ATNF News

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FEATURES IN THIS ISSUE

Interstellar scintillation and PKS 1257-326

Twinkle, twinkle quasi-star
Biggest puzzle from afar
How unlike the other ones
Brighter than a billion suns.
Twinkle, twinkle quasi-star
How I wonder what you are.

George Gamow, "Quasar" 1964.

George Gamow coined the above in 1964 to commemorate the discovery of the first quasar, 3C273, in 1963 by Hazard and Schmidt. Cyril Hazard supplied the accurate radio position from Parkes lunar occultations (Hazard et al. 1963), and Maarten Schmidt provided the optical spectroscopy and redshift from the 200-inch telescope in California (Schmidt 1963). While the above words were written tongue-in-cheek some forty years ago, the "twinkling" part of the traditional childrens' verse has become a powerful tool for radio astronomers in the new millennium.

That old adage "stars twinkle, planets don't" describes very well the results of one area of research that's presently very active at the ATNF. Stars twinkle in optical light because they have very small angular diameters, milli-arcseconds or less, and hence suffer interference as the light passes through the Earth's turbulent

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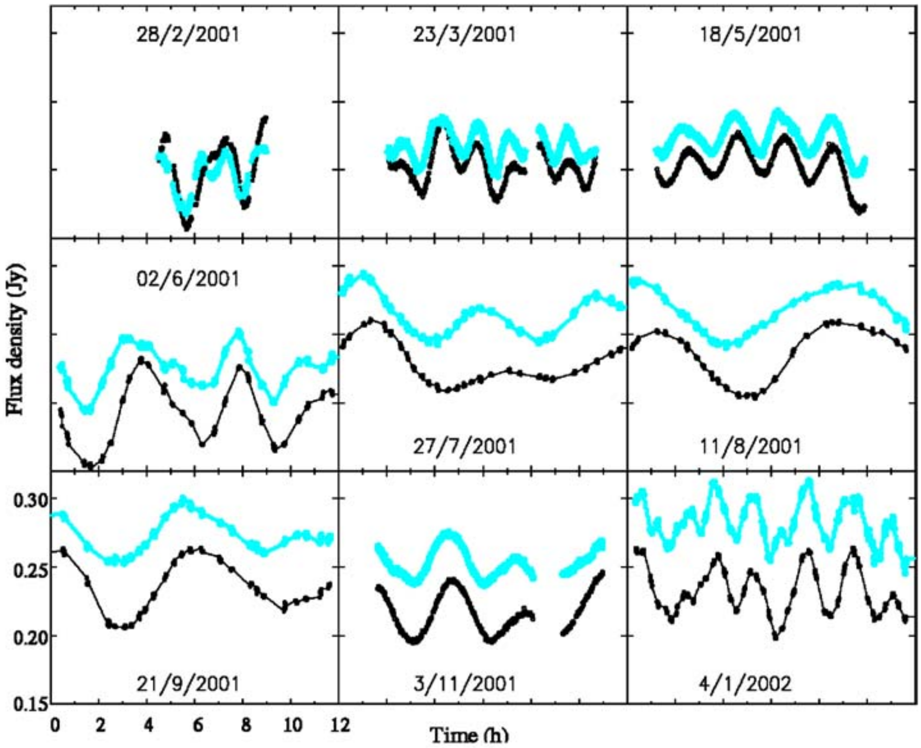

Figure 1: The observed "scintillation pattern" of PKS 1257-326 measured approximately every six weeks during a 12-month period, 2001/2002.

Editorial

Welcome to the October 2002 issue of the ATNF News, containing the usual mix of news, science reports, and organisational information for ATNF users and other interested parties. This issue is the last for one of the ATNF News production team, Steven Tingay. As Steven leaves the ATNF at the end of this year, his place as Editor of the ATNF News will be taken up by Dr Lakshmi Saripalli, who is also based at the Narrabri Observatory. Please welcome Lakshmi on board. Jo, Jessica and Lakshmi thank Steven for the wonderful job he has done as editor.

Steven Tingay, Lakshmi Saripalli, Jo Houldsworth, and Jessica Chapman
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Contents

News items

ATNF Director Ron Ekers awarded a Federation Fellowship

The ATNF Director, Professor Ron Ekers, has been awarded one of the Australian Research Council's Federation Fellowships, the most prestigious and richest publicly-funded research fellowships ever offered in Australia. Dr Brendan Nelson, Commonwealth Minister for Education, Science and Training made the announcement on 29 July, naming the eleven eminent Australian researchers granted Federation Fellowships in this round of awards, selected from a field of 87 applicants from around the world.

Professor Ekers' research proposal is titled "A clearer view of the evolving universe". It has two, complementary, research objectives: a basic research program on problems of star formation, and a strategic research program on interference mitigation. One of the conditions of the Federation Fellowship is that Professor Ekers will cease to have a role in the management of the ATNF and will concentrate solely on research-related activities during the five-year term of the Fellowship. ATNF and CSIRO processes are therefore currently in motion to find and appoint a successor to Professor Ekers as ATNF Director. Progress on these processes will be reported in future issues of the ATNF News.

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New research appointments at ATNF

Following our bonanza of Bolton Fellows announced in the previous ATNF Newsletter, it is good to be able to announce two further appointments. The first is the appointment of Dr Jim Lovell to an indefinite position based in Canberra. This position, which was widely advertised and for which we had a good slate of qualified candidates, has as its primary responsibility the support of radio astronomy activities at NASA's Canberra Deep Space Communication Complex (CDSCC) at Tidbinbilla. As most readers will know, Jim was uniquely qualified for this role, having had a post-doc position at Canberra for the past three years during which he spent much of his time working at Tidbinbilla. VLBI remains an important activity at Tidbinbilla, but recently there has been increasing emphasis on single-dish work, especially spectroscopy in the 22 GHz water-vapour line. The 70-m antenna has about an order of magnitude higher sensitivity than any ATNF antenna for observations at this frequency. Jim and Dave Jauncey will soon move their base from COSSA to Mount Stromlo, facilitating increased interaction with the astronomy community. It's also a bit closer to Tidbinbilla!

Dr Jim Lovell

The second appointment is a joint post-doctoral appointment between the ATNF and the School of Physics, University of Sydney, in

news

Nina Wang with her daughter Leilei.

the area of pulsar astronomy. This position was advertised by the University of Sydney and has been accepted by Dr Nina Wang of the National Astronomical Observatories, Urumqi Observatory (UO), China. Nina is also known to many of us, as she has visited the ATNF a couple of times to work on pulsar projects with Dick Manchester and others. She was largely responsible for setting up a pulsar recording system on the Urumqi 25-m antenna, and used this over the past two years to make pulsar timing and scintillation observations, work which formed the basis of her PhD thesis at Peking University. The system has recently been enhanced with the installation of a cryogenic 18-cm receiver, designed and constructed at the ATNF under contract to Urumqi Observatory. Two UO engineers, Sun Zhengwen and Wang Weixia, spent nearly a year at Parkes assisting with the construction and Martin McColl visited UO to help with the installation and commissioning. Nina and her family hope to arrive in Sydney in November or December, depending mainly on how long the visa-issuing process takes.

Dick Manchester
Chair, Senior Staff Appointments and Rewards Committee
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Symposia and workshops – November 2002 to February 2003

The next AT Users Committee meeting will be held at ATNF, Marsfield on 5 – 6 November, 2002. The program is on the web at *www.atnf.csiro.au/management/atuc/*.

The annual Charlene Heisler AGN workshop will be again held at Mount Stromlo Observatory in Canberra, Thursday and Friday 4 – 5 December 2002. For more details see the Mount Stromlo Observatory website, *www.mso.anu.edu.au*.

The Bolton Symposium, a bi-annual ATNF astrofest meeting, this year featuring the research of all ATNF postdoctoral fellows, is being held at the ATNF Marsfield Lecture Theatre on 11 December 2002. For further details contact Naomi McClure-Griffiths, *Naomi McClure-Griffiths@csiro.au*.

Summer School: The New Cosmology, 16th International Summer School is being held at the Australian National University, Canberra from 3 – 14 February 2003. For more details: *www.mso.edu.au/newcosmology*.

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The Australian AIPS++ Users Group

An Australian AIPS++ Users Group (AAUG) was recently formed. The group includes seven members and it met for the first time on 29 July 2002. The group will assist with feedback on the AIPS++ software and serve as a contact for AIPS++ related matters within the Australian astronomy community. At the first meeting, David Barnes was elected chair until 31 March 2003. The AAUG will meet every two months to discuss and share experiences in AIPS++ usage. A report will be submitted twice each year, in September and March, to the ATNF AIPS++ management prior to the start of each AIPS++ development cycle. Interested persons may contact David Barnes, *dbarnes@isis.ph.unimelb.edu.au*.

Lakshmi Saripalli
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ATNF graduate student program

It is a pleasure to welcome Rachel Deacon, Gianni Bernardi, Aidan Hotan and Haydon Knight into the ATNF PhD co-supervision program. Rachel's project is "Planetary Nebulae - Origin and Morphology". Her supervisors are Anne Green (University of Sydney) and Jessica Chapman (ATNF). Gianni's project is "The Diffuse Galactic Synchrotron Polarized Radiation as a Foreground to CMB Polarization Experiments". His supervisors are Prof Corrado Bartolini, Dr Stefano Cortiglioni, Dr Ettore Carretti (University of Bologna and CNR IASF-Bologna) and Bob Sault (ATNF). Aidan and Haydon were mentioned in ATNF News Issue 46 after having been awarded a 2002 CSIRO top-up scholarship. Their respective thesis projects are: "Pulsar observations and timing" and "Baseband Searching for Millisecond Pulsars" with supervisors Matthew Bailes (Swinburne University), Colin Jacka (CTIP) and Dick Manchester (ATNF).

It's also a pleasure to be able to host Jennifer Donley, a recipient of a Fulbright Fellowship to work on the northern HIPASS/ZOA project. Jennifer graduated from Penn State University and will be based at Marsfield until she commences her PhD at the University of Arizona in late 2003.

Quite a number of theses have been submitted this year. This issue's congratulations go to Vivian Wheaton and Antoine Bouchard for the official acceptance of their Masters theses. Viv's University of Sydney thesis is entitled "Investigation of Radio Emission from Supernova Remnant 1987A". Antoine's Universite de Montreal thesis is entitled (in English) "Distribution and kinematics of the neutral hydrogen clouds around the dwarf galaxies of the Local Group".

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Graduate Student Coordinator
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Parkes telescope to track Mars spacecraft in 2003 – 2004

Four NASA spacecraft and spacecraft from Japan and Europe are planned to be in operation at Mars in early 2004. In addition to the three tracking stations of NASA's Deep Space Network, located in Australia (which CSIRO oversees on behalf of NASA), Spain, and the USA, NASA has enlisted the 64-m Parkes dish of the ATNF to help track these spacecraft during the busy period, November 2003 to February 2004.

NASA's Mars Global Surveyor and Mars Odyssey probes are already orbiting the planet. Four more missions will arrive in 2003 – 2004. NASA's two robotic Mars Exploration Rovers will be looking for evidence of liquid water and analysing rocks and soil. Nozomi, Japan's first Mars probe, will be studying the upper atmosphere and Europe's Mars Express will map surface and subsurface structures. It will drop a British lander, Beagle 2, which will search for signs of water and life.

As part of the ATNF participation in the NASA program, the Parkes telescope will be upgraded, paid for by NASA funds. Some of the wire mesh panels in the outer part of the dish will be replaced with panels of perforated aluminium sheet, to enlarge the smooth part of dish's surface. This will make the dish more sensitive at 8.4 GHz, the frequency at which the spacecraft will downlink. A sensitive new 8.4-GHz receiver will be constructed and installed on the telescope as part of the upgrade. The surface upgrade and the new receiver will double the sensitivity of the telescope at this frequency. The 64-m Parkes telescope has tracked NASA spacecraft from the 1960s through to the 1990s. Its most prominent role, celebrated in the film "The Dish", was supporting the 1969 Apollo 11 Moon landing.

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Articles

Narrabri simple 20-MHz interferometer

Like most good things, it started as a lunchtime joke. Leading up to the 2001 Synthesis Imaging Workshop we were planning to introduce radio astronomy using a 20-MHz receiver, but now we had a new idea: we could build a simple two element radio interferometer. Naturally, the second receiver didn't arrive until the Friday afternoon before the Workshop and it was all something of a fizzer. Since late 2001 however, the Narrabri simple 20-MHz interferometer has been working around the clock.

The equipment behind modern scientific radio interferometers, such as the Compact Array at Narrabri, is a challenge even for experts to understand. The simple 20-MHz interferometer demonstrates many of the same scientific principles using only a few dozen electronic components and a generic PC. The system operates from the Narrabri Visitor's Centre and has proved a popular introduction to radio astronomy for several work experience students. A demonstration of the system was also warmly received at the recent "Science Education in Partnership" Fulbright Symposium.

The system uses two direct conversion receivers to bring 3 kHz of radio bandwidth down to audio frequency – this telescope you can listen to! The kit receivers have been modified so that only a single local oscillator signal is used for the pair. All system delays are fixed with coaxial cable so the system operates as a meridian transit interferometer. The antenna for each receiver consists of two phased, North-South oriented, half wavelength dipoles separated by 7.5 m East-West. This gives each antenna a primary beam of around 60 degrees, pointing at the zenith. A Linux PC uses a stereo sound card to sample the audio output of each receiver. Software, developed after hours by Narrabri staff, calculates the auto-correlation function for each receiver as well as the cross-correlation of the two. The results are integrated for one second then written to disk, from where a network client can request arbitrary data. The prototype client features statistical RFI identification, sidereal averaging of fringes from different days and rudimentary determination of source size/positions using an iterative model fitting algorithm.

To date, observations have been made with 150, 75, 45 and 20-m baselines. The interferometer has proved suitable for detecting a number of astronomical radio sources, including the Galactic plane, Centaurus A and the Sun.

The Galactic plane generally dominates astronomical radio emission at 20 MHz. This is evident in Figure 1A which shows 20-MHz flux against LST for the individual inputs (in arbitrary units). The maxima coincide closely with the transit of Sagittarius A, the centre of our Galaxy, at 17:45 LST. Figure 1B shows the interferometer response for a 45-m baseline, with strong fringes evident around the same time. Figure 1C shows the interferometer response with a 150-m baseline. With this baseline the Galaxy is largely resolved and the dominant fringes are now produced by the more compact, nearby radio galaxy Centaurus A, around 13:24 LST.

In addition to the non-variable sources, the Sun can become a powerful 20-MHz radio source. The quiet Sun is too weak for our interferometer to detect, however during periods of solar activity the Sun can become the brightest object in the 20-MHz sky. Figure 1D shows fringes for the 45-m baseline during a solar loud period. Contrast this with Figure 1B which shows data for the same baseline averaged over solar quiet days. In addition to direct detection of low frequency solar radio emission, our system has proved capable of indirectly detecting solar X-ray flares. These powerful events can greatly enhance solar X-ray flux, making the Earth's ionosphere more opaque. Increased ionospheric absorption leaves less cosmic signal available at our antennas so the system detects a sudden decrease in detected flux, called an ionospheric fadeout.

Construction and operation of a simple interferometer provides a rewarding and interactive format for exploring many aspects of electronics, computing and astronomy. In the longer term we plan to refine the system so that other groups and interested amateurs can consider building simple interferometer systems based on this architecture. As this is written, a self-funded simple 30-MHz interferometer is approaching first light at one author's home. This second system provides a test-bed for alternate hardware and will help to expedite software development. Stay tuned, this joke hasn't laughed its last.

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Tim Kennedy (Tim.Kennedy@csiro.au)
Steven Tingay (Steven.Tingay@csiro.au)
and Daron Brooke (Daron.Brooke@csiro.au)

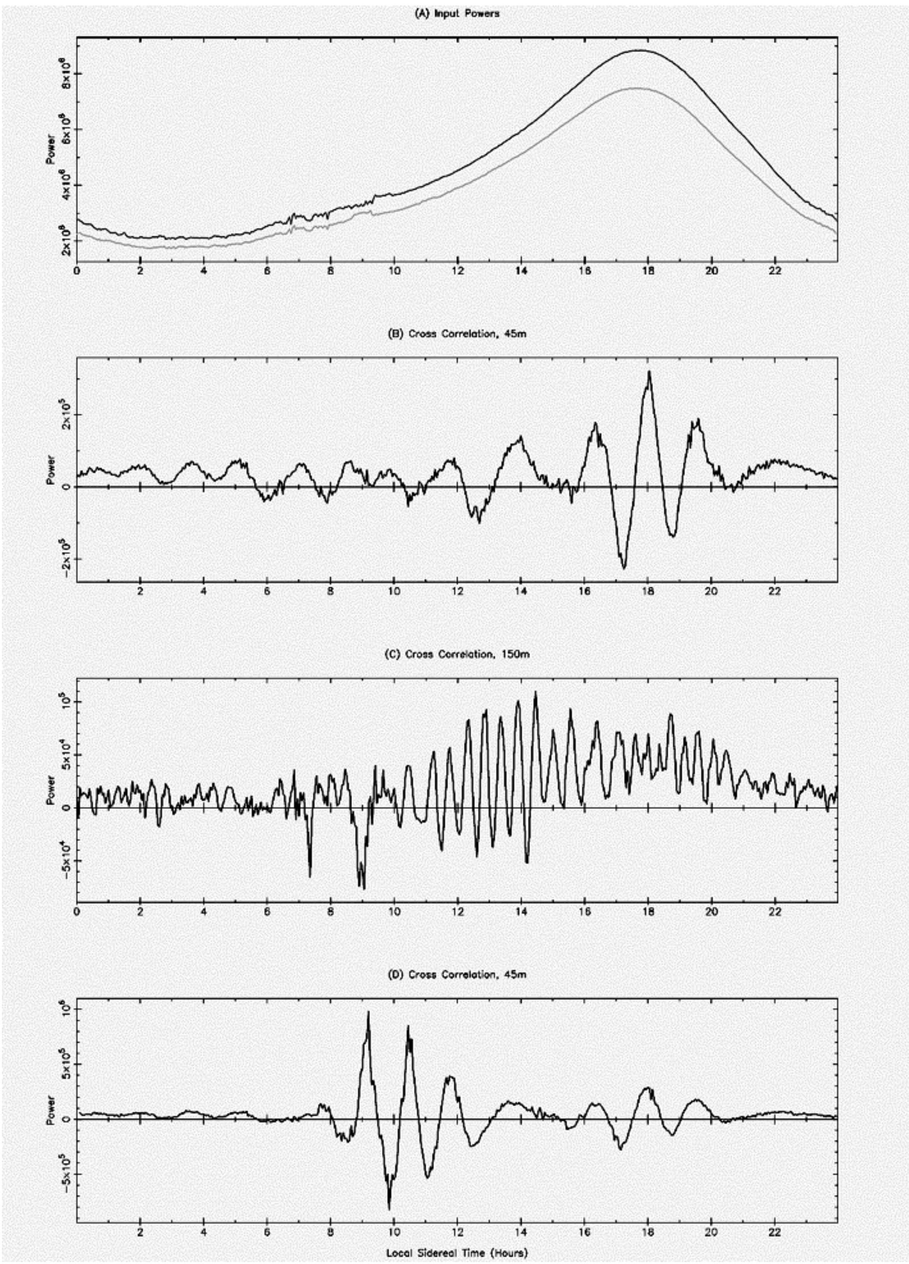

Figure 1A: 20-MHz flux against LST. The maxima coincide closely with the transit of Sagittarius A, the centre of our Galaxy, at 17:45 LST.

Figure 1B: The interferometer response for a 45-m baseline. The strong fringes correspond to transit of Sagittarius A.

Figure 1C: The interferometer response for a 150-m baseline. The Galaxy is largely resolved and the dominant fringes are due to the more compact, nearby radio galaxy Centaurus A.

Figure 1D: Fringes for the 45-m baseline during a solar loud period.

articles

A pilot 20-GHz survey at the Compact Array

On the inauspicious date of Friday 13 September 2002, a pilot 20-GHz survey (C1049) commenced at the Compact Array. Over a continuous observing stretch of 96 hours, about 1000 square degrees of sky were surveyed in a “blind” survey between declinations –60 and –70 degrees. The instrumentation and observing techniques were unusual: the correlator was not the regular ATCA correlator, but was an experimental single-baseline analogue device with a bandwidth of 4 GHz; the survey was conducted by scanning the telescopes up and down the meridian at a rate of 10 degrees per minute; and the antennas were controlled and monitored by new generation Antenna Control Computers (ACCs). The hardware, the survey method, the early results, and future plans are described below.

Both the 12-mm and 3-mm receivers currently installed and operating on the ATCA provide intermediate frequency signals with a maximum instantaneous bandwidth of around 8 GHz in the frequency band from 4 – 12 GHz. The current ATCA correlator is only able to make use of 128 MHz of this bandwidth in each of two frequency bands, or 256 MHz altogether. However, when surveying large parts of the sky at high frequencies and high sensitivity, maximum bandwidth is required. To make use of more of the available bandwidth, signals have to be transported over hundreds of meters without significant degradation. One possible means of achieving this would be to digitise the signals and send the data over a high bit rate communications channel. An alternative approach, which operates in the analogue domain, has become practical in recent years due to the development of broadband fibre-optic modulators. These devices modulate a laser signal in a single mode optical fibre with a broadband radio frequency signal. The modulated light wave can then be transported over long distances with very little loss. At the destination, an optical detector is used to recover the original broadband RF signal. Thanks to the superb efforts of Mark Leach, this was the method used for this experiment.

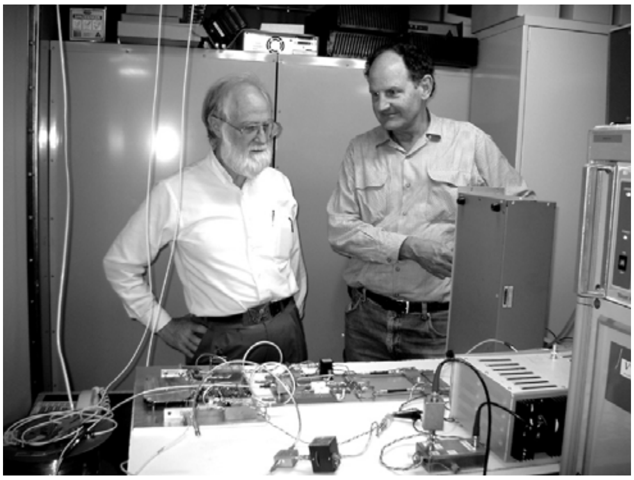

Figure 1: Ron Ekers (Principle Investigator, C1049) and Warwick Wilson discussing the 4-GHz experimental analogue correlator that lies on a bench in the screened room at Narrabri.

In a return to techniques employed in the very early radio interferometers, we were able to remain in the analogue domain by using an analogue correlator to combine the signals from the two antennas. This correlator, built by the ATNF Electronics Group, is composed of sixteen analogue multipliers arranged to sample the correlation function of the input signals over a range of delay of about 2 nanoseconds. In the current system, the multipliers are commercial silicon Gilbert Cell devices. These multipliers limit the overall bandwidth of the system to around 3.8 GHz.

We attached the experimental correlator to antennas CA02 and CA03 both of which were equipped with 12-mm receivers. This gave us a single-baseline sensitivity of 35 mJy, for an integration time of 80 milliseconds, at our central observing frequency of 18 GHz. The downside of having an analogue correlator is that delay compensation (the correction for the variation of geometric delay with time) is not easy. Therefore we dispensed with delay tracking, and made observations solely on the meridian where the delay for an east-west interferometer is zero.

Given the small ATCA primary beam at 20 GHz (about 2.3 arcmin), the most convenient way for us to cover a large solid angle of sky was to scan the antennas up and down the meridian as rapidly as possible. Although continuous scanning is more efficient than the normal point-and-shoot technique of mosaicing, it required the use of the newly commissioned ACCs in order to drive the antennas and constantly monitor their positions. Instead of the

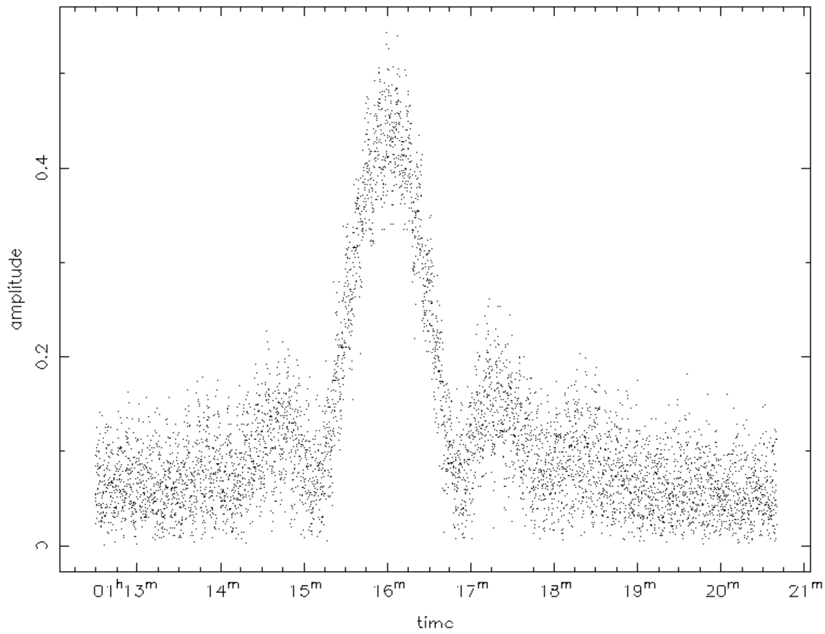

Figure 2: The response of the wideband correlator as Mars crosses the meridian. Antennas 2 and 3 were both tracking the planet, so the width of the peak represents the delay window outside of which the interferometer fringe cannot be seen, except by decreasing the bandwidth. Survey observations were conducted solely on the meridian.

usual 10-second cycle, positions were recorded every 100 milliseconds, commensurate with the antenna drive rate of 10 degrees per minute, and the correlator dump rate of 125 Hz. The reliability of the new ACCs, even in this commissioning phase, was encouragingly good.

After commissioning the software associated with the vital antenna-control, scheduling and communication software (mainly Michael Kesteven, David Brodrick and Mark Wieringa), and doing various calibrations, 65 hours of survey data were taken, covering 1000 square degrees of sky. Even for a pilot survey, this is quite a respectable sky coverage. Several-hundred candidate sources were located and will have their identifications and positions confirmed in separate follow-up observations. For comparison, the largest published high-frequency survey is that of Taylor et al (MNRAS, 327, L1, 2001) who used the Ryle Telescope to find 66 sources in 63 square degrees at 15 GHz (but to higher sensitivity than the present survey). During their spare time following commissioning, Mike Kesteven and Warwick Wilson were able to develop split-array software which allowed the remaining four ATCA antennas to be used for instantaneous follow-up observations of candidates at lower frequencies, as well as being used for override observations of two X-ray transients.

Plans for the near future include replacing the correlator with a device capable of processing the entire 8-GHz bandwidth and extending the system to three antennas, with an expected doubling in sensitivity. It is with this system that we hope to proceed with an all-sky survey in 2003. In the longer term (4 – 5 years), and as part of MNRF 2001, a wideband digital correlator will provide equivalent bandwidth for all antennas at much higher spectral resolution. And, importantly, it will come with a digital delay system so that observing away from the meridian is possible!

Lister Staveley-Smith and Warwick Wilson, on behalf of the 20-GHz survey team.
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Figure 3: The large (!) observing team present at Narrabri for the September pilot survey. From left to right: Lister Staveley-Smith, Ron Ekers, Jenn Donley, Kate Smith, Mike Kesteven, Elaine Sadler, Carole Jackson, Warwick Wilson. Present in later observations were: Roberto Ricci, Ravi Subrahmanyan and Mark Walker. In the background, antennas CA02 and CA03 are scanning up and down the meridian between declinations –60 and –70 degrees.

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Interstellar scintillation and PKS 1257-326

atmosphere. Planets don't, since they subtend a very large angular diameter, many-arcseconds or more, and hence they lose their twinkle.

Much the same applies to radio sources as their radio light passes through the turbulent ionised interstellar medium of our Galaxy, where the "cells" of turbulence allow several ray paths to interfere. If the quasar is small enough, then it will twinkle, if it's too large then there will be no twinkling. Trouble is, radio quasars need to be microarcseconds in angular size to twinkle, and that's pretty small.

Detailed studies of this sort of radio twinkling in the interstellar medium are relatively new. There is another form of radio twinkling that has been known and studied for several decades, and that is the twinkling, or scintillation, of quasars in the interplanetary medium of our solar system. This interplanetary scintillation is strongest at frequencies less than ~1 GHz, and occurs predominantly when the sun, on its annual journey, passes close on the sky to the quasar. The turbulence in the solar wind then causes rapid variations in the apparent source intensity as the radio waves coming from the quasar suffer interference as they pass through the turbulent medium. This phenomenon was used decades ago to probe the centi-arcsecond structure of quasars (e.g. Cohen 1969). Before the advent of VLBI in the late 1960s, inter-planetary scintillation was one of the principal tools for high-resolution radio studies, although it has now been replaced by VLBI.

Now, interstellar scintillation is becoming a particularly useful tool, since it is capable of probing microarcsecond angular sizes that are much smaller than can be reached by any other existing technique, including VLBI and even Space VLBI. For a quasar to scintillate in the turbulent interstellar medium, its angular size must be of the same order as the angular size of the first Fresnel zone. Centimetre wavelengths, typically 3 to 20 cm, are where the variability due to interstellar scintillation is greatest (see Rickett 2002, for an excellent discussion of the effects of ISS). So for a screen at a distance of, say, 100 pc, and a wavelength of 6 cm, a source needs to have an angular size of around 10 microarcseconds.

To get an idea of how small an angle this is, it's about the size of the angle subtended by Neil Armstrong's big toe when he stepped on to the moon, as seen from the Earth! It's about ten thousand times finer resolution than is currently achieved by the Hubble Space Telescope operating at its shortest wavelength. And, for astronomers, it's about 3 light months on a quasar with a redshift of 1, half way across the Universe.

What has revolutionised the study of interstellar scintillation (ISS) has been the discovery of three remarkable sources that scintillate very rapidly. In order of discovery, these are PKS 0405-385, discovered by Lucyna Kedziora-Chudczer as part of her PhD thesis program (Kedziora-Chudczer et al., 1997), J1819+3845 discovered by Jane Dennett-Thorpe at Westerbork in the Netherlands (Dennett-Thorpe & de Bruyn 2000), and PKS 1257-326, discovered by Hayley Bignall, again as part of her PhD program (Bignall et al., 2002). Each of these three quasars has been found to vary by upwards of 40% or more, and to go from a minimum to a maximum in times as short as about half an hour.

The scintillation has a remarkably smooth, quasi-periodic nature at both 4.8 and 8.6 GHz, which we describe by a single time-scale parameter, T_{ISS}. This parameter is determined from the autocorrelation function, but can be most easily understood as about half the time it takes to go between a peak and a trough in the light curve. A strong correlation also exists between the variations at the two frequencies, a characteristic that PKS 1257-326 shares with many of the other known scintillators, and with PKS 0405-385 and J1819+3845 in particular.

The ATCA is the perfect telescope for these sorts of measurements, since it tracks the quasar all the time, giving effectively continuous and precise flux density measurements for the 12 hours that it is above the horizon at Narrabri. The first measurements of this sort of rapid intra-day variability (IDV) as it was called, were made with some of the world's largest single dish telescopes, the 300-foot telescope that was in Green Bank, in wild and wonderful West Virginia in the USA, and the Effelsberg 100-m telescope in Germany. However, the situation has changed and the large array telescopes of the world, the ATCA, the VLA and Westerbork are now the radio telescopes of choice.

It has been known for nearly 40 years that many radio sources vary in intensity, so how do we know that these fast variations are not intrinsic to the quasars themselves? How can we be sure that this is scintillation?

Over the last decade and a half there has been considerable debate as to just what the answers were to these questions. On one hand, it seemed that there was evidence to support the variations being intrinsic to the quasars, but the major concern was that, if it were intrinsic, then the quasars would be much too hot, up to 10^{21} degrees in fact. PKS 0405-385 changed the picture, when measurements of its variations at two widely separated telescopes 10,000 km apart, the ATCA in Australia and the VLA in New Mexico USA, showed clearly that the variation pattern appeared at different times at the two telescopes; in fact they appeared about two minutes apart. If the changes were intrinsic to the sources then the changes should have appeared simultaneously, well actually separated by the light travel time, that is milliseconds, not minutes.

Such measurements can only be made on these very rapidly variable quasars, since accurate timing of the pattern of variations requires rapid changes. Here J1819+3845 and PKS 1257-326 really come into their own; unlike PKS 0405-385, their rapid variability is long-lived, since they have both been scintillating now for three to five years. We prefer to use the term "scintillating" since it focuses on the physical phenomenon, rather than the earlier term "IDV" which merely emphasizes the observational properties, not the underlying astrophysics. For both of these sources, measurements have been made of the variability patterns at widely separated radio telescopes, and for both sources, significant time delays of many minutes found (Dennett-Thorpe & de Bruyn 2002, Bignall et al 2002, in preparation). The time delay for J1819+3845 was measured between the VLA and Westerbork, and for PKS 1257-326, between the ATCA and VLA in May this year.

Remember that the scintillations are caused by the focusing and defocusing patches of the turbulence in the interstellar medium as it moves by the Earth. Living on Earth may be expensive, but it includes an annual free trip around the sun. This gives rise to another remarkable aspect of scintillation that leaves an indelible signature in the observations. This is the change in the time-scale of the scintillation pattern throughout the course of the year. It happens because the speed of the Earth in its orbit around the sun is very close to 30 km per second.

The interesting coincidence is that much of the time the velocity of the ISM is also close to 30 km per second. For roughly half the year the Earth is moving parallel to the ISM, then six months later it's moving against the ISM. So when the velocities are parallel, the relative velocity is low, and hence the scintillation pattern speed is correspondingly low, and the scintillation as viewed from our radio telescopes here on Earth is very slow. Then six months later the situation is reversed, the relative speed is high and the variations appear much faster on Earth. This "annual cycle" as its come to be called, is not only conclusive proof that the variations are caused by interstellar scintillation, but it's a beautiful demonstration that the Earth really does go round the sun, and that Copernicus was right after all.

Figure 1 (page 1) shows the beautiful results of our ATCA monitoring program from 2001 and 2002, where we have plotted the observed "scintillation pattern" of PKS 1257-326 measured approximately every six weeks.

This is a remarkable diagram! What is most noticeable is the dramatic change in the time-scale of the variations over the course of the 12 months. From February through May, the flux density varies rapidly with less than an hour between excursions. In June the variations have begun a slow down that lasts through September. November sees them speed up again, while by January 2002 they have returned to much the same rate as February 2001. That the variations show such a clear signature of the Earth's orbital motion, demonstrates unequivocally that the mechanism that is responsible for the variations cannot be intrinsic to the quasar, but resides right here in our Galactic neighborhood. As Shakespeare has Cassius say in Julius Caesar:

The fault, dear Brutus, is not in our stars,
but in ourselves.

This annual cycle behaviour has been found now in close to half a dozen quasars, including J1819+3845, which was the first time it was recognised (Dennett-Thorpe & de Bruyn 2001), and 0917+624, where its presence was recognised independently by Rickett et al., (2001) and Jauncey & Macquart (2001).

To better quantify this annual cycle, Fig. 2 shows the characteristic timescale of the variations (defined as the HWHM of the autocorrelation function) as determined from the data in Fig. 1, plotted against day of year, at both 4.8 and 8.6 GHz (Bignall et al., 2002). Also plotted is the expected scintillation speed, V_{ISS}, against day of year, for a scattering medium moving with the local standard of rest. There is a very close, but not exact, alignment between the

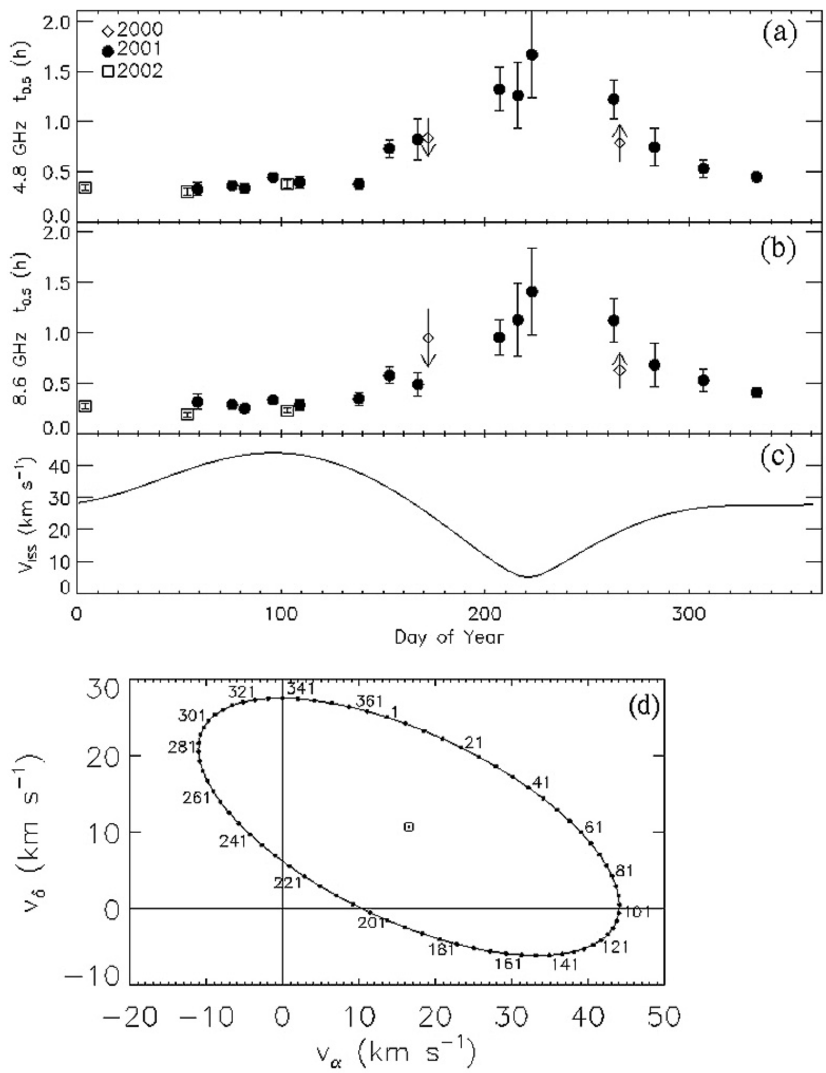

Figure 2: The characteristic timescale of the variations as determined from the data in Fig. 1 for 4.8 GHz (a – top panel) and 8.6 GHz (b – top panel). Also plotted is the expected scintillation speed, V_{ISS}, against day of year, for a scattering medium moving with the local standard of rest (c – top panel) and the variation in scintillation velocity projected against the plane of the sky (lower panel).

characteristic time of the annual cycle and the scintillation speed, confirming the scintillation origin of the variability.

Also plotted is the variation in scintillation velocity projected against the plane of the sky. The velocity is slowest at day 221 (9 August), then changes direction and speeds up through the end of the year, and reaches its maximum value around day 100 (10 April), before swinging round through a further 60 degrees and slowing down again.

As the relative velocity of the interstellar medium changes direction over the year, Fig. 2 shows a change of more than 120 degrees for PKS 1257-326, the ISM not only acts like an “interference screen” producing scintillation, but also much like a synthesis radio telescope such as the ATCA. This particular property has been recognised as a means of “imaging” these scintillating quasars with unprecedented angular resolution. Some of the theory underlying this “imaging” has been outlined by Macquart & Jauncey (2002) and has been applied in some detail very successfully to “image” the linearly polarized structure in PKS 0405-385 present during its discovery scintillation episode (Rickett et al., 2002).

Radio astronomy has certainly come a long way when it is possible for a modest telescope, like the ATCA, to be able to achieve such “imaging” with micro-arcsecond resolution. It’s like extending the ATCA’s railway tracks all the way to the moon!

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Dave Jauncey, Hayley Bignall, Jim Lovell, Tasso Tzioumis, Lucyna Kedziora-Chudczer, J-P Macquart, Steven Tingay, Dave Rayner and Roger Clay
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Square Kilometre Array program report

The major recent event on the SKA calendar was the international meeting held in Groningen, The Netherlands. Prior to the meeting the International Engineering and Management Team (IEMT) had initiated and managed a process, which led to seven SKA concept descriptions being publicized shortly before the meeting. These descriptions, or whitepapers, formed the basic of the Groningen discussions. Four of the whitepapers were “end-to-end” expositions, while the remaining three outlined only antenna technology. The Australian SKA Consortium submitted two full descriptions, one based on Luneburg lenses and one using cylindrical reflectors. Both were prepared by CSIRO engineers in consultation with science colleagues from the University of Sydney and the ANU.

The whitepapers, and the ensuing discussions, raised many astronomy and radio science issues. The descriptions were slices through problem and solution spaces and, not surprisingly, the conceptual designs proved excellent vehicles for extending understanding of SKA requirements and practicalities. No concept selection was made but a shortlist will be compiled in 2004, after a stage-2 (and more rigorous) whitepaper process. Some key points to emerge from Groningen are:

- No single concept meets all science goals;
- Concepts give good high frequency (>20 GHz) or multibeaming operation, but not both;
- The SKA science community currently divides into camps favouring either high frequencies or multibeaming;
- The Australian concepts offer unique compromises in the “10 GHz – 10 beams” parameter space and it behoves us to assess our R&D directions given the recent international discussions;
- The comprehensive Australian submissions made contributions in a number of system design areas apart from antennas, including new receiver concepts and SKA data transport requirements.

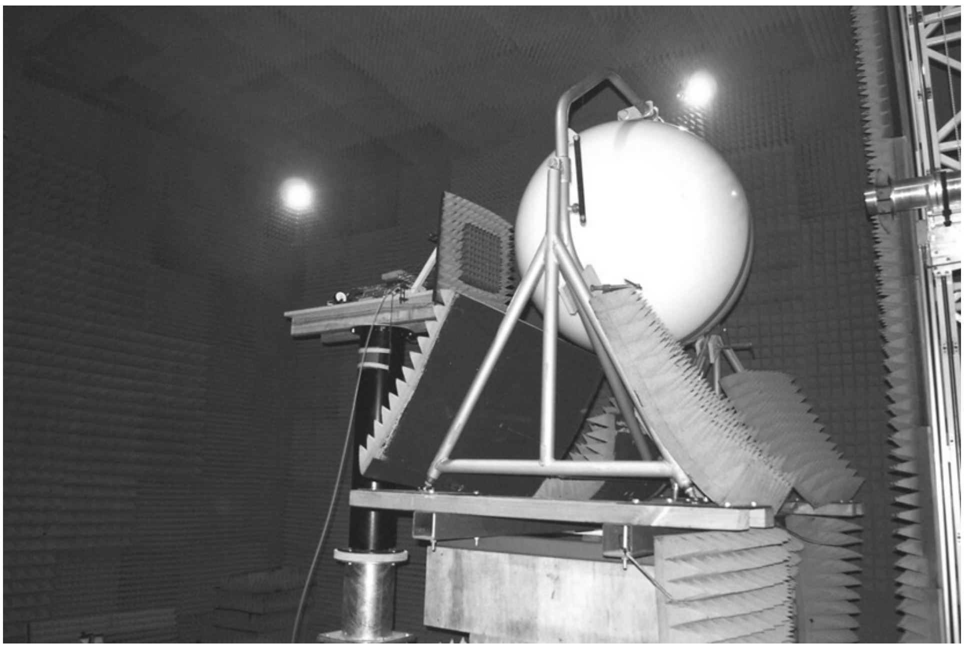

Figure 1: Luneburg lens and focal plane array being tested in the CSIRO near-field test facility.

2.3 GHz, Focal distance: 245 mm, D = 391, 5x5 elements, 45 & 135 degree cuts

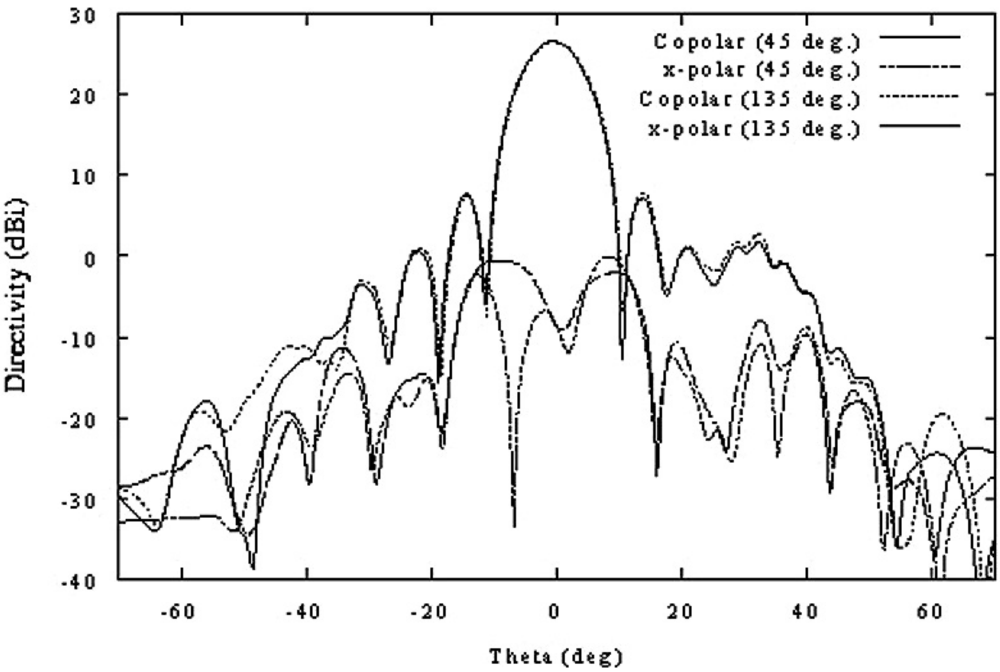

Figure 2: The response plots show typical computed far-field responses for a central array element.

Following my suggestion of an international 100-m class, cm-wave, multibeaming demonstrator in establishing the scientific credentials of multiview interferometers, and the wish to ensure that Australia remains a key player in SKA activities, an opportunity for an increased CSIRO involvement in LOFAR (the low-frequency SKA equivalent and an SKA system demonstrator) is being pursued. Initially, this involves assistance to the WA Government in submitting a LOFAR siting proposal. In the slightly longer term, it will involve working with LOFAR proponents to incorporate the idea of a cm-wave demonstration platform.

In practice, re-assessment of R&D directions could amount to fine-tuning the demonstrator programs proposed under MNRF 2001, with the ATCA New Technology Demonstrator project offering the most scope to incorporate exciting new developments.

Despite the enormous efforts that went into the whitepapers, our SKA group has been active on a number of other technical and outreach fronts. The prototype 2 – 7-GHz GaAs LNA chip is now back from the foundry and Aaron Chippendale is busy with on-wafer diagnostics prior to the wafer dicing operation. In collaboration with ASTRON, CSIRO has been testing an 8x8 Vivaldi horn array. The picture below shows the antenna being used as a focal surface array with our prototype 0.9-m Luneburg lens, giving a “cluster” beam feed and using the lens as a first-stage quasi-optical beamformer. In the outreach area, the SEARFE project continues to grow in strength, with a notable recent event being a foray by the Storey family to the Eyre Peninsula in SA; a highlight was an exhibit at a local agricultural field day. Outreach with a different thrust – that aimed at professional engineers and industry – has produced some fascinating contact with professionals experienced in financing and managing multi-billion dollar international projects; interesting lessons relevant to the SKA are emerging.

The next meeting of the Australian SKA Consortium Committee (ASKACC) will be held on 6 November. On the preceding day, 5 November, there will be a joint ATUC/SKA symposium at Marsfield and we invite everyone to attend. Finally, we have had a significant departure in that Graeme James, who has been associated with Radiophysics and CTIP for many years, has recently retired from CSIRO. On behalf of the SKA community I’d like to record my thanks to Graeme for his invaluable contributions, to wish him well in his retirement, and to assure him that we look forward to his continuing participation as part of his post-retirement fellowship.

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Australia Telescope Compact Array report

Highlights

The winter season has seen a number of milestones reached, with first astronomical use of the north spur, the new antenna control computers and a wideband correlator.

The north spur was christened on 12 August 2002 with the H75 configuration – an ultra compact configuration where the maximum spacing is about 100 metres. This array, which gives high brightness sensitivity imaging and a full synthesis in about 6 hours, was also popular with 3-mm observers (Figure 1). We have since revisited it with H168.

The christening of the north spur coincided with a visit by Michael Murphy and Steve Curran and an accompanying ABC Catalyst filming crew. Michael and Steve are involved with the work suggesting that the speed of light has changed with time. With them doing related ATCA observations, the film crew used the array as a photo opportunity for their story.

The new antenna control computers were first rolled out for astronomical use in mid-July, and then again in early/mid-September. Although there were problems in the July runs, which caused some gnashing of teeth, the September runs were far more successful (Figure 2). All antennas are now outfitted with the new antenna control computers and it is a routine process to switch between the old and new systems. Completing the project and making the new antenna control computers the standard observing system is now well within our sights.

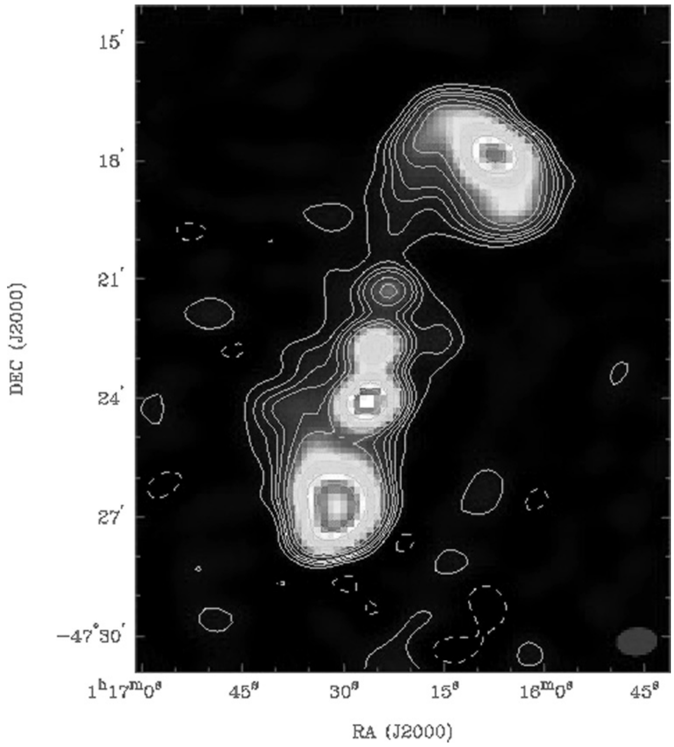

Figure 1: The first image formed using the H75 array: Radio galaxy J0116-473 at 3 cm, observed using a 9-pointing mosaic. The Fourier plane was essentially filled in six hours.

Driving the new antenna control computers towards completion was the need to support a single baseline wideband continuum correlator (3.5 GHz) developed by Warwick Wilson and his group. This correlator, together with the new antenna control computer, has allowed a pilot of large-area 12-mm blind survey to be performed. During this survey, as an after lunch diversion, Warwick Wilson and Mike Kesteven realised that the two correlators (the normal ATCA and the wideband correlator) could be run in parallel. They then implemented a split-array mode within a few hours.

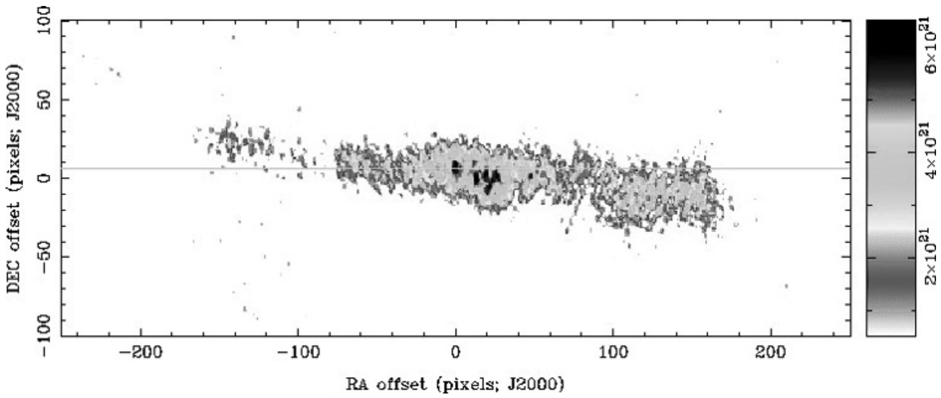

Figure 2: One of the first images produced using data observed with the new antenna control computers. An HI column density image of the edge-on spiral E115-G21. Courtesy of Jess O'Brien.

On top of these achievements, we cannot forget that this winter was the first one where three of the preliminary 12- and 3-

mm systems have been offered. 22% of observing time over the winter was at 12- and 3-mm wavelengths. In some configurations, the antennas were "shuffled" out of the natural order. This allowed the Fourier coverage of the millimetre systems to be optimised. To a significant extent, this winter has been a trial run: it has allowed us to develop a better understanding of the millimetre systems, to start working on some of their problems, and to help start to build up expertise in millimetre interferometry within the ATNF community. Additionally it was an experiment in scheduling: to give some robustness against poor weather, a mode of flexible scheduling was used. In this mode, a millimetre project can swap with a partnering centimetre project. With a pronounced drought, the weather (as seen by an astronomer) has been very good over the winter, with only about one swap in nine being initiated. In total, we have registered only three hours of "lost millimetre time" because of weather. These three hours was reclaimed by a centimetre NAPA project.

Well done to all ATNF staff and observers for their contributions to these milestones!

Staff and visitors

In August, we farewelled Darryl Campbell, who has left us after 13 years to take on a position with the National Parks service in the Narrabri area. We wish Darryl all the best.

Allan Day is going to escape the heat of a Narrabri summer in a serious way: starting in late October, Allan is taking leave-without-pay for 16 months to work at the South Pole on the DASI experiment.

On the positive side of the ledger, we welcome Mike Hill, Scott Munting and Brett Hiscock. All three have recently joined our electronics group. Mike joins us from South Africa, Scott from CSIRO Marine Research in Hobart and Brett from Sydney. Additionally, we will be welcoming Michael Dahlem early in the new year. Michael joins us from ESO in Chile, and will work in a systems role.

Lakshmi Saripalli has taken on a role as the editor of this newsletter, preparing for when Steven Tingay leaves us at the end of the year.

Currently we are advertising for a SKA postdoctoral position as well as an operations-scientist/engineer with duties mainly associated with Mopra.

We have had a number of medium-term visitors at the ATCA recently: Gianni Bernardi, James Urquhart, Jared Cole and Kate Smith have all stayed several weeks to a couple of months, working on observing or engineering projects.

Operations

Figure 3 gives the usage of the Compact Array for the 2002 May term.

Astronomy usage this term is down by 5.0% compared to January term, with all categories of non-astronomical use increasing slightly. This is a reflection on the larger number of array configurations scheduled this term, that two array configurations (EW214 and H75) were used for the first time, and that there was extra maintenance associated with these and the wideband correlator. Lost time was up slightly, mainly as a result of two events: a complete power failure in the Control Building and problems associated with using the new antenna control computers. These two events together cost us 16 hours in lost time.

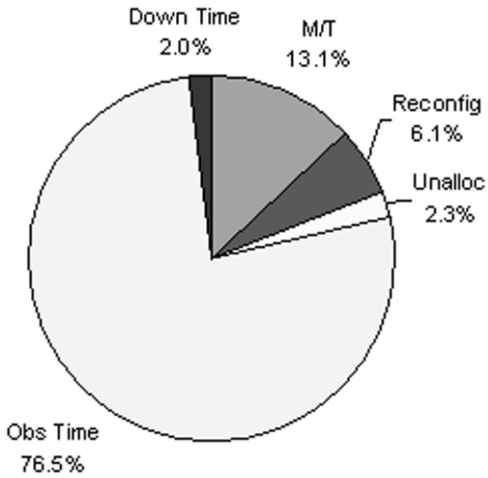

Figure 3: Compact Array usage for the 2002 May term

The pay TV interference that has affected 13-cm observers for the last few years has gone. This, apparently, was a commercial decision on the part of the pay TV operator. As a result, the recommended 13-cm frequency has now changed to 2368 MHz. This is now a good, RFI-free frequency.

Site safety

As part of an effort to improve our safety act, visitors to the ATCA now need to undergo a brief safety induction. There are two levels of induction for visitors – one that caters for visitors who use the Lodge and Control Building only, and a second level that caters for those who may also need to visit the antennas outside work hours (e.g. millimetre observers and duty astronomers). As this second level can only be done when the antennas are idle, please check the observing schedule and plan ahead if you want the antenna induction.

Mopra

Mopra has been almost continuously scheduled from late June to mid-November. The time has been split between "national facility" 3-mm observing time, 3-mm time available to UNSW observers, and about three weeks of VLBI/VSOP time. During most of the "national facility" time, the ATNF has provided a telescope assistant to help support the observers. Although Mopra remains a more difficult observing environment than the other ATNF telescopes, this winter has proceeded reasonably well. Apart from one cryogenics problem (which resulted from a false fire alarm), there have been no major failures.

A late breaking development is that, as part of an ARC proposal with UNSW, Sydney University and the Monash, we have recently won funding to upgrade the Mopra correlator to 8-GHz bandwidth. This bandwidth would be used in conjunction with the new 3-mm front-ends. Given this, and with the current season almost behind us, we are reviewing how best to support the telescope's operation in winter 2003.

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Parkes Observatory report

Staff

Michael Grimshaw has joined the band of casual staff looking after the ever increasing number of people passing through the Visitors Centre. We have been waiting for the "post-Dish" peak for some time, but Visitor Centre numbers and activity continue to grow steadily.

Martin McColl is leaving us in November to take up a position with the Sub Millimetre Telescope group in Tucson, working with Harry Fagg.

Coffee, foccaccia and other goodies

Progress towards the establishment of a cafe in the grounds of the Parkes Visitors Centre continues, and is now clear for all to see after the relocation of the six-sided BBQ shelter from the VC grounds to the Quarters. A contract has been signed with the tenants, Michael and Andrea Carter, who will operate the cafe and are raring to go. The tender for the construction of the cafe and the new BBQ area is to be finalised this week (starting 7 October). Construction is to be completed in 16 weeks, which should see the cafe open at the end of January 2003.

CPSR2

A frenetic fortnight in August saw the installation of a new supercomputer facility in the upstairs control room. Currently called CPSR2 ("Caltech Parkes Swinburne Recorder 2") the equipment makes an impressive sight, comprising 30 Dell 2650 rack-mounting PC servers, each containing two 2-GHz CPUs, interconnected on a GigaNet network (for the data) and a 100 Mb/s ethernet network (for control).

Two of the main design goals of the new system were to (a) significantly increase the recorded bandwidth over the earlier system, and (b) record direct to computer disk and analyse the data on-site in near real time, avoiding the use of tapes. The new system can record 1 Gbit/second, comprising four 64-MHz bands sampled at two-bit precision. This is an order of magnitude more than the first CPSR baseband recorder (or the S2 VLBI recorder), giving access to many more pulsars than any previous baseband system.

The system records direct to IDE disk, and can record at full speed for several hours before the disks fill. Reducing the data on the present system takes about twice real time, but can run in parallel with data-taking, thereby extending the maximum continous observing period.

The system at present is sitting in temporary open racks, but will soon be installed in two fully shielded cabinets to reduce RFI (and fan noise!).

The system is intended primarily for pulsar timing but has stimulated discussion of potential applications in other areas, particularly VLBI. See *www.parkes.atnf.csiro.au/whats_new/cpsr2_first_light.html*.

Mars tracking

A contract between the ATNF and NASA/JPL for the use of the Parkes Telescope for tracking spacecraft over the period September 2003 – March 2004 has recently been signed. The contract will see NASA pay around A$3 million to upgrade the surface of the telescope, commission ATNF to build a new 8.4-GHz receiver, and to operate the telescope for tracking spacecraft for around 1000 hours. The surface upgrade will enlarge the area of perforated Aluminium panelling from 44 m to 54 m diameter, replacing about half of the remaining original steel mesh panels. The new surface will significantly improve performance at all frequencies above about 8 GHz. Combined with the new receiver and feed, the sensitivity of the telescope at 8 – 9 GHz will be approximately twice that of the existing system.

The choice of receivers available for astronomy observations during the five to six month main tracking period will be somewhat constrained. In particular, a choice will need to be made between the HI Multibeam receiver and the new 10/50 cm pulsar receiver. One of these will be unavailable for the duration of the tracking.

The return of Parkes to space tracking is being driven by the large number of spacecraft converging on Mars, or in the same sidereal range, towards the end of 2003, heavily taxing existing NASA tracking resources. The decision on which of these spacecraft will be tracked by Parkes is yet to be made, and may occur dynamically at the time of the tracking. For more information, see *www.csiro.au/index.asp?type=mediaRelease&id=MarsTrafficJam*

Operations news

Generally operations have continued smoothly into 2002, with lost time for the year to date running at about 1.0% for equipment faults and about 3% for bad weather / high winds.

Problems were experienced in June and July with a failed DLT tape drive on the Multibeam Pulsar filterbank system, which seemed to precipitate a number of minor but irritating problems particularly at the faster sampling rates. Much work has since been expended in upgrading the main data-taking computer (to a DEC Alpha XP1000) to improve system performance and reliability, with promising results in preliminary testing.

Commissioning of the Wideband (1 GHz) Correlator during March and April was not as successful as hoped and has been rescheduled for October, during the elevation gearbox replacement shutdown.

The Multibeam receiver continues with one dead channel (10A) and a few others with slightly degraded and/or erratic performance. Approximately 15 new LNAs are in the process of being built at Marsfield with a view to overhauling the Multibeam package sometime in 2003.

Operational developments

New zenith drive gears have just been fitted to the telescope and as we enter the fourth week of the maintenance shutdown for this work, everything is proceeding very smoothly. The gearboxes were removed (for only the second time in 40 years of operation) on 20 September. After a complete new set of gears and bearings were fitted in both boxes, they were reinstalled on 4 October.

For a pictorial representation of the job so far, look at the pointers under ‘Happenings at Parkes’ on *www.parkes.atnf.csiro.au/visitor_info/visitor_info.html*

As this report is being written, two gear experts from Hofman's, a Perth based gear company, have begun grinding each tooth on the racks that the output pinions from the gearbox mesh with to lift the counterweight and tip the dish. The grinding is expected to take all week. We will then have a few days of system tests and be back in normal operation from 18 October.

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Parkes Officer-in-Charge
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At this stage particular thanks are due to staff from other sites who have made a great contribution to the work involved in this major job, namely Brian Wilcockson, Steve Broadhurst, Clive Murphy and Ollie Dowd. Steve's wife had a baby, Penelope Avril, on the last morning Steve was to be in Parkes. As a result Steve missed seeing the gearboxes go back on the telescope, but we believe he made it back to Sydney in time for a very different but equally miraculous event!

Varying stages of the installation of the new zenith drive gears (above), and grinding the rack teeth at the Parkes Telescope (left).

Time assignment information

Compact Array scheduling

During the 2003JANT term arrays 6A, 6B, 1.5B, 750D and EW352 will be scheduled on the ATCA. The term will also start with EW367. The interim 3- and 12-mm systems on three antennas continue to be offered. Given that these systems are still immature, millimetre observations continue to require an ATNF collaborator who is expected to be conversant with their use. Because of summer weather, January term is the worst term for millimetre observing: it is not a millimetre period. As such, there will be no special arrangements for millimetre observers during 2003JANT (e.g. no antenna shuffles or flexible observing). We expect a two – three week shutdown during the term, to allow for millimetre installation and antenna holography. Although more millimetre systems will be available after this shutdown, their full integration is unlikely much before the start of 2003MAYT term.

Replacement time

Following a request from the users' committee, the ATNF now has a formal replacement time policy. This largely reflects existing practice. In particular, if a project is usurped by a NAPA project or target-of-opportunity, or if a significant amount of time is lost because of equipment failure (other than remote observing link failure), then a reasonable effort will be made to reschedule the project promptly. If this is not possible before the next proposal deadline, then the proposal should be resubmitted.

The full guidelines for the replacement of lost time can be seen on the web at

www.atnf.csiro.au/observers/apply/too_apply.html

Data archive requests

The data archives managed by the ATNF are a valuable resource to astronomers.

In general, data obtained from the ATNF facilities is made available to other users on request 18 months after the end of observations, unless a special case for extended proprietary rights is accepted by the Time Allocation Committee. The ATNF Director may override the release of data at his discretion. The end of an observation is defined by the final set of observations requested, either in the original proposal, or in a direct extension of the original proposal.

To improve the accessibility of the ATCA data archive, there is a new web search facility to give the RPFITS files corresponding to particular projects and dates. See

www.narrabri.atnf.csiro.au/observing/archive_requests/

We ask that all data archive requests specifically state which RPFITS files are required. This will help us respond in a timely fashion.

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ATNF publications list

Publication lists for papers which include ATNF data are available on the Web at: *www.atnf.csiro.au/research/publications*.

Please email any corrections or additions to Christine van der Leeuw *(Christine.vanderleeuw@csiro.au)*. This list includes published refereed articles and conference papers, including ATNF data, compiled since the June 2002 newsletter. Papers including one or more ATNF authors are indicated by an asterisk.

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