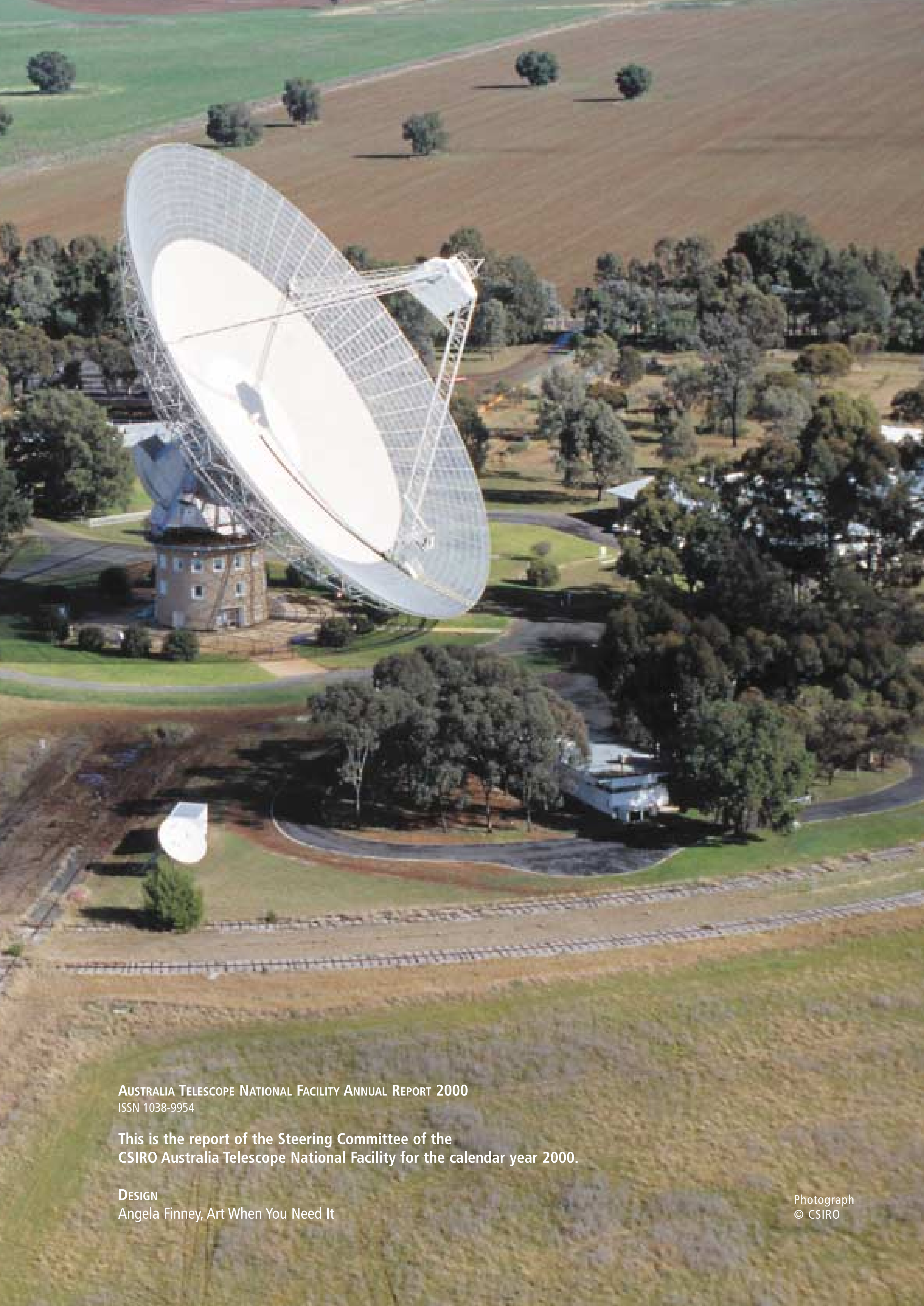
Annual Report 2000



Australia Telescope National Facility Annual Report 2000
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This is the report of the Steering Committee of the CSIRO Australia Telescope National Facility for the calendar year 2000.

Design
Angela Finney, Art When You Need It

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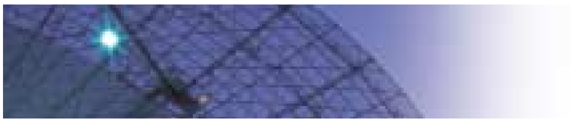
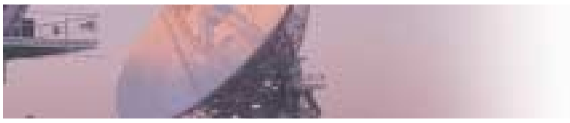
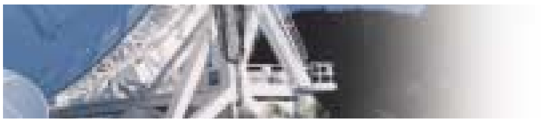
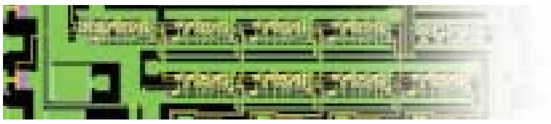








Overview

Science highlights in brief

First millimetre light for upgraded Australia Telescope page 16

After three years of designing, building and testing, first light at millimetre wavelengths for the upgraded Australia Telescope Compact Array occurred on 30 November 2000. Two of the six antennas were fitted with the new 3-mm receiving systems and were used to observe silicon monoxide maser emission from the Orion nebula.

Massive proto-planetary disks detected at radio wavelengths page 18

Observations taken with the Australia Telescope Compact Array reveal the presence of three sources in the starburst cluster NGC 3603, identified as proto-planetary disks on images from the Hubble Space Telescope and the ESO Very Large Telescope. The radio sources are 20–30 times larger than their counterparts in the Orion nebula and are much brighter than expected.

New discoveries of millisecond pulsars in globular clusters page 20

Globular clusters are a rich source of millisecond pulsars. These are compact neutron stars in binary systems that have been “spun up” by mass accretion from the companion stars. In a study of 60 globular clusters, ten new millisecond pulsars have been discovered in four clusters which were not previously known to contain pulsars. The new discoveries were made from sensitive observations taken with the Parkes radio telescope.

A very young pulsar discovered in the Parkes Multibeam Pulsar Survey page 24

In the past four years, the Parkes radio telescope and its multibeam receiver have been used to scan the Milky Way for pulsars. The Parkes survey has nearly doubled the number of known pulsars. Among the discoveries is the pulsar J1119-6127 which rotates just over twice per second. Its spin parameters show that it is only 1,600 years old, making it the fourth youngest pulsar known in the Milky Way. Observations taken with the Australia Telescope Compact Array show that the pulsar is at the centre of a previously uncatalogued supernova remnant.

A new test for general relativity page 26

A team of Australian and US astronomers have used the Parkes radio telescope to measure the distortion of space-time near a star 140 parsecs from Earth, confirming a prediction of Einstein’s general theory of relativity. They measured the arrival times of the pulses received on Earth from the bright millisecond pulsar, PSR J0437-4715, to within a tenth of a millionth of a second.

The HI environment of superbubbles in the Large Magellanic Cloud page 28

One of the most important processes that drives the evolution of galaxies is the injection of energy into the interstellar medium from the winds and supernova explosions of massive stars. In starburst


Photograph © CSIRO


Photograph © S Amy

Overview

regions, groups of massive stars may blow "superbubbles" of hot ionized gas which extend over large distances. A team of researchers has used the Australia Telescope Compact Array to study the neutral hydrogen environment around three young superbubbles in the Large Magellanic Cloud. They find that while the ionized gas shells are similar for the three regions, the neutral hydrogen distributions are strikingly different.

The HIPASS Bright Galaxy Survey

page 30

The HI Parkes All-Sky Survey has provided the first ever survey of extragalactic neutral hydrogen over the southern sky. The survey was completed in March 2000 and the data were released in May 2000. One of the first survey products is the HIPASS Bright Galaxy Catalogue, a catalogue of the 1,000 brightest HI galaxies in the southern hemisphere.

HIPASS turns up new gas in the NGC 2442 group

page 32

The HI Parkes All Sky Survey has revealed a huge cloud of neutral hydrogen gas, near the bright spiral galaxy NGC 2442. The gas cloud, designated J0731-69, contains a thousand-million solar masses of hydrogen but shows no evidence for any stars or star formation activity. The cloud may have been torn out of NGC 2442 during a tidal interaction with another galaxy.

Recurrent activity in giant radio galaxies

page 34

Giant radio galaxies have linear sizes of millions of light years. Observations taken with the Australia Telescope Compact Array for the giant radio galaxy B0114-476 reveal a "double-double" structure with two outer diffuse lobes and two inner jet-like features. Such a structure suggests that the galaxy may experience recurrent nuclear activity.

The gaseous halos of three spiral galaxies

page 36

Observations of three southern edge-on spiral galaxies, taken with the Australia Telescope Compact Array, show that the galaxies have extended gaseous halos. The radio emission occurs from relativistic electrons which are released during multiple supernova explosions. The radio data provide new insights into the star formation history of the observed galaxies.

Technology highlights in brief

MNRF Upgrades

First results at 3 mm

page 16

A major milestone was reached in November 2000 with the first 3-mm observations of the upgraded Australia Telescope Compact Array, taken using two antennas. The success of the millimetre observations highlights the excellence of the MNRF engineering.

Australia Telescope Compact Array local oscillator distribution

page 62

Almost all of the optical fibres for the local oscillator distribution network have been

laid between the Control Room and the antenna station posts.

Extra stations and the north spur page 63

Civil engineering works associated with four new stations on the east-west track and five new stations on the north spur of the Australia Telescope Compact Array were completed in 2000.

MMICS page 64

Monolithic microwave integrated circuits (MMICs) are an essential component of the high-frequency receiver upgrades. After bonding and packaging, 3-mm and 12-mm indium phosphide MMICs were retrofitted to two prototype receivers on the Australia Telescope Compact Array. Both the system temperatures and bandwidths achieved were outstanding.

High-speed two-bit sampler page 64

Considerable progress was made with the development of a high-speed two-bit digitiser using indium phosphide heterojunction bipolar transistor (InP HBT) technology. This is designed to sample astronomical signals at up to eight Gigabits per second.

InP HBT technology was also used to develop a digitiser with integrated photo-receiver circuits which allow the digitiser's output to be passed to optical fibres via externally bonded laser diodes.

The Square Kilometre Array

Antennas for the SKA page 67

Work continued on assessing the feasibility of using spherical refracting antennas (Luneburg lenses) for the Square Kilometre Array.

Interference Mitigation page 67

The ATNF has developed successful new techniques for the removal of interference signals from correlated radio astronomy data.

SKA site testing page 69

Work has continued to identify possible sites for the SKA in Australia and the feasibility of establishing a radio-quiet reserve.

The ATNF in Brief

The Australia Telescope National Facility (ATNF) supports Australia's research in radio astronomy, one of the major fields of modern astronomy, by operating the Australia Telescope, a set of eight individual radio telescopes.

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.

Overview

Size and funding

The ATNF employs 135 staff. In 1999–2000 the organization's total funding was \$16.64M, of which \$12.23M was direct appropriation from CSIRO.

Status within CSIRO

The Australia Telescope National Facility 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. The Australia Telescope Steering Committee, appointed by the Minister for Science to advise the ATNF Director, also acts as the Advisory Committee for CSIRO's Radio Astronomy Sector.

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. More than 80% of the telescopes' users come from outside ATNF.

In 2000 the telescopes were used by:

- 38 researchers from the ATNF;
- 77 researchers from 16 other Australian institutions; and
- 243 researchers from 98 institutions in 23 overseas countries.

The ATNF in the Australian context

The ATNF is the largest single astronomical institution in Australia. Ninety per cent of Australian radio astronomy is carried out through the ATNF. The organization 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 organizations.

The ATNF in the global context

Of the fields of modern astronomy—X-ray, ultraviolet, optical, infrared and radio, Australia's most important contribution to the global practice of astronomy is 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

Photograph
© CSIRO

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 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 astronomers to use telescopes in other countries and international facilities such as space-based instruments. 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 (ATCA), 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; they can be moved to different points along the track to build up detailed images of the sky. A sixth antenna lies three kilometres to the west of the main group. Each of these antennas has a reflecting surface 22 m 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 of the object being studied—a picture equivalent to a photograph, but made from radio waves instead of light.

A further 22-m antenna, known as the Mopra telescope, is located near Mopra rock, in the Warrambungle 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. Recent upgrades to accommodate a 13-beam focal-plane array have maintained its world-class position as a state-of-the-art instrument.

The eight ATNF telescopes can be used together as a 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 Long Baseline Array is used as part of an Australian network of radio telescopes which includes the NASA satellite tracking antennas at Tidbinbilla, near Canberra, and radio antennas in Tasmania, South Australia and West Australia. The LBA is also regularly used as part of the Asia-Pacific Telescope which links radio telescopes in Australia, Japan, China, South Africa, Hawaii and India, and the VLBI space observatory program (VSOP).

Overview

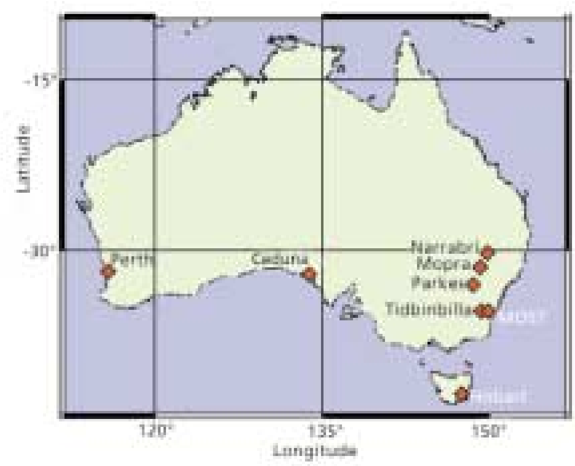


***Figure 1** VLBI telescopes in Australia*

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.

ATNF Steering Committee

ATNF policy is determined by the ATNF Steering Committee, an independent committee appointed by the Minister for Science and Technology. The Committee helps CSIRO to develop the ATNF's long-term strategy. 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 ATNF's host organization, CSIRO, is composed of business units called Divisions; the ATNF has the status of a Division. These Divisions are grouped into 22 research sectors. The ATNF is the sole member of the Radio Astronomy Sector, and the ATNF Steering Committee acts as the CSIRO Sectoral Advisory Committee for radio astronomy.

The Steering Committee appoints an Australia Telescope Users Committee (ATUC) to provide feedback and advice from the user community, and a Time Assignment Committee (TAC) to review proposals and allocate observing time. The committee memberships for the year 2000 are listed in Appendix C.

Australia Telescope Users Committee

The Australia Telescope Users Committee (ATUC) represents the interests of the Australia Telescope's users. In 2000 it consisted of a total of 19 scientists, drawn from eleven institutions. This committee provides feedback to the ATNF Director, discussing problems with, and suggesting changes to, AT operations; it also discusses and ranks by scientific merit various future development projects. As well, ATUC meetings are a forum for informing AT users of the current status and planned development of ATNF facilities, and recent scientific results. ATUC discussions can be found on the Web at
http://www.atnf.csiro.au/overview/atuc.

Members of the ATNF Steering Committee in March 2000. From left to right: Prof P. McCulloch, Dr D. Cooper, Prof K. Menten, Dr E. Sadler, Dr P. Scaife, Prof B. Boyle, Prof J. Storey, Prof K. Lo, Prof P. Goldsmith, Prof R. Ekers, Dr R. Sandland and Prof R. Cannon.

Overview

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 Time Assignment Committee (TAC). The TAC meets three times a year and reviews approximately 90 telescope applications at each meeting.

Strategic objectives

The ATNF is one of the world's leading radio astronomy organizations. The strategic objectives for the ATNF are:

- To continue to operate the Australia Telescope in such a way as to maintain a leading international position

  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%.

- To upgrade the Australia Telescope to maintain its competitiveness in the medium term (3–8 years)

  The Narrabri and Mopra telescopes are now being upgraded, under the Major National Research Facilities (MNRF) Program, to work at shorter (millimetre) wavelengths. The upgraded telescopes will use innovative devices for the detection of extremely weak millimetre-wave signals from space. These are being jointly designed by the ATNF and CSIRO Telecommunications and Industrial Physics, a project funded by the CSIRO Executive Special Project. The MNRF upgrade will also extend the Australian network of telescopes used for very long baseline interferometry (VLBI), which has both astronomical and geodetic applications. The MNRF upgrades will be completed in 2002.

- To position the ATNF to participate in major international radio astronomy projects developing over the next decade

  The MNRF upgrade will allow the ATNF to maintain a leading position for the next eight to ten years. Beyond that, radio astronomy will be dominated by two major international developments: the Atacama Large Millimeter Array (ALMA) and the Square Kilometre Array (SKA). These instruments will allow astronomers to pursue key questions about the early evolution of the Universe. For Australia to maintain its position in

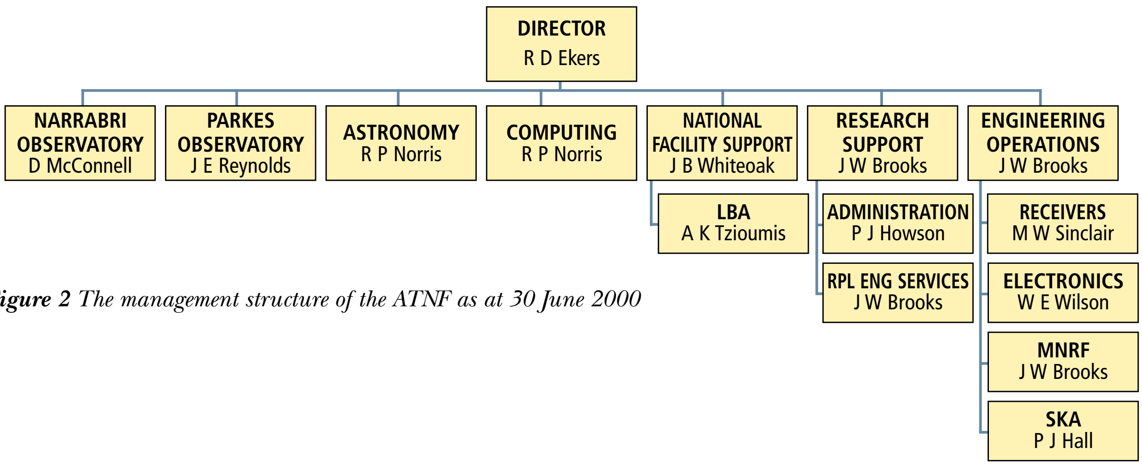


Figure 2 *The management structure of the ATNF as at 30 June 2000*

radio astronomy, it needs to have a significant role in at least one of these projects. The SKA is a billion-dollar project, the "next generation" radio telescope with a collecting area of one square kilometre. Its construction is expected to start in around 2010. Australia is well positioned to play a key role in the development of the SKA. In some respects Australia offers an ideal location for the SKA as it has a number of regions of low population density which are relatively free from radio interference. The technology development required for the SKA will have wide industrial applications and the construction will involve significant industrial contracts.

A preliminary research development program for the SKA, funded by CSIRO, was initiated in 1999.

- To conduct an effective outreach program

  The ATNF operates Visitors Centres at the sites of the Parkes and Paul Wild Observatories and has an active public outreach program which has several goals: to raise the national profile of astronomy and related technology in Australia; to encourage the next generation of scientists by providing educational resources targeted at high school students and their teachers; and to maintain good community relationships.

Photograph © CSIRO

Performance indicators

The ATNF assesses its performance through Key Performance Indicators, based on those used generally by CSIRO but adapted to be appropriate for a National Facility. Wherever possible, the ATNF benchmarks its performance against best international practice.

Unless otherwise noted, figures are for calendar year 2000.

1 Scheduled and successfully completed observing time

For the Parkes and Narrabri observatories, the ATNF sets a target that at least 70% of the time available should be allocated for astronomical observations. (The remaining 30% is needed for maintenance and upgrading the facilities.) A second target is that the time lost during scheduled observations, from equipment failure, should be below 5%.

The following values show the use of time for the year 2000:

	ATCA	Parkes
Time used for scheduled observations	76.3%	82.3%
Downtime during scheduled observations	4.9%	2.4%
Percentage of scheduled observations successfully completed	92.3%	97.1%

The downtime for the Parkes telescope includes time lost for wind stows (1.4%).

In 2000 the downtime during scheduled observations at the Australia Telescope Compact Array was higher than for the previous few years. This was largely due to a failed drive on antenna 2 and an electrical burnout on antenna 6.

The telescope most comparable with the ATCA is the Very Large Array (VLA) in the USA. The percentages of scheduled observations successfully completed are very similar for the ATCA and the VLA.

Further breakdowns of time use for Narrabri and Parkes can be found in the Observatory Reports (pages 50 and 56).

2 Response of the ATNF to recommendations by the Users Committee

The ATNF Users Committee (ATUC) 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 sets priorities for future developments.

Over the last four years, approximately three quarters of ATUC recommendations have been followed up by the ATNF.

3 Adoption by users and organizations of practices, instruments and processes developed by CSIRO

This list includes some of the hardware and software developments at the ATNF which are now in use at other organizations:

Antenna holography developed at the ATNF is used routinely in external industry and defence contracts.

Karma visualization software developed

Photograph
© S Amy

Performance indicators

at ATNF is now used by more than 30 astronomical institutions.

Miriad data reduction software, jointly written at the ATNF and BIMA, is in routine use at radio astronomy institutions around the world.

ATNF digital correlator hardware and control software are in use at the Tidbinbilla, Hobart, SEST, Ceduna, Hartebeesthoek and Jodrell Bank observatories.

Multibeam observing techniques and data management systems developed for the Parkes Observatory have been adopted by Jodrell Bank (UK).

Components of aips++ software, including visualization routines and fundamental measures, written at ATNF, are being used by several institutions including the Herzberg Institute for Astrophysics (Canada), Jodrell Bank and the Joint Institute for VLBI in Europe (JIVE).

A correlator, built at the ATNF for the Swedish ESO Submillimetre Telescope (SEST) was delivered in March 2000.

ATNF staff provided scientific and technical support for the Taiwanese AMiBA project in three ways: as consultants for the receiver construction and MMIC development; the construction of a prototype wide-band correlator; and providing support for system specifications, observing strategies, science and data-reduction issues.

4 Time allocation on ATNF facilities

In 2000 a total of 168 proposals were allocated time on ATNF facilities (each proposal is counted once only per calendar year although some proposals are submitted two or three times). Of these, 112 were for the Australia Telescope Compact Array, 36 were for the Parkes telescope, 10 were for the Mopra telescope and 10 were for the Long Baseline Array. Figures 3 and 4 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.

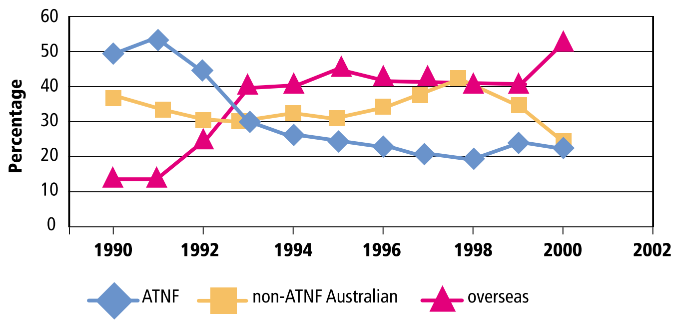


Figure 3 *Compact Array time allocation, 1990–2000*

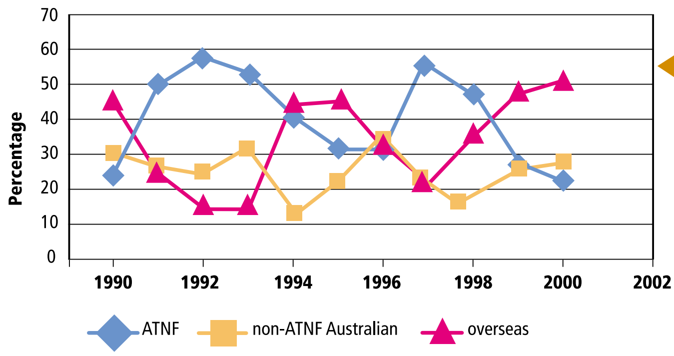
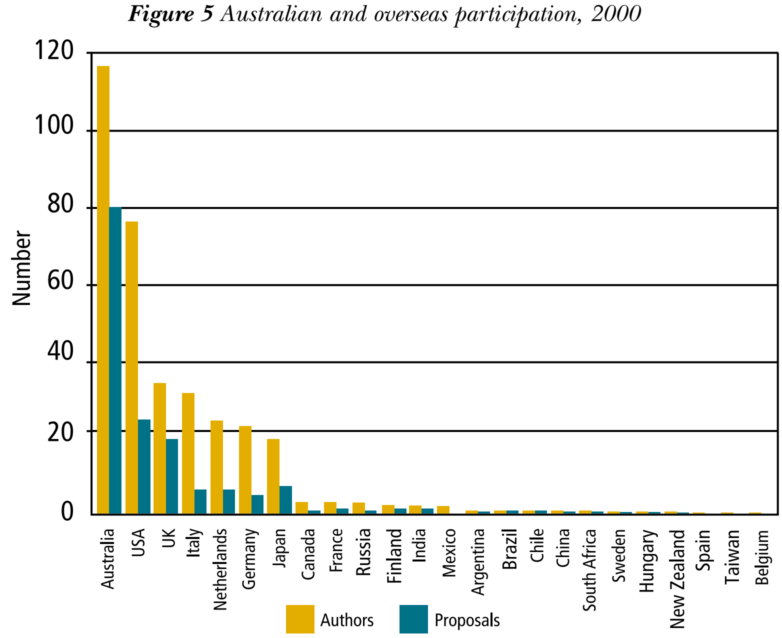


Figure 4 *Parkes time allocation, 1990–2000*

Allocation of time on the ATNF facilities is done on the basis of scientific merit. The ATNF has a guideline that at least 60% of allocated time should be used by astronomers at the ATNF and other Australian institutions, with up to 40% for astronomers at overseas institutions. For the years 1993 to 1999 this was close to the actual allocation of observing time on the Compact Array. In the year 2000 however, the percentage of time allocated to overseas observers increased to over 50%. The strong performance of overseas users of the Australia Telescope facilities is also reflected in a large number of publications by overseas authors. For the Parkes telescope the time allocation is more variable. For the years 1993 to 2000 the time allocated to overseas observers has varied between 15 and 50%.

In 2000 the proposals allocated time on ATNF facilities included a total of 358 different authors. Of these 38 authors were from the ATNF, 77 were from 16 other Australian institutions and 243 were from 98 overseas institutions in 23 countries. Figure 5 shows the number of proposals (counted using the team leaders) and the total number of authors from each country.

Figure 5 Australian and overseas participation, 2000



5 Number of publications

Figure 6 shows the number of publications in journals and conference proceedings, 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. Appendix F (page 89) lists the 106 papers published in refereed journals and the 75 papers published in conference proceedings in 2000.

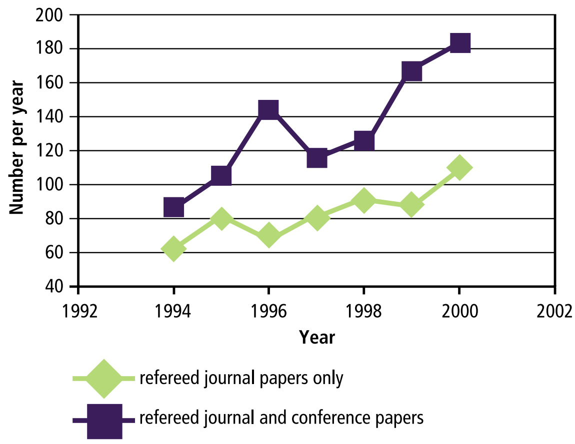


Figure 6 *Papers from data obtained with the Australia Telescope, published in refereed journals and conference proceedings.*

6 Teaching, measured by the number of postgraduates supervised by ATNF staff

In December 2000 the ATNF was co-supervising 18 students from eight universities in Australia and six students from overseas institutions (Appendix G). Of the 24 students 18 were PhD students and six were Masters degree students.

Performance indicators

7 Public communication, measured by the number of media appearances and talks to schools and community groups

In 2000 the media coverage of the ATNF was dominated by reports on the Parkes telescope, following the release of the film *The Dish* in October 2000. During the year the ATNF issued eight media releases (Appendix E). The organization, its staff or research activities, featured in at least 100 press items. ATNF staff gave approximately 25 television interviews and 50 radio interviews while at least 60 talks were given to school, university and community groups.

The counts shown in Figure 7 have been verified where possible. However, the numbers for media reports (TV, radio, newspapers) for all years and the number of public talks given by ATNF staff in 1996 to 1998 are likely to have been undercounted.

Figure 7 also shows the number of Web hits to the central ATNF web site. The counts include internal use by staff and hits generated by external search engines. In the year 2000, the total number of Web hits was 6.7 million, approximately 10 times more than in 1996.

8 User feedback at Narrabri and Parkes

Observers at the Parkes and Narrabri observatories are asked to complete a User Feedback questionnaire. The responses from these are given in the Observatory Reports. These show that the level of satisfaction with facilities provided is generally very high (see pages 51 and 56). For the year 2000 the average over all items ranked was 91% for the Narrabri Observatory and 88% for the Parkes Observatory.

9 ATNF engineering milestones

A performance indicator introduced by the Steering Committee, to gauge instrumentation development, is given by the planned and actual capital costs and timescales for engineering projects. These are given in Appendix H. Typically, projects undertaken by the ATNF take around 30% longer to complete than predicted and cost about 30% more than originally estimated. Such over-runs may be inevitable when dealing with innovative technologies. Further development of this indicator is planned, to establish its usefulness and to compare the ATNF performance with best practice elsewhere.

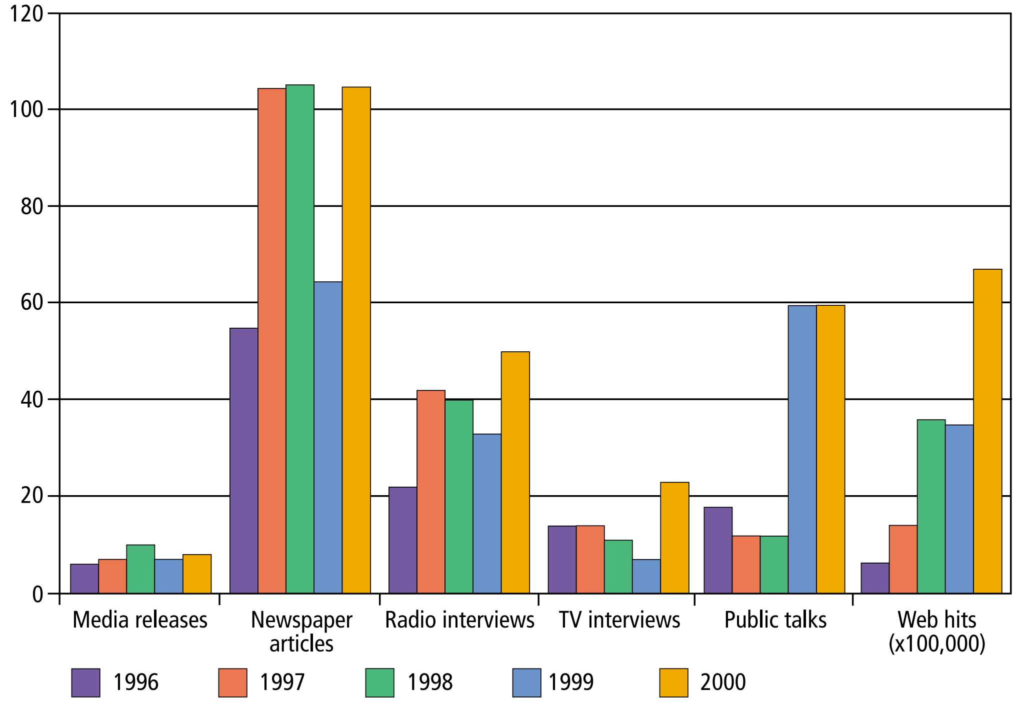


Figure 7 ATNF Public Relations activities for the years 1996 to 2000

First millimetre light for upgraded Australia Telescope

First light at millimetre wavelengths for the upgraded Australia Telescope Compact Array occurred in November 2000, with a 3-mm observation of silicon monoxide maser emission from the Orion nebula.

On Thursday 30 November 2000, three years of designing, building, and testing for the Narrabri and Sydney engineering groups came to a climax at the Compact Array when two of the six dishes were fitted with the new 3-mm receiving systems and trained on a star-forming region within the Orion nebula containing silicon monoxide (SiO) masers. At 11.45 p.m. the telescope captured its first cosmic millimetre-wave photons, achieving "first light". Figure 8 shows the cross-power spectrum resulting from these first observations, at a frequency of 86.243 GHz. The millimetre photons from this source are produced by excited SiO molecules embedded within the star-forming clouds.

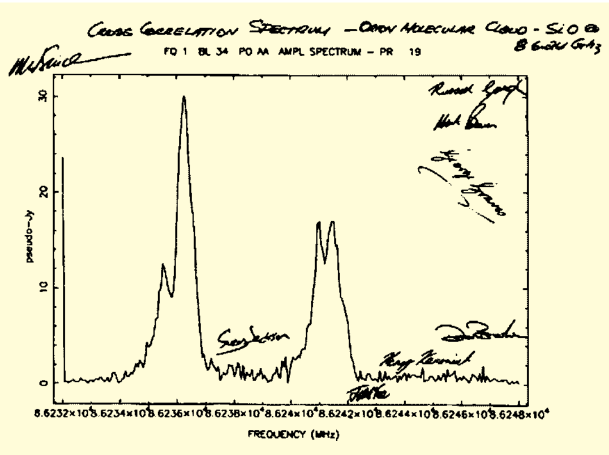


Figure 8 *"First light" – the Australia Telescope's first observation as an interferometer working in the 3-mm band with a single 31-m baseline, between antennas 3 and 4. The spectrum shows the SiO maser emission at 86.24 GHz from a star-forming region in the Orion nebula. The integration time was several minutes. No calibration has been applied.*

A project science team is now using the Compact Array in its 3-mm observing mode, looking at a variety of astronomical sources and investigating the performance of the system. Some of the first observations were of the SiO maser emission from the circumstellar envelopes of the evolved stars VX Sgr, R Dor, and R Aqr. The strong SiO emission from these stars can be detected easily in a single 10-second integration time. The team also observed HCO^+ absorption against the nuclear continuum source in the radio galaxy Centaurus A (Figure 9). Initial results are available on the Web at http://www.atnf.csiro.au/mnrf/3mm_details.html.

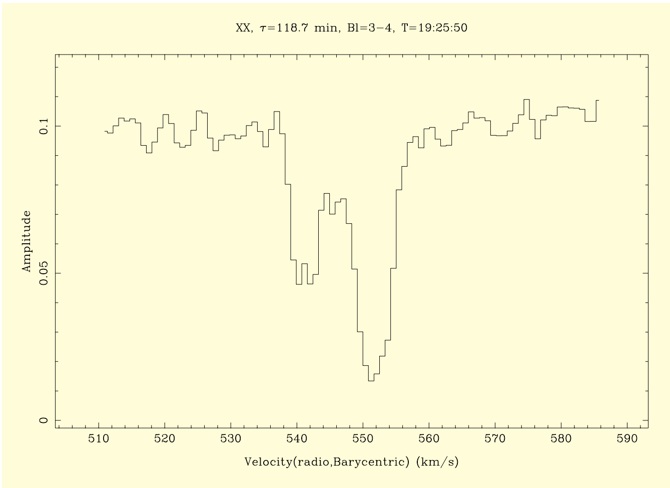


Figure 9 *This spectrum obtained with a single 31-m baseline shows HCO^+ absorption seen against the nucleus of the galaxy Centaurus A. A preliminary bandpass calibration has been applied and the spectrum is Hanning smoothed. The spectrum is centred on the velocity of the galaxy, at 552 km s^{-1}, where the strongest HCO^+ absorption occurs and also shows two narrower absorption features near 540 km s^{-1}. The velocity range shown does not include all of the absorption features known for Centaurus A.*

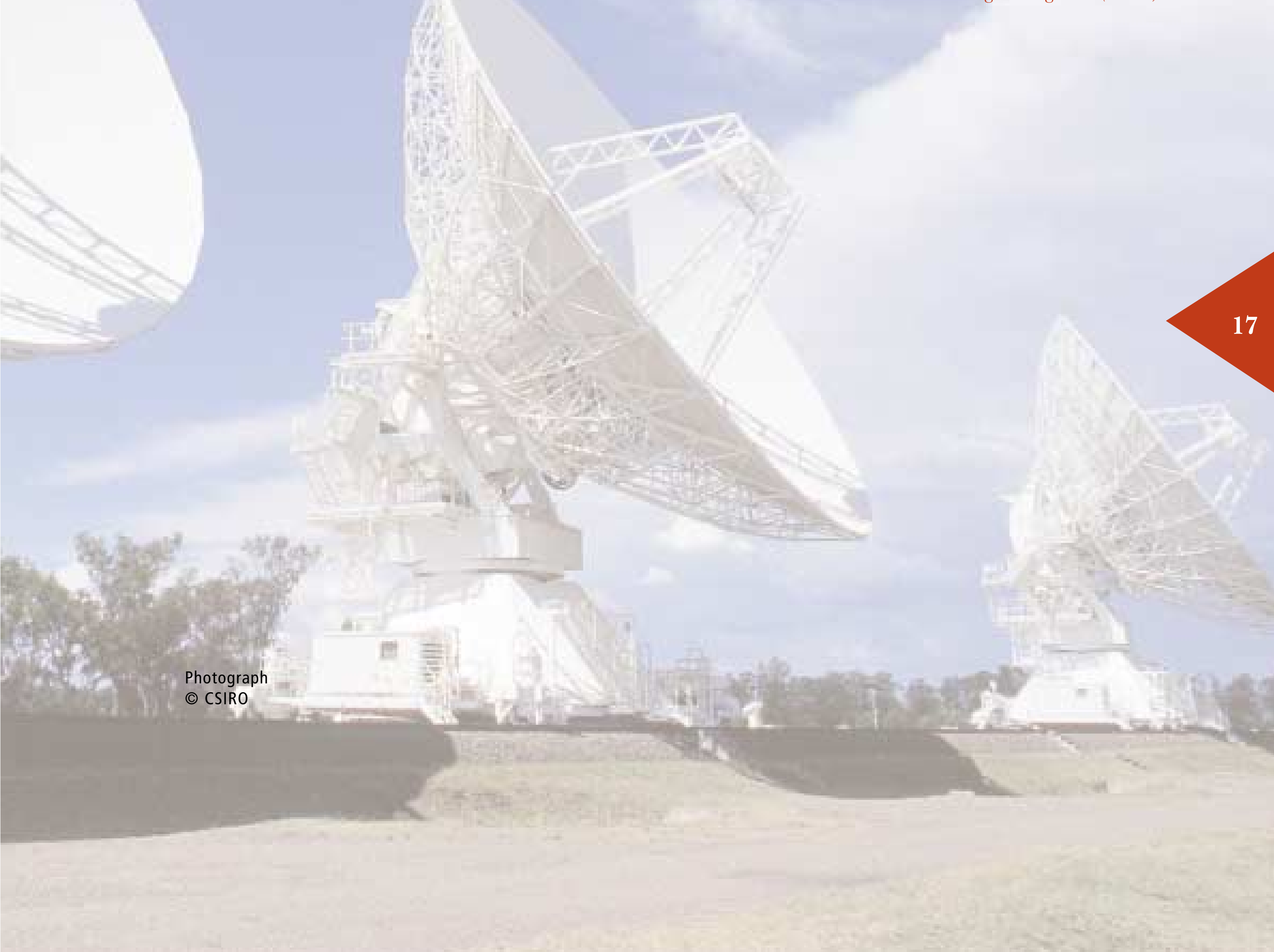
Science highlights

The prototype 3-mm receiving systems, installed on two of the Australia Telescope's six dishes, cover the frequency range 84–91 GHz. This current system will progressively be upgraded to the full array of six antennas with receivers covering a frequency range from 84 GHz to around 115 GHz. Routine millimetre observing is expected to start in mid-2003. In the meantime millimetre testing is under way whenever there is gap in the regular observing schedule.

At the heart of the new millimetre receivers are indium phosphide MMIC chips (page 64), cooled to -253° C, the product of a joint effort between the Australia Telescope National Facility (ATNF) and the CSIRO Division of Telecommunications and Industrial Physics (formerly the CSIRO Division of Radiophysics) under a special program established by former CSIRO Chief Executive Malcolm McIntosh to develop millimetre-wave integrated circuits for radio astronomy and telecommunications.

The upgrading of the Australia Telescope to work at millimetre wavelengths is funded by the Australian Federal Government under its Major National Research Facilities (MNRF) Program, and by CSIRO. More information on the MNRF projects is available on the Web at http://www.atnf.csiro.au/mnrf/mnrf_outline.html.

B. Koribalski and the MNRF science and engineering team (ATNF)



Photograph
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Massive proto-planetary disks detected at radio wavelengths

The giant HII region NGC 3603, located at a distance of about 20,000 light-years in the southern constellation of Carina, contains the Galaxy's most massive visible starburst region. The region has a large complex of molecular clouds and a dense concentration of massive stars in an early stage of evolution. The star cluster contains three Wolf-Rayet stars and around 70 O-type stars, of which an estimated 40–50 are located in a central region of approximately 13 x 13 arcseconds. These highly massive stars, which will eventually explode as supernovae, have an ionizing power about 100 times larger than that of the well-known Trapezium cluster in Orion.

Radio observations provide a means of detecting the individual stellar winds of some of the Galaxy's most luminous, massive hot stars located in the heart of NGC 3603. To study these stars, we obtained 12-hour observations at 3 and 6 cm with each of the 6-km configurations of the Australia Telescope Compact Array, giving a resolution of 1–2 arcseconds, high sensitivity and high dynamic range. This unique data set presents the first complete multifrequency study of this 2–3 million-year-old star-forming region.

The radio data reveal the presence of three sources recently identified as proto-planetary disks (ProPlyDs) on images from the Hubble Space Telescope and ESO Very Large Telescope (see Brandner et al. 2000, AJ 119, 292). The ProPlyDs are located 1–2 parsecs away from the stellar cluster core and roughly form a straight line from northwest to southeast. The radio images show cometary shapes, with a bright head and a faint tail consisting of diluted gas which points away from the cluster centre. These tear-shaped structures are probably formed by the influence of the radiation pressure and strong winds from the massive stars (Figures 10 and 11). Similar structures are also seen in the optical and infrared images of the ProPlyDs.

The ProPlyDs in NGC 3603 are several arcseconds in extent and are 20–30 times larger than their counterparts in Orion. Their radio flux densities are 10–20 times larger than expected, and are stronger towards longer wavelengths. This is a completely unexpected behaviour for these young objects, which are thought to emit optically-thin thermal radio emission. The spectral behaviour suggests optically-thin non-thermal (gyro-)synchrotron emission as the origin of the radiation, indicating that magnetic processes may be important in these ProPlyDs.

The "standard" ProPlyD model consists of a star, embedded in a neutral envelope which is surrounded by ionized material. Within the neutral material a circumstellar disk is presumed to exist and this plays a central role in the formation of stars and planets from interstellar matter. The circumstellar disks serve as a reservoir for accretion of matter and are responsible for angular momentum transport from the central star and the build-up of planetesimals. Such disks are expected to be photo-evaporated by external ultraviolet radiation from a massive star or star cluster. Bow shocks form in the vicinity of the ProPlyDs from an interaction between the evaporating ProPlyD gas and the winds from other massive stars. So far, no disks have been seen in the NGC 3603 ProPlyDs.

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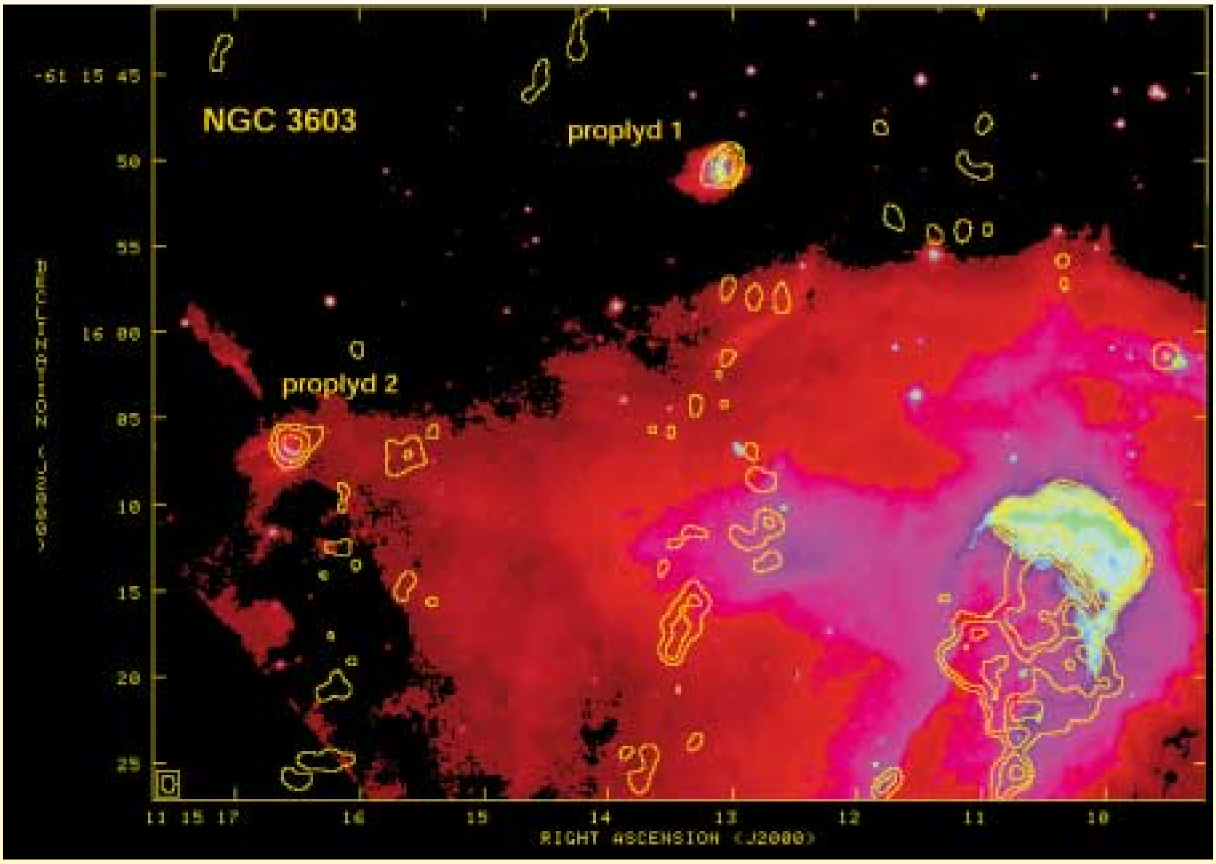

Figure 10 *Compact Array image showing the 3-cm radio continuum emission from the massive HII region NGC 3603 (contours) overlaid on a Hubble Space Telescope image by Brandner et al. (2000). Two of the three ProPlyDs are clearly visible to the north and east. The third ProPlyD is located to the northwest, outside this image. The brightest optical and radio emission is associated with giant gaseous pillars. North is to the top and east is to the left.*

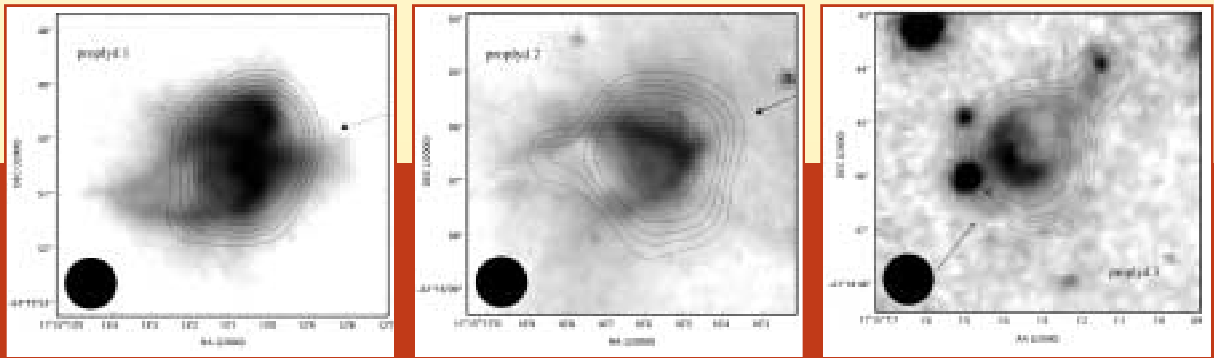

Figure 11 Compact Array images of the 3-cm radio continuum emission (contours) from the three NGC 3603 ProPlyDs overlaid on Hubble Space Telescope images of the ProPlyDs. The arrows indicate the ProPlyD ionization fronts resulting from the winds of the central star cluster.

New discoveries of millisecond pulsars in globular clusters

Globular clusters are a rich source of millisecond pulsars (MSPs). Exchange interactions in the core result in the formation of binary systems containing a neutron star which subsequently evolve, spinning up the neutron star through mass accretion. The MSPs formed in this way are among the most stable clocks in nature and are valuable for studies of the dynamics of clusters and the evolution of binaries embedded in them. However, they are quite difficult to find because the emission is weak and distorted by propagation through the interstellar medium, and the apparent pulse period may change rapidly because of binary motion.

About half of the 33 pulsars known in the Galactic globular clusters in 1994 were discovered at Parkes. From that time until recently, there have been no further discoveries of MSPs in globular clusters. With the advent of the new Parkes 20-cm receiver, we decided to mount a new attack on the globular clusters and attempt to break the long hiatus in such discoveries.

Extensive observations of the relatively nearby cluster 47 Tucanae, already known to be a rich storehouse of MSPs, resulted in the discovery of nine further MSPs, taking the total known in this cluster to 20, nearly a quarter of all MSPs known! Finding pulsars in more distant clusters for which there is no previous detection is more difficult.

In order to improve our search capability, we are using a new filterbank system built at Jodrell Bank and Bologna. This filterbank gives 512 x 0.5 MHz filter channels for each of the two polarizations making possible more effective removal of interstellar dispersion. It allows the detection of MSPs with dispersion measures of more than 200 cm^{-3} pc. The combination of this new equipment with the relatively high frequency of the multibeam receiver and its excellent sensitivity gives a unique opportunity to probe distant clusters.

Because globular clusters are known to contain binary MSPs with short orbital periods, we have implemented a new multi-dimensional code to search over a range of accelerations resulting from binary motion, in addition to the standard search over a range of dispersion measures requires huge computing resources. In Bologna, the new code runs on a local cluster of Alpha-500MHz processors and on the Cray-T3E 256-processor system at the CINECA Supercomputing Center. Data management and storage in this new experiment is also a non-trivial issue. A typical integration of 2.3 hours on a single target produces four Gbytes of data. But the results achieved so far amply justify the effort.

We have selected a sample of about 60 clusters, based on their central concentration and distance, and have so far discovered ten new MSPs in four

Photograph

clusters which were not previously known to contain pulsars.

The first interesting case is NGC 6752 (Figure 12). This cluster is believed to have a collapsed core and was already known to possess a large proportion of binary systems and several dim X-ray sources suggesting that MSPs are likely to be formed in its core. In this cluster we first discovered a 3.26 millisecond pulsar, PSR J1910-59A, in a binary system with an orbital period of 21 hours. This pulsar was first seen in four consecutive data sets of length 2,100 seconds, showing a significant acceleration (~ -2.2 m s^{-2}) on each data set. A characteristic of this pulsar is that, because of the relatively low dispersion measure (34 cm^{-3} pc), it scintillates markedly, similar to the pulsars in 47 Tucanae, and so it is seen rarely. But, as we have already experienced with 47 Tucanae, the amplification due to scintillation might occasionally help in the detection of additional rather weak MSPs in the same cluster. By devoting a large amount of observing to this cluster, we have already found four additional MSPs. Even more interestingly, all of these four seem to be isolated. Such a large proportion of isolated/binaries (4/1) is not very common in globular clusters. It is possible that other hidden binaries might be present in this cluster.

Figure 12 *The globular cluster NGC 6752, now known to contain at least five millisecond pulsars. (Image from the Digital Sky Survey)*

Another interesting case is the MSP (so far the only one) discovered in NGC 6397. This cluster is close and has a very dense and probably collapsed core. It contains at least four X-ray sources which may be related to MSPs. Despite this, there was no known pulsar associated with NGC 6397 prior to this search. In this cluster we have found PSR J1740-53, a relatively weak pulsar with a spin period of 3.65 milliseconds and an orbital period of 1.35 days. This pulsar has been shown to be eclipsed for more than 40% of the orbital phase. Similar eclipses have been seen in other binary systems, for example, PSR B1957+20, PSR B1744-24A in the cluster Terzan 5 and PSR J2051-0827. However, all of these systems are very close binary systems with orbital periods of just a few hours and very light companions (minimum mass < 0.1 solar masses). In contrast, J1740-53 is in a rather wide binary orbit of period 1.35 days, and has a heavier companion, with a minimum mass of 0.18 solar masses. It seems unlikely that a wind of sufficient density to produce the observed eclipses could be driven off a degenerate companion. Follow-up observations of this pulsar will give insight into the eclipse mechanism in MSPs.

The third interesting case is represented by three millisecond binary pulsars found in another dense cluster, NGC 6266. The first one, PSR J1701-30A, has a pulse period of 5.24 milliseconds, an orbital period of 3.8 days, and the mass function gives a minimum companion mass of 0.19 solar masses. This system is typical of many low-mass binary pulsars, both associated with globular clusters and in the Galactic field. But the two other systems, PSR J1701-30B and PSR J1701-30C, belong to the class of short-period binaries. They have respectively a pulse period of 3.6 and 3.8 milliseconds and orbital periods of 3.8 and 5.2 hours. In particular, the detection of PSR J1701-30B was a challenge, because it shows acceleration peaks and significant acceleration derivatives.

The last, but not the least interesting, case is the ultra-short binary pulsar (and so far the only one) discovered in NGC 6544. This cluster is also one of the closest, densest and most concentrated globular clusters known. Although no X-ray sources are known in the cluster, a radio continuum source was discovered at its centre at the Very Large Array, but up to now, pulsar searches have been unsuccessful. PSR J1807-24 has a spin period of 3.06 milliseconds and is a relatively strong pulsar (Figure 13) with a mean flux density of 1.3 milliJansky. Follow-up observations made at Parkes and Jodrell Bank showed that it is binary, with an extremely short orbital period of 1.7 hours, the second shortest known. Even more interestingly, the projected semi-major axis of the orbit is tiny, only 12 light-milliseconds. The corresponding minimum companion mass is only 0.0089 solar masses or about 10 Jupiter masses.

We have proved that one of the key strategies in a search of the globular cluster system for MSPs, is to devote a large amount of observing to each target. MSPs in globular clusters are often difficult to detect: scintillation in clusters with low dispersion measures, abnormally long eclipses, and unfavourable orbital phases in the case of ultra-short binaries might easily prevent the detection during a single observation. On the other hand, the hidden systems are very often the most interesting ones.

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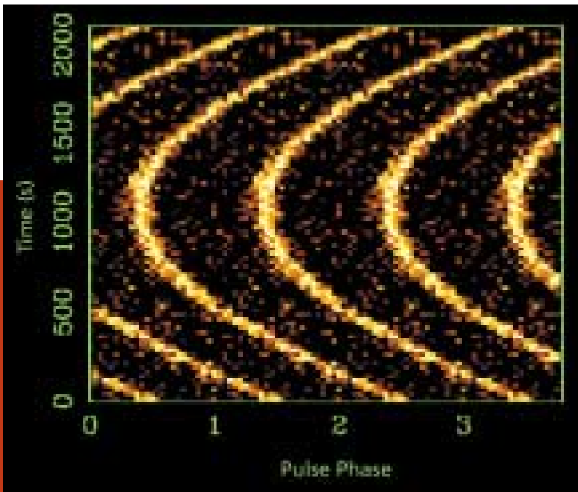

Figure 13 *Variation of observed pulse phase over the 2,100-seconds discovery observation for PSR J1807-24 in the cluster NGC 6544. Each horizontal line in the figure represents the mean pulse profile resulting from 16 seconds of data folded with a period of 3.059415 milliseconds. A pulsar with this apparent period would form a vertical trace in this diagram. The curvature shows that the apparent period varied significantly during the observation due to the pulsar's orbital motion. Although this pulsar is relatively strong (it was not detected in previous searches because of pulse smearing due to dispersion), weaker signals from such binary pulsars are difficult or impossible to detect with conventional "non-accelerated" search code.*

Science highlights

The Parkes radio telescope is the most successful telescope in the world at finding pulsars. Since the initial discovery of pulsars in 1967, over 850 pulsars have been discovered at Parkes. The pulsars can be divided into two main groups. The first group of "normal" pulsars have pulses which typically arrive once a second. The second group are known as the "millisecond pulsars". These stars rotate up to 600 times per second and represent a population of very old stars. These pulsars are believed to be "recycled" neutron stars which have been spun-up after accreting material from a binary companion star.

Photograph
© J Sarkissian

A very young pulsar discovered in the Parkes Multibeam Pulsar Survey

In the past four years, the Parkes telescope and its multibeam receiver have been used to scan the Milky Way for pulsars. Pulsars are ultra-dense rotating neutron stars that pack more mass than the Sun into a radius of a small city. The Parkes Multibeam Pulsar Survey has been phenomenally successful, nearly doubling the known population of these exotic objects.

Among the survey's booty is a pulsar that is among the very youngest known in our Galaxy. PSR J1119-6127 rotates just over twice per second, but is slowing down extremely rapidly owing to the tug of its enormous magnetic field. Its spin parameters can be used to deduce that it is only 1,600 years old, making it the fourth youngest pulsar known in the Milky Way. Young pulsars are exciting to find for a variety of reasons. The youngest of all are usually associated with gaseous nebulae, the result of the cataclysmic supernova explosion that formed them. These supernova remnants (SNRs) are interesting in their own right, teaching us about how the explosion energy is transferred into the surrounding regions of the Galaxy. In addition, young pulsars have a tendency to suddenly start rotating faster. This behavior is known as "glitching" and provides one of the few ways to learn about the interiors of neutron stars. Indeed, a small glitch of magnitude $\Delta P/P = -4.4 \times 10^{-9}$ was observed in the period of PSR J1119-6127 in August 1999. Finally, young pulsars often emit observable X-rays and gamma-rays. Such observations can be used to learn about how neutron stars cool off after their formation, as well as about pulsar emission mechanisms.

An associated supernova remnant

All known pulsars younger than 5,000 years are associated with supernova remnants. Although no supernova remnant was known at the position of PSR J1119-6127, we used the Australia Telescope Compact Array in the 13-cm and 20-cm bands to search for one. The resulting images clearly show a shell of emission of diameter 15 arcminutes centred on the pulsar (Figure 14). This shell shows all the hallmarks of being a previously uncatalogued supernova remnant and we designate it, from its Galactic coordinates, as SNR G292.2-0.5. The estimated ages of the supernova remnant and pulsar are comparable. This and the fact that the pulsar sits precisely at the geometric centre of the shell argues that they are indeed both the result of a supernova explosion that occurred some 1,600 years ago.

We have also observed this system at X-ray wavelengths. Data acquired with the ROSAT and ASCA X-ray satellites reveal extended emission coincident with the supernova remnant (Figure 15). We also detect an X-ray point source, offset approximately 1.5 arcminutes from the pulsar position. No X-ray pulsations are detected from this source, although the upper limit is quite high and does not rule out the source being the pulsar. Our team has requested time on the Chandra X-ray Observatory in order to continue the study of both the young supernova remnant and the point source.

The PSR J1119-6127/SNR G292.2-0.5 system is very different to the famous Crab pulsar and Nebula, which are often cited as being prototypical of young pulsar/supernova remnant systems. The Crab has a rapidly rotating (33 millisecond) pulsar that powers an extremely bright nebula, but shows no evidence for a surrounding shell emission. In contrast, the PSR J1119-6127/SNR G292.2-0.5 system contains a relatively slowly spinning pulsar, no evidence for a pulsar-powered nebula around the pulsar, but a clear shell.

In fact, for the past few years, evidence from a variety of lines of sources has indicated that the Crab pulsar is quite atypical of the young pulsar population. Our discovery of the PSR J1119-6127/SNR G292-0.5 system puts another nail in the coffin of the traditional view.

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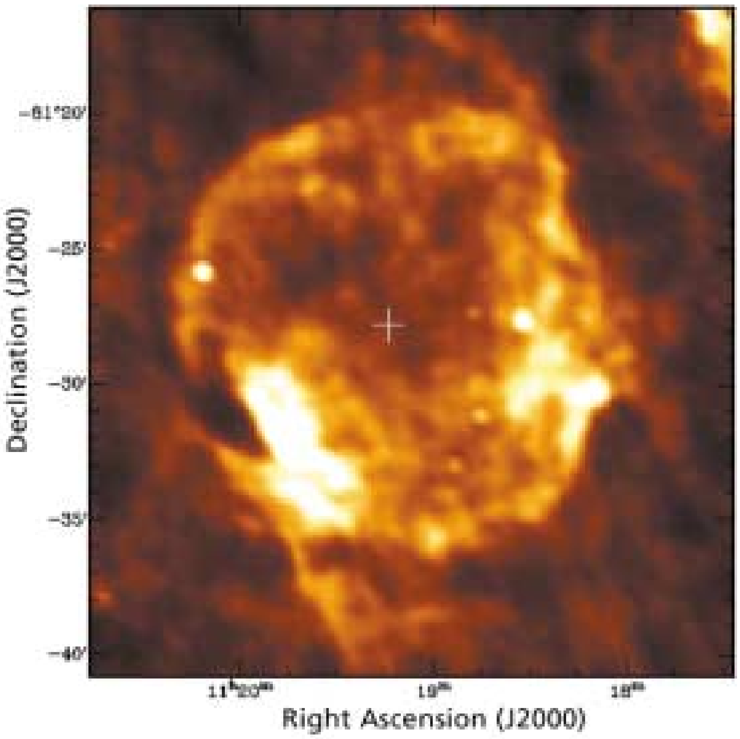

Figure 14 *Compact Array image of the radio continuum emission at 20 cm from a newly discovered young supernova remnant, G292.2-0.5. The cross marks the position of the pulsar.*

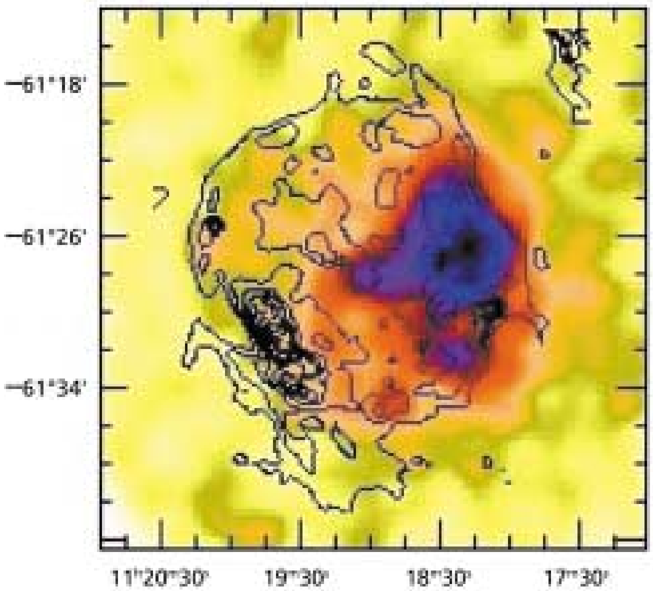

Figure 15 *False colour soft X-ray (0.8–3.0 keV) image of G292.2-0.5, obtained using the Japanese ASCA satellite observatory. The contours represent the 20-cm radio emission seen with Compact Array.*

A new test for General Relativity

A team with members from Swinburne, Caltech and the ATNF has seen General Relativity pass a new test using the very bright millisecond pulsar PSR J0437-4715.

In the early 1990s, the Parkes telescope commissioned an extremely large-scale survey for millisecond pulsars. The survey covered the entire sky south of the equator in 44,000 pointings, each of 2.5 minutes duration. Among the 100 or so pulsars discovered was PSR J0437-4715, a 5.7 millisecond pulsar in a near-circular orbit of 5.7 days around a white dwarf companion. Since then, PSR J0437-4715 has been at the forefront of pulsar timing experiments at the Parkes observatory because of its very close proximity to the Sun, and the range of experiments that are possible with it due to its very bright radio flux.

Early observations revealed that the pulsar was in a nearly-circular orbit and its dispersion suggested a distance of some 140 parsecs (Johnston et al. 1993). It was soon discovered that the pulsar was the source of pulsed X-rays, but notably absent in gamma-rays. PSR J0437-4715 was the first millisecond pulsar to have its white dwarf companion detected, and it soon became obvious that this pulsar had the potential to have its pulse arrival times determined to better than one microsecond accuracies.

Bell et al. discovered that the pulsar had a beautiful bow shock surrounding the pulsar, and after a couple of years the proper motion of the pulsar had been determined to high precision. The standard filterbanks used to observe the pulsar were proving unsatisfactory however, and a new collaboration was begun with Caltech to time the pulsar with a new auto-correlator.

This ultimately led to a determination of the pulsar's parallax. The measurements were so accurate that they permitted a new effect to be observed arising from the changing inclination angle of the system due to the proper motion of the binary. As the pulsar moves one arcsecond every seven–eight years, there is a very small change in the inclination angle of the orbit. Astoundingly, this change is now known to better than one per cent accuracy.

With the arrival of the Swinburne supercomputer in 1998, it became possible to attempt a new, more accurate form of pulsar timing through the method known as "coherent dedispersion". This technique uses a digitised form of the raw voltages and a filtering technique to undo the deleterious effect of dispersion in the interstellar medium. This presents a profile less affected by systematic errors than those induced by filters and other analogue devices but requires the recording of vast amounts of data and many months of supercomputer processing time.

Science highlights

A new instrument known as the CPSR (Caltech-Parkes-Swinburne Recorder) was commissioned in 1998. This can record 20 MBytes of data per second for up to ten hours. 47 Terabytes, or 47,000,000,000,000 bytes of information have now been recorded with this instrument on PSR J0437-4715 alone and the results processed on the Swinburne supercomputer. For every one hour of observing time, it is now possible to determine the arrival time to an accuracy of just 100 nanoseconds. This is the equivalent of a change in the Earth-pulsar distance of just 30 metres!

By accumulating over 600 of these one-hour observations it was possible to detect the annual "wobble" of the pulsar's orbit as the Earth travelled around the Sun and changed the orbital orientation of the binary. This wobble accurately defined the pulsar's 3D orientation, and the inclination angle was determined to an accuracy of just 0.1 degrees. General Relativity predicts that as light travels past a massive body, it is delayed due to space-time distortion. The exact shape of this distortion is well-defined, and shown to be present in our data at a high level of significance. This represents a new and important test of General Relativity in pulsar binaries.

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Photograph

The HI environment of superbubbles in the Large Magellanic Cloud

One of the most important processes that drives the evolution of galaxies is energy injection into the interstellar medium (ISM) from the supersonic stellar winds and supernovae of the most massive stars. These stars are given the spectral designation O and B, and have masses greater than eight solar masses. They are extremely luminous and short-lived, with life expectancies that are, at most, a few tens of millions of years, after which they explode as supernovae. The most massive of these stars are hot enough to ionize hydrogen, thereby producing the beautiful nebulae that are signatures of young star-forming regions.

Most stars, including OB stars, are formed in groups. Thus, the combined energy of multiple stellar winds and supernovae is delivered to the ISM from locations centered on these stellar groups or OB associations. The result is the creation of a large shell of gas, or superbubble, around these stars. Depending on the size and age of the OB association, and the conditions in the ambient ISM, the superbubble can be small, only a few parsecs in radius, or in the case of a starburst, it can potentially blow a gigantic superwind entirely out of the galaxy.

This superbubble action has fundamental consequences for galaxy evolution. In the first instance, there is clearly a great deal of mechanical energy that is transferred to the ISM. However, about half of the available supernova mechanical energy is thought to shock-heat gas in the superbubbles to temperatures of 1–10 million degrees Kelvin. This low-density, hot gas fills the volume of the superbubbles, and its pressure drives their shell growth. Eventually, the hot gas is thought to somehow escape the shells and form a hot component of the ISM. Thus, the more active the star formation and superbubble activity, the more important the hot gas fraction of the ISM. If the hot gas overflows the galaxy and its gravity, it could emerge into the intergalactic medium. The fate of the hot gas is especially critical because it bears the heavy elements created during the supernova explosions, which are a vital record of galaxy evolution.

We are therefore keenly interested in understanding how superbubbles evolve. For the last 30 years, the conventional model has been that of a simple, energy-conserving bubble with constant energy input. However, some discrepancies between the predictions and observations have been reported. Since there are many factors affecting the observed parameters, it is unclear how to interpret the discrepancies and evaluate their importance. One of the critical factors is the density and clumpiness of the ambient ISM which is swept up by the expanding superbubbles. A high-density environment will slow down the growth while a clumpy

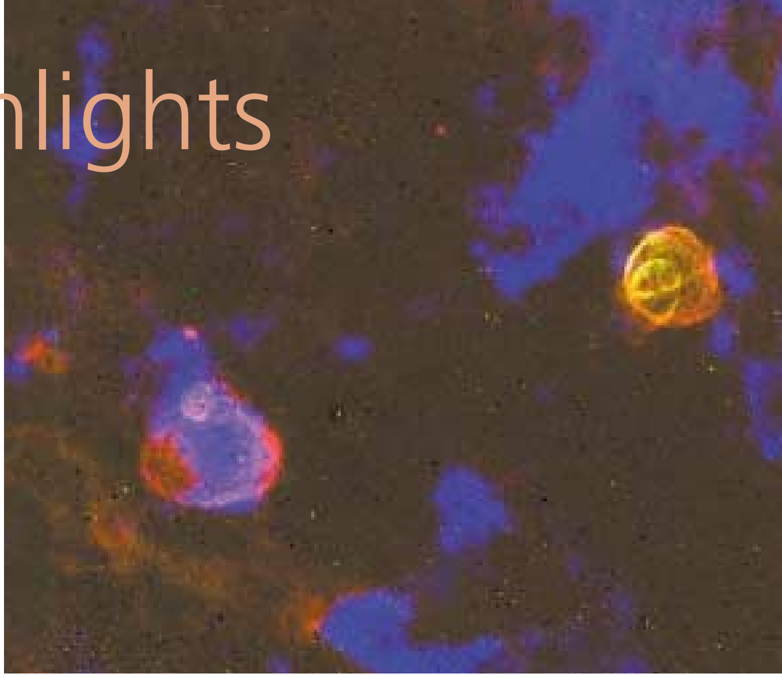

Figure 16 (a) A composite image of the region around DEM L25 (right) and DEM L50 (left). Red and green show optically-emitting ionized hydrogen and doubly-ionized oxygen, respectively; blue shows neutral hydrogen. The superbubbles are each about 100 parsecs in diameter. North is up, east is to the left.

one could cause knots to be engulfed; their evaporation by the shocks and hot gas takes energy away from the rest of the superbubble. If too much material is evaporated into the hot gas, it will cool, also causing the shell to stop growing, and eliminating the superbubble as a source of hot gas for the ISM.

The ambient environment of most superbubbles is cool, neutral hydrogen (HI), which emits light at a wavelength of 21 cm, observable with the Australia Telescope Compact Array. In order to better understand their environment, we mapped the HI distribution around three young superbubbles in the Large Magellanic Cloud. This neighbouring galaxy offers a clear, yet close-up, view of superbubbles, in contrast to our own Galaxy, where we need to peer through confusing material in the plane of the disk. Our three targets have well-constrained parameters, in particular, detailed information on the parent OB stars, and velocity information on the optically-emitting nebular gas.

Figure 16 (above right) shows a composite image of the optical nebular gas (red and green) that is ionized by the OB stars, and the HI gas (blue), for DEM L25 and L50. We also mapped the HI environment for a third object, DEM L301 (below). We find that, although the optical shells are all extremely similar, the neutral environments could not be more different! DEM L25 appears nestled between clouds of HI, and its expansion can be seen to be colliding with an HI cloud on the west. On the other hand, DEM L50 is in a large region devoid of HI, but itself shows a massive neutral component blanketing part of the shell. In contrast to both of these, DEM L301 shows no correspondence whatsoever between the optical and HI distributions. While we have gained some insight on the evolution of these individual objects, this work vividly demonstrates that the ambient environments of superbubbles vary dramatically, and that this is not readily apparent from the optical data alone. It is therefore difficult to infer anything about the neutral gas distribution without obtaining direct observations.

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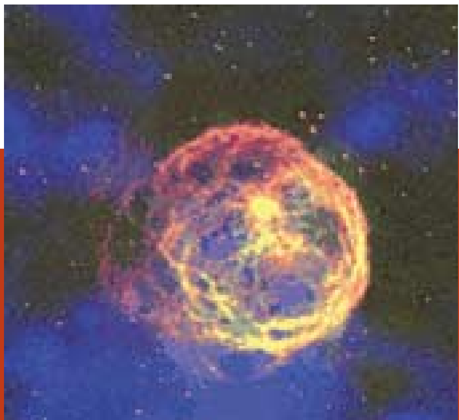


Figure 16 (b) A similar composite image of the region around DEM 301.

The HIPASS Bright Galaxy Survey

The HI Parkes All-Sky Survey (HIPASS) has provided the first ever survey of extragalactic neutral hydrogen (HI) over the southern sky. This survey was completed in March 2000 and the data were released in May 2000 (http://www.atnf.csiro.au/multibeam/release). An extension into the northern hemisphere to the northern limit of the Parkes telescope is ongoing. Extensive efforts are now underway to mine the rich HIPASS data set. The most important effort is in finding and cataloguing the galaxies, both previously known galaxies and newly discovered galaxies. Considerable effort is being contributed by several teams including the University of Melbourne, the Swinburne Centre for Astrophysics and Supercomputing, and the ATNF. One of the first products is the HIPASS Bright Galaxy Catalogue, which is a catalogue of the 1000 apparently brightest HI galaxies in the southern hemisphere.

The HIPASS Bright Galaxy Catalogue represents the first unobscured view of the nearby galaxy distribution in the southern sky. Neutral hydrogen gas in nearby galaxies can be detected easily from radio observations whereas optical and infrared surveys are limited by the obscuration of light from dust and stars of our own Galaxy. HIPASS has provided many new detections of galaxies previously hidden behind the plane of the Milky Way in the so-called Zone of Avoidance (ZOA).

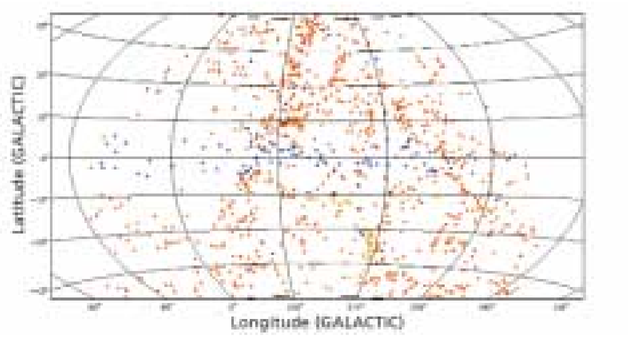


Figure 17 *Aitoff projection showing the spatial distribution of the 1000 brightest HIPASS sources in Galactic coordinates. The new galaxies are marked in blue, HI clouds in green, High Velocity Clouds in orange and all other galaxies in red.*

Figure 17 shows the spatial distribution of the 1000 brightest HIPASS galaxies. Of these, 84 have no counterparts catalogued in the NASA/IPAC Extragalactic Database. Most of the newly discovered galaxies lie in

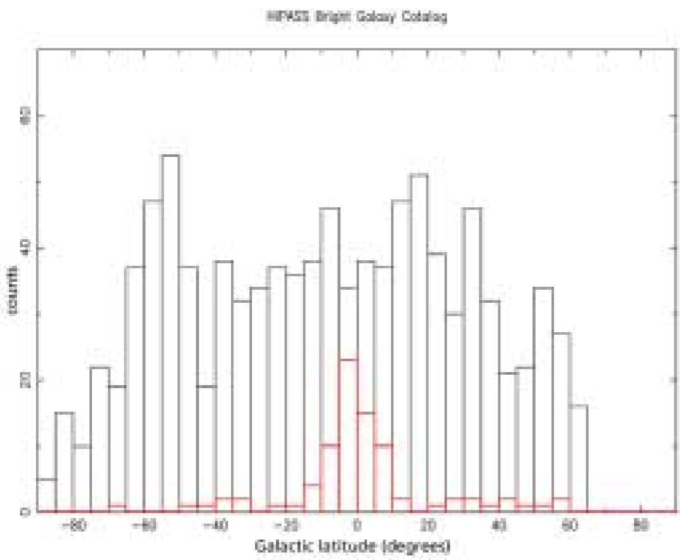


Figure 18 *A histogram showing the Galactic latitude distribution for the 1000 brightest HIPASS galaxies. The distribution for galaxies discovered by HIPASS is shown in red.*

or close to the Zone of Avoidance (Figure 18). 58 of the new galaxies have Galactic latitudes below 10 degrees while 21 have latitudes above 15 degrees. For 17 of the new discoveries, the HIPASS and optical velocities disagree. Compact Array and optical follow-up observations of these and many other galaxies are under way to confirm their identifications.

The new galaxies found outside the Zone of Avoidance can be divided into two groups, those with optical counterparts and those without, the latter being very rare. Figure 19 shows optical images from the Digital Sky Survey for ten of the galaxies with optical counterparts. These are mostly compact, late-type galaxies. We also detected several unusual sources including HI 1225+01 (the Virgo cloud) and a large hydrogen cloud, HIPASS J0731-69, which is well-separated from its apparent host galaxy NGC 2442 and shows no evidence of optical emission or star-formation (page 32). Also remarkable were the detection of HIPASS J1712-64, HIPASS J1718-59 and several other HI clouds which do not have any obvious optical counterparts. Their striking location along the Supergalactic Plane leads to speculation that such HI clouds may be the dregs of the galaxy formation process. An alternative theory is that these clouds may be high-velocity ejecta due to a tidal interaction between our Galaxy and the Magellanic Clouds.

Figure 20 shows the velocity distribution for the 1000 brightest HIPASS galaxies. The distribution is dominated by galaxies with velocities between 800 and 2000 km s^{-1}. For these velocities the most striking structures, shown by the spatial distribution of galaxies, are the Supergalactic Plane and the Local Void. Several new galaxies with velocities above 1000 km s^{-1} have been found which better define the boundaries of the Local Void. Although we know from optical surveys that the galaxy large-scale structure is far from homogeneous, it is important to study the sky uninhibited by obscuration. Many known structures continue into and across the optical Zone of Avoidance and create a beautiful network of galaxies, dominated by groups, strings and bubbles.

B. Koribalski, L. Staveley-Smith (ATNF); V. Kilborn (Melbourne University); S. Ryder (AAO) and the HIPASS/ZOA teams

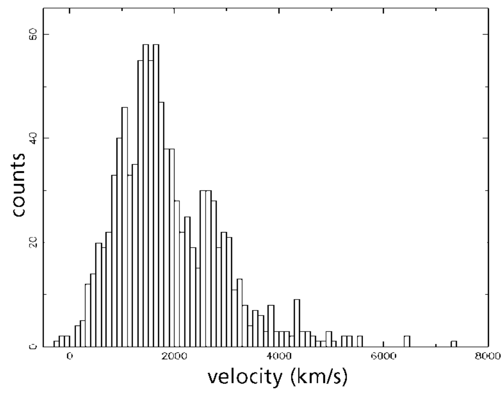


Figure 20 *Histogram of the HI systemic velocities of the 1000 brightest HIPASS galaxies.*

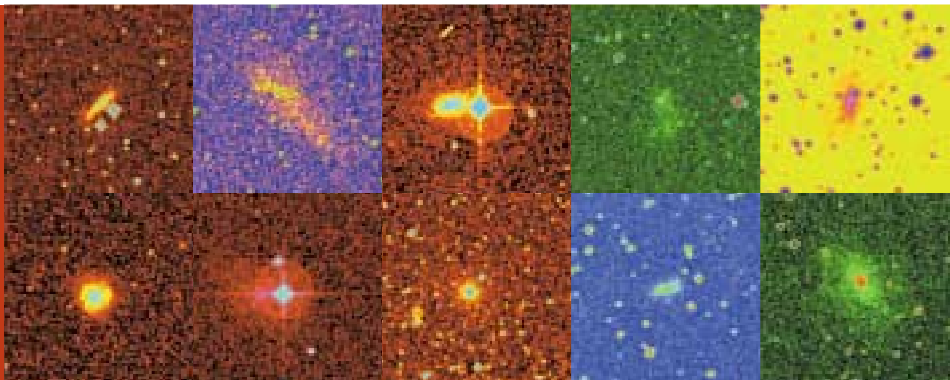


Figure 19 *Optical images from the the Digitised Sky Survey for ten new galaxies detected in the HIPASS Bright Galaxies Survey.*

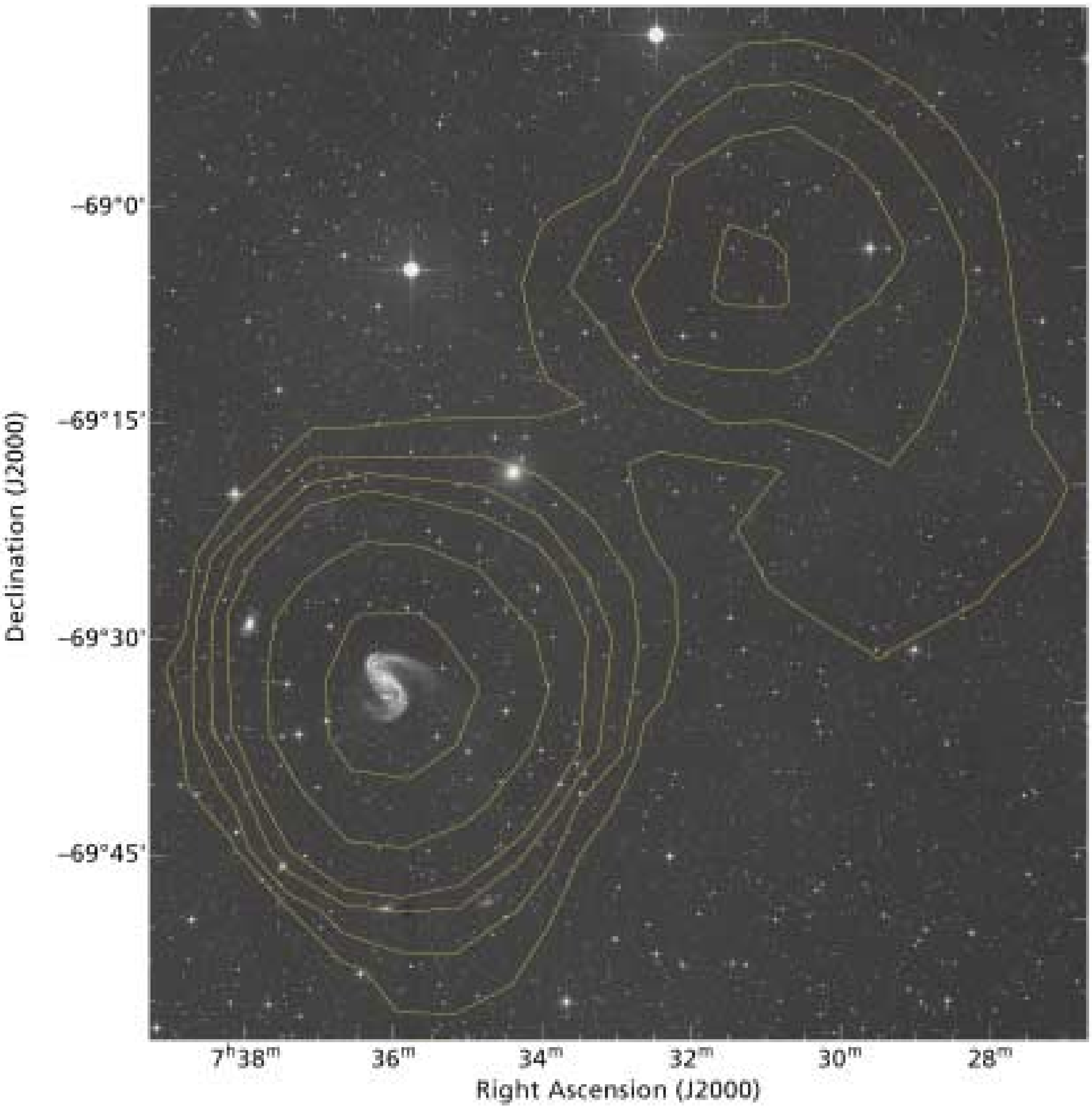
HIPASS turns up new gas in the NGC 2442 group

The HI Parkes All-Sky Survey (HIPASS), carried out between 1997 and 2000 with the Parkes multibeam receiver, continues to yield intriguing new discoveries about the local universe. While studying the properties of the 1000 brightest sources of neutral hydrogen (HI) emission in the HIPASS database, we noticed a previously unknown HI cloud adjacent to NGC 2442, a bright spiral galaxy in the constellation of Volans (Figure 21). What makes this find so unusual and so exciting is that the cloud appears to have almost one third as much gas as NGC 2442 itself, and yet not a single star, or evidence of any recent star formation, has been found to go with it.

While this is not the first such cloud found in HIPASS (see the report by Kilborn et al. in the 1999 *ATNF Annual Report*), it is one of the most massive discovered outside of our Local Group of galaxies. The cloud, designated HIPASS J0731-69, contains of order 10^9 solar masses of hydrogen, which begs the question: where did all this gas come from? NGC 2442 has long fascinated astronomers, because of its somewhat distorted appearance. The two main spiral arms are quite different, with the northern arm being narrow, acute, and cleft by a striking lane of dust; by contrast, the southern arm is broader, more open, and criss-crossed by numerous dust patches. In her PhD study with the Compact Array, Sally Houghton found indications that the gas disk of NGC 2442 is stretched in the direction of HIPASS J0731-69, but saw no other signs of a direct connection between the two.

If HIPASS J0731-69 was indeed torn out of NGC 2442 by a passing galaxy, then it could not be any of the nearby faint dwarf galaxies that have previously been suggested by others as a potential partner. Instead, a much larger object must be involved, such as the elliptical galaxy NGC 2434 (visible in the overlap region between NGC 2442 and HIPASS J0731-69, but apparently lacking any HI of its own), or the more remote galaxy pair NGC 2397 and NGC 2397A. One other possibility is that rather than tidal forces being involved, HIPASS J0731-69 was stripped as the result of NGC 2442 ploughing its way through a dense inter-galactic medium of hot gas. Such a hot medium ought to be visible in X-rays, but none has yet been detected in this region.

Despite the relatively coarse resolution of HIPASS, significant structure in HIPASS J0731-69 is apparent both spatially and in the velocity dimension. At velocities below 1400 km s^{-1}, the cloud appears as two clumps which then appear to merge together (as well as with NGC 2442 itself) at higher velocities. This structure is reminiscent of the Magellanic Stream arcing around our own Galaxy, and is most unlike the kind of motions expected of gas within a typical dwarf or spiral galaxy. Perhaps it is no surprise then that we have



yet to locate any galaxy-like optical counterpart to this gas.

Follow-up observations of HIPASS J0731-69 are underway with the 375-m configuration of the Compact Array, to tell us more about the small-scale structure and internal kinematics of the gas. In addition, a deep optical survey of the region is planned with the Wide Field Imager CCD mosaic on the Anglo-Australian Telescope, to confirm the lack (or otherwise) of stars and ionized gas within this cloud. The very existence of HIPASS J0731-69 has forced us to rethink the origin of the lopsidedness in NGC 2442, as well as revise upwards our predictions for the total amount of mass contained in loose groups such as this.

S. D. Ryder (Anglo-Australian Observatory); B. Koribalski (ATNF) and the HIPASS/ZOA teams

Figure 21 *HIPASS map of HI intensity (contours), overlaid on an optical image from the Digitised Sky Survey. Note the asymmetry of the spiral arms in NGC 2442 at the centre of the source at lower left, and the lack of any galaxy near the peak of HIPASS J0731-69 to the upper right.*

Recurrent activity in giant radio galaxies

Giant radio galaxies constitute a class of radio sources with linear sizes of over a million parsecs.

When a black hole at the centre of an elliptical galaxy is fuelled by matter spiralling in from a surrounding accretion disk, twin beams of matter often emerge from this central engine in opposite directions at relativistic speeds. Radio galaxies are created when the beams form lobes of ionized gas, known as plasma, on opposite sides of the parent galaxy. In powerful radio galaxies, the radio beams appear to end in hotspots with the brightest emission at the extremities of the double-lobed radio sources. The lobes are believed to be formed from plasma which has flowed backwards from the hotspots towards the central galaxy. Usually, the double radio sources are found to have sizes of up to a few hundred kilo-parsecs; however, in the rare giant radio galaxies, the radio sources are at least a million parsecs, about a hundred times bigger than the extent of the optical host elliptical galaxy.

A key problem is to understand why giant radio galaxies are so large. A few years ago, some of us studied the radio morphologies in giant radio galaxies by imaging several southern sources with the Australia Telescope Compact Array. We found a variety of morphological features which indicated that the beams from the central engine, which powered these radio galaxies, might have been interrupted in the past. We concluded that giant radio galaxies may have attained their large sizes as a result of a restarting of their central engines in multiple phases of activity along roughly similar directions.

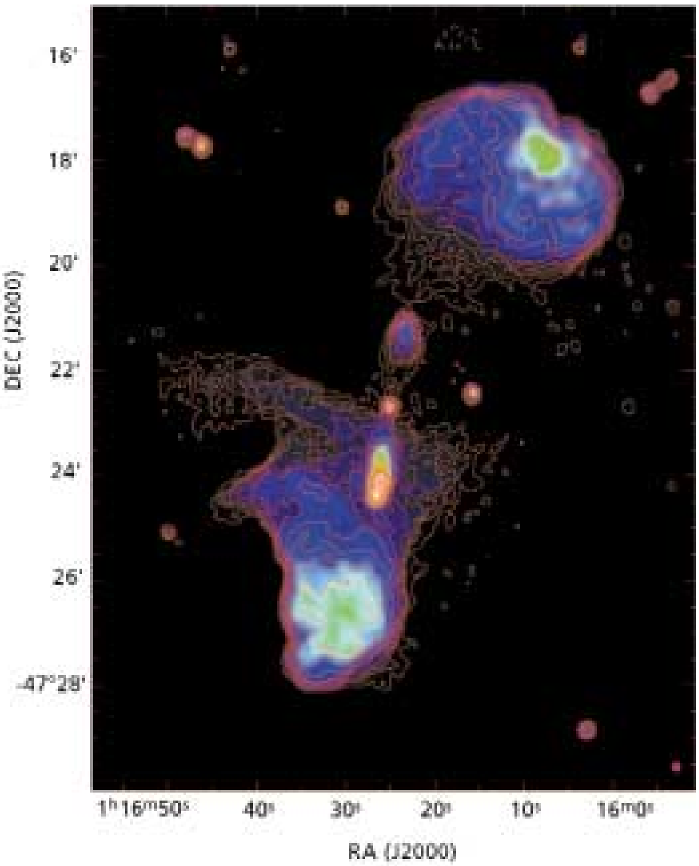
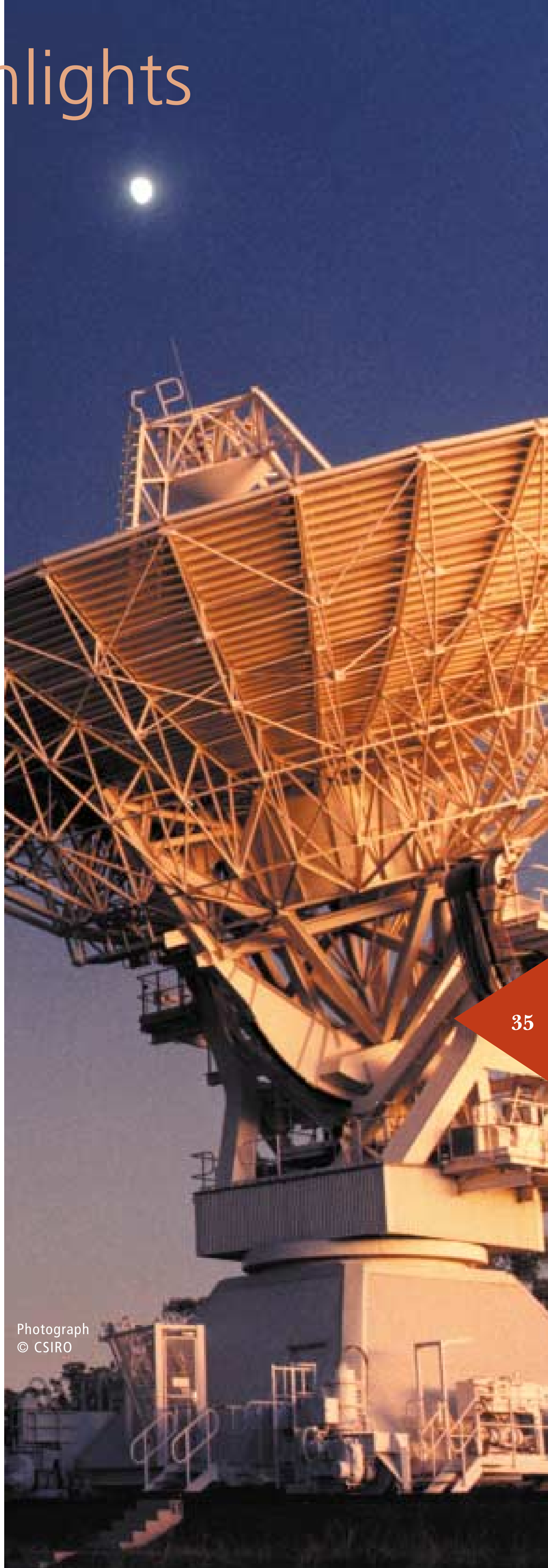


Figure 22 *A Compact Array image of the 20-cm radio continuum emission from the giant radio galaxy B0114-476.*

Recently, we imaged the detailed structure in the giant radio galaxy B0114-476 with the Australia Telescope Compact Array (Figure 22). Surprisingly, this powerful radio galaxy does not have strong hotspots at the ends of the two large lobes — while intense features are seen as bright peaks symmetrically placed on either side of the central galaxy. We seem to have caught this powerful giant radio galaxy in an act of rejuvenation. The likely scenario for this galaxy is that the outer diffuse lobes, which lack hotspots, represent relics of past activity. The beams from the central engine stopped, then restarted, and we are now seeing a new pair of beams emerging through the relict cocoon of relativistic plasma. The inner double itself has a linear size of 700,000 parsecs: its size is much larger than for typical double radio galaxies. The overall morphologies of the two inner lobes mimic the respective outer lobes: the northern inner and outer lobes are broad in contrast to the southern inner and outer lobes which are more cylindrical in shape. This indicates that the external medium on a given side may be affecting the inner and outer lobe morphologies similarly and the differences between the two sides may be attributed to differences in the ambient medium.

The ATCA image tells us that giant radio galaxies can be born again and possibly live multiple lives: could this be the cause for their large sizes?

L. Saripalli, R. Subrahmanyan (ATNF); N. Udayshankar (Raman Research Institute, Bangalore)



Photograph © CSIRO

The gaseous halos of three spiral galaxies

We have observed three southern edge-on spiral galaxies with the Australia Telescope Compact Array: NGC 1511, NGC 7090 and NGC 7462. The aim of these observations was to investigate whether galaxies with unusually warm dust, heated by massive stars, have gaseous halos — in particular radio halos tracing the presence of relativistic electrons expelled from the galaxy disks by multiple supernova remnants. Such halos are seen most easily in edge-on galaxies; for this viewing geometry it is possible to determine directly whether the radio emission arises from the galactic disks or from more extended regions.

Several Compact Array configurations were used to obtain radio continuum data at wavelengths of 13 and 20 cm, with good angular resolution and sensitivity. The success rate of the observations was 100% — all three galaxies show extended radio halo emission. The most spectacular of these, NGC 7090, is shown in Figure 23. The 20-cm radio emission is shown as a set of contours, overlaid on the optical image of the galaxy from the Digital Sky Survey. The radio emission is seen as a gaseous halo which is considerably extended on both sides of the optically-visible disk of the galaxy. The synchroton radio emission is weaker and less extended at 13 cm than at 20 cm. The radio halo of NGC 7090 is one of the most extended halos around a radio galaxy known to date.

The radio properties of the three newly detected halos provide new insights on the star-formation history of the observed galaxies. The radio halo emission occurs from relativistic electrons which are released during multiple supernova explosions over a short period of time. During a supernova explosion, most of the mass of a star is violently ejected into the interstellar medium. Both X-ray emitting gas, heated to temperatures of millions of degrees, and electrons producing synchroton radiation, escape from the explosion site. The transfer of matter away from the sites of supernovae is a cosmologically important process in which heavy elements, the building blocks of all life forms created in stellar nuclear fusion processes, are distributed in galaxies. The propagation of metals through the Universe determines its chemical evolution over cosmological time scales.

In recent years, gaseous halos have been reported from radio, optical or X-ray data for at least 20 galaxies. The gaseous halos are detected in the radio and X-ray regions of the spectrum, because the relativistic electrons and hot gas are produced simultaneously by supernova explosions and escape from the galaxy disks. While some stars have already exploded as supernovae, others, with a longer lifetime or born later, still survive. The surviving stars emit ultraviolet radiation, causing the surrounding gas to glow as diffuse optical light, including gas located in the halo. This is seen most prominently as hydrogen-alpha line emission from hydrogen atoms. The massive stars also heat the surrounding dust. Galaxies with warm dust are therefore good candidates for searching for galaxy halos. The gaseous halos are intrinsically faint and difficult to detect and the number of detections is still rising. The most recent generation of telescopes and instruments, such as the Compact Array, allow us to pick up their faint signals.

Such halos are now known to be an integral part of galaxies with high star-formation rates. Despite its relatively low star-formation rate, our own Galaxy, the Milky Way, also has a gaseous halo, identified in the 1970s from radio observations taken with the Parkes radio telescope and elsewhere. For our own Galaxy, it is difficult to study large-scale evolutionary processes because of the strong obscuration of light within the Galactic plane. Radio observations such as those of NGC 7090 provide a grand overview of large-scale processes occurring in other spiral galaxies and, by comparing the properties of these external systems with those of the Milky Way, new insights into our own Galaxy.

M. Dahlem (ESO, Chile); J. S. Lazendic (University of Sydney); R. Haynes (ATNF); M. Ehle (XMM-Newton Science Operations Centre, Spain); U. Lisenfeld (IRAM, Spain)

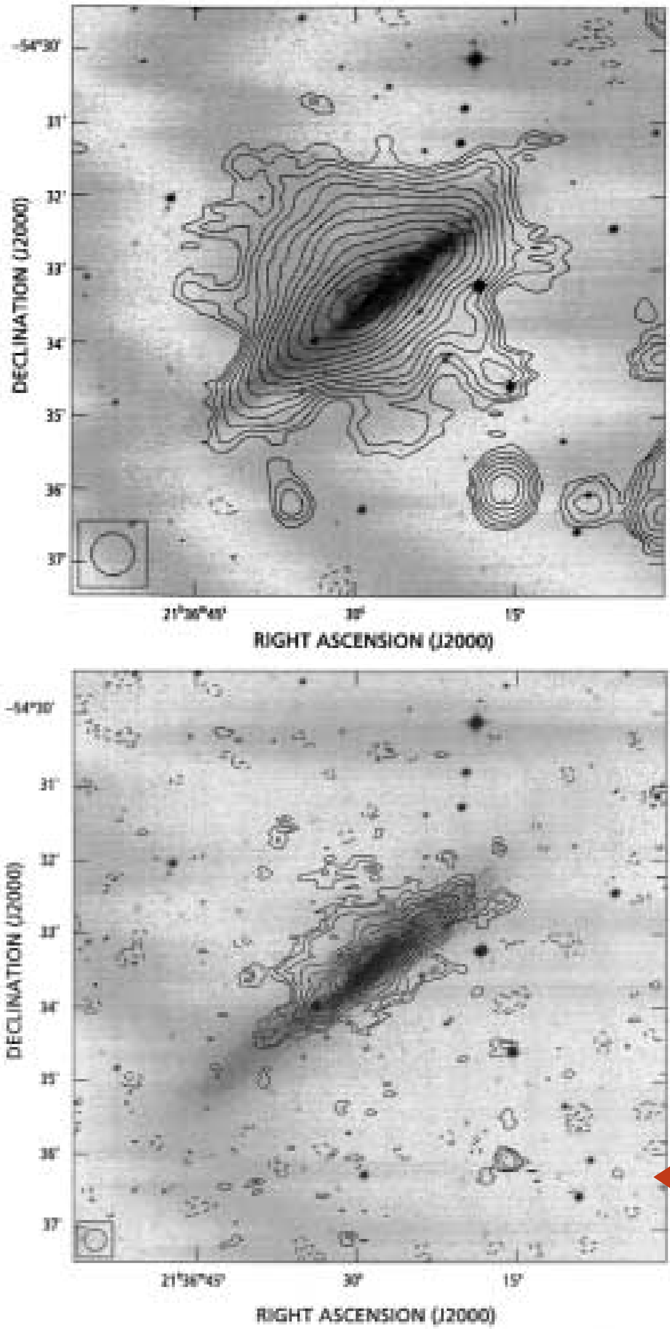


Figure 23 *Australia Telescope Compact Array image of the 20-cm (top) and 13-cm (bottom) radio continuum emission from the edge-on spiral galaxy NGC 7090 (contours), overlaid on an optical image of the galaxy from the Digital Sky Survey.*

Operations

National Facility Support

The ATNF National Facility Support group, located in Marsfield, provides support for public relations activities, external communications, educational programs and time assignment processes.

Staff changes

In September 2000 Dr Raymond Haynes retired from CSIRO after 28 years of service. Raymond held several key roles at the ATNF, most notably as Head of Computing from 1977 to 1983 and later as Head of the Scientific and Community Liaison Group from 1994 until 2000. We also said goodbye to Tracy Denmeade, the ATNF Lodge Manager who worked for ATNF over a period of seven years. Helen Sim, the ATNF Communications Manager, spent four months on secondment to the National Radio Astronomy Observatory, to work on public relations activities for the opening of the 100-m Green Bank Telescope (GBT) in West Virginia, USA.

After some restructuring of the Management group, Jessica Chapman was appointed in September 2000 as the Head of External Relations.

Public service medal

Dr John Whiteoak, Deputy Director of the Australia Telescope National Facility since 1989, was awarded a Public Service Medal in the Australia Day honours list for 2001, for his contribution to the ATNF and his role in establishing high-frequency spectrum allocations for astronomical research.

One of John Whiteoak's major contributions in the international radio astronomy world has been his work on the protection of radio frequencies for astronomy, as chairman of an International Telecommunication Union (ITU) Working Party. This group has proposed vastly increased protection in the radio spectrum at frequencies between 71 and 275 GHz, the proposals endorsed at the recent World Radiocommunication Conference in Istanbul (page 40).

Higher-degree students

Education is one of the ATNF's key performance indicators. ATNF staff members participate in a long-standing program to co-supervise higher-degree Masters and PhD students. This arrangement gives students access to world-class observing facilities and the chance to interact with a range of practising astronomers. At the end of 2000, 24 students were taking part in the program: their projects are listed in Appendix G. Four students completed their PhDs during the year, their theses are listed in Appendix H.

Most of the higher-degree students undertake studies in astronomy, but the ATNF also offers higher-degree projects in areas of engineering such as microwaves, digital and electronics and in computer-related topics.

Melanie Johnston-Hollitt is a PhD student at the University of Adelaide with a co-supervisor at the ATNF.

Summer vacation program

For more than a decade the ATNF has coordinated a program each summer for undergraduates in science, mathematics, computing and engineering who are in at least the third year of their degree. For the 2000–2001 program there were 170 applications for 20 positions, seven with the ATNF (two of these at the Narrabri Observatory) and 13 for CTIP.

The students work on individual research projects under the supervision of research scientists for 10 to 12 weeks. During this time they experience the working environment of a major research facility. The vacation program includes a series of introductory lectures on the work of the ATNF and CTIP; a tour of the CSIRO Marsfield and Lindfield laboratories; and a weekly session where a staff member talks on a research topic.

A highlight of the program is the observatory trip where the students visit either the Parkes radio telescope, or the Australia Telescope Compact Array and are given the opportunity to work in small teams to take observations for a project of their own choice. This year the observatory trips were supported by John Whiteoak (Parkes) and Bob Sault (Narrabri).

At the end of the program the students organize a one-day symposium to report on both their individual and group research projects. In past years, some of the students in the program have later returned to the ATNF, either as employees or to do a co-supervised higher degree under the scheme outlined above. The students are also responsible for the production of a magazine, *The Jubbly Jansky*.

Australian access to SEST

A Memorandum of Understanding (MOU) between the ATNF and the Onsala Space Observatory, signed in August 1997, has been effective in providing Australian astronomers access to the Swedish-ESO Submillimetre Telescope (SEST) in Chile. It was formally established to provide a 10% share of the Swedish observing time on the telescope. This agreement has now been renewed for a further two years, until April 2002.

In return for this access the ATNF has built a wideband digital correlator for SEST to enhance its spectral-line facilities. This was delivered in March 2000 and is now available to SEST observers. Australia also provides part of the observing support for the SEST telescope.

Spectrum management

CSIRO, initially through the Division of Radiophysics and later through the ATNF, has been involved in activities related to spectrum management and the protection of radio astronomy for about 30 years. In preparation for John Whiteoak's retirement in 2001, Tasso Tzioumis has been taking increased responsibilities for these activities. The areas in which the ATNF are currently involved include:

Participants of the summer vacation student program, December 2000.

- Participation in national and international meetings under the auspices of the International Telecommunication Union (ITU). These include regular meetings of ITU Study Group 7 (Science Services).
- Participation by the ATNF director in the Working Party meetings of the OECD megascience forum where an international task force is being set up to investigate radio-frequency interference and protection measures.
- Participation in IUCAF, an Inter Union Commission for the Allocation of Frequencies and in the spectrum planning activities of the Australian Communications Authority (ACA).

A major event in 2000 was a month-long meeting for the World Radiocommunication Conference (WRC-2000), held by the International Telecommunication Union (ITU) in Istanbul during May 2000. This meeting was attended by about 2,500 participants including a dozen radio astronomers.

The purpose of the meeting was to revise pre-selected parts of the ITU radio regulations which form the basis of planned international usage of the radio spectrum. Several of the agenda items for the meeting involved radio astronomy. The most important item concerned spectral allocations to radio astronomy (and the Earth-exploration satellite service) in the frequency range 71–275 GHz.

The WRC-2000 meeting was a huge success for radio astronomy: all of the proposals for improved allocations (almost 100 were needed to cover the 71–275 GHz band) were finally adopted by WRC-2000. Even extra protection proposed only by Asia-Pacific countries for some spectral lines not covered by the allocations was approved.

Figure 24 shows the gain in radio frequency allocations. The line profile shows the variation of zenith atmospheric attenuation with frequency. Atmospheric

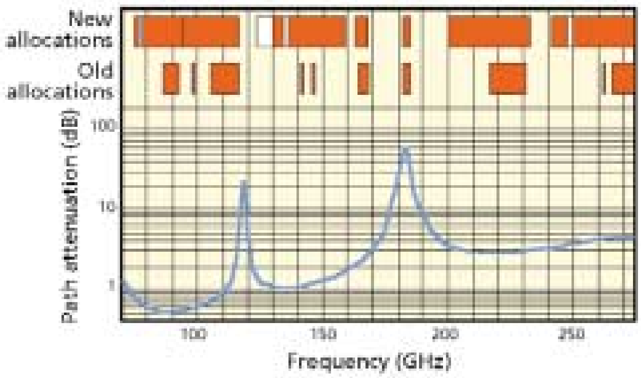


Figure 24 *The radio frequency allocations for 71 – 275 GHz. Unfilled blocks represent secondary allocations.*

"windows" containing attenuation minima occur in the ranges 70–115 GHz, 125–175 GHz, and 195–275 GHz. The new radio astronomy allocations now extend across most of the windows, and for the central window in particular, the improvement in protection is enormous. The radio astronomy allocations also include a band centred near 183 GHz which will be used for calibration purposes to study the attenuation and distortion of astronomical signals caused by atmospheric water vapour.

As a consequence of the bargaining to increase the allocations, some of the allocated frequencies will have to be shared with ground-based fixed, mobile or satellite uplink services. If these services are developed, their operations will have to be coordinated with radio astronomy. However, it is commonly believed that this will not be a problem at these high frequencies where ground-level atmospheric attenuation is high.

Unfortunately, WRC-2000 provided no opportunity to review the radio astronomy allocations at lower frequencies. In any event, the spectrum is so congested with services that it is difficult to see how radio astronomy could gain more allocations without affecting the operation of other existing services. The only possible gain may be in the protection of allocated bands from unwanted emissions of transmitters operating at frequencies outside those bands. A dedicated task group has been working on this problem for several years, and this will continue. Hopefully this work will result in improved radio astronomy protection levels which can be included in the Regulations at the next WRC.

Public outreach

The ATNF supports a wide range of public outreach activities. During the year, ATNF staff gave over 70 public talks. The ATNF also featured strongly in the media with staff involved in approximately 50 radio interviews and 25 television interviews. Over 100 newspaper articles on ATNF research activities and engineering developments were published during the year.

The National Facility Support group provides resources targeted for school students and educators. The group publishes a range of educational material which includes brochures, fact sheets and posters. To help high school teachers with the new HSC astronomy syllabus, a workshop for science teachers on "Peering Inside the Cosmic Engine" was held in Epping and, early in the year, at the University of Western Sydney. This was highly rated by the school teachers who attended.

Work experience students

The ATNF also gives students in Years 10 and 11 the chance to do "work experience". Each year, typically 30 students do a week of work experience at either the Parkes Observatory or at the Compact Array. Over the past few years the ATNF has initiated a Disadvantaged Youth Program for Year 11 high school students. The scheme is aimed at high schools in low socio-economic areas and provides a week-long work experience program for two to three students per year.

Narrabri outreach

At the Narrabri Visitors Centre, the estimated number of visitors for the year 2000 was 8,900, compared with about 9,700

Photograph

during 1999. There were fewer visitors around September, possibly because of the Sydney Olympics. There was another quiet period during the floods and very wet weather in November.

A highlight of the year was an Open Day held at Narrabri on 16 April 2000. The day was a great success, with more than 600 visitors. Two antennas were made available for inspection and were very popular. Tours of the control room, correlator room and receiver lab were also conducted. A series of six talks was given during the day, on a variety of astronomical and engineering topics. All were well attended with the seating capacity (30) of the conference room insufficient for all but the first talk of the day. Narrabri staff were joined by a number of volunteers from Marsfield, and were kept busy until an hour after the nominal closing time at 3 p.m.

Parkes outreach

The year 2000 marked several outstanding events and developments for the Observatory Visitors Centre and Outreach program — a very successful year in every respect.

A major upgrade to the existing Visitors Centre, funded by the CSIRO corporate building development program, was completed in August, furnishing approximately double the former interior space, a refurbished audio-visual theatre and several additional facilities for staff and visitors, including a new toilet block and landscaping of the Centre grounds. Much of the additional space is designed to encourage visits from school groups, particularly from those in the surrounding regions.

In tandem with the reopening of the upgraded Visitors Centre, a new audio-visual show was premiered, replacing a program which had run essentially unchanged for many years. The new show retains the multiple slide projector format, rendering visual material of extremely high quality and creating the illusion of animation. Response to the new show from the public has been excellent, both in direct feedback and increased attendance. The new show was produced for the ATNF by Australian Business Theatre, with assistance from staff at the ATNF and other astronomical research institutions. During 2000, the Visitors Centre attracted 58,700 visitors. Figure 25 shows the number of visitors for 1999 and 2000.

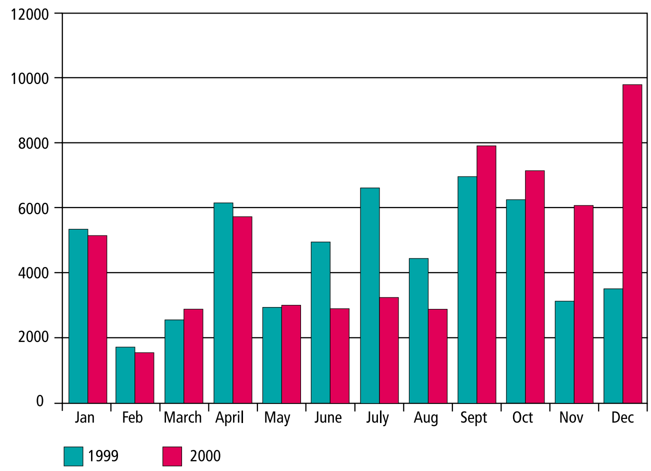


Figure 25 *Number of Visitors in 1999 and 2000 to the Parkes Visitors Centre.*

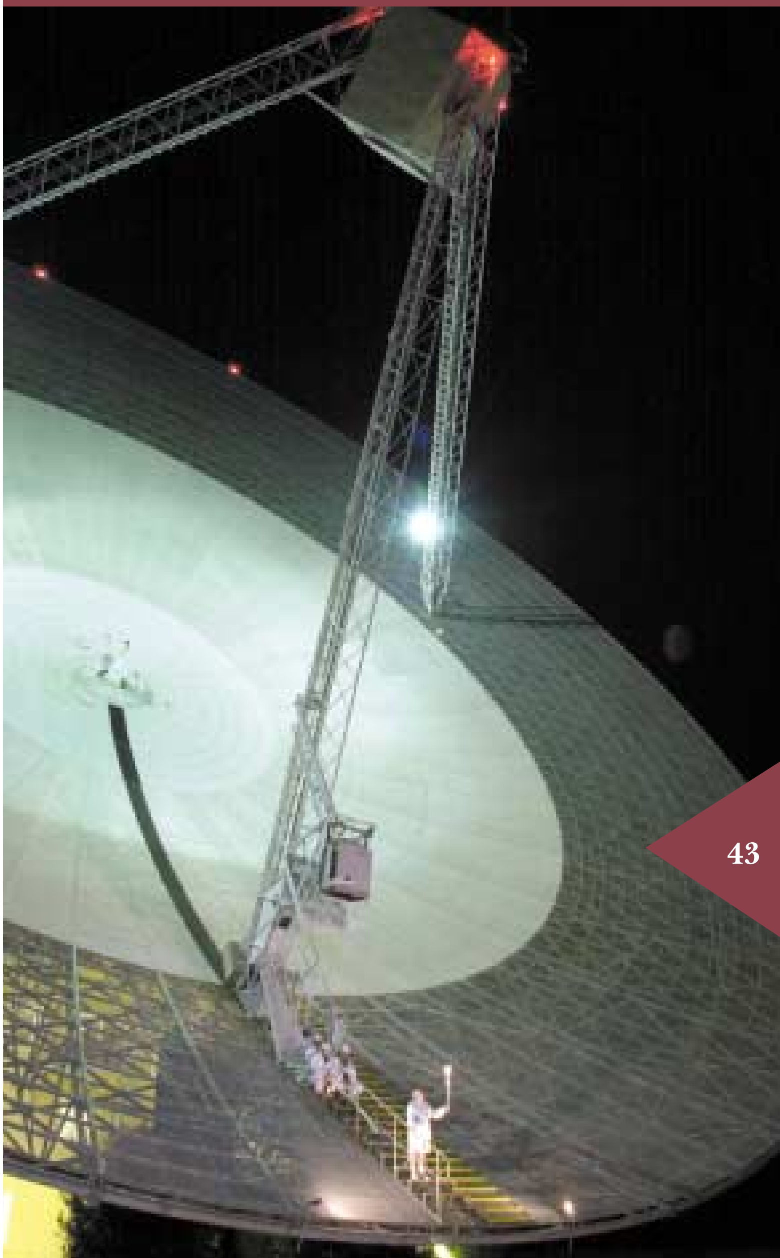
The Visitors Discovery Centre at the Parkes Observatory

Olympic Torch

The Olympic Torch Relay came to Parkes on 18 August, a day which culminated in memorable scenes of the Mayor of Parkes, Robert Wilson, riding the floodlit dish, holding the Torch aloft. The event received good media coverage and was an invaluable opportunity to further consolidate good relations with the local community and council. A TV advertisement incorporating shots of the telescope and a local Olympic athlete, made by IBM to promote their Olympic sponsorship, was shown widely throughout the Olympics both in Australia and overseas, generating wide interest in, and visibility for, the Observatory.

The Dish

An Australian feature film *The Dish*, a dramatisation of the role played by Parkes in the first manned lunar landing, was released commercially in October 2000 to outstanding critical acclaim, becoming in quick time the highest grossing Australian film on record. Produced by Working Dog Productions, *The Dish* was shot on location at the Observatory during 1999 with the cooperation of ATNF and Observatory staff. The film generated excellent and sustained visibility for the Observatory and ATNF in many forms, including wide media coverage over several weeks, and a dramatic increase in public interest at the Visitors Centre.



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Robert Wilson, the Mayor of Parkes, carries the Olympic Torch on the Parkes radio telescope

Computing

Epping computer services

At Epping, the information technology (IT) infrastructure is managed by the computer services group of CSIRO Telecommunication and Industrial Physics (CTIP), while ATNF-specific tasks such as astronomical software and user support are managed by the ATNF. The computer services group was not fully staffed in 2000 (partly because of outsourcing: see below) with some resultant impact on the ATNF.

Staff

In 2000, Henrietta May, David Barnes and David Loone departed the ATNF. Henrietta joined CSIRO in 1978. Her most recent role was in system and astronomical applications support. David Barnes worked for two years in the aips++ astronomical software project, specifically on the visualization of data. David Loone was with the ATNF for some 10 years, most of which was spent in Narrabri. He led the ATOMS software project, to develop object-oriented real time systems, for his last two years from Epping. Thanks are due to each of them for their respective contributions to the excellence of the ATNF.

Vince McIntyre and Malte Marquarding joined in 2000. Vince takes over from Henrietta and Malte from David Barnes. David Loone's position (and the management of ATOMS) has reverted to Narrabri.

Observatory Computer Committee (OCC) and Computerfests

Computer staff at each of the three main ATNF sites report to a local program leader, but coordination across the sites is performed by the four-person OCC. The OCC meets three times a year, with the meetings rotated between the sites.

"Computerfests" are held in association with the OCC meetings. These gather together the many ATNF staff working in computing-related areas. The purpose is both social and technical, and they have been very successful. They enable staff to promote, communicate and coordinate their work activities, and also to socialise.

Outsourcing of IT support

Following a Cabinet decision in 1997, Government policy has been to outsource IT infrastructure services in budget-funded government agencies, subject to the outcome of competitive processes. In mid-2000, the Department of Finance and Administration conducted a "scoping study" for outsourcing IT infrastructure for CSIRO and other scientific agencies. At the end of 2000, following an independent review of implementation risks, the Government accepted a recommendation that the responsibility for the implementation of outsourcing should be devolved to the relevant agencies. CSIRO is therefore responsible for managing any outsourcing of its own IT infrastructure.

During 2000, the impact on CSIRO and

the ATNF of the outsourcing process was substantial. CSIRO formed an outsourcing project team of some 10 people, many seconded from their divisions. Each division also provided an outsourcing coordinator. Then began a process of gathering data describing the IT environment in great detail. These data had to be delivered on a fast schedule, and it became necessary for staff to delay other matters in order to meet the requirements. This clearly had a negative effect on the level of support it was possible to offer users at the ATNF sites. There were also many concerns amongst staff whose jobs were potentially at threat. This contributed to the computer services group's difficulties in retaining and hiring staff.

aips++ development

aips++ is an object-oriented data processing environment being constructed by an international consortium of leading radio astronomy observatory led by Tim Cornwell at NRAO. In 2000, Jodrell Bank rejoined the consortium (which also includes ATNF, BIMA, NRAO and NFRA) as an active member. The ATNF contributes four people who work (part time) on core aips++ development. The ATNF also uses aips++ as its toolkit for the development of the successful multibeam pipeline.

The project continues its development cycle of six months, with a new CD release at the end of each cycle. These are distributed to some 10 institutions in Australia and internationally.

In 2000 the ATNF held its first aips++ workshop. This was well received and another will ensue in 2001. aips++ demonstrations continue, and advice is given as part of the migratory and critical-mass gaining process.

ATNF development is mainly in the area of image visualization (in which we have a strong history) and analysis as well as basic astronomical infrastructure services. The central aips++ display tool, the Viewer, has been largely developed at the ATNF. The Viewer was designed to be "data" oriented (previous ATNF display tools such as the "kview" program were purely image oriented) and its functionality is now being broadened (at NRAO) to handle the display of visibility data. ATNF staff continued to improve the capability of the image-based displays and applications. Progress reports are given at http://www.atnf.csiro.au/aips++/weekly/docs/project/quarterlyreports.html.

Equal Employment Opportunity (EEO)

The ATNF has an active EEO group with five EEO contact officers. Two are based in Sydney, two are at Narrabri and one is at Parkes. Staff at any of the sites can contact any of the EEO officers and are assured that all discussions will be held in confidence. The EEO officers meet several times a year and work to promote good workplace relations, to provide information and advice to staff and management on EEO policies, and to support staff involved in

Photograph

complaints procedures. To promote EEO within the ATNF, staff talks are given at each of the ATNF sites. EEO talks are also given to summer vacation students and to new staff. The group has an EEO resource library and maintains extensive Web pages at http://www.atnf.csiro.au/overview/management/eeo.

Occupational health and safety

Each ATNF site has its own occupational health and safety committee, which meets at least four times a year to review issues and identify any new hazards. Each workplace is assessed annually by a member of the local committee, and a formal report made. Training programs in a number of areas (e.g. ergonomics, correct lifting techniques, electrical safety and defensive driving) are offered throughout the year.

Over a number of years the ATNF's rate of occupational health and safety incidents has been in line with that of similar institutions, such as the Anglo-Australian Observatory and the Very Large Array. In the past year the ATNF recorded a total of 15 incidents with a total time lost of 1.6 weeks. The standardized incidence rate of 115 incidents per 1,000 full-time equivalent employees, was somewhat lower than the standardized rate of 150 for all of CSIRO.

Photograph
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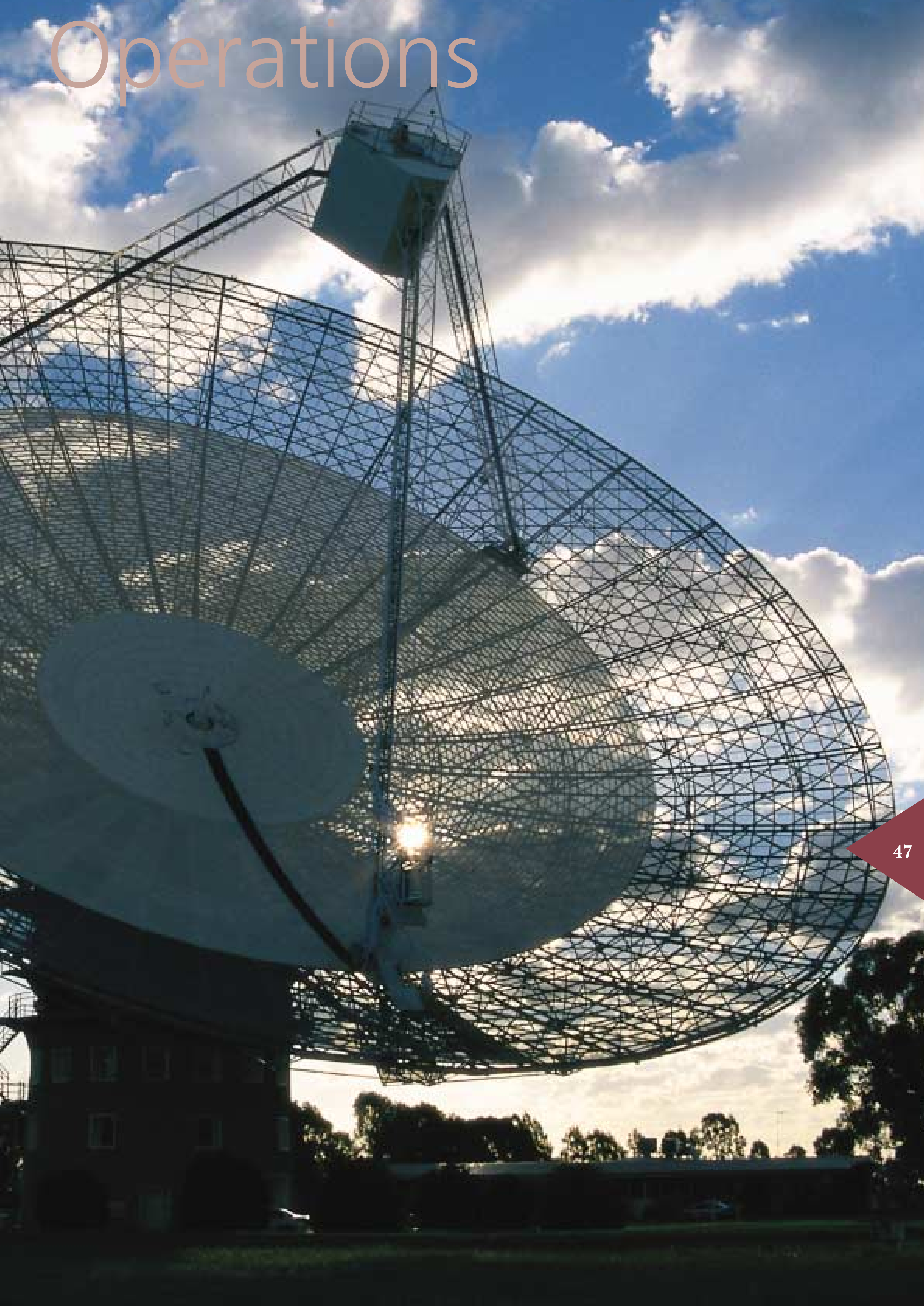
Operations



Observatory reports

Australia Telescope Compact Array

Staff

The overall observatory staff number was relatively stable during 2000 with approximately 32 full-time equivalent members. There were a number of staff changes, both departures and arrivals.

Departures

Tina Earle left after three years as Administrative Assistant.

Longest standing staff member Alan Spencer (Senior Technical Officer) retired after working for CSIRO at the Observatory since 1978 when the Solar Heliograph was in operation. Alan was a great source of knowledge of many aspects of the Observatory and its instrumentation, including the most recent developments. He continued to be very productive right up to his retirement on 31 March 2000.

Mark Bland resigned after more than eight years in the Electronics Group. Mark worked as Senior Technical Officer with the Array's cryogenic systems and also managed the Observatory's engineering drawings.

Graham Baines resigned after seven years at Narrabri. Graham worked first as receiver engineer in the Electronics Group, then took on senior roles, initially as Electronics Group leader then as System and Coordination Engineer. Graham has moved to take up a position at the Deep Space Communication Complex at Tidbinbilla.

Frederic Badia left after three years in the Computer Group where he worked on a number of software developments, including the "Online Imaging" system and a Web-based Compact Array scheduling program.

At the end of the year Electronics Group leader Ben Reddall departed for 12 months exchange leave to work for the University of Chicago at the South Pole on the Degree Angular Scale Interferometer (DASI).

Arrivals

Clive Murphy, a mechanical engineer, formerly working at the Cargill seed oil mill in Narrabri, joined the staff in September and is leading the Site Services and Engineering Group.

Cliff Harvey joined as a technical assistant in the cryogenics area in September.

Rudi Behrendt joined as a technician, also in September.

Anne Reynolds was appointed as administrative assistant in September, and in November began acting for Kylee Forbes who is taking maternity leave. The administrative assistant position was held on a casual basis through the year by Dianne Harris, and during Kylee's absence by Margaret McFee.

David Brodrick joined the Computer Group as a software engineer in December.

Observatory reports

Photograph
© CSIRO

Visitors

From June the observatory was host to visiting scientist Prof. A. Deshpande from the Raman Research Institute, Bangalore, India. Desh lived on site for his six-month visit and was accompanied by his family until September. During his visit Desh worked with ATNF staff on the prototype Pulsar Backend, and also on understanding the interferometer response when one antenna is shadowed by another.

Students

The 1999–2000 summer vacation scholars at the Observatory were Linh Vu and Rachel Deacon. Linh worked with Ravi Subrahmanyan on a mathematical project concerning digital filters. Rachel worked with Dave McConnell producing and analysing a deep 20-cm image of the globular cluster 47 Tucanae.

In December two new vacation students joined the Observatory for the summer: Elizabeth Claridge (University of Tasmania) and Tim Connors (University of Sydney). Liz worked with Steven Tingay, and Tim with Dave McConnell searching for extended radio emission from the globular cluster 47 Tucanae.

During 2000 the Observatory hosted three high school work experience students. All three were from the same school and Tim Kennedy organized a single joint project for them. The project involved purchasing an inexpensive kit to build a simple radio telescope to work at 20 MHz, with the aim of detecting Jupiter's strong decametric radiation. Unfortunately the Jovian ephemeris was not very suitable for the week chosen for the experiment. However the kit was successfully built and a surprisingly accurate measurement of the strength of the Galactic 20 MHz radiation was made.

The Observatory also hosted two older, university undergraduate work experience students who worked with Steven Tingay and Naomi McClure-Griffiths (visiting PhD student observer).

Array performance and time use

The performance and time use of the Compact Array in 2000 is summarized in Table 1. The total number of hours is greater than one year (371 days) because the October 2000 observing term extended into January 2001. Of the 6,705 hours of observations, 12.1% were conducted remotely over the computer networks from a variety of locations within Australia. The downtime figures give the hours lost due to equipment or operational failure during scheduled observations, with the percentage expressing the fraction of scheduled observing time lost. The time used for maintenance and installation work was larger than usual because of several periods of MNRF related installation work, particularly periods in June and July for optic-fibre installation and two weeks in

Table 1 Compact Array time use, 2000

	Hours	%
Observing	6705	76.3
Maintenance/installation	1424	16.2
Reconfiguration	375	4.3
Unallocated	278	3.2
Total	**8782**	**100.0**
Downtime	328.9	4.9

November and December for receiver and local oscillator installation. In spite of that, more than 70% of Array time was used for astronomy. Note the unusually high downtime figure, which was close to the target of 5%. This was dominated by two serious failures in the January observing term. An azimuth gear box on antenna 1 failed and required removal and extensive repairs, and a serious electrical failure occurred in antenna 6 which disabled that antenna for several days.

Table 2 summarizes the sources of lost time on the Compact Array during 2000, clearly showing the two large failures in the January term against antenna drives and power. Note that the downtime tabulated for the full Array is usually computed as one third of the time lost on a single antenna.

User feedback

Each observer is requested to assess the quality of support at the Observatory by giving a rating in the range 1–5 where 1 = poor and 5 = excellent. The results of these questionnaires are published in ATNF newsletters, presented to AT Users' Committee meetings and used by

Table 2 *Time lost on the Compact Array, 2000*

	hr			2000	
	00Jan	00May	00Oct	hr	%
Antenna drives	106.5	2.8	3.3	112.5	34.2
ACC	11.1	14.0	15.4	40.5	12.3
Power	26.0	3.1	5.0	34.1	10.4
Cryogenics	14.9	15.6	0.0	30.3	9.2
Correlator	14.6	11.1	4.6	30.3	9.2
Other electronics	1.4	5.9	7.9	15.2	4.6
General computing	8.8	0.3	2.0	11.1	3.4
Receiver	0.0	5.9	.3	10.2	3.1
Operator	0.8	8.8	0.2	9.7	2.9
Other	8.3	0.4	0.8	9.6	2.9
Comms problems	3.7	5.8	0.0	9.5	2.9
Weather	0.0	1.6	5.3	6.9	2.1
Encoders	1.6	2.4	0.8	4.8	1.4
Operations	1.5	1.3	0.7	3.4	1.0
Phase transfer system	0.0	0.2	0.2	0.3	0.1
Air conditioning	0.0	0.3	0.0	0.3	0.1
Totals	**199.2**	**79.4**	**50.3**	**328.9**	**100.0**

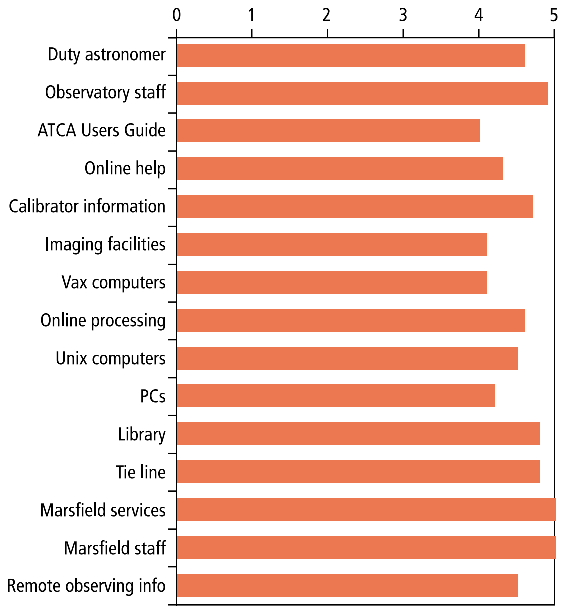


Figure 26 *Narrabri user feedback*

Observatory staff to direct development of observing support facilities. Figure 26 summarizes the questionnaire results from 36 responses received during 2000.

Compact Array calibration sources

During 2000 the program of reviewing all Compact Array calibration sources was continued and by the end of the year each of the 240 sources in the full calibrator list was reobserved at least once in each of the four centimetre-wave bands. A number were also observed at 12 mm and 3 mm. The results of the observations were published on http://www.narrabri.atnf.csiro.au/calibrators/ with information given for time variability, polarization and plots of visibility amplitude against baseline length.

The "Y2K bug"

On 1 January 2000 the Compact Array operated flawlessly through all three relevant "midnights" at 0:00h AEST, Civil

Time, and Universal Time. Over the previous 18 months the operating software for the Array had been examined and tested for the notorious "Y2K bug". The only problems encountered were minor: one with third-party software used in off-line backup of Unix and pc servers; and a curious formatting problem in a rarely used option for labelling export data CD-ROMS.

TECHNICAL DEVELOPMENTS

In 2000 the development work on the Compact Array was again dominated by the MNRF program, a major component of which is funding the upgrade of the Array to operate at high frequencies. The Array upgrade is expected to be complete by the end of 2002 with scheduled mm-wave observing commencing in mid-2003.

North spur and extra stations

Multi-pair cabling to new station posts was completed during the year. In November the north spur was used to reorder the antennas. This was necessary to get a short baseline for the new mm-wave receivers in antenna numbers 3 and 4, while keeping to the advertised 1.5B array configuration. This was an opportunity to do further checks on the modified long-travel drives in these antennas.

12/3-mm receivers

Two prototype receiver packages were installed in November 1999 and operated over the 20.6–22.8 GHz band. During the first part of 2000 they were the subject of a number of performance tests, both of the receivers themselves and of the antenna optics and calibration techniques. Later in the year each was refitted with new single-polarization 22-GHz low noise amplifiers (LNAs) which operated over the 17.5–25 GHz range, and a single channel at 3 mm (84.0–91.1 GHz). The receiver packages were installed in November 2000 and "first light" on a 3-mm interferometer was measured on 30 November (page 16). Since then the performance, optics and calibration testing has continued at both wavelength bands.

Local oscillator distribution

During 2000 optical fibres for local oscillator distribution were laid to almost all of the station posts. Each fibre must be spliced to a connection fibre at the station post and in the screened room; two thirds of the splicing has now been completed. Both the laying and the splicing were major jobs. The fibre laying was done in several sessions using a number of staff from both Narrabri and Marsfield. The splicing at the station posts was done in a specially constructed "splicing van" which provided a controlled environment for the splicing and a degree of comfort for the splicer.

Leigh Panton, an apprentice with the ATNF Narrabri electronics group, splicing fibres at a patch panel in the screened room

Antenna Control Computers

Work on the new Antenna Control Computers continued through 2000. The hardware interfaces between new machines and antenna equipment have been designed and are largely complete. Software development for interfacing the new antenna computers to the existing observing and array monitoring software has continued.

Pulsar Backend

During the last few months of the year outstanding progress was made with the Compact Array Pulsar Backend. This device will allow observations of pulsar profiles from the combined signal of all six antennas, giving a collecting area equivalent to a 54-m dish. The Backend provides spectra with up to 1024 channels in each of 1024 points across the pulsar period. It operates at a number of bandwidths up to a maximum of 64 MHz and can be used in any of the wavelength bands offered by the Compact Array. Martin Oestreich, Scott Cunningham and visitor Prof Deshpande from the Raman Research Institute, Bangalore, have made good progress with the project and made some successful observations with a prototype operating on a single polarization channel. Figure 27 shows a profile of the pulsar J0437-4714 at 1410 MHz, observed using the Pulsar Backend.

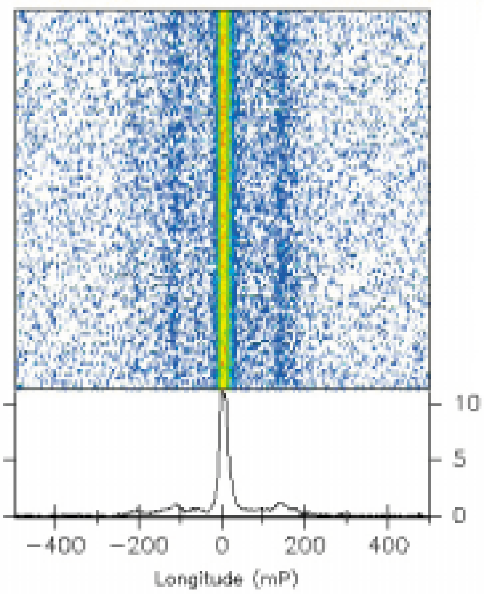


Figure 27 *An averaged profile for the pulsar J0437-4714. The square box shows the strength of the pulsar signal plotted as a function of the pulsar period on the horizontal axis, and time on the vertical axis. The averaged profile is shown below the box.*

Receiver turret positioning

Improving the repeatability of receiver turret positioning has been a goal for more than a year. The small non-repeatability was originally found to limit the precision of circular polarization measurements in 1998. Improvements have been made by providing machined locating notches for each receiver package (replacing the original low precision notches) and careful adjustment of the rollers which bear on the turret ring. These adjustments have been concluded to the point where the expected non-repeatability in axial position is about 0.2 mm. The tangential repeatability is now limited by play in the thruster mechanism itself, which is yet to be measured.

Infrastructure and site works

The site improvement works associated with the north spur construction were completed in 2000. The Observatory roads, which had been damaged during the construction works (because of several periods of very wet weather), were repaired, and most of the roadway around the site centre was resealed. The new access and parking areas around the tourist Visitors Centre has been finished off with a wooden post and rail fence.

Late in 2000, work commenced on rebuilding the stairs in the Control Building. These were in breach of building regulations, being dangerously steep.

Parkes

Performance and time use

The fraction of time scheduled for all observations in 2000 was 82%, down slightly on the figure of 84% for 1999. However, time lost both to equipment faults and to poor weather were also down significantly on the 1999 figures, resulting in an unchanged figure of 79% for the fraction of time successfully used for observations.

The reduced rate of equipment failures reflects in part the increased reliability of two major subsystems overhauled in 1999: the online software, which underwent a major upgrade, and the receiver translator system, which received important corrective repairs.

The multibeam and other receiver systems all performed well throughout the year without any significant problems. Some of the older components of the telescope drive and control subsystems are beginning to show their age and will require attention in the next year or so.

User feedback

The Web-based fault tracking system is continuing to prove an extremely important tool in successful Observatory operations, and a similar system has now been adopted at Narrabri. The Web-based user questionnaire is also working well, with good levels of response from users (both in terms of numbers, and positive evaluations). Figure 28 shows the Parkes user feedback for 2000, on a scale of 1–10 where 1 = poor and 10 = excellent. Responses were received from 32 observers.

The issue of radio frequency interference mitigation continues to be a concern among users, with the incidence of all forms of external interference, both terrestrial and satellite, forever on the increase. Additional shielding measures are also required to protect observations from the rapid increases in CPU clock speed in new Observatory equipment.

Major Activities

Surveys

The HIPASS/ZOA surveys and the Galactic pulsar survey again accounted for approximately 50% of scheduled observing time this year. Observations for the original HIPASS and ZOA surveys were completed around mid-2000, with the northern extensions both well underway and due for completion around mid-2001.

Observations for the Jodrell Bank-ATNF-Bologna pulsar survey are now approximately 88% complete (at January 2001), and are continuing to detect several new pulsars for each day of observing time. The remainder of the survey and the follow-up confirmation and timing observations will continue throughout 2001 and into 2002. The success of the survey has required more time for the follow-up observations than was originally envisaged.

Observatory reports

Photograph
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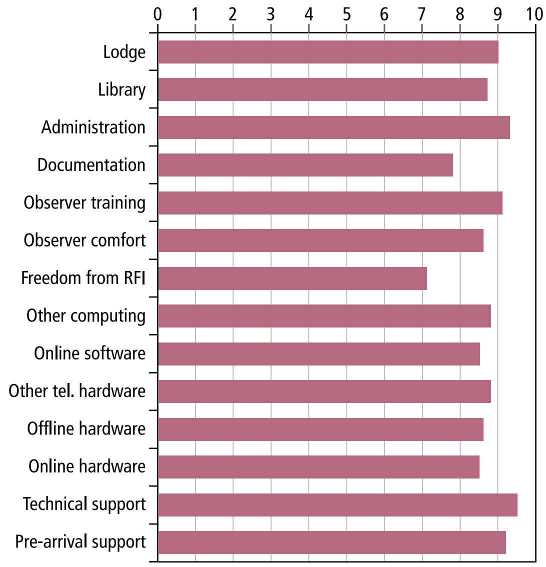


Figure 28 *Parkes user feedback*

Spin-off projects from the major surveys, targeting individual objects or regions of specific interest continue at a steady level, exploiting the excellent performance of the multibeam receiver in this mode.

Pulsar timing

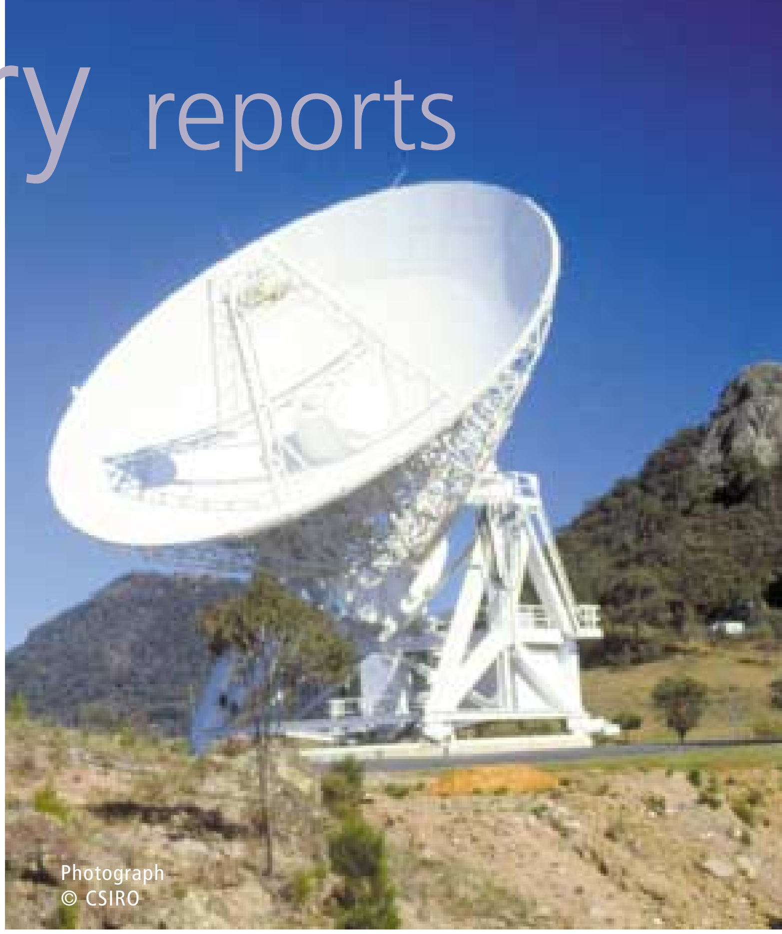
A major new project undertaken at the Observatory in 2000 has begun to yield significant and exciting new results. Timing measurements of the millisecond pulsar J0437-4715 were begun on a semi-daily basis, in a collaborative program between scientists at the University of Swinburne and ATNF. Timing residuals of unprecedented accuracy have been obtained for this binary system (page 26).

Technical developments

With the improvement in the accuracy of pulsar timing measurements made at the Observatory, serious attention has been given to the Observatory GPS systems to ensure the best possible performance in this area. Two additional GPS receivers have been installed on different locations at the Observatory site to overcome the shadowing and multi-path effects of the 64-m telescope itself. A "common-view" GPS receiver is currently being assembled for installation in 2001, which will give access to a second primary time standard, for additional accuracy and intercomparison.

The Telescope Control System (TCS) software commissioned in 1999 performed well in 2000, with only a few minor problems. With a steady flow of improvements and enhancements to this system, a regime of software control implemented at the Observatory ensures quick recovery from software problems by allowing easy reversion to an earlier release at any time.

The Parkes local oscillator conversion system is now fully operational and was used successfully on many occasions in 2000, allowing new modes of operation and reduced setup times.



Mopra

Performance and time use

A Memorandum of Understanding was set up between ATNF and the University of New South Wales (UNSW) in December 1998. Under this agreement, the University operates the Mopra antenna for three months of each year for three years, in return for financial support of the antenna's operations and resurfacing. For half of that time the telescope is used exclusively by the University's staff and students; for the other half, the University operates the telescope as a National Facility. The University run the telescopes in winter, usually the best season for millimetre-wave observing. The UNSW has successfully operated the Mopra telescope during the winters of 1999 and 2000, to the mutual benefit of both the ATNF and the UNSW.

During 2000 the Mopra telescope continued to be used for 3-mm single dish astronomy, for Very Long Baseline Interferometry (VLBI) as part of the Long Baseline Array, and for space VLBI. The University operated the telescope for the period 8 June to 25 September. Table 3 summarizes the telescope usage for the year outside the UNSW period.

Staff

Early in the year, after 31 years with CSIRO, Robina Otrupcek retired. For the last three years Robina was the only member of ATNF staff permanently stationed at the Mopra Observatory. Robina continues to serve the Observatory on a casual basis, particularly for support of VLBI experiments.

Technical developments

Early in the year some effort was put into understanding the telescope optics at 3 mm. This was necessary after the resurfacing out to 22-m diameter with solid panels in 1999 and the new "optics box" installed to illuminate the full aperture. Final verification of the optics and antenna efficiency will not be made until some improved calibration techniques are developed and will possibly require a simpler optical configuration such as that used on the Compact Array antennas.

The computer WARRUM, the Unix file server, was upgraded to a Sun Ultra-10 with a 36-Gbyte disk. It has also been equipped with a 7-Gbyte exabyte magnetic tape drive.

	Days
3.5mm	43
LBA	19
Space VLBI	7
Total astronomy	69

Table 3 *Mopra time use, 2000*

The Australian Long Baseline Array

Staff

A new postdoctoral fellow, Dr Roopesh Ojha, started with the VLBI group in 2000. This position is funded via a collaboration with United States Naval Observatory for work on a large VLBI astrometry program to significantly improve the astrometric grid in the southern hemisphere.

Upgrades

The University of Tasmania is continuing the upgrade of the Hobart and Ceduna telescopes under the MNRF program.

During 2000, the Hobart antenna was upgraded with a new prime-focus cabin and feed translator. The new system allows four feeds to be mounted at prime focus and switched relatively quickly with the translator. This has greatly simplified and speeded up receiver changes in Hobart.

Ceduna is now operating from 2.3–12 GHz, with the 22-GHz system under development and testing. For much of 2000, Ceduna was operated remotely from Hobart, particularly for VSOP observations. However, receiver changes still require manual intervention.

The Long Baseline Array correlator control computer was upgraded and changed to a Unix system and two new 8-GByte hard disks were installed. These changes have significantly improved and streamlined the operation of the LBA correlator facility.

HALCA/VSOP

The radio astronomy satellite HALCA (Highly Advanced Laboratory for Communications and Astrophysics) was launched in February 1977. This satellite is used together with a global network of ground-based radio telescopes, for the VLBI Space Observatory Program (VSOP). In October 1999, serious spacecraft problems interrupted VSOP operations. Observations in a restricted mode began again in March 2000 and continued to the end of the year. The spacecraft has one inoperative reaction wheel and hence lost some operational flexibility. Mopra was again heavily used by the VSOP Active Galactic Nuclei Survey program. NASA tracking will continue only until February 2002. After this it is expected that VSOP observing will be scaled down considerably.

User support

The first Long Baseline Array users meeting was held on 25 October 2000. A report on the operational procedures of the LBA was presented and discussed and feedback sought from users. As a result, the documentation for the LBA is in the process of being extensively rewritten and expanded.

Proposals and scheduling

The demand for time on the LBA in 2000 remained healthy, with an effective oversubscription rate of 1.7, a more typical level than the unusually high rate of 3.0

experienced in 1999. Proposals covered diverse fields of research, with particular emphasis on the unique LBA capabilities in high spectral resolution.

Access to the NASA Deep Space Network (DSN) Tidbinbilla telescopes continued to present problems with the effective scheduling of the LBA array, particularly for sensitive observations requiring the large 70-m antenna. This was also identified as a significant concern at the users meeting. Steps are being taken to liaise more closely with the DSN and improve access.

Operations

Observations on the LBA continued in 2000 at the nominal rate of about one week per term. However, for the October 2000 term the observations were postponed until January 2001 and are not included in this report.

Overall the LBA performed well and a summary is shown in the table below. Most telescopes had a success rate of over 90%. However, the Ceduna antenna was unavailable for a five-day session due to a broken feed and this was the main effect on lowering the overall LBA performance. In addition, VSOP observations at Mopra were severely affected in November following changes in observing software and schedules. For the whole array, after calculating the percentage loss of data due to all known sources, the rate for successful observations with the LBA was 84%. The success rates for LBA observations and for VSOP observations are shown in the following two tables.

Table 4 *Long Baseline Array observations, 2000*

Telescope	Parkes	ATCA	Mopra	Hobart	Ceduna	Tidbinbilla	Hartebeesthoek	LBA
Hours observed	353	358	342	205	202	145	30	374
Success rate %	97	97	92	90	71	92	100	84

Table 5 *VSOP Observations, 2000*

Telescope	ATCA	Mopra	Hobart	Ceduna	Hartebeesthoek
Hours observed	49	133	49	84	75
Success rate %	96	79	96	97.5	96.5

Technology developments

MNRF program

Overview

The ATNF, together with the University of Tasmania, has embarked on a set of substantial projects under the Commonwealth Government's Major National Research Facilities (MNRF) program, governed by a contract signed with the Government in February 1997. The contract provides $11M to:

- **upgrade** the Australia Telescope Compact Array to work at high (millimetre-wave) frequencies;
- **extend** the VLBI capabilities of both the ATNF and the University of Tasmania, and operate the University's Hobart and Ceduna observatories as national facilities;
- **extend** international collaboration in astronomy, with funds administered by the ATNF, acting on advice from the Australian Academy of Science's National Committee for Astronomy; and
- **perform** strategic research on mitigating radio frequency interference and on array technology for the next generation of radio telescopes.

Each of these projects has sub-components, which are described below. The choices involved in determining the content of the upgrade were made after extensive consultation with the ATNF's user community. Full details of the MNRF program can be found at www.atnf.csiro.au/mnrf/.

The upgraded telescopes of the ATNF and University of Tasmania will give Australian astronomers important new observational tools. In particular, the millimetre-wave upgrade of the Compact Array, to be completed in 2002, will give astronomers their first chance to image the signature emission from many cosmically important molecules active in southern hemisphere regions. The upgraded array will be able to work in a "tied-array" mode, which will give it a collecting area equivalent to a 50-m diameter millimetre-wave dish — an unusually powerful instrument.

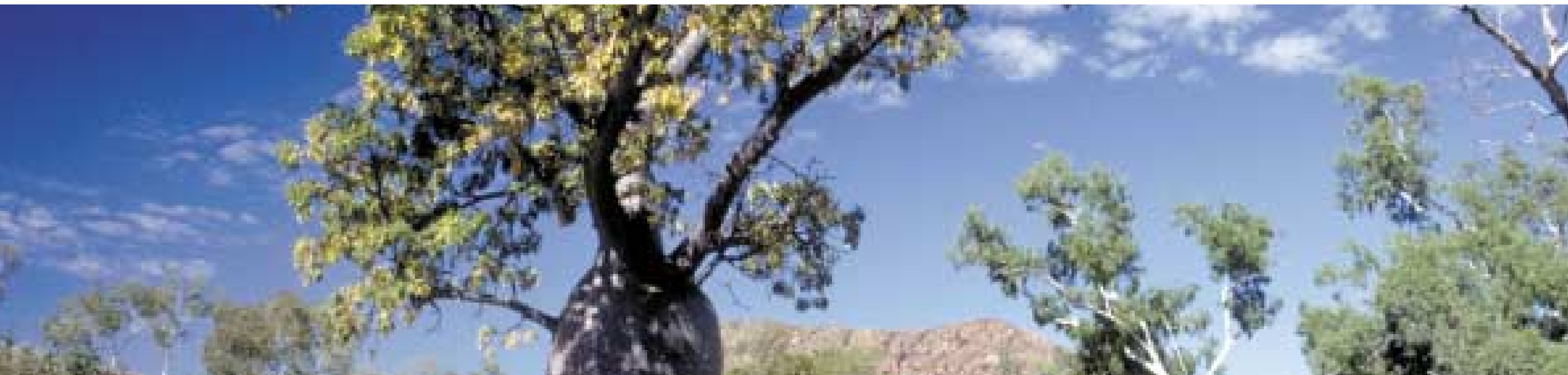
Management of the MNRF program

The ATNF Director acts as MNRF Program Director, while the ATNF Steering Committee provides policy advice and reviews an annual report on its progress. A second, external, committee advises on technical aspects of the upgrade. Committee members are listed in Appendix C.

In September 1999, a sub-group of the ATNF Steering Committee made a formal mid-term review of the MNRF program. Their report found that most of the MNRF projects involved were making excellent progress and were keeping to time and budget estimates.

ATNF MNRF upgrades and extensions in 2000

Good progress continues to be made in the high-frequency upgrade of the AT Compact Array (ATCA) at Narrabri. This



extension adds two new observing bands to the ATCA: 12 mm (16–25 GHz) and 3 mm (85 to >95 GHz); it also increases the maximum angular resolution of the Telescope by an order of magnitude. A major milestone was reached in November 2000 with the first southern hemisphere observations of the upgraded array at 3 mm, taken using two antennas (page 16). While considerable efforts are being used for system testing and commissioning, the success of the first millimetre observations highlights the excellence of the MNRF engineering. It is expected that the full mm-wave systems will be first offered for scheduled observing in 2003.

ATCA high-frequency upgrade

The 12- and 3-mm receivers are a key component of the high-frequency upgrade. An important feature of the high-frequency receivers is that they use MMIC (monolithic microwave integrated circuit) technology in the low-noise systems. In 1999 a decision was made to use Indium Phosphide (InP) MMICs for both the 12- and 3-mm receivers, rather than the Gallium Arsenide (GaAs) MMICs originally proposed for the 3-mm receiver. The InP MMICs will greatly increase the sensitivity of the array.

The high-frequency receivers are contained in a single multiband dewar, with the CSIRO-designed low-noise amplifiers operating at physical temperatures near 20 K. A substantial technology development program has resulted in the ATNF now having the capacity to reliably bond wire connections to the tiny integrated chips and to mount the devices in precision metal housings. Laboratory tests of packaged, cooled, 3-mm amplifiers show typical amplifier equivalent noise temperatures of 55 K at 86 GHz. When used in the test interferometer at Narrabri, system temperatures of approximately 270 K were obtained. At 12 mm, amplifier equivalents of 20 K were measured in the laboratory, and telescope system temperatures of around 100 K were recorded. Interferometer test arrangements were sub-optimal, especially at 3 mm, and system temperatures of less than 200 K at 86 GHz are expected with final (higher gain) designs and average winter observing conditions.

ATCA surface extensions

Five of the ATCA antennas have been resurfaced with solid panels over their full 22-m diameter, doubling their sensitivity at 100 GHz. The antenna panels were adjusted in 1999 and measured to have an

Les Reilly, a member of the ATNF receiver group, working on a newly installed millimetre-wave receiver package.

averaged rms surface accuracy of 0.25 mm.

During the 3-mm interferometry in November 2000, typical antenna efficiencies were still rather low and a pronounced coma lobe was evident in the beam patterns. However, subsequent adjustment of the antennas has led to improved efficiencies and clean beam patterns. At present, the overall antenna efficiencies are approaching 40% at 86 GHz, close to that expected with the originally specified surface accuracy of 0.15 mm.

Atmospheric phase correction

A phase-correction system will be used to correct the wavefront (and hence image) distortion caused, at millimetre wavelengths, by moving cells of atmospheric water vapour. The phase correction system will use a room-temperature four-channel radiometer on each antenna, designed to detect water-vapour emission while rejecting spurious emission from clouds or other sources.

Two prototype water-vapour radiometers have been delivered by Astrowave P/L: these four-channel 22-GHz units were developed in consultation with ATNF engineers and system scientists. The intention is to sense water-vapour emission from the atmosphere, and to use the measurement to correct the image-distorting effects of water-vapour irregularities. First indications are that, while the off-axis optics arrangement will work well, the instrumentation itself requires refinement before further orders are placed. Long-term stability is excellent, but flicker noise in the present high-gain 22-GHz system means that one-second radiometric limits are an order of magnitude too high for satisfactory phase correction. Modifications to the prototypes are currently underway and further tests will be conducted in April 2001.

ATCA local oscillator distribution

The local oscillator (LO) in a synthesis telescope is the master reference signal to which all receivers are frequency-locked, and against which variations in signal phase (caused, for example, by structure in cosmic sources) are measured. The LO distribution must therefore be extremely stable. The new ATCA LO distributor is based on a "star" topology fibre-optic network which uses an optical fibre connection from each of the antenna station posts to the Control Room. Despite weather-related delays, almost all the new fibre has now been installed. However, because of staff changes and accidental damage to a fibre termination facility, the termination schedule has fallen behind the original estimates. While the new LO system will become progressively available for use in test observations, the estimate for completion of the entire system is now June 2002. Field tests of the new LO system indicate that the design specification of

Mark Leach helping with the cable laying for the local oscillator systems at Narrabri. This task involves threading 34 km of optic fibre through the Compact Array cable trenches.

less than five degrees phase jitter at a frequency of 100 GHz will be achieved.

Extra stations and the north spur

Under the MNRF program, four new stations have been built on the east-west track of the Compact Array, to give better short-spacing coverage. Extra funding from the CSIRO Capital Investment program has enabled the construction of a further five stations on a north spur line, 214 m long. This spur will let the array better cover the u-v plane when observing with high antenna elevations; these minimize atmospheric distortion at millimetre wavelengths.

The civil engineering component of these projects was completed in 2000 and, while delays have been experienced at Narrabri in cabling all stations, the new facilities will be available concurrently with the completion of the LO distribution system.

Antenna Control Computers

The stringent demands of high-frequency observing, the expansion of ATCA control and monitoring requirements, and concerns about the reliability of the present Antenna Control Computers (ACCs), have combined to make delivery of new-generation ACCs a priority.

Work has continued for some time to develop object-oriented software to run in the new computers. Development work has also begun on the hardware interfaces between antenna systems and input/output devices in the new computers. Due to some delays in the ATOMS project, mainly associated with staff changes, the new ACCs are expected to be installed by mid-2001, about one year later than originally forecast.

The Australian VLBI array

The MNRF program provides for VLBI upgrades to the ATNF antennas at Mopra, Narrabri and Parkes and the University of Tasmania's antennas at Hobart and Ceduna. The ATNF upgrade of the Australian VLBI network is now complete and the extended network is in routine astronomical use. Figure 29 is an example of the use of the network to probe Centaurus A, a well-known southern radio galaxy.

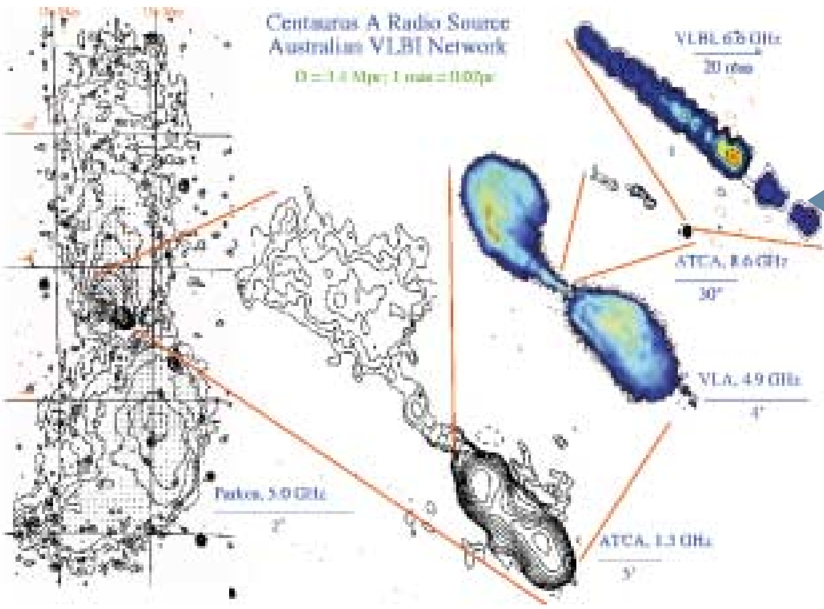


Figure 29 *Images of the radio galaxy Centaurus A obtained using progressively increasing angular resolution. The highest resolution image (right) shows the "jet" of the galaxy and was produced using the Australian very long baseline interferometry (VLBI) array, incorporating the newly commissioned Ceduna antenna operated by the University of Tasmania. The VLBI array has been upgraded substantially in the course of the MNRF Program, with most of the upgrade activities now being complete.*

International collaboration

The MNRF program funding included an allocation of $1.26M for international collaboration. Under this scheme the Australian Academy of Science's National Committee for Astronomy allocated funds for ten projects in 1997 and a further two projects in 1998. Funding for this program is now essentially exhausted and no additional funds were allocated to new projects in 1999 or 2000. Details of the funded projects can be found in the MNRF annual reports, available on the ATNF Web pages.

Executive Special Project

In December 1997 CSIRO's Chief Executive Officer, Dr Malcolm McIntosh, announced a number of projects to be undertaken by large research teams within CSIRO in the 1997–2000 triennium. One of these projects was a joint proposal of the ATNF and CSIRO Telecommunications and Industrial Physics to develop millimetre-wave integrated circuits for radio astronomy and telecommunications. About $2.4M was granted for this work. Devices to be produced under the program include monolithic microwave integrated circuits, a high-speed two-bit sampler and a digitiser with photonic inputs and outputs.

Monolithic microwave integrated circuits

Indium Phosphide (InP) MMICs will be produced for three frequency ranges: 85–110 GHz, 30–50 GHz and 16–26 GHz. The US foundry TRW delivered the first InP high electron mobility transistor (HEMT) wafers in December 1999. Following successful on-wafer tests, the wafers were returned to TRW for dicing in early 2000. The individual chips were then returned to ATNF in August 2000 and bonded and packaged by ATNF staff. The 3-mm and 12-mm InP MMICs were retrofitted to two prototype receivers on antennas 3 and 4 on the Compact Array in November 2000. Both the system temperatures and bandwidths achieved were outstanding. The final foundry run for production numbers of these circuits will take place in late 2001.

A high-speed two-bit sampler (digitiser)

Digitisers sample the radio frequency down-converted from an antenna to produce a coarse digital signal for processing inside a correlator. Leading digitisers sample at a rate of about two Gigabits per second. To improve on this performance integrated circuits need to be

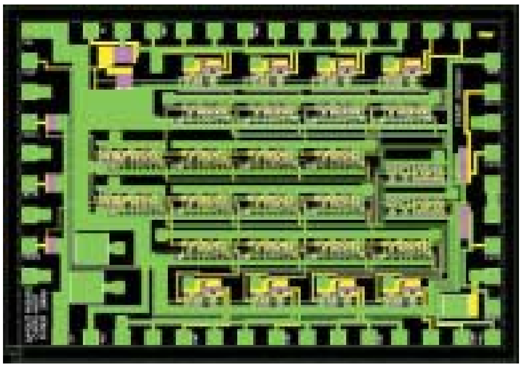


Figure 30 *The circuit layout for a high-speed two-bit digitiser with an integrated demultiplexer, designed by CSIRO to sample astronomical signals at up to eight Gigabits per second. The integrated circuit has a size of 3.2 mm x 2.2 mm.*

Photograph
© J Sarkissian

used, to avoid the parasitics and delay and matching problems that are inherent in discrete components. Several different kinds of digitiser have been designed, the most ambitious of which is a two-bit digitiser with integrated demultiplexer, designed to work at up to eight Gigabits per second. This was implemented in a developmental (not commercially available) InP heterojunction bipolar transistor (HBT) technology.

The HBT designs were completed at the end of March 2000 and submitted to the foundry shortly after, with the fabricated chips being received in mid-October 2000. On-wafer tests of the digitiser were then performed with encouraging results up to at least 10 Gigabits per second. The wafers were returned in late December and work will now proceed on packaging and system integration of the devices, which will allow their performance to be assessed in-system with inputs as expected in typical astronomical use, and hence the real useful speed of the devices to be determined.

A digitiser with photonic inputs and outputs

This device too was fabricated with InP HBT technology, which allows photo-receiver circuits to be integrated with the digitiser. The sampling clock output is delivered by optical fibre and the digitiser's output fed back to fibre via externally bonded laser diodes. This arrangement produces very low radio-frequency interference emission and is an obvious cost-saving pathway for applications such as the Square Kilometre Array.

On-wafer tests for this photonic I/O digitiser were also successful in showing correct operation up to the two Gigabits per second limit determined by the optical source. As indicated before, the wafers were returned in late December. A few test devices will be packaged and placed in a demonstrator system that will initially be sited at Parkes, making use of optical fibres recently installed to the focus cabin.

The Square Kilometre Array

The ATNF is one of a consortium of major radio astronomy institutions in seven countries now planning the world's next-generation large radio telescope, the Square Kilometre Array (SKA). This instrument's one million square metres of collecting area will make it 100 times more sensitive than the best present-day instruments: this area will be distributed across perhaps 2,000 km in a location yet to be decided. Using a combination of technologies, the SKA will cover frequency ranges from 150 MHz to above 10 GHz. Construction of the instrument is expected to start by 2010. The SKA has been identified as the ATNF's major long-term project. A current priority is to secure long-term R&D funding, preferably extending beyond the international technology and site decisions date of 2005.

Technology developments

SKA steering committee

An important milestone in Australian SKA work was reached in late 2000 with the formation of the Australian SKA Consortium, a 14-member steering committee constituted from CSIRO, other research organizations, industry, science policy bodies and professional organizations. The first meeting of the Consortium is scheduled for February 2001 and will include a one-day astronomy and engineering science workshop.

SKA meeting

An international symposium on “Technical pathways to the SKA” was held at Jodrell Bank (UK) in June 2000. The Australian SKA work was well received. A number of oral presentations and poster papers highlighted work in all of the areas outlined in this report and the conference provided a reference against which to check the quality of the ATNF work and the effectiveness of our strategic directions. CSIRO program members will continue to play significant roles in the governance and direction of the international SKA project; these members include R. D. Ekers (Chairman, International SKA Steering Committee), B. MacAThomas (Site Selection Committee) and P. Hall (Engineering and Management Team).

Research program

In late 1999, CSIRO made a $1.5M allocation to the radio astronomy sector for strategic development of the SKA. The SKA research program provides a framework for the coordination of all SKA work. The primary program aims are to:

- produce engineering prototypes of key SKA systems;
- explore the possibility of the SKA being sited in Australia;
- support SKA research by young engineers and scientists; and
- raise public awareness of the international SKA project.

More specifically, the program will include:

- prototyping of a three-dimensional radio lens antenna which will allow many simultaneous, randomly placeable beams on the sky;
- prototyping of an integrated receiver using CSIRO monolithic microwave integrated circuit (MMIC) technology;
- development of radio-frequency interference mitigation techniques and components;
- characterization and testing of potential Australian SKA sites, including the confirmation of possible sites as radio-quiet zones; modelling of different possible array configurations;
- collaboration with other CSIRO divisions and universities on a range of science and engineering issues; and
- liaison with the Australian Government and with international groups on policy issues.

Technology developments

Major projects in the past year have involved work in four areas: antennas, interference mitigation, array configurations and site studies. The antenna work is being undertaken mainly by CTIP staff, with input from the ATNF in framing prototyping and evaluation strategies. In the interference mitigation area, collaborations with US and Dutch colleagues have grown rapidly and have been important in producing impressive early results. Cooperation with the WA Government has been central to framing first-round site and associated outreach projects. For more information about Australian SKA project work, refer to http://www.atnf.csiro.au/SKA

Antennas for the SKA

The SKA specifications call for many simultaneous, widely separated beams. Building antennas which are capable of efficient operation over a wide frequency range, and which yield many beams placeable over the whole sky, is a formidable challenge to designers. CSIRO work is currently assessing the feasibility of spherical refracting antennas (Luneburg lenses) for the SKA application. Cost and loss issues make the refracting solution viable only if new ways of producing artificial dielectrics can be found. Following a number of discussions with materials and manufacturing specialists, small-scale cross-CSIRO projects are now in place. The intention is to produce a range of prototype dielectrics using various processes, including a new chemical technique. In parallel with the materials study, the development of electromagnetic design and analysis software, based on a finite difference time domain formalism, is continuing. If the materials issues are resolved, the intention is to design and fabricate a 3- to 5-m diameter lens by June 2003. A recently established collaboration with Russian radio astronomers and their commercial partner should give CSIRO a demonstration 0.9-m diameter lens by mid-2001.

Interference mitigation

To meet its scientific objectives, the SKA will need to observe outside the narrow bands reserved for radio astronomy. As part of the SKA research program, the ATNF is actively involved in the development of both pre-correlation and post-correlation interference-mitigation techniques.

The ATNF has made extensive use of its “software radio telescope” concept to develop and test interference mitigation algorithms on real data. Using the S2 VLBI system, signals (astronomical and interference) have been recorded coherently from the Parkes radio telescope and individual elements of the ATCA. These recordings have been distributed internationally to several groups interested in new signal processing techniques and, using workstation and super-computer facilities in Australia, it has been possible to experiment with, and evaluate, a number of different approaches. In common with most other groups, initial ATNF work involved coherent adaptive processing. However, new techniques have been developed which invoke post-correlation analogues of the adaptive process, vastly reducing the computational load and making interference mitigation testable, for the first time, on real telescopes (Figure 31). The emphasis is now on evaluating the effectiveness and robustness of the technique using the ATCA and, over the next two years, on making interference mitigation tools available to observers.

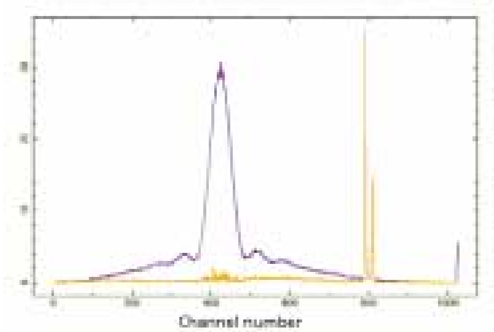


Figure 31 *A post-correlation approach to interference mitigation showing the effectiveness of the technique in suppressing a spread-spectrum satellite signal (centred at channel 420) while leaving an OH-maser source (centred at channel 800) unaffected. The horizontal axis is labelled in ATCA correlator channel numbers over an 8-MHz bandwidth and the vertical axis is an arbitrary linear scale.*

In a complementary interference mitigation study, a research contract with the School of Information and Electrical Engineering at the University of Sydney has produced interesting proposals for incorporating photonic filters into analogue optical-fibre signal transmission systems — potentially useful in the SKA and several present-day telescopes.

Array configurations

At this early stage, SKA designers are studying optimum ways of distributing the one square kilometre of collecting area. In 1999 an initial ATNF investigation of possible SKA array configurations began with the characterization of antenna distributions and u-v plane coverages for a large number of possible configurations. (The u-v plane coverage of an array is related to the image quality that can be achieved). These configurations included random, gaussian, Y-shaped, ring and spiral-shaped arrays of various types. The requirement for both high-brightness sensitivity and good u-v coverage on all scales led to the selection for further study of a close-packed central site, combined with a logarithmic spiral as the best compromise. Sample configurations of VLBI-scale spirals that span the Australian continent have also been generated.

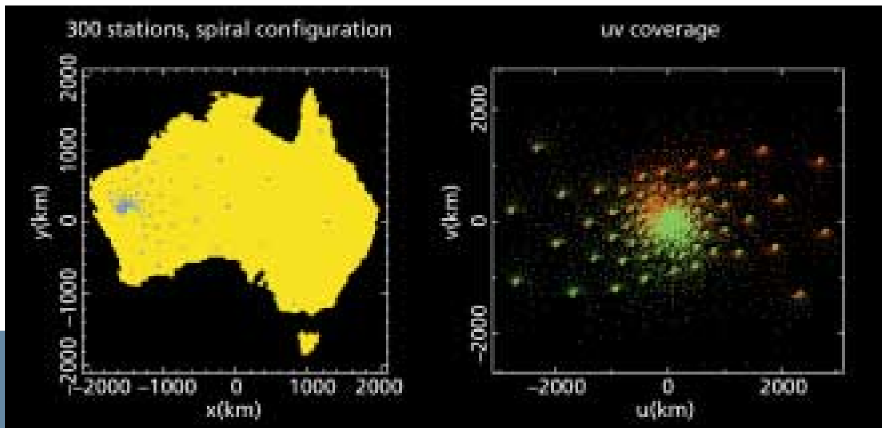


Figure 32 *A possible SKA configuration. The configuration is a combination of a hexagonal central site close-packed with stations and a seven-armed spiral going out to VLBI distances. The total number of stations is about 300 and the effective area per station is 3,300 m^2. Out to about 1,000 km the array has fairly uniform snapshot u-v coverage. To cover the range from 1,000–3,000 km integrations of about 9–12 hours will be needed for optimum u-v coverage.*

While this project has been a small-scale one, it has produced some important insights into array layout principles. As an example, Figure 32 shows a multi-arm "log-spiral" configuration using 300 stations. This configuration yields the required high brightness sensitivity on arcminute scales, good instantaneous u-v (snapshot) coverage to 300 km, and effective coverage on VLBI scales with some time integration. It also produces good synthesised beam patterns and is relatively economical to connect using optical fibre or other media.

Site investigations

While most efforts in this area have centred on formalizing a joint approach with the Government of Western Australia (WA) to evaluate sites in that state, there has also been interest from South Australia and other states in hosting the SKA. In the case of WA, first-round investigations have narrowed the field to two or three promising sites. Contractors funded by the WA Government will begin radio frequency interference characterization around April 2001 and CSIRO will evaluate and present the results. As well as the investigative project, an outreach project aimed at local government and rural communities has also been developed; this promises to be generally useful within Australia. It is important to note that, as well as characterizing specific sites, the CSIRO project is a case study aimed at contributing important principles and guidelines to the international SKA site search. Running in parallel with the site project has been a smaller project to investigate the merits and practicalities of a radio-quiet reserve — an apparently feasible concept in rural Australia and one which could, if implemented, be influential in attracting the SKA to this country.

Integrated RF systems – A new project

From the beginning of 2001, a fifth project will be incorporated into the CSIRO SKA program. Central to the success of the SKA will be low-cost, broadband, low-noise, receivers – probably integrated with feed assemblies and perhaps supporting optical fibre interfaces. With CSIRO's rapidly growing expertise in monolithic microwave integrated circuit (MMIC) design, it is a natural progression to apply this technology to the SKA. The intention is to combine the requirement for a high level of integration with ideas for making "robust" systems able to operate linearly in the presence of man-made interference. Using the mechanism of a shared postdoctoral appointment, much of the expertise generated will be shared with selected honours and postgraduate students at the University of Sydney.

Industry liaison

The ATNF is actively promoting the SKA and welcomes expressions of interest from Australian industry in collaborative research and development programs. Enquiries should be sent to Dr Peter Hall (phall@atnf.csiro.au).

Photograph

Appendices

A: Financial information

Expenditure budget 1999–2000	$1,000s
Operation of the Paul Wild (Narrabri) Observatory[1]	2,845
Operation of the Parkes Observatory[2]	2,030
Research Support Marsfield (ATNF contribution)[3]	1,920
Engineering and development	2,430
Office of Director	680
Astrophysics program	1,171
Computing	1,033
National Facility support	830
Major repairs and maintenance	220
Research grants	90
Executive Special Projects	300
MNRF project	2,720
Square Kilometre Array	300
Corporate repairs and maintenance	160
CSIRO capital investment plan	400
TOTAL	**16,642**

Revenue budget 1999-2000	
Direct appropriation	12,228
Research and services revenue	267
MNRF project	2,030
Other external revenue[4]	700
Corporate repairs and maintenance	160
CSIRO capital investment plan	400
TOTAL[5]	**15,785**

Notes:

1. Includes the operation of the observatory's Visitors Centre and the Mopra Observatory.
2. Includes the operation of the observatory's Visitors Centre.
3. The ATNF shares its Sydney headquarters with CSIRO Telecommunications and Industrial Physics.
4. Revenue generated from ATNF activities such as the ATNF's visitors centres and observatory accommodation.
5. The revenue shortfall was funded from ATNF reserves.

B: Staff list,

1 JULY 2000

ATNF Staff

SYDNEY

J E Archer *(Administration)*
J M H Barends *(Astrophysics/Computing PA)*
J Bell *(ARC Fellow/SKA)*
R J Bolton *(Receivers)*
M A Bowen *(Receivers)*
M L Bromley-Gambaro *(Scientific & Community Liaison)*
J W Brooks *(Assistant Director, & Engineering Manager)*
W N Brouw *(Astrophysics/Computing)*
M R Calabretta *(Computing)*
G J Carrad *(Receivers)*
J L Caswell *(Astrophysics)*
J M Chapman *(National Facility Support)*
R R Chekkala *(Electronics)*
E R Davis *(Electronics)*
E de Blok *(Bolton Fellow/Astrophysics)*
T K Denmeade *(Scientific & Community Liaison)*
A R Dunning *(receivers)*
R D Ekers *(ATNF Director)*
R H Ferris *(Electronics)*
G J Gay *(Receivers)*
T J Getts *(LBA)*
R G Gough *(Receivers)*
G R Graves *(Receivers)*
E Hakvoort *(Receivers)*
P A Hales *(Electronics)*
P J Hall *(Head, SKA Program)*
R F Haynes *(Head, Scientific & Community Liaison)*
A Hopkins *(USyd/ATNF Research Fellow)*
P J Howson *(Divisional Secretary)*
S A Jackson *(Receivers)*
H P Kanoniuk *(Receivers)*
L Kedziora-Chudczer *(AAO/ATNF Post-doctoral Fellow/Astrophysics)*
M J Kesteven *(Astrophysics/Engineering Research)*
N E B Killeen *(Acting Head, Computing)*
B S Koribalski *(Astrophysics)*
M Large *(MNRF Array Technology)*
M R Leach *(Electronics)*
J M J Lie *(Receivers)*
P A Lilie *(Receivers)*
S M Little *(Administration)*
S Magri *(Electronics)*
R N Manchester *(Astrophysics)*
G A Manefield *(Engineering PA)*
H May *(Computing)*
V J McIntyre *(Computing)*
G G Moorey *(overseas)*
R P Norris *(Head, Astrophysics/Head, Computing) (on secondment to Corporate Centre)*
M Oestreich *(Electronics)*
E G Pacey *(Director's PA)*
L J Reilly *(Receivers)*
P P Roberts *(Electronics)*
R J Sault *(Computing/SKA)*
R R Scott *(Administration)*
H L Sim *(Scientific & Community Liaison)*
M W Sinclair *(Head, Receivers)*
L G Staveley-Smith *(Acting Head, Astrophysics)*
M Storey *(SKA Site Studies/PASA)*
P B Sykes *(Receivers)*
B M Thomas *(Engineering Research)*
A K Tzioumis *(Astrophysics/LBA)*
M Walker *(ATNF/USyd Research fellow/ Astrophysics)*
J B Whiteoak *(Deputy Director & Head, National Facility Support)*
W E Wilson *(Head, Electronics)*

Staff shared with CSIRO Telecommunications and Industrial Physics

Administration

S F Clark
O A D'Amico
C Duffy
C D Hodges
K J Lambert
S O'Toole
C K Spence
B Wrbik

Engineering Services

P Bonvino
A F Bugh
G R Cook
P Cooper
P A Dalziel
B A Egan
W Finch
G Hughes
T M Huynh
O Iannello
C R Lobsey
K B MacLeod
M McDonald
R A Moncay
B F Parsons *(Assistant Engineering Manager)*
P A Sharp
J R Uden
B Wilcockson *(Assistant Engineering Manager)*
M R Wright

Library

A Joos
C M van der Leeuw

NARRABRI

F Badia *(Computing)*
R J Beresford *(Electronics)*
D J C Brooke *(Electronics)*
D J Campbell *(Antennas & Site Services)*
S J Cunningham *(Computing)*
A F Day *(Electronics)*
A A Deshpande *(Visiting Scientist)*
O P Dowd *(Antennas & Site Services)*
C F Forbes *(Lodge)*
K Forbes *(Administration)*
J Giovannis *(Computing)*
T M Gordon *(Antennas & Site Services)*
M E Guest *(Lodge)*
D M Harris *(Administration)*
S M James *(Electronics)*
J Houldsworth *(PA)*
B D Johnson *(Antennas & Site Services)*
T J Kennedy *(Visitors Centre)*
C W Leven *(Antennas & Site Services)*
J C McFee *(Electronics)*
D McConnell *(O-I-C, Paul Wild Observatory)*
L A Panton *(Electronics)*
B W Reddall *(Electronics)*
M H Rees *(Lodge)*
A G Ryan *(Antennas & Site Services)*
R Subrahmanyan *(Electronics)*
G J Sunderland *(Antennas & Site Services)*
S Tingay *(Bolton Fellow)*
R M Wark *(Operations)*
J C Wieringa *(Library)*
M H Wieringa *(Computing)*
C A Wilson *(Lodge)*

PARKES

J K Cole *(Lodge)*
J M Crocker *(Site Services)*
H A Fagg *(RF Systems)*
G T Freeman *(Administration)*
M A Freeman *(Administration Trainee)*
J M Glowacki *(Electronics/Servo & RF Systems)*
J Hockings *(Visitors Centre)*
S Hoyle *(Computing)*
A J Hunt *(Electronics/Servo)*
S A Ingram *(Lodge/Site Services)*
R T Lees *(Site Services)*
R J Livingstone *(Site Services)*
S L Mader *(Operations)*
M P McColl *(RF Systems)*
B A Preisig *(Electronics/Servo)*
K F Reeves *(Site Services)*
J E Reynolds *(OIC, Parkes Observatory)*
J M Sarkissian *(Operations)*
S R Scott *(PA/Admin)*
M R Smith *(RF systems)*
G Spratt *(Computing)*
E R Troup *(overseas)*
B Turner *(Site Services)*
R R Twardy *(Visitors Centre)*

CANBERRA

J F Bell *(ARC fellow/Astro)*
D L Jauncey *(Astro)*
J E J Lovell *(Astro)*

C: Committee membership

ATNF Steering Committee, 2000

Chairman

Prof R D Cannon, Anglo-Australian Observatory

Secretary

Mrs E Pacey, ATNF

Members

Ex-Officio

Prof R D Ekers, Director, ATNF

Dr B Boyle, Director, Anglo-Australian Observatory

Dr R L Sandland, Deputy Chief Executive, CSIRO

Dr D N Cooper, Chief, CSIRO Telecommunications and Industrial Physics

Prof P McCulloch, Director, Mt Pleasant and Ceduna radio observatories, University of Tasmania

Astronomers

Dr E Sadler, University of Sydney

Prof J Storey, University of New South Wales

International advisers

Prof P Goldsmith, Director, National Astronomy and Ionosphere Center, Cornell University (USA)

Prof Kwok-yung (Fred) Lo, Director, Institute of Astronomy and Astrophysics, Academia Sinica (Taiwan)

Prof K M Menten, Director, Max Planck Institute for Radio Astronomy, Bonn, Germany

Industry

Dr P Scaife, Director, Centre for Sustainable Technology, University of Newcastle

Dr R H Frater, Vice President Innovation, Res Med, North Ryde

MNRF Technical Advisory Committee

Dr S Guilloteau, Institut de Radio Astronomie Millimetrique (France)

Dr P Napier, National Radio Astronomy Observatory (USA)

Dr R Padman, Mullard Radio Astronomy Observatory (UK)

Dr A Young, CSIRO Telecommunications and Industrial Physics (Australia)

Dr N Whyborn, Space Research Organization Netherlands (Netherlands)

Australia Telescope Users Committee, 2000

Chairman

Dr A Green, University of Sydney

Secretary

Dr B Koribalski, ATNF (outgoing)

Mr V McIntyre*, ATNF (incoming)

Members

Dr Ramesh Balasubrahmanyan, University of New South Wales

Dr D Barnes*, University of Swinburne

Ms H Bignall*#, University of Adelaide

Dr M Britton, University of Melbourne

Dr J Chapman, ATNF

Dr E Corbett, Anglo-Australian Observatory

Dr M Costa, University of Tasmania

Dr S Ellingsen*, University of Tasmania

Dr C Jackson*, Research School of Astronomy and Astrophysics, Australian National University

Dr D Jauncey, ATNF

Ms M Johnston-Hollitt#, University of Adelaide

Dr C Lineweaver, University of New South Wales

Mr E Muller*#, University of Wollongong

Dr M Sevenster, Mt Stromlo and Siding Spring observatories

Dr R Sood, University of Western Sydney

Dr M Walker, University of Sydney

** New member in 2000* *# Student member*

Australia Telescope Time Assignment Committee 2000

Chairman

Prof R D Ekers, Director, ATNF

Secretary

Dr J Chapman, ATNF

Members

Dr M Wardle, University of Sydney

Dr M Drinkwater, University of Melbourne

Dr A Kalnajs, RSAA, Australian National University (to March 2000)

Dr M Sevenster, RSAA, Australian National University (from July 2000)

Dr R Balasubrahmanyan, University of New South Wales (from July 2000)

Dr R Manchester, ATNF

Dr D McConnell*, Officer-in-Charge, Narrabri Observatory, ATNF

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

** non-voting members*

D: Observing programs

Observations made with the Australia Telescope Compact Array, January to December 2000

Observers	Affiliations	Program Title	Number	Hours
McConnell, Sault, Subrahmanyan, Tingay, Reynolds, Wark, Wieringa	ATNF, ATNF, ATNF, ATNF, ATNF, ATNF, ATNF,	ATCA calibrators	C007	208
Dickel, Gallant, Gaensler, Milne, Staveley-Smith, Manchester	UIll/NFRA, Utrecht, MIT, ATNF, ATNF, ATNF	The Plerion and Shell of the Composite SNR 0540-693	C014	13
Manchester, Gaensler, Staveley-Smith, Tzioumis, Wheaton, Kesteven, Reynolds	ATNF, MIT, ATNF, ATNF, USyd, ATNF, ATNF	SNR 1987A	C015	168.5
McConnell, Ables	ATNF, CTIP,	Imaging 47 Tucanae	C059	103.5
Ryder, Staveley-Smith, Schlegel	Hilo, ATNF, SAO,	The 1978 Supernova in NGC 1313	C184	17
Duncan, White	ATNF, UMar	High-spatial resolution observations of Eta Carinae	C186	26
White, Duncan	UMar, ATNF	The Radio Properties of the Luminous Blue Variable WRA 751	C312	13
Caswell	ATNF	Precise 6035 MHz maser positions	C325	16
Johnston, Manchester, McConnell, Ball	USyd, ATNF, ATNF, USyd	Unpulsed Transient emission from the PSR B1259-63 binary system	C326	119.5
Norris, Forbes	ATNF, UBir	Annual Monitoring of the starburst ring in NGC 7552	C434	12
Webster, Whiting, Kilborn, Drinkwater, Peele	UMel, UMel, UMel, UMel, UMel	Spectral energy distributions for Parkes quasars	C484	118
Harnett Beck, Haynes, Ehle, Blank	UTS MPIfR, ATNF, ESA Villafranca, Univ Macquarie	Magnetic fields in southern barred galaxies	C494	26
Tingay, Jauncey, King, Rayner, McCulloch, Tzioumis, Reynolds, Preston, Hirabayashi	JPL, ATNF, ATNF, UTas, UTas,ATNF, ATNF, JPL, ISAS	Flux density monitoring of VSOP survey sources	C540	24
Caswell	ATNF	More methanol maser positions	C558	16
Hopkins, Cram, Afonso, Mobasher	UPitt, USyd, ImCol, ImCol	The ATCA Phoenix large area ultra-deep survey	C572	120
Whysong, Antonucci, Geller, Killeen, Sault, Desai	UCSB, UCSB, UCSB, ATNF, ATNF, WSRT	A search for the ionized intergalactic medium	C575	110
Birkinshaw, Worrall	UBr , UBr	The jet in the unusual AGN J2310-4347	C588	13
Dickey, McClure-Griffiths, Green, Wieringa, Haynes, Gaensler	UMinn, UMinn, USyd, ATNF, ATNF, MIT	The southern Galactic plane survey	C596	530
Kedziora-Chudczer, Jauncey, Wieringa, Reynolds, Tzioumis, Nicolson	ATNF, ATNF, ATNF, ATNF, ATNF, HartRAO	Monitoring observations of PKS 0405-385 (cont)	C611	43.5
Muller, Stanimirovic, Staveley-Smith, Haynes, Zealey	UWoll, NAIC, ATNF, ATNF, UWoll	HI observations of the Magellanic Bridge	C628	51.5
Filipovic, Pietsch, Haberl, White, Jones, Haynes	UWS, MPE, MPE, UWS, UWS, ATNF	Supernova remnant candidates in the Magellanic Clouds. IV: New X-ray candidates	C634	13

Webster, Koribalski, Kilborn, Waugh, Dodd, + High Pass Team	UMel, ATNF, UMel, UMel, UMel	High resolution observations of multibeam detections	C638	106
Bignall, Tzioumis, Bondi, Mantovani, Venturi, Padovani, Kedziora-Chudczer	UAd, ATNF, UBol, UBol UBol, STScI, USyd	Monitoring of Blazars observed with SAX	C639	24
Frail, Kulkarni, Berger, Galama, Wieringa, Wark, Subrahmanyan, McConnell	NRAO, Caltech, Caltech, Caltech, ATNF, ATNF, ATNF, ATNF	The radio afterglows from gamma-ray bursts - NAPA	C651	52.5
Clark, Dougherty, Waters, Goodwin	USuss, Nat. Research Council, UAm, USuss	Compact Configuration Observations of Wd1	C652	26.5
Benaglia, Cappa, Koribalski	IAR, IAR, ATNF	Mass loss rate determination of southern Of stars	C678	35
Harju , Higdon, Lehtinen, Juvela	UHel, KI, UHel, UHel	CrA/IRS 7B -— a prototstar driving synchroton jets?	C711	37
Norris , Badia, Ekers, Ekers, Hopkins, Sault, Wieringa, Williams, Boyle	ATNF ATNF, ATNF, ATNF, ATNF, ATNF, ATNF, STScI, AAO	Observations of the Hubble Southern Deep Field	C727	63
Fender, Spencer, Tzioumis, Wu, Johnston, van der Klis, van Paradijs	UAm, JB, ATNF, USyd, AAO, UAm, UAm	The radio jets and proper motion of Circinus X-1	C737	12
Pisano, Wilcots	UWisc, UWisc	Extended HI and the formation of isolated galaxies	C744	32.5
Stappers , Gaensler, Getts	UAm, MIT, ATNF	Radio emission from SAX J1808.4-3658	C751	7
Gaensler, Moffett, Green, Dodson, Dickel, Slane, Harrus	MIT, UFurman, USyd, UTas, NFRA, CfA, NASA	SNR G327.7-1.1: evidence for a high velocity pulsar?	C772	26
Staveley-Smith, Juraszek, Henning, +ZOA team	ATNF, USyd, UNM	Unveiling the giant galaxies in the Zone-of-Avoidance	C781	98
Chapman, Dougherty, Leitherer, Koribalski, Williams, Moffett	ATNF, DRAO, STScI, ATNF, ROE, UMont	The radio light curve of Gamma Velorum	C787	44
Dodson, Ellingsen	UTas, UTas	Coincidence of OH maser emission at 4765 MHz	C798	24
Vergani, Dettmar, Klein,	UBonn, URuhr, UBonn,	HI in disk galaxies with merging bulges	C801	48
de Blok, Walter	ATNF, Caltech	An HI mosaic of the local group dwarf galaxy NGC 6822	C809	96
Beaulieu, Freeman, Bureau, Carignan, Meurer	IOA, MSSSO, LO, UMont, JHU	Triaxial halos and the outer HI disks of spiral galaxies	C819	12
Putman, Freeman	RSAA, RSAA	Compact High Velocity Clouds	C820	82
Ivison, Couch, Smail, Morrison, Owen	UCL, UNSW, UDur, Caltech, NRAO	A new window on galaxy evolution: obscured starbursts in clusters at z = 0.31	C821	84
Deep Survey Team	UW	ATCA Identification of DEEP 21-cm Multibeam Detections	C822	52
Slee, Roy, Andernach, Tsarevsky	ATNF, MPIfR, UGuan, ATNF	High-resolution imaging of relics in southern clusters	C827	14
Pannuti, Filipovic, Jones, Pietsch, Haberl	UNM, UWS, UWS, MPE, MPE	A Search for Supernova Remnants in Nearby Galaxies (NGC 300)	C828	13
Wardle, Green, Lazendic	USyd, USyd, USyd	OH absorption towards the W28SNR	C839	12.5

Venturi, Dallacasa, Bardelli, Tzioumis, Morganti, Hunstead	CNR, CNR, OBol, ATNF, NFRA, USyd	A radio halo candidate in the merging cluster A3562	C841	25
Agostino, Venturi, Facordi, Kelm, Tzioumis	IRA-CNR, IRA-CNR, IRA-CNR, UBol, ATNF	Probing the Role of Local Environment in Seyfert Galaxies	C842	24.5
Pottasch, Van de Steene	KI, RSAA	The bipolar planetary nebula He2-111	C843	13
Oosterloo, Morganti	NFRA, NFRA	HI observations of a jet-cloud interaction	C844	28
Stevens, Chapman, Rauw, Leitherer, Setia Gunawan	UBir, ATNF, ULiege, STScI, UGron	Radio stars in NGC6231 and the Sco OB1 association	C845	109
Roy, Rao, Subrahmanyan	TIFR, TIFR, ATNF	Magnetic field in the Galactic Centre: RM observation of extragalactic sources	C846	10.5
Roy, Rao, Subrahmanyan	TIFR, TIFR, ATNF	Magnetic field in the Galactic Centre: RM observation of extragalactic sources	C846	50
Johnston-Hollitt, Ekers, Clay	UAd, ATNF, UAd	Probing aspects of a cluster merger: A3667 at 6cm	C847	36.5
Muecke, Koribalski, Moffat, Corcoran, Stevens, Wessolowski	UAd/UMon, ATNF, UMont, GSFC, UBir, MPE	High resolution multifrequency observations of the stellar cluster in NGC 3603	C848	25
Muecke, Koribalski, Moffat, Corcoran, Stevens, Wessolowski	UMon, ATNF, UMont, GSFC, UBir, MPE	High resolution multifrequency observations of the stellar cluster in NGC 3603	C848	36
Muecke, Koribalski, Moffat, Corcoran, Stevens	UMon, ATNF, UMont, GSFC, UBir	High resolution multifrequency observations of the stellar cluster in NGC 3603	C848	12.5
Garay, Norris, Mardones	UChile, ATNF, UChile	The characteristics of the ionized gas within hot molecular cores	C849	51
Garay, Norris, Mardones	UChile, ATNF, UChile	The earliest stages of massive star formation	C850	13
Stevens, Forbes, Norris	UBir, UBir, ATNF	Radio mapping of the starbursts in two dwarf galaxies	C851	25
Ogura, Norris	UKok, ATNF	Radio continuum observations of Herbig-Haro objects	C852	12
Kedziora-Chudczer, Subrahmanyan, Jauncey, Macquart	AAO, ATNF, ATNF, USyd	Monitoring of the HI absorption towards the IDV sources	C853	93
Kedziora-Chudczer, Bailey, Wagner, Macquart	AAO, AAO, UHeid, USyd	The optical and radio polarization of the four IDV sources	C854	31
Beuther, Walsh, Schlike, Menten, Sridharan	MPI, MPI, MPI, MPI, HSS	Methanol maser emission in high-mass protostars	C856	11.5
Fender, Norris, Sault, Pooley, Rayner	UAm, ATNF, ATNF, MRAO, UTas	Circular polarization of radio-bright X-ray transients (NAPA)	C857	14
Umana, Trigilio	CNR, CNR	A survey of post-AGB stars	C858	62
Coe, Haigh, Clark, Goodwin	USHam, USHam, USuss, USuss	A supernova remnant around a Be X-ray binary?	C859	26

Lovell, Jauncey, Tingay	ATNF, ATNF, ATNF	The nature of the jet in PKS 0637-752	C861	12
Tuthill, Monnier, Greenhill, Danchi	USyd, HSS, HSS, UCB	Broadband spectra of selected IR-bright Wolf-Rayet stars	C862	49.5
Mohan, Dwarakanath, Subrahmanyan	RRI, RRI, ATNF	HI 21cm absorption study towards the Galactic centre	C863	24
Shen, Lovell, Jauncey, Edwards, Hirabayashi, Inoue, Kameno	NAOJ, ATNF, ATNF, ISAS, ISAS, NAOJ, NAOJ	Dual frequency ATCA polarization imaging of PKS 0312-770	C864	12
Walsh, Bertoldi	MPI, MPI	Radio continuum emission from methanol maser sites	C865	26
Birkinshaw, Worrall	UBr, UBr	PKS 0521-365: a BL Lac with an exceptional radio source	C867	13
Van der Hulst, Roelfsema, Tielens, Martin-Hernandez, Vermeij	KI, SRON, KI, KI, KI	Compact HII regions in the Local Group galaxies	C868	54
Kregel, de Blok, van der Kruit, Freeman	KI, ATNF, KI, MSSSO	HI structure and kinematics of edge-on spiral galaxies	C869	50.5
Yamaguchi, Moriguchi, Onishi, Mizuno, Fukui	UNag, UNag, UNag, UNag, UNag	Evidence of the Vela SNR/Molecular gas interaction	C870	48
McIntyre, Subrahmanyan, Hunstead	USyd, ATNF, USyd	SUMSS 0515-810: a dying giant radio galaxy?	C871	40
Fender, Norris, Sault, Pooley, Rayner	UAm, ATNF, ATNF, MRAO, UTas	Circular polarization of SS 433	C872	28
Fender, Norris, Sault, Pooley, Rayner	UAm, ATNF, ATNF, MRAO, UTas	Circular polarization of SS 433	C872	10
Bruens, Kerp, Haynes	RAIUB, RAIUB, ATNF	The HI small-scale structure in the Magellanic Stream	C874	106
Ciliegi, Comastri, Fiore, Morganti, La Franca	OABol, OABol, OARome, NFRA, USR	Radio observations of Chandra X-ray sources	C877	24
Edwards, Lovell, Reynolds, Tzioumis, Jauncey	ISAS, ATNF, ATNF, ATNF, ATNF	Imaging and monitoring the gravitational lens B1152+199	C878	13.5
Ellingsen, Sobolev, Cragg, Godfrey	UTas, USU, Monash, Monash	A direct test of Class II methanol maser modellng	C879	14
Gaensler, Dickel, Kaspi, Crawford, Milne, Piovaroff	MIT, NFRA, MIT, MIT, MIT	Radio Imaging of the 87-ms X-ray pulsar AX J0043-737	C882	25
Johnston, McConnell	USyd, ATNF	A search for exotic millisecond pulsars in globular clusters	C883	96
Kalberla, Klein, Salucci, Borriello, Ratnam, Pignatelli	UBonn, UBonn, SISSA-ISAS, SISSA-ISAS, SISSA-ISAS, SISSA-ISAS	The dark matter distribution in disk galaxies	C885	86
Kardashev, Cherepashchuk, Slee, Tingay, Tsarevsky, Popov, Zhuravlev	ASC, Sternberg Inst, ATNF, ATNF, ATNF, ASC, ASC	Search for new Galactic Microquasars among ROSAT sources	C886	46
Lazendic, Wardle, Whiteoak, Green	USyd, USyd, ATNF, USyd	Absorption-line observations of shocked molecular gas around SN	C887	51.5
Leahy, Killeen	NRAL, ATNF	Pinning down the physics of FRII Radio Galaxies	C888	37

Lehtinen, Higdon, Harju, Kontinen	UHel, KI, UHel, UHel	Protostars in the Cederblad 110 star formation region	C889	24.5
Lovell, Marshall, Jauncey, Tingay, Murphy, Preston, Piner	ATNF, MIT, ATNF, ATNF, JPL, JPL, JPL	ATCA and Chandra Survey of Radio Jets	C890	95
Lovell, Winn, Jauncey, Edwards, Reynolds, Tzioumis	ATNF, MIT, ATNF, ISAS, ATNF, ATNF	Snapshot Imaging of Gravitational Lens Candidates	C891	24
Ludke, Adornes, Norris	Univ. Santa Maria, U. Rio Grande do Sul, ATNF	HI imaging survey of southern Seyfert Galaxies	C892	24
Minier, Ellingsen, Norris, Booth	OSO, UTas, ATNF, OSO	A search for 6.7 GHz methanol masers towards class 0 and class 1 protostars	C893	24
O'Brien, Bosma, Freeman	RSAA, Obs. de Marseille, RSAA	Probing the dark matter halos of thin edgbe-on Galaxies	C894	100
Robinson, Slee	GSFC, ATNF	Radio Observations of Flares on the dMe star Prox Cent	C895	28
Subrahmanyan	ATNF	Recurrent activity in the giant radio galaxy 0707-359	C899	43.5
Subrahmanyan, Tingay	ATNF, ATNF	Evolution in morpholigies of radio galaxies	C900	31
Whiteoak, Lazendic	ATNF, USyd	Accurate Positions of 22 GHz H2O LMC Masers	C901	11.5
Budding, Slee, Carter, Mengel	CITNZ, ATNF, USQ, USQ	Rotation phase dependent radio emission from HR 817	C902	25
Chapman, Stevens, Rauw	ATNF	A new radio galaxy with an unusual jet morphology	C904	12
Gruppioni, De Zotti, Prandoni, Sault Padova, Padova, Bologna,	ATNF	22 GHz Observations of southern Kuhr sources	C905	24
Caswell	ATNF	OH Flare of a maser in a star formation region	C906	16
Manchester, Possenti, D'Amico, Ferraro, Lyne	ATNF, Bologna, Bologna, Bologna, Jodrell Bank	Positions for binary millisecond pulsars in globular clusters	C907	11.5
Hardcastle, Sakelliou, Werner	UBristol, Mullard, UBristol	The jet termination in the nearest WAT PKS 1610-608	C908	22.5
Prandoni, Gregorini, Parma, Vettolani, Ruiter, Wieringa, Ekers	IRA-CNR, IRA-CNR, NCR, NCR, OAB, ATNF, ATNF	The nature of the faint radio population	C909	131.5
Tingay, Subrahmanyan	ATNF, ATNF	An ATCA search for jet deflections in powerful radio galaxies	C910	48
Tingay, Slee, Sadler	ATNF, ATNF, USyd	ATCA Imaging of Pictor A at 1.4, 2, 5 and 4.8 GHz	C911	55.5
Kedziora-Chudczer, Bignall	AAO/ATNF, UAd	Full synthesis imaging of the IDV blazar PKS 1144-379	C912	12.5
Filipovic, Pietsch, Read, Jones	UWS Nepean, MPE, MPE, UWS	Large Scale Radio Jets in the Galaxy Cluster Abell S0102	C913	13
Kwok, Lee, Lim	Calgary, Calgary, Academica Sinica	Radio Imaging of southern hemisphere planetary nebulae	C914	24

Bryant, Hunstead	USyd, USyd	The inner structure of the giant radio galaxy MRC B0319-454	C916	25
Fender, Spencer, Tzioumis, Wu, Johnston, van der Klis	UAm, JB, ATNF, USyd, AAO, UAm	Periodic superluminla motions from Cir X-1	C917	82
Kesteven, Bell, Sault, Hall, Wilson, Briggs, Mitchell	ATNF, ATNF, ATNF, ATNF, ATNF, Kapteyn, USyd	Implementation of post-correlation interference suppression	C919	20

Observations made with the Parkes Telescope, January to December 2000

Observers	Affiliations	Program Title	Number	Hours
Johnston, Fagg, Manchester, Nicastro	ATNF, ATNF, IRA-CNR	Periastron observations of PSR B1259-63	P116	7.2
Kaspi, Manchester, Bailes	MIT, ATNF, Swin	Timing of the pulsar/B Star binary J0045-7319	P138	1.33
van Straten, Bailes, Sarkissian, Manchester, Anderson, Kulkarni	Swin, Swin, ATNF, ATNF, Caltech, Caltech	Precision pulsar timing	P140	16.5
Young, Manchester, Burman	UWA, ATNF, UWA	Pulsar pulse dynamics	P221	2.83
Han, Manchester, Qiao	BAO, ATNF, UPek	Polarization and Faraday rotation of southern pulsars	P236	4.75
Freeman, + MB team	RSAA	Northern extension of HIPASS	P248	67.2
van Loon, Zijlstra	IoA, IoA	H2O maser emission from evolved stars in the LMC	P260	4.28
Manchester, Lewis, Sarksissan, Bailes, Kaspi	ATNF, UTas, ATNF, Swin, MIT	Timing of young pulsars	P262	1.50
Edwards, Bailes, van Straten	Swin, Swin, Swin	Baseband searching for ultrafast pulsars	P263	8.0
Lyne, Kramer, Manchester, Bell, Camilo, Stairs, D'Amico, Morris, Kaspi, Crawford, Possenti	JB, JB, ATNF, ATNF, JB, JB, UBol, JB, MIT, MIT, UBol	Pulsar multibeam survey	P268	48.5
Crawford, Kaspi, Manchester, Lyne	MIT, MIT, ATNF, JB	A deep pulsar survey of the Small Magellanic Cloud	P269	7.64
Kaspi, Manchester, Lyne	MIT, ATNF, JB	A deep pulsar survey of the Small Magellanic Cloud	P269	7.31
Manchester, Bell, Camilo, Lyne, Morris, Kaspi, Crawford, D'Amico, Possenti	ATNF, ATNF, Columbia, JB, JB, MIT, MIT, UBol, UBol	Timing of multibeam pulsar survey discoveries	P276	20.6
Johnston, Koribalski, Wilson, Walker	USyd, ATNF, ATNF, USyd	Small scale structure in the Interstellar Medium	P280	5.15
Lyne, Camilo, Freire, Manchester, Lorimer, D'Amico	JB, JB, JB, ATNF, NAIC, UBol	Timing and searching for millisecond pulsars in 47 Tucanae	P282	17.5
D'Amico, Lyne, Manchester, Possenti, Gheller, Camilo, Lorimer	UBol, JB, ATNF, UBol, CINECA, JB, NAIC	Search and Timing of Pulsars in Globular Clusters	P303	2.55
Dickey, McClure-Griffiths, Haynes, Wieringa, Green, Gaensler	UMinn, UMinn, ATNF, ATNF, USyd, MIT	The Southern Galactic Plane Survey	P307	2.08
Webster, Waugh, Drinkwater, Ekers, Nulsen	UMel, UMel, UMel, ATNF, UWol	Galaxy evolution in the Fornax Cluster	P315	2.21

Crawford, Pivovaroff, Kaspi, Manchester	MIT, MIT, MIT, ATNF	A search for young pulsars in composite SNRs	P327	0.21
Toth, Hotzel, Lemke, Harju, Whiteoak	UEot, MPIA, MPIA, UHel, ATNF	The coldest cloud cores of Chamaeleon 1	P336	5.00
Edwards, Bailes	Swin, Swin	Timing of Swinburne Multibeam Pulsar Discoveries	P337	9.2
Johnston, Bailes, Britton	USyd, Swin, Swin	Observations of single pulses from strong pulsars	P338	1.01
Young, Manchester, Burman	UWA, ATNF, UWA	The longest period pulsar and PM nullers	P339	3.04
Lyne, Stairs, Kramer, Manchester	JB, JB, JB, ATNF	Magnetospheric changes in PSR B1828-11	P340	1.0
Stairs, Manchester, Lyne, Bell, Camilo	JB, ATNF, JB, ATNF, UColumb	Periastron studies of PSR 1740-3052	P341	2.95
Crawford, Pivovaroff, Kaspi, Manchester	MIT, MIT, MIT, ATNF	Timing of pulsars discovered in a search of SNRs	P342	0.81
Takano, Takano, Nakai, Kawaguchi	Chiba University, Nobeyama Nobeyama, Okayama Univ	Ortho/Para Ratio of Ammonia in Galactic Star-forming Regions	P344	5.42
Bouchard, Staveley-Smith	UMont, UMont, ATNF	HI around dwarf spheroidal galaxies	P347	3.01
McClure-Griffiths, Dickey, Taylor, Gibson, Gaensler, Green	UMinn, UMinn, UMinn, UCal, MIT, USyd	A Global HI survye of the Milky Way: The VGPS	P348	
3.22Koribalski, Staveley-Smith, Putman, Kilborn, Gibson	ATNF, ATNF, RSAA, UMel, Swin	Protogalaxies, High Velocity Clouds or Magellanic Debris?	P349	1.98
Caswell	ATNF	Water Masers in southern SFRs	P350	1.46
Caswell	ATNF	12 GHz methanol masers at sites of 6.6 GHz methanol masers	P351	0.69
Forbes, Mundell, Barnes	Swin, Liverpool John Moores, Swin	Formation and Evolution of Galaxies in Groups – the role of HI	P352	3.92
Mader, Zealey, Walker, Parker, Cohen	ATNF, UWol, UWol, ROE, Berkely	The role of the Enivornment in Star Formation: CMa OB1/R1	P355	1.52
Deshpande, Rankin, McConnell	ATNF, Uni VermonA, ATNF	Subpulse fluctuation properties of southern pulsars	P356	2.35
Staveley-Smith, Koribalski, Henning, Kraan-Kortweg, Sadler, Schroeder, Stewart	ATNF, ATNF, Uni New Mexico, Uni Guanajuato, USyd, Nice, Univ Leicester	A northern extension to the ZOA survey	P357	2.02
Stairs	JB	ToO Observations of AX J0043-737	PX003	0.08

Observations made with the Mopra Telescope, January to December 2000

Observers	Affiliations	Program Title	Number	Hours
Whiteoak, Hunt	UWS Nepean	Interaction of HII region RCW36 with an associated cool cloud	M095	12.6
Durouchoux, Sood, O'Neill, Flohic	CEA, ADFA, ADFA, CEA	Millimetre Observations of elongated SNRs, Search for jet signatures	M096	13
Ludke, Migenes	SMFU, UGuan	A 3mm survey of southern OH-IR stars	M097	10

Bourke, Myers, Allen, Wright	CfA, CfA, CfA, ADFA	Large-scale inward motions in young stellar clusters	M098	8
Deguchi, Balasubramanyam, Nakashima	NRO, UNSW, NRO SiO	Maser survey in the Galactic disk, 270 < l < 350.	M099	10
Allen, Myers, Bourke	CfA, CfA, CfA	Dense gas in the rho Ophiucus dark cloud	M100	6
Muller, Staveley-Smith, Haynes, Zealey	UWol, ATNF, ATNF, UWol	Search for CO Molecules in the Western Magellanic Bridge	M101	5
Ellingsen, Costa	UTas, UTas	Search for Hot Molecular Cores	M103	8
Wright, Maldoni, Boonman, Dishoeck, Smith	ADFA, ADFA, Leiden, Leiden, ADFA	The gas and dust content of YSOs and OH/IR stars	M104	5
Balasubramanyam, Kim, Carrad, Burton, Storey	UNSW, UNSW, ATNF, UNSW, UNSW	Spectral line survey towards hot molecular cores	M105	13

VLBI Observations, January to December 2000

Observers	Affiliations	Program Title	Number	Hours
Caswell, Reynolds	ATNF, ATNF	LBA maps of 18cm OH masers in star-forming regions	V108	36
Corbett, Norris, Appleton, Heisler, Dopita	ATNF, ATNF, IASU, MSSSO, MSSSO	VLBI search for compact radio cores in COLA galaxies	V110	28
Gwinn, Reynolds, Tzioumis, McCulloch, Jauncey, Britton, Quick	UCSB, ATNF, ATNF, UTas, ATNF, UMel, HartRAO	Polarization of the Vela Pulsar's Emission Region	V112	14
Corbett, Norris, Appleton, Heisler, Dopita	ATNF, ATNF, IoSU, RSAA, RSAA	VLBI imaging of selected COLA galaxies	V133	19
Greenhill, Moran, Norris, Reynolds, Ellingsen, Jauncey, Tzioumis, Ellingsen, McCulloch, Booth	CfA, CfA, ATNF, ATNF, UTas, ATNF, ATNF, UTas, UTas, OSO	Tracking the acceleration of H2O masers in Circinus	V137	18
Whiteoak, Reynolds, Getts, Lazendic	ATNF, ATNF, MU, USyd	First epoch proper motion positions of LMC H2O masers	V139	10
Shen, Edwards, Hirabayashi, Inoue, Kameno, Jauncey, Lovell, Reynolds, Tzioumis, McCulloch, Costa, Nicolson	NAOJ, ISAS, NAOJ, NAOJ, NAOJ, ATNF, ATNF, UTas, UTas, HartRAO, ATNF	VLBI investigations on a southern quasar PKS 0312-770	V140	14
Blank, Harnett	USyd, UTech	VLBI observations of NGC 7213	V141	13

Affiliations

AAO	Anglo-Australian Observatory, Australia
AAT	Anglo-Australian Telescope, Australia
ADFA	Australian Defence Force Academy, Australia
AIPr	Astronomical Institute Prague, Czech Republic
AITub	Institute of Astronomy, University of Tubingen, Germany
ANU	Australian National University, Australia
AO	Arecibo Observatory, USA
AOUpp	Astronomiska observatoreit, Uppsala, Sweden
ArO	Armagh Observatory, UK
ASC	Astrospace Centre, Russia
ASCR	Academy of Sciences of Czech Republic, Czech Republic
ASIAA	Academia Sinica, IAA, Taiwan
ATNF	Australia Telescope National Facility, Australia
BAO	Beijing Astronomical Observatory, China
BIMA	Berkeley-Illinois-Maryland Association, USA
Caltech	California Institute of Technology, USA
CDSSC	Canberra Deep Space Communications Complex, Australia
CEA	Centre d'Etudes d'Astrophysique, Saclay, France
CfA	Center for Astrophysics, Harvard University, USA
CO	Carter Observatory, New Zealand
Cornell	Cornell University, USA
COSSA	CSIRO Office of Space Science & Applications, Australia
CRALOL	CRAL Observatoire de Lyon, France
CSR	Center for Space Research, USA
CTIP	CSIRO Telecommunications & Industrial Physics, Australia
DEMIRM	Département d'Etudes de la Matière interstellaire en InfraRouge et Millimétrique, l'Observatoire de Paris, France
DRAO	Dominion Radio Astrophysical Obs., Canada
ESO	European Southern Observatory, Germany
ESTEC	ESTEC Astrophysics Division, Netherlands
GBT	Green Bank Telescope, USA
GMU	George Mason University, USA
Gray Data	Gray Data Consulting, USA
GSFC	Goddard Space Flight Centre, USA
HartRAO	Hartebeesthoek Radio Astron. Observ., South Africa
Harvard	Harvard University, USA
HatCreek	Hat Creek Radio Observatory, USA
IAC	Instituto de Astrofisica de Canarias, Spain
IAFE	Instituto d'Astronomia y Fisica del Espacio, Argentina
IAG	Instituto Astronomico e Geofisico, Brazil
IAP	Institute d'Astrophysique Paris, France
IAR	Instituto Argentino de Radioastronomica, Argentina
IASp	Institut d'Astrophysique Spatiale, France
IFCTR	Instituto de Fisica Cosmica - CNR, Italy
ImCol	Imperial College London, UK
IoA	Institute of Astronomy, UK
IPAC	IPAC, Caltech, USA
IRA-CNR	Institute of Radio Astronomy, CNR, Bologna, Italy
ISA	ISAS, JAPAN, Japan
ISU	Iowa State University, USA
JAC	Joint Astronomy Centre, USA
JBO	Jodrell Bank Observatory, UK
JHU	Johns Hopkins University, USA
JILA	JILA, University of Colorado, USA
JPL	Jet Propulsion Laboratory, USA
KI	Kapteyn Institute, Netherlands
LLNL	Lawrence Livermore National Laboratory, USA
LO	Leiden Observatory, Netherlands
LSW	Landessternwahrte Heidelberg, Germany
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
MPIfA	Max Planck Inst. für Astrophysik, Germany
MPIfR	Max Planck Inst. für Radioastronomie, Germany
MRAO	Mullard Radio Astronomical Observatory, UK
NAOJ	National Astronomical Observatory, Japan
NASA-RC	NASA Ames Research Centre, USA
NFRA	Netherlands Foundation for Research in Astronomy, The Netherlands
NOAO	National Optical Astronomical Observatory, USA
NRAO	National Radio Astronomy Observatory, USA
NRL	Naval Research Laboratories, USA
NRO	Nobeyama Radio Observatory, Japan
NWU	Northwestern University, USA
OABol	Osservatorio Astronomico di Bologna, Italy
OARome	Osservatorio Astronomico di Roma, Italy
OCat	Osservatorio Astronomico di Catania, Italy
OHP	Observatoire de Haute Provence, France

Appendices

OMs	Observatorire de Marseille, France
ON	Observatorio Nacional, Brazil
Open	Open University, UK
OPM	Observatoire de Paris, Meudon, France
OSO	Onsala Space Observatory, Sweden
PLab	Phillips Lab, USA
PMO	Purple Mountain Observatory, China
PUCC	Pontificia Universidad Catolica de Chile, Chile
Queens	Queens University, Canada
RAIUB	Radio Astronomy Institute, University of Bonn, Germany
RMC	Royal Military College, Canada
ROB	Royal Observatory of Belgium, Belgium
ROE	Royal Observatory Edinburgh, Scotland
RRI	Raman Research Institute, India
RSAA	Research School of Astronomy & Astrophysics, Australia
SETI	SETI Institute, USA
ShO	Shanghai Observatory, China
StO	Stockholm Observatory, Sweden
STScI	Space Telescope Science Institute, USA
Swin	Swinburne University of Technology, Australia
TGU	Tokyo Gakugei University, Japan
TIFR	Tata Institute for Radio Astronomy, India
UAd	University of Adelaide, Australia
UAl	University of Alabama, USA
UAm	University of Amsterdam, Netherlands
UBir	University of Birmingham, UK
UBonn	University of Bonn, Germany
UBos	Boston University, USA
UBr	University of Bristol, UK
UC	University of Colorado , USA
UCal	University of Calgary, Canada
UCB	University of California, Berkeley, USA
UCha	University of Illinois, Champagne-Urbana, USA
UChi	University of Chile, Chile
UChig	University of Chicago, USA
UCL	University College London, UK
UCLO	University of California Lick Obs., USA
UCSB	University of California, Santa Barbara, USA
UCSC	University of California , Santa Cruz, USA
UCSD	University of California, San Diego, USA
UDur	University of Durham, England
UEdin	University of Edinburgh, UK
UEot	Eotvos Lorand University , Hungary
UGuan	University de Guanajuato, Mexico
UHel	University of Helsinki, Finland
UHerts	University of Hertfordshire, UK
UHilo	University of Hawaii, Hilo, USA
UIL	University of Illinois, USA
UKok	Kokugakuin University, Japan
UKST	United Kingdom Schmidt Telescope, Australia
UKT	Kyushu Tokai University, Japan
UKyoto	University of Kyoto, Japan
ULeeds	University of Leeds, UK
UMac	Macquarie University, Australia
UMan	University of Manchester, UK
UMar	University of Maryland, USA
UMaur	University of Mauritius, Mauritius
UMelb	University of Melbourne, Australia
UMinn	University of Minnesota, USA
UMont	University of Montreal, Canada
UNag	Nagoya University, Japan
UNAM	Universidad Nacional Autonoma de Mexico, Mexico
UNM	University of New Mexico, USA
UNSW	University of New South Wales, Australia
UOx	Oxford University, UK
UPenn	Pennsylvania State University, USA
UPitt	University of Pittsburgh, USA
UQld	University of Queensland, Australia
URh	University of Rhodes, South Africa
URuh	Ruhr-Universitaet, Germany
USMF	Santa Maria Federal University, Brazil
USNA	US Naval Academy, USA
USNO	US Naval Observatory, USA
USouth	Southampton University, UK
UStan	Stanford University, USA
USuss	University of Sussex, UK
USyd	University of Sydney, Australia
UTas	University of Tasmania, Australia
UTex	University of Texas, USA
UTor	University of Toronto, Canada
UTS	University of Technology and Science, Australia
UW	University of Wales, UK
UWA	University of Western Australia, Australia
UWash	University of Washington, USA
UWis	University of Wisconsin, Madison, USA
UWol	University of Wollongong , Australia
UWS	University of Western Sydney, Australia
Yale	Yale University, USA
YU	Yunnan Observatory, China

E: ATNF media releases 2000

Astronomers wipe clean their cosmic window	24 May
Astronomers win protection for key part of radio spectrum	20 June
Astronomers plan world's largest telescope	11 August
Australian to head world's top astronomy body	17 August
Apollo and the dish down under	12 October
The dish in the paddock at Parkes	12 October
"First Light" for upgraded Australia Telescope	8 December
"Red Dots" may re-write the history of the universe	28 December

ATNF media releases can be found on the Web at

http://www.atnf.csiro.au/news/press/atnf_press.html

and through

http://www.csiro.au

F: 2000 publications

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Theses of students co-supervised by the ATNF, 2000

Brooks, K. "An investigation of the Carina HII region/molecular cloud complex", PhD thesis, University of New South Wales (2000).

Kilborn, V. "Distribution of HI in the local universe", PhD thesis, University of Melbourne

Rayner, D. "Circular polarization of quasars and active galaxies", PhD thesis, University of Tasmania

Sandhu, J. "High precision dual frequency timing of millisecond pulsars", PhD thesis, California Institute of Technology

G: Postgraduate students co-supervised by the ATNF

As at December 2000

Name and Affiliation	Project Title
Boris Babic (University of Queensland)	Mass distributions in rich clusters of galaxies
Hayley Bignall (University of Adelaide)	Multiwavelength studies of Blazars
Antonie Bouchard (University of Montreal)	Search for HI in dwarf spheroidal galaxies
Christian Bruens (University of Bonn)	Interaction of the Magellanic Stream and other HVCs with the Galactic Halo
Scott Cunningham (Swinburne Uni. of Technology)	The construction of a digital receiver for radio astronomy
Tracy Getts (Macquarie University)	Dynamical study of southern interacting galaxies
Scott Gordon (University of Queensland)	Star formation in interacting galaxies: A multiwavelength study
Matthew Howlett (Swinburne Uni. of Technology)	Galaxy detection in HIPASS images
Maria Hunt (University of Western Sydney)	Molecular spectral line observations of southern molecular clouds
Melanie Johnston-Hollitt (University of Adelaide)	Examining magnetic fields through Faraday rotation measures
Sebastian Juraszek (University of Sydney)	Nearby galaxies in the Zone of Avoidance
Jasmina Lazendic (University of Sydney)	Interstellar chemistry in shocked molecular gas around supernova remnants
David Legge (University of Tasmania)	Accurate astrometry of southern radio pulsars
Dion Lewis (University of Tasmania)	Timing of young pulsars
Robert Minchin (University of Wales, Cardiff)	The bivariate luminosity/surface brightness distribution of an HI selected sample of galaxies
Daniel Mitchell (University of Sydney)	Interference mitigation in radio astronomy
Erik Muller (University of Wollongong)	The kinematics and structure of the Magellanic Bridge
Paul Roberts (University of Sydney)	High-speed digitisers for radio astronomy
Emma Ryan (University of Melbourne)	Column density distribution function of the local universe
Daniel Santos-Costa (Office National d'Etudes et de Recherche)	Physical modelling of the inner radiation belts of Jupiter
Daniel Christopher Sheppard (Uni. of Manchester)	A multibeam survey for pulsars over the southern part of the Galactic Plane
Nina Wang (Peking University)	Timing of strong pulsars
Vivienne Wheaton (University of Sydney)	Hydrodynamical models and an investigation into radio emission from SN 1987A in the Large Magellanic Cloud
Matthew Young (University of Western Australia)	An investigation of pulsar dynamics using improved methods of time series analysis

H: ATNF engineering milestones

This table compares planned and actual capital costs and timescales for major engineering projects. Actual/estimated cost and time ratios are also given where available.

	ESTIMATES			ACTUAL			RATIOS: actual/estimated		
Project	Start	Finish	Total cost $M	Start	Finish	Total cost $M	Cost:	Time:	Notes
PARKES									
21-cm Multi-beam System	Feb 1995	Sept 1996	0.47	Feb 1995	Feb 1997	0.6	1.28	1.3	scope increased from 9–13 beams
Broadband correlators	June 1996	June 1999	0.1	June 1996	in progress		>1.6	–	scope increased to provide SEST correlator
Parkes Conversion system	Feb 1997	Sept 1998	0.25	Feb 1997	June 2000	0.33	1.32	2.1	scope changed to add frequency switching system
Parkes 10/50-cm 2000 receiver	June 2000	June 2003	0.32	June 2000	in progress		–	–	
NARRABRI									
N-Spur	Feb 1997	Oct 1999	1.14	Feb 1997	Dec 1999	1.18	1.04	1.1	some delay from Narrabri floods
Extra E–W stations for ATCA	Feb 1997	Oct 1999	0.44	Feb 1997	Dec 1999	0.46	1.05	1.1	
12/3.5-mm receivers	Feb 1997	Jan 2002	2.86	Feb 1997	in progress	1.40 (to date)	–	–	
Surface extension for ATCA	Feb 1997	Sept 1999	0.91	Feb 1997	Oct 1999	0.83	0.89	1.0	minor improvements in progress
LO distribution upgrade	Feb 1997	Feb 2000	0.75	Feb 1997	in progress	0.50 (to date)	>1.3	>0.7	
Antenna Control Computers upgrade	Feb 1997	July 1999	0.2	Feb 1997	in progress	0.45 (to date)	>1.7	>2.2	
Water Vapour Radiometer	Feb 1997	jan 2002	0.16	Feb 1997	in progress	0.19 (to date)	–	>1.2	
VLBI UPGRADE									
Hydrogen maser, VLBI timing, S2 playback unit	Feb 1997	March 1998	0.34	Feb 1997	March 1999	0.33	0.97	1.9	
12-mm receivers	Feb 1997	Feb 2000	0.20	Feb 1997	Jun 1999	0.10	0.5	0.8	prototype only
Strategic									
InP MMIC devices	Jan 1998	Jan 2001	1.38	Jan 1998	in progress	0.89 (to date)	>1.0	>0.6	
SKA	Jan 1999	July 2003	1.44	July 1999	in progress	0.23 (to date)	–	–	
External Contracts									
Broadband Correlator	Jun 1996	Jun 1999	0.2	Jun 1996	March 2000	0.2	1.0	1.3	

Appendices

I: Glossary and abbreviations

3-mm band	The 85–115 GHz band of radio frequencies.
AAO	Anglo-Australian Observatory.
AAT	Anglo-Australian Observatory 4-m optical telescope.
ACC	Antenna Control Computer (used in the ATCA).
AMiBA	Array for Microwave Background Anisotropy.
AIPS	Astronomical Image Processing System developed by NRAO (USA) for synthesis radio images.
aips++	An object-oriented data processing system for radio telescopes, largely implemented in C++, which is being constructed by an international consortium of leading radio astronomy observatories.
ALMA	Atacama Large Millimetre Array. A US/European/Japanese project to build a large-mm array in Chile.
APT	The Asia-Pacific Telescope, an organization of Asian/Pacific observatories, to coordinate VLBI observations in the region.
ARC	The Australian Research Council, which funds university research in Australia.
ASA	Astronomical Society of Australia.
AT	The Australia Telescope, consisting of the six-element Compact Array at Narrabri, NSW, the 64-metre antenna at Parkes, NSW, and the 22-metre antenna at Mopra, NSW.
ATCA	The Australia Telescope Compact Array, consisting of six 22-metre antennas near Narrabri, NSW.
ATNF	The Australia Telescope National Facility, a National Facility for radio astronomy managed by CSIRO as a CSIRO division.
ATOMS	Australia Telescope Observatory Management System: object-oriented real-time telescope control software.
AT Steering Committee	A committee of leading Australian and overseas technical and scientific experts who provide policy advice to the Director of the ATNF, and are appointed by the Minister for Science.
ATUC	The AT User Committee, representatives (~20) of the Australian astronomical community, who provide feedback to the Director of the ATNF on operations and development issues.
Ceduna	A 30-metre antenna given to the University of Tasmania by Telstra, for use by the radio astronomy community. It is situated at Ceduna, South Australia.
CMB	Cosmic Microwave Background.
CSIRO	Commonwealth Scientific and Industrial Research Organization.
CTIP	CSIRO Telecommunications and Industrial Physics, a division of CSIRO partly co-located with the ATNF.
DAS	Data Acquisition Systems used for VLBI recording systems.
DASI	Degree Angular Scale Interferometer.
DSN	Deep Space Network.
EEO	Equal Employment Opportunity.
ESA	European Space Agency.
ESO	European Southern Observatory.
ESP	Executive Special Projects. A funding source set up by CSIRO to be used for outstanding, high-profile, high-risk projects.
GaAs MMIC	Gallium Arsenide Monolithic Microwave Integrated Circuit.
GPS	Global Positioning System.

HALCA	Highly Advanced Laboratory for Communications and Astrophysics. The Japanese VLBI satellite, previously called VSOP, launched on 12 February 1997.
HBT	Heterojunction Bipolar Transistor.
HIPASS	HI Parkes All Sky Surveys using the 21-cm multibeam system.
IAU	International Astronomical Union.
InP MMIC	Indium Phosphide Monolithic Microwave Integrated Circuit, a key technology for building our mm receivers; has better performance than GaAs at high frequencies.
ISAS	Institute of Space and Aeronautical Science (Japan).
ITU	International Telecommunication Union.
IUCAF	The Inter-Union Commission for the Allocation of Frequencies.
LBA	Long Baseline Array for Australian VLBI observations.
LMC	Large Magellanic Cloud. The LMC is the nearest galaxy to our own, and is a key target for the AT. It is visible only from the southern hemisphere.
LNA	Low Noise Amplifier.
LO	Local Oscillator.
MIRIAD	Multichannel Image Reconstruction Image Analysis and Display. A data-processing package for synthesis data, developed by Bob Sault, ATNF.
MMIC	Monolithic Microwave Integrated Circuit.
MNRF	Major National Research Facilities. An Australian Federal Government program to fund the development of National Facilities.
Mopra	The 22-m AT antenna at Mopra, near Coonabarabran, NSW.
Narrabri	The site of the AT Compact Array in northern New South Wales.
NASA	National Aeronautics and Space Administration. The US space agency.
NOAA	National Oceanographic and Atmospheric Administration.
OCC	Observatory Computer Committee (ATNF).
OECD	Organisation for Economic Cooperation and Development.
Parkes	The site of the AT 64-m antenna in central NSW.
RFI	Radio Frequency Interference.
S2	Video tape recorder used for VLBI.
SEST	Swedish-ESO Submillimetre Telescope in Chile.
SETI	Search for Extraterrestrial Intelligence.
SKA	Square Kilometre Array (previously referred to as the 1kT).
SMA	Spectrum Management Agency (Australia).
SMC	Small Magellanic Cloud. The SMC is a key target for the AT. It is visible only from the southern hemisphere.
Space VLBI	A technique whereby one antenna is carried on a spacecraft, thereby increasing the angular resolution available to radio astronomy by an order of magnitude.
TAC	Australia Telescope Time Assignment Committee, appointed by the Steering Committee.
TCS	Telescope Control System.
Tidbinbilla	NASA's tracking station located near Canberra, managed by CSIRO Telecommunications and Industrial Physics for NASA, and part of NASA's Deep Space Network.
VLBI	Very Long Baseline Interferometry. A technique where signals from widely separated antennas are correlated to provide very high spatial resolution images.
VSOP	VLBI Space Observatory Program.
WRC	World Radiocommunication Conference.
ZOA	Zone of Avoidance. The region of sky obscured by our galaxy. Also the name of the Parkes HI multibeam survey of this region.

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