ATNF News

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FEATURES IN THIS ISSUE

The Compact Array Galactic Centre ammonia survey

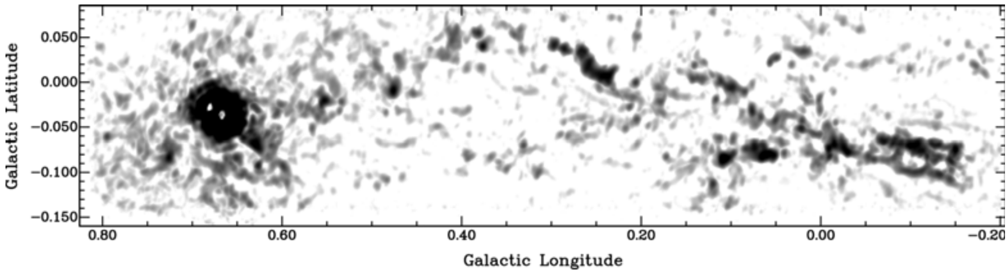


Figure 1: Compact Array ammonia (1, 1) peak intensity map of the Galactic Centre Region (logarithmic representation). The map consists of 840 individual pointings. Sgr A*, the massive central black hole of the Galaxy is located toward the right of the map (see also Figure 3). The very prominent emission to the left is emitted by Sgr B2. Notable are also the two 'holes' on top of Sgr B2 which exhibit ammonia in absorption.

The Galactic Centre Region (GCR) is the most nearby core of a galaxy. A large number of very different features are present in the GCR, e.g., the central black hole in Sgr A* and its circumnuclear disc, as well as a variety of massive star forming regions such as Sgr B2 and Sgr B1 which exhibit quite different morphologies and kinematics. The region is furthermore subject to extreme physical conditions such as shear, magnetic fields, and strong tidal forces. For a reliable understanding of the physics involved in galactic cores a large number of direct measurements of parameters such as the density and the temperature of different gas phases is indispensable.

Owing to its particular tetrahedral structure, transitions of ammonia can be used as a perfect thermometer for dense molecular gas. This property is the main driver for the wide-field Compact Array ammonia survey toward the Galactic Centre. A few weeks ago we observed the first part of the Galactic Centre Region stretching from the central black hole, Sgr A* to the massive star forming region, Sgr B2. Here, we present the first results of this survey, which covers an area 1° × 0.2° in size. The observations were made using the ultra-compact H75 array configuration and demanded mosaicing of 840 pointings to cover the large field. Both, the metastable ammonia (1, 1) and (2, 2) inversion lines were measured simultaneously. The resulting map, displayed in Figure 1, has a physical resolution of ~1 pc (synthesized beam ~20 arcsec) and is the most detailed, wide-field map of molecular gas toward the Galactic Centre Region to date. Over most of the regions we find a very good correspondence between the ammonia features and the dust distribution. Toward Sgr B2 we observe ammonia in absorption against the bright radio continuum flux. The absorption spectra, as well as some emission lines exhibit multiple line components indicating a rather complex distribution of the molecular gas.

The ammonia (1, 1) and (2, 2) inversion lines trace a Boltzmann distribution and therefore the temperature of the gas.

Continued on page 23

Editorial

Welcome to the October 2005 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!

Our cover article highlights the capabilities of and growing interest in using the Compact Array at mm wavelengths. Juergen Ott describes the first results from the most detailed wide-field imaging to date of molecular gas at the centre of our Galaxy, as well as the first wide-field continuum map of the region at 12 mm. In another project Compact Array continuum observations at centimetre wavelengths are being used to search for radio galaxies at very high redshifts, as described by Julia Bryant on page 19.

Important information on OPAL, a new telescope application system for the ATNF, is given on page 4. On page 10 Chris Phillips and Tasso Tzioumis inform us of the new trends and developments in long baseline interferometer observations and describe how these are being implemented at the LBA.

The changes at the Mopra telescope and the excitement over the installation of a new 3/12-mm receiver can be found in separate articles by Graeme Carrad on pages 8 and 9 as well as in the observatory report by Bob Sault. Read also about the prototype Pulsar Digital Filter Bank and its successful installation on the Parkes dish in an article on page 6 by Grant Hampson and colleagues.

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 last for one of us at the ATNF News production team, Lakshmi Saripalli. The ATNF, and especially Jessica Chapman and Joanne Houldsworth, thank Lakshmi for all her excellent work on the newsletter.

Lakshmi Saripalli, Jessica Chapman and Joanne Houldsworth
The ATNF Newsletter Production Team
(newsletter@atnf.csiro.au)

Contents

From the Director

As part of CSIRO's science investment process, the CSIRO Executive recently published a document setting out broad directions for future research. I am delighted to reproduce the text on radio astronomy in full below.

> *The importance of radio astronomy as a leading science initiative in Australia was recognised. Support of the Australia Telescope National Facility (ATNF) as a research facility, and the world class research that CSIRO undertakes using the ATNF, are intimately interlinked.*
>
> *The Square Kilometre Array (SKA), and its forerunner the xNTD, are seen as key planks of Australia's determination to remain at the forefront of radio astronomy. It was noted that progressing the SKA proposal will require significant input from existing resources, and if ultimately successful, additional investment.*

These recommendations will form the basis for CSIRO's investment decisions in radio astronomy over coming years and augur well not only for the continued support of our existing facilities, but also for the support of strategies outlined in the SKA roadmap produced by the Australian SKA consortium last year. The recommendations are also well aligned with priorities for radio astronomy mapped in early exposure drafts of *New Horizons*: The Australian Astronomy Decadal Plan 2006 – 15.

It is precisely because of the ongoing scientific impact of ATNF's telescopes and the remarkable coherence of the Australian astronomy community exemplified by the Decadal Planning process, that CSIRO is able to re-affirm its commitment to radio astronomy with confidence in the outcomes.

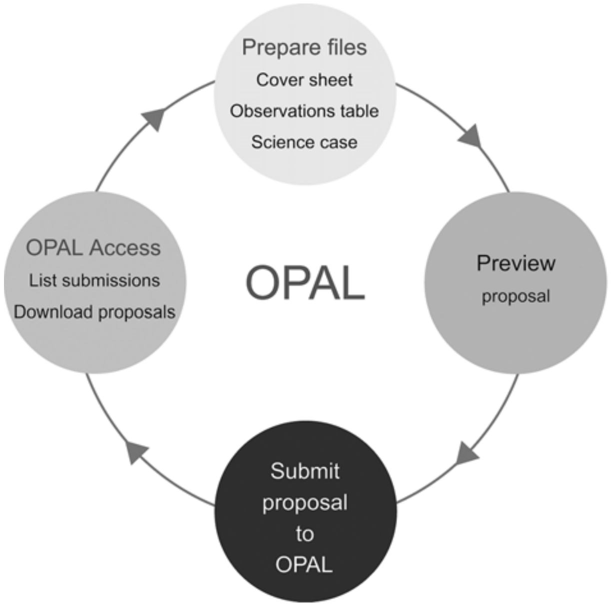
A number of significant upgrades of the existing facilities will occur over the next few years and the ATNF is committed to ensuring that sufficient resources are dedicated to supporting these upgrades to ensure their scientific impact is maximised. During the past few weeks, the Engineering Group have successfully installed the 3-mm Mopra receiver and spectrometer (MOPS). First observations made with the new system look magnificent. Other upgrades on the way include the 6-GHz multibeam receiver and the polyphase digital filterbank for Parkes, and the 7-mm system and Compact Array Broadband Backend for the Compact Array.

CSIRO's support for the xNTD, Australia's SKA science prototype, builds further the significant international momentum that now exists towards the SKA. This includes the recently announced success of the EU SKA design study (SKADS) program via the Sixth Framework protocol and the significant support for SKA prototype work in South Africa. In the context of both the xNTD and the current New Technology Demonstrator, ATNF remains committed to working with all its SKA partners to deliver science and technology solutions in the SKA domain that are truly international in both concept and delivery.

Maintaining this momentum towards the SKA, while continuing to support the existing telescopes will not be without its challenges. Following publication of the Decadal Plan in November, the ATNF looks forward to working with its users and other stakeholders, to develop an implementation plan which will successfully implement the strategies outlined in the Plan. With the appropriate levels of support, the ATNF is confident that it can both sustain existing telescopes and deliver new facilities at performance levels required by the community to achieve its aspirations in radio astronomy over the coming decade.

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

Getting started with OPAL



We are pleased to announce the release of OPAL. OPAL is a web-based application system that includes a set of proposal tools that are used to prepare and submit telescope applications to the ATNF.

Please note that from now on all telescope applications to the ATNF **must** be submitted using OPAL.

Connecting to OPAL

To use OPAL go to the OPAL home page on the ATNF website at *http://opal.atnf.csiro.au.*

This page contains all of the links that you will need, including a link to the *OPAL Users Guide*.

Browsers

For the initial release, OPAL supports the following browsers:

Firefox version 1.0 and above;
Mozilla Suite 1.6 and above;
Internet Explorer 6.0 and above;
Netscape 7.0 and above.

For Windows and Mac users, if you do not have one of these browsers, then we recommend that you download Firefox which is freely available. A link to the Mozilla Firefox website is given in the *OPAL Users Guide*.

OPAL registration

We recommend that all users of OPAL register with the system. OPAL may be used without registration to create and save local files. However, registration is required to submit proposals or access previous submissions. OPAL user registration is very straight forward.

Writing applications

A proposal application to the ATNF will, in general, consist of three separate files; the science case, a cover sheet and an observations table. Proposals that have been granted a continuing status are not required to submit the science case. OPAL also provides a tool to create source lists. The source lists are not submitted as part of an ATNF telescope application but they can be loaded into the observations tables.

OPAL provides a set of tools that are used to prepare cover sheets, observations tables and source lists. OPAL-generated files are saved as .xml files on the user's local disk and can be reloaded and edited as required.

The science case may be written in any preferred format (for example, latex or Microsoft Word) but must be converted to a pdf file for submission. In general the Science Case should not exceed three pages in length, or 10 Mbytes in size.

Proposal submission

Any member of a proposal team, who is a registered OPAL user, may submit a proposal to the ATNF. This involves loading the three files for the science case, cover sheet and observations table. All members listed on a proposal (with valid email addresses) will receive email acknowledgment of the proposal submission.

Once the proposal has been submitted, it may be updated or withdrawn within the period before the applications deadline, either by the person who made the submission, or by the person listed on the proposal as the principal investigator (PI). Other team members will be able to download and view proposal files but will not be able to withdraw or replace a proposal that has already been submitted by the PI or original submitter.

Using OPAL

We recommend that new users of OPAL register and try the system out well before the proposal deadline on 15 December. Note that you can generate and submit dummy proposals and then withdraw these until the deadline is reached.

We hope that OPAL will make it easier for users to write telescope applications. If you require any assistance with OPAL then please send an email to *atnf-opal@csiro.au*. We will respond promptly.

Jessica Chapman and Christopher Owen
(Jessica.Chapman@csiro.au, Christopher.Owen@csiro.au)

Compact Array calibrators

Calibration of the Compact Array is an essential part of any observation and a calibrator catalogue is maintained to assist with this. Information and a search engine for calibrators can be found at *www.narrabri.atnf.csiro.au/calibrators*. There is an on-going program to monitor the flux densities, to better characterise calibrators and to add to the calibrator list (particularly at high frequencies).

The different observations with the Compact Array can span two orders of magnitude in both array compactness and frequency range. Few calibrators are "good" over all of this parameter space. Consequently observers are warned that just because a source is in the calibrator list, this does not imply that it is useful for your particular observation. Please check the web information for your prospective calibrator.

As of 12 October 2005, the calibrator list has been updated with four new sources added, and improved positions entered for 86 existing sources. Generally the positional changes have been less than 0.5 arcseconds. However there was a cluster of poor calibrator positions near RA = 23 hours, DEC = -40^{o}.

In addition to those interested in high astrometric accuracy, the updated position can have an effect on observations where multiple epochs are involved. If the nominal position of the calibrator changes between the epochs, then this will lead to a mis-registration between the epochs. If the change in nominal calibrator position is "significant" relative to the resolution and the dynamic range requirements, then care is required. One way to avoid these issues, where positional accuracy is of secondary importance, is to continue to use the old calibrator positions. To use the old positions, in SCHED select the old calibrator catalogue as the default one with the command

```
defcat old_calibrators
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Note that the change in the calibrator catalogue does not affect schedule files that have already been developed.

Bob Sault
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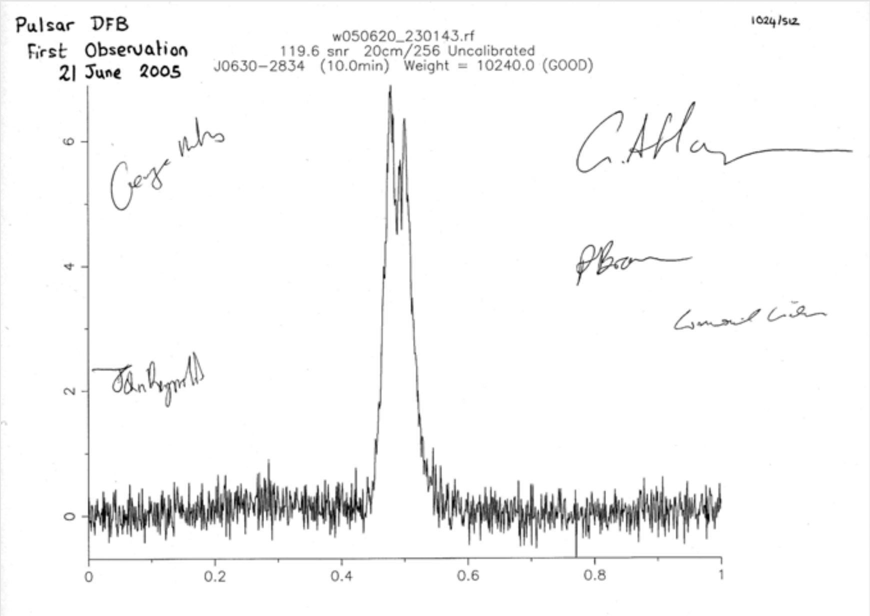
Success for the prototype Pulsar Digital Filter Bank!



First light for Pulsar Digital Filter Bank. Image credit: John Sarkissian

The prototype Pulsar Digital Filter Bank (PDFB) was successfully installed at Parkes on 21 June 2005. The installation went quickly and smoothly, with project scientist, George Hobbs, obtaining pulse profiles with full Stokes parameters on several pulsars on the evening of the same day.

To counter the effects of interstellar dispersion, all pulsar observing systems require a method of dividing the observed bandwidth into narrow channels. Analogue filterbanks, correlation spectrometers and baseband coherent de-dispersion systems have all been employed in the past and each type of system has its own advantages and disadvantages for a particular application. To provide the very wide bandwidths and high time-resolution required for current precision timing and polarization observations, the ATNF is developing a Pulsar Digital Filterbank (PDFB) system based on implementation of a polyphase filter in FPGA processors.

Project engineers Grant Hampson and Andrew Brown are pictured in front of the prototype PDFB system. The prototype has the ability to process 8-bit sampled data with 256 MHz of bandwidth. These data are processed using a Nallatech FPGA hardware development platform. A custom Radix-4 digital filter bank has been developed by the Electronics Group.

The Nallatech board provides the necessary pulsar binning memory which can handle 2048 phase bins, 2048 frequency channels, four products, all with 32-bit resolution. Using this configuration it is possible to observe pulsars with a minimum period of 84 ms. By reducing the number of pulse phase bins or frequency channels it is possible to observe pulsars with millisecond periods.

Many thanks to Warwick Wilson for writing the necessary software to integrate the prototype PDFB system into the telescope software. George Hobbs and Dick Manchester have analysed much of the collected data and in some situations find that the prototype performs significantly better than its predecessor. The prototype is still operational and being used by many pulsar astronomers.

Our first visit to Parkes was very enjoyable — it was great for us to observe real pulsars (instead of simulated ones) in a real telescope environment, complete with RFI! Thank you to all of the Parkes staff for making our visit a success.

Since the installation at Parkes our time has been devoted to developing a custom hardware design that meets the user requirements. This hardware will process 1 GHz of bandwidth with 8-bit sampled data (part of CABB upgrade developments). It will process this data using the latest FPGA technology from Xilinx

Photo: John Sarkissian

Project engineers Grant Hampson and Andrew Brown.

and Quad Data Rate memory from Samsung. A Radix-8 digital filter bank design has been simulated in Matlab/Simulink to process the data. It will be possible to measure 4-ms pulsars using the binning memory configuration discussed previously — a 20-fold increase!

Grant Hampson, Andrew Brown, Dick Manchester and George Hobbs
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Single dish polarimetry mini-workshop

On 7 September 2005 ATNF hosted a small half-day workshop on single-dish polarimetry. The workshop was designed to bring together researchers working on different aspects of single dish polarimetry in order to share their experiences with observing, calibration and analysis techniques. We were particularly motivated by the realisation that there are many distinct groups around the ATNF working with Parkes polarization data in a range of fields including pulsars, masers and continuum imaging. Polarimetry with a single dish involves a slightly different set of techniques to the familiar ones applied with an interferometer; although the experience of handling these data exists, it does not often cross the boundaries between scientific disciplines.

The workshop was a great success, with about 15 participants, including six speakers. The talks covered a wide range of topics with Jim Caswell and Rachel Deacon talking about observations of the polarization of OH masers, Simon Johnston telling us how polarization helps us understand pulsars, Ettore Carretti (Bologna) discussing continuum polarization imaging at 2.4 GHz for CMB foreground studies, Dave McConnell and Naomi McClure-Griffiths talking about continuum polarization imaging at 1.4 GHz for the Southern Galactic Plane Survey and Chris Phillips demonstrating the use of the new ASAP software for polarimetry.

The workshop was designed to be highly discussion oriented with short, 20-minute talks followed by 25 minutes for discussion after each talk. The format was very effective and the discussions were active and valuable. It was refreshing to see the similarity of techniques applied to the very disparate scientific fields. We also benefited greatly from the presence and input of a few technical experts. At the end of the day we concluded that single dish polarimetry isn't easy, but it's worth doing!

Naomi McClure-Griffiths
(Naomi.McClure-Griffiths@csiro.au)

Distinguished visitors to the ATNF

We've had our usual healthy number of visitors in the middle of the year making use of the northern hemisphere summer vacation period. However, even more visitors will arrive at the end of the year, always a busy time at the ATNF and even more so this year with a couple of low-frequency meetings at the Universities of Sydney and Tasmania.

Our recent visitors have included Don Backer (Berkeley), Tam Helfer (Berkeley), Busaba Hutawarakorn Kramer (NECTC, Thailand), Michael Kramer (JBO), John Lugten (Berkeley), John Storey (UNSW), Juan Uson (NRAO) and Joel Weisberg (Carleton).

Confirmed future visitors include Katherine Blundell (Oxford), Jayaram Chengalur (NCRA), Jim Cohen (JBO), Ralf-Juergen Dettmar (Bochum), Nissim Kanekar (NRAO), Ken Kellerman (NRAO), Yuri Kovalev (NRAO), Karl-Heinz Mack (Bologna), Padelis Papadopoulos (ETH, Zurich), Mary Putman (UMich), Mal Ruderman (Columbia), Nathan Smith (Colorado) and Bob Williams (STScI).

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

Visitors are funded by the ATNF DV program and the two ATNF Federation Fellowship programs.

Lister.Staveley-Smith
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Memories of the Mopra 3-mm SIS receiver

It was the end of an era when on 13 September 2005 the Mopra SIS receiver and its two-stage compressor were decommissioned and replaced by the brand new Mopra 3/12-mm receiver and its compressor. The cheers of astronomers who hated tuning the SIS receiver could be heard from as far away as the University of New South Wales (UNSW) but the SIS receiver has proved to be a useful beastie nonetheless. Its operation was complicated by the need for cooling to 3.5 Kelvin but considering it was installed in mid-1994 it has done sterling service.

John Whiteoak embraced the SIS receiver and put it to its best use. Under him it served as a collector of data for PhD students as well as for his own research. He pushed the limits of the observing range (83.5 – 116 GHz) as well as pushing the limits of use by observing well outside the accepted “millimetre observing period” that spans only the winter months. Mike Kesteven did much to ensure the Mopra software kept ticking over and contributed immensely to the knowledge of beam shape, efficiencies and where the sub-reflector should be. Later years have seen UNSW making most use of it and their “Friend of Mopra” scheme and recording of tuning settings made the need for outside support minimal.

The automation that allowed tuning from the control room at Mopra was not available in the early years of operation and more than once a bedroom at the site’s building or a tent on the grass on the other side of the site fence was the home for a receiver group member who would be woken to re-tune in the middle of the night. The automation didn’t stop the call outs completely but problems could be resolved remotely.

Its construction by Graham Moorey, Russell Bolton, Simon Hoyle, Pat Sykes, Mark Bowen, Peter Seckold and Les Reilly all those years ago was quite an accomplishment. The SIS mixers have never failed and the electronics in general have been most reliable. It is just as well as there never were any spare mixers. Most downtime was attributed to cryogenic maintenance but ironically in this last season there were no faults at all. The two-stage scroll compressor developed in the receiver group now serves as the model for those to be used on the ALMA array in Chile.

Its folded optics arrangement has undergone various changes firstly to allow turret rotation and then to facilitate illumination of the full surface of the dish and all the while the most precious part – the polarising grids – have survived. Their destruction would have stopped all operation of the receiver.

Coonabarabran and in particular “the big China” and Imperial Hotel have benefited from the receivers’ presence and the untiring assistance from the Narrabri staff…though some in the town may wish to dispute how much benefit ATNF staff brought and whether it was more of a “cost neutral” arrangement. Mopra Rock has had more than its fair share of climbers in this time as well.

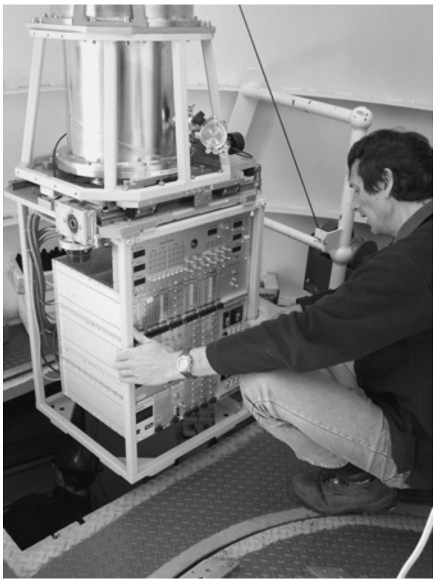
The main function of the equipment was an odd one however. Receiver installation normally acted as a drought breaker so farmers would crack a smile as Jack, and more recently Mick, drove the CSIRO air ride truck along Timor road knowing that rain was on the way to spoil observations. The new receiver has continued the tradition and the first day that measurements were to be undertaken at the end of the first installation week the rain came and hung around ensuring the memories of drips down the back of the neck in cold weather live on.

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

Photo: Graeme Carrad

The old Mopra receiver.

Installation of a new 3/12-mm receiver at Mopra



Derek Aboltins winching the new receiver package to the turret.

The timely installation of a new millimetre-wave capable receiver at Mopra has been achieved. This receiver can truly be described as 3/12-mm because observations at 115 GHz on 22 September have already detected the tell-tale line of carbon monoxide.

With installation scheduled in the week starting 12 September staff from Narrabri and Marsfield converged on Mopra on the Monday. The SIS receiver (see page 8) and its compressor were removed and the new items slotted into their places nicely all within two hours on the Tuesday morning…well not quite that nicely. The rest of Tuesday was spent aligning the new package. This required the repositioning of the L/S feed and package and evening had descended by the time the final location was determined. The cryogenics crew looked after the new compressor and lines while all this was going on.

The cryostat was evacuated overnight and the fridge purged next morning so cooling could commence at about 10 am. By 4 pm we had a cold receiver with all cryostat related electronics, both monitor and control, hooked up and operational.

Thursday was taken up with getting the receiver, local oscillator and conversion system installed and functioning while others worked to complete changes that had begun on Monday to the AT conversion rack. In the background the necessary software modifications had been going on and this allowed the receiver to be configured remotely and noise-temperature measurements to be made after dinner that night. These indicated that all was well. A repeat of the measurements on the Friday confirmed this though the weather had closed in making measurements of the sky temperature less than meaningful. The calibration injection system functioned and workers were able to pack up and return to Narrabri and Sydney…well most of them anyway.

Little had to be done to achieve a decent pointing solution and the beam patterns indicate that no coma lobe problems, seen at Mopra previously, have surfaced so the subreflector won't require significant repositioning.

All in all the installation was as smooth as could be expected with the package having more capability than originally envisioned. Thanks are in order for those who got the bits made on time, for those who put in the preparatory work to have the antenna ready and particularly to those whose "no fuss" attitude made the fit out a pleasurable experience.

Graeme Carrad
(Graeme.Carrad@csiro.au)

The crew: Derek Aboltins, Graeme Carrad, Michael Laxen, Les Reilly, Brett Hiscock and Russell Bolton.

ATNF graduate student program

We welcome the following students into the ATNF co-supervision program:

- Joris Verbiest (Swinburne) has commenced his project entitled "High Precision Pulsar Timing" with Prof Matthew Bailes (Swinburne) and Dr Dick Manchester (ATNF). Joris will be using the new-generation high-performance timing instrumentation to study pulsars and will be part of the global / Australian effort to detect a gravitational-wave background.

- Katie Kern (Swinburne) has commenced her project "Galaxy Groups and their Evolution: What GEMS and LVHIS can tell us". Her supervisors will be Dr Virginia Kilborn and Prof Duncan Forbes (Swinburne) and Dr Baerbel Koribalski (ATNF). Katie will be studying the HI content of galaxies in the Group Evolution Multi-wavelength Study (GEMS) and the Low-Velocity HI Survey (LVHIS).

Lister Staveley-Smith
Graduate Student Convener
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Long Baseline Array news

In collaboration with the University of Tasmania and Swinburne University of Technology, we have been developing new disk-based recorders that interface with the existing data acquisition systems. These systems are based on a plug-in digital interface card built by Metsahovi Radio Observatory, Finland, and record the raw 2-bit sampled baseband data onto normal PC hard-disk drives. We have been using Apple Xserve RAID systems as well as an array of four normal PC disks with no special hardware.

Disk-based recording allows wider recorded bandwidth than the current tape-based S2 recorders, interface directly with software correlators (which are being developed at Swinburne as part their contribution to SKA developments), and are a possible replacement for the aging S2 systems. Numerous tests involving the full Long Baseline Array (LBA) plus international telescopes have been run since 2003 and correlated on the Swinburne software correlator. These tests have all run very successfully and disk-based recording, with software correlation, has been added as a standard observing mode for the OCT05 observing semester. Currently a recording rate of 512 Mbps (4×16 MHz bands) at Parkes, Mopra and the ATCA is available and 256 Mbps at the other LBA stations. Within the next six months we plan on doubling the recording rate to 1 Gbps at the ATNF stations and to 512 Mbps elsewhere. Anyone wanting to submit an LBA proposal using the disk-based recording must contact the LBA National Facility. Details are given on the website at *www.atnf.csiro.au/vlbi/documentation/VLBI_National_Facility_upgrade.html*.

Disk-based recording is the first step towards e-VLBI, which has a long term aim of removing the requirement to record the sampled data onto temporary media (i.e. tapes or disks) and directly connecting the observatories with wide bandwidth network links. CSIRO is participating in the AARNET Regional Network and we expect to have Parkes, Mopra and the Compact Array connected to 1-Gbps network links by the end of 2005. This will allow us to do real-time (or near real-time) VLBI correlation of the three ATNF antennas at a data rate of 512 Mbps. The University of Tasmania has also recently been awarded a LEIF grant to connect the Mount Pleasant observatory (near Hobart) to the University. Once fast network links on Basslink are available in the near future, the 26-m telescope in Hobart will also be connected to the real-time VLBI network.

One advantage of the disk-based recorders is that they can record data in parallel with the existing S2 systems. For the last four VLBI sessions we have been using these systems to make real-time fringe checks to all LBA stations. A small amount of data (0.1 – 1 seconds only) is captured from each observatory and sent to Swinburne using a specifically written suite of programs. The data is then correlated on the Swinburne software correlator and the result posted on a webpage. Currently the program runs interactively, but has been written to easily allow scheduled operation if this becomes desirable. The real-time fringe checker is now run routinely for all VLBI experiments and has caught a number of set-up problems that would otherwise have gone unnoticed until correlated weeks later. LBA users should be aware that they significantly increase the chance of problems being found if they schedule a strong fringe finder near the beginning of their experiment (and preferably every few hours).

One of the problems with wide-bandwidth, long-haul networks is efficiently utilising the full bandwidth as existing network protocols are not well tuned for this purpose. For example, on the dedicated 1-Gbps link experiment set up for the Huygens experiment from the ATNF headquarters in Sydney to JIVE in the Netherlands, standard networking protocols could only be used to send data at 10 Mbps which is only 1% utilisation. To help us experiment with a variety of data transport protocols, the CSIRO CeNTIE project has provided access to a 1-Gbps link from Marsfield in Sydney to the University of Western Australia in Perth.

e-VLBI is rapidly being developed around the world, especially in Europe, USA and Japan. An annual e-VLBI international workshop has been held in the last four years, with the most recent workshop (12 – 15 July 2005) hosted by Australia at the ATNF headquarters in Marsfield. About 50 participants from around the world attended and it was very successful. A special "networks" day was held, with extensive participation from the computer networking community, and this led to very useful cross-discipline links. All the presentations from this workshop are available on-line at *www.atnf.csiro.au/vlbi/evlbi2005/abstract.html*.

Chris Phillips & Tasso Tzioumis
(Chris.Phillips@csiro.au,
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At the end of August, VLBI at 86 GHz was attempted for the first time between Mopra and the Compact Array (currently the highest frequency that the LBA operates at is 22 GHz). Three hours of Director's time was used for an ad-hoc experiment. Good fringes were detected for the SiO maser emission from the source o Ceti using a 10-second integration, see Figure 1.

Full correlation of the data has been done on the Swinburne software correlator and awaits analysis. 3-mm wavelength observing is not available for standard LBA observations; however interested observers should contact the ATNF if they have a strong scientific need to observe at these frequencies.

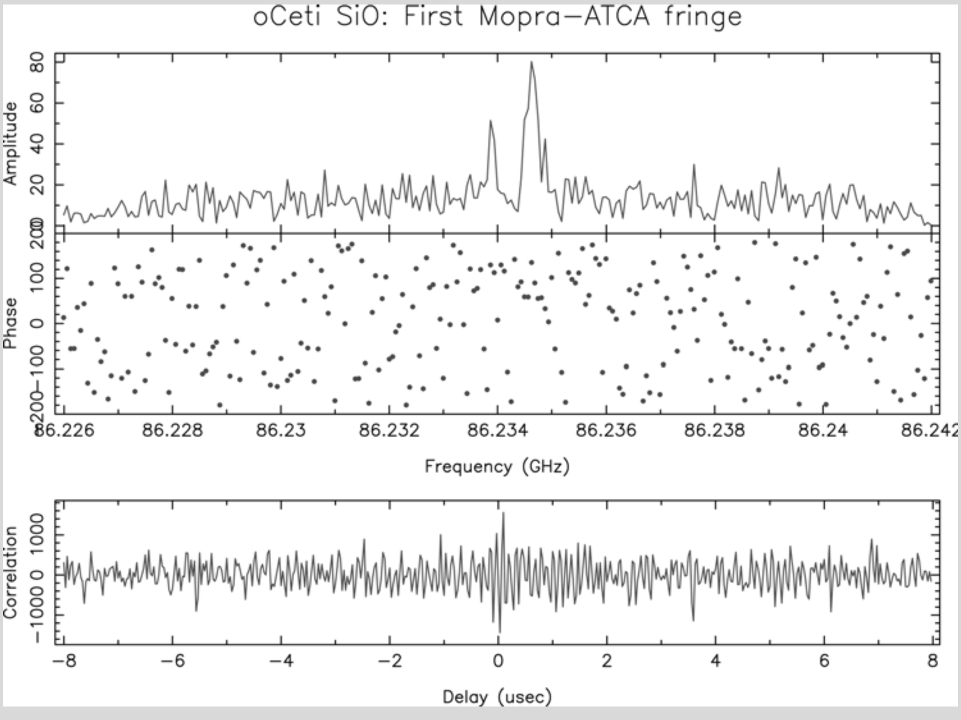

Figure 1: First VLBI fringes at 3-mm between ATCA and Mopra. The correlation is for a 10-second integration on the 86-GHz SiO maser oCeti. The top two panels show the power and phase spectrum, while the lower panel shows the correlation function. This data was correlated using the Swinburne software correlator used for real-time fringe finding.

SKA and xNTD news

Australian SKA planning news

Photo: Tony Sweetnam

Figure 1: Delivery of the hub of an NTD dish at CSIRO Radiophysics Laboratory at Marsfield, August 2005.

New Technology Demonstrator dishes arrive at CSIRO Radiophysics Laboratory

The Major National Research Facilities program, the New Technology Demonstrator (NTD) project is to design and develop a technology demonstrator for the SKA. This CSIRO project will lead to the construction and operation of two parabolic dishes equipped with focal-plane arrays.

Refurbished antennas from the old Fleurs radio telescope run by the University of Sydney are being installed on the CSIRO Radiophysics site at Marsfield in NSW by the engineering company, Sydney Engineering. Final adjustments are being made for a new surface mesh, and new drive and control systems are being installed and tested.

A prototype 24-channel beam-former has been built and a prototype version of software has been written for polyphase filtering. In this first stage of the demonstrator, focal-plane arrays are being sourced from overseas suppliers. A key milestone is the completion of the antenna test-platform using the dishes, a Thea tile from ASTRON in The Netherlands, and the prototype beam-former ready to conduct initial experiments. The target date is October 2005.

Australian SKA Planning Office (ASPO)

As the SKA project gathers momentum in Australia the Australian SKA Planning Office (ASPO) has been formed within CSIRO ATNF to implement the policy of the Australasian SKA Consortium and to manage the coordination of SKA activities in Australia. Professor Brian Boyle has been appointed the Australian SKA Director.

Information on ASPO activities can be found in the ASPO newsletters at *www.atnf.csiro.au/news/press/ASPOnewsletter1.pdf* and *www.atnf.csiro.au/news/press/ASPOnewsletter2.pdf*.

Further information on the SKA project can be found on the international SKA website at *www.skatelescope.org*. If you would like to become a member of the Australian SKA email group to receive information about SKA activities and events, please contact Dr Michelle Storey, ASPO Leader.

Michelle Storey
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Photo: Tony Sweetnam

Figure 2: Early meccano training comes into good use in reconstruction of the NTD antenna! Ken Skinner and Craig Best of Sydney Engineering starting to put together the dish structure.

Cost-effective antenna designs for the xNTD

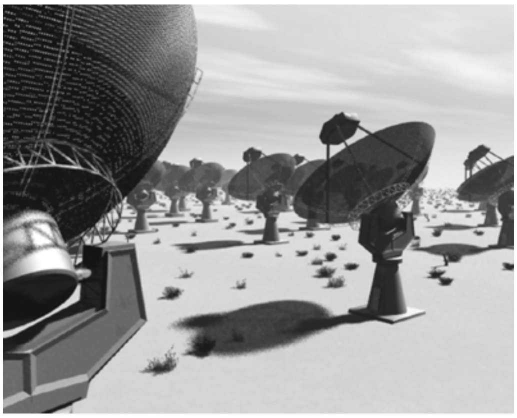

Figure 1: Simulation based on 15-m antennas, each equipped with a focal-plane array. Image credit: CVA Film & Television/Chris Fluke, Centre for Astrophysics and Supercomputing, Swinburne University of Technology.

CSIRO's extended New Technology Demonstrator (xNTD) project, led by the ATNF, will build a new radio telescope based on an array of 20 antennas. Each antenna will be equipped with a focal-plane array (FPA) and the xNTD will be based at Mileura in Western Australia.

The antennas (dish, drive and mount) are a critical element in the xNTD project, yet at the present time there is no design that meets all of the requirements in terms of cost and specification. The xNTD antennas will be between 12 and 20 m in diameter and will operate across the 500 MHz to 2.5 GHz frequency range. The target cost of one entire xNTD antenna (dish, mount and drive) is AUD 250 K. The "xNTD antenna challenge" for the xNTD project is driven to the extreme by the SKA project: The target cost for a 15-m antenna corresponds to a cost of AUD 1,415 per square meter of collecting area; for comparison the target within the SKA budget is AUD 735 per square meter assuming it is based on 15-m antennas.

As both the xNTD and SKA projects require minimalist antennas there are significant efforts around the world in the SKA community in this area. Novel solutions are being investigated by the South African Karoo project (which has a similar overall specification to the xNTD) as well as SKA R&D underway in India.

Possible cost reduction options already identified by the xNTD team include approximating a true paraboloid in the reflector shape, allowing some gravitational deformation, and using a lightweight 6-mm × 6-mm mesh as the surface material to reduce wind loading and weight bearing requirements.

To explore the interest within industry in developing the xNTD antenna, we held a half-day workshop at Marsfield on 15 September 2005. Twenty representatives from Boeing Australia Ltd, Connell Wagner, Australian Institute for Commercialisation, Sinclair Knight Mertz, Ball Solutions, BAE Systems Australia, Tenix Pty Ltd, Raytheon Australia Pty Ltd and Radio Frequency Systems attended and the initial feedback has been very positive.

The xNTD project has invited industry to prepare brief proposals of interest to conduct a design study for the xNTD antenna. These proposals are due by 25 November 2005. When these have been reviewed we anticipate that more detailed design concepts will be developed under paid contracts, to be completed in mid-March 2006. Depending on the outcome of these proposals the xNTD team will consider progressing one (or more) to the prototyping stage.

Follow-up information from the workshop, including the presentations made on the day can be found at *www.atnf.csiro.au/projects/ska/industry_2/pw-antennas.html*.

Carole Jackson (ATNF Business Development Manager and ASPO Industry Liaison),
Colin Jacka (xNTD Project Leader) and
Mike Kesteven (xNTD Antenna Development Leader)
(Carole.Jackson@csiro.au)

Photo: Diana Londish

Figure 2: Participants at the "Antenna design for the xNTD" workshop admire one of the two 13.8-m diameter Fleurs telescope dishes, currently being refurbished on the Marsfield range. These antennas will form the NTD.

IAA award to VSOP team

The International Academy of Astronautics (IAA) has awarded its Laurels for Team Achievement Award for 2005 to the VLBI (Very Long Baseline Interferometry) Space Observatory Programme (VSOP) Team. The Award, presented on 16 October at the 56th International Astronautical Congress in Fukuoka, Japan, was made to an international group of 15 scientists and engineers including the ATNF's David Jauncey.

Australian involvement in space VLBI goes back almost 20 years to the TDRSS (Tracking and Data Relay Satellite System) experiments first conducted in 1986 with a geostationary TDRSS satellite, the Usuda 64-m telescope in Japan and the Tidbinbilla 64-m telescope (as it was then). These were the first successful space-to-ground VLBI observations ever undertaken (Levy, G.S. et al. 1986, Science, 234, 187). The links with Japan were strengthened during the first Space VLBI Work Week, held at Epping in April 1991. It was at this meeting that the first steps were made by radio astronomers from Australia and Japan toward an Asia-Pacific VLBI network, which led to the establishment of the Asia-Pacific Telescope (APT, *www.vsop.jaxa.jp/apt/)*, providing a boost for regional VLBI collaboration and a vehicle through which the regional telescopes were able to contribute to the mission.

The radio astronomy satellite HALCA carrying an 8-m radio telescope was launched from Kagoshima by Japan's Institute of Space and Astronautical Science (ISAS) on 12 February 1997 to participate in VLBI observations with arrays of ground radio telescopes across the world. Radio telescopes from 14 countries contributed observing time to the VSOP mission, and in turn VSOP observing time was open to peer-reviewed proposals from astronomers all around the world. Five dedicated tracking stations, one at Tidbinbilla, one in Japan, two in the USA, and one in Spain, provided the critical real-time two-way link to HALCA, uplinking the LO phase (suitably Doppler shifted to take into account the satellite's motion), and receiving the satellite's digitized VLBI data-stream at 128 mega-bits per second. Three correlators, in Japan, the USA, and Canada, and two orbit determination teams, in Japan and the USA, rounded out the mission.

Australia is the principal radio astronomy nation in the southern hemisphere and our telescopes at Ceduna, Hobart, Parkes, Mopra, Narrabri and Tidbinbilla, have made a major contribution to VSOP. The involvement of Australian scientists was described in Richard Dodson's article in the previous issue of the ATNF News. Mopra has the distinction of participating in 25% of all VSOP observations! VSOP is arguably the most sophisticated and complex space science mission to date in terms of the variety and complexity of its globally distributed resources and the amount of data transmitted from a scientific spacecraft to the Earth.

Simultaneous observations with HALCA's 8-m diameter radio telescope and arrays of ground radio telescopes synthesize a radio telescope almost three times the size of the Earth, enabling the highest angular resolution 1.6-GHz and 5-GHz images to be made. The role of coordinating all ground and space elements was carried out by the small but dedicated team at ISAS (now part of the Japan Aerospace Exploration Agency, JAXA) and the National Astronomical Observatory of Japan (NAOJ).

HALCA has participated in over 780 VSOP observations, predominantly of the cores and relativistic jets in active galactic nuclei. Two-thirds of HALCA's observations have been made for observing projects selected by international peer-review from proposals submitted by the astronomical community in response to Announcements of Opportunity. The remainder have been devoted to a mission-led all-sky survey of active galactic nuclei at 5 GHz — the VSOP Survey Program.

The IAA citation notes that the technique of Very Long Baseline Interferometry has enabled the longest astronomical wavelengths to be used to produce the highest angular resolution images. VSOP realized the long-held dream of radio-astronomers to extend those baselines into space, by observing celestial radio sources with the HALCA satellite, supported by a dedicated network of tracking stations, and arrays of ground radio telescopes from around the world. On behalf of the entire VSOP Team the award highlighted the astronomers and engineers who made key contributions to realizing, and operating, a radio telescope bigger than the Earth: Hisashi Hirabayashi (ISAS/JAXA), Haruto Hirosawa (ISAS/JAXA), Peter Dewdney (DRAO, Canada), Edward Fomalont (NRAO, USA), Leonid Gurvits (JIVE, The

Figure 1: Members of the international VSOP team, including 12 of the recipients of the IAA award, pictured at ISAS. Circa 1995.

Back row: **Dave Murphy, Eiji Nakagawa, Seiji Kameno, Jim Ulvestad, Dave Meier, Phil Edwards, Jon Romney, Dave Jauncey, Leonid Gurvits, Bob Preston, Richard Schilizzi, Glen Langston, Noriyuki Kawaguchi.**

Front row: **Makoto Inoue, Kazunori Shibata, Hisashi ("Hirax") Hirabayashi (Project Scientist), Alex Wiercigroch, Peter Dewdney, Masaki Morimoto, Larry d'Addario, Hideyuki Kobayashi, Yasuhiro Murata, Haruto Hirosawa (Project Manager), and Joel Smith.**

Netherlands), Makoto Inoue (NAOJ), David Jauncey (ATNF), Noriyuki Kawaguchi (NAOJ), Hideyuki Kobayashi (NAOJ), Kazuo Miyoshi (Mitsubishi Electric Corporation, Japan), Yasuhiro Murata (ISAS/JAXA), Takeshi Orii (NEC, Japan), Robert Preston (JPL, USA), Jonathan Romney (NRAO, USA), and Joel Smith (JPL, USA).

The Laurels for Team Achievement Award was created by the International Academy of Astronautics in 2001 to recognize extraordinary performance and achievement by a team of scientists, engineers and managers in the field of Astronautics. The previous recipients are the Russian Mir Space Station Team (2001), the US Space Shuttle Team (2002), the Solar and Heliospheric Observatory (SOHO) Team (2003), and the Hubble Space Telescope Team (2004).

The VSOP mission is nearing its end. However, having received their Laurels, the VSOP team are not resting on them! Planning for a next generation mission, currently dubbed VSOP-2, is well underway. The formal VSOP-2 proposal was one of three submitted to ISAS/JAXA in September, with the successful mission being decided early next year. VSOP-2 will provide ten times better angular resolution and ten times better sensitivity than VSOP, indicating a bright future for space VLBI.

The International Academy of Astronautics was founded in August 1960 in Stockholm, Sweden, during the 11th International Astronautical Congress. The Academy aims to foster the development of astronautics for peaceful purposes; recognize individuals who have distinguished themselves in a related branch of science or technology; provide a program through which members may contribute to international endeavours; and foster cooperation in the advancement of aerospace science.

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Articles

Compact Array traces the frequency drift and temporal structure in coherent stellar emission

We have known for some years that certain active binary stars and flare stars occasionally emit highly circularly polarized radiation at L and S-bands (at 20 and 13 cm); this emission implies that the electrons responsible are not being accelerated in the random manner that characterizes synchrotron radiation, but in a much more ordered fashion that results in the source having high polarization and high brightness. Examples of coherent emission occur in the most common bursts from the Sun, and the nearest star, Proxima Centauri, was recently found to emit coherent radiation for as long as two days (Slee et al. 2003). Coherent emission comes in two main flavours, plasma emission and electron-cyclotron maser emission (ECME); both types are highly polarized, but they differ in that ECME has much finer time-resolved structure with burst durations in the millisecond range.

Up until now, the large synthesis arrays such as the VLA and the Compact Array have had sufficient sensitivity to detect coherent emission, but insufficient time-resolution to discriminate between plasma and ECME. During 2004 we managed to set up the correlator of the Compact Array to deliver samples at a rate of 12.8 samples per second, which is 128 times faster than that used for earlier work on stellar emissions. Mark Wieringa also modified the on-line display software (VIS) to show the flux density of circular polarization; this permitted us to switch to the high sampling rate only at times when the polarization was high enough to yield useful results. We observed with this modified system on 28 March and 8 April 2005, and on both occasions we were lucky enough to catch the well-known RS CVn binary HR 1099 in a coherently emitting state. Here we shall describe our results of 28 March.

We observed HR 1099 with the Compact Array in a 6-km configuration for ten hours, recording simultaneously at 1.384 and 2.368 GHz with the usual integration time of 10 s. The flux density measurements are shown in Figure 1, in which the total flux, I is seen in panel (a), the circularly polarized flux, V in (b) and the polarized fraction, V/I in (c). Figure 1 shows that there was a moderate amount of polarized flux in the first hour, but it was not considered strong enough to initiate the high sampling rate. However, beginning at 06 h the polarized fraction rose

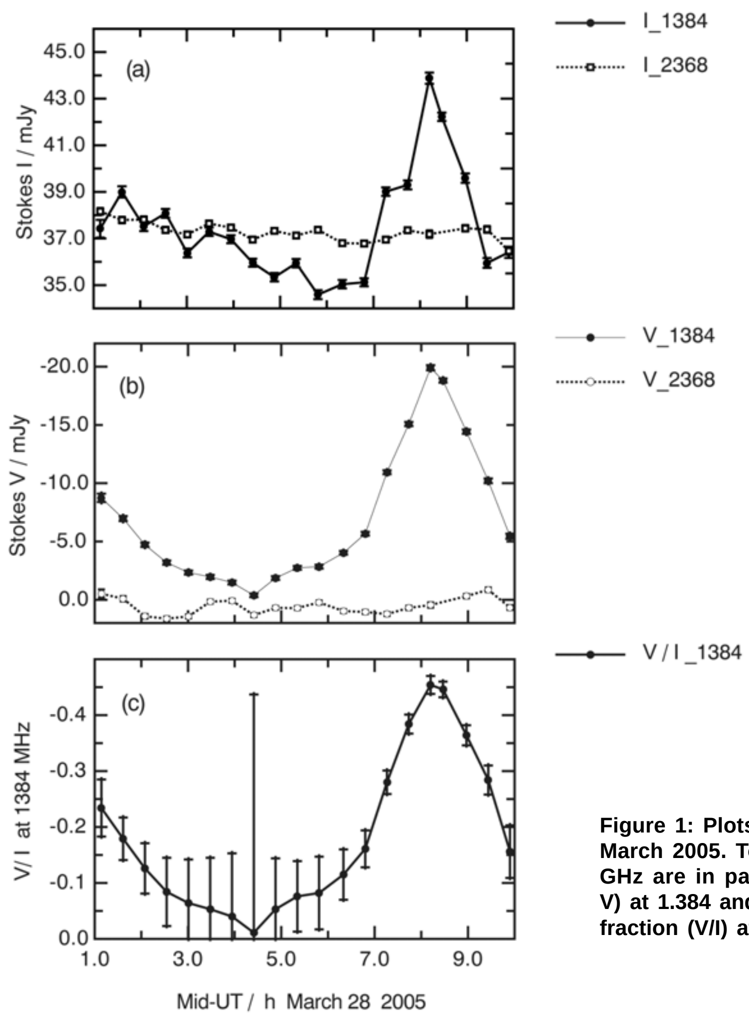

Figure 1: Plots of 25-min integrations against UT on 28 March 2005. Total intensities (Stokes I) at 1.384 and 2.368 GHz are in panel (a); circularly-polarized intensities (Stokes V) at 1.384 and 2.368 GHz are in panel (b); the polarized fraction (V/I) at 1.384 GHz is shown in panel (c).

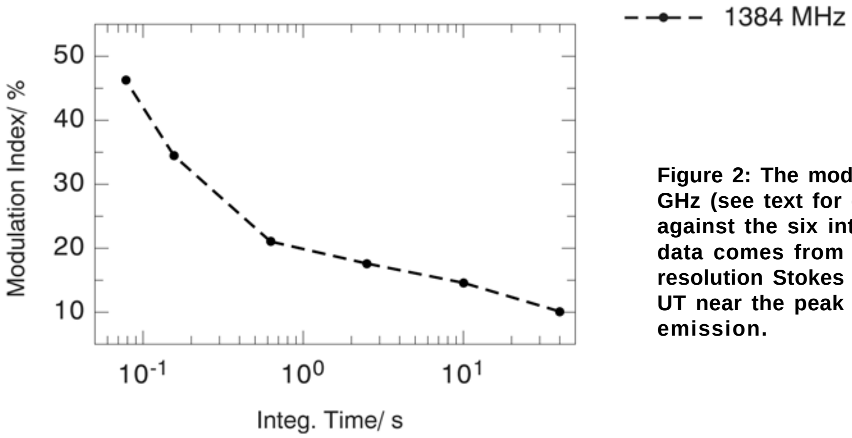

Figure 2: The modulation index at 1.384 GHz (see text for definition) is plotted against the six integration times; this data comes from the high-time resolution Stokes V data taken at 08:28 UT near the peak of the coherent emission.

rapidly at 1.384 GHz, reaching a peak near 08 h UT. The high sampling rate in V was initiated just after this peak for about 20 minutes. The 2.368-GHz polarization remained slightly positive, i.e. polarized in the right-handed sense over the 10-hour run; this is the normal state of polarization for synchrotron emission from this star.

Our first step in the analysis was to elucidate the temporal structure in the highly time-resolved data. We did this by allocating the data to 40, 10, 2.5, 0.625, 0.156 and 0.078-sec bins, We found the variance in flux-density between the samples in each bin, var (b); we also found the average variance within each sample in a bin, var (w) (this is due mainly to system noise). By subtracting var (w) from var (b) and taking the square root, we now have the root-mean-square (rms) variation in flux-density due to the coherent source only; then dividing the rms by the average value of V yields a modulation index, $m = V_{rms} / |V|$. These values of modulation index are plotted against bin size in Figure 2, which demonstrates that the intrinsic variability is still increasing at the limit of our time resolution (0.078 milliseconds). It seems clear, therefore, that the coherent emission from HR 1099 is ECME and not plasma emission.

We next investigated the spectral structure of the ECME, i.e. how the flux density changes with frequency. The IF output of the Compact Array consists of 13 contiguous channels, each 8-MHz wide, permitting us to show the radio spectrum over a total width of 104 MHz. Figure 3 shows the spectra, each of which is derived from one of the 25-min integrations shown over the peak of circular polarization in Figure 1. We are obviously seeing narrow-band peaks that slowly drift across the 104-MHz bandwidth of the receiver. Beginning at 06:48 UT on the top left of Figure 3, we note that the peak with bandwidth about 30 MHz drifts to lower frequencies at about 0.7 MHz per minute, disappearing off the low-frequency end at just after 07:44 UT. As the first peak disappears, a second peak of emission has already appeared at the high-frequency end of the spectrum; this peak has a larger bandwidth of about 45 MHz and drifts to lower frequencies at about the same rate of 0.7 MHz per minute, finally beginning to disappear off the end of the spectrum at 09:26 UT. It is clear from the values for V/I in Figure 1c that the maximum polarized fraction, when averaged over the 25-min integrations from which Figure 1 is constructed, reached about 45% at UT's of 08:08 and 08:28. However, because of narrow band emission, these same integrations contained peak values of V/I of about 100%, and minimum values of less than 10%. The instantaneous bandwidth of the ECME can be lower than 2% of the operating frequency centred on 1.384 GHz, especially when the frequency drift during each integration is taken into account.

The theory of ECME has been summarized recently by Melrose (2005), and further theoretical details are given in connection with the ECME detected from Proxima Centauri by Slee et al. (2003). ECME has been detected from a variety of sources including the Sun, Jupiter, close binary stars, flare stars and the Earth's aurorae; this form of emission is generated by celestial objects with very different magnetic field strengths and plasma densities. While many of the details of ECME are yet to be satisfactorily explained, it seems to be well accepted that the emission that reaches the observer is the second harmonic of the gyro-frequency, i.e. the frequency at which injected electrons gyrate around magnetic field lines. Thus ECME emission near 1.4 GHz implies a source region field strength of 250 G, while the plasma density needs to be less than 6×10^9 electrons cm^{-3} if the radiation is to escape from the source to the observer. Our observation that narrow-band ECME bursts, each composed of fine structure of duration less than 78 milliseconds, drift slowly to lower frequencies, introduces another parameter that needs to be explained. A frequency drift in the observed sense suggests that the emitting electrons may somehow drift slowly across magnetic field lines to lower field intensities further out in the corona of HR 1099. At present we have little idea of how long these drifting narrow-band sources can retain their identities.

Acknowledgements

We thank Mark Wieringa for his modifications to the VIS software, and Vince McIntyre for software that was essential for the analysis of the high-time resolution data.

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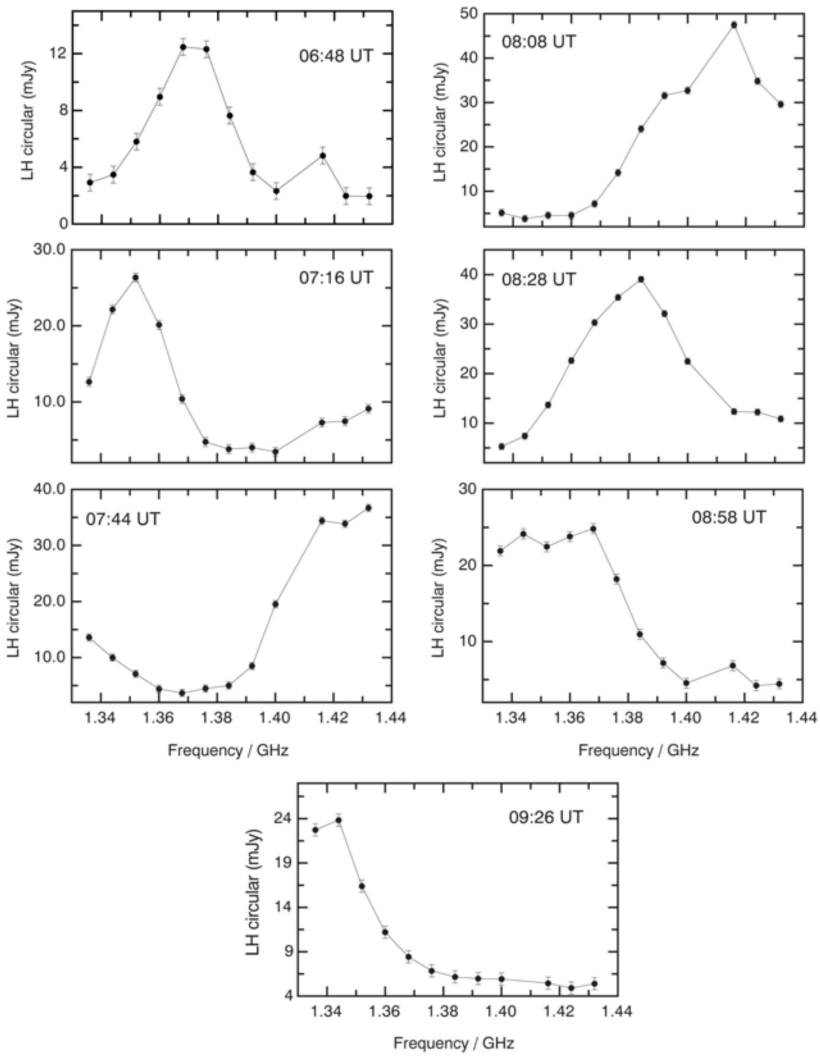
Bruce Slee (CSIRO ATNF), Warwick Wilson (CSIRO ATNF) and Gavin Ramsay (Mullard Space Science Laboratory / University College London) (Bruce.Slee@csiro.au)

Figure 3: Spectra of the 1.384 GHz circularly-polarized intensity (V) from the seven 25-min integrations over the peak in Figure 1. The frequency range is defined by the bandwidth of the receiver. The peak fractional polarization is near 100% at 08:08 and 08:28 UT. The highly time-resolved data were taken during the integration at 08:28.

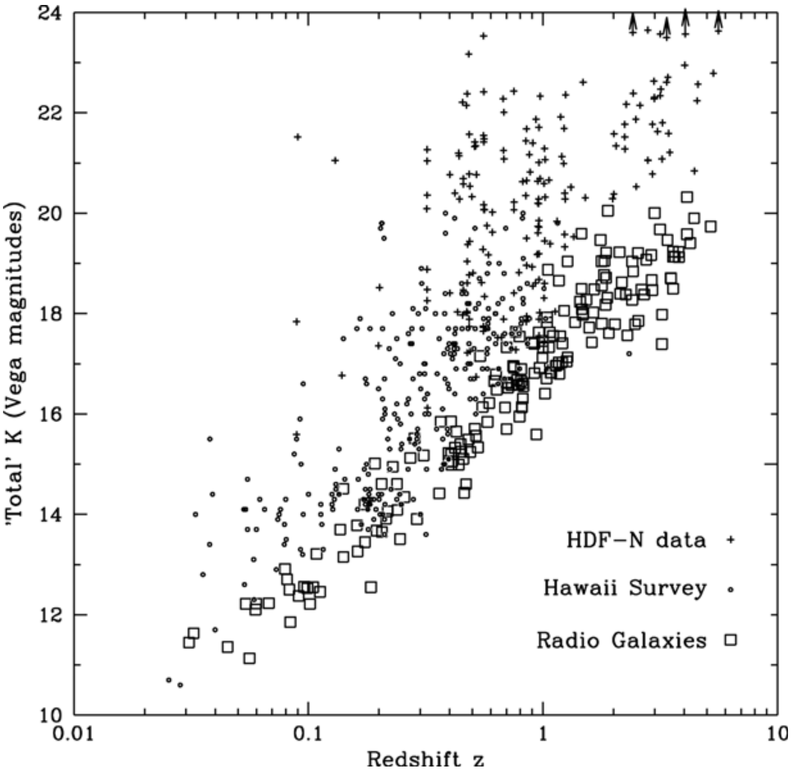


Searching for the earliest massive galaxies

We are conducting a program to find the first massive galaxies to form in the early universe, the "high-redshift radio galaxies" (HzRGs). These are the earliest galaxies in which we can deduce, from their powerful radio emission that a supermassive black hole (10^9 $M_\odot$) is in place. Powerful radio galaxies in the local universe are hosted *only* by elliptical galaxies, with a close connection between the mass of the black hole and that of the galaxy (Kormendy & Richstone 1995, Gebhardt et al. 2000). The presence of a supermassive black hole establishes a direct link between HzRGs and present day giant ellipticals, making HzRGs particularly important for testing current theories of galaxy formation.

The motivation for selecting high redshift candidates from radio surveys is illustrated in Figure 1 which shows the relationship between redshift and K-band magnitude. It is clear from this diagram that at z > 1, radio-selected galaxies are 2 – 3 mag *brighter* than optically-selected galaxies. Their near-IR K-band light is dominated by stellar emission rather than AGN 'contamination' (e.g. Jarvis et al. 2001). Radio selection therefore traces the most massive and luminous galaxies out to very high redshift. The furthest radio galaxy found to date is at z = 5.19 (van Breugel et al. 1999). All this makes HzRGs ideal probes for investigating the formation and evolution of massive galaxies, and even protoclusters (e.g. Kurk et al. 2000, Pentericci et al. 2000, Venemans et al. 2002). However, HzRGs are extremely rare, and the only way to find them is by "data mining" observations of very large areas of sky at radio wavelengths using selection techniques that isolate the most likely high redshift candidates.

Figure 1: K-z diagram for optically selected (o, +) and radio-selected (squares) galaxies (De Breuck et al. 2002). The radio galaxies trace the bright upper envelope in K-band luminosity, suggesting that they are also the most massive galaxies at a given redshift.



Steep spectrum selection

In the late 1970s, Blumenthal & Miley (1979) found that radio sources without optical counterparts generally had steeper spectral indices. Therefore, in order to separate the high redshift candidates from the bulk of the nearby radio galaxy population, galaxies are chosen to have an ultra-steep radio spectral index ($\alpha < -1.0$, where $S_\nu \propto \nu^\alpha$). A number of HzRG surveys have adopted this technique, which has proved to be very successful, with thirty new z > 3 galaxies found so far.

The relationship between spectral index and redshift is shown in Figure 2 (De Breuck et al. 2000, 2004) for the MRC and 3CR samples and for samples selected to have ultra-steep spectra (USS). The combined USS samples have ~70% with z > 2 and ~30% with z > 3.

The success of steep-spectrum selection in finding high redshift objects has previously been attributed to several effects. The spectral energy distributions of radio galaxies tend to steepen towards high frequencies and this steeper region is then redshifted to lower frequencies (below 1 GHz); the so-called k-correction. Other effects, such as inverse Compton losses, enhance the spectral steepening.

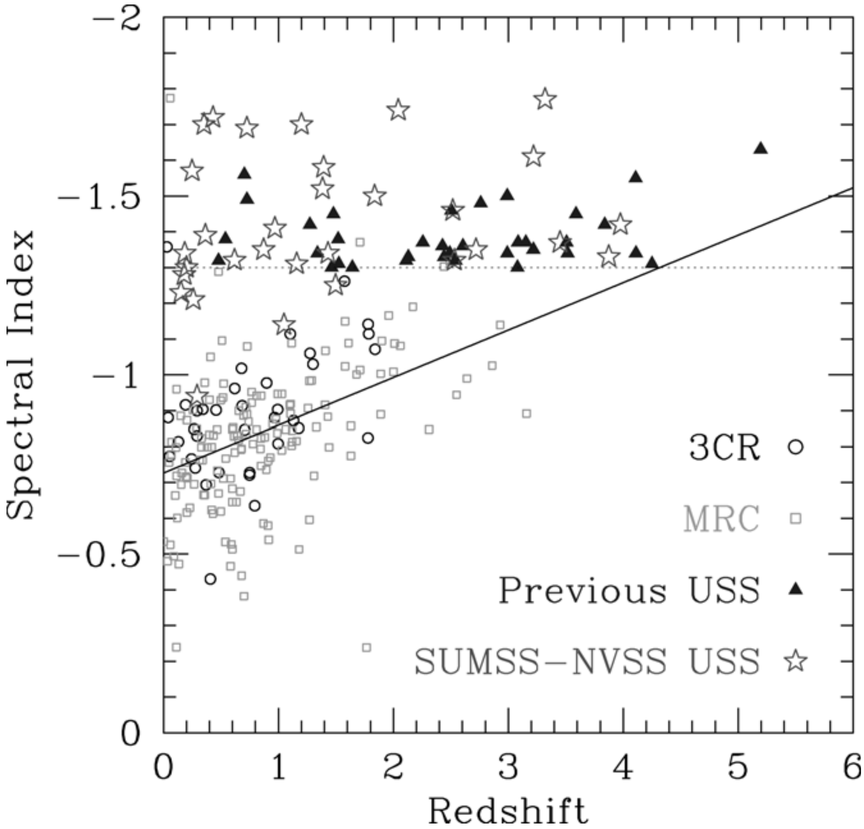


Figure 2: Spectral index vs redshift for radio galaxies from our 843 – 1400 MHz USS sample, previous USS samples and samples with no spectral bias (3CR, MRC). The dotted line marks the nominal cut-off at α = –1.3, while the solid line defines the trend for the 3CR and MRC samples.

While USS techniques have resulted in discovery of the most distant radio galaxies known, many low-redshift radio galaxies also have a steep spectrum and need to be eliminated from the sample. Spectroscopic redshifts cannot be measured for every steep spectrum target because this would require a prohibitively large observing time. Therefore, other selection criteria are needed to refine the steep spectrum sample to include only the most likely high-redshift candidates for spectroscopic follow-up.

- Regions with |b| < 20° are excluded to avoid confusion.
- Targets with optical counterparts are removed as they are likely to be at low redshift.
- High resolution radio images from the Compact Array at 13 and 20 cm are then essential to pinpoint the exact position of the nucleus and hence find the K-band counterpart.
- Using the K-z relation, the faintest K-band magnitudes indicate the best high redshift candidates. These are selected for spectroscopic follow-up.
- Once a redshift is measured, the Compact Array images again come into play in looking at the relationship between the morphology and the spectral energy distribution.

The Southern HzRGs sample

Until recently, radio searches for these rare galaxies were based almost exclusively in the northern hemisphere, due to a lack of large, sensitive multi-frequency radio surveys in the south. This imbalance has now been removed with the advent of the 843-MHz Sydney University Molonglo Sky Survey (SUMSS; Bock et al. 1999, Mauch et al. 2003), which covers the sky south of declination –30°. Furthermore, the 408-MHz survey from the original Molonglo Cross telescope in the 1970s has been re-analysed (D. Crawford 2005, priv. comm.), and the flux density limit lowered from 1 Jy to 200 mJy. The highest redshift objects are likely to have 408-MHz fluxes below the limit of the MRC because the maximum flux density of known USS radio sources drops well below 1 Jy at 408 MHz for z > 3.

The new 408-MHz catalogue and SUMSS overlap the NVSS 1.4-GHz catalogue in the range –40°< DEC < – 30°. We have therefore limited our project to these declinations so that two pairs of selection frequencies are available, 408 – 843 MHz and 843 – 1400 MHz. We can then compare the effect of selection at different frequencies to test which is more efficient for finding high redshift galaxies. The extra frequency also allows us to characterise the spectral energy distribution. Selection in the narrow frequency ranges of 408 – 843 MHz and 843 – 1400 MHz is a slightly different approach to previous USS searches which have used a wide frequency range (~300 to ~1400 MHz) or high frequencies (> 1400 MHz).

Results so far

The 843 – 1400-MHz sample was observed in the infrared using a combination of the AAT and NTT, followed by spectroscopy on the NTT and VLT. The highest redshift from the 843 – 1400-MHz sample so far is z = 3.980 (Figure 3). Five galaxies have z > 3 and nine have z > 2. A further six are undetected in deep VLT integrations implying z > 7 or heavy dust obscuration (De Breuck et al. 2004, De Breuck et al. 2005) and Gemini time has been awarded for NIR spectra of these. Our results increase the number of z > 3 galaxies in the southern hemisphere to 12.

An interesting member of the 843 – 1400-MHz sample is shown in Figure 4. A deep I-band image with the VLT showed only one object aligned with the 1.4-GHz Compact Array contours (marked b). A spectrum gave a redshift of only 0.8 despite having a K-band magnitude of K > 20, making us suspicious of the identification because the point lay well off the radio galaxy K-z distribution (see Figure1). A higher resolution 4.8-GHz Compact Array image, when overlaid on a deep NTT/SofI K-band image, revealed the true counterpart for this radio source. It is interesting that there is almost no correspondence between the K-band and I-band images. The I-band image does not have an obvious detection at the location of the K-band source (an I-band dropout), which indicates that the radio source may be at very high redshift.

The 408-SUMSS sample is in the K-band imaging stage, with 42 galaxies already observed by IRIS2. Follow-up spectroscopy of the faintest two of these has been awarded GEMINI time, while the brighter ones are being observed with the ANU MSSSO 2.3-m telescope.

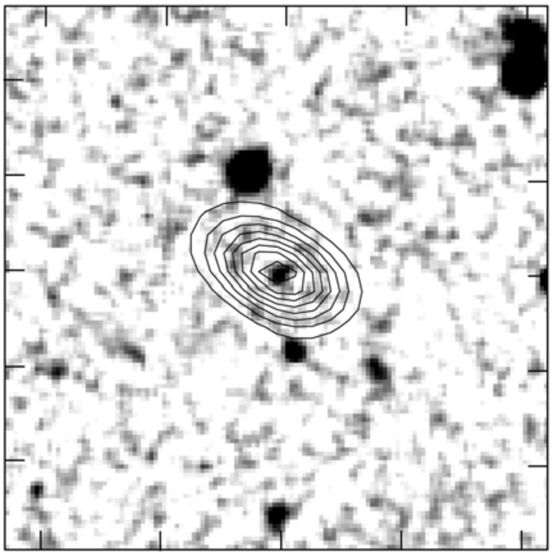


Figure 3: Compact Array 20-cm radio contours overlaid on the K-band IRIS2 image of the most distant radio galaxy confirmed in our sample so far, at z = 3.980. Image size is 56″, and the beam is 11.4″ × 6.4″, p.a. = 68º.

Automatically constrained CLEANing

In order to identify the faintest K-band targets in confused fields, and to improve flux densities for our spectral energy analysis, we have had to look more carefully at the Compact Array radio reduction. This has led to the adoption of new techniques which have benefits beyond our current project.

Most CLEAN algorithms work effectively for isolated point sources. However, the presence of other sources of significant flux density results in their sidelobes contributing to the measured flux density of the source of interest. Clearly how large an effect these sources have is a function of their brightness and their proximity to the source of interest in the image; the brighter, closer sources cause the most significant problems. Running unconstrained CLEAN on an image containing multiple sources can result in a significant underestimate of the flux density of the source of interest. It can also introduce spurious sources into the image. The standard way of resolving these problems is to manually select CLEAN regions around all of the sources in the field. However, this process is time-consuming when dealing with a large number of observations. In order to measure reliable flux densities for our sources we have developed a technique to define CLEAN regions without manual intervention.

Large radio surveys such as NVSS and SUMSS have catalogued the positions of the majority of strong radio sources in the southern sky. Hence it makes sense to use this information to pre-define CLEAN regions around these known source positions. Our technique involved searching these catalogues for all sources within the image region, above a pre-defined flux density cut-off. Then a box is fitted around each of these sources and passed to the normal Miriad CLEAN routine.

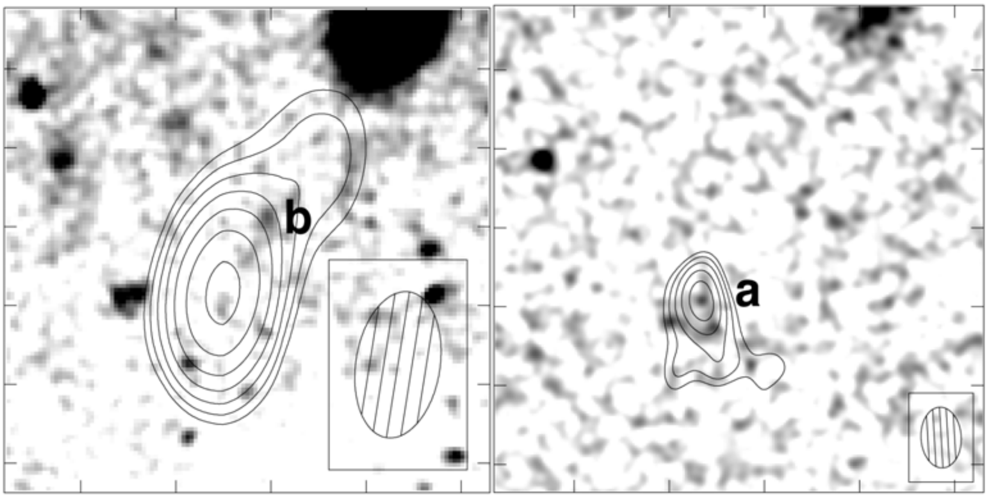


Figure 4: ***Left***: **Compact Array 1.4-GHz radio contours on a VLT I-band image showing the I-band identification, marked b, which proved to not be the counterpart to this radio source.** ***Right***: **Compact Array 4.8-GHz contours overlaid on the NTT K-band image isolating the correct counterpart, marked a. Both images are 30″ on a side and cover the same sky area. Note that the two images have very few objects in common.**

We tested this method on a sample of 147 radio galaxies, comparing the 20-cm Compact Array flux density with values from the NVSS catalogue. As expected, constraining CLEANing to specific regions around known sources improved the flux densities obtained and removed the artefacts. We also compared the results against the same process using manually selected CLEAN regions. Again, our flux densities were closer to the NVSS in all cases. For example, one of our sources has a 1400-MHz NVSS flux density of 43.2 ± 1.7 mJy, and the flux density measured after unconstrained CLEANing was 31.7 ± 1.1 mJy. However, constrained CLEANing using our automatically defined regions (for the same number of iterations) gave 41.5 ± 1.4 mJy, consistent with NVSS.

Future plan

We plan to continue our campaign of NIR and radio imaging with follow-up spectroscopy for our full sample of targets matched among the three catalogues. The aim is to identify 50 z > 3 galaxies, enough for statistical studies of their radio spectrum and space density.

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The Compact Array Galactic Centre ammonia survey

Continued from page 1

This temperature, called "rotational temperature" can be converted into kinetic temperature by applying radiative transfer models. At high temperatures, however, the ratio of line strengths exhibits only slight variations and, therefore, the (1, 1) and (2, 2) rotational temperature is a tracer for cold gas. Quantitatively, rotational temperatures up to ~30 K correspond well to kinetic temperatures, while higher rotational temperatures indicate a very hot environment. In Figure 2 we show a preliminary temperature map of the Galactic Centre Region. In the molecular gas south of Sgr A* and in the arc-like region between Sgr A* and Sgr B2, the temperature is ~20 – 30 K, significantly lower than at other positions. Across Sgr B2, the molecular gas shows a clear temperature gradient with cooler gas towards the Galactic Centre.

In addition, we also obtained the first wide-field 12-mm continuum map (Figure 3). This clearly displays the well-known filaments close to the core of the Milky Way, e.g., the prominent thin radio filaments perpendicular to the Galactic plane and the "mini-spiral" around Sgr A*. A comparison of the ammonia temperature map indicates that the gas may be somewhat warmer in regions where the radio continuum is prominent.

The full analysis will encompass virial masses of individual clouds, the clump mass-function down to the lowest masses ever determined in the GCR, and more detailed temperature and pressure maps. In addition, a wealth of observations of all wavelengths is available for the Galactic Centre which will be compared to our data in terms of heating / cooling mechanisms and within large velocity gradient radiative transfer models. The data presented here also forms a cornerstone for the comparison with molecular gas properties within the cores of other galaxies.

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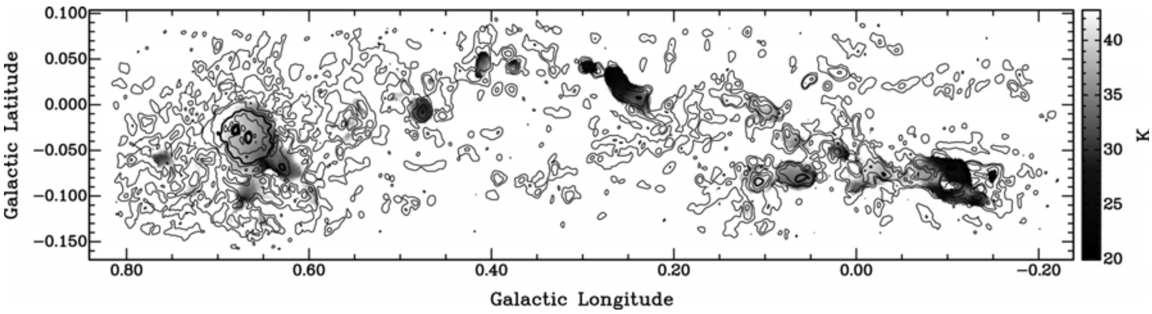

Figure 2: Rotational temperature map of the Galactic Centre (logarithmic representation). Cool molecular clouds are displayed in dark shades. Contours of the ammonia peak flux distribution are plotted on top.

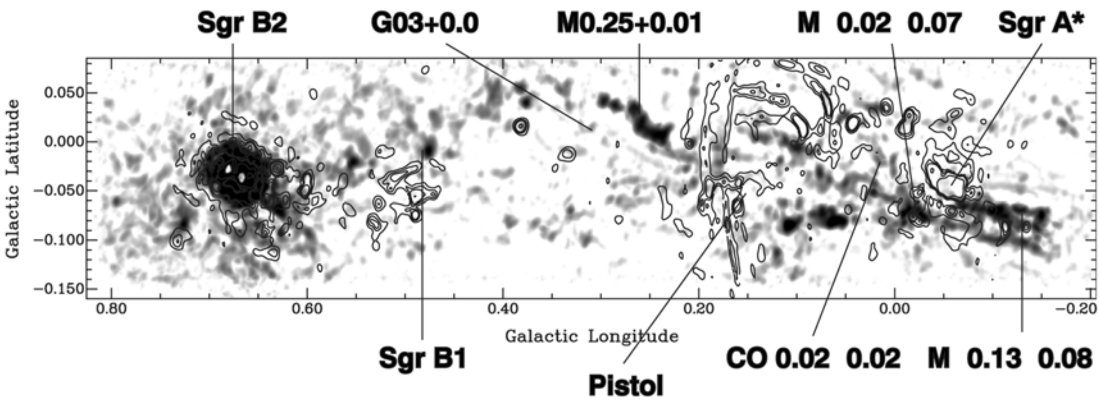

Figure 3: 12-mm radio continuum map overlaid as contours on the ammonia distribution (logarithmic representation). Some of the most prominent features of the region are labelled. Note the very thin, prominent radio continuum filaments around the Pistol region.

Regular items

ATNF outreach

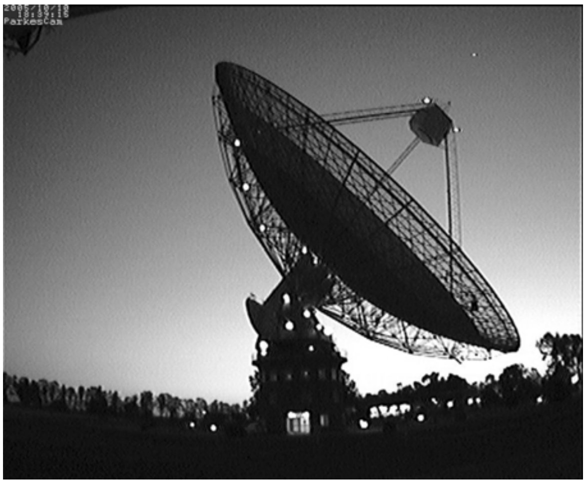

Photo: Enno Middelberg

Figure 1: A webcam image of the Parkes radio telescope at sunset.

A webcam for Parkes

In June 2005, a webcam was installed at the Parkes telescope to illustrate the telescope operations. A computer takes a snapshot of the telescope every 30 seconds and uploads this image to the ATNF's public outreach web pages (*http://outreach.atnf.csiro.au*). The images of the past 24 hours are stored, and once every hour a time-lapse movie is made and provided for download, illustrating the last 24 hours at Parkes in just under two minutes.

Before the camera could be installed it was examined for radio frequency interference, or RFI, which has to be shielded from the telescope. Containing a self-contained computer operating at several MHz clock speed, the webcam was found to emit an entire spectrum of radio lines, and a suitable Faraday cage was built. The camera's network connection was converted to optical fibres inside the cage, and the window for the lens was electrically terminated using a piece of glass with a conductive layer of indium tin oxide.

The time-lapse movies can be entertaining and instructive. Kangaroos have been spotted grazing in the early morning, receiver changes are a regular sight and, being sensitive enough to detect objects of magnitude zero or brighter, the occasional interesting constellation of moon, planets and stars can be seen.

News from the Parkes Visitors Centre

The Parkes Observatory blasted off into National Science Week in August with a Double Helix Science Club Rocket Day. Over 40 keen children and about 20 parents learnt how to build and launch several types of rockets. Among the most popular were the water rockets and film-canister rockets powered by vinegar and bicarbonate soda. Local camera shops have noted a strong increase in requests for film canisters since the rocket day as young rocket scientists put their new-found skills to work. The event supported both National Science Week and CSIRO's Double Helix Club.

Despite a downturn in tourism and concern over the impact of high fuel prices, visitor numbers and spending remained strong at the Parkes Visitors Centre over the September and October school holiday season. Visitor numbers over the holiday period slightly exceed last year's numbers with over 13,500 visitors in September and almost 4,000 visitors over the four-day October long weekend.

The Visitors Centre staff did a great job coping with the numbers and high sales, paying particular attention this holiday season to talking to visitors. This will pay dividends in awareness of the ATNF and CSIRO and support for the continued development of both the ATNF's visitors centres at Parkes and Narrabri.

Visitors were willing to spend up big on watching shows at the theatres, and on souvenirs, science toys and books. Sales over the October long weekend were 25% higher than for previous October long weekends, with Sunday being the biggest sales day ever, and exceptionally high sales during September. Sales of books are up 40% hopefully pointing to visitors wanting to continue their learning after their visit.

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Parkes Observatory report

Chief Executive visit

The CSIRO Chief Executive Officer Geoff Garrett visited the site on 5 August, accompanied by his wife Janet, their first return visit since 2001. The visit included an informal “Q&A” session which was much appreciated by staff, and a comprehensive inspection of the site. Peter May, recently appointed as Executive Director, CSIRO People and Culture, was also present and this was his first visit to the site. The visit also gave Dr Garrett an opportunity to talk at length to two overseas-based astronomers currently visiting the Observatory.

The visit was “double-headed” with a visit by a group of CSIRO Alumni, accompanied by Susan Smith from the CSIRO communications group. The visiting alumni, about 15 in number, were formally welcomed by Dr Garrett before joining him, Janet, Peter, and local staff in the *Dish Cafe* for lunch. The alumni were then given a tour of the telescope, which was very well received. The feedback from all visitors on the day was enthusiastic, and the inaugural CSIRO Alumni event at the Observatory pronounced a great success.

Operations

Operations continue to run smoothly, with time lost (year-to-date) around 3% (comprising 1% equipment faults and 2% high wind).

Planning for a two-week shutdown in November continues, with the main activities being the refurbishment of the translator drive system, replacement of the focus-cabin hoist and preparatory work for the installation of the new seven-beam Methanol Multibeam receiver. (At the time of writing it appears that the full commissioning of the Methanol Multibeam receiver will be delayed until January).

A longer shutdown, of four to five weeks is planned for April 2006 to refurbish the Azimuth gearboxes. This work will include replacement of all original gears and pinions in these boxes. Most of the gearbox components have run essentially untouched since 1961. It is also planned to remove the 20-cm Multibeam receiver during this shutdown to complete its refurbishment. This work will comprise replacement of all remaining original low noise amplifiers (LNAs), and some modifications to the refrigeration system. The receiver is expected to be out of service for three to four months.

Receivers

Completion of the Methanol Multibeam receiver in time with scheduled delivery on 15 November now looks unlikely, owing to unforeseen delays in construction. Preparatory installation work will proceed in November, but full commissioning will be delayed until January.

The 20-cm Multibeam receiver continues to exhibit instabilities in three or four channels, but no further deterioration has been seen in recent months. These instabilities affect spectral-line users relatively lightly but pulsar search observations are more heavily affected. The problems are evidently due to microphonic instabilities in some of the older (original) LNAs, all of which will be replaced in or after April 2006.

The analogue pulsar filterbank has been rejigged slightly to allow an increased bandwidth of 864 MHz at 3-MHz resolution (centre beam only). The improved system has been used successfully to search for highly dispersed pulsars near the Galactic Centre at both 10 cm and 3 cm.

The MARS (3 cm) receiver was trialled recently with a interim conversion system to deliver approximately 1-GHz bandwidth (8.0 – 8.9 GHz), as opposed to the 400 MHz of bandwidth previously available. Plans are in hand to rebuild the new system for routine use in 2006.

A proposal to construct a new K-band (16 – 26 GHz) receiver has formally been approved, and a full project plan is now in process. The present estimate is for a two-year construction time, approximately. The receiver will follow the highly-successful design of the Compact Array 13-mm receivers as closely as possible, and is expected to deliver a 4 or 5 dB improvement over the existing K-band receiver at Parkes as well as greatly increased frequency coverage.

Backends

The wideband correlator (WBC) continues to work well, apart from fundamental limitations in timing fast pulsars (P < 20 ms). These limitations are mostly in the form of periodic artifacts in the amplitude versus pulse phase domain, which are suspected to arise from small differences between the individual correlator chips at short pulsar periods.

The Digital Filterbank Mark 1 (DFB1) continues to work very well, with none of the artifacts at short periods that affect the WBC. This prototype is restricted to the single bandwidth of 256 GHz, and also has some time resolution limitations for fast pulsars. The Mark 2 version of the DFB expected later this year will have 512 MHz maximum bandwidth and time resolution limits meeting the original specification. An upgrade to the full design bandwidth of 1 GHz is not expected until the April 2006 semester.

It is now possible to run the DFB and WBC in parallel using the TCS observing program, though with a little extra complexity in observing.

Upgraded Observatory network access

All is in readiness at the Observatory for arrival of a new broadband fibre-link, which is expected at anytime in the next few months. This connection will initially provide a 1 Gbit/s external data link, compared to the existing link of 512 kbit/s (or .0005 Gbit/s) however the new link will have a total capacity of > 50 Gbit /s if fully utilised. Similar link upgrades at Narrabri and Mopra will follow close behind, providing greatly expanded capabilities for e-VLBI. The highly successful VLBI observations of the Huygens probe in January provided a tantalising taste of what could become routine in the future with the faster links replacing chartered aircraft!

Staff

Lewis Ball has accepted a position as Deputy Director at Marsfield, effective from July 2005. We wish him every success in his new post. Lewis has remained a regular visitor to the site since July — a presence we are only too happy to encourage!

Gina Spratt was delivered of a healthy baby boy, Jack, on 19 July and is currently on maternity leave. Gina is expected to return to work on a part-time basis in October, and all here are awaiting her return with eager anticipation.

Tom Lees is now back at work full-time following his successful shoulder surgery last year.

John Reynolds
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Compact Array and Mopra report

Compact Array system developments

The first millimetre observing season (May – October) for the new 3-mm receivers is nearly complete. Overall it has been very encouraging. The new systems performed very well, with a lowest system temperature of 150 K on one receiver at times. Observing at 3-mm wavelength is now routine, although it still requires the observer to be more attentive than for centimetre observing. During the winter a second set of 16-MHz filters was installed on the array, and is now a normal part of the observing system. There is now a broad understanding of some instrumental phase problems that hindered 3-mm projects in the past, and a workaround for these problems is being used. Problems with the pointing model, at the level of interest to 3-mm observers, are also broadly understood and partially resolved. Monitoring of the atmospheric sky brightness is now available through the MoniCA monitoring application and directly through the web. One shortcoming of this monitor is that it only sees the sky when the 3/12-mm receiver package is in use. A new lightning monitor has been installed.

One problem that has come to light over the winter is high system temperatures occurring in some 12-mm receivers. This can result from both condensation on the outside of the dewar window and from icing up within the dewar. Heaters have been placed on the feedhorns of the most problematic antennas, and this largely eliminates the condensation problem. A design modification to eliminate the icing is in hand, but will require opening all of the millimetre dewars to effect the change. Planning for the required work is in hand.

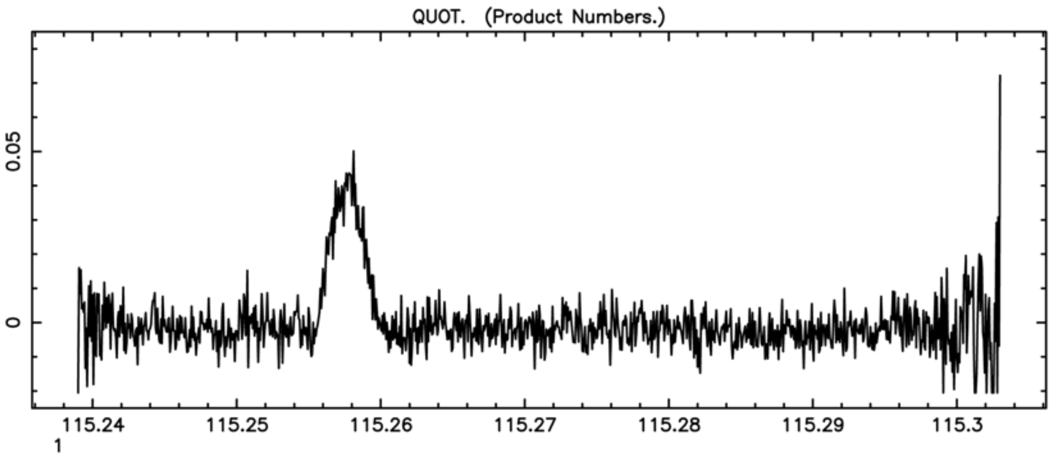

Figure 1: First light – Mopra 3-mm MMIC receiver (Courtesy Juergen Ott and Michael Kesteven).

One less obvious achievement has been to eliminate the antenna control computer (ACC) crashes. Previously an ACC would crash every day or so. The crashes were traced to a hardware-related interaction within the ACC operating system, pSOS. Apart from some crashes after loading new control software on 7 and 8 September, there have been *zero* ACC crashes during observing since 16 July. Congratulations to those who have finally rid the Compact Array of this nuisance!

In other software news, the LINUX observing system is now quite complete and regularly used. In particular, it was used for two weeks in September as part of "split array" observing where the Compact Array was used at the same time for two different projects. However there remain some issues which mean that LINUX cannot yet be promoted to the normal observing system.

Mopra system developments

The millimetre season has been also highly successful for Mopra. In 2004 cryogenic problems plagued the SIS receiver. In 2005, apart from an early hiccup, these cryogenic problems have been resolved. The 600-MHz wide "POCS" backend (a proof of concept system for the full Mopra digital filterbank) was used for a set of observations. At the start of the season, the Mopra Lodge facilities received a facelift, with a new coat of paint, new carpet and some new furniture and fixtures.

However the highlight at Mopra came late in the millimetre season. A shutdown in September saw

- the successful installation of a 16 – 26-GHz and 77 – 117-GHz MMIC receiver (see separate article on page 9);
- associated upgrades to the cryogenics, primary monitoring, and system monitor and control hardware;
- the switch-over to a LINUX-based observing system; and
- the installation of a wideband IF system.

Performance after all the changes has been excellent (see Figure 1). To quote an observer: "the new system is a joy". The system temperature of the new receiver is at least as good as, and in many cases better than, the SIS system (see Figure 2). In addition it has a broader frequency range, broader

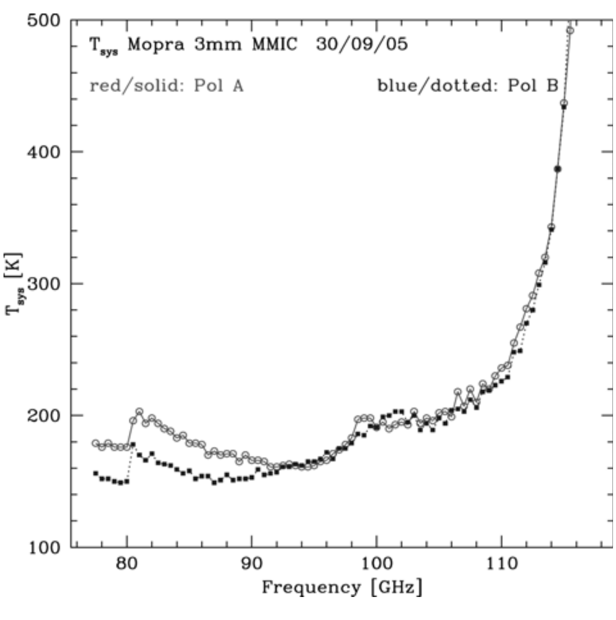

Figure 2: Mopra system temperature with the new 3-mm MMIC receiver (Courtesy Juergen Ott).

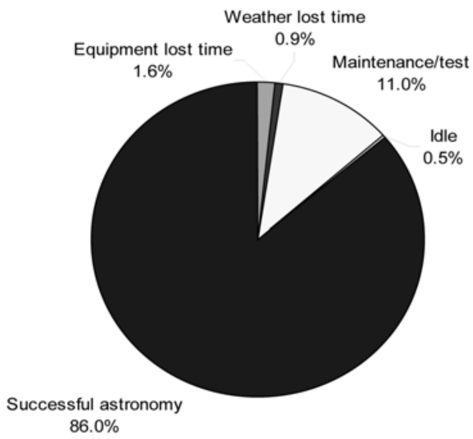

Figure 3: Usage statistics for the Compact Array. 1 June to 30 September 2005.

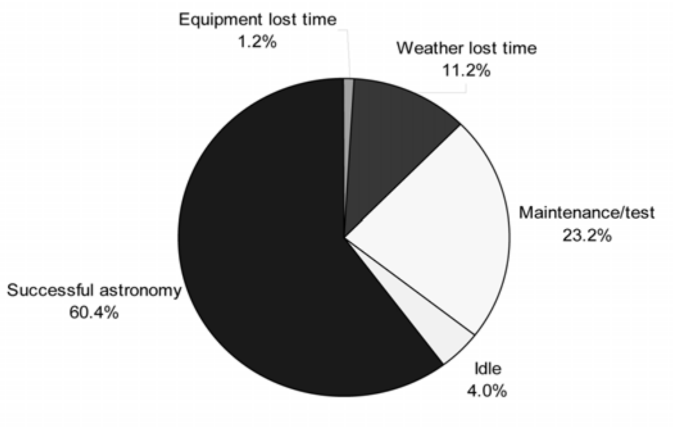

Figure 4: Usage statistics for Mopra. 1 June to 30 September 2005.

instantaneously accessible bandwidth and requires no mechanical tuning. It is a lower maintenance and more robust system.

To cap off the season, the first 2-GHz segment of the Mopra digital filterbank – MOPS – was commissioned on 15 October, and was quickly put into use for routine observing. *All those associated with all the Mopra upgrades can be deservedly proud of the results.*

It is hoped the broadband network connection will be installed at Mopra around the end of the year.

Other developments

As noted in the previous newsletter, funding has been approved for a major refurbishment and extension of the Narrabri Control Building. Work on the design of this development is proceeding well, with the design team in place and draft plans being produced. The indicative plan for the start of construction remains mid-2006. An important part of this development has been to produce a building which helps reduce RFI from the Control Building. As part of this, an RFI consultant has been appointed to the design team.

The redevelopment work at the Visitors Centre is nearing completion. A "re-opening" ceremony is planned for late November.

Operations

Usage statistics for the Compact Array and Mopra are given in Figures 3 and 4, for 1 June to 30 September. Equipment lost time remains around 1 – 2%. Mopra's large maintenance fraction reflects the shutdown through most of September.

Overall the winter was wetter than normal. In particular, floods on 30 June blocked access to the Narrabri Observatory for much of the day and prevented staff from coming to work. The proportion of time where projects could not proceed as scheduled because of weather was 5.5% for the Compact Array and 11.2% for Mopra. For the Compact Array the weather-affected observations consisted of swaps (2.6%), project overrides requiring a change to centimetre observing (2.0%), and lost time due to weather (0.9%). Mopra is located at a site with poorer weather, and it is not usually switched to longer wavelengths to avoid weather effects. Its portion corresponds completely to lost time due to weather.

These statistics do not account for two-week period in September when the Compact Array operated in a "split array" mode, with two projects being observed in parallel.

Two final events to note are the first VLBI fringes at 3-mm wavelength between Mopra and the Compact Array and, on the same night, the first centimetre VLBI fringes between the Compact Array and New Zealand. Congratulations to all those involved with these.

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Time assignment information

Proposal applications for 2006 APRS

The next deadline for telescope applications to the ATNF is on 15 December 2005, for a six-month semester that will be scheduled from 01 April 2006 to 30 September 2006.

We advise ATNF users that all applications for 2006APRS must be prepared and submitted using a new web-based application system called OPAL. Applications sent by email using the previous latex forms will not be accepted unless there are exceptional circumstances.

For further information on OPAL please see the separate report on page 4.

Compact Array configurations

With the completion of the millimetre upgrade, there has been a significant change in the science that Compact Array observers are pursuing. As a consequence, the mix of array configurations that are offered will be adapted to best meet observer needs. Table 1 gives the suggested array configurations that will be offered over the next three years. These are still tentative, and will be discussed at the upcoming Users Committee meeting. The rationale is as follows:

- The scheme cycles through all offered arrays within 18 months.
- Two 6-km array configurations will be offered each term to meet the needs of the high-resolution science. Given that 6A is the "best" 6-km configuration, this will be offered every term.
- A single 750-m and 1.5-km configuration will be offered during the millimetre semester, and two are offered in the non-millimetre semester.
- The EW352 array will be offered each term. Of the two 350-m arrays, EW352 has a better complement of short baselines. The EW367 will be offered only in the non-millimetre semester.

	2006		2007		2008	
	AprS	OctS	AprS	OctS	AprS	OctS
6A	●	●	●	●	●	●
6B		●			●	
6C			●			●
6D	●			●		
1.5A		●		●		
1.5B		●			●	
1.5C			●			●
1.5D	●			●		●
750A		●			●	
750B	●		●			●
750C				●		●
750D		●		●		
EW367		●		●		●
EW352	●	●	●	●	●	●
EW214						
H214	●	●	●		●	●
H168	●		●	●	●	
H75	●		●		●	

Table 1: Tentative array configuration timetable for 2006 – 2008.

- The EW214 array will no longer be scheduled routinely. EW214 has many spacings in common with EW352. Additionally the hybrid arrays can be used as alternatives to EW214.
- The hybrid arrays (H214, H168 and H75) will be scheduled every millimetre semester. In addition one hybrid (either H168 or H214) will be scheduled in the non-millimetre semester.

As in the past, observers can request "wildcard" array configurations that are not part of the standard set being offered in a semester. In this case, observers are requested to discuss this as early as possible with the ATCA staff so that the possible scheduling of an array as a wildcard can be advertised to other potential proposers.

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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 June 2005 newsletter. Papers which include ATNF staff are indicated by an asterisk.

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