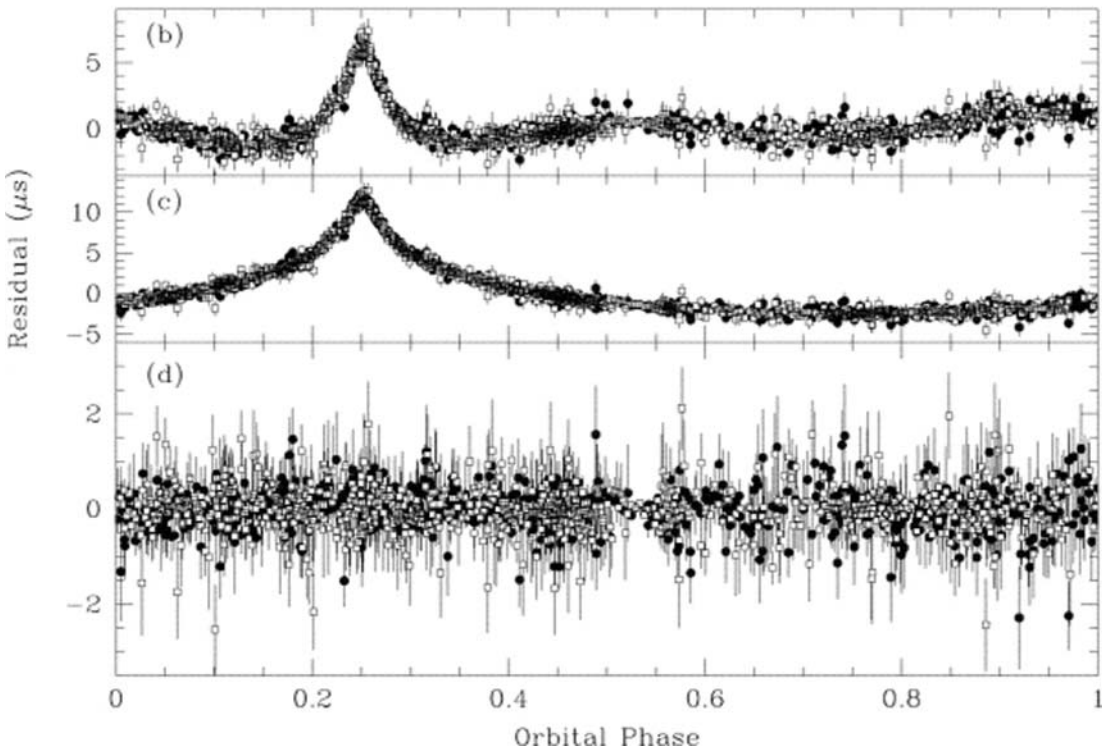


Figure 5: Pulse timing residuals as a function of orbital phase for PSR J1909–3744 showing the Shapiro delay as the pulsar passes behind the companion. The upper part of the figure shows the observed residuals after fitting for all pulsar and binary parameters except Shapiro delay. The middle plot shows the total Shapiro delay term which peaks near orbital phase 0.25 when the pulsar is behind the companion. A portion of this Shapiro delay function is absorbed by other binary terms in the upper plot. The lower part shows the final residuals. (Jacoby et al. 2005)

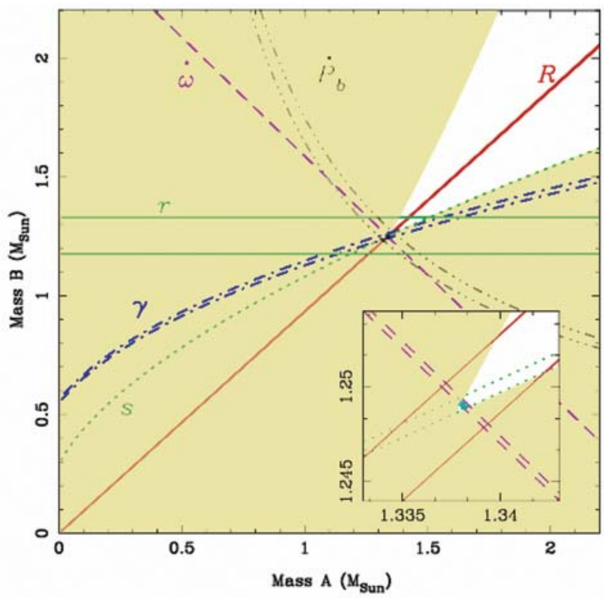


Figure 6: Constraints on the masses of the two neutron stars in the double-pulsar system PSR J0737–3039A/B. The orange shaded areas are excluded by the condition that the sine of the orbital inclination angle cannot exceed 1.0 and the red line is from the measurement of the mass ratio R of the two stars. Other constraints are from relativistic effects interpreted within general relativity. Measurement of the precession of periastron gives the purple dashed lines, the blue dot-dashed lines are from variations in the relativistic time dilation and second-order Doppler effect as pulsar A moves around its eccentric orbit, the green lines are from measurements of the Shapiro delay as the signal from A passes over B and the black dash-double-dot lines are from measurement of orbit decay due to emission of gravitational waves from the system. The inset shows an expanded view of the region around the intersection of the various constraints. (Kramer et al. 2006)

A total of five independent relativistic effects have now been observed in PSR J0737–3039A/B, more than for any other double-neutron-star system. Taken together with the mass ratio, these provide unprecedented tests of relativistic theories of gravity. Figure 6 shows a "mass–mass" diagram for PSR 0737–3039A/B with relativistic effects interpreted within the framework of Einstein's general theory of relativity (GR). All constraints are consistent with the very small blue region (visible on the inset), providing an outstanding confirmation that GR is an accurate theory of gravity under strong-field conditions. It also provides highly precise measurements of the masses of the two neutron stars. The precise agreement of the Shapiro delay inclination-angle constraint ($s = \sin i$) with the masses determined by the intersection of the mass-ratio and periastron-precession constraints provides the most stringent test of GR under strong-field conditions currently available, verifying the theory at the 0.05% level. Furthermore, this is a test of a non-radiative prediction of GR and hence is qualitatively different to that from the Hulse-Taylor binary system.

All of these results have been obtained in less than three years of timing of this remarkable system. Future observations will lead to improvements in these constraints and, even more importantly, new and independent tests of other predictions of theories of relativistic gravitation. The measurement of orbit decay rate improves rapidly with data span and for PSR J0737–3039A/B it will exceed the precision of the measurement for the Hulse-Taylor binary system in three to five years. In contrast to the Hulse-Taylor system, the precision of the GR test in PSR J0737–3039A/B will not be significantly limited by the uncertainty in the relative acceleration of the binary system and the Sun in the Galactic gravitational field, at least for the next few decades. One exciting prospect is measurement of the effects of spin-orbit coupling on the observed precession of periastron. In principle, this can be used to constrain the moment of inertia of the neutron stars which would put significant limits on possible equations of state for neutron-star matter.

## Conclusions

The Parkes multibeam pulsar surveys have had an extraordinary impact, not only on pulsar astronomy and astrophysics, but also on physics and astronomy in general. In just a few years they have doubled the number of known pulsars and revealed some fascinating individual objects, most notably the first-known double-pulsar system, PSR J0737–3039A/B. Studies of these pulsars will continue for years to come and will undoubtedly reveal many new and important results over this diverse range of topics. This success is a tribute to the skill and dedication of many people including the engineers and scientists who designed, constructed and now maintain the system and the astronomers in the various collaborations involved in the surveys and follow-up observations.

## Acknowledgements

I thank my colleagues, especially those in the Parkes Multibeam Pulsar Survey and Parkes High Latitude Survey teams, without whose efforts this article could not have been written. Pulsar data shown in Figures 2 and 3 were obtained from the ATNF Pulsar Catalogue (www.atnf.csiro.au/research/pulsar/psrcat).

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# Discovery of a planetary nebula around the OH/IR star V1018 Sco

Jessica Chapman (ATNF); Martin Cohen (University of California, Berkeley, US); Quentin Parker (Macquarie University/Anglo-Australian Observatory); Rachel Deacon (University of Sydney); Robert Sault (ATNF); Anne Green (University of Sydney)

V1018 Sco is a well known OH/IR star with strong infrared and radio maser emission. The OH 1612-MHz maser spectrum of V1018 Sco, shown in Figure 1, has a double-peaked profile that is characteristic of asymptotic giant branch (AGB) stars. The AGB stars are evolved pulsating stars which have high mass-loss rates and strong stellar winds. The OH maser emission from AGB stars occurs from the outer regions of an expanding circumstellar envelope. For V1018 Sco the stellar wind has an expansion velocity of 15 kilometres per second, while the OH emission is detected from an exceptionally large shell with a diameter approximately 11,000 times larger than the distance between the sun and earth. Monitoring observations of the OH maser emission with the Parkes radio telescope have shown that the central star has large amplitude pulsations with a period of about 1500 days.

During a systematic search for Galactic Planetary Nebulae (Parker et al. 2005), a survey exposure showed a faint circularly-symmetric ionised nebula that was almost centred on the position of the OH maser emission from V1018 Sco. This position also coincides with a strong infrared source. The optical nebula has an outer diameter of 39 arcsec, approximately 10 times larger than the OH shell. Follow up long-slit spectroscopy confirmed the presence of the nebula with the detection of Hα, [NII] and [SII] emission lines, typical of planetary nebulae.

The detection of an ionised planetary nebula around a still-pulsating AGB star was remarkable. V1018 Sco is the only known source where a planetary nebula has been detected around an AGB star that is still pulsating and thus still in the AGB stage of evolution. AGB stars are the precursors of planetary nebulae and represent an earlier stage of stellar evolution. Models of stellar evolution predict that towards the end of the AGB phase, stars lose so much mass from their outer envelopes that they can no longer support strong pulsations. As a star evolves away from the AGB, the pulsations cease and the star changes from losing mass in slow dense winds to losing mass in a hotter, faster wind. During the post-AGB phase, the hot winds sweep up the remnant material and the swept-up shells become visible as planetary nebulae as the central stars become hot enough to ionise the shells.

To investigate the nebula around V1018 Sco, radio continuum emission observations were taken with the Compact Array using four observing bands at 3, 6, 13 and 20 cm. As shown in Figure 2, two regions of radio continuum emission were detected with stronger emission from the western part of the nebula (Source A), and fainter emission to the north (Source B). Both sources were offset by about 10 arcsec from the stellar position.

Figure 3 shows the spectral energy distribution for Source A and Source B. In both cases, a power law fitted to the data gives a slope (or "spectral index") of about –0.8, and this shows that the radio continuum emission is strongly non-thermal. Source A while was detected in all four bands while source B was only detected at 3, 6 and 13 cm. This can be interpreted as showing the source B is likely to be located towards the back of the nebula, so that the 20-cm radio emission is strongly absorbed within the nebula. Source A is likely to be located towards the front of the nebula.

The spectral index of the nonthermal radio emission from V1018 Sco is similar to that detected from Wolf Rayet stars. In the much more massive Wolf-Rayet stars, nonthermal radio continuum emission is detected from shocks that are generated when a wind from a massive Wolf Rayet star collides violently with the wind from a second massive star. For V1018 Sco, the presence of nonthermal emission also indicates a wind-wind collision.

For V1018 Sco, the Compact Array data suggest a previously unobserved phase where a planetary nebula has just started to form around an AGB star that is still pulsating. A fast wind from the central star has recently "turned on" and this ploughs into the slow AGB wind creating shocks, non-thermal emission and a compressed shell which is visible as an ionised optical nebula. Such wind-wind collisions are likely to play an important role in shaping the nebula during the transition of a star as it evolves from the AGB to become a planetary nebula.

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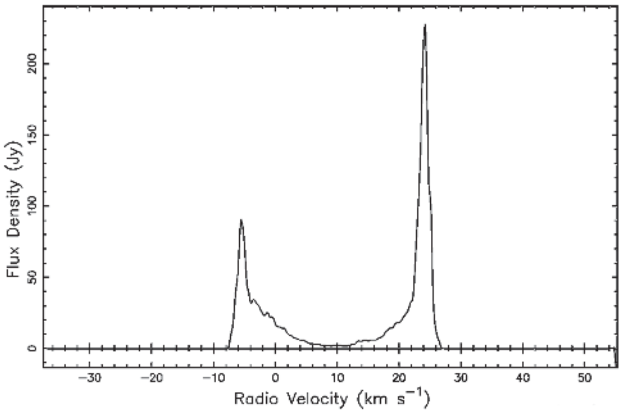


Figure 1: An averaged OH 1612-MHz spectral profile of V1018 Sco, from 36 separate epochs of observations taken with the Parkes radio telescope. The two emission peaks correspond to the strongest maser emission seen from the front and back of the expanding circumstellar envelope.

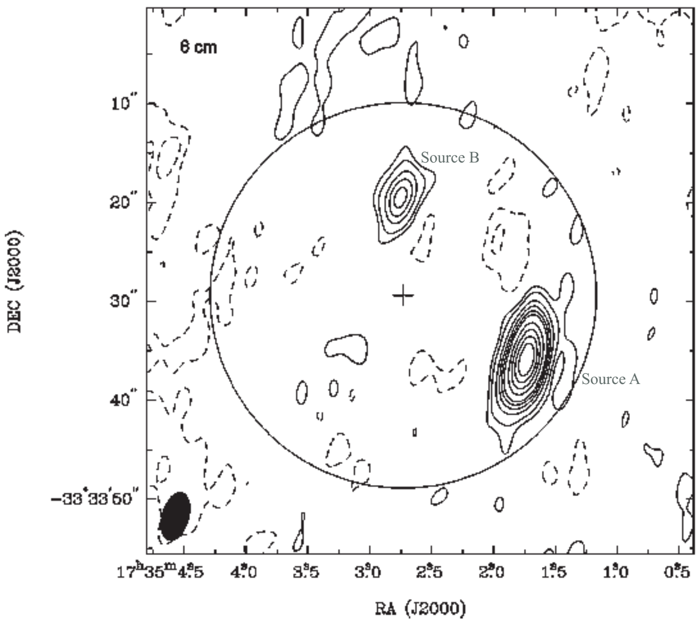


Figure 2: A Compact Array image obtained in 2005 showing the 6-cm radio continuum emission from V1018 Sco. The large circle indicates the approximate size of the optical planetary nebula. The ring has a diameter of 39 arcsec and is centred on the position of the central star which is marked by a small cross. The peak flux density of the 6-cm emission is 3 milliJansky.

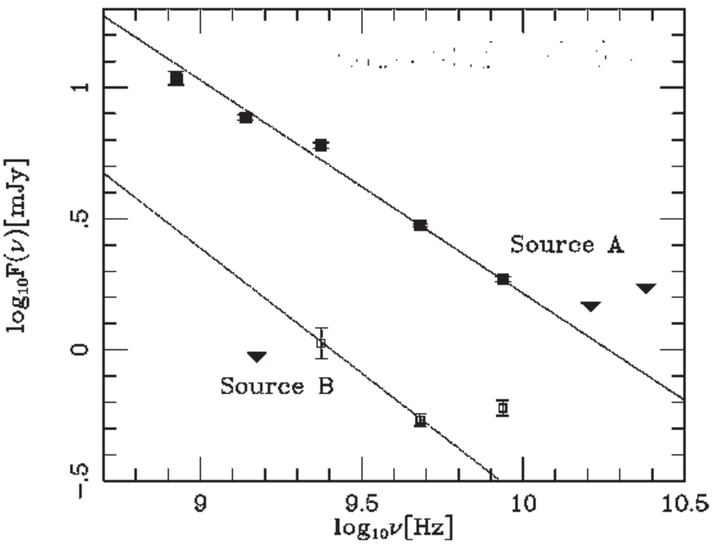


Figure 3: The spectral energy distribution of the two radio continuum sources A and B. The solid lines are power law fits to the data. The negative slope of the lines (with a spectral index of –0.8) shows that the emission is largely nonthermal.

# Shining a bright light on cold gas in the Magellanic Clouds

Jürgen Ott (ATNF), Jorge Luis Pineda Gálvez (AIfA, University of Bonn, Germany), Tony Wong (University of New South Wales & ATNF), Annie Hughes (Swinburne University of Technology & ATNF), Erik Muller (ATNF), and the LMC/SMC team

The Large and Small Magellanic Clouds (LMC and SMC respectively) are two gas-rich galaxies that are interacting with each other as well as with our Milky Way. Due to their proximity, the Magellanic Clouds are excellent laboratories for studying processes on scales that are difficult to investigate in the Milky Way due to our position within the Milky Way's disk. Furthermore, the LMC and SMC are dwarf galaxies that are less evolved than giant spiral galaxies like the Milky Way. Having experienced fewer generations of star formation, the interstellar medium in the Magellanic Clouds has a low metal content (LMC: 30%, SMC: 10% of solar metallicity), similar to the enrichment levels observed in the early Universe.

A key ingredient to form stars is molecular gas. This gas phase is formed in regions that are cool and dense enough to favour the formation of molecular hydrogen ($H_2$) from neutral hydrogen (HI). Stars are formed at a range of masses; the most massive exhausting their nuclear fuel quickly and returning large amounts of energy to the ambient interstellar medium. This process of "feedback"— which takes the form of strong stellar radiation and winds as well as supernova explosions—exerts a strong influence on the physical and chemical properties of the molecular gas phase.

The most massive star-forming region in the Local Group of galaxies is the 30 Doradus (30 Dor) region, located in the LMC (see Figure 1). Due to the presence of massive young stars, the 30 Dor region exhibits a very high radiation field, observable in the H$\alpha$ line of ionised hydrogen (shown in red in Figure 1 and the first panel in Figure 2). The formation of stars in this region is sustained by a chain of molecular clouds extending south from 30 Dor. This combination of an extreme radiation field and the long chain of molecular gas that stretches from 30 Dor into a relatively quiescent region of the LMC is a rare find. It is therefore an unparalleled laboratory to study the influence of the interstellar radiation field on molecular gas.

A team of researchers from ATNF, University of Bonn and Max-Planck-Institute for Radioastronomy (Germany), Nagoya University (Japan), University of NSW, and Swinburne University of Technology was formed to observe this molecular feature in the LMC with the ATNF Mopra telescope. The observations were taken for the most prominent molecular line, carbon monoxide (CO (1–0)), at the highest spatial resolution to date. The observed field consists of about 140 individual 5 x 5 arcmin sub-maps and required approximately 200 hours of total observing time. The observations were performed at a spatial resolution of approximately 35 arcsec (corresponding to 9 parsecs). This is about a five times higher linear resolution as compared to that previously observed with the NANTEN telescope (Fukui et al. 1999, see the overlay of the NANTEN and the Mopra maps in Figure 2). The resulting map is shown in Figure 1 (right panel), smoothed to a resolution of 45 arcsec to improve the signal-to-noise.

Figure 2 shows contours of the Mopra molecular gas data overlaid on observations at other wavelengths. The radiation field is traced by the H$\alpha$ emission line of hydrogen, for example, and also by far-infrared emission from dust. About half of the molecular ridge appears to be immersed in a very intense field of ionising radiation. Molecular clouds seem to be rarer where the ionising radiation is strongest, but the most massive clouds of molecular gas—associated with the N159 HII region —are also located in the strong field. As shown in the third panel of Figure 2 the molecular gas appears to occur where there are large aggregations of neutral gas (as traced by HI). However, a close inspection reveals that the peaks of the HI and CO emission never coincide, but are separated by a few tens of parsecs, i.e. the molecular gas usually occurs in local minima of the neutral gas. This may indicate that a certain column density threshold must be reached in order to form molecules, but the conversion of atomic gas into molecular gas depletes the neutral HI.

The high spatial resolution of the Mopra data is indispensable for a decomposition of the molecular ridge into individual clouds. In a first analysis, the team were able to identify about 150 individual molecular clouds, using a Gaussian decomposition method (Kramer et al. 1998). Applying the virial theorem, they derived the CO masses and hence the amount of $H_2$ in the gas. $H_2$ is the most abundant molecular species but is notoriously hard to observe (because the $H_2$ molecule lacks a permanent dipole moment). To determine the amount of $H_2$, and thus the total molecular gas mass, a CO-to-$H_2$ conversion factor (the "$X_{CO}$ factor") is used to convert a measured flux of the CO (J = 1–0) line to a $H_2$ column density. For many galaxies, in

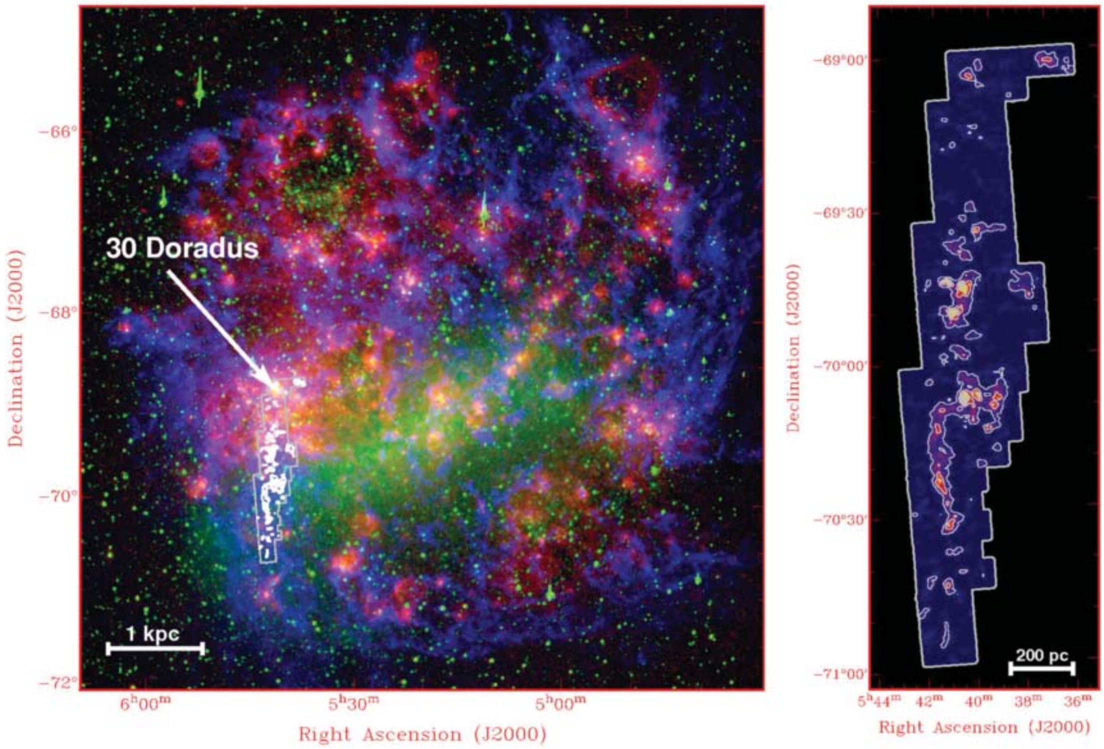


Figure 1: The left panel shows a three-colour composite image of the Large Magellanic Cloud. Neutral hydrogen (HI) is coloured blue, H$\alpha$ emission is red, and green is an optical (R-band) image. The 30 Doradus region, marked by the arrow, is the most actively star forming region in the Local Group. The grey area marks the region covered by our Mopra observations of the CO molecule (white contours) and a blow-up of the corresponding map is shown in the right panel.

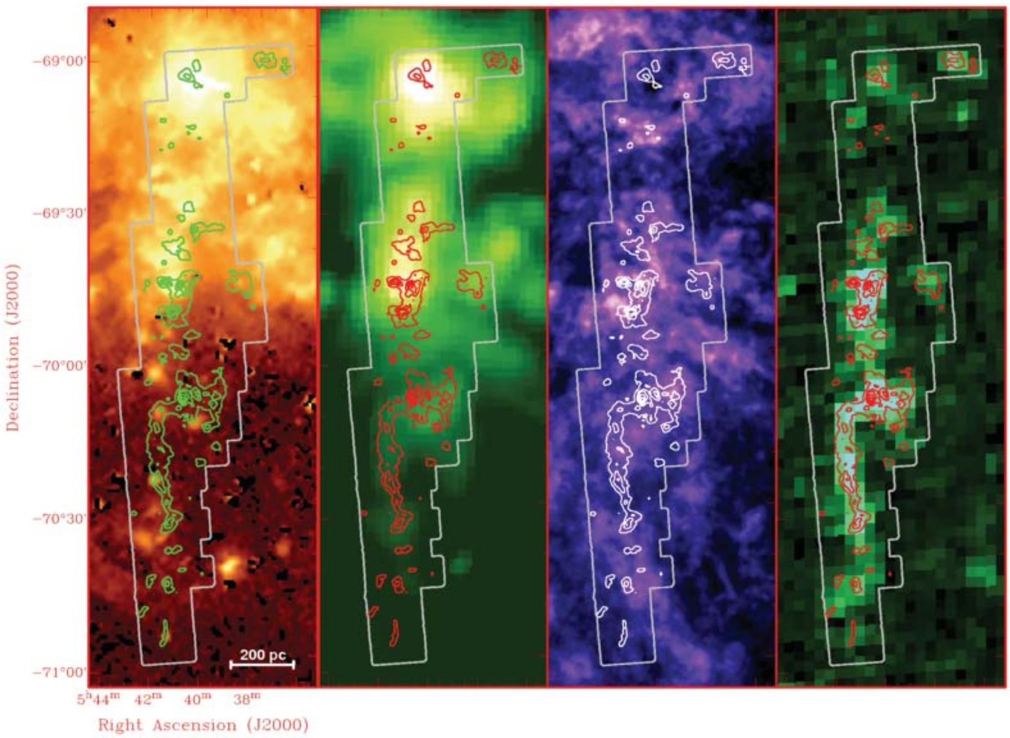


Figure 2: An overlay of the contours of the CO map shown in the right panel of Figure 1 on images at other wavelengths. From left to right: H$\alpha$ emission (SHASSA survey), far-infrared IRAS 100-micron emission from dust, neutral hydrogen (Kim et al. 1998), and the CO (J = 1–0) emission previously observed with the NANTEN telescope (Fukui et al. 1999).

particular those observed in the very young Universe, the $X_{CO}$ factor is often the only means to derive the amount of molecular gas present and hence determine the galaxy's star-formation efficiency. However, the dependence of $X_{CO}$ on parameters such as metallicity and the ambient radiation field remains unclear and controversial.

With the new Mopra data, the team were able to investigate the dependence of $X_{CO}$ on the strength of the radiation field. It was possible to disentangle this variable from other variables that do not change within the LMC. Figure 3 shows a graph of $X_{CO}$ (in units of the Galaxy's value) as a function of distance from 30 Dor. They found that $X_{CO}$ in the LMC is larger than measurements of $X_{CO}$ in the Milky Way. The Mopra data also places $X_{CO}$ in the LMC below previous estimates which suffer from poorer resolution. The analysis further indicates that $X_{CO}$ in the LMC is influenced by the intensity of the radiation field, i.e. the $X_{CO}$ factor increases towards the stronger radiation field near 30 Dor.

As part of this Magellanic-wide survey, the group has also begun a survey for CO towards the brightest identified star formation region within the SMC: N27 and surrounds. The CO emission within the SMC is extremely weak, being an order of magnitude lower than that of the LMC, and requires substantially deeper observations. At this preliminary stage, the CO emission regions appear to be generally well correlated with

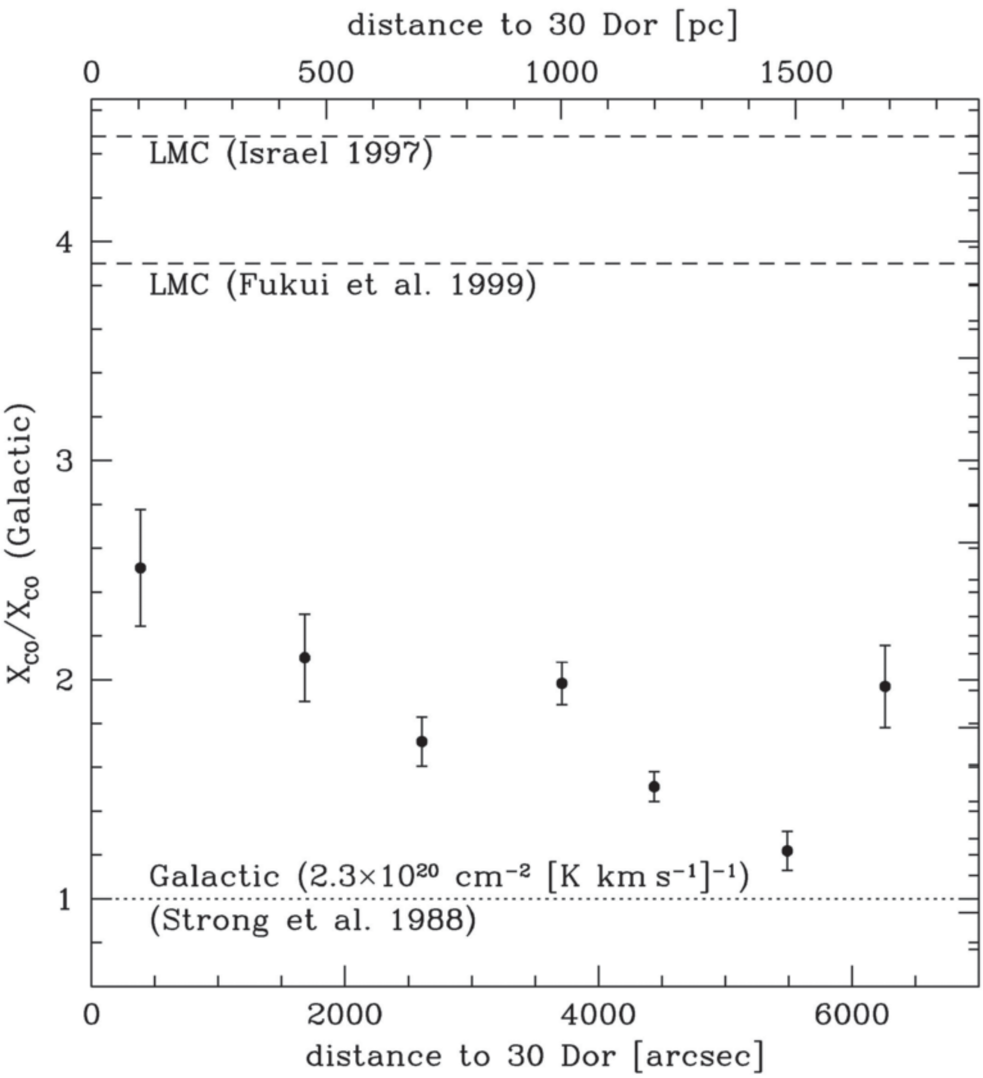


Figure 3: The CO-to-$H_2$ ($X_{CO}$) conversion factor (normalised on the Galactic value from Strong et al. 1988) along the molecular ridge as a function of distance from 30 Dor. Previous measurements of $X_{CO}$ in the LMC are marked as dashed horizontal lines.

bright infrared emission. The distribution of dust, measured from the Spitzer telescope (24-micron image, Bolatto et al. 2006) is shown in Fig. 4, overlaid with contours of CO emission detected by Mopra. The spatial coincidence of the dust and gas highlights the important role that dust plays in forming, and shielding the molecular gas within this very metal-poor galaxy.

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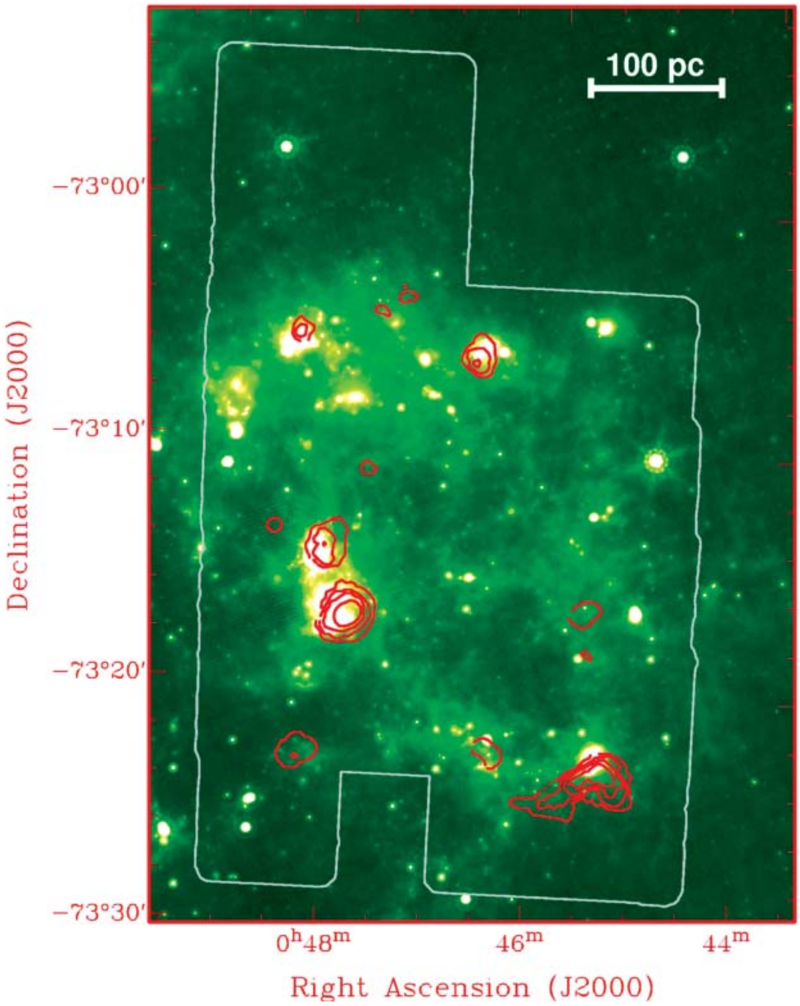


Figure 4: Contours of the first Mopra CO (J = 1–0) observations toward the south-west of the SMC overlaid on a Spitzer 24-micron image of dust (taken from Bolatto et al. 2006).

# Pinpointing Huygens: VLBI observations of the probe's descent

Chris Phillips (ATNF) on behalf of the Huygens team

On 14 January 2005 the European Space Agency (ESA) Huygens probe descended on to the surface of Saturn's moon, Titan. During the descent and for the three hours that the probe continued transmitting after it landed on the surface, the ATNF radio telescopes - Parkes, the Compact Array and Mopra, along with the University of Tasmania's telescopes in Hobart and Ceduna and 12 other telescopes in the USA, China and Japan were used to track the trajectory of the descent using the technique of Very Long Baseline Interferometry (VLBI).

As the probe parachuted to the surface of Titan, the data gathered by its on-board science packages was transmitted back to the Cassini spacecraft which stored the data and then re-transmitted it back to Earth after the descent. The ground based observations consisted of two experiments which eavesdropped on this transmission from Huygens.

The Doppler Wind Experiment (DWE) used ultra-precise spectrum analysers at both Parkes and the Greenbank telescope (in the USA) to measure the Doppler shift of the carrier signal. This allowed the line-of-site velocity of the carrier signal to be measured. This was to complement a similar onboard instrument allowing the velocity to be measured in two directions.

The second part of the ground based observations was a coordinated Very Long Baseline Interferometry experiment, coordinated by the Joint Institute for VLBI in Europe (JIVE), to accurately measure the location in the sky of the probe during its descent. Simulations by JIVE had shown that the position of the probe can be measured to an accuracy better than one kilometre every minute and the velocity measured to better than one metre per second. Combined with the DWE, the full three-dimensional trajectory of the descent could be reconstructed.

Because the signal from the probe was so weak, and the VLBI data needed to be processed using specially designed software, the standard tape based S2 recording systems were not suitable. Instead newly commissioned "LBADR" (LBA Data Recorder) systems were used which record the raw VLBI data directly onto computer hard disk drives, at a data rate four times faster than that achievable with the S2 recorders (512 Mbps, enough to fill a CD every 10 seconds). On the night of the experiment, the signal was first picked up by Greenbank confirming that the parachute had successfully deployed and the probe was transmitting. At 11:29 ADST, when Titan became visible at Parkes, the signal could immediately be detected. Sixteen minutes later Parkes could see that the probe had landed on the surface based on the characteristic of the changed Doppler shift. Three and a half hours later, when Titan was no longer visible at Parkes, the probe was still transmitting strongly. The probe had been expected to only survive a few minutes on the cold surface.

Because the participating VLBI telescopes were not connected by network links with enough bandwidth required for real-time correlation of the data, it was impossible to know if the observations were successful until the data were shipped to the central VLBI correlator. However, the team at JIVE was keen to determine the success of the experiment quickly, so it was decided to get the data from the ATNF telescopes to JIVE, in the Netherlands, as quickly as possible. At the end of the experiment, at 3:30 am local time, a twin-engine Cessna 310R was chartered to bring back the Compact Array, Mopra and Parkes data disks to Sydney. To facilitate a speedy transfer of data, nine research and education networks collaborated to give a dedicated door-to-door gigabit network connection from Sydney to JIVE in the Netherlands. The organisations involved included CeNTIE and AARNet within Australia, Pacific North West in the USA, CANARIE in Canada, and SURFnet in the Netherlands. This allowed a subset of the recorded Parkes and Mopra data to be transmitted to JIVE to process on their VLBI correlator. After a brief period translating the data format, JIVE was able to confirm fringes on the calibrator sources between Parkes and Mopra only a few hours after the observations were made.

The ground based observations were originally envisaged to complement the Doppler Wind Experiment on Cassini. However one of the two receiving channels on Cassini was misconfigured, meaning all the spacecraft Doppler measurements were lost. The DWE data from Parkes and Greenbank can replace the Cassini data, but there was a 20-minute gap where Titan was below the horizon at both Parkes and Greenbank. It now looks like JIVE will be able to use the VLBI data from the smaller telescopes to bridge this gap and allow Doppler measurements for the entire descent. Processing of the VLBI experiment is ongoing.

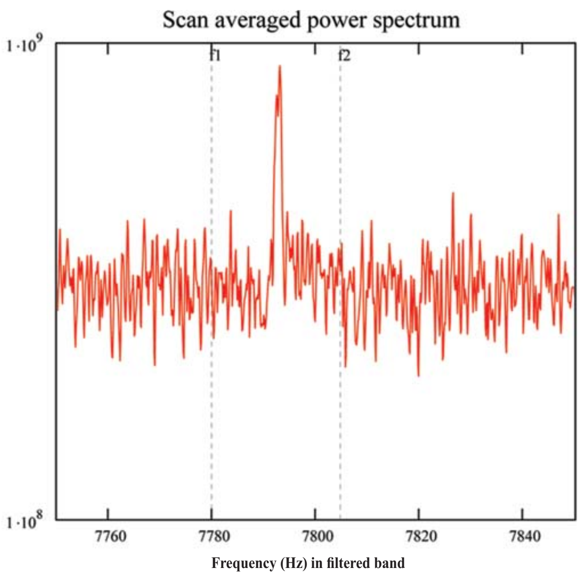


Image credit: Sergei Pogrebenko, JIVE

Figure 1: A scan-averaged power spectrum showing the Huygens carrier signal detected in the Parkes VLBI data.


Photo: © Liz Cutts

Figure 2: A tired-looking Tasso Tzioumis handing over Mopra observatory data disks to Chris Phillips at Coonabarabran airport in the early hours of the morning.

# Supersonic jets from massive stars

Kate Brooks (ATNF)

Now equipped with new 12- and 3-mm receivers, the Australia Telescope Compact Array can measure the flux of an astronomical source over discrete wavebands spanning the frequency range 1 to 100 GHz. In an ongoing project, Brooks and her collaborators are using this valuable capability of the Compact Array to study one of the most massive young stellar objects known to harbour a supersonic jet of ionised gas. The jet is associated with the infrared source IRAS 16547–4247, located at a distance of 2.9 kpc with a bolometric luminosity that is equivalent to that of a single O8 zero-age-main-sequence star. This is the first reported case of a radio jet associated with a young O-type star, supporting the notion that the accretion mechanism that produces jets in low-mass star formation also operates in the higher-mass regime.

Observations of IRAS 16547–4247 using the Compact Array were first made in 2000 as part of a larger study of a sample of objects thought to be very young massive stars (masses greater than eight times the mass of our Sun). Data were obtained over four radio continuum bands centred on 1.4, 2.5, 4.8 and 8.6 GHz. What set IRAS 16547–4247 apart from the rest of the sources in the sample was that the detected radio emission for IRAS 16547–4247 was confined to three discrete sources all in a line and with the outer sources symmetrically offset from the central source. From his previous work on radio jets, collaborator Garay from the University of Chile immediately recognised this striking morphology. On further inspection of the flux intensities at each frequency band, the central unresolved source was found to have a spectral index consistent with an ionised thermal jet and the two outer sources were found to have spectral indices consistent with non-thermal emission arising from the working surfaces of the jet as it interacts with the surrounding ambient medium.

Subsequent observations at near-infrared wavelengths were carried out in 2002 using the Very Large Telescope (VLT) in Chile. A complex chain of $H_2$ 2.12-micron emission knots was detected that traces a collimated flow extending over 1.5 pc (see Figure 1). The alignment of the $H_2$ flow and the central location of the radio jet imply that these phenomena are coupled. It is reasonable to assume that the radio jet is the driving force of the collimated flow. Follow-up observations using the VLA were made in 2003 using continuum bands

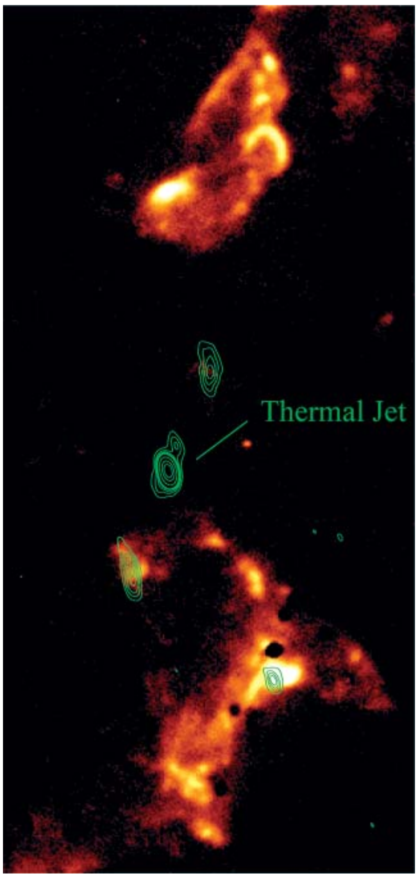


Image credit: K. Brooks (ATNF) and M. Voronkov (ATNF)

Figure 1: Collimated jet source associated with the massive protostar in IRAS 16547–4247. VLT $H_2$ 2.12-micron emission image overlaid with contours of emission at 24.9 GHz (12 mm) detected with the Australia Telescope Compact Array.

centred on 8.46 and 14.9 GHz. These data resolved angularly the central thermal radio jet and yielded an estimate of ~25 degrees for the opening angle of the jet, indicating significant collimation.

In 2005 data was taken again with the Compact Array but this time using the new continuum bands centred on 24.9 GHz (12 mm) and 88 GHz (3 mm). At 24.9 GHz, all three radio components were detected plus an additional source offset to the southwest from the central radio jet and corresponding to a bright $H_2$ emission knot (see Figure 1). Emission at 88 GHz was detected towards the central radio jet. The measured spectral energy distribution of the central radio jet is shown in Figure 2. A model for the thermal emission from a collimated jet has been fit to the data at low frequencies and a model for the thermal dust emission from a circumstellar envelope/disk has been fit to the data at high frequencies. The changeover occurs at 50 GHz.

The findings made with the Australia Telescope Compact Array towards IRAS 16547–4247 are significant because they confirm that collimated jets can be present in young massive stars and provide tantalizing evidence for the presence of circumstellar disks as well. The new receivers operating in the 7-mm wave band (30 – 50 GHz) to be installed at the Australia Telescope Compact Array in 2007 will open a window of opportunity in the study of young massive stars, particularly in the hunt for more stars with collimated jets and circumstellar disks. As evident in Figure 2, 7-mm marks the turnover between emission from ionised gas and emission from dust. It is in this waveband that the jet will not only be at its brightest but also at its smallest angular size, and therefore closest to the powering star.

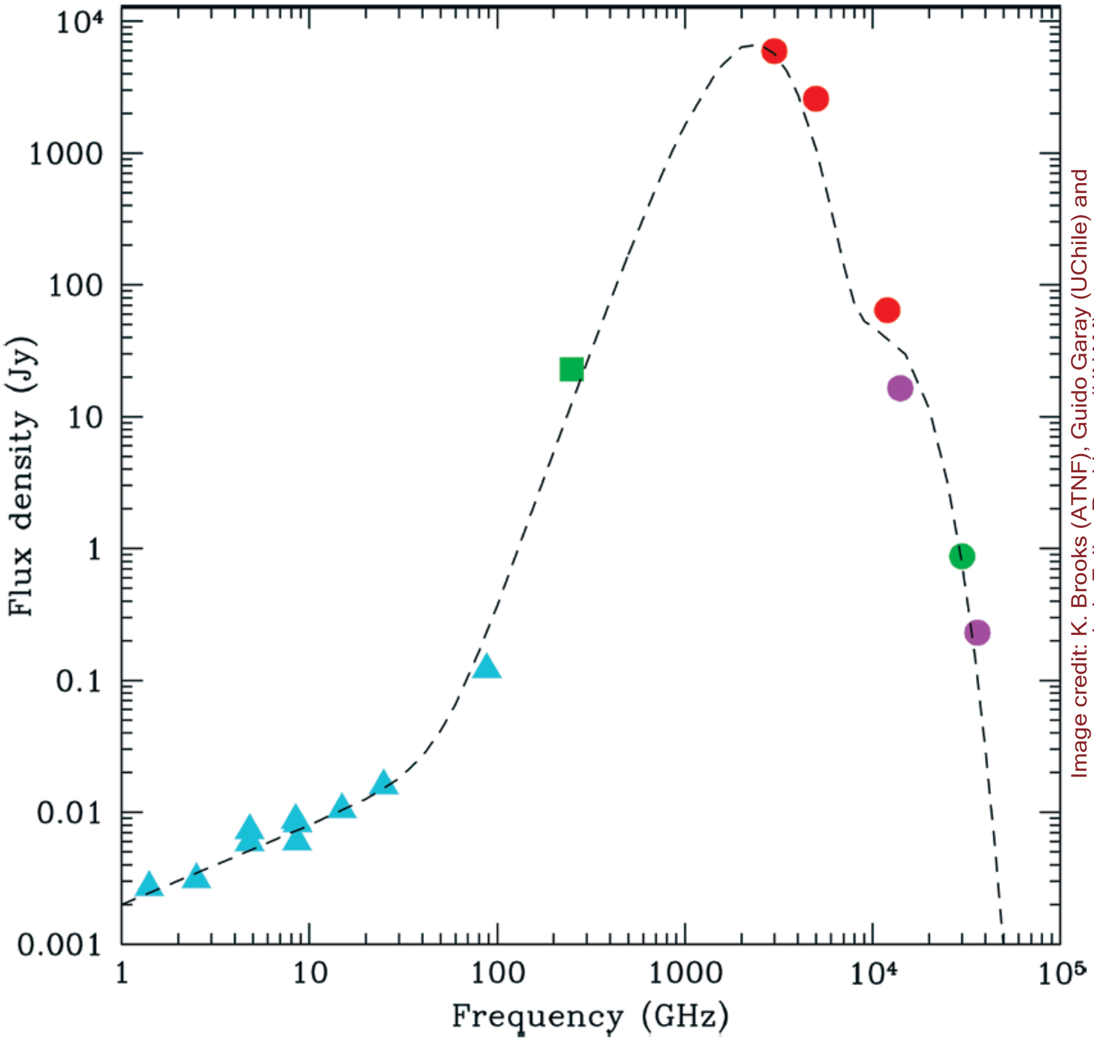


Image credit: K. Brooks (ATNF), Guido Garay (UChile) and Luis-Felipe Rodriguez (UNAM)

Figure 2: Spectral Energy Distribution of IRAS 16547–4247. Data have been obtained over a variety of telescopes. Australia Telescope Compact Array and VLA data are indicated by blue triangles. Emission less than ~50 GHz corresponds to ionised thermal emission (in this case arising from a thermal jet) whereas emission greater than ~50 GHz is primarily from thermal dust emission from a circumstellar disk or envelope.

# Compact Array images dense gas in a circumnuclear ring

Tony Wong (University of New South Wales & ATNF), Stuart Ryder (Anglo-Australian Observatory), Michael Dahlem (ATNF), Kotaro Kohno (University of Tokyo), & Ron Buta (University of Alabama)

Starbursts are regions of enhanced star formation efficiency, where gas is being converted into stars at much higher rates than can be sustained over billions of years. Aside from merging or dwarf galaxies, one of the most common sites for starbursts is the central kiloparsec of barred spiral galaxies. There they appear as bright circumnuclear rings and can be seen in emission tracers of ionised gas such as hydrogen recombination lines or radio continuum. A good example is the nearby galaxy NGC 7552 in the southern Grus Quartet, which has been imaged with the Compact Array at a wavelength of 3 cm by Forbes et al. (1994) (see Figure 1(b)). NGC 7552 has been extensively studied, not only as a starburst but as a classic example of a multiple-ringed galaxy: in additional to a circumnuclear ring that has a radius of three arcsec, Forbes et al. identify an inner ring of dimensions 150 arcsec x 95 arcsec and an outer ring of dimensions 180 arcsec x 160 arcsec.

In 2005 this galaxy was observed with the Compact Array in the 3-mm lines of HCN and $HCO^+$. These lines trace the densest molecular gas and thus provide information on where star formation is likely to occur. The two lines were observed simultaneously, allowing a direct comparison of their line strengths. Both lines were detected at comparable strength with a peak signal-to-noise ratio of about 15. The images, which show both the rotation velocity of the ring and the distribution of dense gas along it, are among the best 3-mm images produced thus far from Compact Array data. The quality of the images can be directly attributed to three factors. Firstly, data were combined from three configurations of the Compact Array to provide nearly complete coverage of the visibility plane from baselines of 30 m to 200 m. Secondly, the observations were taken in good weather condition. Finally, the use of a nearby phase calibrator (within five degrees) minimised errors in calibration.

Although analysis is still in progress, a few results are already apparent. The $HCO^+$ molecule shows a somewhat more extended distribution than HCN, even though the two molecules require similar densities for excitation. This may be attributable to the strong ultraviolet radiation near a starburst, which may enhance the $HCO^+$ abundance. Both molecular tracers display a double or "twin peaks" morphology, which is commonly seen in barred galaxies. This has been attributed to crowding of gas orbits as they shift from being oriented parallel to perpendicular to the bar. The twin peaks occur approximately where the bar dust lanes (oriented east-west) intersect the ring (see Figure 2). Inside the ring there doesn't seem to be much gas, consistent with the relative lack of star formation there. This indicates that the inflow of gas along the bar which feeds the ring does not continue on to the nucleus, presumably due to orbital "resonances" associated with the bar. Any central black hole is therefore "starved" of fuel by the inability of gas to flow inwards.

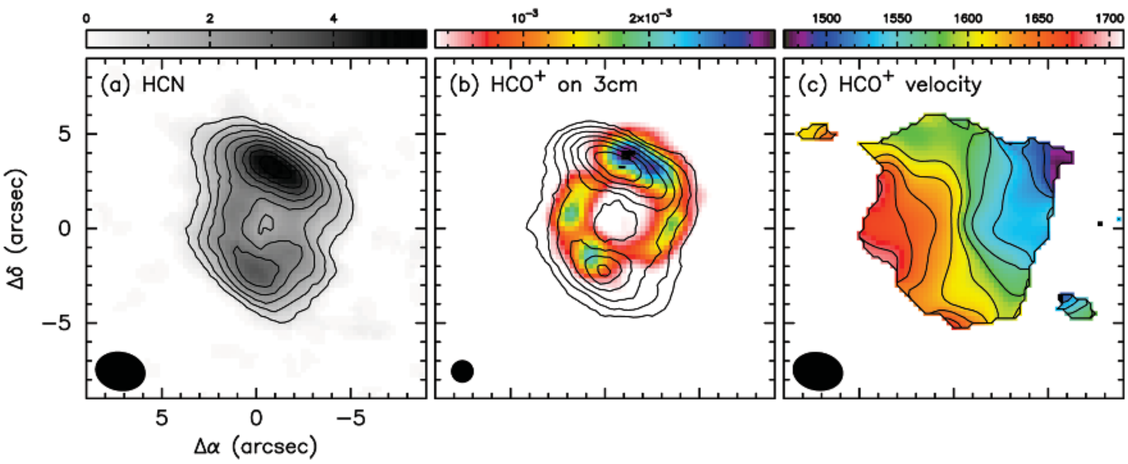


Figure 1: (a) A Compact Array HCN intensity image, shown as both greyscale and as contours. The beam size of 2.6 arcsec x 2 arcsec is shown at lower left. (b) Compact Array $HCO^+$ contours overlaid on the Compact Array 3-cm image of Forbes et al. (1994), recently reprocessed by Wong et al. (c) A velocity image derived from Gaussian fitting to the $HCO^+$ data cube. The units are in kilometres per second, with contours spaced by intervals of 20 kilometres per second from 1500 to 1700 kilometres per second.

Figure 1(b) shows that the dense gas is distributed somewhat differently from the 3-cm radio continuum emission, which is believed to be mostly non-thermal in origin (Forbes et al. 1994). Since extinction does not affect the radio image, the offset may be related to a time delay between the peaks in the dense gas (which are tied to the pattern speed of the bar), and the locations of recent star formation (which may revolve at a different angular velocity). The symmetry of the 3-cm emission suggests that there may be a regular timescale on which bursts of star formation occur. Further comparison with recently released Spitzer Space Telescope infrared images at a wavelength of 8 microns is currently underway (see Figure 2).

The distribution of dense molecular gas can differ significantly from that of the more diffuse molecular gas traced by the CO line, as pointed out for instance by Kohno et al. (1999), who compared CO and HCN images of NGC 6951. They found that CO tends to occur in the bar dust lanes as well as the ring, but HCN is concentrated in the circumnuclear ring. This points to relatively low densities in the shocked gas associated with the dust lanes, with higher densities being achieved only once gas falls into more circular orbits in the ring. Already our $HCO^+$ data reveal evidence for non-circular gas motions towards the outer edge of emission, in the form of "S-shaped" contours of constant velocity (Figure 1(c)). Upcoming CO (2–1) observations with the Submillimeter Array should provide a clearer picture of how gas is transported in towards the ring.

## Acknowledgments

We thank the ATNF engineers and Narrabri staff for their efforts which have led to significant improvements in the 3-mm receiver temperatures and antenna gains.

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Kennicutt, R. C., et al. 2003, PASP, 115, 928

Kohno, K., Kawabe, R., & Vila-Vilaró, B. 1999, ApJ, 511, 157

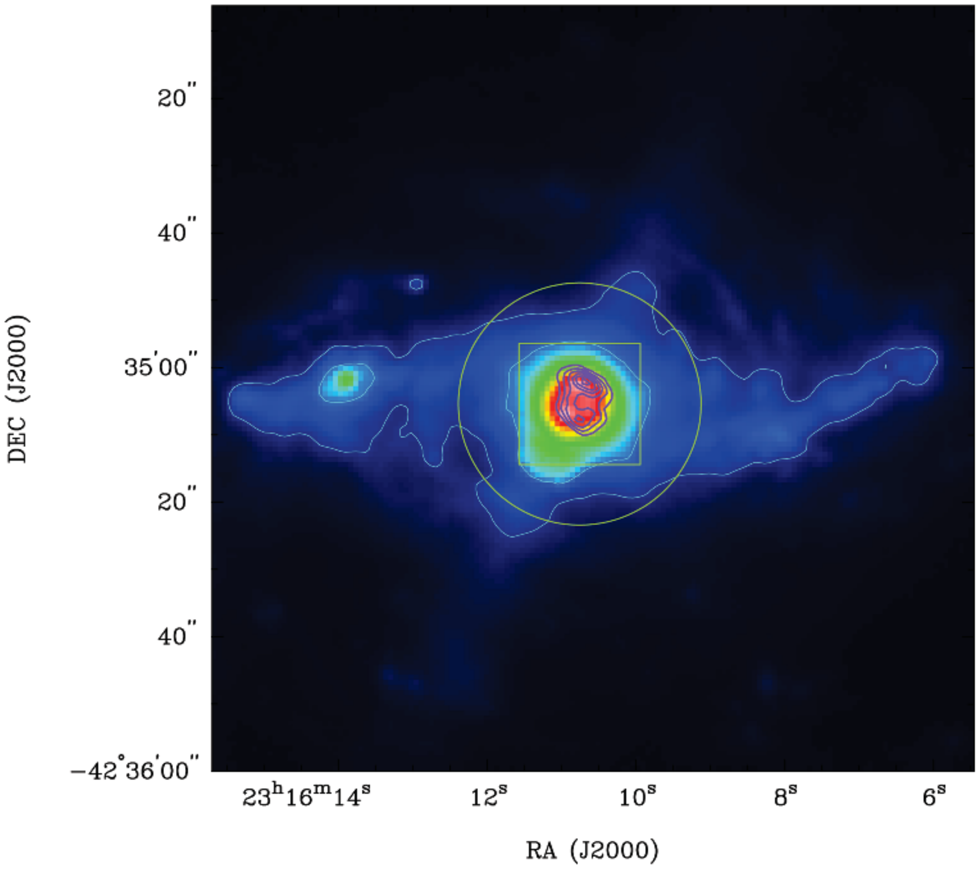



Figure 2: A Spitzer 8-micron infrared image from the SINGS Legacy Project (Kennicutt et al. 2003). The dark contours at the centre show the HCN emission. The box represents the region shown in Fig. 1, whereas the circle represents the Compact Array field of view. The infrared image shows emission from heated molecular aggregates known as PAHs.

# Observatory reports

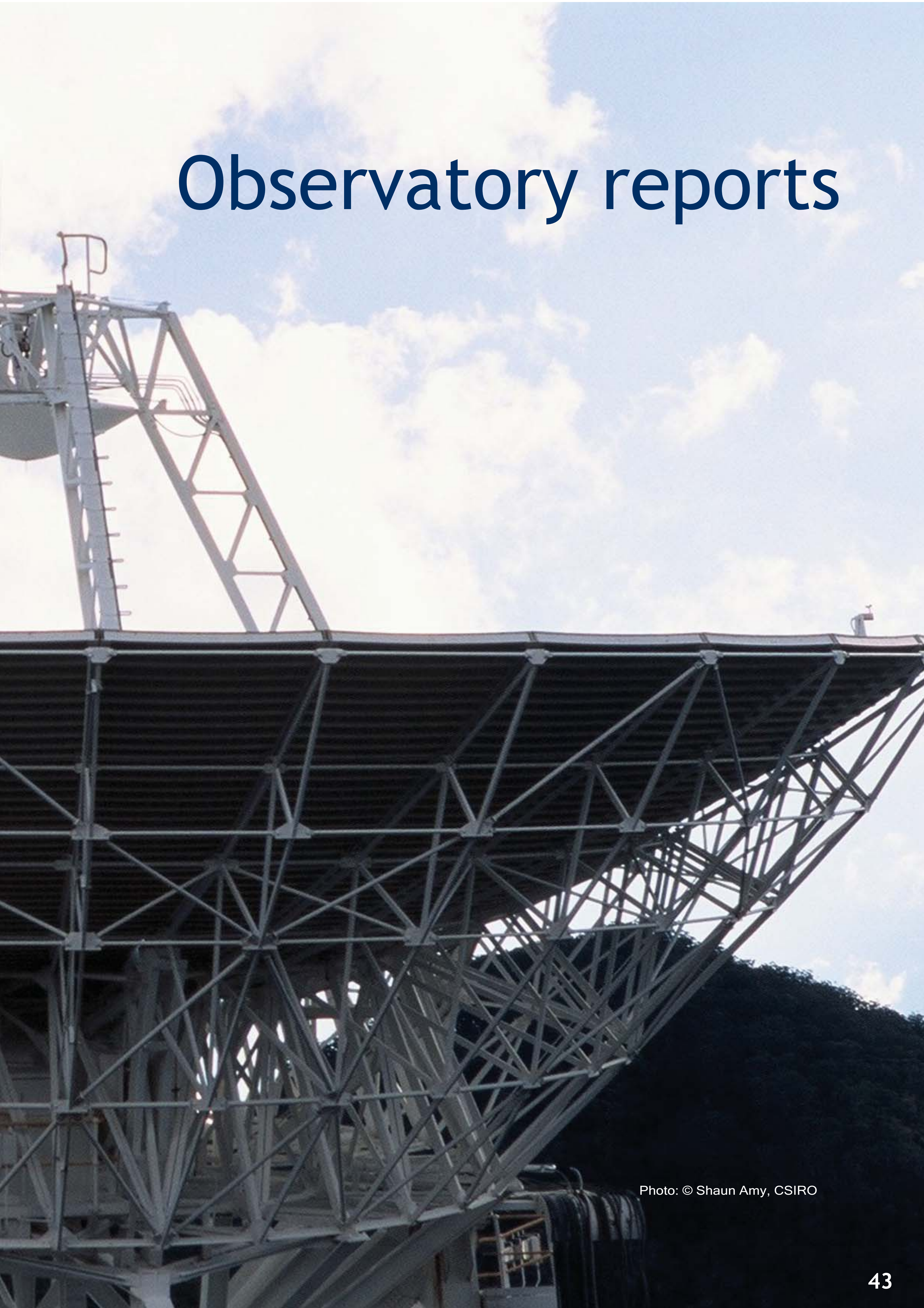


Photo: © Shaun Amy, CSIRO

# Australia Telescope Compact Array

## Upgrades and developments

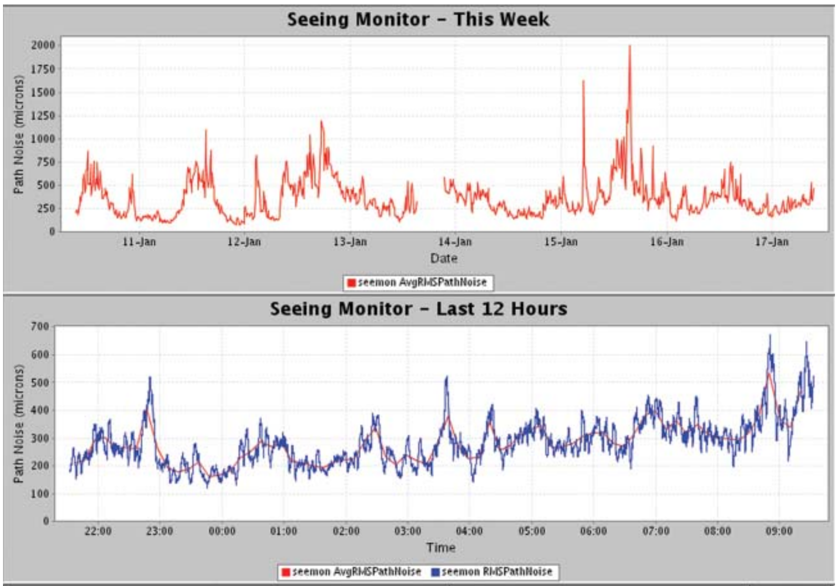
### Millimetre system developments

2005 saw the first full millimetre observing season for the new 3-mm receivers. Observations were scheduled in the winter season between May and October. Overall the new systems performed very well with 3-mm above atmosphere system temperatures of typically 250 K and lowest system temperatures (for antenna 4) of 150 K. During the semester, observing at 3-mm wavelength became far more routine, although it was still necessary for observers to be more attentive than for centimetre observing.

A number of operational issues with the millimetre systems became apparent during the year including subtle and unexpected instrumental phase terms and the care needed with antenna pointing during calibration observations. Investigations of these problems led to a deeper understanding of the systems.

One problem that was resolved was the optics of antenna 1. When the 3-mm system was installed on antenna 1 in October 2004, it became apparent that the gain and beam pattern of antenna 1 was substantially poorer than for the other antennas. Following photogrammetry on antennas 1, 2 and 6, the reasons for this poor performance were clarified. All of the subreflectors on the Compact Array antennas are somewhat under-engineered. They are not naturally rigid and conform to the design shape only to about one millimetre; this is a large error for 3-mm observations. Following holographic measurements, previous adjustments had shaped the main dish surface to counter the subreflector errors. However, later work on antenna 1 had modified the subreflector, so that the subreflector and main surface were no longer a "matched pair". Further holographic measurements and main-surface adjustments for this antenna were carried out in early February 2005. This reduced the rms surface error of the subreflector/main-surface combination from 290 microns to 150 microns. During March, adjustments were also made to the subreflectors on other antennas in the array. The overall improvements to the antenna gains led to more robust reference pointing.

Another system problem that was investigated during the year was that high system temperatures were recorded on some receivers in the 12-mm band. This is caused by condensation on the outside of the dewar window and from icing within the dewar. Planning commenced for a design modification that will use a dry air system to fix the condensation problem. This will first be tested on the Mopra millimetre receiver.




| Point | seemon | Units |
|---|---|---|
| Averaged RMS Path Length Noise | 469.9 | microns |
| RMS Path Length Noise | 501.2 | microns |
| | | |
| Data Time-Stamp | 2006-01-16 22:33:01.309 | UT |

A sample screen-shot from MoniCA showing two plots for the atmospheric phase stability over different time intervals.

During the winter a second set of 16-MHz filters was installed on the Compact Array. These are now a normal part of the observing system and are available for use with any of the observing bands. However, it is expected that the filters will be mostly requested for millimetre observing.

After the first year of use the atmospheric seeing monitors were shutdown for maintenance and checks. Modifications were made to each unit to improve their cooling. The units provide an excellent diagnostic of atmospheric phase conditions.

## Computing developments

The Narrabri Observatory is pursuing a program to modernise the computing infrastructure used to operate the telescope. This includes the computing hardware, software and networks.

Over the last three years the old VMS operating system, which has been in use for 17 years, has been phased out to be replaced by the LINUX operating system, and the online software has been translated to operate in the new environment. The LINUX-based observing system was first used in 2004 to support some special astronomy observations. The switch to LINUX initially encountered some problems with system bugs. However, since November 2005 the LINUX-based observing software has been fully functional and used as the standard observing system.

During 2005 the Narrabri Computing Group developed and released a powerful application for inspecting telescope monitor points at the Compact Array and Mopra. The client software, called MoniCA, is a Java-based graphical user interface program that enables both observers and technical staff to monitor the thousands of data points available at each site, including data for cryogenic temperatures and pressures, sampler statistics, site weather information, power supply voltages and so on. MoniCA also allows monitoring of the atmospheric sky brightness and may be used with real-time or archived data. One shortcoming of this monitor is that it only sees the sky when the 3/12-mm receiver package is in use. A new lightning monitor was also installed as part of the monitoring systems.

One "quiet achievement" was the almost total elimination of antenna control computer (ACC) crashes, with no such crashes occurring since mid-2005. ACC crashes previously occurred almost daily and were a significant contribution to the telescope downtime. The crashes were finally traced to a hardware-related interaction within the ACC operating system.

## Operations

### Duty astronomers

Duty astronomers at the Compact Array are rostered from ATNF staff and students to provide support to observers at Narrabri for periods of one week at a time. The duty astronomers assist observers prepare observing schedules, help set up the Compact Array at the start of an observing run, diagnose and attempt to solve problems that arise in the course of the observations, and help observers with the initial analysis of their data.

Following input from the user community some changes were made to the duty astronomer system with the aim of improving the reliability of the support provided to observers. Since 1 April 2005 the ATNF has reinforced the requirement that duty astronomers are expected to arrive at the Observatory before the start of their rostered period. Inexperienced duty astronomers receive a detailed induction during this time from a member of the telescope staff. Experienced non-ATNF astronomers may serve as duty astronomers, but require prior approval of the Assistant Director for Operations.

### Major observing projects

Two projects stand out as large users of Compact Array time in 2005. LVHIS – the Local Volume HI Survey (Koribalski et al.) makes deep HI line and 20-cm radio continuum observations of all nearby, gas-rich galaxies identified in HI Parkes All-Sky Survey (HIPASS). This project used 600 hours of Compact Array time in 2005. The 20-GHz continuum survey (Ekers et al.) began in 2002 and continues to be a major project. This survey has now accumulated more that 1500 hours with the Compact Array and observed for 835 hours during 2005.


ATNF staff at the Narrabri Observatory.

Photo: © Vincent McIntyre, CSIRO

## Road damage and storms

On 9 – 10 December 2004 the Narrabri district experienced an extreme rain fall, resulting in significant flooding and road damage. A 100-m section of road on the main access route to the Observatory was washed away and the road remained unusable until late January 2005. Despite these events the Observatory operated normally with visitors and staff using a different access road between the Observatory and town.

On 20 January 2005, a severe storm and high winds caused considerable damage to the town of Narrabri. Fortunately the Observatory sustained little damage.

## An explosive event

In the early hours of the morning on 9 December 2005 the main 22kV transformer, supplying power to the Control building and Visitor Centre, exploded. The resulting power surges caused a power loss to equipment in the Control Building and overwhelmed the uninterruptible power supply (UPS). The systems were recovered by mid-morning with the Control Building under generator power and the UPS restarted. By early evening the failed transformer was shipped off for repair, and replaced using a transformer from the north spur. Country Energy provided a very fast response and moved heavy equipment and several expert technicians to the site with very little notice. The repaired transformer will be reinstalled in 2006.

## Visitor Centre redevelopment

In 2005 the Narrabri Visitors Centre received about 11,000 visitors. Small groups of visitors are self-guided while staff guides are provided for pre-arranged tours.

Plans for the re-development of the Visitors Centre at Narrabri  progressed well during 2005. The goals for the Visitors Centre are to provide a high-quality experience for visitors, to maintain the Observatory as a major tourist attraction in the Narrabri area and to capitalise on what the Observatory has in abundance: a pleasant bush environment and impressive views of the Compact Array.

Designs for a range of new displays, including interpretive panels, sculptures and other exhibits were completed by the company Convergence Design, in consultation with ATNF staff. The initial on-site installation

Photo: © Derek Aboltins, CSIRO

Floodwaters eroding away a section of the Yarrie Lake road from Narrabri to the Observatory.


Photo: © John Smith, CSIRO

One of the new displays of the Narrabri Visitors Centre, showing a sculptural representation of the Milky Way and Magellanic streams and one of the new information panels.

took place in December. The new displays are located in the grounds around the Visitors Centre building and provide visitors with a wealth of information about the Compact Array, the Narrabri site, the ATNF, CSIRO and astronomy. Several sculptures were installed to show visitors three-dimensional models of the Magellanic Clouds, radio galaxies and the expanding universe. These, together with interpretive panels, lead visitors on a tour from our Galaxy to the distant universe. Other exhibits show the more technical side of radio astronomy with information provided about radio waves and how radio telescopes work. It is expected that the installation and changes to the landscaping around the Visitor Centre will be completed in early 2006.

As well as the outdoor developments, a new exhibit was installed in the theatre of the Narrabri Visitors Centre in late 2005 and proved popular with visitors. ViewSpace is a free-running multimedia presentation from the Space Telescope Science Institute designed for museums, planetaria and visitor centres. It shows some of the latest imagery from a variety of space missions and ground-based observatories, animations, interpretive captions and evocative music. Display segments are updated automatically with a typical section lasting several minutes.

## Site infrastructure

Late in 2004, funding was granted for a major refurbishment and extension to the Control Building. The original part of the Control Building was built in 1964 and is now showing signs of its age. During the year the building plans progressed well with major design decisions made and the layout of the building well established. It is anticipated that ground breaking will occur late in 2006 with occupation in 2007. An RFI consultant was appointed to the design team as part of an effort to reduce RFI from the Control Building. A new extension to the control building will house administration, visitors services, and the electronics group which includes the receiver and cryogenics laboratories. The refurbished Control Building will house the observers area, support scientists, library, and computer group. It will include storage for administration and the screened room. During the construction phase there will be some inconvenience, but only minor interruptions, to Compact Array operations.

Late in the year approximately 30 kilometres of broadband fibre was installed connecting the Observatory to the AARNET3 network running down the Newell Highway. A similar connection was made for Mopra. When commissioned these will give the Narrabri and Mopra observatories a 1 Gbit/s links and will be used for VLBI observing (page 54).

# Mopra

Astronomical use of the Mopra telescope can be divided into two main classes: as an antenna in a VLBI array and as a single-dish telescope used for spectroscopy at 3-mm wavelengths.

2005 was an excellent year for Mopra publications with eight refereed papers that include Mopra data, a significant increase from two refereed papers in 2004. The scientific productivity of Mopra, as measured by papers published per dollar spent, was comparable to that of the Compact Array and Parkes.

## Developments

In 2005 a concerted effort took place at Mopra to improve both the technical performance of the telescope and the site systems in general. These aimed to increase the capabilities of the instrument to deliver science, allow for future remote operations from Narrabri, and to make more general improvements for visitors to the site.

During a shutdown in September, the old 3-mm SIS receiver system was removed and a MMIC receiver design, based on the Compact Array-style millimetre receiver, was installed. The new MMIC receiver covers the bands 16 – 26 GHz and 77 – 117 GHz. The removal of the SIS receiver also saw the decommissioning of the dual stage scroll compressor, a special cryogenics compressor that had been purpose built for the SIS receiver.

Tests showed that the system temperature of the new receiver is at least as good as, and in many cases better than, the SIS system. In addition it has a broader frequency range, broader instantaneously accessible bandwidth and requires no mechanical tuning. The new receiver also requires less maintenance and is a far more robust system. Observer reports confirm that the new receiver is far easier to use.

Associated with this work the Mopra cryogenic system was upgraded for the new receiver, as were various hardware modules for system monitoring and control. This included updating the conversion systems to a similar standard as at the Compact Array. A new millimetre conversion system was put in and the control of the conversion rack was made to operate in the same way as at the Compact Array.

In addition, the new wideband IF system was installed with the first 2-GHz "trial" segment of the Mopra digital filterbank (MOPS). This system is a step up from the 600-MHz "Proof-of-Concept" (POCS) digital filterbank which was used in the previous year and for an observation run in July 2005.

As a result of these developments, the LINUX-based operating and monitoring software developed in 2004 were further refined to control the new receiver and conversion system. The end result was hardware and software essentially ready for remote operations of the telescope. The "on-the-fly mapping" feature also developed in 2004 continued to be significant and several projects during the millimetre season exploited this ability.

A number of hardware improvements were also made early in the year to tidy up redundant hardware primary monitoring and alarm systems. MAPS, the primary alarm monitor system, was significantly updated so that its reliability would be improved and to allow for further improvements. The site video monitoring system was also updated. The end goal of this work was to have systems in place to allow safe remote operations of Mopra from the Narrabri Control Building.

Some upgrades were also made to the Mopra lodge which received a facelift with a new coat of paint inside, new carpet and some new furniture and fixtures.

## Operations

The Mopra millimetre observing season ran was scheduled from 20 May to 31 October. Two VLBI runs were scheduled for the year at each end of the season.

The annual "Mopra Introduction Weekend" was again held on 27 to 29 May. This workshop aims at developing better understanding of millimetre astronomy and the practicalities of observing with Mopra. It included formal talks, tutorials, and practical sessions. In total 24 people participated.

Effort continued to bring Mopra in line with the operational practices of the other ATNF Observatories. Changes were made to the way that Mopra is scheduled with time allocated according to the sidereal time requirements of each project, rather than in longer blocks. The scheduling changes allowed Mopra to be used for a larger fraction of time as well as over a longer observing season.

The Mopra user feedback for 2005 (page 19) shows that users were more satisfied with the documentation and with the on-line observing systems and off-line software. However, some effort is still needed to improve these, particularly as the systems have changed considerably.

Mopra observing and operations were again supported by an operations scientist based in Narrabri. Typically the operations scientist provided observing assistance in Mopra for the first few days of an observing run. Engineering support for Mopra continued to be provided by Narrabri staff with some additional assistance from technical personnel at the Anglo-Australian Telescope.

Photo: © Ray Moncay, CSIRO

The new 3-mm receiver for the Mopra telescope.

# Parkes

## Methanol Multibeam receiver

Construction continued for a new seven-beam receiver covering the frequency range 5.9 – 6.9 GHz, and including the important 6.7-GHz transition of the methanol molecule and this made good progress. Design and construction of this state-of-the-art receiver are being shared between ATNF and Jodrell Bank Observatory (JBO), building on the very productive multi-beaming technology exploited so well with the 20-cm Multibeam receiver still in high demand at Parkes, and the ALFA receiver built for Arecibo.

Commissioning of the new receiver was originally scheduled for October – November 2005. This was delayed until January 2006 by unforeseen construction problems. The new receiver will initially undertake two large surveys. The first of these will be a complete and “blind” survey of star forming regions along the Galactic plane using the 6.7-GHz methanol maser transition. (The methanol molecule is a key tracer of star formation regions). This survey will be far more sensitive than any comparable survey attempted in the past. The second survey will aim to detect pulsars deep in the Galactic Plane and particularly towards the Galactic Centre, where the pulsed signals are strongly dispersed by the interstellar medium at the lower frequencies used in earlier surveys.

A second conversion chain is planned for the receiver to allow a 6035-MHz blind survey for OH (the hydroxyl molecule) to be piggy-backed onto the methanol survey. This piggy-back mode also makes excellent use of the partial merging of the multibeam and wideband correlators implemented initially for the GASS survey (see below). The second frequency chain also doubles the total bandwidth of the pulsar survey. It is intended that once these two main surveys are complete, the new receiver will be transported to Jodrell Bank Observatory, probably in 2008, for similar surveys of the northern sky.

## Pulsar digital filterbank

The prototype of a new polyphase digital filterbank (DFB) designed for high precision pulsar timing was successfully installed and commissioned at Parkes in June 2005. The prototype unit is limited to 256 MHz bandwidth but has significantly improved time resolution and sensitivity over the Wideband Correlator (WBC) for pulsar periods of ~20 milliseconds or less. (The WBC has low-level timing noise at fast periods that is difficult to eliminate). The fully-functional DFB when delivered will have one GHz of bandwidth and two microsecond time resolution for pulsar periods down to 0.5 milliseconds. At present delivery of the final unit is uncertain owing to the inability of manufacturers Xilinx to deliver chips to the specifications used in the DFB design.

## GASS

The Galactic All-sky Survey (GASS) is a fully-sampled survey of Galactic HI over the whole southern sky with 15-arcmin angular resolution, a spectral resolution of one kilometer per second and a sensitivity limit of 70 mJy. GASS represents a big leap forward in sensitivity and resolution over the very successful Leiden-Dwingeloo and IAR surveys. GASS observations commenced at Parkes in January 2005 and proceeded at regular intervals since then. The bulk of the survey is expected to be completed in 2006, prior to the removal of the 20-cm multibeam receiver for the second stage of its refurbishment. Observations for this project use the multibeam correlator and pulsar wideband correlator in a combined mode to provide 2048 spectral channels for all 13 beams of the receiver, an innovation implemented specifically for this project but with potential benefits for other surveys. Preliminary results from the survey are very promising. In particular the investigators have refined a simple and effective technique for controlling for stray radiation, without the need for mapping the far-sidelobe pattern of the 20-cm multibeam system.

## Huygens results

Parkes' highly successful and much publicised role in tracking the Huygens probe during its descent to the surface of Titan on 14 Jan 2005 is described on page 36 of this report. The first tranche of publications from the Huygens mission appeared in the 8 December 2005 issue of Nature. Several articles, particularly "The Vertical profile of winds on Titan" (Bird et el., pp 800 - 802), include results from the "radio science" data taken at Parkes.

## Usage statistics for 2005

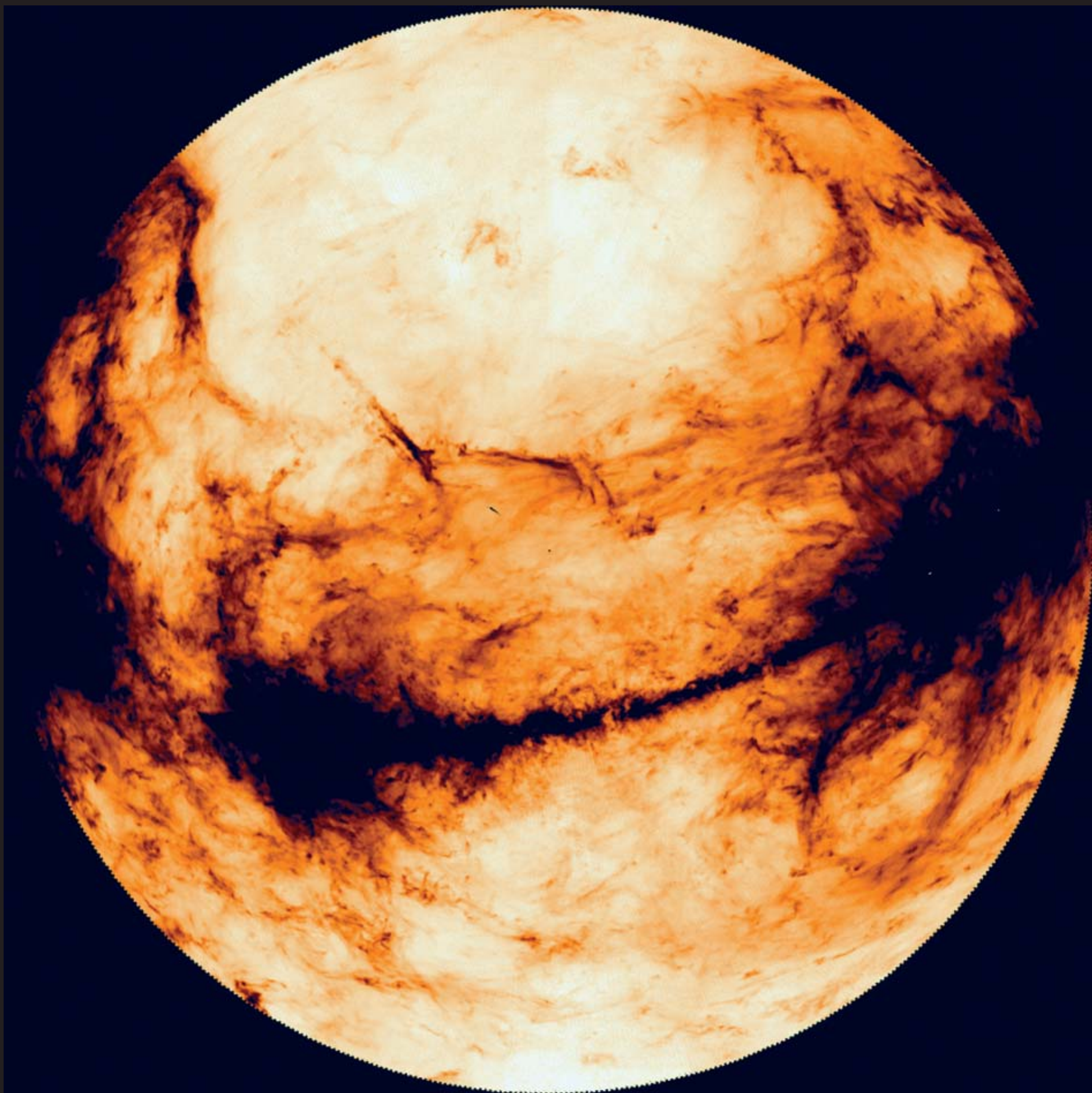
The Parkes usage statistics for 2005 are shown on page 12. Time lost to equipment and wind are typical of those over recent years and are once again well below the target maximum of 5% total lost time.

## User feedback

The Web-based fault reporting and Observer feedback system remain important tools in monitoring and maintaining Observatory operations and levels of service. User participation in the feedback system remains healthy and in 2005 confirmed generally high scores in most areas. Once again, RFI remains the issue of single greatest concern to users, and considerable resources remain committed to ensuring that the RFI environment at Parkes remains world-class, or indeed superior to many comparable Observatories elsewhere.

This image (on the right-hand page) from the Galactic All Sky Survey (GASS) shows local atomic hydrogen emission at a velocity of 9.7 kilometres per second (relative to the local standard of rest). The image covers the entire sky south of a declination of zero degrees. GASS is a new survey currently underway with the Parkes 20-cm multibeam receiver aimed at understanding the distribution and kinematics of all of the hydrogen associated with the Milky Way. Some noteworthy features in this image are the Galactic Centre lobes centred around the Galactic plane on the right side of the image.

Image credit: Naomi McClure-Griffiths et al.



# The Australian Long Baseline Array

## The LBA

The Long Baseline Array (LBA) operates as a Very Long Baseline Interferometer (VLBI) array utilising most radio telescopes around Australia. It includes all the ATNF antennas (Parkes, Mopra, Compact Array), the Hobart and Ceduna antennas of the University of Tasmania and antennas of NASA's Canberra Deep Space Communications Complex at Tidbinbilla. It also frequently operates in collaboration with overseas antennas, especially the Hartebeesthoek antenna in South Africa, the Kokee Park antenna in Hawaii, the Kashima antenna in Japan and the Shanghai antenna in China.

The LBA uses the S2 VCR-based recorders and the ATNF correlator in Sydney to achieve a maximum data rate of 128 Mbps. Increases in data rate and hence sensitivity are only possible by adopting different recording and correlating systems.

## Disk-based recording and software correlation

Disk-based recording systems have been implemented at all LBA antennas, based on the LBA Data Acquitision System (DAS), the Metsakovi Radio Observatory (Finland) disk interfaces and commercial computers. In 2005, these systems were upgraded to achieve 512 Mbps rates at all antennas and new computers were installed. The ATNF antennas have been equipped with duplicate systems to achieve a maximum data rate of 1 Gbps.

This disk-recorded data cannot be correlated on the LBA correlator and software correlators have been developed by Swinburne University of Technology. The new FX software correlator can achieve correlation speeds close to real-time for the most common observing modes, by using about 30 nodes of the Swinburne supercomputer cluster. The FX correlator software has also been ported to the new Cray XD-1 at the University of Western Australia (UWA), as part of a collaboration between UWA, Swinburne and ATNF, funded by a WA government grant.

The combination of disk recorders and software correlation has enabled near "real-time" fringe checking for all LBA observations. Such checking has been automated using the Swinburne software correlator and results are posted on the web within minutes of data recording. This has greatly increased the reliability and robustness of the LBA.

Starting in the OCT2005 observing semester, the disk-based recording system and software correlation has been offered as a National Facility observing mode for the LBA. Available time and data rates are restricted primarily by the expense and availability of disk units, but capabilities are slowly increasing.

## VLBI tracking of the Huygens probe

As reported on page 36, the LBA participated in a world-wide VLBI tracking of the Huygens probe as it descended onto Titan, after its release from the Cassini spacecraft on 14 January 2005. This utilised the new disk-based recording systems at 512 Mbps and data were transferred quickly to the JIVE correlator over a special 1-Gbps network link between the ATNF and JIVE.

## e-VLBI developments

e-VLBI uses the new fast networks to bypass data recording and instead correlate VLBI data directly in real-time. Development of e-VLBI capabilities has been gathering pace at VLBI networks in Europe, USA, Japan and more recently in Australia.

The ATNF antennas at Parkes, Mopra and the Compact Array have been connected with an optical fibre network, as part of the AARNET3 Regional Network. The "last-mile" fibre runs to the telescopes were constructed at the end of 2005 and 1 Gbps connectivity are expected to be available in 2006. The network operates on a 10 Gbps backbone and the telescope connections will be upgraded to 10 Gbps in a few years, to connect directly to the new CABB correlator at Narrabri.

The latest e-VLBI developments were highlighted at the fourth international e-VLBI workshop hosted by ATNF, on 12 – 14 July 2005. About 50 people attended, 20 from overseas. It was a very successful workshop and in particular facilitated closer links with the networking community.

Significant new e-VLBI collaborations were initiated in 2005 and new resources were obtained for further e-VLBI research and development. These include:

- A successful ATNF, UTas and Swinburne Australian Research Council (ARC) special research initiatives proposal. This will fund two FTEs over 12 months for e-VLBI research.
- A successful ARC Discovery proposal by Swinburne, ATNF, UWA and AUT, to provide funding over 3 years for astrophysics research using the new disk and e-VLBI capabilities.
- Under a UWA, Swinburne and ATNF collaboration, a grant was obtained from WA and a Cray XD-1 was acquired for a software correlator system.
- ATNF and AARNeT are participating in the European e-VLBI EXPReS proposal, led by JIVE, that was recently funded by the EC at a level of 4 million Euro with the aim of realising production e-VLBI observatories at up to 1 Gbps.

## Development of Trans-Tasman VLBI capability

A collaboration has developed between the ATNF, the Swinburne University of Technology, and the Auckland University of Technology (AUT) to develop a significant VLBI facility in New Zealand for use in conjunction with the Australian LBA. A 1.6 GHz receiver system was constructed by AUT in 2004 – 2005 and installed on a 6-m antenna near Auckland. A prototype VLBI recording system was also constructed and extensively tested.

Test VLBI observations between New Zealand and the LBA were performed in May, August and November 2005 and correlated on the software correlator at Swinburne. Fringes were detected but required integrations over a few minutes. This demonstrated the feasibility of trans-Tasman VLBI but also highlighted the need for a larger antenna in New Zealand with higher sensitivity.

## mm-VLBI tests

In August 2005 the first mm-VLBI observations in Australia were performed between Narrabri and Mopra, the only two Australian antennas currently capable of operating at 3-mm wavelengths. Fringes were detected very quickly using the real-time fringe testing machinery on the Swinburne software correlator. This mm-VLBI capability will be developed further and participation in pilot observations by the astronomy community has been invited.

## Operations

Proposal demand for the LBA in 2005 continued to be strong, with an oversubscription rate of 1.4:l, similar to previous years. A significant amount of time was again allocated to the ATNF-USNO astrometric program.

There were three major LBA observing sessions in 2005 from 9 – 14 March, 12 – 20 May and 1 – 6 November, again avoiding the main winter mm observing season (June – October). During the 19 days allocated to VLBI, significant time (14%) was also devoted to disk-based system tests, including setup and real-time fringe checking via the software correlator at Swinburne.

## LBA time allocation

| | |
|---|---|
| LBA allocated time | 456 hours |
| Disk-test | 56 hours |
| Total scheduled astronomy observations | 346 hours |
| Time lost due to weather during observations | 4% |
| Time lost due to other failures during observations | 1.5% |

Overall the LBA achieved a 94.5% success rate, about 2% improvement on the previous year, to a large extent due to the success of real-time fringe checking. Most of the telescopes continued with success rates over 97%, and the Parkes 6% failure rate was mostly due to high winds (4.8%). A summary is given in the following table.

| **Telescope** | Parkes | Compact Array | Mopra | Hobart | Ceduna | Tidbin-billa | Hartebees-thoek | Kokee | Shanghai | **All LBA** |
|---|---|---|---|---|---|---|---|---|---|---|
| **hours observed** | 332 | 334 | 334 | 318 | 272 | 50 | 114 | 48 | 17 | **346** |
| **% success** | 94 | 98 | 97.5 | 97 | 97.5 | 100 | 99 | 100 | 100 | **94.5** |

# Tidbinbilla spectroscopy

2005 saw the continuation of single-dish service spectroscopy observations with the Tidbinbilla 70-m antenna. Access to antennas at the Canberra Deep Space Communications Complex at Tidbinbilla is provided under the Host Country agreement with NASA and made available to the astronomical community though the ATNF. Observations were made in the 1-cm band. The 70-m antenna provides the most sensitive system in the southern hemisphere for this band, with a system temperature of 60 Jy. Spectroscopy observations were conducted until July when the 70-m antenna was brought off-line for six months to upgrade the hydrostatic (azimuth) bearing and replace the antenna control system.

During the 2004OCT and 2005APR semesters, data were taken for nine projects targeting ammonia, water and methanol line transitions in star-forming regions as well as water megamasers in nearby galaxies. Mapping observations were also carried out for the first time and these provided zero-spacing data to complement Compact Array observations. The Tidbinbilla maps were made in a relatively inefficient point-by-point mode but their success provided impetus to implement on-the-fly mapping, and software development work began for this in 2005.

Another development project that started in 2005 was an upgrade of the 1-cm system from single to dual-channel. This will make dual polarisation observations possible and decrease the observing time needed to reach a given sensitivity by a factor of two. It is expected that this upgrade will be completed in 2006.

A total of 176 hours of antenna time was used for service spectroscopy. The oversubscription rate was similar to the previous year at approximately 2:1.

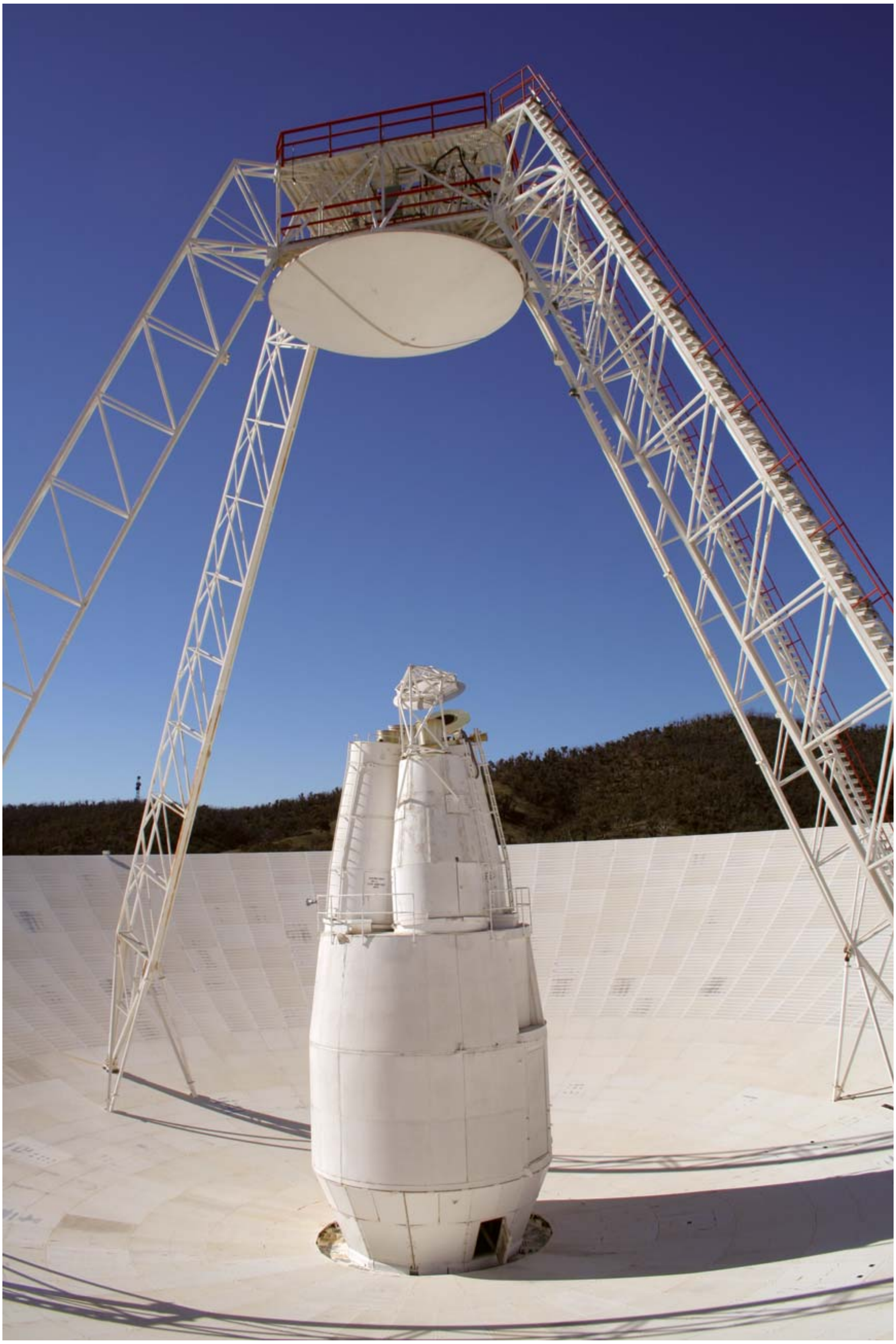


Photo: © Jim Lovell, CSIRO

A view from the surface of the 70-m DSS-43 antenna. At the top of this picture is the six-tonne, 7.8-m diameter subreflector suspended above the dish. Below it is a pedestal on top of which are the three receiver “cones”. The cone of the left contains radio astronomy equipment including the 12-mm system.

# General activities

Photo: © Barnaby Norris

# Astrophysics & Federation Fellowship groups

The major goal of members of the Astrophysics and Federation Fellowship groups is to conduct world-class research in astrophysics using the telescopes operated by the ATNF in order to best exploit scientific opportunities and to best plan for future upgrades. A significant amount of time is spent supporting regular National Facility operations, and hosting visiting observers.

## Staff

The sole astrophysics appointment for the year was the 2005 Bolton Fellow, Erik Muller, who joined the ATNF from the Arecibo Observatory. In addition to his research role, Erik has taken on responsibilities at the Tidbinbilla and Mopra telescopes. Tim Cornwell and Matthew Whiting joined the ATNF to work on scientific computing for future facilities, but both also have research roles.

## Graduate student program

ATNF staff continue to co-supervise PhD students from (mainly) Australian Universities. This program helps strengthen training in radio astronomy science and techniques, and furthers collaboration between the ATNF and the Universities. The number of co-supervised postgraduate students has slowly risen to the current number of 30. The main student event (see below) is the Annual Student Symposium. The 7th Synthesis Imaging School was postponed until September 2006 for financial reasons.

## Colloquia and events

During the year staff members gave over 60 invited talks at Australian and overseas institutions, and were involved in organising the following workshops and symposia:

- "Surveys and the ISM of the Galaxy and LMC" on 17 February;
- "xNTD Science Workshop" on 6 April;
- "Australian Workshop on Simulating the Dynamics of Galaxies and the ISM" on 28 – 29 April;
- "Annual Student Symposium" on 11 May;
- Swinburne "Galaxy Groups" workshop on 24 – 25 May;
- "Scientific Opportunities with the Compact Array at 25 – 50 GHz" on 31 May;
- "Gemini and SKA MNRF Symposium" on 7 June;
- "ALMA discussion forum" with Tony Beasley on 9 June;
- "4th Australian SKA Simulations Workshop" on 11 July;
- "4th International e-VLBI Workshop" on 12 – 14 July;
- "ATNF Single-Dish Polarisation Mini-Workshop" on 7 September;
- "Orange Pulsar Meeting" on 21 – 23 November;
- "High Dynamic Range Imaging Workshop" on 2 December; and
- "Astrofest" on 16 December.

Details of the above events can be obtained by browsing the events archive on the ATNF's web pages.

## Visitors program

Under the auspices of the Distinguished Visitors program, the ATNF enjoyed extend visits from many colleagues during the year including: Don Backer (Berkeley), Katherine Blundell (Oxford), Jayaram Chengalur (NCRA), Tam Helfer (Berkeley), Christian Henkel (MPIfR), Rick Jenet (Univ. Texas, Brownville), Ken Johnston (USNO), Nissim Kanekar (NRAO), Ken Kellerman (NRAO), Busaba Hutawarakorn Kramer (NECTC, Thailand), Michael Kramer (JBO), Yuri Levin (Leiden), John Lugten (Berkeley), Karl-Heinz Mack (Bologna), Padelis Papadopoulos

(ETH, Zürich), Mary Putman (Univ. Michigan), Nathan Smith (Colorado), John Storey (UNSW), Juan Uson (NRAO) and Joel Weisberg (Carleton).

# Marsfield scientific computing

## Software review

In May the ATNF conducted a review of the Scientific Computing Group's activities. The review committee members comprised staff from the ATNF and colleagues from the user community. Their report and ATNF's response are available on the web at www.atnf.csiro.au/management/reviews_and_reports/.

The review highlighted the importance of the radio astronomy data reduction package, MIRIAD, to the user community and urged the ATNF to ensure resources were available to support it. The need for resources to support MIRIAD was emphasized towards the end of the year when Bob Sault, the primary author of MIRIAD, announced his decision to leave the ATNF in early 2006. ATNF is now considering how it will support and develop MIRIAD into the future, a process which will involve consultation with the user community.

## Software developments

A major software release for the year was ASAP, a new software package for processing single dish data. Version 1.0 of ASAP was released on 11 March. This and version 1.1 were mainly intended for users at ATNF sites. Version 1.2 was released on 30 November; this was a full public release in a form suitable for individuals to install at their home institutions. During 2005 the software was used by approximately 50 individuals and downloaded from 47 unique locations.

Another significant software release was version 4 of WCSLIB, the reference implementation of World Coordinate System handling for FITS files. A major milestone this year was submission and acceptance of a paper by Calabretta (ATNF) and Greisen (NRAO) describing how to handle spectral coordinates (frequency, velocity, etc) – "Representation of Spectral Coordinates in FITS", after many discussions with the FITS community. During 2005, WCSLIB was downloaded from over 250 unique locations around the Internet. More details are available on the web at www.atnf.csiro.au/people/mcalabre/WCS/.

A new area of activity in the Scientific Computing Group was to develop software for a package called "Duchamp" that will be used locate radio astronomy sources within data cubes. Initial results were presented at the AstroFest in December. The software is being used in collaboration with the Methanol Multibeam Survey project, and reanalysis of the HIPASS data cubes, to name two.

After the review recommendations and the conclusion of the LIEF-funded programmer contracts, work on Virtual Observatory projects slowed. Software for the remote visualization server (RVS) was maintained, as it is heavily used by some ATNF projects, but not actively developed.

## Computer support

Integration with CSIRO IT continued though at a slow pace. The ATNF continued to put significant support effort into specialist services that CSIRO IT was not yet able to provide, such as UNIX support and providing a rapid response for visiting scientists. Beyond general visitor support, the Scientific Computing Group provided technical assistance to several ATNF projects including the NTD and e-VLBI, GASS and the 20-GHz survey, OPAL and the ATOA (page 62).

## Software for the xNTD

Both the xNTD and the SKA reference design are based around the use of focal plane arrays to expand the field of view of synthesis arrays (see chapter 6). In 2005 a new project was initiated to investigate and develop algorithms for calibration and imaging of radio astronomy data using such systems, including adaption of existing software to support interferometric observations made using many feed systems, and simulations addressing the expected imaging performance and necessary computational resources.

High sensitivity science with the new generation of radio telescopes such as xNTD and SKA will require accounting for the sidelobes of sources not just in the main antenna response but also in the antenna sidelobes. Procedures were developed to accurately model the effect of such confusing sources, using deep mosaic observations with the Compact Array as input data. A major limitation remains the knowledge of the antenna response.

Self-calibration of antenna-based errors has been an essential tool in increasing the scientific productivity of radio synthesis arrays. Conventional self-calibration can correct for calibration errors that are independent of position within the field of view. This approach was extended to allow correction of calibration errors that are a function of position within the field of view, such as pointing errors.

### Australia Telescope Online Archive

The Australia Telescope Online Archive (ATOA) is an archive of all Compact Array data that has been recorded since 3 June 1990. The data are stored in files in RPFITS format, with approximately two terabytes of data in total. The ATOA facility was released in December 2004. It allows users to directly access and download data using a web-interface. In 2005 good use was made of the archive with approximately 3600 data downloads , corresponding to 120 Gbytes of data from 150 different users. This is a significant increase over the previous system when archive requests were received by email and the data provided on CDs.

### OPAL

During 2005, a new web-based application called OPAL was developed to replace an email-based system for telescope proposal applications. The old system had been in place for almost 15 years and had become outdated and unwieldy.

OPAL provides a set of user-friendly web-based tools for astronomers, that are used to prepare and submit telescope proposals. These are available through an application that runs on the ATNF website, with a graphical user interface (GUI). This enables astronomers to:

- create or modify proposal cover sheets;
- create or modify observations tables and source lists;
- submit, resubmit, withdraw and print proposals;
- share proposal files with co-authors; and
- access other online facilities such as sensitivity calculators and data archives.

Following a proposal submission, email acknowledgment is automatically sent to all authors on the proposal. OPAL provides an electronic archive of submitted proposals and astronomers are able to access their previously submitted proposals.

OPAL was released on 1 November and was used for all applications submitted for the deadline on 15 December. For the December deadline, 178 applications were received, with 111 of these submitted during the final 24 hours. In general, users had very few problems using OPAL and there were no network or database-related problems that might have arisen from handling a fairly large number of submissions. During the application period, OPAL supported 1506 user-sessions, with 280 user registrations and 483 different authors listed on the proposals.

## Outreach and education

One of the strategic objectives of the ATNF is to conduct an effective outreach program. Astronomy generates a high level of public interest and is ideally suited to promoting science and to encouraging the next generation of students towards a science-based career. The key outreach goals for the ATNF are to attract young people into science, raise the profile of astronomy and science in Australia and maintain and foster good relations with local communities.

### Media and public outreach

The ATNF's communications with the general public are carried out through the media, through the observatory visitors centres, and by means of specific events such as open days, talks, and temporary exhibitions.

Photo: © Robert Hollow, CSIRO

Science in the Pub, Tucson style. Helen Sim chairs a panel of US scientists in a lively discussion on the merits of exploring Mars.

2005 was a busy year for media activities: the organisation issued 10 media releases and was involved in two high-profile missions: the landing of the European Space Agency's (ESA) Huygens probe on Titan in January and NASA's Deep Impact mission in July. Other major activities during the year included creating ATNF content for CSIRO's new website, csiro.au; providing text and images for the new outdoor exhibits at the Narrabri visitors centre; editing the new newsletter of the Australian SKA Planning Office; and helping to finalise, and organising the launch for, the Australian Astronomy Decadal Plan.

## Outreach collaboration

In September 2005 the ATNF Communications Manager and Education Officer attended the 117th annual meeting of the Astronomical Society of the Pacific—a meeting dedicated to education and outreach in astronomy. Talks and posters were also given on the ATNF educational programs and outreach website and a popular workshop session was held on Science in the Pub.

The ATNF has now joined Startec, a consortium of outreach professionals from observatories that include NRAO, NOAO, Gemini, Keck, Jodrell Bank, STScI and others.

## Teacher workshops & school talks

The ATNF ran two workshops for school teachers in 2005. *Astronomy from the Ground Up!* was held at Parkes in May, as a three-day event aimed at teachers of junior science with no expertise in astronomy. In conjunction with Scitech in Perth, the Science Teachers' Association of Western Australia and the WA Office of Science and Innovation (OSI), two scholarships were awarded to enable WA teachers Lance Taylor from Rockingham Senior High School and Darren Hamley from Willeton Senior High School to attend the workshop. A one-day *Astrophysics for Physics Teachers* workshop held at Marsfield in June targeted the requirements of the senior physics course. Workshop sessions were also held at other teacher professional development events in Victoria and NSW.

Dr Kate Brooks gave the annual Ruby Payne-Scott Lecture at Danebank Girls School in October. Other ATNF staff also gave approximately 50 talks to a range of school groups. These presentations provide an effective way to highlight the work and role of the ATNF and to engage students in science.

## Outreach in Western Australia

During 2005, the ATNF in collaboration with five schools from the Mid-West region of WA, Charles Sturt University, Scitech and OSI developed a grant proposal for the federally-funded Australian Schools Innovation in Science, Technology and Mathematics (ASISTM) scheme. The *Wildflowers in the Sky* project would involve the Education Officer and two astronomers spending two one-week blocks working with students and teachers at the diverse partner schools near Mileura to foster greater awareness and understanding of science through astronomy during 2006. The application was short-listed for funding.

### Outreach and education website

The Australia Telescope Outreach and Education website (see http://outreach.atnf.csiro.au) provides educational resources in astronomy for high-school teachers and students, as well as information and images for the general public. New material added to the site included a live webcam of the Parkes radio telescope, images of the ATNF telescopes and a resource section for teachers. Visits and usage continues to grow with approximately 2.5 million hits in 2005.

### Summer vacation program

Seven students took part in the 2005/2006 Summer Vacation Scholarship Program, selected from over 130 who applied. Five of the students were based at ATNF headquarters in Sydney whilst two were based at the Compact Array in Narrabri. Each student tackled a research project in engineering, computing or astrophysics, supervised by an ATNF staff member. The students took part in a four-day observing trip to Narrabri, with each of two groups getting a twelve hour observing slot on the Compact Array. The program concluded with a half-day symposium where students presented the results of their observing trip and their individual projects.

## Parkes outreach

The Parkes radio telescope remains one of the most prominent attractions in western New South Wales with 110,000 visitors to the Visitors Centre and Dish Cafe in 2005.

Photo: © Robert Hollow, CSIRO

Meekatharra District High School, one of the partner schools for the *Wildflowers in the Sky* ASISTM proposal.

Photo: © Robert Hollow, CSIRO

2005/2006 summer vacation students at Narrabri. Left to right: Thanh Pham, Yadav Kanniah Padmanaban, Lewis Mitchell, Rachel Poldy, Chris Easton, Jenny Thompson (ICT Centre), Shari Breen, Chenni Shettigara

The Visitors Centre provides an important contact point between CSIRO and the public, supporting other CSIRO communication initiatives. Chief among them is the support for the Double Helix science club by promoting the club and its two magazines, *Scientriffic* and *The Helix*, and by running several events for members through out the year. A very popular rocket workshop was held as part of celebrations for National Science Week in August. The Observatory also hosted a CSIRO Alumni function and displays about CSIRO's Flagship program.

As the premier attraction in the Shire, the Observatory contributed considerably to the development of a new Parkes Shire Tourism Strategy which outlines the direction of tourism in the shire over the next five to ten years. This plan is essential to countering the decline of tourist numbers seen across western New South Wales in the last few years.

During the year the Observatory hosted several events:

- In April a concert was held with performances by students from the Sydney Conservatorium of Music. Canowindra's Rosnay wines provided wines for tasting and sale, and the Dish Café catered. Many people from across the region attended, and the event was well received.
- In May the Observatory was the focus of the culmination of the *Paint the West Red* relay across western New South Wales to promote reading and literacy for young children.
- In July the Central West Astronomy Society, who meet regularly at the Visitors Centre, held their second annual Astrofest. The included several associated events including the public display of the finalists in the David Malin Astrophotography competition and the handing over of ashes, from radio astronomy pioneer Grote Reber, to the Parkes Observatory.

Staff efforts were acknowledged in November when the Visitors Centre was awarded best hospitality or tourism business in the inaugural Parkes shire business awards.

During the year the Observatory also supported several local events that draw visitors to the area such as the Parkes Elvis Festival in January, Picnic Races on the June long weekend and the annual Christmas parade.

## Spectrum Management

Spectrum management relating to the protection of radio astronomy has been an important activity for CSIRO since the 1970s. The ATNF has continued to support such activities and at present is involved in the following areas:

- Participation in national spectrum planning and protection activities through the Australian Communications and Media Authority (ACMA). This involves not only national spectrum planning issues, but also participation in study groups of the International Telecommunications Union (ITU) and preparations for World Radio Conferences (WRC).
- 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 for the protection of Radio Astronomy.
- Participation in IUCAF (Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Sciences), an inter-union committee of the International Astronomical Union (IAU), the International Union of Radio Science (URSI) and the Committee on Space Research (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).

## Activities in 2005

Activities at the ITU have been concentrated in the technical studies in preparation for WRC 2007. Studies have shown that the 1400-MHz passive band for radio astronomy and earth exploration can be adequately protected from emissions by proposed satellite services. However, studies are still continuing on the protection of the 1612 MHz band (which includes the hydroxyl line) from unwanted emissions by radio navigation Satellites in nearby bands.

IUCAF and RadioNet sponsored the second Summer School in "Spectrum management for Radio Astronomy" in June 2005 at Bologna, Italy, with aim of fostering the involvement of new people in radio spectrum management. ATNF staff contributed to the lectures and the discussions.

The international SKA "Task Force on Regulatory Issues" (set up to define the protection criteria for the SKA) produced a detailed report, to be used in the assessment of proposed SKA sites. The ATNF participated in the drafting of this report and contributed detailed studies on propagation issues and possible definitions of radio quiet zones.

The RAFCAP annual meeting was hosted by ATNF in July 2005, with participants from the Asia Pacific region and Europe. Meetings were held at Parkes and Narrabri, combined with a tour of all ATNF observatories as most participants had not visited before.

The work between ATNF and ACMA on defining "radio sensitive sites" around existing radio telescopes, as recommended by the Productivity Commission review in 2002, reached its conclusion in 2005. A Radiocommunications Assignment and Licensing Instruction (RALI) was published for public comment in August 2005, and will become part of the regulations in Australia.

The ATNF and WA government reached an agreement to partly fund work by ACMA towards the definition of a "radio quiet zone" (RQZ) at the Australian candidate SKA site in Mileura WA. A radio-license spectrum embargo was declared by ACMA in this area for a radius of about 100 kilometres and for frequencies between 100 MHz and 25 GHz. Detailed studies on the RQZ definition and requirements are continuing. Information and discussion papers on the RQZ formed part of the SKA site proposal from Australia.

Proposed SKA site at Mileura, WA — Photo: © Bruce Thomas, CSIRO

# Human resources and awards

The outstanding quality of people working at the ATNF continues to be evident and has facilitated provision of world-class facilities for astronomical research and delivery of significant facility upgrades in 2005. The ATNF is widely recognised for achievements derived from the combined expertise and commitment of its staff.

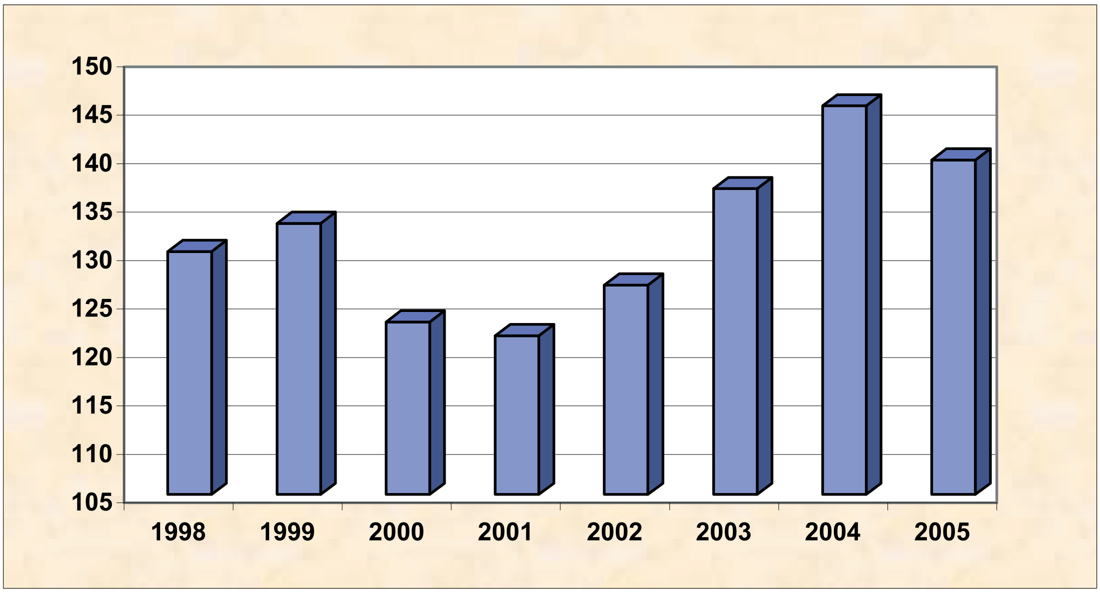
Achievements for which individuals and teams were recognised in 2005 included:

- Australia Telescope Online Archive (ATOA) This facility provides users with direct access to all of the data files recorded with the Compact Array since 1990.
- 3-mm receivers on the Compact Array The successful installation and commissioning of the 3-mm receivers on the Compact Array marked the completion of the high frequency upgrade of this instrument that delivered a new world-class capability to ATNF users.
- Huygens mission The ATNF played a major role in the scientific success of the Huygens mission (page 36).
- IAA award The International Academy of Astronautics (IAA) awarded its Laurels for Team Achievement Award for 2005 to the VLBI Space Observatory Programme (VSOP) Team. The Award was made to an international group of 15 scientists and engineers including the ATNF's David Jauncey.

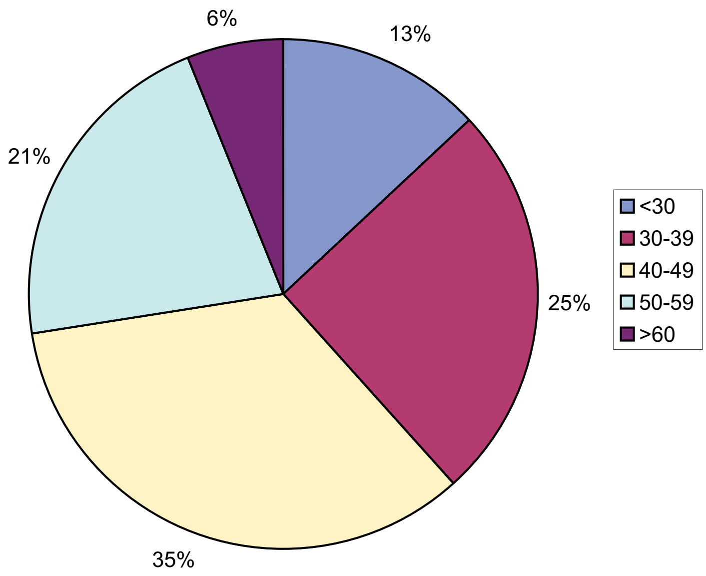
Attraction of staffing excellence remains a key focus for the ATNF to ensure continued provision of world-class facilities as we move into the fulfilment of the Decadal Plan for Australian Astronomy. This focus balances the fostering of well seasoned experience and excellence within the ATNF with the introduction of new innovative thinking from emerging younger scientists.

In 2005 the ATNF had 140 "full time equivalent" staff. Currently 38% of all staff are aged under 40. The ATNF recognises the importance of retaining a balanced staffing structure and attracting more emerging scientists to learn from, and support, the proven experience of more experienced scientists.

In addition to internal structural and directional changes through the course of 2005, the ATNF commenced implementation of several significant CSIRO change initiatives affecting its funding, technology, project management capabilities and the staffing of our support services. This change program continues over the next three years and will bring a strong focus on learning and development with provision of enhanced technology to ensure staffing excellence and science delivery are optimised.




ATNF total full time equivalent staff numbers for 1998 – 2005




Age distribution within the ATNF

# Occupational health, safety and environment

In order to prevent accidents in the workplace, the ATNF continues to drive a pro-active approach to health, safety and environment management. This requires commitment by all staff and visitors demonstrated by their active participation in safety practices to minimise their exposure to risk in the workplace.

The focus on integrating risk management into all activities continued through 2005 with the planning phase of all projects incorporating staff consultation to review and control health and safety risk factors associated with the project's work activities.

An annual OHS&E action plan ensures that continuous improvement is made in controlling risk of injury presented by the myriad of hazards in the ATNF risk profile. In addition to targeting the most significant risk factors, risk management activity has focused on other risk factors including working alone, emergency management, safe use of machinery and equipment, chemical storage and handling.

The ATNF risk profile recognises that its most significant injury factors are:

- travel to/from Sydney to rural locations;
- electrical contact;
- manual handling & ergonomics; and
- working at heights.

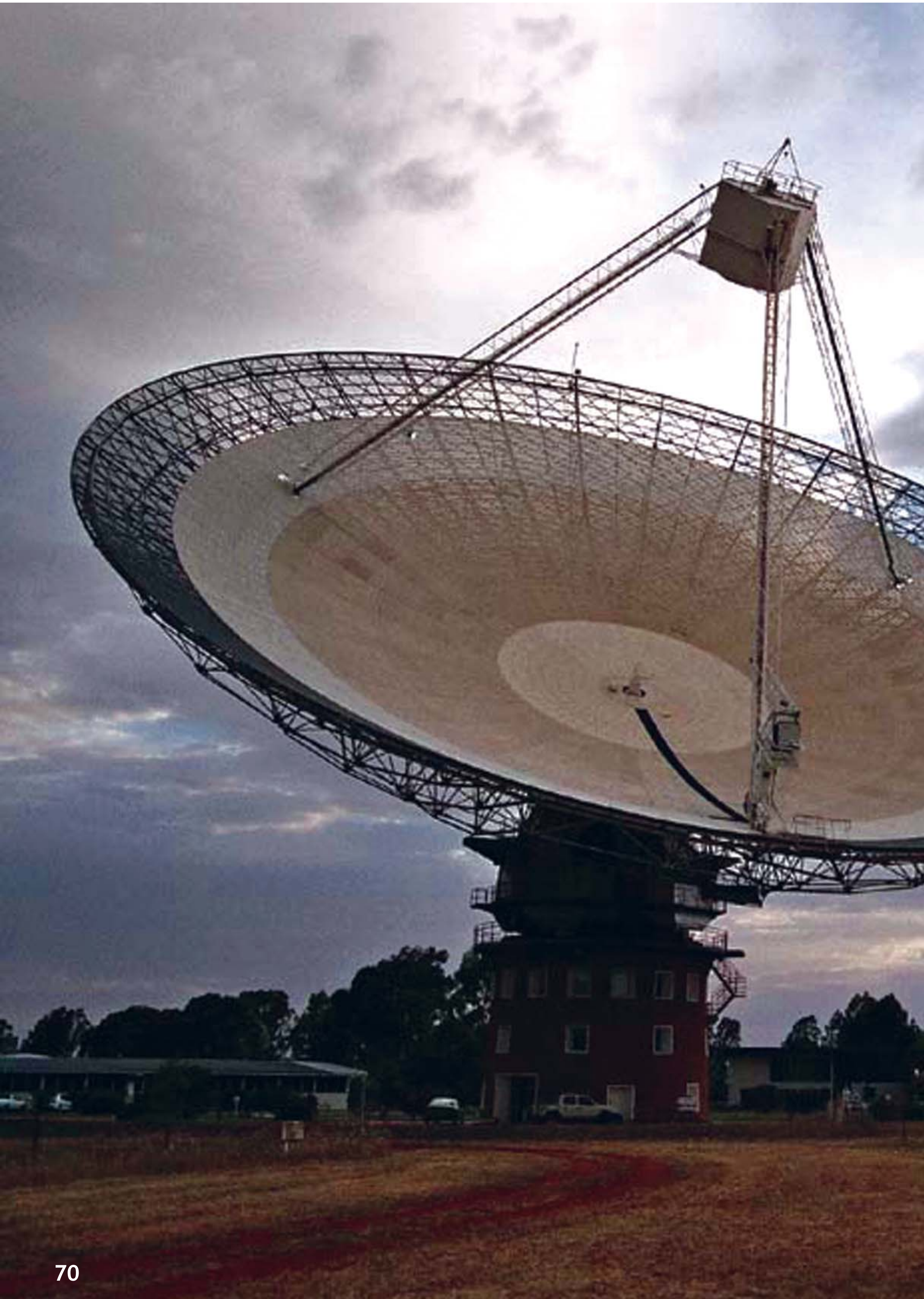
Some interesting challenges were presented during the year such as finding space for a large innovative machining centre in an already cramped work environment. A consultative process involving all workshop staff led to the relocation and disposal of existing machinery giving in improved workspace usage and a safer work environment.

All ATNF supervisors have received training in OHS&E with a refresher course conducted every three years. However, anyone is welcome to join this training as it focuses on the practical implementation of CSIRO policy and procedures with a heavy emphasis on developing a "safety culture" in the ATNF.

The ATNF operates an Environmental Management System at each of the sites to minimise impact on the environment from ATNF activities.

At Marsfield, staff continued to work towards a reduction in resource usage, improved recycling and waste disposal methods in conjunction with our colleagues from the ICT Centre and Industrial Physics.

At Narrabri and Parkes, environmental initiatives address the more unique issues presented by a rural location. Environmentally conscious staff members maintain a keen focus on resource minimisation and recycling despite limited country based outlets.



# Technology developments

Photo: © John Sarkissian, CSIRO

# Technology developments

## Marsfield engineering developments

### 7-mm Compact Array upgrade

Following the successful first full season of 3-mm observations with the Compact Array in the winter of 2005, a further significant step towards expanding the millimetre capabilities of the instrument was taken in November 2005 with the signing of a collaborative agreement between the ATNF and NASA. The agreement covers the outfitting of the array with receivers in the 7-mm band. It will provide NASA with a backup for their Australian tracking facility at Tidbinbilla for the new generation of spacecraft using Ka-band (32 GHz) downlinks. National Facility users will benefit from the opening up of an important new observing band covering the 30 – 50 GHz frequency range.

The upgrade involves adding components for the new frequency band to the existing 12/3-mm receiver packages. These receivers had been designed from the outset to accommodate such an upgrade. Prior to the signing of the contract, the ATNF was required by NASA to demonstrate that the Compact Array could meet the special requirements of spacecraft tracking. In particular, the need for an uninterrupted data stream from the array, generally not a requirement for astronomy applications, necessitated the development of a new mode of operation. This new mode was successfully demonstrated in a series of tests involving the tracking of spacecraft with 8.4-GHz downlinks, using the existing centimetre-wave receivers. A report detailing these tests was presented to NASA in September.

The contract calls for the installation of the new band to be completed by May 2007, with acceptance tests beginning in June 2007, followed by the commencement of tracking operations in September 2007. For the period September 2007 to October 2013 the Compact Array will be available for spacecraft tracking at an average rate of 10 hours per week.

### Mopra 3-mm MMIC receiver

A new 3-mm receiver was installed at Mopra in September 2005. The new receiver is a copy of the Compact Array millimetre receivers, but with enhancements providing expanded frequency coverage. Whereas the frequency range of the Compact Array receivers is 85 – 105 GHz, the Mopra receiver covers 78 – 115 GHz. The extension to 115 GHz is particularly important as it gives access to spectral lines from the very important CO molecule. The key component in achieving the improved frequency coverage is a new low noise amplifier (LNA) design. The design, developed in-house, uses the same indium phosphide monolithic microwave integrated circuit (MMIC) process used for the Compact Array LNAs, but is based on a broadband coplanar waveguide structure in place of the microstrip structure in the older design.

The new receiver offers a number of advantages over the 3-mm SIS receiver, which has served Mopra so well over the past 11 years, and which it replaces. The SIS junction in the old receiver required a special cryogenic refrigerator to achieve the required sub-4K operating temperature. The new receiver uses the same cryogenic systems used in all other ATNF receivers. Although operating at a higher temperature of around 15 K, it delivers an improvement in sensitivity of up to 50%. The SIS receiver was a tuneable receiver with a maximum instantaneous bandwidth of around 300 MHz. Tuning the SIS receiver to a particular frequency was a complex manual process, often requiring an experienced on-site operator to achieve good results. The new MMIC receiver provides immediate access to any frequency in the 78 – 115 GHz band, with the final instantaneous bandwidth of 8 GHz being determined by the conversion system downstream from the LNA. This wide bandwidth will be fully exploited in the new spectrometer being built for Mopra (page 74). The ease of use of the new MMIC receiver paves the way for the future remote operation of Mopra.

The excellent performance of the Mopra MMIC receiver has demonstrated that the ATNF now has the capability to extend the upper frequency limit of the Compact Array from 105 to 115 GHz. Although commitments to the 7-mm upgrade would prevent this proceeding in the short term, it remains an interesting proposition for future planning.

### Parkes 6-GHz Multibeam receiver

ATNF has further enhanced its pre-eminent position in the development of centimetre-wave multibeam receivers with the design and construction of a new seven beam receiver in the 6 –7 GHz frequency band.


The 6-GHz multibeam receiver before final assembly in the laboratory. The feed horns are at the top, divided into three vertical sections, which are cooled to 300 K, 70 K and 20 K respectively.

This follows the earlier development of two highly successful multibeam receivers in the 21-cm band for the Parkes and Arecibo radio telescopes.

The new receiver is a joint development of the ATNF and the Jodrell Bank Observatory. Adaptable to either the Parkes or Lovell radio telescopes, initial installation is planned at Parkes in early 2006. The ATNF was responsible for the design and construction of the major mechanical components of the receiver, such as the feed systems and the cryogenic dewar, whereas Jodrell Bank provided the LNAs and frequency conversion electronics.

The smaller scale of the higher frequency receiver inspired an innovative approach to the design of the feed system. Rather than having separate feed horns, as was necessary at the lower frequency because of the bulk of the structure, the seven feed horns in the new receiver are machined out of three solid cylindrical billets of aluminium. The major part of the resulting feed system is easily cooled, resulting in a significant improvement in sensitivity.

## Compact Array Broadband Upgrade

The Compact Array Broadband Upgrade (CABB) project is aimed at increasing the maximum bandwidth of the Compact Array from 128 MHz to 2 GHz. A major milestone was reached in October 2005 with the successful use of the CABB prototype digital signal processing circuit board in the first stage of an 8-GHz bandwidth spectrometer at Mopra. This was the first demonstration of the complex signal processing hardware and firmware that will be required for CABB. The board is by far the most complex development of its type carried out at the ATNF.

Based on experience gained from the development of the signal processing system, and on the status of design work in other areas of CABB, a re-evaluation of the overall project was carried out in late-2005. The result is a new implementation plan, which includes a more detailed model of the installation and commissioning phase of the project and how this interacts with other major activities in mid- to late-2007, particularly the NASA 7-mm acceptance testing and spacecraft tracking. The new plan indicates a significant overrun compared to the originally planned June 2007 completion date for CABB.


The CABB prototype digital signal processing circuit board. The board has 17 large field programmable gate arrays (FPGA), interconnected by 136,000 traces on 21 layers. Each FPGA has 21,000 logic cells and 1,152 pins.

The new plan sees a "Stage 1" CABB becoming available for testing in July 2007. Stage 1 will be a single frequency system with the antenna equipment installed in such a way as to allow parallel operation of the existing backend and the new CABB backend. The existing backend will be required to provide Ka-band tracking for NASA, due to begin in July 2007. The period from July 2007 to early 2008 will be used to thoroughly test the CABB system. Testing will also be necessary to confirm that the CABB backend is able to provide the required spacecraft tracking facility. Initial operational use, with one frequency only, will also be possible during this time. At the completion of this period an extended shutdown will be required to remove the existing backend systems from the antennas and install the full CABB antenna equipment in its final position.

A major issue arose in November 2005 concerning uncertainty in the supply of the complex processing chips—the FPGAs—which are a fundamental component of the overall CABB system design. An indefinite delay in the delivery of FPGAs for the sampler/data transmitter prototype, originally due in October, forced a major re-work of the design of this component. The revised design was completed and work in this area is back on schedule, as defined in the new plan.

## Mopra 8-GHz spectrometer (MOPS)

The MOPS spectrometer is a by-product of the signal processing development being carried out as part of the broadband upgrade of the Compact Array. The instrument was funded largely by a grant from the Australian Research Council to a consortium of universities, led by the University of New South Wales, and the ATNF. Using prototype hardware developed for CABB, in its basic mode MOPS will provide at least 8,000 frequency channels across the 8-GHz bandwidth available from the new Mopra 3-mm receiver. Other modes will provide higher frequency resolution across selected sub-bands within the 8 GHz. The resulting 32-fold increase in available bandwidth will greatly enhance Mopra's position as a major facility for millimetre-wave observations in the Southern Hemisphere.

Initial observations with one 2-GHz quadrant of MOPS were carried out at Mopra in October 2005. The configuration included digital signal processing of the full 2-GHz band, producing two 138-MHz sub-bands, each with 4096 frequency channels, centred on selected molecular spectral lines. The initial results from the combination of the new MMIC receiver and the first stage of the new spectrometer proved to be very promising, and have given rise to great expectations for the 2006 millimetre season at Mopra, when the full MOPS spectrometer will be available.

## Pulsar digital filterbank

This project also builds on the experience gained in the development of digital filterbanks for the CABB project. The aim is to develop a 1-GHz bandwidth, multi-channel spectrometer/polarimeter with sufficient time resolution to resolve the fastest milli-second pulsars.

A prototype 256-MHz bandwidth pulsar digital filterbank, based on commercially available hardware, was installed at Parkes in June 2005 and has been operating very successfully since. The design of the 1-GHz production unit is largely complete, but is currently stalled, awaiting delivery of Xilinx FPGAs. It now appears unlikely that the FPGAs will be available before late 2006. Depending on actual delivery times, an alternative design, possibly using the final CABB signal processing boards, may have to be considered.

## The SKA and pathfinder projects

The ATNF is committed to the SKA as its primary strategic development project. The SKA is a next generation radio telescope which will have a collecting area of approximately one square kilometre, making it one hundred times more sensitive than any existing radio telescope. It will operate at centimetre wavelengths. In 2005 the ATNF continued to make contributions to the SKA international project in a number of ways.

### New Technology Demonstrator

The New Technology Demonstrator (NTD) project is to design and develop a technology demonstrator for the SKA. This project will lead to the construction and operation of two parabolic dishes equipped with focal-plane arrays (FPAs) that use all-digital beamforming. Funding for the NTD project runs until July 2007 with a Critical Design Review due in 2006. Some of the measurement goals for the NTD project are to obtain a better understanding of FPAs, reconcile antenna range measurements with astronomical measurements, determine optimum beamformer parameters and develop calibration methods.

In August 2005 two refurbished 13.7-m diameter antennas, from the old Fleurs radio telescope run by the University of Sydney, were installed on the CSIRO Radiophysics site at Marsfield by the engineering company Sydney Engineering. The antennas were equipped with new mesh surfaces, control systems, a quadrupod (to contain various focal-plane arrays) and cabling.

During the year a prototype digital beamformer was built that has 24 input channels, a bandwidth of 24 MHz and 24 prototype receivers. In late 2005 the NTD group took delivery of a thousand element array (THEA) tile purchased from ASTRON. This will be used for the initial focal plane array tests.


Photo: © CSIRO

The 24-channel protype receiver for the NTD.

### Extended New Technology Demonstrator

The extended New Technology Demonstrator (xNTD) project aims to build a path-finder instrument for the SKA that will also provide a powerful radio astronomy facility. The specification for the xNTD will be based on an array of 20 antennas, each equipped with a focal plane array. The design and cost of the antennas are a critical element in the xNTD project with a cost target of approximately AUD 250,000 per antenna. The array will be built at the Australian proposed SKA site at Mileura in WA.

Major funding from CSIRO for the development of the xNTD, Australia's SKA Demonstrator, is planned to begin in July 2006. This funding, together with infrastructure support from the Western Australian Government will allow the knowledge gained from the NTD project to be extended into a working radio telescope on the Mileura site. The xNTD project aims to demonstrate that FPAs on small dishes can meet key cost and performance goals that are applicable to the SKA. The target completion date for the xNTD is 2009, in line with the planned global SKA timeline for national SKA Demonstrator facilities.

## SKA radio spectrum characterisation in Western Australia.

After preliminary tests at Marsfield and Narrabri, in January 2005 a solar powered RFI trailer housing radio spectrum monitoring equipment was transported to Western Australia to test the radio spectrum characteristics at the Mileura Station. The station is located 650 kilometres north of Perth and 90 kilometres west of Meekatharra. The CSIRO portable equipment allows radio interference data to be collected for frequencies between 50 MHz and 26.5 GHz, using a suite of directional and omni-direction antennas.

The radio spectrum characterisation commenced on Australia Day (26 January) 2005 and will continue until March 2006. The project involves logistically difficult work in remote areas with both equipment reliability and workplace safety primary concerns, particularly during the extremely hot summer months. With periodic support from the ATNF SKA RFI team and weekly attendance from the Mileura Station manager, data were collected throughout 2005, with nearly half a terabyte of data archived during the year. The datasets processed during the year indicated that Mileura is an excellent radio quiet site. During the last quarter of 2005 the Australian Communications and Media Authority assisted in the identification of detected transmissions in the captured spectrum.

In September 2005 additional International SKA RFI measurement equipment arrived at Mileura. Engineers from ASTRON cross-calibrated the international equipment with the Australian equipment and then collected a continuous one month of Mileura spectral data for the International SKA project office (ISPO).

## Site proposal

A proposal to site the SKA in Australia was submitted to the International SKA Planning Office (ISPO) on 5 December 2005. The proposal was developed by the Australian SKA Planning Office on behalf of the Australasian SKA Consortium, with the assistance of a large number of organisations and agencies. Connell Wagner, in particular, provided invaluable assistance and expertise in the compilation of the site bid.

Under the proposal, the core site for the SKA would be on the Mileura Station in the Mid West of Western Australia, while remote array-stations would span the continent with maximum east-west baselines in excess of 3,200 km. Further array-stations in New Zealand would provide an east-west baseline of more than 5,500 km.

The proposed configuration is a five-arm, symmetric, log-spiral arrangement of array-stations out to a distance of 350 km from the core. This ensures optimum uv-coverage and beam-shape for this fraction of the array. A deliberately "dithered" configuration would extend the array beyond 350 kilometres to over 3000 kilometres, in a predominantly east-west configuration. The vast and very sparsely populated interior of Australia allows

Photo: © CSIRO

An aerial view of the proposed SKA core area showing ASTRON and CSIRO equipment.

enormous freedom in selecting the final configuration. All array-stations for the principal configuration lie within Australia, greatly simplifying administrative arrangements for establishing and managing the SKA.

The Australian sites for the SKA array-stations satisfy all of the international evaluation criteria for scientific and technical considerations and infrastructure cost. In particular the Australian site for the SKA Facility exhibits:

- excellent sky coverage. Assuming an elevation limit of ten degrees for the telescope, a declination range from – 90° to +48° will be visible;
- radio-quietness at the very high sensitivity levels needed for the SKA. At the low- to mid-SKA frequencies, signal levels of order −220 dBm/Hz would cause significant interference to the SKA. Interference at these levels could be detected from typical transmitters located up to 550 kilometres away. The nearest large urban centre to the candidate central site is Perth, at a distance of 620 kilometres;
- ionospheric stability, with Total Electron Content (TEC) values of less than 100 TEC Units (a conservative upper bound), and with no strong scattering overhead; and
- a troposphere that will not significantly affect observations below 17 GHz, with sky brightness temperatures below 5 K at frequencies below 10 GHz. Precipitable water vapour is less than 20 mm from May to December inclusive and less than 10 mm from June to September inclusive at the central site. Results are similar on the other side of the continent at Narrabri in NSW, indicating that uniformly good troposphere results can be expected, enabling long-baseline high-frequency observations.

The New Zealand SKA committee has proposed remote SKA sites that would make it possible to extend the array into New Zealand, increasing the available baselines to over 5,500 kilometres. It would also be possible to make intercontinental VLBI observations with current facilities in China, Japan, Korea, India and South Africa.

The siting proposal also noted:

- the international strength of Australia's radio astronomy community, and continuing strong Australian Government support for radio astronomy, including radio-quietness protection;
- Australia's ability to provide reliable and cost-effective infrastructure and maintenance to the SKA throughout its lifetime; and
- the Western Australian Government's commitments to provide legal protection to preserve the unique, radio-quiet environment at Mileura Station through establishment of a Radio Astronomy Park.

A further report on the radio-frequency environment of the Australian candidate SKA site is due to be submitted in March 2006.

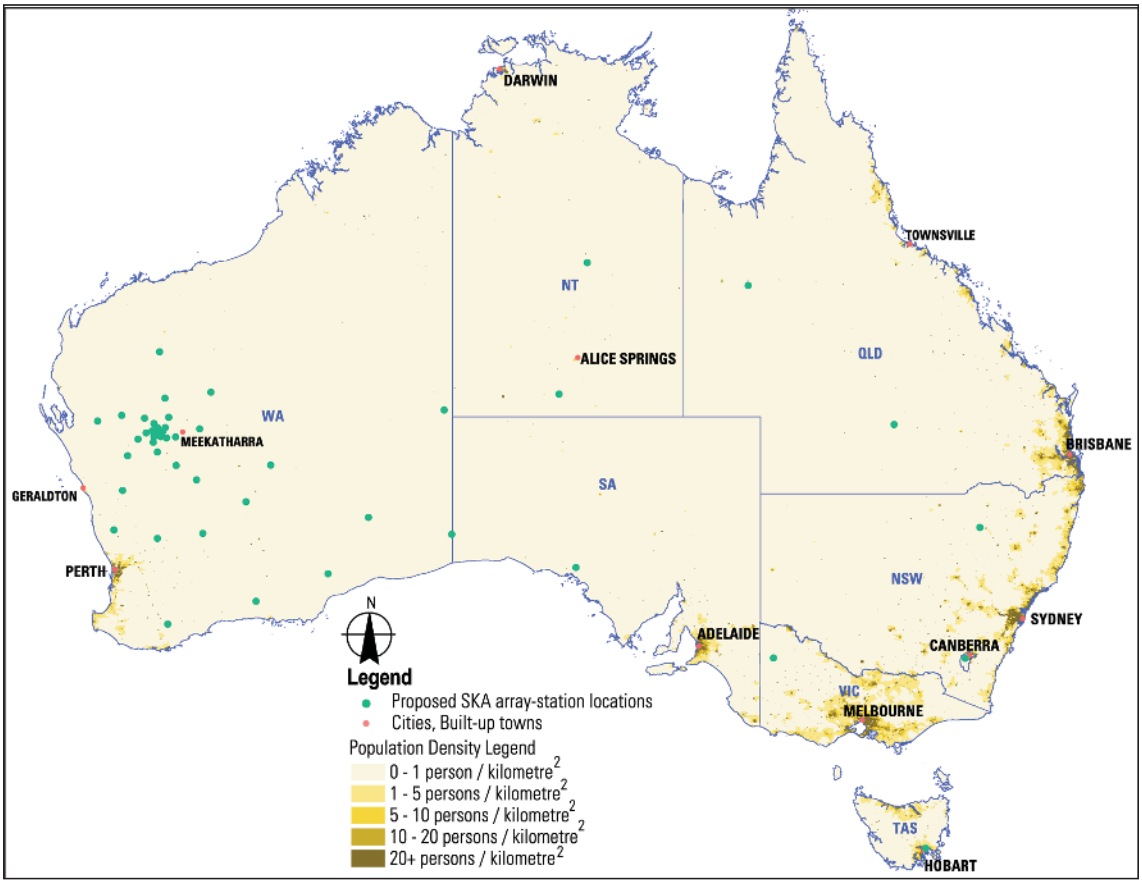
## SKA industry activities

The Federal Government Department of Industry, Tourism and Resources Electronics Industry Action Agenda Implementation Group has endorsed the SKA project. An SKA Cluster Mapping Project has been started, which will determine capability, gaps and strategic goals within the Australian-based electronics and ICT industry.

The key activities of the SKA Cluster Mapping Project are to:

- produce an industry cluster map of companies with SKA capabilities;
- produce a technology roadmap of Australian capabilities regarding the xNTD project;
- identify projects and prototyping activities suitable for SKA cluster development; and,
- produce the investment profile for xNTD-SKA development in collaboration with overseas entities.

An initial core consortium, comprising Global Innovation Centre Pty Ltd, CSIRO, AEEMA, Cisco Systems, RLM Management Pty Ltd, Boeing Australia Ltd, BAE SYSTEMS Australia, Radio Frequency Systems Pty Ltd,




The proposed configuration for the SKA in Australia, overlaid on a map indicating population density. The Australian SKA proposal places array-stations in very radio-quiet locations, with good access to infrastructure and excellent geophysical conditions.

Tenix Pty Ltd R.F. Aust Technologies Pty Ltd, and Raytheon Australia Pty Ltd has been identified with all partners expressing strong support for the aims of the cluster mapping project. On 5 December 2005 the ATNF hosted, at its Sydney headquarters, a first meeting for parties interested in participating in the cluster. The main purpose of the meeting was to brief attendees on the system requirements of the xNTD project, discuss the potential for industry collaboration, and initiate networking among the participants. The event attracted 60 attendees.

The Cluster Mapping Project has now been funded by AusIndustry's Industry Cooperative Innovation Program.

## Governance

In July 2005 Professor Brian Boyle, ATNF Director, was appointed as Australian SKA Director, and the Australian SKA Planning Office was established within ATNF to implement the policies of the Australasian SKA Consortium. New Zealand joined the Australasian SKA Consortium in March 2005.

Internationally, Australians hold 17% of committee positions in the SKA project, significantly more than our 10% membership level of the project. Professor Brian Boyle is Vice-Chair of the International SKA Steering Committee, Peter Hall from ATNF is the International Project Engineer and Professor Ron Ekers from CSIRO is the at-large member of the ISSC.

The first intergovernmental funding agency meeting related to SKA was held in June 2005, and was attended by the Director of International Science Policy from the Australian Government Department of Education, Science and Training.

## Radio-quiet zone for the Mileura Station site

The Australian Communications and Media Authority (ACMA) has been developing a regulatory framework for a radio-quiet zone (RQZ) to help maintain the radio-quietness of the Mileura site. The challenge is to provide sufficient protection for radio astronomy observations without unnecessarily denying radio communications services to the local community. To achieve this balance, the ACMA plans to define an inner zone, where licensing of radio communications is tightly restricted, and an outer zone, where radio communications are coordinated in such a way as to minimise interference to radio astronomy. The ACMA is developing coordination procedures to achieve the best possible result for radio astronomy.

In April 2005 the ACMA implemented a spectrum embargo for the area around the proposed SKA core site. This embargo (Embargo 41) applies to new radio communications licenses within 150 km of the site for frequencies 100 to 230 MHz, and within 100 km of the site for the frequencies 230 MHz to 25.25 GHz. It applies to licensed, coordinated terrestrial stations, and earth stations. The embargo is expected to be an interim short-term solution until detailed coordination procedures are introduced.

# Appendices

Photo: © Barnaby Norris

# A: Statement of financial performance

| | Year ending 30 June 2005 | Year ending 30 June 2004 |
|---|---|---|
| **Revenue** | $ | $ |
| External | 2,604,315 | 10,099,232 |
| Interest | 561,469 | 249, 017 |
| Appropriation | 22,312,668 | 20,348,400 |
| **Total Revenue** | 25,478,452 | 30,696,649 |
| **Expenses** | | |
| Salaries | 11,665,693 | 11,029,642 |
| Travel | 817,480 | 741,365 |
| Other Operating | 8,032,286 | 9,648,090 |
| Corporate Support Services | 3,229,968 | 1,751,200 |
| Depreciation & Amortisation | 4,694,109 | 4,699,526 |
| Doubtful Expense | 0 | 0 |
| **Total Expenses** | 28,439,536 | 27,869,823 |
| Profit/(Loss) on sale of assets | 41,914 | -9,143 |
| **Operating Result** | -2,919170 | 2,817,683 |

**Notes**

In 2004/05 a discrepancy in the treatment of the ATNF's external revenue was discovered and corrected. This discrepancy means that the surplus reported in 2003/04 was overstated and the deficit reported for 2004/05 is primarily due to the correction. Therefore, the reported change in financial performance of approximately six million dollars from 2003/04 to 2004/05 is not due to a major change in the actual operations of the ATNF.

# B: Staff list, January to December 2005

## Marsfield

S Amy (Computing)
J Archer (Finance & Administration)
P Axtens (Receivers)
L Ball (Deputy Director)
A Barends (PA, Office of Director)
R Beresford (Electronics)
R Bolton (Receivers)
P Bonvino (Machine Shop)
M Bourne (Machine Shop)
M Bowen (Receivers)
B Boyle (ATNF Director)
K Brooks (Bolton Fellow/Astrophysics)
W Brouw (Astrophysics/Computing)
A Brown (Electronics)
M Calabretta (Computing)
G Carrad (Receivers)
J Caswell (Astrophysics)
A Chandra (Computing)
J Chapman (Head, National Facility Support)
R Chekkala (Electronics)
A Chippendale (Electronics)
T Cornwell (SKA)
G Cook (Machine Shop)
E Davis (Electronics)
J Daw (Electronics)
L de Souza (SKA)
M Death (Machine Shop)
N Derwent (Finance)
P Doherty (Receivers)
V Drazenovic (National Facility Support)
A Dunning (Receivers)
D Ede (Finance & Administration)
R Edwards (Postdoctoral Fellow/Astrophysics)
R Ekers (Federation Fellow)
T Elton (Electronics)
J Flores (Workshop)
R Ferris (Electronics)
D Gain (Receivers)
G Gay (Receivers/overseas)
R Gough (Receivers)
G Graves (Receivers)
E Hakvoort (Receivers)
P Hall (On secondment to Int. SKA Project Office)
G Hampson (Electronics)
D Herne (SKA)
G Hobbs (Astrophysics)
M Hobbs (Astrophysics)
R Hollow (National Facility Support)
P Howson (Finance & Administration)
T Huynh (Machine Shop)
O Iannello (Machine Shop)
C Jackson (Business Development Manager)
S Jackson (Electronics)
S Johnston (Astrophysics)
A Jones (OHS&E Human Resources)
E Kachwalla (National Facility Support)
H Kanoniuk (Receivers)
M Kesteven (Astrophysics/Engineering Research)
V Kilborn (Swinb/ATNF/ARC CSIRO Fellow)
N Killeen (Head, Computing)
B Koribalski (Astrophysics)
M Leach (Electronics)
J Lie (Receivers)
S Little (Astrophysics/Federation Fellow PA)
D Londish (SKA)
M Marquarding (Computing)
S Magri (Electronics)
R Manchester (Federation Fellow)
G Manefield (PA, Executive Officer)
M McAuley (Executive Officer)
N McClure-Griffiths (CSIRO Fellow/Astrophysics)
D McConnell (Assistant Director Operations)
V McIntyre (Computing)
E Middelberg (Bolton/CSIRO Fellow/Astrophysics)
R Moncay (Machine Shop)
G Moorey (Receivers)
E Muller (Bolton/CSIRO Fellow/Astrophysics)
T Murphy (Computing)
R Norris (Astrophysics)
J O'Sullivan (SKA)
R Ojha (Astrophysics)
W Orchiston (National Facility Support)
J Ott (Astrophysics/Mopra)
S O'Toole (Human Resources)
C Owen (National Facility Support)
B Parsons (Engineering)
C Phillips (Astrophysics/LBA)
G Powell (Receivers)
R Ricci (AT20G Postdoctoral/Astrophysics)
L Reilly (Receivers)
P Roberts (Electronics)
S Saunders (Electronics)
G Scott (LBA Correlator)
H Sim (National Facility Support)
L Staveley-Smith (Assistant Director Astrophysics)
M Storey (SKA)
T Sweetnam (SKA)
P Sykes (Receivers)
A Teoh (Federation Fellowship Pulsar)
P Tokachichu (Computing)
A Tzioumis (Astrophysics/LBA)
T Uppal (Astrophysics)
N Wang (ATNF/USyd Postdoctoral Fellow)
B Wilson (Finance & Administration)
W Wilson (Assistant Director Engineering)
M Whiting (Emerging Science Postdoctoral Fellow)
T Wong (UNSW/ATNF ARC/CSIRO Fellow/Astrophysics)

M Wright (Receivers)

## Marsfield Staff shared with CSIRO Industrial Physics

S Clark (Canteen)
O D'Amico (Store)
C Duffy (Reception)
C Hodges (Reception)
A Joos (Library)
K Lambert (Store)
B Wrbik (Canteen)
P Cooper (Engineering Services)
W Finch (Engineering Services)
M McDonald (Site Services)
P Sharp (Engineering Services)
C van der Leeuw (Library)
B Wilcockson (Assistant Engineering Manager)

## Narrabri

D Aboltin (Electronics)
B Adamson (Administration)
R Behrendt (Electronics)
D Brennan (Lodge)
D Brodrick (Computing)
D Brooke (Electronics)
M Dahlem (Operations & Astrophysics)
E Darcey (Antennas & Site Services)
A Fairfull (Administration)
K Forbes (Administration)
C Gay (Administration)
J Giovannis (Computing)
M Hill (Electronics)
B Hiscock (Deputy Officer-in-Charge)
J Houldsworth (Visitor Services)
B Johnson (Antennas & Site Services)
P Kelly (Visitor Services)
S Koljatic (Electronics)
M Laxen (Electronics)
C Leven (Antennas & Site Services)
J McFee (Electronics)
M McFee (Visitor Services)
P Mirtschin (Electronics)
S Munting (Electronics)
M Rees (Lodge)
S Robertson (Operations & Astrophysics)
D Rowe-McDonald (Visitor Services)
L Saripalli (Operations & Astrophysics)
R Sault (Officer-in-Charge)
R Subrahmanyan (Operations & Astrophysics)
G Sunderland (Antennas & Site Services)
B Tough (Electronics)
E Troup (Computing)
M Voronkov (Computing)
R Wark (Operations)
N Webster (Antennas & Site Services)
J Wieringa (Library)
M Wieringa (Computing)
C Wilson (Lodge)
T Wilson (Antennas & Site Services)

## Parkes

G Ballantyne (Visitors Centre)
S Brady (Site Services)
J Cole (Lodge)
J Crocker (Site Services)
B Dawson (RF Systems)
R Eslick (Site Services)
A Evans (Site Services)
G Freeman (Administration)
C Grover (Site Services)
A Hockings (Site Services)
J Hockings (PA/Visitors Centre)
S Hoyle (Computing)
A Hunt (Electronics/Servo)
S Ingram (Lodge/Site Services)
R Lees (Site Services)
D Lewis (Operations)
S Mader (Operations)
L Milgate (Visitors Centre)
B Preisig (Electronics/Servo)
K Reeves (Site Services)
J Reynolds (Officer-in-Charge)
T Ruckley (Research Support)
J Sarkissian (Operations)
J Smith (Visitors Centre Manager)
M Smith (RF systems)
G Spratt (Computing)
K Strudwick (Administration Trainee)
T Trim (Visitors Centre)
B Turner (Site Services)
S Turner (Site Services)
K Unger (Visitors Centre)
J Vera (RF Systems)
T Wilkie (Visitors Centre)
L Williams (Site Services)
B Wilson (Visitors Centre)

## Canberra

F Briggs ANU/ATNF (Astrophysics/SKA)
D Jauncey (Astrophysics)
J Lovell (Astrophysics/Tidbinbilla)

# C: Committee membership

## ATNF Steering Committee at April 2005

### Chairman

Prof Matthew Bailes, Swinburne University of Technology

### Secretary

Mrs Anne Barends, CSIRO ATNF

### Members

#### Ex-Officio

Prof Brian Boyle, Director, CSIRO ATNF

Dr Matthew Colless, Director, Anglo-Australian Observatory

Dr Alex Zelinsky, Director, CSIRO ICT Centre

Dr Ron Sandland, CSIRO, Deputy Chief Executive

#### Astronomers

Prof Frank Briggs, Research School of Astronomy and Astrophysics, Australian National University

Associate Prof Anne Green, School of Physics, University of Sydney

#### International advisers

Prof Rajaram Nityananda, National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Pune, India

Prof Phil Diamond, Director, MERLIN and VLBI National Facility, Jodrell Bank, UK

Dr Ken Kellermann, National Radio Astronomy Observatory, Charlottesville, USA

#### Industry

Dr Robert Frater, Vice President, Innovation, Res Med, North Ryde

Mr Brett Biddington, Space Initiative Manager - ASIAPAC, Global Defence and Space Group Cisco Systems Inc.

# Australia Telescope Users Committee

## January to December 2005

### Chair

Dr S Tingay, Swinburne University

### Secretary

Dr J Lovell, CSIRO ATNF

### Members

Dr J Bland-Hawthorn, Anglo-Australian Observatory

Dr K Brooks, CSIRO ATNF

Dr M Cunningham, University of New South Wales

Mr A Hotan*, Swinburne University

Ms A Ford*, Swinburne University

Dr H Jerjen, Research School of Astronomy & Astrophysics, Australian National University

Dr S Johnston, University of Sydney/CSIRO ATNF

Dr M Johnston-Hollitt, University of Tasmania

Ms K Newton-McGee*, University of Sydney

Dr J Ott, CSIRO ATNF

Dr S Ryder, Anglo-Australian Observatory

Prof E Sadler, University of Sydney

Associate Prof M Wardle, Macquarie University

Prof R Webster, University of Melbourne

Dr C Wright, Australian Defence Force Academy

* student member

# Australia Telescope Time Assignment Committee

## January to December 2005

### Chair

Dr L Staveley-Smith, CSIRO ATNF (Acting Chair to June 2005)

Prof J Dickey, University of Tasmania (from July 2005)

### Executive secretary

Dr J Chapman, CSIRO ATNF

### Members

Ex-Officio

Prof B Boyle, Director, CSIR, ATNF

Dr J Lovell, VLBI and Tidbinbilla Scheduler, CSIRO ATNF

Dr J Reynolds, Officer-in-Charge, Parkes Observatory, CSIRO ATNF

Dr R Sault, Officer-in-Charge, Narrabri Observatory, CSIRO ATNF

Voting members

Dr P Francis, Research School of Astronomy & Astrophysics, Australian National University

Associate Prof A Green, University of Sydney

Dr S Johnston, CSIRO ATNF

Dr R Subrahmanyan, CSIRO ATNF

Dr W Walsh, University of New South Wales

# D: Observing programs

## Observations made with the Australia Telescope Compact Array October 2004 to September 2005

| Observers | Affiliations | Program | Number | Hours |
|---|---|---|---|---|
| Sault, Wong, Beasley | ATNF, ATNF/UNSW, NRAO | ATCA calibrators at 3mm | C007 | 34.5 |
| Staveley-Smith, Manchester, Ball, Gaensler, Kesteven, Tzioumis | ANTF, ATNF, ATNF, CfA, ATNF, ATNF | SNR 1987A | C015 | 116.5 |
| Ryder, Smith, Bottcher | AAO, URice, OSU | The 1978 supernova in NGC 1313 | C184 | 13.5 |
| White, Chapman, Koribalski | UMar, ATNF, ATNF | High-spatial resolution observations of Eta Carinae | C186 | 12.0 |
| Gelfand, Gaensler, Slane, Hughes, McClure-Griffiths | CfA, CfA, CfA, URutg, ATNF | G328.4+0.2: pulsar wind nebula or old supernova remnant? | C266 | 13.0 |
| Gallo, Fender, Corbel, Tzioumis | UAm, UAm, CEA, ATNF | Simultaneous ATCA and CHANDRA observations of GX 339-4 | C767 | 13.0 |
| Caswell, | ATNF | Rise and fall of OH maser flares in 339.884-1.259 | C906 | 13.0 |
| Wang, Zhang, Bourke, Sridharan, Balasubramanyam | CfA, CfA, CfA, CfA, RRI | A systematic study of isolated high-mass protostars | C988 | 11.5 |
| Brocksopp, Corbel, Fender, Hannikainen, Tzioumis | MSSL, CEA, UAm, UHel, ATNF | NAPA: Radio jets in recurrent and new black hole X-ray transients | C989 | 17.0 |
| Wright, van Disoeck | ADFA, LO | Molecular outflows and disks toward massive young stars | C996 | 24.0 |
| Hunstead, Bryant, Sadler, Johnston, De Breuck, Klamer | USyd, USyd, USyd, USyd, ESO, USyd | High redshift radio galaxies from SUMSS | C1000 | 61.0 |
| McClure-Griffiths | ATNF | Vacation student Narrabri observing session | C1012 | 37.0 |
| Ekers, Calabretta, Jackson, Kesteven, Newton-McGee, Phillips, Ricci, Sadler, Staveley-Smith, Subrahmanyan | ATNF, ATNF, ATNF, ATNF, USyd, ATNF, SISSA, USyd, ATNF, ATNF | Wideband 20-GHz sky survey | C1049 | 835.0 |
| Burgasser, Putman, Curz | UCLA, UMich, AMNH | Radio emission from nearby cool dwarf stars and brown dwarfs | C1062 | 89.5 |
| Fender, Jonker, Tzioumis, Tudose, Migliari, Gallo | USouth, CfA, ATNF, UAm, UAm, UAm | Rapid secular evolution of Cir X-1, the most relativisitic jet source in the galaxy | C1073 | 24.0 |
| Hoare, Busfield, Lumsden, Oudmaijer, Burton | ULeeds, ULeeds, ULeeds, ULeeds, UNSW | Massive star formation in the Galaxy: Red MSX sources | C1088 | 79.5 |
| Pisano, Barnes, Gibson, Staveley-Smith, Freeman | ATNF, UMelb, Swinb, ATNF, RSAA | Intragroup HI in local group galaxies | C1107 | 154.0 |
| Buxton, Bailyn, Tzioumis | Yale, Yale, ATNF | NAPA: Jet energetics in low-mass x-ray binaries | C1150 | 7.0 |
| Doyle, Drinkwater, Webster, Stevens, Ryan-Weber, Wong, Koribalski, Ryder, Zwaan, Meyer | UQld, UQld, UMelb, UMelb, UMelb, UMelb, ATNF, AAO, ESO, STScI | Star formation efficiency and environment | C1154 | 178.5 |
| Purcell, Minier, Bontemps, Herpin, Jones, Burton, Hunt | UNSW, CEA, OBordeaux, OBordeaux, ATNF, UNSW, UNSW | Unveiling warm amonia clumps in NGC 3576 | C1158 | 10.5 |
| Ramsdale, Ellingsen | UTas, UTas | 19.9 GHz methanol masers in star forming regions | C1163 | 13.5 |
| White, Chapman, Koribalski | UMar, ATNF, ATNF | High-resolution millimetre images of the Eta Carinae system | C1167 | 32.0 |
| Wright, Maddison, Hughes, Bourke, Wilner, Lomme, van Dishoeck, Burton | ADFA, Swinb, Swinb, CfA, CfA, LO, LO, UNSW | 3-mm observations of protoplanetary disks | C1173 | 59.0 |

| | | | | |
|---|---|---|---|---|
| Hoare, Urquhart, Voronkov, Gibb, Purcell | ULeeds, ULeeds, ATNF, UBC, UNSW | Massive YSO disks and class I methanol masers | C1176 | 14.5 |
| Nurnberger, Koribalski, Reimer | ESO, ATNF, URuhr | High angular resolution 3-mm observations of NGC 3603 | C1182 | 36.0 |
| Caswell | ATNF | Strategic studies for a 22-GHz water maser survey | C1189 | 7.5 |
| Staveley-Smith, Matthews, Bruens, Putman, Gibson, Thom, McClure-Griffiths | ATNF, LaTrobe, RAIUB, UMich, Swinb, Swinb, ATNF | The structure of the Magellanic Stream | C1197 | 80.0 |
| Corbel, Fender, Tziousmis, Kaaret, Orosz, Tomsick | CEA, UAm, ATNF, CfA, UCSD, UCSD | Large scale radio jets in microquasars | C1199 | 24.0 |
| McIntyre, Dickel, Milne, Gruendl | ATNF, UIL, ATNF, UIL | A 4.8 and 8.6-GHz survey of the SMC | C1207 | 121.0 |
| Gelfand, Gaensler, Slane, Rakowski, Haverkorn, McClure-Griffiths, Green, Hughes, Dickey | CfA, CfA, CfA, CfA, CfA, ATNF, USyd, URutg, UTas | A search for pulsar nebulae in small supernova remnants | C1213 | 96.0 |
| Klamer, Ekers, Sadler, Hunstead | USyd/ATNF, ATNF, USyd, USyd | Resolving the molecular gas in a z=5.2 radio galaxy | C1214 | 64.5 |
| Ott, Jackson, Norris, Jogee, Wiklind, Weiss, Huynh, Koekemoer, Mobasher | ATNF, ATNF, ATNF, UTex, STScI, IRAM, RSAA, STScI, STScI | Molecular gas in the reionisation era | C1223 | 56.0 |
| Ott, Henkel, Weiss, Walter | ATNF, MPIfR, IRAM, NRAO | Temperature variations of dense molecular gas in starburst cores | C1224 | 121.0 |
| Olofsson, Wong, Schoier, Lindqvist, Kerschbaum | StO, ATNF, StO, OSO, VObs | Thermal SiO emission as a probe of circumstellar grain formation and dynamics | C1227 | 30.0 |
| Serra, Trager, van der Hulst, Oosterloo, Morganti, Sadler | KI, KI, KI, NFRA, NFRA, USyd | The evolution of gas-rich early-type galaxies | C1238 | 39.0 |
| Middelberg, Norris, Voronkov, et al Koekemoer, Condon, APEX, Team, SWIRE, Team, XMM, Team | ATNF, ATNF, ATNF, STScI, NRAO, UDur, IPAC, UBol | Wide-area deep radio observations of SWIRE/APEX fields | C1241 | 554.5 |
| Slee, Willes, Wilson | ATNF, USyd, ATNF | Coherent radio emission from RS CVn binaries | C1252 | 20.5 |
| Subrahmanyan, Ekers, Saripalli, Sadler | ATNF, ATNF, ATNF, USyd | The low-surface-brightness radio source population | C1261 | 50.0 |
| Voronkov, Sobolev, Ostrovskii, Menten, Ellingsen | ATNF, USU, USU, MPIfR, UTas | Search for 25 GHz methanol masers | C1267 | 20.0 |
| Gentile, Pizzella, Ott | SISSA, UPad, ATNF | The sigma - circular velocity relation and the dark matter density profiles | C1272 | 96.0 |
| Ferrari, Hunstead, Feretti, Schindler | IAI, USyd, OABol, IAI | Low-power radio galaxies in the merging cluster A3921 | C1276 | 25.0 |
| Voronkov, Sobolev, Ostrovskii, Ellingsen, Caswell, Cragg, Godfrey | ATNF, USU, USU, UTas, ATNF, Monash, Monash | A multi-transitional study of the class I methanol masers | C1279 | 15.0 |
| Bock, Gaensler | OVRO, CfA | Millimetre-wave spectra of pulsar wind nebulae | C1282 | 16.0 |
| Longmore, Burton, Barnes, Brooks | UNSW, UNSW, USyd, ATNF | Ammonia survey of high-mass protostars | C1287 | 29.5 |
| Lundqvist, Bjornsson, Fransson, Ryder, Schmidt, Perez-Torres | StO, StO, StO, AAO, RSAA, IAA-CSIG | NAPA: Probing the radio emission from a young Type 1a supernova | C1303 | 7.5 |
| Buyle, Ferrarese, Dejonghe, Gentile, De Breuck | UGent, URutg, UGhent, SISSA, ESO | Supermassive black holes and DM holes | C1304 | 96.0 |
| Bourke, Joergensen, Myers, Lai, Brede, Launhardt | CfA, CfA, CfA, UMar, URuhr, MPIA | Tracing the evolution of low mass protostars | C1310 | 60.0 |
| Kilborn, Forbes, Koribalski | Swinb, Swinb, ATNF | The role of gas in galaxy groups | C1311 | 36.0 |
| Manchester, Camilo, Possenti, Burgay | ATNF, UClmba, CAO, CAO | SNR associations with Parkes multibeam pulsars | C1313 | 23.0 |

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| Launhardt, Bourke | MPIA, CfA | Distribution of angular momentum in binary protostars | C1314 | 48.0 |
| Ott, Henkel, Weiss, Walter | ATNF, MPIfR, IRAM, NRAO | Dense molecular gas heated by starbursts and AGNs | C1321 | 128.0 |
| Ott, Henkel, Weiss, Staveley-Smith | ATNF, MPIfR, IRAM, ATNF | Ammonia survey of the Galactic Center region | C1322 | 74.0 |
| Hobbs, McConnell, Manchester | ATNF, ATNF, ATNF | Forming pulsar flux density standards | C1323 | 25.0 |
| Wong, Ryder, Kohno, Buta | ATNF/UNSW, AAO, TMU, UAI | Circumnuclear rings as probes of star formation | C1328 | 40.0 |
| Caswell, McClure-Griffiths | ATNF, ATNF | Polarisation of W49B; probing the Galactic magnetic field | C1329 | 25.5 |
| Caswell | ATNF | Positions of 22-GHz water masers relative to methanol masers | C1330 | 25.5 |
| Slee, Ball, Robinson, Orchiston | ATNF, ATNF, CUWDC, ATNF | Orbital radio emission from the polar V834 Centauri | C1332 | 9.5 |
| Slee, Budding, Carter, Osten | ATNF, UCan, USQld, NRAO | Magnetic fields and coronal emission from CC Eri | C1333 | 32.5 |
| Meyer, Zwaan, Webster | STScI, ESO, UMelb | Intrinsic scatter of the Tully-Fisher relation | C1336 | 55.5 |
| Chapman, Cohen, Parker, Deacon, Sault, Green | ATNF, UCB, UMac, USyd, ATNF, USyd | $H_2O$ maser observations of the OH/IR star V1018 Sco | C1339 | 36.0 |
| Klamer, Hunstead, Sadler, De Breuck | USyd, USyd, USyd, ESO | Characterising the properties of high redshift radio galaxies | C1340 | 36.5 |
| Koribalski, Staveley-Smith, Karachentsev, Ott, Jerjen, de Blok | ATNF, ATNF, ASC, ATNF, RSAA, UCardiff | The local volume gas-rich galaxy survey | C1341 | 458.0 |
| Willes, Ramsay, Wu, Slee | USyd, UCL, UCL, ATNF | Magnetic interactions in double-degenerate binaries | C1342 | 11.0 |
| Koribalski, Staveley-Smith, Henning | ATNF, ATNF, UNM | A new member of the Orion group: HIZOA J0630+08 | C1343 | 8.0 |
| Soria, Stevens, Hannikainen, Motch, Read | UCL, UBir, UHel, Strasb, ULeic | Radio emission from a ULX in NGC 5408: microblazar or milliquasar? | C1345 | 32.0 |
| Rosenberg, Ryan-Weber, Stocke, Keeney | CASA, UMelb, CASA, CASA | Mapping two "gaseous-halo selected" galaxies at 21 cm | C1346 | 49.0 |
| Smith, Bally | CASA, CASA | A search for $NH_3$ in the Homunculus Nebula of Eta Carinae | C1348 | 24.0 |
| Myers, Mason, Readhead | NRAO, NRAO, Caltech | A survey for radio sources in CBI SZ clusters | C1349 | 62.5 |
| Nurnberger, Chini, Hoffmeister | ESO, URuhr, URuhr | Exciting new vistas on the formation of high mass stars | C1351 | 18.0 |
| Haverkorn, Gaensler, McClure-Griffith, Dickey, Green | CfA, CfA, ATNF, UTas, USyd | High dynamic range polarimetric imaging for the SGPS | C1352 | 51.0 |
| Cimo, Senkbeil, Carter, Ellingsen, Jauncey, Lovell, Tzioumis, Kedziora-Chudczer, Bignall, Macquart | UTas, UTas, UTas, UTas, ATNF, ATNF, ATNF, USyd, JIVE, NRAO | Changes in the IDV behaviour: source-intrinsic or due to the ISM? | C1354 | 19.0 |
| Rakowski, Gaensler, Gelfand, Slane, Hughes | CfA, CfA, CfA, CfA, URutg | G337.2-0.7: an asymmetric type Ia supernova remnant? | C1355 | 12.0 |
| Wilcots, Doane, Sanders | UWis, UWis, UWis | HI observations of the ISM in IC 5332 | C1356 | 24.5 |
| Newton-McGee, Ekers, Green | USyd/ATNF, ATNF, USyd | Searching for spinning dust in the interstellar medium | C1357 | 58.0 |
| Thom, Gibson, Chrstlieb, Flynn, Beers | Swinb, Swinb, UHam, TuO, MSU | High resolution spectra of high-velocity cloud sightlines | C1359 | 24.0 |
| Urquhart, Thompson, White, Morgan | UKC, UKC, UKC, UKC | Infall survey of protostellar cores within bright-rimmed clouds | C1362 | 32.0 |
| Kanekar, Combes, Briggs, Subrahmanyan, Wiklind | KI, OPM, ATNF, ATNF, ESA | Molecular absorption in a z ~ 0.7645 gravitations lens | C1363 | 23.0 |

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| McCallum, Modjaz, Ellingsen, Greenhill, Lovell | UTas, CfA, UTas, CfA, ATNF | Polarised emission in Circinus | C1368 | 12.0 |
| Pogrebenko, Avruch, Bignall, Sault, Gurvits, Foley | JIVE, JIVE, JIVE, ATNF, JIVE, NFRA | Variability check of reference sources in the Huygens field | C1369 | 8.5 |
| Buyle, De Rijcke, Michielsen, Dejonghe | UGhent, UGhent, UGhent, UGhent | The HI content of Fornax Cluster dwarf elliptical galaxies | C1370 | 24.5 |
| Ott, Weiss, Henkel, Staveley-Smith, Walter | ATNF, IRAM, MPIfR, ATNF, NRAO | Ammonia in nearby LIRGs and ULIRGs | C1372 | 31.0 |
| Ott, Staveley-Smith, Henkel, Walter, Weiss | ATNF, ATNF, MPIfR, NRAO, IRAM | Ammonia detection experiment and 12-mm radio continuum in the LMC | C1374 | 30.0 |
| Henkel, Ott, Whiteoak, Hunt, Curran, Wang, Ruiz | MPIfR, ATNF, ANTF, UNSW, UNSW, PMO, IRAM | A molecular line survey of NGC 4945 | C1381 | 72.0 |
| Emonts, Morganti, Oosterloo, van der Hulst, Tadhunter, Sadler | KI, ASTRON, ASTRON, KI, USheff, USyd | Neutral hydrogen & the origin of radio galaxies | C1382 | 50.5 |
| Jones, Filipovic, Biver, A'Hearn, Burton | ATNF, UWS, OPM, UMar, UNSW | HCN jets from comet 9P/Tempel 1 after deep impact collision | C1384 | 9.5 |
| Lyne, McLaughlin, Kramer, Lorimer, Johnston, Stairs, Camilo, Manchester, Hobbs | JB, JB, JB, JB, USyd, UBC, UClmba, ATNF, ATNF | Unpulsed transient emission from a massive binary system | C1387 | 145.5 |
| Brooks, Garay, Burton, Mardones | ATNF, UChi, UNSW, UChi | 3-mm observations towards the IRAS 16547-4247 radio jet | C1390 | 36.0 |
| Sadler, Staveley-Smith, Ricci, Ekers, Jackson | USyd, ATNF, ATNF, ATNF, ATNF | The radio-source population at 100GHz | C1392 | 48.0 |
| Ogley, Tingay, Dahlem | Swinb, Swinb, ATNF | New tools for RFI surveys, characterisation, and mitigation at the ATCA | C1393 | 5.5 |
| Klamer, Hunstead, Sadler, Ekers | USyd/ATNF, USyd, USyd, ATNF | Characterising the ultra-steep spectrum radio galaxy population | C1394 | 108.0 |
| Gaensler, Haverkorn, Staveley-Smith, Dickey, Dickel, McClure-Griffiths | CfA, CfA, ATNF, UTas, UIL, ATNF | Parsec scale turbulence in the Large Magellanic Cloud | C1395 | 64.0 |
| Walsh, Purcell, Longmore, Burton, Wardle | UNSW, UNSW, UNSW, UNSW, UMac | The chemical signatures of high mass star formation: 12 mm | C1401 | 12.0 |
| Walsh, Purcell, Longmore, Burton, Wardle | UNSW, UNSW, UNSW, UNSW, UMac | The chemical signatures of high mass star formation: 3 mm | C1402 | 11.0 |
| Friesen, Johnstone, Di Francesco, Walsh, Myers | UVictoria, UVictoria, UVictoria, UNSW, CfA | $NH_3$ mapping of star forming cores in Ophiuchus | C1403 | 27.0 |
| Friesen, Johnstone, Di Francesco, | UVictoria, UVictoria, UVictoria, | $N_2H^+$ observations of the Ophiuchus B Core | C1404 | 42.5 |
| Benaglia, Vink, Koribalski, Maiz-Apellaniz, Marti | FCAG, ImCol, ATNF, STScI, UJaen | Testing the mass loss bi-stability jump with ATCA | C1408 | 24.0 |
| Leinert, Ratzka, Launhardt | MPIA, MPIA, MPIA | The circumstellar disks of VV CrA | C1411 | 16.0 |
| Green, Cohen, Roberts | USyd, UCB, UMcGill | The shell source G313.3+00.3: an unusual PN or a young SNR? | C1412 | 12.5 |
| Oosterloo, Morganti, Saripalli | NFRA, NFRA, ATNF | The nature of the inner gas disk of Centaurus A | C1414 | 43.0 |
| Ellis, Ekers, Massardi, Maughan | AAO, ATNF, SISSA, CfA | A massive, high redshift cluster of galaxies in the process of formation | C1422 | 24.0 |
| Muller, Lebron, Pantoja | AO, AO, UPuert | A new study of HVC continuum absorption: dedicated measurements of the HIPASS HVCs | C1423 | 12.0 |
| Ghosh, Saripalli, Swartz, Tennant, Wu | USRA/NASA/MSFC, ATNF, USRA/NASA/MSFC, NASA/MSFC, UCL | Probing the radio nature of ultraluminous X-ray sources | C1424 | 72.0 |
| Lenc, Tingay, Tzioumis | Swinb, Swinb, ATNF | ATCA 4.8, 8.6 and 18-GHz follow up observations of candidate radio jet interactions | C1425 | 24.0 |
| Cimo, Carter, Ellingsen, Jauncey, Lovell, Bignall, Kedziora-Chudczer, Senkbeil | UTas, UTas, UTas, ATNF, ATNF, JIVE, USyd, UTas | Monitoring of southern scintillators: ISM and micro-arcsecond jets | C1426 | 260.0 |

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| Curran, Whiting, Webb, Murphy | UNSW, UNSW, UNSW, IoA | Millimetre-wave molecular absorption in red gravitational lenses | C1428 | 28.0 |
| Balasubramanyam, Parthasarathy, Burton | RRI, RRI, UNSW | Making a PN. A 12-mm study of a rare, rapidly evolving planetary nebula | C1431 | 24.0 |
| Bouchard, Ott, Da, Costa, Jerjen, Staveley-Smith | RSAA, ATNF, RSAA, RSAA, ATNF | ISM distribution in low $M_{HI}/L_B$ galaxies | C1432 | 59.0 |
| Walsh, Tothill | UNSW, CfA | Mapping the physical properties of non-star-forming cores | C1434 | 32.0 |
| Frail, Wieringa, Wark, Soderberg, Kulkarni, Schmidt, Davis, Rich, Peterson, Subrahmanyan | NRAO, ATNF, ATNF, Caltech, Caltech, RSAA, RSAA, RSAA, RSAA, ATNF | Radio afterglow studies in the Swift era | C1435 | 6.0 |
| Zinnecker, Stecklum, Correia, Burton, Maddison | AIP, TLS, Tautenburg, AIP, UNSW, Swinb | Circumstellar environment of young stellar objects in the Gum Nebula | C1436 | 19.5 |
| Newton-McGee, Ekers, Gaensler, Haverkorn, Green, McClure-Griffiths | USyd, ATNF, CfA, CfA, USyd, ATNF | Measuring Farady rotation in Molecular clouds | C1442 | 51.5 |
| Godfrey, Lovell, Jauncey, Bicknell, Schwartz, Marshall, Gelbord, Worrall, Birkinshaw + 3 others | RSAA, ATNF, ATNF, RSAA, CfA, MIT, MIT, UBr, UBr | 3-mm imaging of PKS 1421-490: A unique X-ray bright jet | C1448 | 8.0 |
| Bains, Deacon, Chapman | UNSW, USyd, ATNF | Observing the onset of ionised winds in post-AGB stars | C1450 | 27.5 |
| Carpenter, Meyer, Mamajek, Henning, Wong | Caltech, UAz, CfA, MPIA, ATNF | The circumstellar disk around PDS 66 | C1452 | 50.0 |

## Observations made using the Mopra Telescope October 2004 to September 2005

| Observers | Affiliations | Program | Number | Hours |
|---|---|---|---|---|
| Hoare, Urquhart, Moore, Lumsden, Burton | ULeeds, ULeeds, LivJMU, ULeeds, UNSW | Completion of kinematic distances of the RMS survey | M121 | 136.0 |
| Urquhart, Thompson, Morgan, White | ULeeds, UHerts, UKC, UKC | Star formation in bright-rimmed clouds - is it induced? | M126 | 207.0 |
| Wong, Ladd, Mizuno, Mizuno, Wright, Bourke | UNSW, UBuck, UNag, UNag, ADFA, CfA | OTF mapping of dense cores in Chamaeleon | M130 | 89.5 |
| Voronkov, Robertson | ATNF, ATNF | A search for southern 104.3 GHz methanol masers | M131 | 77.0 |
| Muller | AO | Mapping CO (1-0) in the Magellanic Bridge | M136 | 54.0 |
| Lazendic, Hunt, Slane, Dame, Green | CfA, UNSW, CfA, CfA, CfA | Identifying molecular clouds associated with SNR G347.3-0.5 | M137 | 96.0 |
| Oshima, Kuno, Ota | ISAS, NRO, TMU | Mapping CO emission from the NGC 55 chminey candidate | M142 | 91.0 |
| Ojha, Ellingsen, Tzioumis, Reynolds, Jauncey, Fey, Johnston | ATNF, UTas, ATNF, ATNF, ATNF, ATNF, USNO, USNO | Search for astrometric candidates | M145 | 48.0 |
| Moore, Hoare, Urquhart, Lumsden, Allsopp | LivJMU, ULeeds, ULeeds, ULeeds, LivJMU | Outflow properties for massive young stellar objects | M146 | 112.0 |

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| Jones, Burton, Biver, A'Hearn | ATNF, UNSW, OPM, UMar | HCN from Comet 9P/Tempel1 after deep impact collision | M147 | 45.0 |
| Herpin, Minier, Bontemps, Marseille, Burton, Purcell, Walsh | OBordeaux, CEA, OBordeaux, OBordeaux, UNSW, UNSW, UNSW | A multi-frequency mapping of high-mass protostellar objects | M148 | 60.0 |
| Li, Novak, Krejny | NWU, NWU, NWU | Test of grain alignment theories: grains aligned by turbulence and magnetic fields | M150 | 48.0 |
| Mercer, Clemens, Rathborne, The GLIMPSE Team | UBos, UBos, UBos | CO mapping of two GLIMPSE molecular clouds | M151 | 39.0 |
| McClure-Griffiths, Dickey, Gaensler, Green | ATNF, UTas, CfA, USyd | Tracing the Galactic ecosystem from supershells to molecular clouds | M152 | 70.5 |
| Rathborne, Chambers, Jackson, Simon | UBos, UBos, UBos, UKoeln | Kinematic distances to southern infrared dark clouds | M153 | 48.0 |
| Sparks, Hunt, Curran, Jones, Wong, Henkel, Helfer | UNSW, UNSW, UNSW, ATNF, UNSW, MPiFR, UCB | Dense gas in spiral galaxies | M155 | 189.0 |
| Bains, Hunt, Burton, Wong + DQS team | UNSW, UNSW, UNSW, UNSW | Turbulence in molecular clouds: The Delta Quadrant survey | M156 | 415.0 |
| Voronkov, Bains, Burton, Ellingsen, Caswell | ATNF, UNSW, UNSW, UTas, ATNF | A search for isolated Class I methanol masers | M157 | 77.0 |
| Minier, Burton, Hill, Andre, Peretto, Purcell | CEA , UNSW, UNSW, CEA, CEA, UNSW | Probing the dynamics of massive mid-IR dark clouds | M158 | 70.0 |
| Hughes, Wong, Maddison | Swinb, ATNF, Swinb | OTF mapping of molecular gas in Ara OB1 | M160 | 99.0 |
| Barnes, Yonekura, Mizuno, Fukui, Wong, Ladd | USyd, OSPU, UNag, UNag, UNSW, UBuck | CHaMP: A Galactic census of high and medium mass protostars in dense gas | M161 | 91.0 |
| Koo, Lee, Moriguchi, Burton, McClure-Griffiths | SNU, SNU, UNagoya, UNSW, ATNF | Search for shocked molecules associated with southern Galactic SNRs | M162 | 67.5 |
| Barnes, Bourke, Myers, Ladd | USyd, CfA, CfA, UBuck | The evolution of low-mass protostellar cores | M163 | 120.5 |

## Observations made with the Parkes Telescope October 2004 to September 2005

| Observers | Affiliations | Program | Number | Hours |
|---|---|---|---|---|
| Kaspi, Manchester | UMcGill, ATNF | Long-term monitoring of PSR J0045-7319 | P138 | 31.5 |
| Bailes, Ord, Hotan, Knight, Manchester, Anderson, Kulkarni, Jacoby | Swinb, Swinb, Swinb, Swinb, ATNF, Caltech, Caltech, Caltech | Precision pulsar timing | P140 | 195.3 |
| Manchester, Hobbs, Lewis, Sarkissian, Kaspi | ATNF, ATNF, UTas, ATNF, UMcGill | Timing of young pulsars | P262 | 136.0 |
| Manchester, Hobbs, Camilo, Lyne, Kramer, Faulkner, Stairs, D'Amico, Possenti | ATNF, ATNF, UClmba, JB, JB, JB, UBC, UBol, UBol | Timing of multibeam pulsar discoveries | P276 | 368.0 |

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| Freire, Lyne, Kramer, Manchester, Lorimer, Camilo, D'Amico | AO, JB, JB, ATNF, JB, UClmba, UBol | Timing and searching for pulsars in 47 Tucanae | P282 | 144.8 |
| Staveley-Smith, Mader, Koribalski, Kraan-Korteweg, Harnett, Henning, Schroeder, Stewart | ATNF, ATNF, ATNF, UCT, UTS, UNM, ULeic, ULeic | A bulge extension to the ZOA survey | P357 | 217.2 |
| Bailes, Ord, Verbeist, Hotan | Swinb, USyd, Swinb, UTas | Studies of relativisitic binary pulsars | P361 | 119.5 |
| Danziger, Seibel, Grosbol, Staveley-Smith | OAT, UJC, MPIfA, ATNF | Tully-Fisher HI widths of spirals containing type 1a supernova | P364 | 96.5 |
| Ryan-Weber, Wong, Webster, Barnes, Kilborn, Garcia, Staveley-Smith, Meyer, Zwaan | UMelb, UMelb, UMelb, UMelb, Swinb, UCardiff, ATNF, STScI, ESO | Completeness & reliability of northern HIPASS | P387 | 278.8 |
| Kramer, Lyne, Stairs, Kaspi, Manchester, Hotan, Camilo, Burgay | JB, JB, NRAO, UMcGill, ATNF, Swinb, UClmba, CAO | Geodetic precession in PSR J1141-6545 | P400 | 78.5 |
| Gaensler, McClure-Griffiths, Haverkorn, McConnell, Dickey, Green | CfA, ATNF, CfA, ATNF, UTas, USyd | Diffuse polarisation from the galactic plane: single dish observations | P409 | 27.8 |
| Kramer, Lyne, Esamdin, McLaughlin, Wang, Manchester | JB, JB, JB, JB, ATNF, ATNF | A new class of pulsar-like neutron stars | P417 | 64.4 |
| D'Amico, Lyne, Manchester, Sarkissian, Possenti, Corongiu, Camilo | CAO, JB, ATNF, ATNF, CAO, CAO, UClmba | Timing and searching millisecond pulsars in globular clusters | P427 | 200.3 |
| van Loon, Zijlstra, Whitelock, Wood, Oliveira | UKeele, JB, SAAO, ANU, UKeele | Circumstellar OH masers in the Small Magellanic Cloud | P433 | 104.0 |
| Hobbs, Kramer, Johnston, Lyne | ATNF, JB, USyd, JB | Properties of neutron star kicks | P439 | 55.2 |
| Karastergiou, Johnston, Manchester | USyd, USyd, ATNF | High frequency polarimetry of radio pulsars | P452 | 71.8 |
| Burgay, Kramer, D'Amico, Possenti, Manchester, Stairs, Faulkner, McLaughlin, Lyne, Camilo | UBol, JB, CAO, CAO, ATNF, UBC, JB, JB, JB, UClmba | Timing & geodetic precession in the double pulsar & the DNS PSR J1756-2251 | P455 | 103.8 |
| Manchester, Bailes, Hotan, Ord, Hobbs, Edwards, Sarkissian, Kesteven, Kulkarni, Jacoby | ATNF, Swinb, Swinb, Swinb, ATNF, ATNF, ATNF, ATNF, Caltech, Caltech | A millisecond pulsar timing array | P456 | 1003.0 |
| Knight, Bailes, Ord, Kulkarni | Swinb, Swinb, Swinb, Caltech | Searching for giant pulses from millisecond pulsars | P460 | 162.5 |
| Burgay, McLaughlin, Kramer, Lyne, D'Amico, Possenti, Manchester, Camilo | UBol, JB, JB, JB, CAO, CAO, ATNF, UClmba | Timing and confirmation of high-latitude survey discoveries | P465 | 101.6 |
| McClure-Griffiths, Pisano, Staveley-Smith, Bruens, Kalbera, Gibson, Ford, Lockman | ATNF, ATNF, ATNF, UBonn, UBonn, Swinb, Swinb, NRAO | GASS: The Galactic All Sky Survey project | P467 | 787.8 |
| Camilo, Lorimer, McLaughlin | UClmba, UMan, UMan | Deep multibeam pulsar survey at 50 < l < 60, \|b\| < 1 | P471 | 151.0 |
| Carretti, McConnell, Bernardi, McClure-Griffiths, Cortiglioni, Poppi, Haverkorn | IASF-CNR, ATNF, IASF-CNR, ATNF, IASF-CNR, IRA-CNR, CfA | Parkes galactic meridian survey (PGMS) at 2.3 GHz | P472 | 49.0 |
| Bouchard, da Costa, Jerjen, Ott, Staveley-Smith | RSAA, RSAA, RSAA, ATNF, ATNF | The HI content of early-type dwarf galaxies in the ScL group | P475 | 86.0 |
| Lyne, D'Amico, Burgay, McLaughlin, Possenti, Lorimer, Kramer, Manchester, Hobbs, Camilo, Stairs | JB, CAO, CAO, JB, CAO, JB, JB, ATNF, ATNF, UClmba, UBC | The "Perseus Arm" pulsar multibeam survey | P477 | 316.8 |
| Lyne, McLaughlin, Kramer, Lorimer, Johnston, Stairs, Camilo, Manchester, Hobbs | JB, JB, JB, JB, USyd, UBC, UClmba, ATNF, ATNF | Monitoring of an eclipsing pulsar with a massive companion | P478 | 134.5 |
| McGlaughlin, Lyne, Kramer, Lorimer, Hobbs, Manchester, Stairs, Camilo, Faulkner | JB,, JB, JB, JB, ATNF, ATNF, UBC, UClmba, JB | Investigating a new population of repeating radio transients | P479 | 194.8 |
| Titov, Govind | GeosAus, GeosAus | Improving the terrestrial and celestial reference frames | P483 | 48.0 |

| | | | | |
|---|---|---|---|---|
| Caswell, Phillips | ATNF, ATNF | Full Stokes spectra of 1665 and 1667-MHz OH masers in SFRs | P484 | 62.2 |
| McConnell, Ord, Knight | ATNF, Swinb, Swinb | Single pulse study of pulsar J0437-4715 | P485 | 4.0 |
| Azcarate, Cerosimo, Mader | IAR, UPuert, ATNF | Searching for a warp in the ionised gas layer of the outer galaxy | P486 | 183.2 |
| Donavon, Camilo | UClmba, UClmba | Deep searches for young pulsars in "shell" supernova remnants | P487 | 41.0 |
| Tarchi, Pasquali, Ott, Castangia + APPLES team | CAO, ETHZ, ATNF, CAO, STScI | HI content of the newly-discovered dwarf spheroidal field galaxy APPLES1 | P488 | 12.0 |
| Hobbs, McConnell, Manchester | ATNF, ATNF, ATNF | Forming pulsar flux density standards | P489 | 25.5 |
| Johnston, Romani | ATNF, UStan | A search for extra-galactic giant pulses | P490 | 24.5 |
| Johnston, Kramer, Lyne, Lorimer, McLaughlin, Manchester | ATNF, ATNF, JB, JB, JB, JB, ATNF | Pulsar searches of the Galactic Centre | P491 | 77.2 |
| Weisberg, Johnston, Koribalski, Stanimirovic | Carleton, ATNF, ATNF, UCB | Recombination line observations toward pulsar B1641-45 | P492 | 32.5 |
| Jones, Sarkissian, Colom, A'Hearn | ATNF, ATNF, OPM, UMar | OH from comet 9P/Tempel 1 after deep impact collision | P493 | 27.0 |
| Vranesevic, Manchester | ATNF/USyd, ATNF | Integrated and individual radio pulsar properties | P494 | 34.0 |
| Walsh, Tothill, Martin | UNSW, CfA, Oberlin | Physical properties of Galactic Center molecular clouds | P497 | 22.2 |
| Buyle, Pisano, De Rijcke, Michielsen, Dejonghe, Freeman, | UGhent, NRL, UGhent, UGhent, UGhent, RSAA | HI detection in E+A galaxies | P498 | 40.8 |
| Edwards, van Straten, Ord, Bailes, Manchester | ATNF, NFRA Swinb, Swinb, ATNF | Single pulse properties of millisecond pulsars | P499 | 52.5 |

## VLBI Observations
## October 2004 to September 2005

| Observers | Affiliations | Program | Number | Hours |
|---|---|---|---|---|
| Ojha, Reynolds, Fey, Johnston, Tzioumis, Jauncey, Ellingsen, Cimo, Nicolson, Quick | ATNF, ATNF, USNO, USNO, ATNF, ATNF, UTas, UTas, HartRAO, HartRAO | Astrometry/imaging of southern hemisphere ICRF sources | V131 | 176.0 |
| Dodson, Johnston, Reynolds, Karastergiou | ISAS, USyd, ATNF, USyd | Distance and proper motion of PSR B1259-63 | V156 | 21.0 |
| Dodson, Johnston, Ord, Reynolds | ISAS, USyd, Swinb, ATNF | Pulsars: where are they from, where are they going? | V162 | 12.5 |
| Edwards, Tingay | ISAS, Swinb | The parsec-scale morphology of new GPS sources | V170 | 18.0 |
| Cimo, Jauncey, Ellingsen, McCulloch, Carter, Lovell, Ojha, Tzioumis, Reynolds, Fey | UTas, ATNF, UTas, UTas, UTas, ATNF, ATNF, ATNF, ATNF, USNO | Milliarcsec structure of micro-arcsecond sources | V172 | 48.0 |
| Caswell, Reynolds | ATNF, ATNF | Understanding magnetic field and velocity field patterns of maser sites in star | V174 | 12.0 |
| Horiuchi, Stootman, West, Tingay, Filipovic | Swinb, UWS, Swinb, Swinb, UWS | Measuring the deviation of an OH maser spectral line profile from the ideal | V177 | 6.0 |
| Edwards, Ojha, Tzioumis | ISAS, ATNF, ATNF | The strongly absorbed core of PKS 1814-7637 | V180 | 12.0 |

| | | | | |
|---|---|---|---|---|
| Lenc, Tingay, Tzioumis | Swinb, Swinb, ATNF | A high resolution, high sensitivity, wide field study of jet interactions and starburst galaxies | V181 | 31.5 |
| Hirabayashi, Edwards, Dodson, Lovell, Tzioumis, Jauncey, Tingay, Horiuchi, Ellingsen | ISAS, ISAS, ISAS, ATNF, ATNF, ATNF, Swinb, Swinb, UTas | Imaging the remaining VSOP 5-GHz survey sources | V183 | 24.0 |
| Godfrey, Lovell, Jauncey, Ojha, Bicknell, Sowartz, Marshall, Gelbord, Worall | RSAA, ATNF, ATNF, ATNF, RSAA, CfA, MIT, MIT, UBr | High angular resolution imaging of PKS 1421-90 | V185 | 12.0 |

## Tidbinbilla Observations
## October 2004 to September 2005

| Observers | Affiliations | Program | Number | Hours |
|---|---|---|---|---|
| Valdetto, Chapman, Palla | OAAI, ATNF, OAAI | Star formation in bright rimmed coulds: any water masers? | T001 | 5.8 |
| Phillips, Lovell, Beuther | ATNF, ATNF, MPIfR | Methanol masers: tracers of high mass protostars and discs? | T002 | 7.2 |
| Ellingsen,Cragg, Lovell, Godfrey | UTas, Monash, ATNF, Monash | Class II methanol masers at 19.9 GHz | T003 | 12.3 |
| McCallum, Ellingsen, Lovell, Jauncey | UTas, UTas, ATNF, ATNF | The Circinus Galaxy: simply scintillating? | T004 | 7.0 |
| Kondratko, Greenhill, Moran, Lovell, Jauncey, Kuiper | CfA, CfA, CfA, ATNF, ATNF, JPL | Monitoring of water megamasers newly discovered at DSS43: an update | T010 | 6.7 |
| Curran, Whiting, Wiklind, Webb, Murphy | UNSW, UNSW, STScI, UNSW, IoA | High redshift molecular absorption in optically faint quasars | T011 | 20.6 |
| Friesen, Johnstone, Walsh, Myers, Francesco | UVictoria, NRC-HIA, CfA, CfA, NRC-HIA | Ammonia observations of the Ophiuchus B core | T013 | 9.1 |
| Purcell, Minier, Bonetemps, Herpin, Jones, Burton, Hunt | UNSW, CEA, OBordeaux, OBordeaux, ATNF, UNSW, UNSW | Unveiling warm ammonia clumps in NGC 3576 | T014 | 39.7 |
| Tarchi, Castangia, Henkel, Greenhill, Ott | CAO, CAO, MPIfR, CfA, ATNF | Extragalactic water masers in southern bright IRAS sources | T015 | 67.5 |

# E: Affiliations

| | |
|---|---|
| AAO | Anglo-Australian Observatory, Australia |
| AAS | American Astronomical Society, USA |
| ADFA | Australian Defence Force Academy |
| AIP | Astrophysical Institute Potsdam, Germany |
| AMNH | American Museum of Natural History, USA |
| ANU | Australian National University |
| AO | Arecibo Observatory, USA |
| ASC | Astrospace Centre, Russia |
| ASIAA | Academia Sinica, IAA, Taiwan |
| ATNF | Australia Telescope National Facility, Australia |
| BIMA | Berkeley-Illinois-Maryland Association, USA |
| Caltech | California Institute of Technology, USA |
| CAO | Cagliari Astronomical Observatory, Italy |
| Carleton | Carleton College, USA |
| CASA | CASA, University of Colorado, USA |
| CDSCC | Canberra Deep Space Communications Complex, Australia |
| CEA | Centre d'Etudes d'Astrophysique, Saclay, France |
| CfA | Center for Astrophysics, Harvard University, USA |
| CL | Cavendish Laboratories, UK |
| Cornell | Cornell University, USA |
| CSR | Center for Space Research, USA |
| CIP | CSIRO Industrial Physics, Australia |
| CUWDC | Catholic University, Washington DC, USA |
| DRAO | Dominion Radio Astrophysical Observatory, Canada |
| ESO | European Southern Observatory, Germany |
| ESTEC | ESTEC Astrophysics Division, The Netherlands |
| FCAGLB/ IAR | Facultad de Ciencias Astronómicas y Geofísicas, Argentina |
| GBT | Green Bank Telescope, USA |
| GeosAus | Geoscience Australia |
| GSFC | Goddard Space Flight Center, USA |
| HartRAO | Hartebeesthoek Radio Astronomical Observatory, South Africa |
| Harvard | Harvard University, USA |
| IAA-CSIG | Intituto de Astrofisica de Andalucia, Spain |
| IAC | Instituto de Astrofisica de Canarias, Spain |
| IAFE | Instituto d'Astronomia y Fisica del Espacio, Argentina |
| IAI | Institute of Astrophyics Innsbruck, Austria |
| IAP | Institute d'Astrophysique Paris, France |
| IAR | Instituto Argentino de Radioastronomica, Argentina |
| IASF-CNR | Instituto di Astrofisica Spaziale e Fisica Cosmica, CNR, Italy |
| IFCTR | Instituto de Fisica Cosmica - CNR, Italy |
| ImCol | Imperial College London, UK |
| INAOE | Instituto Nacional de Astrofisica, Optica y Electronica, Mexico |
| IoA | Institute of Astronomy, UK |
| IPAC | IPAC, Caltech, USA |
| IRA-CNR | Institute of Radio Astronomy, CNR, Bologna, Italy |
| IRAM | Institut de Radioastronomie Millimétrique, Spain |
| ISAS | Institute of Space and Astronautical Science, Japan |
| ISU | Iowa State University, USA |
| JAC | Joint Astronomy Centre, Hilo, USA |
| JB | Jodrell Bank Observatory, UK |
| JILA | JILA, University of Colorado, USA |
| JIVE | Joint Institute for VLBI in Europe, The Netherlands |
| JPL | Jet Propulsion Laboratory, USA |
| KI | Kapteyn Institute, Netherlands |
| LAEFF | LAEFF-INTA, Spain |
| Latrobe | Latrobe University, Australia |
| LivJMU | Liverpool John Moores University, UK |
| LLNL | Lawrence Livermore National Laboratory, USA |
| LO | Leiden Observatory, The Netherlands |
| MSFC | Marshall Space Flight Center, USA |
| MERLIN | Multi-element Radio Linked Interferometry Network, UK |
| MIT | Massachusetts Institute of Technology, USA |
| Monash | Monash University, Australia |
| MPE | Max Planck Inst. für Extraterrestrische Physik, Germany |
| MPIA | Max Planck Insitut. für Astronomie, Germany |
| MPIfA | Max Planck Inst. für Astrophysik, Germany |
| MPIfR | Max Planck Inst. für Radioastronomie, Germany |
| MRAO | Mullard Radio Astronomical Observatory, UK |
| MRO | Mesahovi Radio Observatory, Finland |
| MSFC | Marshall Space Flight Centre, USA |
| MSSL | Mullard Space Science Laboratory, UCL, UK |
| NAOJ | National Astronomical Observatory, Japan |
| NASA-RC | NASA Ames Research Center, USA |
| NFRA | Netherlands Foundation for Research in Astronomy, The Netherlands |
| NRAO | National Radio Astronomy Observatory, USA |
| NRC-HIA | Hiesberg Institute of Astrophysics - NRC, Canada |
| NRL | Naval Research Laboratories, USA |
| NRO | Nobeyama Radio Observatory, Japan |
| NSSTC | National Space Science and Technology Center, USA |
| NWU | Northwestern University, USA |
| OAAI | Osservatorio Astrofisico di Arcetri, Italy |
| OABol | Osservatorio Astronomico di Bologna, Italy |
| OAP | Osservatorio Astonomico di Padova, Italy |
| OARome | Osservatorio Astronomico di Roma, Italy |
| OAT | Osservatorio Astronomico di Trieste, Italy |
| OBordeaux | Observatoire de Bordeaux, France |
| OCat | Osservatorio Astronomico di Catania, Italy |

| | |
|---|---|
| OPM | Observatoire de Paris, Meudon, France |
| OSO | Onsala Space Observatory, Sweden |
| OSPU | Osaka Prefecture University, Japan |
| OSU | Ohio State University, USA |
| OVRO | Owens Valley Radio Observatory, USA |
| PMO | Purple Mountain Observatory, China |
| RAIUB | Radio Astronomy Institute, University of Bonn, Germany |
| ROB | Royal Observatory of Belgium, Belgium |
| ROE | Royal Observatory Edinburgh, Scotland |
| RRI | Raman Research Institute, India |
| RSAA | Research School of Astronomy & Astrophysics, ANU |
| SISSA | Scuola Internazionale Superiore di Atudi Avanzati, Trieste, Italy |
| SNU | Seoul National University, Korea |
| StO | Stockholm Observatory, Sweden |
| StrasbO | Observatoire Astronomique de Strasbourg, France |
| STScI | Space Telescope Science Institute, USA |
| Swinb | Swinburne University of Technology, Australia |
| TGU | Tokyo Gakugei University, Japan |
| TLS | Thuringer Ladnessternwarte Tautenberg, Germany |
| TMU | Tokyo Metropolitan University, Japan |
| UAd | University of Adelaide, Australia |
| UAm | University of Amsterdam, The Netherlands |
| UAz | University of Arizona, USA |
| UBC | University of British Columbia, Canada |
| UBir | University of Birmingham, UK |
| UBol | University of Bologna, Italy |
| UBonn | University of Bonn, Germany |
| UBos | Boston University, USA |
| UBr | University of Bristol, UK |
| UBuck | Bucknell University, USA |
| UCal | University of Calgary, Canada |
| UCan | Canakkale University, Turkey |
| UCB | University of California, Berkeley, USA |
| UCardiff | Universiy of Cardiff, UK |
| UCha | University of Champagne-Urbana, USA |
| UChi | University of Chile, Chile |
| UChig | University of Chicago, USA |
| UCL | University College London, UK |
| UClmba | Columbia University, USA |
| UCLO | University of California Lick Observatory, USA |
| UCSB | University of California, Santa Barbara, USA |
| UCSC | University of California, Santa Cruz, USA |
| UCSD | University of California, San Diego, USA |
| UDel | University of Delaware, USA |
| UDur | University of Durham, England |
| UEdin | University of Edinburgh, UK |
| UFSSA | University of the Free State, South Africa |
| UGhent | Universiteit Ghent, Belgium |
| UHam | University of Hamburg, Germany |
| UHawaii | University of Hawaii, USA |
| UHel | University of Helsinki, Finland |
| UHerts | University of Hertfordshire, UK |
| UHilo | University of Hilo, USA |
| UIL | University of Illinois, USA |
| UJaen | Universidad de Jaen, Spain |
| UJC | James Cook University, Australia |
| UKC | University of Kent, UK |
| UKeele | University of Keele, UK |
| UKoeln | University of Koeln, Germany |
| UKyoto | University of Kyoto, Japan |
| ULeeds | University of Leeds, UK |
| ULeic | University of Leicester, UK |
| UMac | Macquarie University, Australia |
| UMan | University of Manchester, UK |
| UMar | University of Maryland, USA |
| UMcGill | McGill University, Canada |
| UMelb | University of Melbourne, Australia |
| UMich | Univerity of Michigan, USA |
| UMinn | University of Minnesota, USA |
| UMont | University of Montreal, Canada |
| UNag | Nagoya University, Japan |
| UNM | University of New Mexico, USA |
| UNSW | University of New South Wales, Australia |
| UOx | University of Oxford, UK |
| UPad | University of Padova, Italy |
| UPuert | University of Puerto Rico, USA |
| UQld | University of Queensland, Australia |
| URice | Rice University, USA |
| URuhr | Ruhr-Universitaet, Germany |
| URutg | Rutgers University, USA |
| USAND | University of St Andrews, UK |
| USheffield | University of Sheffield, UK |
| USNA | US Naval Academy, USA |
| USNO | US Naval Observatory, USA |
| USouth | Southampton University, UK |
| USQld | University of Southern Queensland, Australia |
| USRA | Universities Space Research Association, USA |
| UStan | Stanford University, USA |
| USU | Ural State University, Russia |
| USyd | University of Sydney, Australia |
| UTamk | Tamkang University, Taiwan |
| UTas | University of Tasmania, Australia |
| UTS | University of Technology, Sydney, Australia |
| UVictoria | University of Victoria, Canada |
| UVir | University of Virginia, USA |
| UW | University of Wales, UK |
| UWA | University of Western Australia, Australia |
| UWash | University of Washington, USA |
| UWis | University of Wisconsin, USA |
| UWol | University of Wollongong, Australia |
| UWS | University of Western Sydney, Australia |
| VObs | Vienna Observatory, Austria |

## F: ATNF media releases, 2005

| | |
|---|---|
| Australian telescopes ready for historic space mission | 12 January 2005 |
| Magnetic mystery solved | 28 January 2005 |
| CSIRO telescopes help rescue Titan experiment | 17 February 2005 |
| Monster star blast "brighter than full Moon" | 19 February 2005 |
| Hassled galaxy "thriving on chaos" | 11 March 2005 |
| Ron Ekers elected a Fellow of the Royal Society | 31 May 2005 |
| Double pulsar puts Einstein to the test | 31 May 2005 |
| Aussie astronomers prepare for smash hit | 28 June 2005 |
| Cheap Aussie telescope captures world's biggest solar flare | 03 October 2005 |
| Telescope bigger than Earth nets international award | 13 October 2005 |

## G: 2005 Publications

Papers which include ATNF authors are indicated by an asterisk.
C = Compact Array data, M = Mopra data, P = Parkes data, T = Tidbinbilla data, V = VLBI data.

### Papers using ATNF data, published in refereed journals


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AUDARD, M., BROWN, A., BRIGGS, K.R., GUDEL, M., TELLESCHI, A. & GIZIS, J.E. "A deep look at the T-type brown dwarf binary e Indi Bab with Chandra and the Australia Telescope Compact Array". ApJ, 625, L63-L66 (2005). (C)

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BEUTHER, H., THORWIRTH, S., ZHANG, Q., HUNTER, T.R., MEGEATH, S.T., WALSH, A.J. & MENTEN, K.M. "High spatial resolution observations of $NH_3$ and $CH_3OH$ toward the massive twin cores NGC 63341 and NGC 63341(N)". ApJ, 627, 834-844 (2005). (C)

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BOOMSMA, R., OOSTERLOO, T., FRATERNALI, F., VAN DER HULST, J.M. & SANCISI, R. "Extra-planar HI in the starburst galaxy NGC 253". A&A, 431, 65 (2005). (C)

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BOURKE, T.L., HYLAND, A.R. & ROBINSON, G. "On the identification of high-mass star forming regions using IRAS: contamination by low-mass protostars". ApJ, 625, 883-890 (2005). (P)

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## Theses of students co-supervised by the ATNF, 2005

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Stevens, J., "Neutral hydrogen in galaxy groups", PhD thesis, University of Melbourne.
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# H. Postgraduate students co-supervised by the ATNF

## As of December 2005

Bouchard, A., "The evolution of dwarf galaxies in nearby groups", RSAA, Australian National University

Chippendale, A., "High dynamic range imaging with many baseline synthesis interferometry", University of Sydney

Deacon, R., "Planetary nebulae - origin of morphology", University of Sydney

Deller, A., "Software correlation for advanced very long baseline interferometry, with applications in pulsar and extragalactic astrophysics", Swinburne University

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Godfrey, L., "Dynamics of large-scale extragalactic Jets: A multi-wavelength study of X-ray bright jets", Australian National University

Gurovich, S., "Investigating the Baryonic Tully-Fisher relationship", Australian National University

Hayman, D., "Densely packed focal plane arrays", Macquarie University

Hughes, A., "Molecular gas in the interstellar medium of the Large Magellanic Cloud", Swinburne University

Jackson, S., "Integrated systems for next generation telescopes", Macquarie University

Kern, K., "Galaxy groups and their evolution: What GEMS and LVHIS can tell us", Swinburne University

Klamer, I., "CO in high redshift galaxies", University of Sydney

Knight, H., "Baseband searching for millisecond pulsars", Swinburne University

Lenc, E., "Studies of radio galaxies, starburst galaxies, and gravitational lenses using wide-field, high spatial resolution radio imaging", Swinburne University

Leung, M., "The development of a new wideband feed for a cylindrical reflector", University of Sydney

Lewis, D., "Timing of young pulsars", University of Tasmania

Longmore, S., "Uncovering the top end of the initial mass function", University of NSW

Massardi, M., "Observations of the large-scale structure of the universe", SISSA/ISAS Trieste, Italy

Matthews, D., "High velocity clouds around the Galaxy", La Trobe University

McCallum, J., "A Study of $H_2O$ megamasers in AGN", University of Tasmania

Newton-McGee, K., "The magnetic universe", University of Sydney

O'Brien, J., "Probing the shape of dark halos of thin edge-on disk galaxies", RSAA, Australian National University

Safouris, V., "Environmental influence on the evolution of radio jets from AGN", RSAA, Australian National University

Senkbeil, C., "A study of the interstellar scintillation and intraday radio variability of active galactic nuclei", University of Tasmania

Verbiest, J., "High precision pulsar timing", Swinburne University

Vranesevic, N., "Galactic distribution and evolution of pulsars", University of Sydney

Waugh, M., "Galaxy populations, dynamics and evolution of the Fornax Cluster", University of Melbourne

Wong, O.I., "Neutral hydrogen in galaxy cluster environments", University of Melbourne

You, X., "Pulsar timing studies", Chinese Academy of Sciences (NAOC)

Young, M., "An investigation of pulsar dynamics using improved methods of time series analysis", University of Western Australia

# I: Abbreviations

| | |
|---|---|
| AARNET | Australia's Academic and Research Network |
| ACA | Australian Communications Authority |
| ACC | Antenna Control Computer |
| AGB | Asymptotic Giant Branch |
| ALFA | Arecibo L-band Feed Array |
| ALMA | Atacama Large Millimetre Array |
| APT | Asia-Pacific Telescope |
| ARC | Australian Research Council |
| ASKACC | Australian SKA Consortium Committee |
| ATCA | Australia Telescope Compact Array |
| ATNF | Australia Telescope National Facility |
| ATOA | Australia Telescope Online Archive |
| ATUC | Australia Telescope Users Committee |
| AUT | Auckland University of Technology |
| CABB | Compact Array Broadband |
| CIP | CSIRO Industrial Physics |
| CMOS | Complementary Metal Oxide Semiconductor |
| CO | Carbon Monoxide |
| CONASTA | Conference of the Australian Science Teachers Association |
| COSPAR | Committee on Space Research |
| CPSR | Caltech-Parkes-Swinburne Recorder |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DAS | Data Acquisition System |
| DEST | Department of Education, Science and Training |
| DFB | Digital Filter Bank |
| DSN | Deep Space Network |
| DWE | Doppler Wind Experiment |
| ESA | European Space Agency |
| FITS | Flexible Image Transport System |
| FPA | Focal Plane Array |
| FPGA | Field Programmable Gate Array |
| FTE | Full Time Equivalent |
| GASS | Galactic All Sky Survey |
| HEMT | High Electron Mobility Transistor |
| HI | Neutral Hydrogen |
| HIPASS | HI Parkes All Sky Survey |
| HVC | High-velocity Cloud |
| IAA | International Academy of Astronautics |
| IAU | International Astronomical Union |
| ICRF | International Celestial Reference Frame |
| ICT | Information and Communications Technology |
| IF | Intermediate Frequency |
| InP | Indium Phosphide |
| ISM | Interstellar Medium |
| ISPO | International SKA Project Office |
| 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 |
| JIVE | Joint Institute for VLBI in Europe |
| LBA | Long Baseline Array, used for Australian VLBI observations |
| LFD | Low Frequency Demonstrator |
| LMC | Large Magellanic Cloud |
| LNA | Low Noise Amplifier |
| LO | Local Oscillator |
| LVHIS | Local Volume HI Survey |
| MMIC | Monolithic Microwave Integrated Circuit |
| MNRF | Major National Research Facilities |
| MOPS | Mopra Spectrometer |
| MSP | Millisecond Pulsar |
| MSX | Midcourse Space Experiment |
| NASA | National Aeronautics and Space Administration |
| NTD | New Technology Demonstrator |
| OHS | Occupational Health & Safety |
| OPAL | Online Proposal Applications and Links |
| OSI | Office of Science and Innovation (WA) |
| OTF | On The Fly |
| PCB | Printed Circuit Board |
| PMPS | Parkes Multibeam Pulsar Survey |
| POCS | Proof-of-Concept Spectrometer |
| RAFCAP | Radio Astronomy Frequency Committee in the Asia Pacific Region |
| RFI | Radio Frequency Interference |
| RRAT | Rotating Radio Transient |
| RQZ | Radio Quiet Zone |
| RVS | Remote Visualisation Server |
| SIS | Semiconductor-Insulator-Semiconductor |
| SKA | Square Kilometre Array |
| SMC | Small Magellanic Cloud |
| TAC | Time Assignment Committee |
| UPS | Uninterruptible Power Supply |
| URSI | International Union of Radio Science |
| VLA | Very Large Array (US) |
| VLBI | Very Long Baseline Interferometry |
| VLT | Very Large Telescope (Chile) |
| VO | Virtual Observatory |
| WBC | Wideband Correlator |
| WCS | World Coordinate System |
| WRC | World Radiocommunication Conference |
| xNTD | Extended New Technology Demonstrator |
| ZOA | Zone of Avoidance |

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