# ATNF News

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## FEATURES IN THIS ISSUE



# First light at Parkes for the methanol multibeam receiver

The new seven-beam methanol multibeam (MMB) receiver has been successfully commissioned at Parkes and has begun surveying the Milky Way for newly forming stars that are pinpointed by strong methanol maser emission at 6.7 GHz. The methanol masers turn on while the young stars are still forming, deep inside giant molecular clouds of gas and dust, and are detectable long before the stars become visible to optical telescopes.

Installation began on 16 January 2006, when the receiver was lifted to the focus cabin. Epping engineers (Graham Moorey, Pat Sykes, Les Reilly and Paul Doherty) worked with local Parkes staff (with late-night and weekend efforts from Brett Dawson, Ken Reeves and John Reynolds and the Epping lads) to achieve first light in the small hours of Sunday 22 January. The first maser spectra show methanol emission at 6668 MHz and excited OH emission at 6035 MHz from the source G309.21+0.48 (Figure 1).

The receiver has already broken two records. It is the first Parkes receiver to have feeds within the cooled dewar; and it has more cables coming off it than any previous Parkes receiver. There are 28 receiver channels covering seven beams and two radio frequency (RF) bands in

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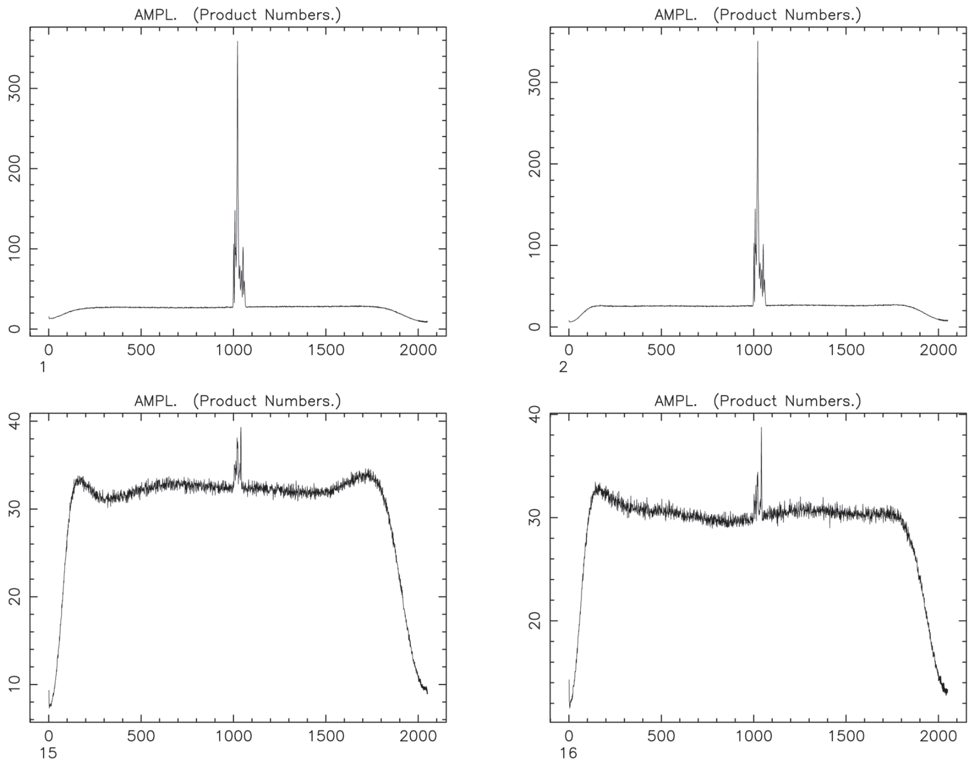


**Figure 1: First light spectra of the source G309.21+0.48 in the methanol 6668-MHz and OH 6035-MHz lines (upper and lower plots respectively).**

CSIRO

# Editorial

Welcome to the February 2006 edition of the ATNF News.

Once again we bring you an issue filled with articles and news items on activities happening at the ATNF. A thank you to all our contributors!

This issue's cover describes a major survey now underway at Parkes following the successful commissioning of the methanol multibeam receiver.

Maxim Voronkov describes the power of the Compact Array in the field of maser line studies, where many transitions have been made accessible by the advent of our 12-mm and 3-mm receiver systems that could not be studied previously.

The second science article is about the most sensitive wide-angle radio deep survey, ATLAS, which is currently being conducted with the Compact Array.

Stephen White reports his amazement about the capabilities of the Compact Array at 3 mm wavelength for observations of strong sources, such as Eta Carinae.

The now mature, powerful monitoring system of the Compact Array (and Mopra) called MoniCA is presented by David Brodrick, who wrote the code single-handedly.

Bob Sault has contributed news about Compact Array 3 mm data calibration.

Steven Tingay presents the launch of a campaign to establish radio astronomy as a research branch in New Zealand.

This newsletter also includes several other news items and our regular observatory reports besides reports on NTD and SKA developments. We hope you enjoy the newsletter! As always your comments and suggestions are welcome. The web version of this and previous issues can be found at *www.atnf.csiro.au/news/newsletter*.

This issue is the first for one of us at the ATNF News production team, Michael Dahlem. He will strive to continue the excellent work on the newsletter done by Lakshmi Saripalli over recent years.

*Michael Dahlem, Jessica Chapman*
*and Joanne Houldsworth*
*The ATNF Newsletter Production Team*
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# Contents

# News

## From the Director

2005 was a seminal year for the Square Kilometre Array (SKA); the SKA science case was published; the site selection process moved forward with four proposals being received at the end of the year and comparative site characterisation for radio frequency interference being completed; over AUD150M of investment in SKA R&D and demonstrator projects was committed around the world; the funding agencies of interested governments met to discuss the project for the first time at Heathrow in June. In addition, the International SKA Steering Committee, the International SKA Project Office and its working groups have produced a detailed project plan and have defined an SKA reference design. In each of these areas Australia played a leading role; the Australasian SKA consortium submitted a proposal to site the SKA on the unique radio-quiet site at Mileura, WA; through its science investment process CSIRO supported Australia's 1% SKA Pathfinder—the extended New Technology Demonstrator (xNTD); and Australian scientists made up over one sixth of the total membership of the international SKA working groups.

2006 will be an equally critical year as the SKA project begins to address the issues that will lead towards the project having a more formal international structure, with strong engagement and participation by the funding agencies of the countries involved in this global project. An important step forward in this process began at an agency meeting in The Hague in February. At this meeting, agencies resolved not only to have regular six-monthly meetings on the SKA in the future, but also to establish a seven-member working group to consider issues of governance, site selection, and time scales. Indeed, it is the phasing of the funding time scales in the different contributing nations, whether it is for the 10% SKA Phase 1 or the full project, which is probably one of the greatest issues currently facing the SKA. The issue of site selection will also be brought to the fore in late 2006 with the International SKA Steering Committee's recommendation on SKA siting to be made in September 2006. Again, it is encouraging to note that, as a member of this seven-member agency working group, Australia continues to play a key role at all levels in this international project.

CSIRO ATNF has played a major role in Australia's involvement in the SKA. Through the Major National Research Facility (MNRF) program, it continues to make significant contributions to all aspects of the SKA, including next-generation correlator architecture via the Compact Array Broadband Backend, and to the critical small dish/focal plane array element of the reference design via the NTD/xNTD project. An equally important aspect of the design of the SKA is international collaboration. To that end, the recent successful commissioning of the methanol multibeam receiver, jointly built by the ATNF and Jodrell Bank Observatory, on the Parkes radio telescope, also serves as an excellent example of Australia's ability to work with international partners in the delivery of leading-edge technology solutions. The Compact Array Broadband Backend and the methanol multibeam also demonstrate the ATNF's commitment to extending the scientific capability of existing radio telescopes while continuing to look towards the next generation of radio astronomy facilities. This balance is not easy to achieve, and as the ATNF continues to look towards the future, we must ensure that investment in existing facilities continues to be directed towards capabilities that maintain world-class performance in targeted areas.

*Brian Boyle*
*ATNF Director and Australian SKA Director*
*(Brian.Boyle@csiro.au)*

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## First light at Parkes for the methanol multibeam receiver

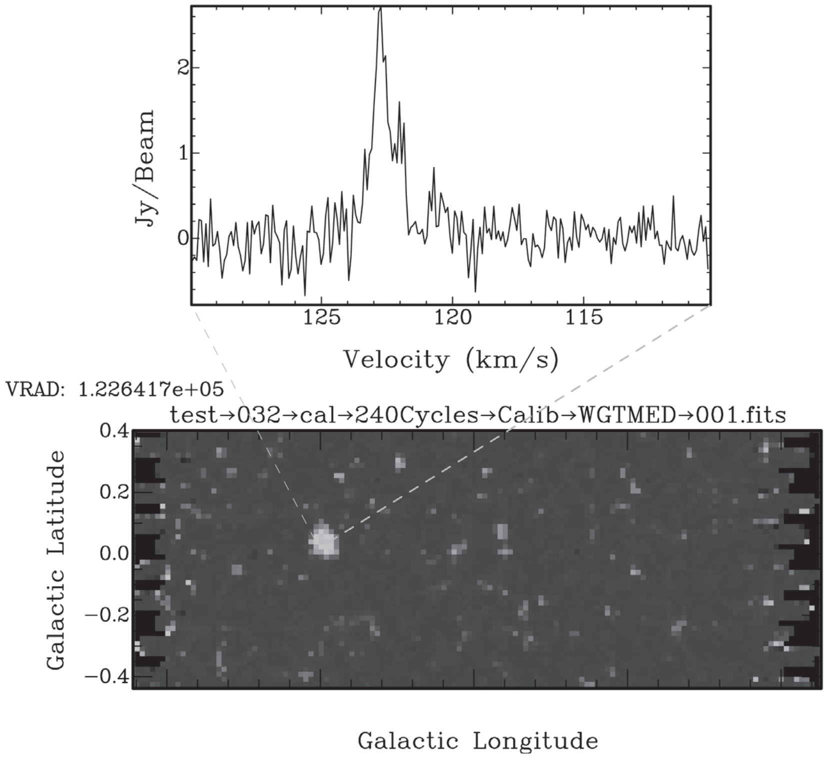


**Figure 2: First discovery from the methanol multibeam survey.**

dual circular polarisation. The receiver must be continuously rotated while observing so as to maintain the beam pattern on the sky—quite a challenge for the engineers. The two intermediate frequencies (IFs) normally cover the methanol 6668 MHz and OH 6035 MHz lines. By using the multibeam correlator in parallel with the wideband (pulsar) correlator we can measure the two lines in dual circular polarisation at high (2 kHz) frequency resolution. The receiver can also provide two broadband (300 MHz) IFs for continuum (e.g. pulsar) observations.

The receiver was jointly constructed by the ATNF and Jodrell Bank Observatory (UK), with ATNF's role described in an accompanying news note by Graeme Carrad. The project was catalysed by a PPARC grant obtained by a consortium of seven UK institutes, led by UK project scientist Jim Cohen (Jodrell Bank). James Caswell is the ATNF project scientist, while the project manager, leader and engineer is Graham Moorey. For the record there are two other Jims in the team, PhD students James Cox (Cardiff) and Jimi Green (Jodrell).

Using the high gain of the Parkes telescope, the sensitivity of the low-noise amplifiers and the seven beams, the MMB survey of the Milky Way is two orders of magnitude faster than previous systematic surveys using 30-m class dishes. The first of many discoveries from the survey, shown in Figure 2, is a star-forming region that lies in the inner Galaxy at a distance of 22,000 light years. The source appears in the figure as the bright spot, and the corresponding spectrum at this position is shown. Once the southern Milky Way has been searched, the multibeam receiver will be transported to Jodrell Bank Observatory to survey the northern Milky Way.

*Jim Cohen (Jodrell Bank Observatory) and James Caswell (ATNF)*
*(James.Caswell@csiro.au)*

# Methanol multibeam receiver at Parkes

The installation of the 6 GHz methanol multibeam (MMB) receiver at Parkes in January was the culmination of a concerted effort by members of the Receiver section of the Engineering Development Group and the painstaking workmanship of Marsfield workshop staff.

Graham Moorey led the team that collaborated with a team at Jodrell Bank Observatory and took the Jodrell Bank supplied low noise amplifiers and conversion modules, measured and modified them to improve their performance and built them into a world class seven beam system.

There were hiccups along the way, one that needed a substantial redesign, but these were overcome rapidly, thanks to Pat Sykes and the workshop efforts. Pat gave a new 3-D drawing package its first real challenge in designing the dewar and its internal components, the dewar mounting hardware and cable snake. The tight packing of the input waveguide components made the layout and cable routing a bit of a headache. It all managed to fit together nicely and then the redesign reared its ugly head and it was made to fit together nicely again.

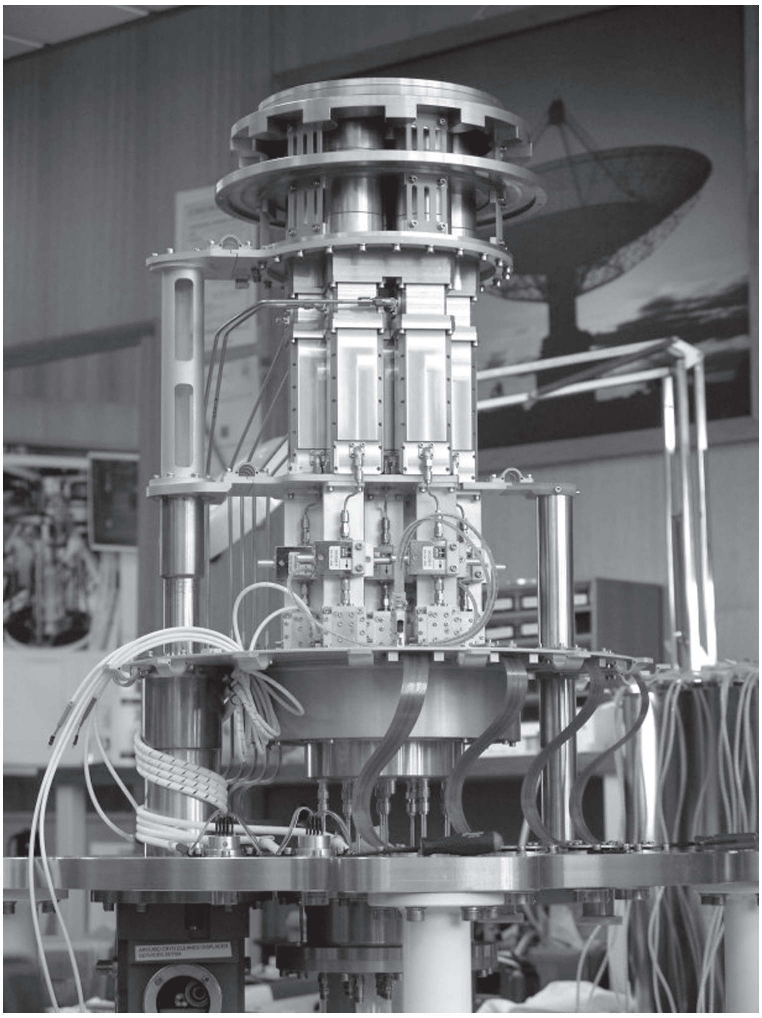

Photo: Russell Bolton

**The new 6 GHz Methanol Multibeam (MMB) receiver at Parkes.**

Alex Dunning's great talent in waveguide component design was once again invaluable in producing the orthomode transducer, needed to extract both polarisations from the signal, and the calibration noise coupler. It was a new challenge working in square waveguide for a lad more accustomed to rectangular and circular cross sections.

Les Reilly's complex, yet ever reliable, electronics worked a treat and some of the credit for that must go to Jennie Lie for her soldering and cabling efforts.

Other expertise in construction and measurement was contributed by Henry Kanoniuk, Russ Bolton, George Graves, Peter Axtens and Daniel Gain. New boy on the block, Paul Doherty, proved his worth with his machining skills complementing those of Eliane Hakvoort.

Graham Moorey was not only Project Leader, but led by example at project's end by rolling up the sleeves and helping in the fabrication of the countless cables required with a cast of thousands.

The "in lab" receiver measurements returned noise temperature measurements in the low 20 K region for all channels and this seems to have been replicated in the "on telescope" measurements. Parkes is now equipped with another powerful tool for generating more great science. See the separate report by Jim Cohen on the commissioning of the MMB, on the front page of this newsletter.

*Graeme Carrad*
*(Graeme.Carrad@csiro.au)*

# SKA and xNTD news

## Additional CSIRO funding for SKA/xNTD

CSIRO has recently undertaken a review of its general directions of research. The communiqué of the outcomes from this "science investment process" recognised radio astronomy as "a leading science initiative in Australia", reaffirmed CSIRO's support for the ATNF, and described the Square Kilometre Array (SKA) and extended New Technology Demonstrator (xNTD) as "key planks of Australia's determination to remain at the forefront of radio astronomy". As a result of this review, CSIRO will allocate an additional AUD 0.51M in 2006/07 to support radio astronomy and SKA/xNTD development. In addition, CSIRO Corporate Communications, Science Planning and Commercialisation will deploy specific resources to assist the SKA bid, and provision will be made for increased capital investment in the xNTD.

## New Technology Demonstrator (NTD) developments

The NTD project provides initial research and development (R&D) for a "small-dish + focal-plane array" concept using all-digital beamforming. Deliverables from this project are critical components for the xNTD, the project recently initiated with additional funding from CSIRO to develop Australia's SKA Demonstrator.

During the last 12 months we have produced a prototype digital beamformer that has 24 input channels, a bandwidth of 24 MHz and 24 prototype receivers. These will be used in a two-element interferometer at the ATNF's Marsfield site. As described in the October 2005 edition of ATNF News, we have refurbished two 13.7 metre diameter parabolic dish antennas: they are now equipped with new mesh surfaces, control systems, a quadrupod (to contain various focal-plane arrays) and cabling. In late 2005 we took delivery of a thousand element array (THEA) tile purchased from ASTRON: this is now being tested on the ground (figure 1).

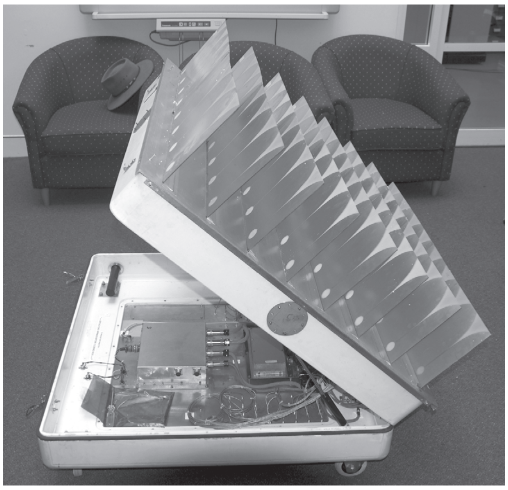

Photo: Robert Hollow

Figure 1: The THEA tile relaxing after its long flight to Australia.

In the next quarter we will commission and develop this test-bed system and assess various Focal Plane Array (FPA) research activities. Our goals in this project are to better understand FPAs, reconcile antenna range measurements with astronomical measurements, validate models for reflector/FPA/coupling/receiver/beamformer, determine optimum/practical beamformer parameters, and develop calibration methods. A Critical Design Review for the NTD will be held in March 2006. MNRF funding for the NTD runs until July 2007.

## Progress with the xNTD antenna design project

The specification for CSIRO ATNF's extended New Technology Demonstrator (xNTD) radio telescope will be based on an array of 20 antennas, each being equipped with an FPA. The antennas are a critical element in the xNTD project; at the present time there is no obvious design that meets the requirements.

The aim of the xNTD antenna design project is to understand the likelihood of realising the xNTD antenna cost target based on the xNTD antenna specification, coupled with current manufacturing and design capabilities.

The xNTD project is now engaging with three Australian companies to deliver feasibility studies for the xNTD antenna, which meet, as closely as possible, the base specification and the cost target of AUD 250,000 per antenna. We expect that these companies will draw on in-house and outside expertise as necessary, will provide a detailed feasibility study on the provision of materials, skills and infrastructure required for manufacturing, testing, transporting and assembling xNTD specification reflector antennas in Australia.

When these feasibility studies are complete we expect to prepare an AusTender for the design and build of the xNTD antennas.

### Inaugural industry cluster briefing

Following the identification of a "core" consortium of companies to act as both financial sponsors and leading industry supporters of the SKA cluster mapping project, CSIRO ATNF hosted the inaugural Australian SKA industry cluster event "The SKA Cluster Initiative – Australian Industry Capabilities & Project Opportunities" on Monday 5 December 2005.

The "SKA cluster mapping project" is determining capability, gaps and strategic goals within Australian-based electronics and information and communication technologies (ICT) industries, and we anticipate using up to six briefings Australia-wide to educate and enthuse industry about the xNTD and SKA projects. The industry cluster mapping project is expected to foster the development of industry-led SKA R&D projects, offering global exposure to potential new astronomy markets, as well as the exploitation of SKA technologies beyond radio astronomy.

The briefing day on 5 December attracted 60 participants from industry, government, CSIRO and other agencies from all Australian states (with the exception of NT and Tas) and New Zealand. A strong "networking" buzz was evident throughout the event, with very positive feedback from a number of attendees. Presentations covered the aims of the industry cluster, its link to the Electronics Industry Action Agenda, xNTD project R&D—both current challenges—and the "extended" challenges presented by the SKA. A discussion of opportunities for Australian industry engaging in the xNTD and SKA projects concluded the event.

All presentations from the briefing are now on-line at

*www.atnf.csiro.au/projects/ska/industry_2/cluster1_followup.html*

More information on the industry cluster activities can be found on the Australian SKA Project Office (ASPO) industry web pages

*www.atnf.csiro.au/projects/ska/industry_2/antennas.html*

or contact Dr Carole Jackson, ATNF Business Development Manager and ASPO Industry Liaison, *Carole.Jackson@csiro.au.*

### DITR funding for the SKA industry cluster mapping project

We are pleased to announce that the core consortium, of which CSIRO ATNF is a member, has been successful in its application for Department of Industry, Tourism and Resources (DITR) AusIndustry "ICIP" funds. These funds are the first industry-based grant towards Australian SKA activities, and will enable the cluster to fulfil its aims, most importantly to produce an industry capability map to Government in mid 2007.

The core consortium comprises AEEMA, CSIRO, Boeing Australia Ltd, BAE SYSTEMS Australia, Cisco Systems, Global Innovation Centre Pty Ltd, Raytheon Australia Pty Ltd, RLM Management Pty Ltd, Tenix Pty Ltd, RF Technologies Aust Pty Ltd and Radio Frequency Systems Pty Ltd and we sincerely thank them for their ongoing support and interest in the project.

### EU SKA design study project commences

Following two years of preparation and negotiation, an international consortium has been awarded an EU Sixth Framework Programme (FP6) grant for an end-to-end design study for the SKA, named "EU SKADS". The project brings together thirty groups from Europe, Canada, Australia, South Africa, USA, China and industry partners. ASTRON is the project leader of this EUR 38M project, with a focus on front-end array antenna development from the existing THEA tile to a fully-digital, dual-polarisation aperture array "2-PAD" over the four-year project. Australia, through CSIRO and the universities of Swinburne, Adelaide, Sydney and Melbourne, is participating in EU SKADS, with CSIRO's NTD/xNTD R&D being a major contribution.

Further information can be found at the EU SKADS website:

*www.skads-eu.org/*

### Australasian siting proposal submitted

The formal proposal to site the SKA in Australia was submitted to the International SKA Planning Office

(ISPO) on 5 December 2005. The proposal was developed by the Australian SKA Planning Office on behalf of the Australasian SKA Consortium, with the assistance of a large number of organisations and agencies.

Under the proposal, the core site for the SKA would be on Mileura Station in the midwest of Western Australia, while remote array-stations would span the continent with maximum east-west baselines in excess of 3200 km. Further array-stations in New Zealand would provide for a maximum east-west baseline of more than 5500 km.

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

*Helen Sim on behalf of the SKA/xNTD team* (*Helen.Sim@csiro.au*)

# First steps towards radio astronomy in New Zealand

A bit more than 18 months ago, Marilyn Head, then a student of Swinburne’s Astronomy Online course, had occasion to write an essay on radio astronomy for her instructor, Steven Tingay. As a New Zealander, Marilyn lamented the fact that her country was not a strong radio astronomy nation. And as a person of almost boundless energy, Marilyn sought to explore some ideas as to how this situation could be rectified. She rounded up about 20 interested people from around New Zealand and organised Steven Tingay to give a colloquium in Auckland, pitching radio astronomy as a new field for Trans-Tasman scientific collaboration.

Immediately following this successful initial meeting, Sergei Gulyaev, Tim Natusch, and Slava Kitaev of the Auckland University of Technology and Steven Tingay of the Swinburne University of Technology initiated a collaboration that aims to develop a serious long-term radio astronomy program in New Zealand. The motivations behind the collaboration are broad:

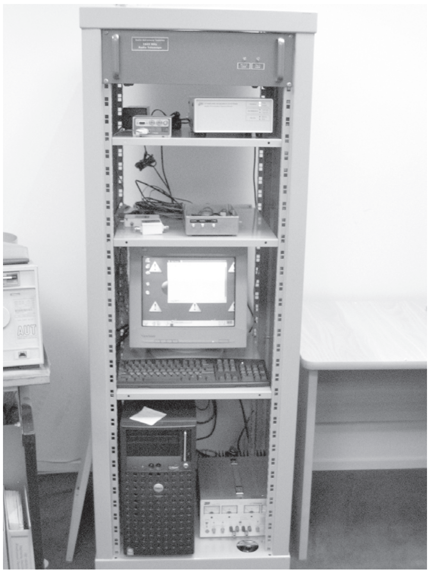

Photo: Steven Tingay

**Figure 1: The downconversion system, receiver, clocks, and recording system developed by Tim Natusch at the Auckland University of Technology.**

- There are obvious scientific benefits to be gained by adding a New Zealand antenna to the Australian array of radio telescopes used for very long baseline interferometry (VLBI). This will add substantially longer baselines to the array and hence achieve higher angular resolution.

- Radio astronomy is an ideal vehicle for engaging in cutting edge supercomputing, long-distance high speed networking, and advanced signal processing research. An aim of the program is to develop these fields in New Zealand.

- A long-term interest of the program is for New Zealand to participate in the international Square Kilometre Array (SKA) project, as a partner in Australasia’s bid to host this next generation instrument.

Over the last 12 months of this collaboration, the work effort has gathered pace and has been generously supported from a number of quarters. This brief article outlines progress on a number of different fronts and outlines some plans for the future.

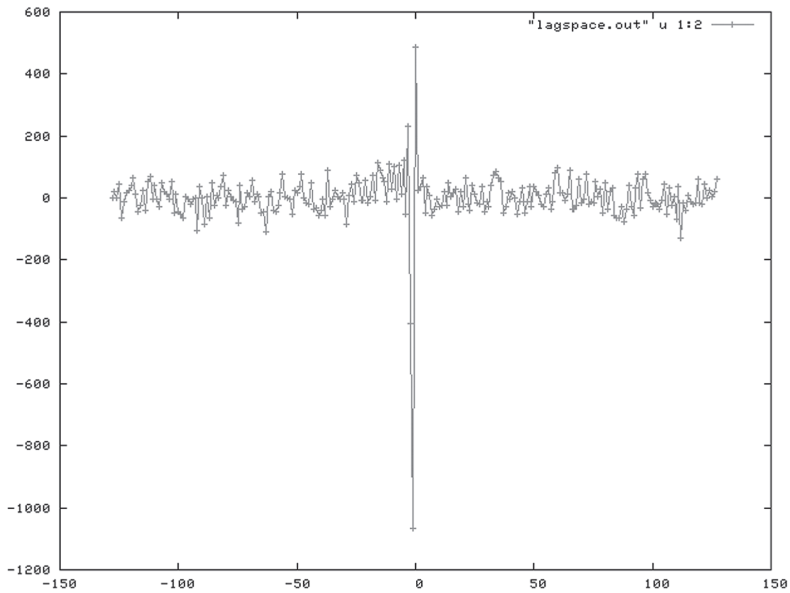


**Figure 2: First detected fringe using the New Zealand radio astronomy package. The New Zealand equipment was mounted on the 14 m antenna at the Mt Pleasant observatory in Hobart and recorded data which was correlated with data recorded at the ATCA.**

In late 2004, the Auckland University of Technology (AUT) formed the Centre for Radiophysics and Space Research (CRSR), chaired by Sir Ian Axford, with Prof Sergei Gulyaev as Director. The Centre, with a great deal of help and support from many individuals and institutions, has provided the core drive behind many of the recent developments, including:

- A series of radio astronomy workshops and seminars held in Auckland in April 2005.

- New Zealand representation on the Australasian (formerly Australian) SKA Committee (ASKAC).

- New Zealand subscription to the International SKA Consortium, with representation via ASKAC.

- Obtaining access to, and building the capability for, new radio astronomy facilities in New Zealand.

The technical side of the collaboration has recently been an area of heavy focus. The CRSR obtained a grant of NZD 200,000 through the New Zealand Ministry of Economic Development to undertake a technical proof of concept project. The project was to develop the hardware and software required to demonstrate the operation of a radio telescope in New Zealand for astronomy, specifically to participate in VLBI observations with the Australian array of radio telescopes and obtain the first Trans-Tasman fringes. Given New Zealand's track record in radio astronomy, this was a suitably ambitious and challenging project. Over the last 12 months, Mr Tim Natusch, the first postgraduate student of the CRSR, has developed and built components for a self-contained radio astronomy system for VLBI, including a 1.658 GHz (centre frequency), 16 MHz bandwidth RF system (feed and downconversion system locked to a Rubidium maser and GPS clock), an 8-bit sampler/digitisation system, and a disk-based recording system built around a commodity PC (Figure 1). This was designed as a portable system for use on different radio telescopes, since the one thing that New Zealand lacks at the moment is ready access to a large collecting area, fully steerable antenna.

Testing of the CRSR system has been extensive, and at times exhausting. Initially the system was mounted on a 6-m parabolic reflector owned by Mr Brent Addis, for testing and VLBI observations involving the 64-m Parkes telescope and the 6 x 22-m antennas of the Australia Telescope Compact Array. VLBI data were thus obtained from a series of experiments in March, May, and July 2005.

In addition, for debug tests on two occasions, the portable system was taken to the Mt Pleasant Observatory of the University of Tasmania, where it was mounted on the 14-m antenna, approximately 100 m away from the main 26-m antenna facility at Mt Pleasant. Fringes were obtained between the 14-m and 26-m antennas, confirming the operation of the CRSR system as effective for VLBI. First fringes were found on 25 August 2005 (Figure 2), following a trying 48 hours during which the equipment tested the patience of all concerned, including an all night session and 3 a.m. callouts for Observatory staff Brett Reid and Eric Baynes, whose powers of persuasion over stubborn hardware saved the day. It was worth it in the end however, as the relief on the tired faces of the workers shows (Figure 3). An experiment that involved the 14-m antenna, the 26-m antenna and the Compact Array took place soon after, on 28 August. Other aspects of testing some components of the New Zealand system were undertaken during a visit to the Parkes Observatory in July.

Photo: Steven Tingay

**Figure 3: Jubilation following first fringes, demonstrating the success of the CRSR VLBI system. In the control room of the Mt Pleasant Observatory near Hobart, very soon after sunrise on 26 August 2005 are (from left to right): Mr Adam Deller (Swinburne), Prof Sergei Gulyaev (AUT), Mr Tim Natusch (AUT), Mr Brett Reid (University of Tasmania), and Mr Eric Baynes (University of Tasmania). Not shown is Dr Steven Tingay (Swinburne).**

With the success of the Hobart tests under our belt, we set about fully correlating the Trans-Tasman VLBI experiments from July, using the software correlator running on the Swinburne supercomputer. A convincing detection of the quasar PKS 1921-293 was made using the data from a one hour observation of 31 July between the 6-m antenna in New Zealand and the phased Compact Array. Figure 4 shows an image from this single-baseline VLBI experiment, the first Trans-Tasman VLBI image!

All involved with these initial successes are very pleased with the progress, as it lays a very solid technical basis for a substantial new proposal to fund a serious radio astronomy facility in New Zealand. A number of ideas are under discussion at the moment as to what might constitute such a facility. It will most likely be aimed primarily at astronomical and geodetic applications of VLBI, contributing to the radio astronomy capabilities of Australasia.

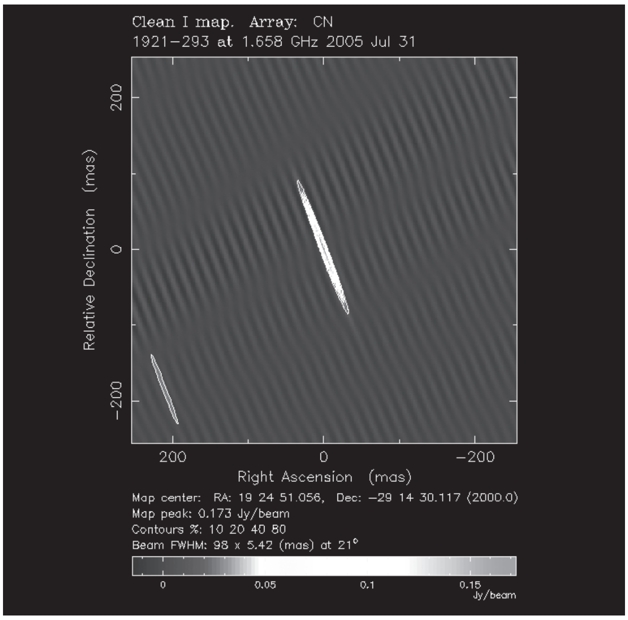


**Figure 4: The first Trans-Tasman VLBI image, PKS 1921-293 observed for one hour at 1.658 GHz using the 6-m telescope in New Zealand and the ATCA.**

In addition to the generous support and encouragement received from the authors' home institutions and funding sources, the authors acknowledge with great appreciation offers of support and advice from staff of the Australia Telescope National Facility, in particular the free use of facilities and expertise in testing equipment, and the provision of Director's time in the Parkes and Compact Array schedules which were used for VLBI test observations.

As the collaboration continues to make progress toward its ultimate goals, periodic updates will be made via the CRSR website (see above) and perhaps occasionally in this Newsletter.

*Steven Tingay on behalf of*
*Sergei Gulyaev, Tim Natusch (Auckland University of Technology), Steven Tingay, Adam Deller, Craig West (Swinburne University of Technology), Simon Ellingsen, Peter McCulloch, Brett Reid, Eric Baynes (University of Tasmania), Tasso Tzioumis (ATNF)*
*(stingay@astro.swin.edu.au)*

# MoniCA – New monitoring software for the Compact Array and Mopra

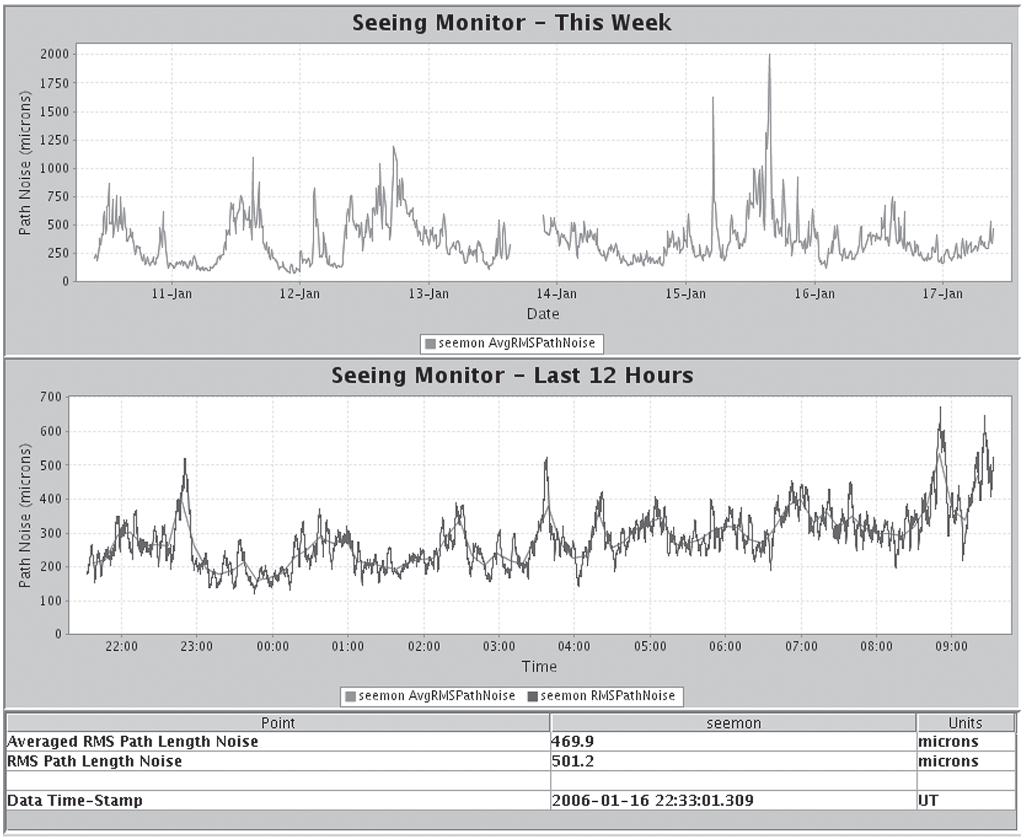


**Figure 1: A sample screen-shot from MoniCA. This page shows two plots of the atmospheric phase stability (covering different time spans) and also displays the latest values in a table format. The Atmospheric Seeing Monitor (ASM) was described in *ATNF News* Issue 53 (June 2004).**

The Narrabri Computing Group recently released a new powerful application for inspecting telescope monitor points at the Compact Array and Mopra. The client software, called MoniCA, is a Java-based graphical user interface (GUI) program that enables both observers and technical staff to monitor the thousands of data points available at each site, including things such as cryogenic temperatures and pressures, sampler statistics, site weather information, power supply voltages and so on.

The system was designed from the ground up to meet the needs of the observatories for years to come, including remote operation of Mopra. It can be used to monitor values in real-time, make graphs of monitor point values over time (including graphs of archived data) and plot the values of different monitor points against each other. Data points stored in databases can be recalled and plotted at a later time for analysis, statistical and maintenance use. Frequently used pages can be called up immediately, but the user can also define new pages on the fly to view data and graphs of interest. The server component even has a network interface with a simple ASCII text protocol, to make it easy to gain access to the monitor data from any programming language—this has already proved popular with the VLBI group and the new ATCA Live! web page is also implemented using this feature.

The software has been tested on Windows, Linux, Solaris and Apple platforms. You can download it from *www.narrabri.atnf.csiro.au/monitor/monica/* but please note, the software will only work within the ATNF network! There are still a couple of known bugs but the software is already very usable. We are always eager to hear user feedback, please email David Brodrick if you have any comments or suggestions.

*David Brodrick*
*(David.Brodrick@csiro.au)*

# Who needs high altitudes?

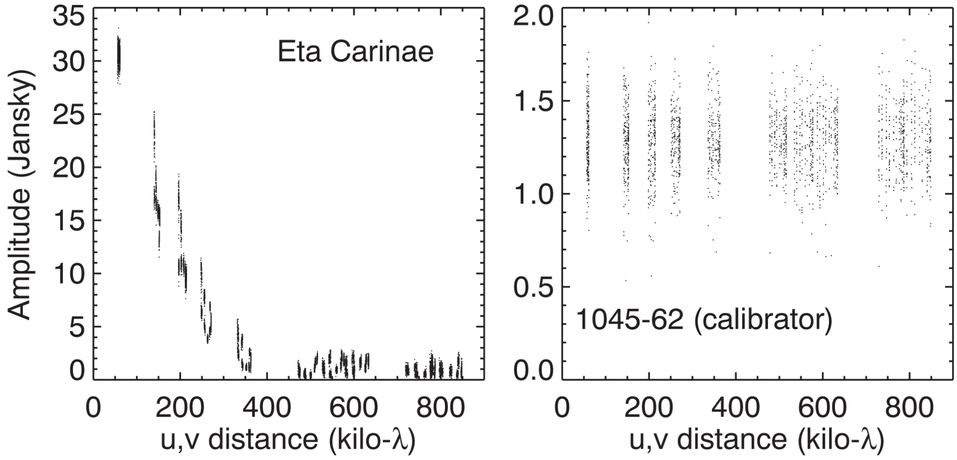


**Figure 1:_Amplitude versus *u,v* distance over 3 km baselines at 3 mm wavelength for Eta Carinae (left) and the phase calibrator 1045–62 (right).**

There are several maxims that millimetre astronomers live by, borne out by bitter experience. Principal among these is that weather is your enemy, any weather really. Cold, clear skies are always best. Next, that higher is always better. In this context, an altitude of 200 m (Narrabri) is nothing. Finally, millimetre interferometry over long baselines, longer than a few hundred metres, is not possible except in the very best conditions, specifically a very dry atmosphere well below freezing at high altitude, otherwise atmospheric phase fluctuations are so large that they make observing impossible.

I thought gloomily about these maxims as I drove from Sydney to Narrabri for a Compact Array observation at 3 mm wavelength on 3 km baselines and saw cloudy skies. I was in a bit of a hurry, actually, since my observing time had already started. As per usual, I had been cutting it fine, planning to arrive just the day before the observation, but my flight from Washington to Los Angeles had mechanical problems and by the time they flew in a spare part from Boston, it was way too late to connect to the Sydney flight, and I had to spend an extra day in Los Angeles. This turned out to be an experience in itself. When I woke up late the local TV stations were already providing wall-to-wall helicopter coverage of a freeway chase. We don't have that on the east coast. We have plenty of freeways, so we must have freeway chases, but there's no TV coverage. It's a California thing.

Then after lunch there was an earthquake. Quite a big earthquake. I was sitting on the bed working at my laptop, in a room on the first floor of the hotel near the airport, when everything started shaking. It lasted about 10 seconds and everything shook pretty well: if it had gone on any longer the enormous TV would have fallen off the table it was on. The earthquake was big enough to interrupt the freeway chase coverage, and an hour later we were promised a press conference live from the Jet Propulsion Laboratory. I duly watched the tectonics expert from Caltech assure the press that this was just an ordinary earthquake, not related to the much larger one that occurred a week earlier, hundreds of miles offshore, a thousand miles away on a completely different fault. It was just another day in LA. (It's a California thing.)

Anyway, there I was driving up the Hunter Valley, watching the high cloud increase and listening to the forecast of rain moving into the state from the south-west. I was resigning myself to an unsuccessful track, which was OK; after all, you can't expect to do millimetre interferometry on 3 km baselines at just 200 m altitude near the tropics in a warm country. Every millimetre astronomer knows that.

So I get to Narrabri and blearily make my way to the control building (for the second time: I had of course forgotten the combination and it was the weekend). I had sent an e-mail to Bob Sault warning him that I would be late and he agreed to run the observation until I arrived. Bob is sitting there in the control room, programming away. I greet him and start to commiserate about the weather. But Bob stops me and says, with that inflection of his that makes it sound as if he had been sagely pondering this for hours, that it's going fine. Even on the long baselines, I ask? Yep, he grunts. And sure enough, I look at the screen and it is going fine. Really fine. Who would believe it? Millimetre interferometry on 3 km baselines practically at sea level, almost in the tropics, with clouds. It's just not right.

Now, I probably should have mentioned that the target was Eta Carinae. Sometimes I think that Eta Car was put in the southern sky just for the Compact Array. The spatial scales of Eta Car's emission match the Compact Array's longest baselines perfectly and scale with wavelength as the array's resolution does. Plus, it satisfies the other maxim of millimetre interferometry, the one I omitted above: it has flux. Lots of flux, concentrated in a small area. In fact, more flux than any of the calibrators and most of the planets. There is no source remotely like it in the northern sky. The flux comes from gas in the dense outflow from a binary system containing two hot stars in a highly elliptical 5.5 year orbit. As the hotter secondary star moves out of the very dense wind of the primary, its UV photons are able to ionise increasing amounts of gas some distance away in the outflow and the resulting optically-thick thermal emission at about $10^4$ K brightness temperature provides the radio flux. At 87 GHz it was 2 Jy at its minimum in 2003, when the hot star was buried deep in the wind of the primary, 14 Jy a year later, and now, as Bob sat by calmly, it was an astonishing 30 Jy from a region not much more than 1 arcsec across. Plots of amplitude versus baseline length are shown in Figure 1 for the phase calibrator (1045–62) and for Eta Car (different amplitude scales). This flux level is the key to the observation, since it permits self-calibration to remove atmospheric phase fluctuations on the shortest timescales; without this the observation would not have been successful.

The benefit of this success is that we can achieve a nominal resolution of 0.2 arcsec with 3 km baselines at 3 mm wavelength. The resulting image is compared in Figure 2 with the 21 GHz image from a few days later, both at 0.2 arcsec resolution (the 21 GHz image is somewhat super-resolved, and the astrometry of the 86 GHz image could not be preserved so the relative positions of the 21 and 86 GHz images are arbitrary). The 86 GHz image shows what the visibility plot already foretold: the source is well resolved at this spatial scale. The dynamic range in the 86 GHz image is over 100. The peak brightness temperature is 9400 K at 21 GHz, but almost 15,000 K at 86 GHz, suggesting that the temperature increases as you go in towards the central region of the source.

Normally the problem with observing over long baselines at millimetre wavelengths is that within one integration time the phase difference along the atmospheric paths to a pair of telescopes varies by so much that the vector sum of the visibility data suffers amplitude loss. However, you can't always tell what atmospheric conditions will be like just by looking at the sky. Frequently at Hat Creek we would have cold clear days right after a front passed through that looked like great observing days, but the atmospheric phases fluctuated rapidly due to turbulent moisture at a certain height that made the data useless. Similarly, in this case the high cloud actually represents a smooth atmosphere at the appropriate height, so that despite the extra moisture in the atmosphere the timescale for large phase fluctuations is not too severe, minutes rather than seconds, allowing a successful observation for an object with enough flux to be self-calibrated. But the bottom line is that we were a bit lucky that this track was so successful: millimetre astronomers don't have those morose maxims for nothing!

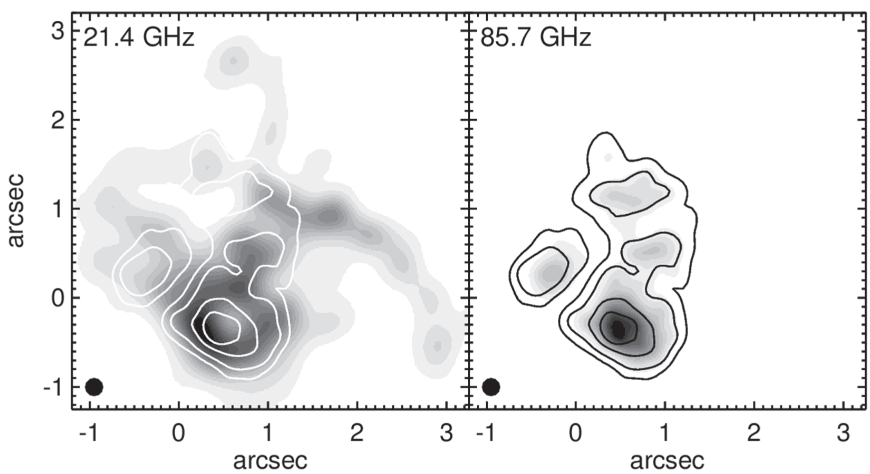


**Figure 2: Compact Array observations of Eta Carinae in 2005 June at 21 GHz (left) and 86 GHz (right). The resolution is 0.2 arcsec in both images (beam size shown at lower left). Contours of the 86 GHz emission are overplotted in white on the 21 GHz grey scale image. The overlay is chosen to try to match the 86 to the 21 GHz emission: the astrometry at 86 GHz did not survive self-calibration.**

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# An update on the calibration of Compact Array 3 mm data

By many measures, the Compact Array 3 mm observing band is in a completely different domain to the other Compact Array bands. The science is different, weather is much more important, and the approach to observing is different. Of interest in this article is the approach to calibrating 3 mm data. This article considers improvements and refinements in calibrating 3 mm data, particularly from the perspective of a *Miriad* user. The chapter on 3 mm data reduction in the *Miriad* manual has recently been updated to reflect these. For more information, see *www.atnf.csiro.au/computing/software/miriad*.

### System temperature correction

Currently the Compact Array uses a paddle to implement the "chopper wheel" method for measuring an above-atmosphere system temperature. While the other Compact Array bands measure system temperature continuously, the paddle measurement is done only occasionally. The *Miriad* task atfix now implements an interpolation algorithm to correct the data for a continuous estimate of system temperature. This interpolation algorithm attempts to account for changes in elevation and weather, and works regardless of whether system temperature correction was applied online or not.

### Antenna gain variation

The Compact Array antennas are large enough that both elevation (gravitational) and thermal changes can significantly affect the antenna gain and beamshape at 3 mm wavelength. For example time-varying thermal distortions have been implicated in antenna gain changes of 25% over the course of an observation. Unless the flux calibration is planned with care, it will not be possible to correct these sorts of gain errors.

To first order, the gain change will be calibrated out provided the secondary calibrator is very close to the target source. Applying the canonical gain/elevation curve built into *Miriad* atfix also helps. However, this will not solve the change in the beamshape and this may be an important issue for widefield imaging and mosaicing. The best way to avoid thermally-induced gain variations is by observing in the pre-dawn hours, or on a calm cloudy day! The best way to avoid large elevation changes in a synthesis is to observe in a hybrid array!

These gain variations must be considered when bootstrapping the flux density scale. The best approach to ensuring a good flux scale is to ensure that the secondary and flux density calibrators are observed nearly simultaneously and at the same elevation. In most cases there will be a specific time during an observation when these calibrators are at the same elevation.

### Flux density calibration

At 3 mm wavelength, the planets are used as the primary flux standards. Previously Mars was recommended as the best 3 mm flux density calibrator, with Uranus as a second choice. However, last season showed that the departure of Mars from a simple disk at constant temperature is readily detected by the Compact Array. Uranus is now the recommended flux standard. Mars can still be used, but with more care.

An issue that some observers have had is that Uranus and Mars were not available during their observing run—these planets were in the same part of the sky in 2005. To provide a flux density standard at other parts of the sky, an observing program was held in 2005 to regularly monitor 1921–293 and 1253–055. The results from this were promptly fed back into the Compact Array on-line calibrator database. To a degree this flux monitoring was affected by a lack of appreciation of the antenna gain issues mentioned above.

In 2006 Uranus and Mars will be well spaced on the sky. Despite this, 1921–293 and 1253–055 will need to be monitored regularly. When relevant, observers should check the calibrator web pages for the latest measurements.

### Bandpass and phase calibration

Phase calibration at 3 mm wavelength is significantly more challenging than at longer wavelengths. This is because the atmospheric phase errors can be larger, the calibrator grid is sparser and the system sensitivity is poorer. A calibrator close to your target is likely to be weak, in which case observing with 128 MHz bandwidth is desirable. An alternative may be to use a nearby SiO maser as the phase calibrator.

The *Miriad* task mfcal has been generalised so that observers can readily exploit the dual frequency bands of the Compact Array when determining antenna gain solutions. Looking to the future, it also handles many frequency bands, which will become relevant with Compact Array Broadband (CABB) correlator. mfcal now allows the two bands and the two polarisations to be calibrated simultaneously. This allows one band to be used as the "calibration" band, whereas the other band can be tailored to the science of interest. For example, the calibration band could be set to a wide bandwidth, or set to a configuration chosen to allow calibration with a SiO maser. mfcal takes care of phase offsets that typically exist between the different bands and different polarisations. It is possible to include both bands and polarisations together in a solution to maximise the sensitivity to the secondary calibrator. In this way, a better antenna gain solution is possible, or a weaker secondary calibrator can be used. This approach is also useful for SiO masers where the flux density of the linear polarisation measurements is significantly affected by source polarisation.

### Instrumental phase and antenna baseline solutions

Prior to mid-2005 an issue variously described as a "frequency-dependent baseline solution" and "wrap-dependent phase" affected the Compact Array. This was most severe for 3 mm observations. This issue has now been resolved, and should not affect observations. At the same time, some lower-level instrumental phase effects have been found. Currently a correction for these is implemented in *Miriad* atfix.

Experience in 2005 showed that the baseline solution derived at a reconfiguration is not always the best one possible. For example in June 2005 there was so much rain the night of one baseline solution that the site was flood-bound the following day. In principle it would be possible to incrementally update the baseline model in the online system as better solutions become available. In practise this has been deemed likely to create more confusion than benefit for observers. Consequently 3 mm observers should continue to check whether an updated baseline solution exists for their data and to use that as appropriate.

*Bob Sault*
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# New NTD software scientist

We are pleased to announce that Dr Maxim Voronkov will join the New Technology Demonstrator (NTD) team in Marsfield on a two-year software scientist position funded by the CSIRO Emerging Science program. He will join the NTD team at the end of his SKA postdoctoral fellowship at Narrabri in March 2006 and relocate to Marsfield. Maxim's research will concentrate on developing the calibration, imaging and simulation techniques for interferometers with focal plane arrays.

Maxim has previously worked on mathematical software in an object-oriented environment and gained AIPS++ experience during simulation studies of the imaging performance for the SKA. In addition to studying focal plane arrays, Maxim will continue to work on methanol masers, which were the main topic of his MSc (1999) and PhD (2002) research at the Moscow State University and the Astro Space Center in Moscow (cf page 20). He will contribute to the Parkes survey of the Southern Galactic plane using the methanol multibeam receiver as well as continue his Compact Array surveys.


Photo: Maxim Voronkov

Dr Maxim Voronkov

*Tim Cornwell*
*(Tim.Cornwell@csiro.au)*

## New Bolton fellow

Photo: Diana Londish

Ilana Klamer

We are pleased to announce that Ilana Klamer has been awarded the 2006 Bolton Fellowship. Ilana is currently a graduate student at the University of Sydney, working hard on her PhD Thesis entitled "Active galaxies at high redshift: gas, jets and star formation". Her supervisors at Sydney University are Dick Hunstead and Elaine Sadler, and at the ATNF Ron Ekers. Ilana plans to submit her PhD thesis around the end of March 2006. She will commence her Bolton Fellowship at the beginning of May 2006 at the ATNF in Epping. Ilana is going to be a full time member of the Astrophysics Group, and plans to spend a lot of her time on studying the influence of plasma jets on the environments of radio galaxies.

*Bärbel Koribalski*
*(Baerbel.Koribalski@csiro.au)*

## Distinguished visitors to the ATNF

Current distinguished visitors are Jayaram Chengalur (NCRA) who is visiting for most of 2006, Jim Cohen (JBO) who will be at the ATNF until June, and Ralf-Jürgen Dettmar (Bochum) who is visiting until July.

We have greatly enjoyed hosting recent visits from Katherine Blundell (Oxford), Nissim Kanekar (NRAO), Padelis Papadopoulos (ETH, Zürich), Karl-Heinz Mack (Bologna), Nathan Smith (Colorado), Mark Wardle (Macquarie) and Mary Putman (UMich).

Future visitors include Ken Kellerman (NRAO), Bob Williams (STScI), Bill Coles (Univ. California, San Diego) and Andrea Lommen (Franklin & Marshall College, USA).

Details on our visitor program can be found at: *www.atnf.csiro.au/people/distinguished_visitors.html*

Visits are partially funded by the Distinguished Visitors and Federation Fellowship programs.

*Lister Staveley-Smith (ATNF, on behalf of the Distinguished Visitors Committee)*
*(Lister.Staveley-Smith@csiro.au)*

## Raman Research Institute Directorship for Ravi Subrahmanyan

Quietly and unassumingly in early 2005 Ravi Subrahmanyan of the Narrabri Observatory started to make public that he had accepted the very prestigious position of Director of the Raman Research Institute in Bangalore, India. The Raman Institute is a government-funded research organisation of some 300 staff devoted to the study of fundamental sciences. Particular areas of interest include astronomy and astrophysics, soft condensed matter, physics of biological systems, theoretical physics and optics. The institute was founded in 1948 from private funding provided to the Nobel laureate Sir C. V. Raman. Prof Subrahmanyan expects to move to Bangalore and take on the full roles of the Directorship in late March.

During a postdoctoral position during 1990 – 1992 and then again over the last eight years, the contributions to the ATNF and CSIRO by Prof Subrahmanyan and his wife Dr Lakshmi Saripalli have been deep and far reaching. Ravi's work included studies of the early universe (Cosmic Microwave Background and Epoch of Reionisation), radio galaxies, antenna optics and the groundwork and commissioning of the MNRF millimetre systems. Lakshmi's science focused on radio galaxies, both in the radio and optical, whereas her other contributions include being ATNF Newsletter Editor and working for CSIRO Global Development. Both have mentored a number of students. Their contributions to the ATNF will be missed.

*Bob Sault*
*Officer-in-Charge, Narrabri Observatory*
*(Bob.Sault@csiro.au)*

# Farewell to Bob Sault

Photo: David Smyth

Bob at Narrabri

Dr Bob Sault, the Officer-in-Charge of the ATNF observatories at Narrabri and Mopra has announced that he will step down from his position from 3 March 2006. Bob has worked with the ATNF since 1990 and was appointed as OIC at Narrabri in January 2002.

Bob has made great contributions to radio astronomy and his knowledge and expertise will be greatly missed at the ATNF. He was the principle author of the *Miriad* software package used for aperture synthesis imaging with the Compact Array, and brought it with him when he joined the ATNF. Bob is a co-author of three definitive papers on polarimetry in radio astronomy, and he worked closely with Neil Killeen to understand polarimetric calibration of the Compact Array. This work has allowed the Compact Array to make the most sensitive measurements of circularly polarised emission of any radio telescope. Bob's expertise has been critical in the development of many other features of the Compact Array that have made it a distinctive and world-class instrument. These include multi-frequency synthesis, mosaicing, and the ability to use single-dish data from Parkes to provide the low spatial frequencies for Compact Array images.

Over the past four years Bob has worked tirelessly as Officer-in-Charge to provide extraordinary technical and staff leadership in the development and operation of both the Compact Array and the Mopra 22-m telescope. This period has seen the installation of the 12 and 3 mm observing bands on the Compact Array, and the upgrade of the Mopra telescope with a new mm-wave receiver and digital spectrometer. Bob's leadership in making these new systems operationally efficient and scientifically productive has its direct result in the increases in time proposals and published output of both facilities.

We wish Bob the very best for his future endeavours.

*Dave McConnell*
*Assistant Director for Operations*
*(David.McConnell@csiro.au)*

# Graduate student program

I would like to officially welcome the following students into the ATNF co-supervision program:

- Annie Hughes (Swinburne University) has commenced the project "Molecular Gas in the Interstellar Medium of the Large Magellanic Cloud" with supervisors Dr Sarah Maddison (Swinburne), Drs Tony Wong (ATNF/UNSW), Jürgen Ott (ATNF) and Lister Staveley-Smith (ATNF).

- Cliff Senkbeil (University of Tasmania) has commenced the project "A Study of Scintillation and Intraday Variability of Active Galactic Nuclei" with supervisors Dr Simon Ellingsen and Prof John Dickey of the University of Tasmania and Dr Dave Jauncey of the ATNF.

Cliff and Annie are well-known to ATNF staff, having been summer vacation students at Epping in 2003/4.

Congratulations to Aidan Hotan on the successful submission of his Swinburne PhD thesis *High-Precision Observations of Relativistic Binary and Millisecond Pulsars*, and to Jamie Stevens on the successful submission of his University of Melbourne PhD thesis *Neutral Hydrogen in Galaxy Groups*. Both now have positions at the University of Tasmania.

The next student symposium is scheduled for 10 May 2006. Contact Katherine Newton-McGee or Adam Deller for details.

*Lister Staveley-Smith*
*ATNF, Graduate Student Convener*
*(Lister.Staveley-Smith@csiro.au)*

# Articles

## Using an ATLAS to find early galaxies

How were the first galaxies born? And how come they were born at such an early stage of the Universe, well before the time predicted by most standard models? And why are Active Galactic Nuclei (AGN) also found at these early stages, indicating that black holes were born long before their expected gestation time?

ATLAS (Australia Telescope Large Area Survey) is one of several deep survey programs around the world aiming to answer these questions. ATLAS started life in 2002 as a radio survey of the Chandra Deep Field South (CDFS), and expanded in 2004 to encompass the fields imaged at infrared wavelengths by SWIRE (Spitzer Wide-area Infrared Extragalactic Survey). It was re-christened as ATLAS when we announced the first results in December 2005.

It differs from most other deep survey programs in several respects. First, it operates at radio wavelengths (20 cm), thus cutting through the dust which obscures the view of the nuclei of many of these early galaxies at shorter wavelengths. Second, it covers a much wider area than other radio surveys. When complete, it will be the widest (6 sq. deg) deep (10 – 15 microJy rms) radio survey ever attempted. One advantage of such a deep wide survey is its ability to discover rare objects, and another is to see cosmic structure—the walls and voids of galaxies which are already well-known from optical surveys, but which cannot be reliably traced optically at high redshifts because of the obscuring effect of dust.

ATLAS is not yet complete, but we decided at the end of 2004 to analyse and publish the results so far from part of the survey. All the data up to the end of 2004 covering a four-square degree area of the region surrounding the CDFS has been analysed, reaching down to an rms of 30 – 40 microJy. 805 radio sources were identified, corresponding to 761 galaxies, as some galaxies have multiple radio components.

Conventional wisdom told us that all of these would be visible in the infrared observations of this entire field taken by the Spitzer Space Telescope, as part of the SWIRE project. We were therefore surprised to find that about 50 of our sources were not listed in the SWIRE catalog. After eliminating those sources which had been missed in the infrared observations because of reasons we understand (e.g. confusion by a nearby bright source), we were left with 11 sources which are clearly visible in the radio but are not seen in the Spitzer infrared images.

We have dubbed these objects Infrared-Faint Radio Sources (IFRS). They are puzzling, because any mechanism, whether starburst or AGN, which can generate radio emission should also generate sufficient infrared energy to be visible by Spitzer. It is possible that they are active galaxies buried so deeply in dust that the infrared emission is being radiated at wavelengths too long for Spitzer to pick up. Alternatively, their explanation may be more prosaic (e.g. radio lobes from unidentified and spatially separate host galaxies) or more exotic (an AGN which generates radio waves without generating the optical or infrared radiation). We are proposing further observations to explore these hypotheses.

The IFRS are rare, which is why they have not previously been identified as a class. This was one of the original justifications for the ATLAS proposal: only a survey covering such a large area is expected to uncover rare types of object.

Another justification for ATLAS was that it was the first large radio survey to be conducted in conjunction with a large state-of-art infrared survey. The ATLAS survey has access to more data at other wavelengths than any other previous radio survey. As a result, each of our 761 galaxies has been carefully matched to infrared and optical data. Most of them now have infrared and optical photometry, enabling us to fit galaxy templates to their spectral energy distributions (SEDs), yielding classifications and photometric redshifts. Roughly half seem to be powered primarily by star formation, and about half by AGN. In many cases, we expect both mechanisms to be active, with the fraction generated by star formation to increase as we probe to deeper flux densities. However, we

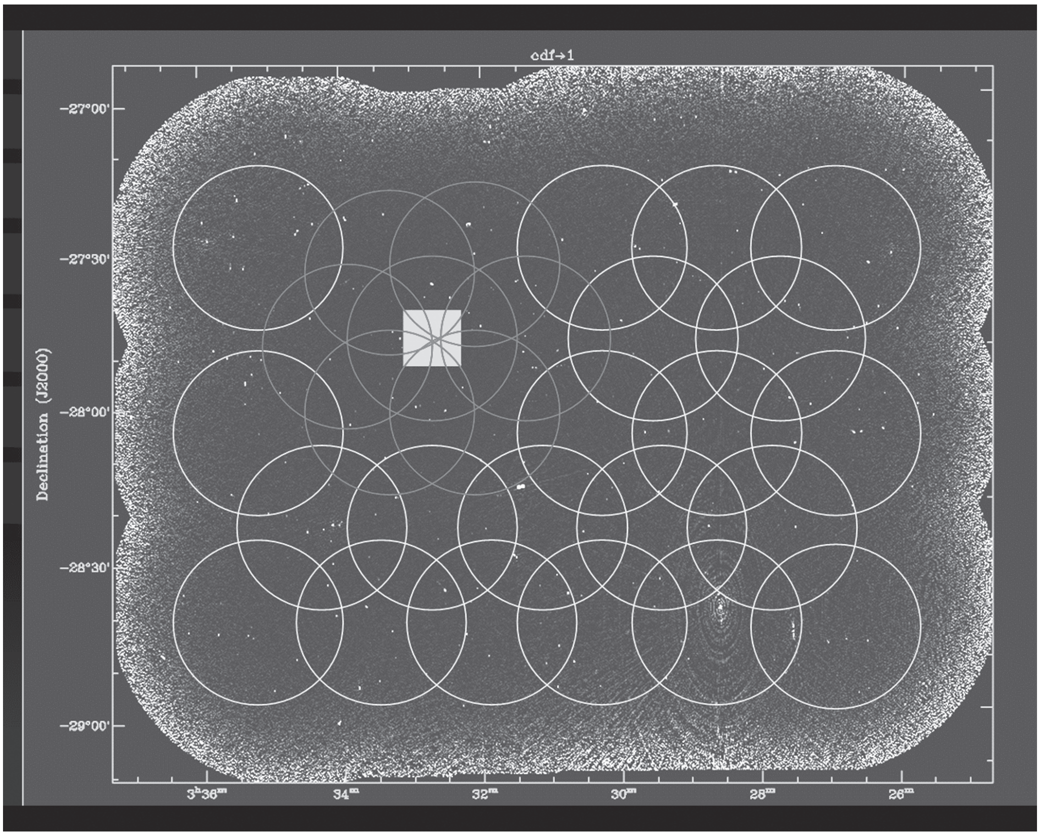


**Figure 1: Compact Array radio image (greyscale) of the region surrounding the Chandra Deep Field South (CDFS). Circles show the half-power beamwidths of the Compact Array antennas for this 28-pointing mosaic. The highlighted square at the top left shows the location of the CDFS-GOODS (Great Observatories Origins Deep Survey) field. The 1 Jy source which challenges our calibration algorithms can be seen on the lower right.**

do not yet understand the role or cause of AGN in these early galaxies, or how AGN are related to the formation of the galaxies themselves. We hope to shed light on this as the project continues to penetrate to lower flux densities, and by using all available data at other wavelengths. We hope also to measure spectroscopic redshifts using AAOmega and the IRS spectrometer on board Spitzer, and to obtain data at X-ray wavelengths, as well as longer radio wavelengths.

These results have been obtained from the first half of the project. As the project reaches its eventual flux limit, the number of galaxies will swell to many thousands, raising even further the potential for finding rare objects. Even more importantly, this will be the first time that a survey has enough radio objects at the tens of microJy level, with accompanying data at other wavelengths, to examine how the relative numbers of AGN and starburst galaxies change with redshift and luminosity.

In processing the radio data, we encountered an unexpected problem. Our CDFS field contains a 1 Jy radio source, and our current calibration procedures are unable to remove its sidelobes completely. As a result, not all areas of our image are reaching the required dynamic range. The cause seems to be that the simple primary beam models used in packages such as AIPS and *Miriad* do not model the antennas sufficiently well, and to do so will require a more sophisticated primary beam model, such as a holographic image of an antenna. This problem will be an important one for xNTD and SKA, and so it is fortunate that we have encountered it in this project, giving us time to develop solutions well before the construction of these next-generation telescopes. A team led by Tim Cornwell, Mike Kesteven and Enno Middelberg is actively working to solve this calibration problem.

Naturally, this large project requires a large team, whose names are listed on the poster which was presented at the AAS in January 2006 and is available on *www.atnf.csiro.au/people/rnorris/AASposter.pdf*. A full paper is expected to be submitted to AJ shortly.

*Ray Norris (ATNF) and the ATLAS team (Ray.Norris@csiro.au)*

# What type of objects are class I methanol masers associated with?

IRAS 16547–4247 (G343.12–0.06) is the most luminous young stellar object (YSO) known to harbour a thermal radio jet. At a distance of 2.9 kpc, the YSO has a bolometric luminosity of $6.2 \times 10^4$ $L_{\odot}$, equivalent to that of a single O8 zero-age main sequence (ZAMS) star. The jet was first detected by Garay et al. (2003) using the Compact Array at 1.4, 2.5, 4.8 and 8.6 GHz and subsequently observed with the VLA at 8.5 and 14.9 GHz (Rodríguez et al. 2005). This is the first reported case of a radio jet associated with a young O-type star. Located at the centre of a massive dense molecular core (approximately $10^3$ $M_{\odot}$), the jet is driving a molecular outflow traced by $H_2$ 2.12 μm emission that extends over 1.5 pc (Brooks et al., 2003).

Methanol masers are quite common in massive star-forming regions. They fall into two categories first defined by Batrla & Menten (1988) and further considered by Voronkov et al. (2005): class II masers (of which the 6.7 GHz emission is the best known) are closely associated with sites of strong continuum emission, infrared sources and reside in the close environment of existing stars. In contrast, class I masers (emitting e.g. at 95 GHz) are usually found offset (up to a parsec) from continuum sources. Theoretical calculations strongly suggest that these masers are pumped via collisions of molecular hydrogen in contrast to class II masers, which have a radiative pumping mechanism (e.g. Cragg et al., 1992). For more information on classification see Ellingsen (2005), Ellingsen et al. (2004) and Voronkov (2005).

Class I masers are relatively poorly studied. There is direct observational evidence for a relationship between these masers and outflows in a number of sources (Menten, 1996). However, other scenarios have been proposed (Mehringer & Menten, 1996). The outflow scenario is attractive for two reasons: The methanol abundance is significantly increased in the shock-processed regions (e.g. Gibb & Davis, 1998) and the gas is heated and compressed, providing more frequent collisions and, therefore, more efficient pumping. From the theoretical side, Sobolev et al. (2005) have recently identified four different regimes of pumping, each corresponding to a different set of physical parameters such as temperature, density and beaming (elongated geometry). It follows from these calculations that relatively rare masers at 9.9 and 104 GHz as well as bright masers in the $J_2$–$J_1$ series near 25 GHz require higher densities and temperatures than the masers at 84 GHz and 95 GHz. One may argue that these rare class I masers exclusively trace the interface regions where an outflow interacts with the ambient material.

Maser line surveys (Val'tts et al., 2000; Voronkov, 2005; Voronkov et al., 2005) have revealed that IRAS 16547–4247 is the only source where masers in all class I transitions falling into the frequency range of the ATCA receivers have been detected together, including the relatively rare 9.9 and 104 GHz masers. No class II maser emission at 6.7 GHz has been detected towards this source (Walsh et al., 1998). To investigate the relations of different maser transitions with the outflow and provide the data for theoretical studies we have undertaken interferometric observations at 9.9 and 25 GHz (we observed 8 transitions of the 25 GHz series, J=2 to J=9) in May and June 2005 and 84, 95 and 104 GHz in August 2005 using the ATCA. Such multi-transitional observations of class I masers are the first of their kind. The ATCA is currently the only interferometer in the world equipped with suitable receivers to carry out this task.

Figure 1 shows a VLT image of $H_2$ 2.12 μm emission (which traces shocked gas) towards IRAS 16547–4247 (Brooks et al., 2003). There is a complex chain of emission with three major concentrations consistent with the morphological characteristics of Herbig-Haro (HH) objects arising from the interaction of a collimated flow with the ambient medium (Reipurth & Bally, 2001). The outer concentrations are located approximately symmetrically offset from the radio jet detected by Garay et al. (2003), which is marked by a cross in Figure 1. The central concentration has a complex bow-shaped morphology curved away from the jet direction. This could be explained by a number of factors such as irregularities of the ambient medium, a precession of the jet, or an additional outflow from

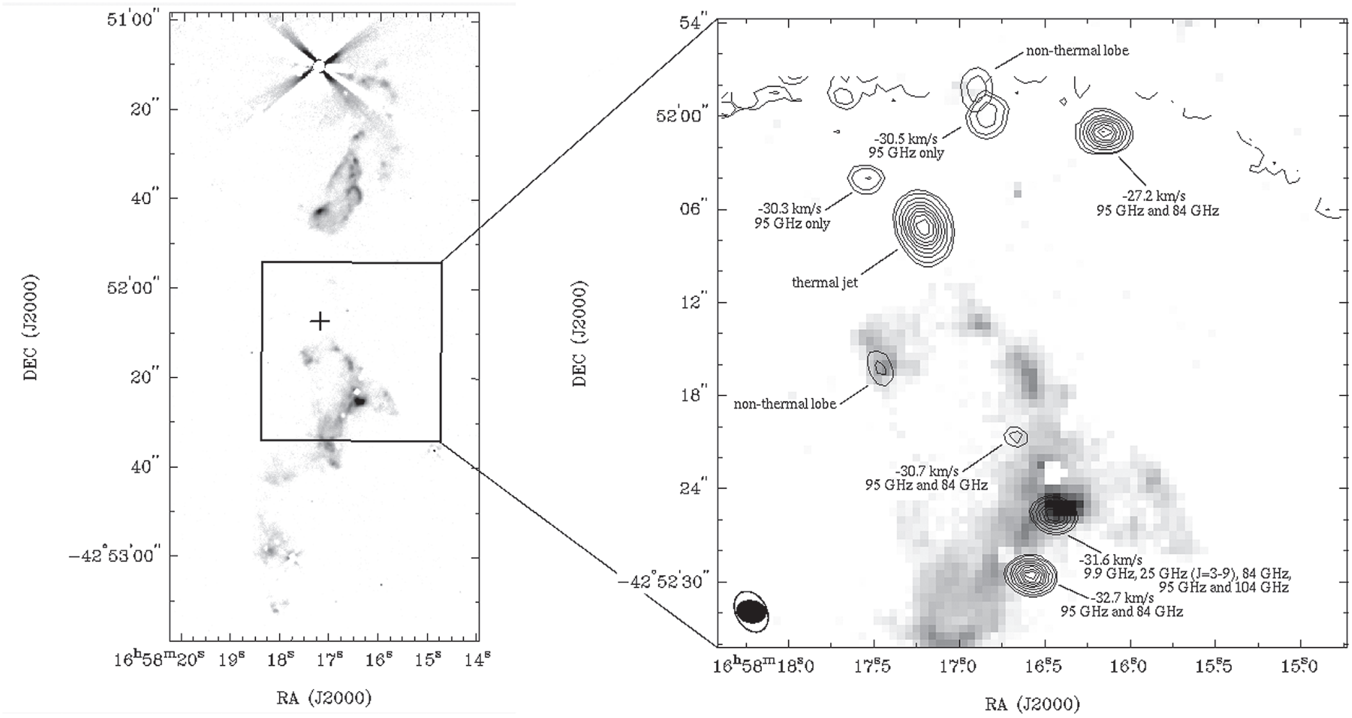


**Figure 1: VLT $H_2$ 2.12 µm image of IRAS 16547–4247 (Brooks et al., 2003). The cross denotes the position of the thermal jet. The inset shows the positions of the 95 GHz maser spots and the 25 GHz continuum sources. The synthesised beam is shown in the bottom-left corner of the inset (open and filled ellipses at 25 GHz and 95 GHz, respectively).**

a star less massive than the luminous YSO. The inset in Figure 1 shows the location of all detected maser spots at 95 GHz in the vicinity of the thermal radio jet and the central $H_2$ 2.12 µm emission concentration (note that the outermost lobes of the $H_2$ emission are outside the Compact Array field of view at 3 mm). Also shown is the associated 25 GHz continuum emission, which closely resembles the triple-source morphology found at lower frequencies by Garay et al. (2003). The central continuum source is the thermal jet, while the two satellites mark the internal working surfaces of the collimated flow (i.e. where the supersonic flow slams into the slower moving gas within the flow). The satellites are characterised by non-thermal emission (with negative spectral indices).

All the detected masers are located within a dense molecular core (with a deconvolved FWHM of 27 arcsec, Garay et al., 2003), with velocities close to that of the ambient molecular material in the core (of –30.0 km $s^{-1}$). The behaviour of the detected maser spots also depends on the transition. All 95 GHz maser spots, except those at –30.3 km $s^{-1}$ and –30.5 km $s^{-1}$, show 84 GHz maser emission. However, only the –31.6 km $s^{-1}$ spot is active at 9.9 GHz, 25 GHz and 104 GHz.

The southern maser spots clearly trace the bow-shaped shocked gas delineated by the 2.12 µm $H_2$ emission. This correlation points to an association between the class I methanol masers and the interface region where the outflow interacts with the dense molecular core. The maser at –31.6 km $s^{-1}$ is located near the edge of the brightest $H_2$ knot. This may be an indication that indeed more energetic conditions are required to form rare 9.9 GHz, 104 GHz and bright 25 GHz masers.

The northern maser spots show no association with the $H_2$ emission. However, this may be attributed to higher extinction in the northern region which diminishes the strength of $H_2$ 2.12 µm emission. For instance, the northern satellite radio continuum source has no associated detected $H_2$ 2.12 µm emission, unlike its southern companion. There is little doubt, however, that the northern satellite radio continuum source represents the working surface of a collimated flow. Moreover, it is evident from the large-scale $H_2$ 2.12 μm emission that an outflow lobe extending northwards is present. The –30.5 km $s^{-1}$ spot resides close to the northern non-thermal continuum lobe and we therefore assume that all the northern maser spots are associated with the outflow as well. More data are required to confirm this.

Further observations of masers can help to elucidate the connection between outflows and class I methanol masers in detail. For example, a proper motion study will be able to reveal the nature of the shock associated with the masers and test whether it is related to another YSO. The similar radial velocities of the maser spots suggest that the shock is moving in the tangential plane on the sky. Therefore, proper motions are expected to be detectable with ATCA observations on timescales of approximately 3 – 10 years, depending on the outflow velocity (typically $10^3$ km $s^{-1}$ for jets associated with luminous objects). The association with outflows encourages us to extend searches for class I methanol masers to sites of intermediate- and low-mass star formation. Outflows are common in these sites (Reipurth & Bally, 2001) and, indeed, a few class I masers have recently been found (Kalenskii et al., 2005). Further observations of $H_2$ 2.12 μm as well as other shock tracers towards known class I methanol masers, particularly rare masers at 9.9 GHz and 104 GHz and bright 25 GHz masers, are required to understand whether or not class I masers are always associated with shocked gas.

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# Regular items

## ATNF outreach

### 2005/2006 summer vacation program

Seven successful ATNF summer vacation scholars commenced their scholarships in early December 2005. They came from across Australia including Adelaide, Hobart, Townsville, Sydney, Wollongong and Melbourne. Each student spent ten weeks working on a project under the supervision of ATNF staff. Projects included engineering and astrophysics topics with two students based at the Compact Array in Narrabri and the other five at our Marsfield headquarters.

An important part of the summer vacation program is the observing trip to Narrabri to use the Compact Array. Kate Brooks' talks on radio astronomy and observing techniques prepared the students. The students split into two groups and each devised their own observing program. One group decided to image a gravitational lens and also observed SN 1987A. The other decided to image a bow shock associated with a pulsar wind. The students were ably supported at Narrabri by Tony Wong.

The summer vacation program concluded with a half-day symposium and lunch held on 9 February at Marsfield. Students presented the results of their projects and confidently fielded questions from the audience.

**A student's perspective from Lewis Mitchell**

For the past 10 weeks I have been working as a summer vacation student at the ATNF Marsfield site, along with six other students at both Marsfield and Narrabri. During this time I've worked on a supervised project, visited the Narrabri site and observed using the Compact Array, attended many interesting symposia and had countless discussions with staff, experiencing all facets of working life at the ATNF, from research to lunchtime table tennis matches. It has been a fantastic experience to work in one of Australia's pure science research facilities, and the opportunity to interact with and work amongst other researchers has been rare indeed.

A highlight of the program was the Compact Array observing trip, where we were entrusted with 24 hours of telescope time. This was an opportunity that many of us would never have had in our usual academic careers, and one that was ultimately highly rewarding.

On behalf of all of the summer vacation students I would like to sincerely thank all the staff at ATNF for making us all feel so welcome and for giving us an experience we will not forget. I have made many new friends and contacts at the ATNF over the past few months, and I hope it will not be long until I meet you all again.

Photo: Robert Hollow

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

Photo: John Smith


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

## New displays at the Narrabri Visitors Centre

Staff from ATNF, ADS Solutions from Melbourne and local contractors installed new displays for the Compact Array visitors centre in December and January. The installation is the culmination of almost two years of planning and design by ATNF outreach staff and Convergence Design with help from Astrophysics and Operational staff. Large sculptures representing astronomical phenomena, such as the Magellanic System and Milky Way, are a feature of the displays which also include a number of panels with information and images. The displays progress through a range of topics that include the electromagnetic spectrum, observing with radio telescopes, the history of CSIRO Radiophysics and the ATNF, the workings of the Compact Array and the astronomical achievements of those that use the array.

As well as the outdoor exhibits, a new audiovisual, *ViewSpace*, developed by the Space Telescope and Science Institute (STScI) is now running in the Visitors Centre theatre and is proving to be very popular with visitors. The presentation is of a very high quality and includes the latest astronomy news, feature reports and outstanding images from around the world. *ViewSpace* is regularly updated with automatic updates downloaded across the internet. ATNF outreach staff plan to develop content about the ATNF and radio astronomy for inclusion in the *ViewSpace* presentations.

## Children at Parkes

In November an education initiative was held throughout the Central West region of New South Wales to encourage parents to read to their children and children to read for themselves for enjoyment. As part of this a group of local children and their entourage visited the Parkes telescope on 3 November 2005. A local dance and school group "Wagambilla" and "Lotus Flowers" performed for an audience of proud parents and friends in the Visitors Centre grounds.

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Photo: Julia Hockings

Children performing at the Parkes Visitors Centre

# Parkes Observatory report

## Operations

Operations since the last newsletter have remained largely trouble free, with the exception of wind—it has been a particularly windy period recently, with a record-breaking 59.6 hours lost time logged in January alone.

## Methanol multibeam receiver

The seven-beam methanol multibeam receiver was delivered and successfully installed on the 64-metre dish in the week of 16 January 2006, with the first users, the Galactic Methanol Maser Survey team (P502), up and running on the following weekend (see separate reports). The receiver is performing well, with more than 50 new maser detections in the first survey session of nine days observing. Science results have already begun to flow—see e.g. the Parkes home page at *www.parkes.atnf.csiro.au* and the cover article in this newsletter.

Grahame Moorey, Pat Sykes, Les Reilly and Paul Doherty from Marsfield worked tirelessly alongside local staff Brett Dawson, Ken Reeves and Jeffrey Vera to ensure the installation was effected as smoothly as possible (see report on page 5).

The receiver appears to be performing to all specifications although analysis of the commissioning tests is not complete at the time of writing. It has two independently-tunable conversion chains, which in principle allow full dual-frequency operation. At the present time only six beams out of the full seven on the second frequency can be used, owing to limitations in the downstream signal processing. It is expected that the full seven beams will be operational on both frequencies for both spectral line and pulsar observing sometime during the 06APRS term.

The next large project to use the receiver will be the Methanol Multibeam Pulsar Survey (P512), which will shortly commence a new high frequency survey of pulsars in the Galactic plane.

## Backends

The prototype Digital Filterbank (DFB) continues to work extremely well for pulsar timing observations, and has recently been used with great success for an entirely different purpose—broadband continuum polarimetry mapping. A new configuration has been provided that produces all three polarisation products (AA* BB* and AB*) at a fixed one second time resolution (other periods also may be possible on request). This configuration was successfully used in January by the Parkes Galactic Meridian Survey team at 2.3 GHz to produce images of diffuse Galactic emission in full Stokes parameters. The bandwidth of the DFB is currently restricted to 256 MHz.

Previous attempts at polarised continuum imaging over the last 18 months using the Wideband Correlator (WBC) have struck difficulties with low-level artefacts in the cross-product, which appear to arise in the Wideband Correlator itself.

Plans for the full version of the Digital Filterbank are currently on hold, as delivery of the Xilinx field programmable gate arrays (FPGAs) required for the project did not materialise as advertised, and remain uncertain.

## Upgraded Observatory network access

At the time of writing two Caterpillar bulldozers (a D8 towing a D6) are within a kilometre of the Observatory, laying the fibre connection from the former NextGen backbone 10 kilometres to the West. The backbone itself is now “lit” and currently under test by its new owners, AARNet. It is now anticipated that the Observatory will have a 1 Gbit/s connection to the Marsfield laboratory by mid-March. Thanks go to all those responsible for bringing this landmark development to fruition, particularly to Shaun Amy, Tasso Tzioumis, Andrew Hunt, Brett Preisig and, not least, our colleagues at AARNet who are making this enterprise possible.

The new fibre connection will initially constitute an improvement of three orders of magnitude in data speed in and out of the Observatory (which is currently 512 kbit/s), but bandwidths of 10 Gbit/s or more are now within relatively easy reach, when required.

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# Compact Array and Mopra report

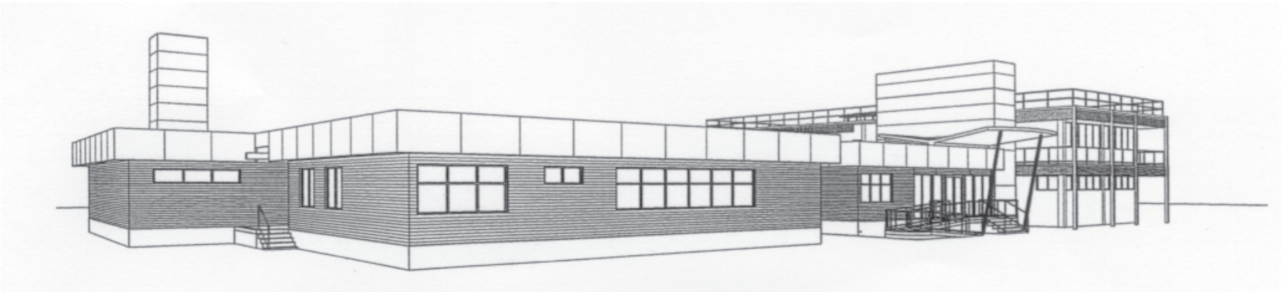

**Figure 1: A sketch of the southern side (main entrance area) of the new Control Building. The existing building can be seen on the right edge of the structure.**

## LINUX at the Compact Array

Since November 2005, the standard observing system offered to the astronomers on site has been based on the LINUX operating system. The LINUX-based observing system is fully functional. However, when compared to the VMS system which has been in use for 17 years, it is understandable that the new system is somewhat less robust and may contain some bugs. Feedback from observers on the LINUX system is appreciated, particularly when enough detail can be given to help track down the problems. For the time being the VMS system continues to be the one recommended for remote observers.

The change to LINUX has resulted in changes to some CAOBS commands such as the commands used to switch generators on and off. Observers are advised to note that as LINUX is case-sensitive, some care needs to be taken with filenames. The simplest way for observers to avoid case problems is to use lower case names for all their files.

Please see the "Current Issues" web page on the Narrabri site for a summary of changes and issues with the LINUX-based system.

## Narrabri control building

The development of plans for the major refurbishment of the Control Building is progressing steadily. The major design decisions have been made, and the layout of the building is being fine-tuned. During the period when the existing Control Building is being refurbished, the Control Room, Observers Area and the offices of the operations staff will be relocated to the current Receiver Laboratory. This will happen in late 2006 or early 2007. During the construction phase, there will be some inconvenience, but only minor interruptions, to the Compact Array operation.

## Broadband fibre at Narrabri

Thirty kilometres of broadband fibre was installed in late-December and January, connecting the observatory to the AARNet3 network running down the Newell Highway. The final commissioning of the fibre and network is expected to happen in late February or early March. When completed, this will increase the network speed to the Observatory from 512 kbits/s to 1 Gbit/s. Amongst other improvements, this fibre will usher in new approaches to VLBI and observing data retrieval.

Photo: Peter Mirtschin

**Figure 2: A cable-laying machine burying the broadband fibre near the central area of the Narrabri Observatory.**

## Mopra developments

As with Narrabri, a broadband fibre connection to Mopra and Siding Spring Observatory was installed in early December, with commissioning again expected in late February or early March.

The major development at Mopra in 2006 will be the installation of the MOPS digital filterbank backend. In its initial configuration it will allow observations in four 2.2 GHz windows (at least 2048 channels per window), or in eight 137.5 MHz windows (4096 channels per window). This will give Mopra an impressive multi-line capability. Installation is expected in late May or early June, and will be available to the bulk of observations during the Mopra millimetre season.

## Operational statistics

For the period 1 October 2005 to 31 January 2006, the equipment lost time fraction at the Compact Array was 1.7%—close to the long-term average. The weather lost time fraction (1.5%) and fraction of weather overrides (also 1.5%) are somewhat higher than usual: in addition to the usual thundery summer, a wet October disrupted a number of millimetre observations. Mopra similarly had a wet October, with 14.4% of October lost to the weather. The Mopra observing season finished on 6 November.

## Explosive events

A noteworthy event happened on 9 December 2005: The main 22 kV transformer within the central area of the Narrabri Observatory failed explosively in the early hours of the morning. The surges that accompanied the failure overwhelmed the Control Building uninterruptible power supply, causing a power loss to the Control Building equipment. The local grid also experienced a brief blackout. Systems were brought back for normal observing by mid-morning—under generator power and with the uninterruptible power supply restarted. By early evening the failed transformer was shipped off for repair, and replaced with a transformer from the north spur. With the site then reconnected to the local power grid, all was back to normal. We are indebted to fast assistance from Country Energy, who moved heavy equipment and several expert technicians here at zero notice. The repaired transformer is expected to be re-installed in late March or April—in time for the millimetre season.

Another even more spectacular event happened at Mopra near midnight on 12 January 2006: Mopra received a major lightning strike. A broad range of Mopra systems were damaged in the event and these are being assessed and repaired. The damage caused some electronics chips to explode while wires fused and the cryogenics systems failed. As of writing the Mopra uninterruptible power supply has yet to be brought back online and receiver health is yet to be tested. At present this event is not expected to have a major impact on VLBI or the start of the millimetre season.

## Staff

After four years of tireless service, at all hours of the day and night, Derek Aboltins, the site's senior cryogenics technician, left CSIRO to take up a position at the Melbourne Synchrotron. We wish Derek all the best with this change. To help plug the hole left by Derek, we welcome John Wilson and his family to the Narrabri district.

We were sad to farewell John Giovannis, who left the Observatory at the end of January to work for CSIRO in Melbourne. In addition to keeping Windows and other computing gremlins at bay, John contributed to the life of the Observatory and the community in many ways.

Ravi Subrahmanyan and Lakshmi Saripalli will be moving to India in March to enable Ravi to take on the Directorship of the Raman Research Institute; see the separate article on page 16. We congratulate them on this very exciting and prestigious move in their lives. Their contributions will be sorely missed.

Maxim Voronkov has accepted a position in Marsfield to work on issues associated with the NTD and so will be moving to Sydney in the near future. At the same time Jürgen Ott has completed his term as Mopra Scientist, and will revert to a full-time Bolton postdoctoral fellow. The process to appoint a successor Mopra Scientist is in progress.

Excellent contributions were made over the summer by vacations students Rachel Poldy and Yadav

Padmanaban. Rachel worked on a variety of problems related to RFI, whereas Yadav studied the Compact Array antenna power usage and worked towards understanding the energy budget of SKA-like antenna arrays.

Finally, this is my last report as Officer-in-Charge (OIC) for Narrabri and Mopra. I would like to thank the broad ATNF community for their continuing support of Narrabri and Mopra Observatories and their assistance to me over the last four years. The OIC position has been advertised externally. An outcome from this appointment process is likely in February. In an interim period, Brett Hiscock will be Acting OIC, and Mark Wieringa will be Assistant OIC.

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# Time assignment information

## OPAL – the dust settles

The Online Proposal Applications and Links (OPAL) software is a web-based application system that is used to prepare and submit telescope applications to the ATNF. OPAL was released on 1 November 2005 and was used for all applications submitted for the deadline on 15 December.

For the December deadline, we received 178 applications in total, with 111 of these submitted during the final 24 hours. This provided a very thorough testing of OPAL and we were pleased that there were very few problems with the proposal submissions. In almost every case where problems did arise, the user was not using one of the OPAL-supported browsers. We encourage all users of ATNF facilities to register with OPAL, and to use one of the recommended browsers.

To our relief, apart from a short power outage in early November, there were no network or database-related problems that might have arisen from handling a fairly large number of submissions. During the application period, OPAL supported 1506 user-sessions, with 280 user registrations and 483 different authors listed on the proposals.

From the first round of applications, we have received many useful suggestions and plan to further develop OPAL and to extend the facilities it provides for telescope users. For the next round of applications OPAL will provide better handling for multiple email accounts and will allow individuals to control whether they receive email notifications when proposals are resubmitted. More generally we will also be working on improving the integration of OPAL with other ATNF facilities such as the Australia Telescope Online Archive (ATOA).

OPAL was developed by Christopher Owen and Jessica Chapman. Sadly for the ATNF, Chris leaves in February to take up a position with a rapidly growing software engineering company and his position is now being advertised. We thank Chris for his tremendous contributions to the ATNF which have included the ATNF outreach website, the ATOA and OPAL.

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# ATNF publications list

Publication lists for papers which include ATNF data or ATNF authors are available on the web at *www.atnf.csiro.au/research/publications*. Please email any updates or corrections to this list to Christine van der Leeuw (*Christine.vanderleeuw@csiro.au*).

This list includes published refereed papers compiled since the October 2005 Newsletter. Papers which include ATNF authors are indicated by an asterisk.


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