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ATNF News

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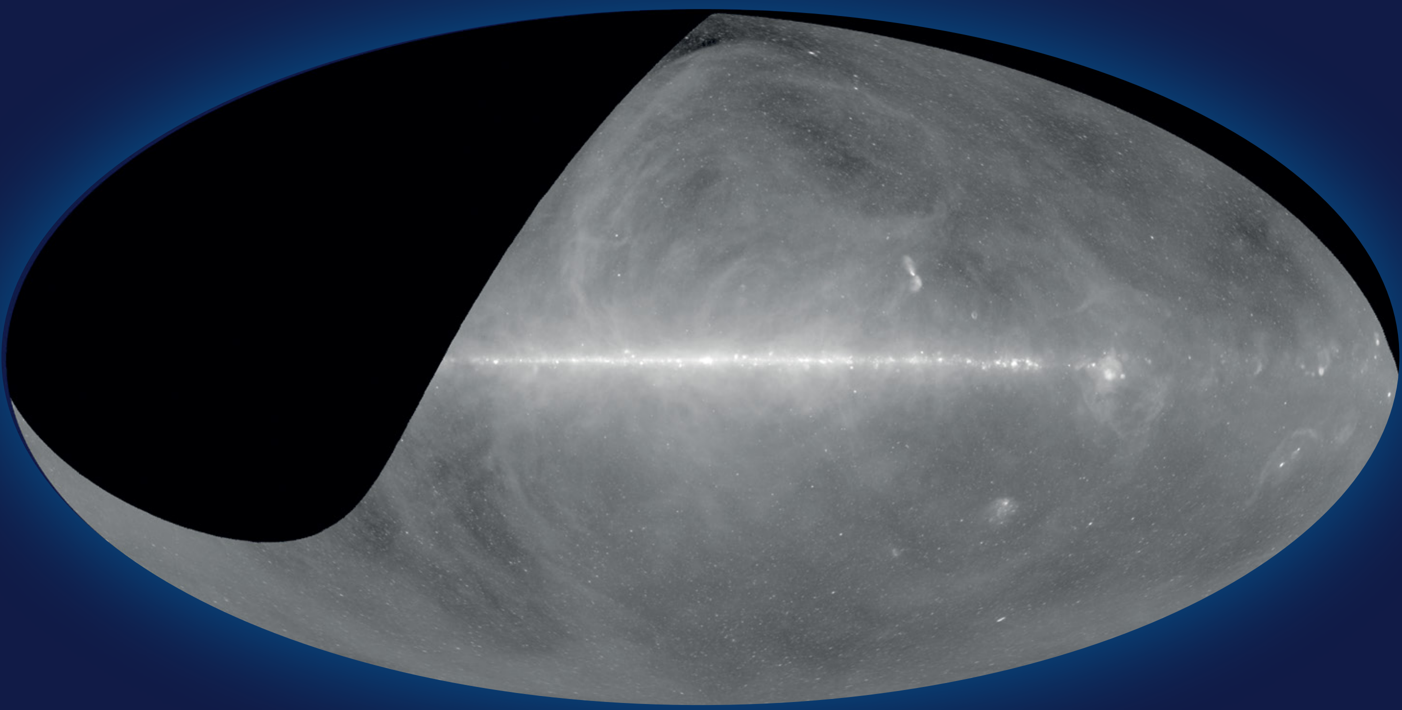

Front cover image

The CHIPASS 1.4-GHz continuum map of the southern sky, derived from HIPASS and ZOA data (Calabretta *et al*., 2014). See article on page 3 for details.

Editorial

Welcome to the April 2014 issue of *ATNF News.*

Commissioning of the Australian SKA Pathfinder has moved apace since the time of the last newsletter. In December the commissioning team made the first HI absorption-line measurement, using three antennas. Then in February it made the first six-antenna continuum image. Both sets of observations corresponded well with previous observations of that part of the sky made with the Westerbork telescope.

Square Kilometre Array pre-construction work has also progressed on a number of fronts. As the October newsletter mentioned, CSIRO leads the *Dish* and *Infrastructure Australia* consortia, is a key partner in the *Assembly Integration and Verification* consortium, and contributes to four other consortia. In the past few months CASS has hosted several visits by members of various consortia and the international SKA Organisation. In March we also hosted a visit to the Murchison Radio-astronomy Observatory by Foreign Minister Julie Bishop and the UK Science Minister, David Willetts.

The established ATNF telescopes are continuing to do diverse science. In this newsletter we report on:

- CHIPASS – a new continuum map of the southern sky at 1.4-GHz;
- the Mopra Southern Galactic Plane CO Survey; and
- a (likely) Galactic origin for one of the 'fast radio bursts' discovered with the Parkes telescope in recent years.

In other news, CSIRO Fellow and first ATNF Director, Ron Ekers, is to receive the 2014 Grote Reber Medal for lifetime achievements in radio astronomy. The award will be presented at the General Assembly of the International Union of Radio Science in Beijing in August. We also report on graduate students, education and outreach, engineering developments, publications and meetings, past and future.

We hope you enjoy this issue of *ATNF News*. Your comments and suggestions are always welcome. If you would like to contribute to a future issue, please contact the newsletter editors, below.

Helen Sim and Tony Crawshaw

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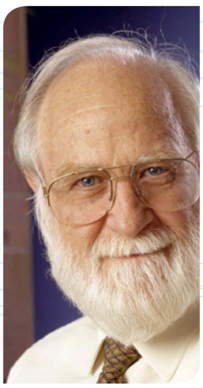
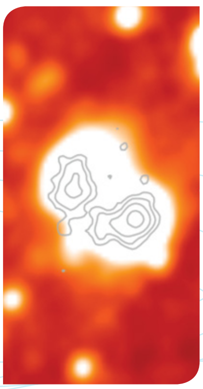

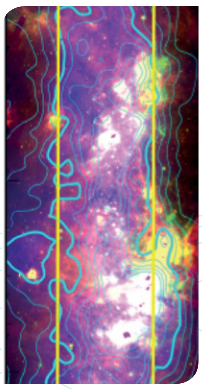


From the Chief of CSIRO Astronomy and Space Science

LEWIS BALL (CHIEF OF CASS)

One of the highlights of the past few months has been the good progress made on the commissioning of the Australian Square Kilometre Array Pathfinder, ASKAP. The six ASKAP antennas that make up the Boolardy Engineering Test Array (BETA) had previously been operated as two three-element arrays: we have now begun to use them as a six-antenna array. Details of the commissioning are described on page 12 and following pages. A key performance indicator, but not one we can quantify easily, is that members of the commissioning team have been smiling noticeably more!

On the hardware side, a prototype second-generation phased array feed (PAF) for ASKAP has achieved excellent system noise temperature, close to 50 K across the entire ASKAP band. This confirms that the second-generation PAF will meet its performance targets when installed. The engineering excellence of the PAF was recognised last year by awards from Engineers Australia: flowing on from this, a PAF is now on display at Sydney's Powerhouse Museum.

As this newsletter goes to print, we farewell one of our longest-serving staff members: Graeme Carrad, Assistant Director Engineering. Graeme has made an enormous contribution over the years to the excellence of ATNF engineering and technology development, initially as a member of the Receiver Group and more recently in his Assistant Director role. I would like to pay tribute to his hard work and conscienciousness, always present behind his jocular style. We will miss Graeme's contribution very much. Tasso Tzioumis, well known in the VLBI community, will be stepping into the role as interim Assistant Director Engineering.

Turning to science with our established telescopes, we have reports of two projects designed to produce key resources for their respective areas of radio astronomy. Mark Calabretta (CASS) details the painstaking work involved in creating a new 1.4-GHz continuum map of the southern sky, CHIPASS – a map he describes as being "of unprecedented resolution and fidelity, unlikely to be surpassed in the foreseeable future". In a similar vein, Michael Burton (UNSW) outlines the Mopra Southern Galactic Plane CO Survey, which is set to create the next pre-eminent view of the southern 'molecular sky'.

Our third science report presents a case for a probable Galactic origin for one of the mysterious fast radio bursts found with Parkes. This exciting breakthrough was made possible by a series of happy coincidences, as authors Keith Bannister (CASS) and Greg Madsen (University of Cambridge) describe.

Finally, I would like to highlight the ATNF's engagement with both the scientific community and general community. In the past few months we have run three significant scientific meetings, described on page 19, which are a testament to the initiative of ATNF staff. Staff are also contributing actively to the development of the next Australian Astronomy Decadal Plan. Our program of outreach to students, teachers and the general public continues to be vigorous. In December we took a new step in this field, through the involvement of ATNF staff in a 'citizen science' project, Radio Galaxy Zoo. Lessons from this will feed into similar public programs that we intend to run using data from ASKAP.

CHIPASS: a continuum map of the southern sky at 1.4 GHz

MARK CALABRETTA

Although designed as blind surveys of extragalactic 21-cm HI line emission, the HIPASS (HI Parkes All-Sky Survey) and ZOA (Zone of Avoidance) surveys carried out with the Parkes telescope continue to bear fruit for secondary purposes. While a hydrogen recombination-line map of the Galactic Plane has been produced and is currently being analysed, here I will describe the 1.4-GHz continuum map of the southern sky, CHIPASS, which was published recently (Calabretta *et al*. 2014).

Observing for HIPASS and ZOA, with their various extensions, ran between 1997 and 2005, with many consequent publications relating to the HI line. It was, of course, understood that the surveys also contained a wealth of 1.4-GHz continuum data, and in fact little development was needed to generate compact-source continuum maps matching each of the HIPASS and ZOA spectral cubes. A few such maps were produced and found to be crowded with point sources, and this provided a strong incentive to pursue the work.

Rather than dealing with hundreds of small tiles, it seemed natural to grid all of the continuum data together into a single all-sky map. However, the problem size (the product of the number of input spectra and the number of pixels in the output map) would be at least 100,000 times larger than for one plane of a HIPASS cube. The map-gridding software *gridzilla* would also have to handle wide-field mapping properly, and consequently it required extensive redevelopment. Thus began a protracted series of incremental improvements to both *livedata* and *gridzilla*, many of which would later prove also to be important for other projects, notably GASS, the Galactic All-Sky Survey.

Eventually the all-sky, compact-source continuum map was produced (see Figure 1, below). Certainly the map was replete with extragalactic point sources, and the Galactic plane itself and other large-scale structures such as Cen A, the Large Magellanic Cloud, and the North Polar Spur were also easily recognisable. However, the high-pass spatial filter, effectively applied by the bandpass calibration, produced deep negatives surrounding strong extended sources. In fact, so much information was missing at low spatial frequencies that it was difficult to make proper sense of the map, particularly of the strange structures emanating from the Galactic plane.

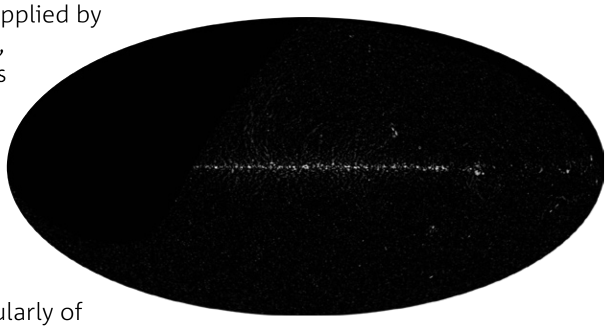

Figure 1. HIPASS 'point-source' continuum map at 1.4 GHz produced using the HIPASS/ ZOA compact-source algorithm, which is sensitive only to regions of emission much less than 8° in extent.

The high-pass filter problem had already been addressed in the High Velocity Cloud survey, an off-shoot of HIPASS. A different bandpass estimator was used to preserve as much large-scale spatial structure as possible, the spatial cut-off then being imposed by the 8°.5 scan length. A very different image of the sky emerged once the continuum data had been reprocessed using this bandpass calibration method (Figure 2). However, it was hardly less problematic!

It's not hard to see how the problems arise. Whereas emission lines, such as the 21-cm HI line, are referenced to a spectral baseline defined by many adjacent channels, the continuum is defined by all of the channels that make up the spectral baseline itself. Consequently, a reference can only be obtained spatially, that is, by observing how the spectral baseline rises and falls across the length of the scan. Ground-based surveys designed specifically to map the sky at large angular

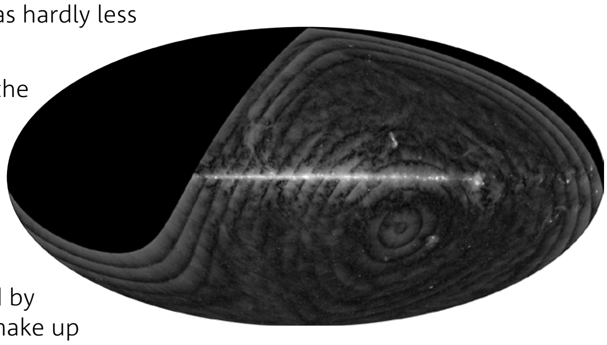

Figure 2. HIPASS 1.4 GHz continuum data now processed with the running-median algorithm, which is sensitive to extended emission. The 15 HIPASS declination zones are readily apparent.

scales, such as S-PASS, normally use a long-azimuth-scan technique. Elevation-dependent variations in T_{sys} due to spillover and atmospheric opacity are (mostly) eliminated by scanning at constant elevation, while the long scans preserve low spatial frequencies. Usually the scans are also arranged to provide many crossing points so that they can be tied together using a basket-weaving technique or similar. Of course, such observing strategies were beside the point for HIPASS and ZOA, which were already completed.

Fortuitously though, and perhaps to a remarkable extent, HIPASS and ZOA complemented each other so that high-quality corrections could be derived from within the surveys themselves. Firstly, the elevation dependence of T_{sys} was obtained statistically from the HIPASS data by observing how T_{sys} changed as a function of elevation in areas of the sky away from the Galactic plane and other strong continuum emission. In fact, the derivation from such a large amount of data was almost certainly more accurate than would have been obtained from even a large set of traditional sky-dips. Applying the correction (in *livedata*) did indeed produce a great improvement in the map (see Figure 3).

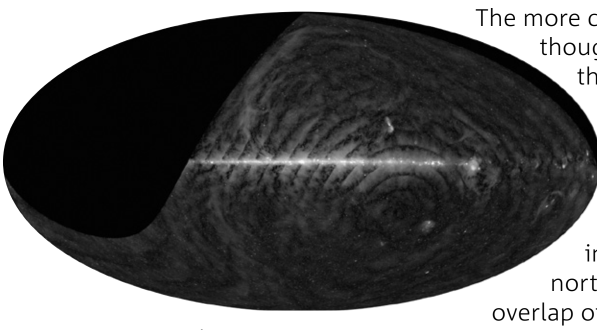

Figure 3. HIPASS 1.4 GHz continuum data now corrected for the elevation dependence of T_{sys}.

The more challenging problem, though, was in dealing with the short scan lengths. Somehow the scans in each of the 15 HIPASS declination zones had to be tied to the corresponding scans in adjacent zones to the north and south. The small overlap of barely 11 integrations between zones provided the main handle on this. However, it was clear that small errors in computing the step between zones would compound themselves after 15 such steps. Essentially this was a 1-D random walk, where the variance in position after N steps is equal to the sum of variances of the N steps. Thus considerable effort was devoted to making *livedata* validate HIPASS/ZOA data according to a number of criteria, particularly relating to the scan rate. A small but potentially significant number of integrations were flagged, particularly at the scan end-points, which might otherwise have proved detrimental.

Despite these efforts, the set of 81,000 zone corrections did indeed exhibit at least some of the hallmarks of a drunken walk! A map of the HIPASS zone levels, each obtained by summing the 15 offsets from the South Celestial Pole northwards, showed pronounced 'streamers' starting at points where the 'drunkard' had lurched, mostly on the Galactic plane and going north (see Figure 4 below). These arise where the end of one scan, and the start of its neighbour, coincide with a strong source; even very small flux-density calibration errors could result in a relatively large error in the value determined for the step.

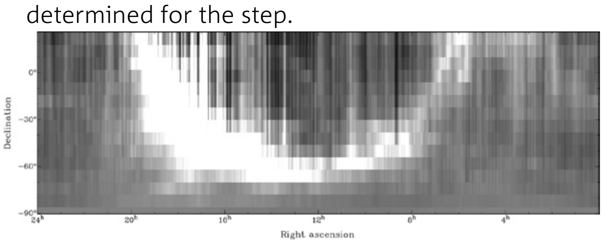

Figure 4. HIPASS zone levels derived from the overlaps, before correction provided by ZOA. Particularly strong streamers emanate from the inner Galactic region (left).

In preliminary work, the streamers were handled by ad hoc methods, mostly by trying to identify them individually and applying a correction to make them disappear into the background, followed by rather heavy smoothing of the zone levels. While of limited validity, this did allow the necessary software to be developed, and produced a spectacular map that inspired greater effort to do the job properly. This is where ZOA came to the rescue.

Without ZOA, the streamer problem would certainly have limited the usefulness of CHIPASS. It provided corrections in just those regions where the worst streamers were formed. The key here is that, while HIPASS scanned in declination, ZOA scanned in Galactic longitude, and luckily along the Galactic plane these are always oblique, never parallel. The angle between the two is important! It allowed ZOA levels to be derived from the median of a **set** of HIPASS scans, thus minimising the potentially detrimental effect of streamers. The ZOA map, once obtained, could then be used to correct the HIPASS levels. The refined HIPASS map was then used to produce a better ZOA map, and so on until no further improvement could be obtained in either.

This works because, in the ZOA survey area, where the HIPASS zones meet, each ZOA scan crosses obliquely from one zone to the next, thus forming a bridge between sets of HIPASS scans on either side. Conversely, where ZOA zones meet, each HIPASS scan bridges sets of ZOA scans on either side. While the geometry is complex, it can be handled by gridding the data onto the appropriate map projection. The process is best understood graphically as in Figures 10, 11, & 12 of the CHIPASS paper, which also details a couple of difficult technical problems glossed over here. In fact, the iteration was sufficiently large and complex as to be unforgiving of even slight errors in methodology or software, and convergence after 10 iterations was hard won. The result is a 1.4-GHz continuum map of unprecedented resolution and fidelity, unlikely to be surpassed in the foreseeable future (Figure 5).

Apart from the 1.4-GHz map, the CHIPASS effort leaves a legacy of improvements to the Parkes multibeam processing software, particularly *gridzilla*. These appeared progressively, without fanfare, over many years. In fact, many would have been noticed only by the most observant as enhancements in processing speed and memory usage. Amongst them, the technique of iterative gridding is probably the most novel. Median statistical gridding, while so useful in some ways, has the nasty trait of producing maps where the flux-density scale depends on source size. This problem, which lingered as the main impediment to CHIPASS publication, was finally solved by iterative gridding. Full details may be found in the CHIPASS paper.

Reference

Calabretta, M. R.; Staveley-Smith, L.; Barnes, D. G. PASA 31, e007 (2014). **doi**:10.1017/pasa.2013.36

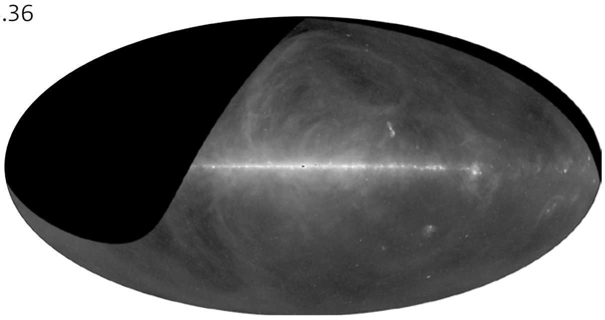

Figure 5. The final CHIPASS map. The map and associated data products can be accessed at *www.atnf.csiro.au/research/CHIPASS*.

Radio Galaxy Zoo launched

JULIE BANFIELD (CASS), on behalf of the Radio Galaxy Zoo team

What is Radio Galaxy Zoo?

Radio Galaxy Zoo is a citizen-science project in which participants 'hunt' for supermassive black holes at the centre of galaxies. We have a database of more than 200,000 radio galaxies from the Faint Images of the Radio Sky at Twenty Centimeters project (FIRST; White *et al.* 1997) and the Australia Telescope Large Area Survey (ATLAS; Norris *et al.* 2006): we wish to match these with mid-infrared observations from the *Wide-field Infrared Survey Explorer* (WISE; Wright *et al.* 2010) and the *Spitzer Space Telescope*. The radio images at 1.4 GHz provide the information on the black-hole jets while the mid-infrared data show the galaxies hosting the black-hole jets.

The procedure is straightforward. We overlap the mid-infrared image with the related radio image and ask the participant to match the host galaxy with the corresponding radio emission originating from the host galaxy (see Figure 1). A tutorial is available to provide instructions on how a classification is achieved: this takes 5–10 minutes to complete. A single classification can take as little as 30 seconds to complete; 'difficult' objects might take a few minutes.

We launched the project through the Zooniverse (*www.zooniverse.org*) on 17 December 2013. Within the first 24 hours we had over 20,000 galaxy classifications and over 1,300 citizen scientists working on the project. As of 20 March 2014 we had 558,000 classifications and over 3,600 citizen scientists participating from around the world.

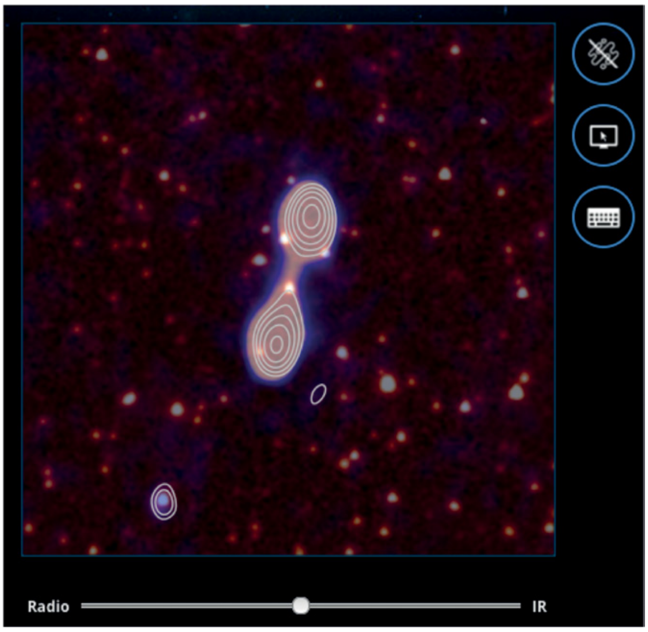

Figure 1. The Radio Galaxy Zoo interface. The red image is the mid-infrared *Spitzer Space Telescope* image and the blue image with white contours is the 1.4 GHz ATLAS image over the same area of the sky. The slider at the bottom of the image transitions between the radio image and the mid-infrared image. The buttons on the upper right indicate various other tools available to help make the classification.

Science goals

Radio Galaxy Zoo has three main science goals: to determine the shapes and sizes of radio galaxies; to help us understand the formation of supermassive black holes (SMBH); and to clarify the relationship between the SMBH and the host galaxy.

RADIO GALAXY MORPHOLOGY

Radio galaxies come in all shapes and sizes, as Figure 2 shows. The emission from the SMBH can be symmetric or have bends and wiggles. The morphology of radio sources can provide information about the local environment the galaxy lives in.

THE FORMATION OF SUPERMASSIVE BLACK HOLES

Questions remain about how supermassive black holes form and grow. It is believed that small black holes might merge together to form larger black holes and continue to swallow surrounding material, merge again with other black holes, until they become the supermassive black holes we observe at the centre of massive galaxies. The problem is that this process takes many billions of years, yet there are supermassive black holes less than a billion years after the Big Bang. Radio Galaxy Zoo will create a large database that combines radio jets with host galaxies, giving information about black holes at all stages of their lives. We expect that this will help us to better understand how supermassive black holes form.

THE RELATIONSHIP BETWEEN THE SUPERMASSIVE BLACK HOLE AND THE HOST GALAXY

There is strong circumstantial evidence that the supermassive black hole can change the rate at which stars form in their host galaxies. It is possible that the jets from the supermassive black hole heat up and disrupt the gas within the galaxy. This might either regulate the star-formation rate by expelling and heating the gas; alternatively, it might compress the gas in some parts of the galaxy and actually increase the star-formation rate. The Radio Galaxy Zoo database will contain a wide range of local environments and galaxy types, which may help us to better understand this relationship.

Unexpected outcomes

As with all astronomical surveys and projects, there is always the possibility of unexpected results. Computer programs only detect or measure what a human requires them to. People, on the other hand, are curious by nature and will question and explore unusual features that they see. Other citizen-science projects built by the Zooniverse have lead to unexpected and amazing discoveries: they includes objects such as Hanny's Voorwerp and the 'green peas' in Galaxy Zoo, or the potentially new seaworm species discovered in Seafloor Explorer.

Within a week of the launch of Radio Galaxy Zoo, two citizen scientists, Ivan Terentev and Matorny Tsimafei, discovered the unexpected: they found a rather large U-shaped radio galaxy extending over 3' on the sky. The object is interesting as each jet is around 700 kpc in size, and the galaxy is located at a redshift of 0.08 and lives in what is probably a 'poor' environment. The team investigating this object is led by Lawrence Rudnick (University of Minnesota) and Heinz Andernach (University of Guanajuato).

Head to *radio.galaxyzoo.org* to begin hunting!

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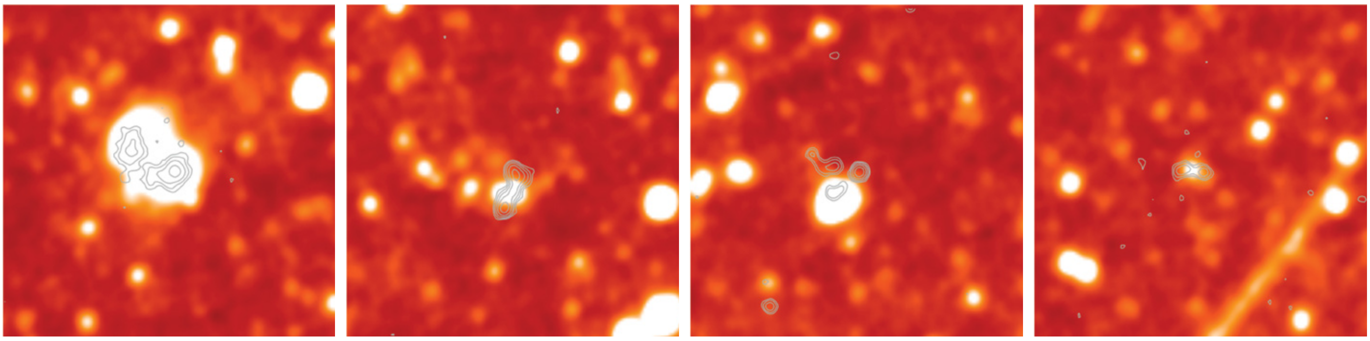
Norris, R.P.; Afonso, J.; Appleton, P.N.; *et al.* MNRAS, 132, 2409 (2006)

White, R. L.; Becker, R. H.; Helfand, D. J. *et al.* ApJ, 475, 479 (1997)

Wright, E.L.; Eisenhardt, P.R.M.; Mainzer, A.K. *et al.* AJ, 140, 1868 (2010)

Figure 2. Four images from Radio Galaxy Zoo showing the variety of morphology the radio sources can have. The red image is the WISE mid-infrared image and the white contours are the 1.4-GHz radio image from FIRST.



Engineering

GRAEME CARRAD (CASS)

Compact Array Centimetre Upgrade

The Compact Array Centimetre Upgrade has taken up most Technologies theme effort in recent months. All receivers are now operational and production modules and spares have rounded out the project. The next mode for CABB, a 16-MHz mode, is progressing, and commissioning is expected at the end of 2014.

FAST receiver

CASS has finished investigating the feasibility of a 19-beam, 1.05–1.45 GHz receiver for China's Five Hundred Meter Aperture Spherical Telescope (FAST). But this will not be the end of our interactions over FAST. There will be great interest from both CASS and FAST engineers in the 3D-printed, metal-clad plastic feed and the differential, four-port orthomode transducer (OMT) that Jodrell Bank Centre for Astrophysics is investigating, and the results that come from those components will guide the discussions that are soon to be undertaken on the fabrication of the actual receiver. Technologies theme staff have conceived of a different OMT to the quad-ridged design that came from CSIRO Computational Informatics. It has evolved from an 'Alex Dunning concept' to a prototype awaiting fabrication, and may offer a less weighty, and therefore more attractive, option for the final receiver.

ATNF receiver engineer Santiago Castillo, with the CASS-designed feed for China's FAST telescope. Photo: Tim Wheeler

Parkes receivers

In parallel with these activities much consideration has been given to the next generation of Parkes receivers. Three receiver systems have been suggested and discussed in the ATUC forum. Following examination of the science outcomes, the technical challenges, the 'fit' with operational plans, and the resources available to undertake their fabrication, commissioning and operation, CASS has decided that it is in a position to tackle a 700 MHz–4 GHz, or ultra-wideband – low (UWB-L), receiver. Support from the astronomy community will be needed to ensure sufficient resources are available for the project to be completed. There is recognition that a PAF and a receiver covering the 4–24 GHz band are also desirable, but it is not possible to run both or either of these concurrently with the UWB-L; however, investigation into some elements of these other systems may be undertaken to retire risks and benefit future planning.

RFI mitigation

Success in securing a CSIRO Office of the Chief Executive (OCE) postdoc appointment has sparked some significant activity. Greg Hellbourg, who has spent time at Nançay and ASTRON, has arrived and will work with Aaron Chippendale, Michael Kesteven and, for a limited period, Brian Jeffs, on RFI mitigation (see page 22 for more details). The 'limited period' is due to Brian returning to Brigham Young University in the USA after his 11-month stint at the Marsfield site. The time has flown, but never so much as in the past few months, as he and Michael Kesteven, along with many helpers in the Technologies and Operations themes, have built a receiving system (including a 3.7-m antenna) that is now operational at Parkes, following assembly and testing at Marsfield. It will be used for tracking satellites and obtaining accurate signatures of the RFI they present to ATNF telescopes. Brian will be missed but his visit has established a strong link and it will form the basis for ongoing collaboration.

Epoch of Reionization

Work continues on EOR research, although at a low level. Keith Bannister is a driving force on this when his time permits; likewise, the Front End Group contributes when it can. A recent 'run' at Parkes has returned encouraging data.

Meetings

In November 2013 Yoon Chung delivered two papers at the *Asia Pacific Microwave Conference* in South Korea that reflected work undertaken in the 6/13 cm upgrade: he spoke about a filter to attenuate RFI, and the 4–12 GHz OMT. Grant Hampson and Ron Beresford have recently returned from the *Optical Fibre Communications* show (OFC 2014) in San Francisco: the expectation is that the new 'toys' on show might well form part of future receiving systems. Andrew Brown was one of CASS's representatives at the *Science meets Parliament* workshop in Canberra in March and has new insight into dealing with those who make the decisions that affect all of us.

Students

Two students, both from the University of Wollongong and studying Mechatronics, joined the Engineering program for short periods. Daniel Gain, previously a trainee with CASS, returned to the fold for a 12-week stint, as is the usual requirement for a University placement in the field, and contributed to the power systems for the ADE PAF. Ronnie Venables is a newly recruited cadet and spent two weeks in February with the Backend Group to give herself a flavour of the work she will return to at the end of the University year in November.

Visit by Don Campbell

Engineering was also pleased to host a three-month sabbatical visit by Don Campbell from Cornell University. With his experience from decades of engineering and astronomical research at Arecibo, Don was able to contribute much to discussions on telescope systems and the direction that the Engineering program might take.

Other activities

CASS staff have also been pursuing projects in their personal lives. Aaron Chippendale and Alex Dunning recently became parents of potential engineers, a first for Alex and a third for Aaron. All births were roughly on time, on budget and within scope. Commissioning activities, however, are necessarily ongoing.

This will be my last Engineering update, as I am retiring from CSIRO on 2 May. My time with CSIRO has been one surrounded by talented people with an ethic and attitude that has made working with them inspiring, focused and fun. I value the relationships I have developed over the years and the positive effect those relationships have had on my life. I know that the great work of years past will continue and ensure that innovative instrumentation continues to grace antennas both in Australia and at overseas facilities.

Operations

DOUGLAS BOCK and PHIL EDWARDS (CASS)

The operations team based in Geraldton continues to grow to support ASKAP. Across ATNF Operations we are looking for opportunities to support ASKAP PAF installation, commissioning and early science. At the same time we seek to maintain the high output from our other telescopes.

Parkes maintenance

The Parkes telescope had a two-week maintenance block in early February. The main tasks undertaken in this time were photogrammetry of the receiver translator in the focus cabin, work on the uninterruptible power supplies in the tower, and non-destructive testing of the tower structure. Additional work was done characterising the radio-frequency interference (RFI) environment on top of the focus cabin, and also in installing a 3.8-m antenna on site for future use in RFI monitoring and mitigation. Last, but by no means least, was the installation of the 74-MHz 'Erickson' feed for a pilot study program. The feed itself is large and heavy, and its mounting under the focus cabin requires the removal of the focus-cabin radome cover. The pilot study ran over the weekend, and revealed that, as expected, the worst RFI seen at this frequency is locally generated: focus-cabin equipment not in use had to be switched off before a celestial signal could be detected.

Installation of the 'Erickson' feed at Parkes during the February shutdown.

Mopra holography

In January 2013 a bushfire swept through the Mopra site. Following the fire, we made photogrammetric measurements of the dish surface to check that its accuracy had not been compromised by the fire's heat. Those tests revealed no adverse effects, but reports of reduced 3-mm efficiency, coupled with experience gained in commissioning ASKAP antennas, prompted us to make the first holographic measurements of the Mopra surface. Initial attempts were troubled by some phase-stability issues but the final observations were very productive, leading us to improve the rms surface accuracy from 260 microns to 160 microns.

National Time and Frequency Network trials

Over the last year the ATCA and Mopra have participated in trials with the National Time and Frequency Network (NTFN) consortium (funded by the Australian Research Council), which is trialling the distribution of time and frequency signals over an optical fibre network. The work has implications for the Square Kilometre Array, as an ability to transfer time and frequency signals from a central location, using the same optical fibre network required to transfer the data to the correlator, would do away with the need for atomic clocks at each site. The ATCA and Mopra tests have used several set-ups, such as looping the ATCA maser signal to Mopra and back before using it at the ATCA, to test the technique.

LBA Mars Express observation

One of the more unusual Long Baseline Array proposals received for the 2013OCT semester was the one to track ESA's Mars Express (MEX) spacecraft as it made a close fly-by of Phobos, one of Mars' two moons. This event was scheduled for 29 December (not a date we would normally contemplate scheduling VLBI!) and was successfully supported by the ATCA, Hobart and Ceduna antennas, and others around the globe. The observations (combined with telemetry from the spacecraft) were to measure the deflection of the spacecraft's trajectory caused by Phobos's gravitational field, thus providing an improved estimate of the moon's mass and composition.

TAC report

The Time Assignment Committee (TAC) met at Marsfield on 4 and 5 February to review and grade the 193 proposals received for the 2014APR semester. Jill Rathborne has taken on the role of TAC Executive Officer; Andrew Walsh, Jimi Green and Jim Lovell all completed terms or stepped down from the TAC before the meeting, and we thank them for their contributions to the TAC. As noted in the 2014APR call for proposals, OPAL has been upgraded with version numbering of cover sheets and observations tables, to ensure that resubmissions are reloaded through the cover-sheet and observation-table editors, as appropriate, to incorporate any changes made to these forms. In its Feburary meeting, the TAC noted the importance of the outreach abstracts the proposers must include in their cover sheets. Whereas the scientific abstract should be comprehensible to a fellow astronomer, the outreach abstract should be comprehensible to members of the general public. Indeed, the outreach abstracts for the 64-m telescope are displayed in the Parkes Visitors Centre, while those for the ATCA are used as part of the ATCA Live webpage. Proposers who simply reproduce their scientific abstract for the outreach abstract can expect to be reproved by the TAC!

ACES

The ASKAP Commissioning and Early Science (ACES) team, under the leadership of Dave McConnell, was created in late 2013 to enhance the commissioning resources, to conduct early science, and to prepare for routine science operations. ACES brings together staff from Operations, the ASKAP project, and Astrophysics. Funding from the NCRIS program administered by Astronomy Australia Limited in part supports these staff, including secondments from Australian universities.

To date the group has been assisting with completing BETA integration: first with BETA-3, the two three-element arrays used to integrate and test the BETA correlator, and now with BETA in its final form as a six-element array (antennas 1, 3, 6, 8, 9 and 15), which has nine formed beams and a bandwidth of 304 MHz. The progress of the commissioning is described on pages 12 to 14. ACES will use BETA, once its operation is routine, to establish regular performance measurements for various aspects of the telescope, and to prepare observing strategies and scripts. BETA-3 data has already been analysed to assess the degree of source structure in calibration fields. This kind of work will continue with BETA, to help the team forecast the kinds of problems to be solved in taking science-quality data with the early stages of the Mark II PAF-equipped AKSAP.

Staff changes

With the departure of Barry Turner as Site Manager at the Murchison Radio-astronomy Observatory last year, Shaun Amy has taken on the role as Acting Site Manager. Shaun's role leading the Computing Infrastructure group is in the interim being filled by Chris Phillips. Also departing last October was Gina Spratt, who had worked at Parkes for 16 years in the various incarnations of the Computing group.

ASKAP and SKA news

FLORNES CONWAY-DERLEY, KATE CHOW and CAROL WILSON (CASS)

Commissioning activities have continued steadily at the Murchison Radio-astronomy Observatory (MRO) over recent months, with a number of 'firsts' achieved with the six Mk I phased array feed (PAF) receivers installed on the ASKAP antennas there.

Additionally, the design of the second-generation (Mk II) PAF receiver system has been validated. Tests of the prototype system have shown excellent system noise-temperature performance of close to 50 K across the entire ASKAP frequency band.

A close-up of a phased array feed (PAF) receiver installed on an ASKAP antenna at the Murchison Radio-astronomy Observatory. Following the successful installation of the first six PAFs at the MRO, commissioning activities are now underway with the engineering test array, 'BETA'.

In November the Square Kilometre Array Organisation announced that CSIRO will lead key research and development pre-construction work packages for the international SKA project, including the Dish and Infrastructure–Australia consortia. CSIRO will also play a key role in the work package for Assembly, Integration and Verification (AIV) and five other consortia.

News from the MRO

AUSTRALIAN AND UK MINISTERS VISIT THE MRO

On Saturday 1 March, Australian Foreign Minister Julie Bishop and UK Minister for Universities and Science David Willetts visited the MRO to learn more about Australia's role in the Square Kilometre Array project. They were accompanied by CSIRO Information Sciences Group Executive Dave Williams and CSIRO Astronomy and Space Science Chief Lewis Ball. ASKAP Project Director Ant Schinckel gave the group a guided tour of ASKAP and the MRO.

Minister Bishop was impressed by the projects under way at the MRO, and noted the importance of collaboration within the SKA project. "Australia and the United Kingdom, together with the other SKA partner countries, are working very hard to design and develop the telescope, and the two SKA precursor telescopes already in place in Western Australia are already leading the way," she said.

Minister Willetts too expressed his enthusiasm for the progress of the SKA project, which is headquartered in Manchester.

Just one week later, Minister Willetts announced funding for the SKA of £100 million — a significant portion of the construction budget for Phase 1.

"After the International Space Station and the Large Hadron Collider, the world's next great science project is the Square Kilometre Array," declared the Minister. "Investment in science is a crucial part of this government's long-term economic plan. It's about investing in our future, helping [to] grow new industries and create more jobs."

Lewis Ball (CASS), Svetozar Kovacevic (UK Science and Innovation Network Australia), Tony Brennan (Deputy British High Commissioner to Australia), Brian Boyle (Department of Industry), Dave Williams (CSIRO), David Willetts (UK Minister for Science), Linda Reynolds (Liberal Party, WA), Joanna Newman (King's College London), Steven Tingay (ICRAR/Curtin University) and Peter Quinn (ICRAR).

ASKAP CORRELATOR RECONFIGURATION CREATES BETA TESTING PLATFORM

The ASKAP hardware correlator at the MRO, which until recently handled two simultaneous three-antenna sub-arrays, has now been reconfigured to process data from a six-element interferometer.

The correlator and the six antennas it serves — the first six ASKAP antennas installed with Mk I phased array feed (PAF) receivers — together form the Boolardy Engineering Test Array, BETA. This system will let the commissioning team prepare for the fit-out of the full 36-antenna telescope.

To integrate the correlator we had to do a significant amount of recabling, and update the associated software to cater for the almost four-fold increase in the correlator's data output.

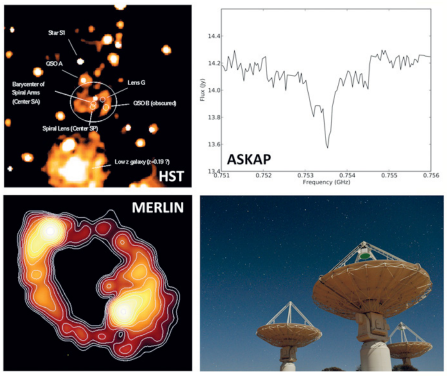
The six-antenna array has greater sensitivity, higher resolution, and greater UV-plane coverage than the previous sub-arrays. Its 15 baselines produce over eleven-and-a-half million data products for every five-second correlator integration cycle.

The successful verification of the hardware correlator output following the reconfiguration (mentioned above) marked the end of basic hardware testing for BETA. The team then turned its attention to carrying out the first astronomical observations using BETA as a 15-baseline array, and soon achieved 'first fringes' on all 15 baselines.

HI ABSORPTION-LINE MEASUREMENT

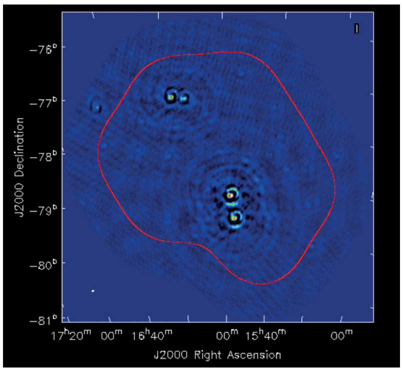
In December 2013, the first HI absorption-line was measured with three ASKAP antennas installed with Mk I PAF receivers. The result showed that the HI spectral-line mode of ASKAP faithfully reproduces results in a well-characterised astronomical region.

A six-hour observation of the gravitationally lensed system PKS 1830-211 was conducted with the three baselines. The data were captured at full spectral resolution using the full bandwidth of the hardware correlator, and a baseline-averaged cross-correlation spectrum was produced.



Using three ASKAP antennas fitted with ASKAP's first-generation phased array feed (PAF) receiver system and the hardware correlator, a baseline-averaged cross-correlation spectrum was produced of the gravitationally lensed system PKS 1830-211. This system has an absorbing galaxy at z=0.89.

The prominent HI absorption feature from an intervening galaxy at z=0.89 can be seen at a frequency of 753.5 MHz. The ASKAP Survey Science Teams were welcome to access the raw data from the test, and found that they agreed well with a spectrum from the Westerbork Synthesis Radio Telescope (Changalur *et al*. 1999) in both the depth and shape of the hydrogen absorption. This bodes well for the ASKAP Early Science spectral-line observations with BETA, and was a great way to end the year.

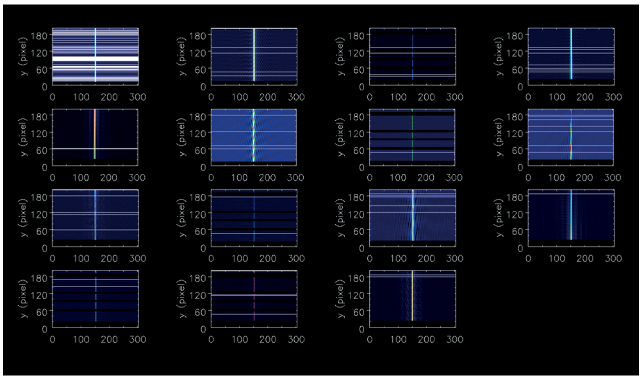


The first continuum image produced with two separate three-antenna 'sub-arrays'.

FIRST SIX-ANTENNA CONTINUUM IMAGE

Back at work in February 2014, the commissioning team achieved the first continuum image made with six ASKAP antennas.

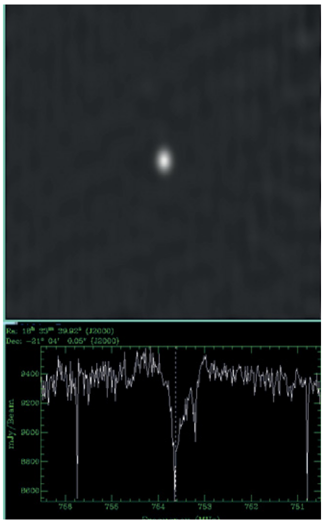
The six were operated as two three-antenna sub-arrays, each producing a separate image. The commissioning team used antennas 1, 3, and 6 to create the first image, taking advantage (for the first time) of the full 304-MHz bandwidth available to BETA. The additional sensitivity this created revealed a number of weaker sources not visible in earlier images. An image made with the second sub-array, antennas 8, 9 and 15, was then combined with the first to create the six-antenna image. The data was processed using the ASKAP central processor at the iVEC Pawsey Centre.

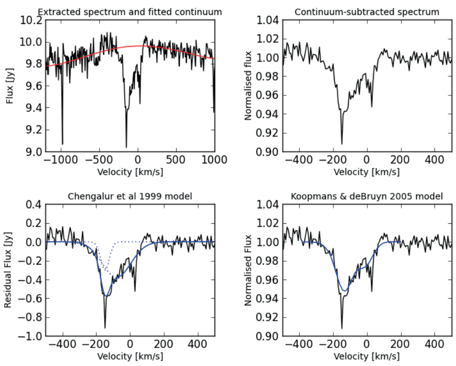


The first 15-baseline observation with BETA yielded fringes on each of the separate baselines.

Most recently, the first result from full BETA commissioning was achieved after a six-hour observation of PKS 1830-211.

The strong HI absorption feature of the chosen source is an ideal target for BETA, as it is one of the few telescopes capable of such an observation at this frequency. The resulting image was the first to use all 15 baselines of the BETA system, and also the first to be made with the array's full spectral resolution of 18 kHz.





The HI absorption feature in PKS 1830-211 as observed with BETA (left), and a comparision with previous observations (right).

Although the image is still preliminary, the spectrum is of particular interest to the ASKAP team. Comparisons between this spectrum and previously observed spectra (made with the Westerbork Radio Telescope, for example) demonstrate the success of the system design and suggest interesting opportunities for scientific follow-up.

The spectral-line image data can be downloaded from the ATNF website.

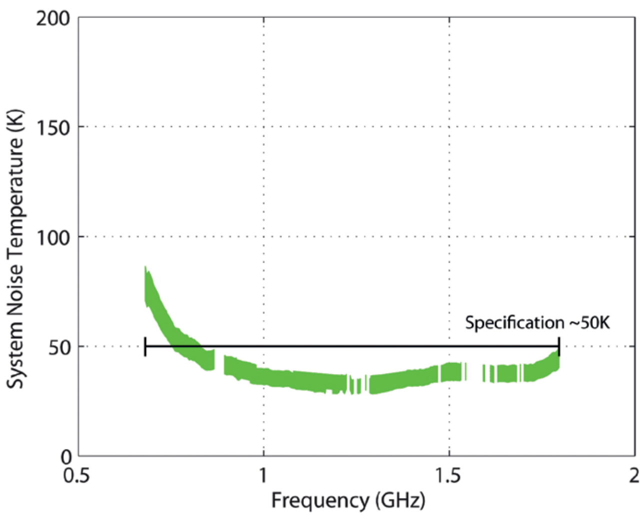
CASDA

The CSIRO ASKAP Science Data Archive (CASDA) is being developed by a team comprising members of CASS and CSIRO Information Management and Technology. The Science Data Archive will be the site at which calibrated ASKAP data products are stored and made available to Survey Science Teams and, after quality verification, other users. (BETA data will be stored in a separate commissioning archive.) The CASDA Preliminary Design Review was held at Marsfield on 11 and 12 March. The review panel comprised experts from the International Centre for Radio Astronomy Research, the Large Synoptic Survey Telescope Corporation, iVec, Swinburne and CSIRO. Preliminary findings and recommendations were provided to the CASDA team at the end of the meeting, and will be followed by a final report in the future.

ASKAP PAF RECEIVERS ACHIEVE PERFORMANCE GOAL

Development of the second-generation (Mk II) receiver chain for ASKAP has been under way through a design optimisation program called ASKAP Design Enhancements (ADE). The ADE program focuses on cost-effective technologies to increase efficiency and digital-processing flexibility while reducing manufacturing complexity, leading to reductions in overall cost and build time.

Successful system-temperature tests of the prototype Mk II system showed excellent system noise-temperature performance of close to 50 K across the entire ASKAP frequency band (0.7–1.8 GHz). These results confirm that the Mk II PAF system will reach performance targets.



The system noise temperature from measurements of a prototype ASKAP Mk II PAF, with estimated uncertainties (currently being refined).

The representative array has 40 elements and was tested as a directly receiving array with the Parkes 'aperture array' test facility.

The result demonstrates very good low-noise performance across the 0.7–1.8 GHz frequency range required for ASKAP. A larger array will perform better at the lower end of this frequency range.

Aperture array tests were performed on a 40-element PAF system, including the Mk II ADE-style tiled chequerboard, front-end assembly and low-noise amplifiers, using a ground-based test facility at the Parkes Observatory.

The test team achieved system-temperature measurements with the 40-element array that are near optimal for the current generation of electronics. The full-size Mk II PAF, made up of 188 elements, is expected to perform somewhat better at the lower end of the frequency range when installed on an ASKAP antenna at the MRO.

These test results are a significant step towards meeting the cost/performance demands of ASKAP and the future international SKA project. Successful verification has led into the production phase of full sized Mk II PAFs, with deployment to the MRO expected later this year.

ADE MK II PAF SUCCESSFULLY TESTED 'END-TO-END'

In March, the ASKAP 'prototype' team achieved the first successful 'end-to-end' test on the Mk II prototype PAF, in a shielded room on site at CASS headquarters in Marsfield.

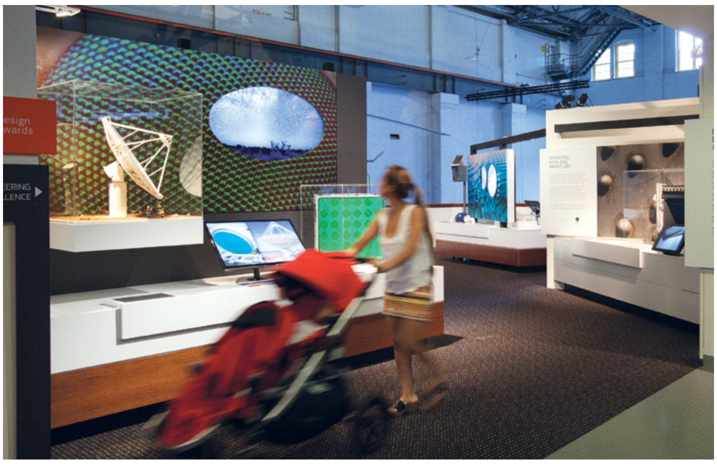
To conduct the 'end-to-end' test, all 188 radio-frequency signals were transported from the PAF via optical fibre to the digital backend located in an adjacent room. The tested system is equivalent to one ASKAP antenna's worth of RF, optical, and digital electronics, and allows the team to test the monitoring, control, and basic function of the RF to digital pathways of the full Mk II prototype PAF.

This is a great step towards preparing the Mk II PAF for a test on site at the MRO. Before testing begins at the Observatory, the Mk II PAF will be equipped with site-ready thermoelectric coolers, power supplies, and a special casing. In parallel, the ADE team is also currently preparing mechanical, cabling, and power system items for installation and testing at the MRO.

The prototype Mk II PAF set up in the SKA Lab, an RF-shielded room at CASS headquarters in Sydney. During the tests all 188 RF signals were successfully transported from the PAF to the digital backend, located in an adjacent room.

ENGINEERING EXCELLENCE ON DISPLAY

As noted in the October 2013 issue of *ATNF News*, CSIRO's PAF technology was a winner in the 2013 Engineering Excellence Awards run by Engineers Australia, at both the Sydney division level and the national level. The PAF is now one of five 'outstanding projects' on show in the Engineering Excellence exhibition at Sydney's Powerhouse Museum, which will run until January 2015. The exhibition also features another prize-winning CSIRO project: the WASP tracking technology (a joint submission with Catapult Sports).



The phased array feed display for Engineers Australia Engineering Excellence Awards, on display at the Powerhouse Museum in Sydney throughout 2014. The display includes a prototype 5 x 4 chequerboard, a moving model of an ASKAP antenna and a series of videos that explain the technology. Credit: Powerhouse Museum.

News from Perth

'GALAXY' GOES LIVE FOLLOWING SUPERCOMPUTER'S OPERATIONAL LAUNCH

The ASKAP central processor, also known as 'Galaxy', is the real-time computer housed in the iVEC Pawsey Centre in Perth. Following the official operational launch of the iVEC Pawsey Centre in 2013, the central processor is now 'live', allowing the ASKAP team access to the supercomputer to support commissioning activities.

With dedicated data processing software, known as ASKAPsoft, now installed at the Centre, the ASKAP Computing team has been working on calibration and imaging of data collected with ASKAP at the MRO, and refining processing pipelines by running simulated observations with Galaxy.

The advantage of the simulations is that the input is completely controlled: any idealised image of the sky can be fed in as an input, producing data files that are processed in exactly the same way as a real ASKAP observation would be. This allows the team to develop and test processing pipelines for the new system and see how ASKAP will respond to different types of observations.

Due to the large size of a typical ASKAP dataset, specific simulation software was developed to accurately model the telescope and handle the large images. The diagnostics taken from the tests provide vital information for planning science observations with the telescope.

SKA activities

LEAD ROLE FOR CSIRO IN SKA RESEARCH AND DEVELOPMENT

In November the SKA Organisation announced a lead role for CSIRO in the next stage of the international SKA project and the development of the world's largest radio telescope, which is to be located in Australia and in Southern Africa.

This followed confirmation that the SKA Organisation had allocated research and development 'work packages' to consortia from around the world (mentioned in *ATNF News* October 2013).

The consortia, involving science institutes and industry, will progress the design and validation processes of the SKA to a stage that will enable tendering and construction of the telescope from 2017.

CSIRO is leading the largest of these consortia, the SKA Dish Array Consortium, responsible for the design work relating to the SKA antenna dishes and receivers, and the development of PAF receivers. CSIRO also leads the Infrastructure–Australia Consortium, which will design and cost critical SKA infrastructure at the MRO (the Australian SKA site), such as that required to provide power, communications, and water, as well as buildings and access to the site.

CSIRO will be a key partner in the Assembly Integration and Verification Consortium, which will prepare for the integration of CSIRO's ASKAP and the South African MeerKAT precursor telescopes into Phase 1 of the SKA telescope. It will also participate in four other SKA consortia, including those designing the telescope control system, and signal processing and data transport.

SKA PRE-CONSTRUCTION UPDATE AND PLANNING WORK

Technical work during 2013 and the first quarter of 2014 mainly focused on defining the system requirements and the interfaces between the different consortia. We have also been providing technical input to the Hosting Agreement for SKA, helping to develop memoranda of understanding and consortium agreements for SKA pre-construction work, and providing technical advice to the Australian SKA Office on site issues.

Over the last few months, CASS has hosted at Marsfield visits by SKA Organisation staff and members of the members of the Low-Frequency Aperture Array (LFAA) and Assembly, Integration and Verification (AIV) consortia, who have come to work on the system requirements and interfaces, and detailed planning for each consortium, as they prepare for upcoming design milestones.

Members of the AIV consortium and SKA Organisation staff also visited the MRO and the Pawsey Centre. The group included included Martin Austin, SKA Organisation

Members of the SKA AIV consortium, SKA Organisation staff and CASS staff at the MRO.

(Engineering Project Manager for Site and Infrastructure in both Australia and South Africa); Peter Hekman, SKA Organisation (Engineering Project Manager for AIV from the SKA Organisation); Adriaan Schutte, SKA Organisation (Power Engineer); Richard Lord, SKA South Africa (consortium lead of AIV); and Mark Bentum, ASTRON (AIV engineer).

All negotiations between consortia and the SKA Organisation on the memoranda of understanding and consortium agreements have been completed, and have been signed by all consortia and their member institutions and organisations. This was a major milestone for the SKA project. The CASS SKA team greatly appreciated CSIRO Legal's expert input into the process.

RADIO QUIET ZONE POLICY AND STAKEHOLDER RELATIONS

The CASS Radio Quiet Zone team continued to provide technical advice to the Australian SKA Office, industry stakeholders and ACMA on the impact on radio astronomy of activity within the Australian RQZ (WA).

Highlights over the past year included working with the Government of Western Australia's Department of Mines and Petroleum on revised guidelines for the Mineral Resource Management Area, followed by successful interactions with industry as they followed the new guidelines; providing technical advice to governments on the Australian SKA Office RQZ work plan; and working with ACMA and governments to provide technical advice on the proposed revisions to RALI MS32, which covers the Australian RQZ (WA).

Collaborator projects

STEVEN TINGAY (ICRAR / CURTIN UNIVERSITY)

The Murchison Widefield Array (MWA) has now completed its first six-month observing semester (July 2013 – December 2013) and is now well into its second semester (January 2014 – June 2014). Full details, including all approved observing proposals, are available at *www.mwatelescope.org*.

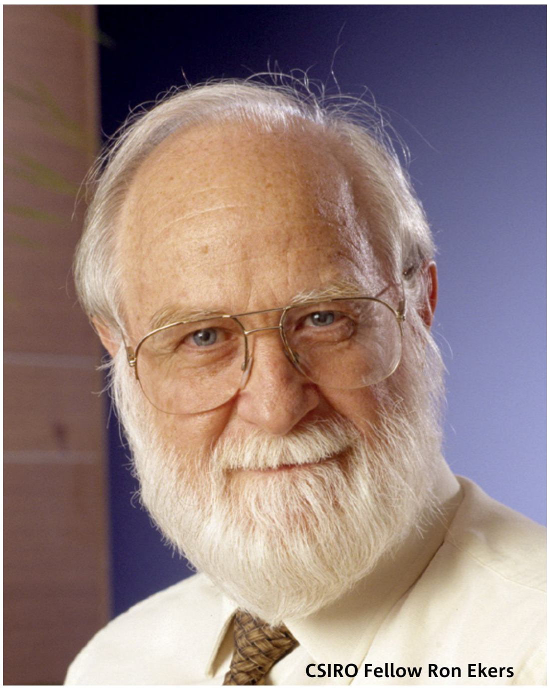
The scientific productivity of the MWA is increasing rapidly, with 14 collaboration papers now published in refereed journals, three papers submitted to refereed journals, four papers circulated for review within the MWA collaboration, and 16 more collaboration papers in preparation.

An open discussion of future MWA extension/upgrade options is currently under way amongst the MWA partner organisations and user community. An open workshop on this topic will be scheduled for a date in September or October, in Sydney. A further open workshop will be held in December in Arizona. Possible MWA upgrade options include the deployment of additional collecting area, deployment of longer baselines, or signal-path upgrades. Views on these and other options will be invited and discussed at the two workshops.

An MWA tile at the Murchison Radio-astronomy Observatory in Western Australia. Credit: Neil Pritchard.

Awards

HELEN SIM (CASS)



CSIRO Fellow Ron Ekers

Ron Ekers awarded Grote Reber Medal

The Grote Reber Medal. Photo: Martin George

CSIRO Fellow and first Director of CSIRO's Australia Telescope National Facility, Ron Ekers, is to receive the 2014 Grote Reber Medal for his lifetime of achievements in radio astronomy. The award will be presented in August, at the General Assembly of the International Union of Radio Science (URSI) in Beijing.

As many in the radio-astronomy community would know, the award is named after pioneering American radio astronomer, Grote Reber. An electrical engineer by training, Reber built the world's first radio dish in the 1930s. He was the world's first radio astronomer — and for about a decade, the only one.

In 1954 Reber moved to Tasmania, where he lived and worked for the rest of his life. The Grote Reber Medal was established by the Grote Reber Foundation to honour Reber's achievements, and is administered by the Queen Victoria Museum in Launceston, Tasmania. It is awarded to astronomers around the world.

Reber lived until 2002, and crossed paths with Ron Ekers, whose career started in the late 1960s.

Ron graduated from the University of Adelaide in 1963 and received his PhD from the Australian National University in 1967 for research done with an interferometer built at CSIRO's Parkes Observatory. He then headed overseas, working in the USA, the UK and the Netherlands before returning to Australia in 1988.

The Grote Reber Medal recognises both Ron's scientific achievements and his technical contributions to radio astronomy. The former include making some of the first high-resolution images of the radio emission from the centre of our Galaxy, work leading to the first measurements of our Galaxy's magnetic field, studies of gamma-ray bursts and merging black holes, and hunting for ultra-high-energy cosmic rays. On the technical side, Ron developed the first interactive computer language for analysing radio astronomy images (GIPSY, the Groningen Image Processing SYstem) and invented a technique that makes it possible to 'mosaic' radio images together.

A third way in which Ron has fostered the growth of the field, and the discoveries and careers of many colleagues, is as a leader of organisations. He was the first Director, post-construction, of the Very Large Array in the USA. In 1988 he returned to Australia to become the first ATNF Director. From 2003 to 2006 he was the president of the International Astronomical Union. He is a Fellow of the Australian Academy of Science, the American Philosophical Society and the Royal Society of London.

Participants of the Astroinformatics 2013 workshop.

Meetings

SIMON JOHNSTON (CASS)

Recent meetings and workshops

PHASE TRANSITIONS IN THE DIFFUSE ISM, 25–27 NOVEMBER 2013 WENTWORTH FALLS, NSW

www.atnf.csiro.au/research/workshops/2013/phasetrans/

This workshop brought together numerical and observational experts (and their datasets) to address questions about the distribution of temperatures and pressures in atomic hydrogen and the conditions under which star-forming clouds form out of the diffuse interstellar medium. The 20 participants were drawn from Australia, the US, France, Mexico, China, and Japan. New collaborations on the nature of 'dark' gas in the Milky Way were built and have already resulted in telescope and grant proposals. The workshop was partially funded through Naomi McClure-Griffiths' CSIRO Newton Turner Award (reported in *ATNF News* October 2013).

ASTROINFORMATICS 2013: KNOWLEDGE FROM DATA, 9–13 DECEMBER 2013 SYDNEY, NSW

www.atnf.csiro.au/research/workshops/2013/astroinformatics/

Astroinformatics is a new discipline that has emerged at the intersection of astronomy/astrophysics and applied computer science and engineering, driven by the challenges and opportunities of exponential growth of data volumes, rates, and complexity from next-generation telescopes such as the Square Kilometre Array and its pathfinders. This international meeting, attended by 100 people, was designed to be a forum for discussion, an occasion for forming cross-disciplinary collaborations, and a starting point for generating the new techniques we will need for next-generation telescopes. It was successful on all three counts. The next measure of success will be when ASKAP turns on and our innovative new algorithms are put to the test! This meeting was sponsored by CSIRO, Microsoft, and eight other partners from industry and academia.

Attendees of the *Phase transitions in the diffuse ISM* workshop. Photo: Di Li (NAOC)

CALIM 2014: THE 8TH SKA CALIBRATION AND IMAGING WORKSHOP, 3–6 MARCH 2014 KIAMA, NSW

www.atnf.csiro.au/content/calim-2014-workshop

This workshop focused on progress in algorithms, software and computing to address the challenges of calibration and imaging with the Square Kilometre Array, its pathfinders, and other major new radio telescopes. It drew 45 participants – 16 from Australia and the rest mainly from South Africa and The Netherlands. The workshop was sponsored by CSIRO, the SKA Organisation and the International Centre for Radio Astronomy Research. Most talks were streamed live and are available to watch on youtube. In particular, see *https://www.youtube.com/watch?v=ZhMb5I_iTjk* for the conference summary.

Future meetings

POWERFUL AGN AND THEIR HOST GALAXIES ACROSS COSMIC TIME, 16–20 JUNE 2014 PORT DOUGLAS, QUEENSLAND

www.atnf.csiro.au/research/workshops/2014/SouthernCrossVII/

THE PERIPHERY OF DISKS, 3–6 NOVEMBER 2014

SYDNEY, NSW

www.atnf.csiro.au/research/conferences/2014/ThePeripheryOfDisks

Science meets Parliament

MATTHEW KERR (CASS)

'Science meets Parliament' is an annual event organised by Science and Technology Australia. This year's CASS representatives were Julie Banfield, Andrew Brown, and Matthew Kerr.

A golden late-summer sun saw 200 scientists swing into Canberra for the 14th iteration of 'Science meets Parliament' on 17 and 18 March 2014.

The event kicked off with a day-long workshop with journalists, policy makers, and politicians offering advice on effectively communicating science to MPs and the world at large. One tidbit: the rising Twitter tide spares no one, so forget your beloved paragraphs, your cherished complete sentences. Short science sells. #whataworld

The focus of the event is the pilgrimage to Parliament House on the second day: roughly 100 MPs met individually with small groups of scientists. Agendas were set by the meeting participants, but generally focused on the importance of a national interest in science from both Parliament and population. The level of engagement was quite high: aside from the meetings, 'Science meets Parliament' delegates were also addressed by the Opposition Leader (Bill Shorten), the Deputy Greens Leader (Adam Bandt), and the Minister for Industry (Ian Macfarlane).

My own meeting, with NSW Greens Senator Lee Rhiannon, was a pleasure, and she was supportive of science funding, outreach, and education. From conversations with other delegates, this type of receptiveness was the norm rather than the exception. Of course, on the road to policy, there is many a slip twixt the cup and the lip! I would encourage anyone interested to attend next year's 'Science meets Parliament': the workshop and meetings are valuable, and meeting other scientists in all their varied fields was a true delight.

A Galactic origin for a fast radio burst?

KEITH BANNISTER (CASS)
AND GREG MADSEN
(UNIVERSITY OF CAMBRIDGE)

'Fast radio bursts' (FRBs) are millisecond-long, dispersed bursts of radio emission. The first of them was reported in 2007 by Lorimer *et al*.; Keane *et al*. (2012) discovered a second, and an additional four were described by Thornton *et al*. (2013). To date, they've been found only with the Parkes radio telescope. The discovery of FRBs has all the makings of a great scientific controversy: there's a paucity of data, a glut of opinion, the observers are baffled and the theorists are having a field day.

What makes these bursts so interesting is their dispersion: it's huge. In most cases, it's much larger than the dispersion we'd expect from our own Galaxy. If our model of the electron distribution of the Galaxy is even vaguely right, then FRBs must be well and truly extragalactic, in fact cosmological. If they're cosmological, then we don't know what type of object makes them. That's why they're interesting.

We have six FRBs. But one of them is markedly different from the others.

The burst reported by Keane was very close to the Galactic plane (b = - 4), which is where pulsars live. Pulsars make dispersed pulses. But the burst's dispersion measure (DM) was larger than that accepted for the Galaxy (DM_{burst} = 746 pc/cm^3, DM_{model} = 533 pc/cm^3), which put it in the extragalactic camp.

What happened next is a long story of happy coincidences. This burst came from a part of the Galaxy called the 'Scutum star cloud', which is not so much a cloud of stars as a hole in the dust in the Galaxy. In 2005 Greg Madsen wrote a paper about the electron distribution in the Scutum star cloud using Hα and Hβ observations from the WHAM telescope. And, fortunately, the Scutum star cloud is in the first Galactic quadrant.

We used Greg's Hα and Hβ data to estimate an extinction-corrected emission measure

(EM) along this line of sight. That gives us an estimate of the integral of the square of the electron density along the line of sight out to some distance where either the dust extinguishes all the photons, or we run past the edge of the Galaxy. The EM by itself can't tell us how the gas is distributed, because the same EM could come from a big clump of gas near us or a lot of gas distributed thinly along the line of sight.

But, the second piece in the puzzle was the position in the first Galactic quadrant. At this position the rotation of the gas around the Milky Way makes it look like all the gas is coming towards us. Greg noticed that, in the Scutum star cloud, you can see all the way out to where the gas velocity is at its theoretical maximum, a distance of 8 kpc. This means we know that gas contributing to our EM is at least 8 kpc away. We also took a guess to say that the Galaxy finishes at about 22 kpc along this line of sight. We don't exactly know where our view of the gas ends, but dust probably extinguishes it somewhere between 8 and 22 kpc. We call that distance the Hα distance.

A final piece of the puzzle: EM is not the same as DM, and it's the DM we really want to know. The one is related to the other by a 'filling factor'. We don't know the filling factor at this position, but a few people have made decent measurements around the Galaxy. Those measurements generally fall in the range of $0.03 < f < 0.3$.

So we have a range for filling factor, a range for the Hα distance, and equations that relate those numbers to the pulse distance. We applied a little 'Monte Carlo' magic to those numbers and got an answer, or rather a range of answers. How? We chose f and the Hα distance at random between the ranges, and computed the implied distance of the pulse. We did that for 10,000 random choices, and looked at the range of implied pulse distance.

The result? In 90 per cent of cases, the pulse distance was less than 22 kpc — that is, within the Galaxy. This implies that if this pulse came from a pulsar, it must be an unusual pulsar (such as a very-low-duty-cycle rotating radio transient). And if the pulse is Galactic but not from a pulsar? It could have come from an evaporating black hole, but we'll never know for sure. What about the 10 per cent chance the pulse is extragalactic? Well, then it's just another FRB.

So, what about those other FRBs? They're safe for the moment. All of the Thornton and Lorimer bursts had a much larger excess DM, and our knowledge of the Galactic DM is arguably better for high Galactic latitudes. We just can't find enough gas in the Galaxy to explain their DM. Sadly, we can't play our game with the rotation curve of the Galaxy that high up either, we can't investigate those bursts. But if someone finds one near the plane again, we might just be able to do something ...

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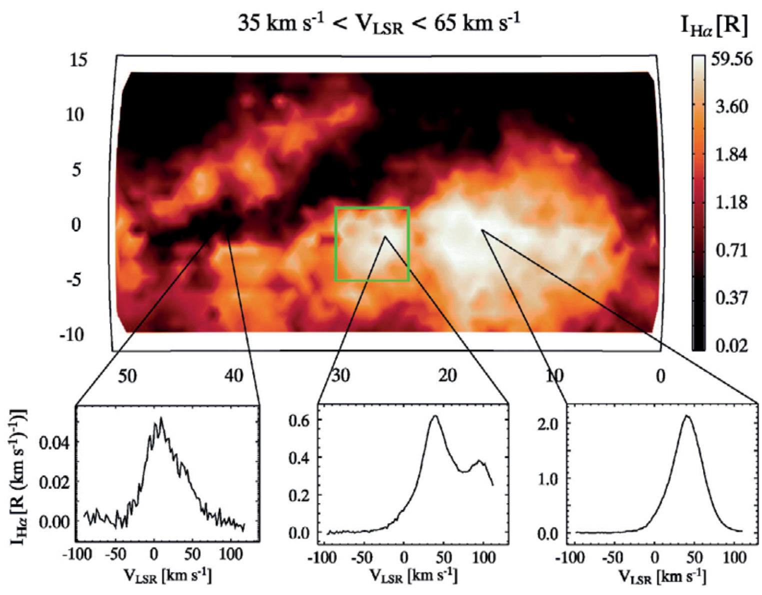

Figure 1. Hα map and spectra from the WHAM-NSS toward the inner Galaxy. The green box is the low-extinction window towards the Scutum star cloud. (Madsen G.J. and Reynolds R.J., ApJ, 630, 925 (2005). Reproduced by permission of the AAS.)

New postdoc appointment

HELEN SIM (CASS)

Since the October 2013 edition of *ATNF News* was published, CASS has welcomed Gregory Hellbourg, an engineering postdoc, who has previously worked at ASTRON and Nançay. He will be working with Aaron Chippendale on radio-frequency interference (RFI) mitigation techniques, and describes his project below.

GREGORY HELLBOURG

PhD: University of Orleans, France, 2014

"My research interests lie in spatial and statistical signal processing. My PhD was about spatial RFI processing for antenna array-based radio telescopes. I worked particularly on statistical approaches to estimating the RFI subspaces, this information being crucial for subtracting them from observations. I am now working on RFI mitigation with phased array feeds for ASKAP. The main goal of this project is to build reliable interference-suppression algorithms, using all the information available for tracking and predicting the RFI subspaces."

Undergraduate Vacation Scholarship program

ROB HOLLOW (CASS)

CASS welcomed eight students for the 2013–2014 Undergraduate Vacation Scholarship program. Each carried out a research project under the supervision of one or more CASS staff.

STUDENT	CASS SUPERVISOR(S)	PROJECT
Addison Clune (University of Sydney)	Matthew Kerr	A timing treasure trove: tackling the rich legacy of Fermi and Parkes pulsar data
Ly Duong (ANU)	Tim Shimwell	Characterising a local radio galaxy
Stanley He (UNSW)	Malte Marquarding	Monitoring airborne RFI sources
Kelvin Hsu (University of Sydney)	Matthew Whiting	Astronomical source finding
Mitchell Kiczynski (University of Newcastle)	George Hobbs	Why do some pulsars suddenly switch off?
Janet McKeown (Open University)	Shari Breen and Yanett Contreras	How are the biggest stars in our galaxy formed?
Gabriel Murphy (University of Sydney)	Amy Kimball and Nick Seymour	Hunting for hidden black holes
Mia Walker (University of Western Australia)	Aidan Hotan	Beamforming with ASKAP phased array feeds

The students were introduced to the breadth of radio-astronomy science and technology through a series of talks by CASS staff. They took part in a dedicated PULSE@Parkes session in December before travelling to Narrabri in January for a week to observe with the Australia Telescope Compact Array under the guidance of Ioannis Gonidakis and Amy Kimball. All the students presented talks about their research at the annual CSIRO Big Day In held at the University of New South Wales in February. Some are continuing their research informally with us, and we hope to see many of them back as co-supervised PhD students in the near future.

Many CASS staff contributed to the success of this year's program, generously giving their time as supervisors, as speakers, or in helping the students with their observations.

The vacation scholarship students at Narrabri. Photo: Ly Duong

Graduate Student program

GEORGE HOBBS (CASS)

The CASS Graduate Student program continues to attract high-quality students from around the world to study a huge array of different astrophysical problems. Current students are researching various astrophysical objects including masers, pulsars, black holes and galaxies and developing new techniques related to radio polarimetry, broadband observations and wide-field VLBI. Details of the program are available at *www.atnf.csiro.au/research/student/*.

We congratulate the following students who have recently completed their PhD projects:

Guillaume Drouart (European Southern Observatory): "AGN and star formation history in high redshift powerful radio galaxies"

Claire-Elise Green (University of New South Wales): "The relationship between starbursts and black holes in galaxies"

Rai Yuen (University of Sydney): "Pulsar magnetosphere revisited: emission geometry and the synthesis of the vacuum-dipole and the rotating-magnetosphere models".

We would like to officially welcome the following students into the program:

Francesco Cavallaro (University of Catania): "Stellar radio emission in the SKA era: surveys of the Galactic plane"

Timothy Galvin (University of Western Sydney): "Radio emission from star-forming galaxies at high and low-z"

Daniel Reardon (University of Monash): "Bayesian analysis of pulsar timing array data to study noise properties of pulsars"

Stuart Weston (AUT University): "Data mining for statistical analysis of the faint radio sky: the pathway to EMU".

If you are interested in joining the program, or wish to learn more about it, visit *www.atnf.csiro.au/research/student* or contact George Hobbs (George.Hobbs@csiro.au).

Scientific Visitors program

NAOMI MCCLURE-GRIFFITHS (CASS)

CASS welcomes applications to the CASS Scientific Visitors program for visits of between two weeks and one year. Typical financial support covers the cost of on-site accommodation at CASS headquarters in Marsfield or its equivalent (approximately A$500 per week). Visitors may be located at any of the ATNF sites and are expected to deliver at least one colloquium or seminar during their stay at CASS.

We also encourage extended visits of six or twelve months. For these longer visits there is the possibility to seek additional funds through CSIRO. Please contact the Head of Astrophysics, Simon Johnston, for more information.

Potential visitors should make contact with a local member of staff or Simon Johnston to develop a proposal. Proposals to the program should include a brief description of a collaborative project to be conducted during the visit, an estimate of the dates of the visit and support required, a current CV and a list of publications.

Over the past six months we have hosted seven visitors through the Scientific Visitors program:

Marios Karouzos (Seoul National University)

Tony Willis (Dominion Radio Astronomical Observatory)

Tanio Diaz-Santos (Caltech)

Marcello Giroletti (INAF Istituto di Radioastronomia)

Hayley Bignell (ICRAR/Curtin University)

Snezana Stanimirovic (University of Wisconsin-Madison)

Lei Zhu (National Astronomical Observatories of China).

For more on the scientific visitors program visit *www.atnf.csiro.au/people/scientific_visitors.html* or contact Simon Johnston (Simon.Johnston@csiro.au).

The Mopra Southern Galactic Plane CO Survey

MICHAEL BURTON, CATHERINE BRAIDING (UNIVERSITY OF NEW SOUTH WALES); AND GAVIN ROWELL (UNIVERSITY OF ADELAIDE)

The Mopra telescope

Molecules in the Milky Way

Molecular gas lies at the heart of the Galactic ecology. One of the basic activities in a spiral galaxy like our own Milky Way is the continual collection of gas and dust into giant clouds of molecular gas with masses of order 10^5 $M_\odot$. It is within these clouds that stars then form. Surveys of the molecular medium of the Galaxy play an essential part in understanding where and how star formation takes place. Yet the bulk of the molecular gas (that is, the H_2) is impossible to see directly: at the 10–20 K temperatures typical of molecular clouds the hydrogen molecule is found virtually entirely in its ground rotational states. We need to use the second-most abundant molecule, carbon monoxide (CO), so that the distribution of the molecular gas can be charted in interstellar space, as CO is readily excited at the prevailing temperatures and densities within molecular clouds.

CO provides one of the three wayside markers along the Galactic 'carbon trail' — the element carbon found in its ionised (C^+), atomic (C) and molecular (CO) forms in clouds of gas. The carbon trail provides a means of following the life cycle of the interstellar medium as it shifts between the different phases of the gas, as clouds are continually formed and destroyed during the star-gas cycle underlying the galactic ecology. Stars form within the densest parts of the molecular gas. Molecular clouds provide the reservoir from which the next generation of stars are conceived, as well as a dump where the waste products of stellar nucleosynthesis end up, expelled through winds from previous generations of stars. Through mapping the molecular gas we can see both where star formation is occurring now, and where it will do so imminently. The brightness and kinematics of the various CO lines tell us what the physical state of the gas is. When combined with the other principal tracers of the gas (that is, the C, C^+ and the H), the transitions between the different physical states can be followed. Further, those places where atomic carbon resides *without* molecular carbon (that is, CO) may indicate the presence of dark molecular gas — an as-yet uncharted portion of the molecular medium which might actually comprise as much as one-third of it (see, for example, Wolfire *et al*. 2010). Molecular clouds also provide the columns of nuclei with which high-energy cosmic rays interact, so producing TeV-energy gamma rays. Properly interpreting the maps produced by gamma-ray telescopes (see, for example, Aharonian *et al*. 2006), of emission processes related to some of the highest energy particle accelerators in the cosmos, requires knowledge of the distribution of the molecular gas — where nature is at its most quiescent.

The pre-eminent view currently available of the southern molecular sky comes from the Colombia survey, a composite of several independent projects undertaken with a 1.2-m telescope in Chile that was put together by Dame *et al*. in 2001. Their data cubes of the ^{12}CO J=1–0 line emission are the prime source used today by many astronomers when they need to know where the molecular gas lies in the fourth quadrant of our Galaxy. They provide this view with an angular and spectral resolution of 9 arcminutes and 1 km/s for the principal isotopologue of the CO molecule. This was adequate when the corresponding continuum view of the dust emission came from the Infrared Astronomical Satellite (IRAS), with its several-arcminute resolution. Now, however, with infrared and terahertz imaging from Spitzer and Herschel at better than 30-arcsecond resolution, this is no longer the case. A better view of the molecular sky is needed for the science that is now being undertaken.

The Mopra Survey

Only one facility is capable of obtaining a picture of the molecular gas of the southern sky that is comparable to that which we now have for the dust: the Mopra telescope. With on-the-fly mapping and the 8-GHz-wide correlator of the UNSW–MOPS (built as the result of a successful Australian Research Council linkage project with CSIRO), multiple lines can be mapped simultaneously with spectral resolutions of ~0.1 km/s. The downside is that, with just a single-pixel detector, the mapping of tens of degrees of sky needed for a survey is a big challenge, requiring the investment of many weeks of telescope time. This inspired the implementation of a ‘fast-mapping’ mode of operation, whereby the data is divided into 8 x 256-ms bins during each 2-sec cycle time of the telescope. This has allowed scanning rates to be increased by an order of magnitude without degrading the angular resolution. Of course, there is a penalty in sensitivity, of a factor $\sim\sqrt{8} \approx 3$. Fortunately the CO lines are sufficiently bright that this loss does not seriously affect performance. Both ^{12}CO and ^{13}CO can be readily measured along the Galactic plane, and even the $C^{18}O$ line is detected at the brightest regions. Mapping multiple isotopologues

PARAMETERS OF THE MOPRA SOUTHERN GALACTIC PLANE CO SURVEY					
Line	**Frequency (GHz)**	**Spectral Resolution (kms)**	**Bandwidth (km/s)**	**Sensitivity (K (per channel))**	**Angular Resolution (arcmin)**
CO J=1–0 (^{12}CO)	115.27	0.1	1050	1.5	0.6
^{13}CO J=1–0	110.20	0.1	740	0.7	0.6
$C^{18}O$ J=1–0	109.78	0.1	730	0.7	0.6

also provides an additional gain over the previous surveys: it allows us to estimate the optical depth, from which we can determine the column density of the gas — an essential parameter for quantifying how much material is out there.

Maps are obtained by scanning the telescope 1° in either latitude or longitude, then moving to a sky-reference position. The next scan is then taken, shifted by 24", and the routine repeated. This provides a footprint that is 1° x 6′ in size and takes an hour to complete. Twenty such scans allow a 1°x1° block to be mapped, with each position covered twice (in longitude and latitude). With overheads, typically four transits are needed to survey one square degree of sky in this manner. The end result is a survey with both an order of magnitude better angular and spectral resolution than the Colombia survey, and in three lines of CO not one. Figure 1 shows a representative image from our dataset in the G323 region, illustrating the gain in angular resolution for the Mopra survey.

Our plan is to survey half the fourth quadrant, *l* = 300°–345°, extending 0.5° out of the plane (that is, *b* = ±0.5°). After three seasons of observing we have managed to cover 28 square degrees of sky. With the survey funded for two further seasons this target remains on track. The survey region is shown in Figure 2, overlaid on a Spitzer infrared image. Contours of CO emission from the Colombia survey are overlaid with the corresponding contours from the Mopra survey data for the *l* = 320°–330° region that we so far have fully processed — though at the scale shown here, these appear as fine wrinkles, such is the improvement in resolution!

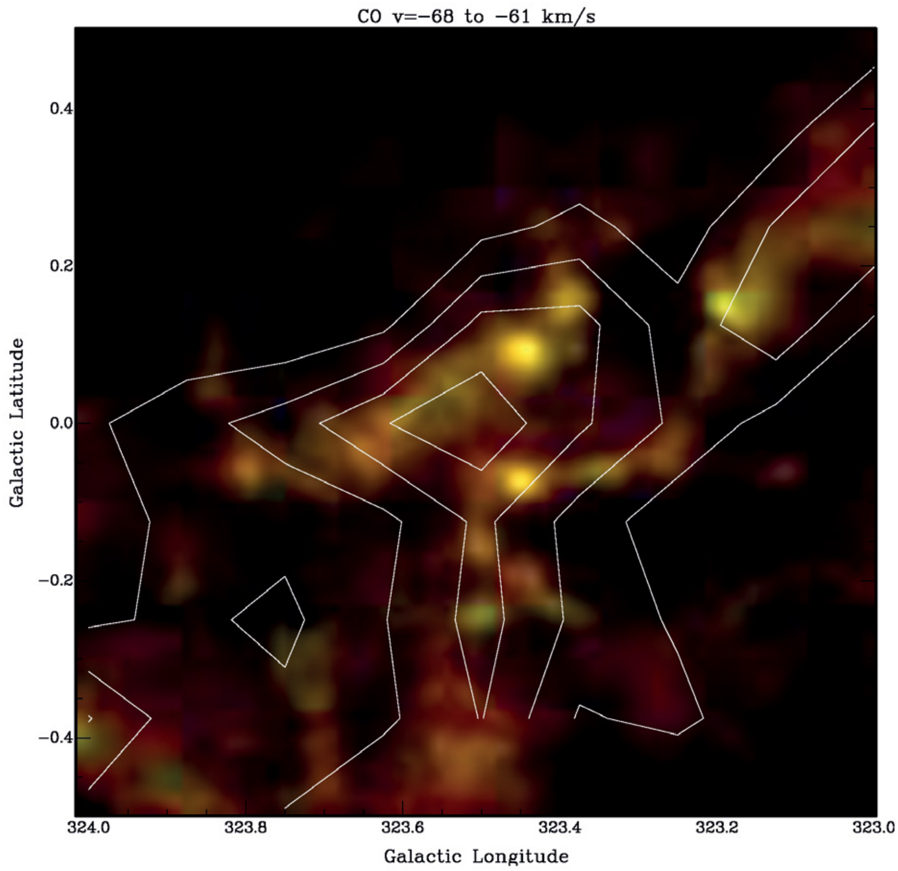

Figure 1. Integrated flux image for the CO emission in the G323 region of the survey. In red is the ^{12}CO data and in green the corresponding ^{13}CO data. They are overlaid with contours of ^{12}CO line flux from the Colombia survey (Dame *et al*. 2001), illustrating the improvement in resolution of the Mopra survey. The velocity range shown is from V_{LSR} −68 to −61 km/s.

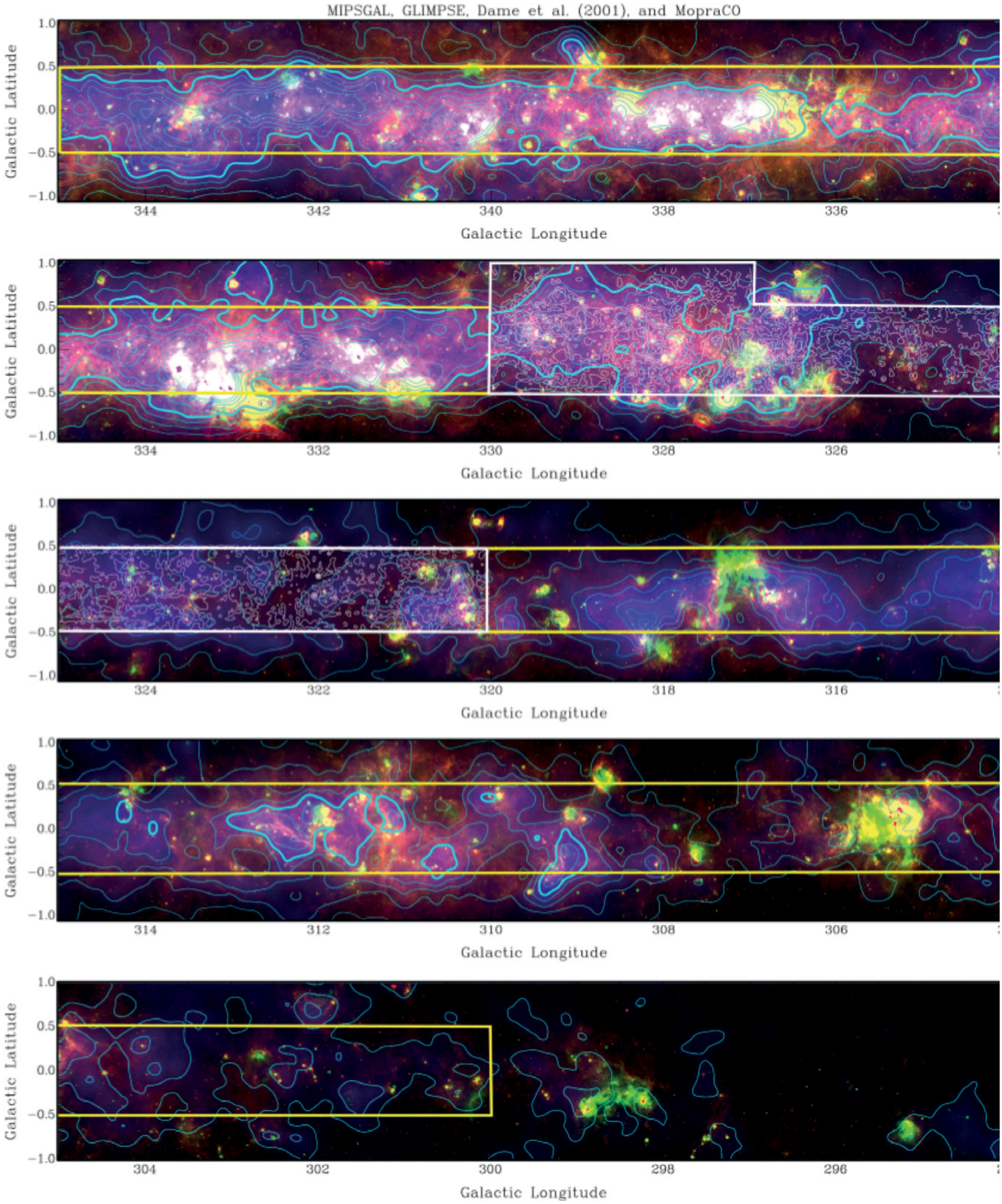

Figure 2. Spitzer/GLIMPSE+MIPSGAL 8 (red)+24 (green) µm image, with the Dame *et al*. (2001) ^{12}CO data in blue along the Galactic plane in the 4th quadrant, shown as a series of panels with 1° overlap between each. These are overlaid with contours of ^{12}CO emission. The smooth blue contours are from the Colombia survey of Dame et al. (2001), in spacings of 20 K.km/s, with the thick line being 100 K.km/s. The wrinkled white contours within the white box show corresponding data from our Mopra survey (integrated over –100 to 0 km/s; note that the survey has indeed been extended to *b* = +1° from *l* = 327°–330°). The yellow rectangle, from *l* = 300° to 345°, *b* = ±0.5°, shows the region planned for our survey; currently we have surveyed from *l* = 314° to 342°.

Related survey programs are also being undertaken of the Central Molecular Zone and Carina regions of the Galaxy, covering slightly larger ranges in *b*. Of course, it would be desirable to extend the survey further, all the way across the fourth quadrant, as well as to ±2° to include the bulk of the molecular gas of the Galaxy, but such a project would require a multibeam receiver before it became a feasible proposition. There will be a need for such capability, however, in order to properly interpret the data from the forthcoming Cherenkov Telescope Array (CTA; Acharya *et al*. 2013), which will image the southern gamma-ray sky at ~1 arcminute resolution. The molecular gas is one of the main sources of the nuclei which, when impacted by high-energy cosmic rays, become one of the sources of gamma-rays that the CTA will see.

Some sample results

The science that can be addressed with a new view of the southern Milky Way is extensive. Our own principal objectives are twofold. One is to probe the connection between gamma rays, cosmic rays and the molecular gas. The other is to understand the formation of molecular clouds — a rate-limiting step for star formation — by following the evolution of elemental carbon through its ionised, atomic and molecular forms. There are many other applications, however, and we hope that the dataset will provide an invaluable resource for others. We show some results here to illustrate what the survey can provide.

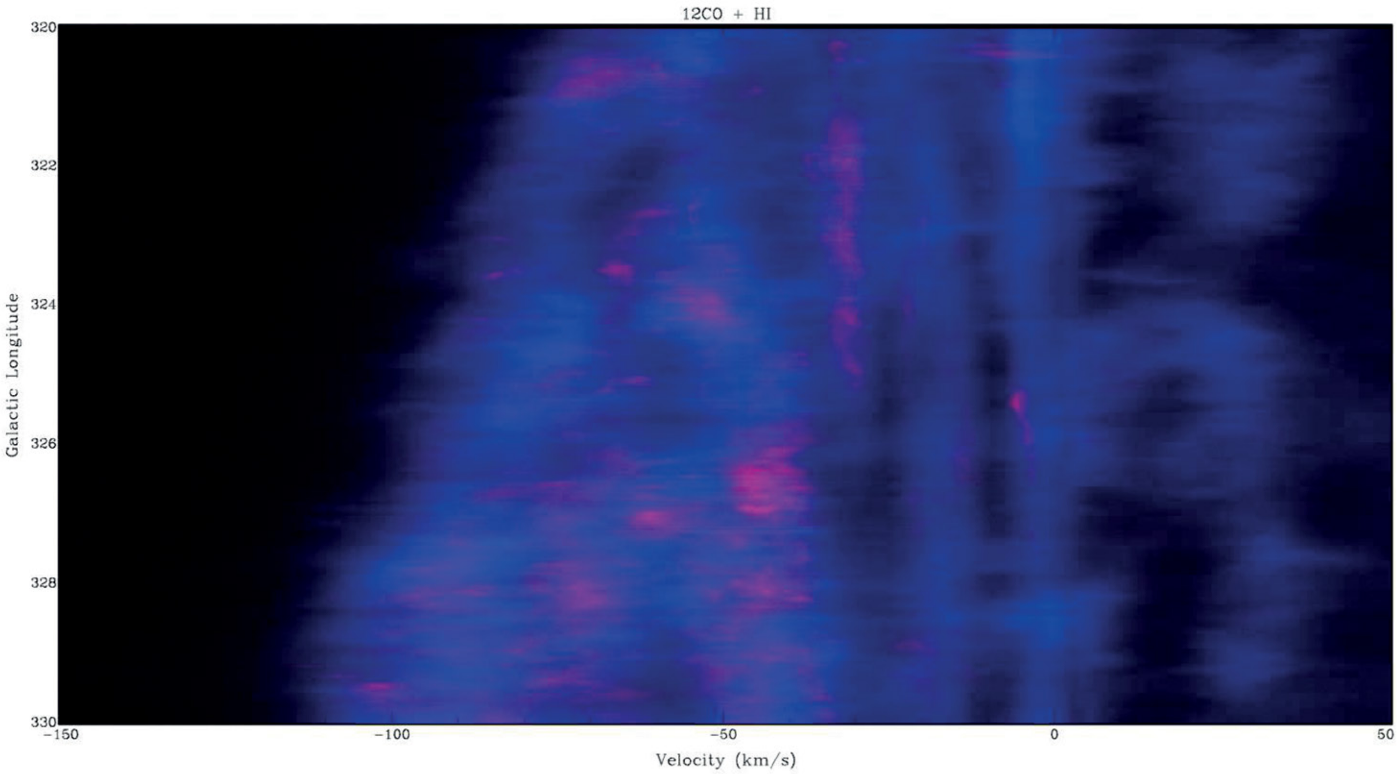

Figure 3. Position-velocity images from data cube for the ^{12}CO line (in red) together with the corresponding 21cm HI data (in blue) from the Parkes–ATCA Southern Galactic Plane Survey (SGPS; McClure-Griffiths *et al*. 2005). V_{LSR} radial velocity is plotted against Galactic longitude, *l*, running from 320° to 330°. The data has been averaged over the entire degree. Several bands are seen running across the images at roughly constant velocities. These may be identified with spiral arms crossing this sight line (the Sagittarius–Carina arm around –20 km/s, Scutum–Crux arm around –50 km/s and the Norma–Cygnus arm around –80 km/s).

The position-velocity diagram in Figure 3 illustrates the complexity of the emission structure in comparison to the much smoother distribution of the atomic gas. The bands in this image represent the spiral arms crossed along the sight line through this sector of the Galaxy. Such structure bedevils the interpretation of dust continuum data, for the various contributing regions to the emission cannot be separated out. The kinematic information obtained from spectral-line data, however, does allow such a separation to be performed. Figure 4 illustrates the kind of cartographic view we aim to produce: a 3D-distribution of the molecular gas through the fourth quadrant of the Galaxy shown as a plot of density versus distance, here averaged over the 1° survey region of G323.

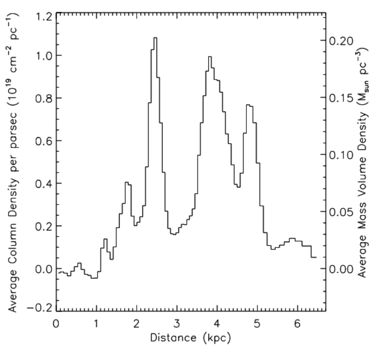

Figure 4. Column density per parsec integrated over the entire 1° aperture of the G323 region. Distances from the Sun, in kpc, assume the near-solution for the radial velocity and the data has been averaged over 1 km/s bins. The column density per parsec, in units of 10^{19} cm^{-2} pc^{-1}, is shown on the left-hand axis, and as average mass density in $M_\odot$ pc^{-3} on the right-hand axis.

In this region we see concentrations of molecules associated with six distances along the sight line. CO emission extends for ~300 pc through each of these, and is separated by ~1 kpc from the next molecular-cloud concentration. Molecular column densities within the spiral arms are ~10^{19} cm^{-2} per pc, yielding total columns of several times 10^{21} cm^{-2} per spiral arm. Corresponding molecular densities are ~0.1 $M_\odot$ pc^{-3} or n_{H2} ~1 cm^{-3}. The total molecular mass through the *l* = 323° square degree of the Galaxy is ~2 x 10^6 $M_\odot$. A 3D rendering of the view is shown in Figure 5, here for another sight line along G328, of the ^{12}CO and ^{13}CO line emission.

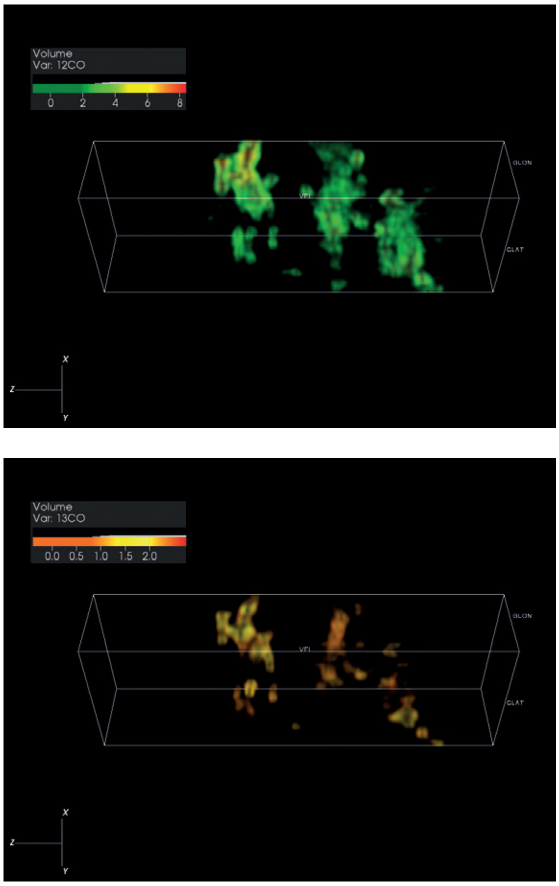

Figure 5. Volume renderings of the ^{12}CO (top) and ^{13}CO (bottom) data cubes in the G328 portion of the Mopra survey. The giant molecular clouds from three separate spiral arms are clearly identified. The long axis is the velocity, related to the distance from the Sun through application of the Galactic rotation curve. The two short axes are Galactic longitude and latitude. Credit: Geoff Sims.

Data availability

The project is described in detail in a recently published PASA paper (Burton *et al.* 2013), which presents the data for the first degree surveyed (the G323 region). The data cubes are being made publicly available as they are published; see the project website for details (*www.phys.unsw.edu.au/mopraco*). The data is also being placed on the ATNF online archive for such access. The next data release is planned to cover the l = 320°–330° sector (Braiding *et al.* 2014, in preparation). However, if your interests take in other regions of the survey area, please contact us to discuss early access to the requisite data.

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Acknowledgements

The Mopra Southern Galactic Plane Survey is supported through the award of a Discovery Project grant by the Australian Research Council (DP120101585) and by the University of New South Wales and the University of Adelaide for the purchase of telescope time from CSIRO. The project is made possible by the superlative performance of the Mopra telescope, whereby remote observation is routine and problems are few. We are grateful for the tremendous contributions made by many CASS staff to making this possible.

Education and outreach

ROB HOLLOW (CASS)

CASS staff have been busy in the past few months with a range of outreach and education activities around Australia.

Mentoring in the Murchison

Lisa Harvey-Smith, Yanett Contreras and Rob Hollow visited the Pia Wadjarri Remote Community School, in the Murchison region of Western Australia, on 18 November 2013, to provide mentoring. The next day, staff and students of the school visited the Murchison Radio-astronomy Observatory for hands-on activities and a tour of the control building and the central antennas.

CASS astronomer Maxim Voronkov with a student from the Pia Wajarri Remote Community School.

Pulse@Parkes

PULSE@Parkes continues to attract strong interest. Observing sessions are now routinely held in the Science Operations Centre at Marsfield, giving participating students an even better feel for what happens during normal observing. Rob Hollow, the project coordinator, presented a talk on the evolution of the project at the IAU *Communicating Astronomy with the Public* conference in Warsaw in October 2013. An observing session in December allowed our undergraduate vacation scholars to use the Parkes radio telescope for the first time. In February we visited the Victorian Space Science Education Centre for another observing session involving several schools. Additional sessions have been added for the next semester, allowing more schools to get involved.

Radio Galaxy Zoo

CASS scientists, particularly Julie Banfield and Ivy Wong (now at ICRAR), have played an important part in developing an exciting new citizen-science project. Radio Galaxy Zoo (described on page 6–7) launched just before Christmas 2013 as one of the Zooniverse projects. Participants match radio images with those from infrared surveys, helping astronomers to identify potential supermassive black-hole candidates. The project is helping us learn how the public interacts with radio-astronomy data, which will allow us to create engaging citizen-science projects that use the massive data stream expected from ASKAP.

Teacher workshops

Teacher workshops have continued apace. We ran a special one-day workshop in western Sydney in December as part of CASS's involvement in Opening Real Science: Enhancing the Teaching of Mathematics and Science Teachers. This is a new, three-year program, led by Macquarie University, which is designed to improve the quality of science and mathematics teaching by exposing current and trainee teachers to real science. We held other workshops at teacher conferences in Melbourne and Brisbane, both in November; at a physics teachers' conference at Monash University in February; and at a primary-school teachers' conference in Brisbane in March. This last workshop was the first formal session of the Universe Awareness program in Australia. CASS's Ray Norris gave the keynote address, on Indigenous astronomy and navigation.

Phil Crosby, Ray Norris and Rob Hollow represented CASS at the popular *Astrofest* held in Perth on 8 March. Ray spoke about Indigenous astronomy and our SKA stand was swamped by people wanting to make Lego SKA antennas! The event was incredibly popular, with more than 3,500 people attending.

CASS's Phil Crosby helping children build their own Lego SKA antennas at the Perth *Astrofest*.

Other outreach

Several CASS staff have been actively involved with specific schools as part of the CSIRO-managed *Scientists in Schools* program. CASS has also been well represented on the Working Group for education, careers and training for the upcoming Australian Astronomy Decadal Plan.

The Australia Telescope Compact Array

Publications

The list below is of published refereed papers that use ATNF data or are by CASS authors, and has been compiled since the publication of the October 2013 issue of *ATNF News*. Papers that include CASS authors are indicated by an asterisk. Please email any updates or corrections to this list to *Julie.Tesoriero@csiro.au*.

Publication lists of papers that include ATNF data or CASS authors are also available on the ATNF website at *www.atnf.csiro.au/research/publications*.

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Removing the radome cover from the Parkes telescope's focus cabin in February. Photo: John Sarkissian

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