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FRONT COVER IMAGE Image of the centre of the Milky Way Galaxy taken at the Boolardy Accommodation Facility that supports the Murchison Radio-astronomy Observatory in Western Australia. Credit: Andrew Ng

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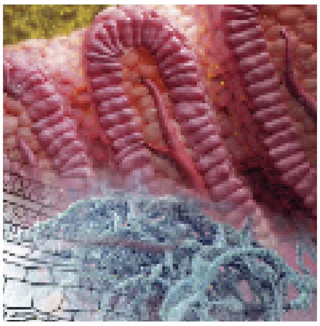
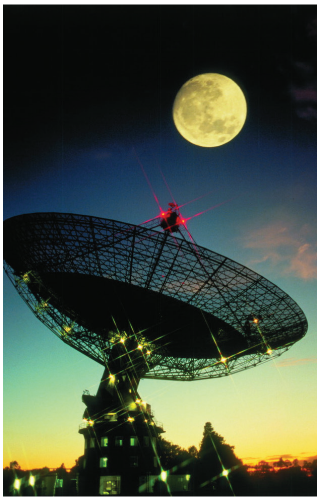
issue 78





From the Director

This newsletter covers a remarkably wide range of activities and events, reminding us of the breadth of the Australian astronomy community and the many ways that CSIRO Astronomy and Space Science (CASS) contributes to that community.

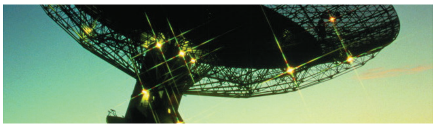
As operators of Australia's national facility for radio astronomy we strive to be a strong member of a strong astronomy research community. The partnerships that underpin our contributions to the Square Kilometre Array project; the delivery of the exciting new ultra-wideband low-frequency receiver being developed for the Parkes telescope; the collaboration with the Max Planck Institute that will soon see a CSIRO-designed phased-array feed commissioned on the Parkes telescope and then deployed on the Effelsberg telescope in Germany: all demonstrate the importance of collaboration.

The commissioning of our Australian SKA Pathfinder (ASKAP) continues apace and in this newsletter we report on the very exciting progress being achieved by the ASKAP Commissioning and Early Science team as it works with the first six-antenna system we call BETA (the Boolardy Engineering Test Array). The commissioning team is made up of CSIRO staff and experts seconded from a number of universities all working together to explore this very new way of doing radio astronomy. We have now submitted three scientific papers describing results achieved in the course of commissioning: each paper demonstrates a unique new capability that ASKAP will bring to astronomers. One of the results, a detection of neutral hydrogen, is described by Paolo Serra in this newsletter.

As operators of Australia's national facility for radio astronomy we strive to be a strong member of a strong astronomy research community.

Of course a (very) small army of dedicated engineering, technical and administrative staff underpins the delivery of all such facilities and ASKAP is no exception. The recent Australian Innovation Award given to ASKAP was wonderful recognition for all those who have worked so hard to deliver the project. The whole team is continuing that hard work to complete the second-generation of phased-

Our other facilities are continuing to deliver world-class science, and this newsletter covers some examples.



array feeds. I have just seen the first few of those complete, packed and ready for transport to the Murchison Radio-astronomy Observatory.

Our other facilities are continuing to deliver world-class science, and this newsletter covers some examples. Emily Petroff (Swinburne University) describes how Parkes is playing a leading role in the detection and study of the enigmatic 'fast radio bursts' (and giving her plenty of media experience in the process). Martin Bell (CSIRO) reports on a survey of the Chandra Deep Field South using the Compact Array that gives insights into science that ASKAP will deliver. Finally, Amy Kimball (CSIRO) relates some of the fascinating results coming from data collected through the extremely competitive observing program of ALMA (the Atacama Large Millimeter/submillimeter Array).

I am especially proud of the leadership provided by the CASS Diversity Committee that has resulted in a bronze Pleiades Award. Preparing to enter the Awards was a valuable exercise in itself, and we will build on the momentum that generated, and the strong commitment of our staff, to strengthen our performance in the areas of gender equity, diversity and indigenous engagement.

In recent months Australian astronomers have continued to wrestle with three big issues: SKA re-baselining, the governance of Australia's national and international astronomical facilities, and the National Collaborative Research Infrastructure Scheme (NCRIS). On the last, the Federal Government recently confirmed NCRIS funding would continue for 2015–16 and 2016–17. The governance issue is still under consideration. The SKA re-baselining decisions are outlined on page 8: the process was necessary to reconcile the scope and cost of the first phase of the project, but the deferral of the expansion of ASKAP into a much larger SKA Survey telescope is extremely disappointing and is requiring a very difficult re-evaluation of CSIRO's role in the SKA, and to some extent a reconsideration of Australia's role also. Nevertheless, even in its reduced form SKA1 will produce amazing science and we hope to find a way forward that works for everyone.

All this is taking place in parallel with the development of the new Decadal Plan for Australian Astronomy, which will help to guide us all through the next ten years of discovery of the Universe. I thank every member of the community that has contributed to the working groups and invite all of you to express your appreciation to the members of the Editorial Committee, who have put in a great effort.

Finally, I want to acknowledge the tremendous contributions from CSIRO's Jim Caswell over a long and distinguished career. Jim will be very fondly remembered, and sorely missed.

Lewis Ball

Director
CSIRO Astronomy and Space Science

Observatory and project reports

Changes to ATNF operations

Following feedback from observers and staff, and in line with recommendations from the Australia Telescope User Committee, a number of changes have been made to the ATNF Operations model. Broadly, these serve to separate 'observing qualification' from regular scientific visits to Marsfield. They are intended to ensure that teams can observe successfully but remove the onerous travel requirements for large, experienced teams.

Each Parkes project team is required to designate a Project Expert from within the team who is the first point of contact for observing matters for that team. Teams with no member suitable to be the Project Expert must send an observer to the Marsfield Science Operations Centre (SOC) to be trained by Operations and Astro staff ahead of the scheduled observing. First-time observers will be required to come to the SOC, where they will be trained to use observing systems and monitoring tools, and helped with schedule preparation and data reduction. Observers will no longer have to return to the SOC each year: each Principal Investigator (PI) will be responsible for ensuring that the observers on the team are trained and competent.

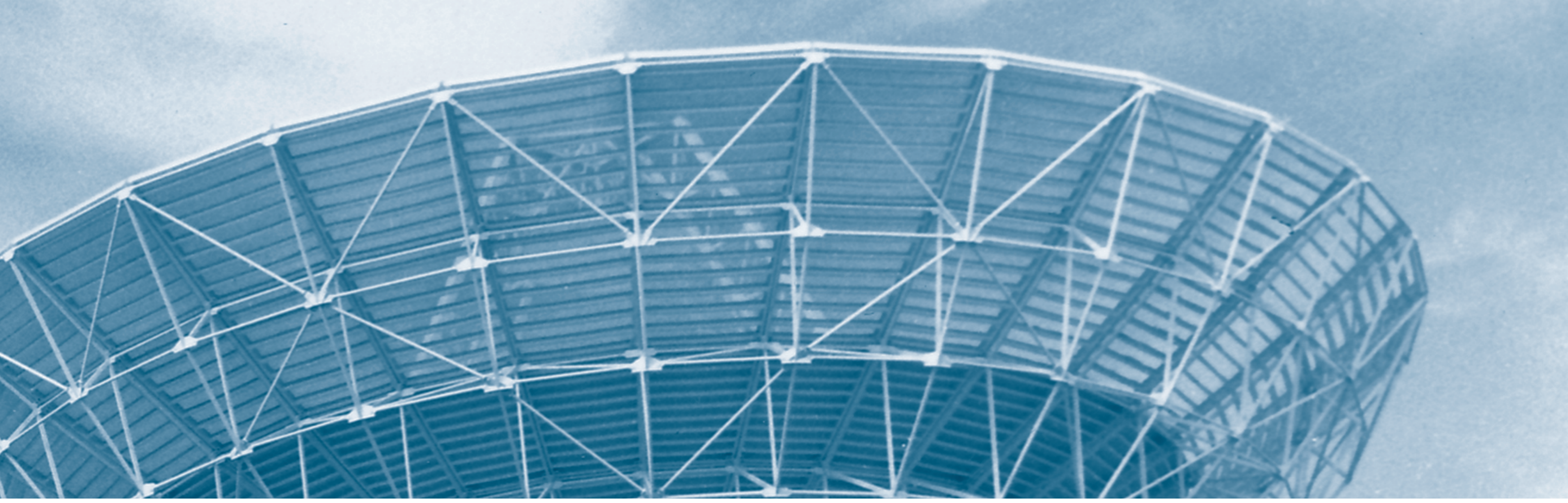
As setting up and calibrating the ATCA is a more complex process, first-time Compact Array observers will still be required to observe from the SOC, where they will be supported by the Duty Astronomer (DA) and Operations staff. All Compact Array observers coming to the SOC will be provided with an ATNF 'Friend', drawn from Astro and Operations staff, for the duration of their stay. Most observers will still have to observe from the SOC at least once a year to remain 'remote qualified'; however, regular, competent observers (typically, people observing on at least three separate occasions, or for more than 10 days, per semester) can extend the time between their return visits by six months (that is, they need visit the SOC only once every 18 months).

Parkes

In recent months the Parkes Observatory has welcomed several film crews, including a French documentary team that interviewed former ATNF staff members Dave Jauncey and Ray Norris on the role Parkes played in the discovery of quasars, and an SBS crew that interviewed Emily Petroff on her discovery of a 'fast radio burst' with the Dish (discussed further on page 29).

Over the same period there have also been a number of farewells, with Ettore Carretti, Parkes Senior System Scientist, returning to Italy to take up a position there, and long-serving support staff Julia Hockings and Shirley Ingram leaving too.

A major piece of equipment has also left the scene: the ATNF Parkes Swinburne Recorder (APSR) has been decommissioned after many years of fruitful pulsar searching. It has been replaced by the GPU-based CASPSR backend. (CASPSR is a nested acronym: it is the CASPER Parkes Swinburne Recorder, where CASPER is the Center for Astronomy Signal Processing and Electronics Research at Berkeley.)



Compact Array

STAFF CHANGES

The 2014OCT semester was the first for which the default observing location for Compact Array observers was the SOC at Marsfield. Accompanying this change, Robin Wark moved from Narrabri to Sydney to continue to provide support to visiting observers and the Duty Astronomer (with the DA role now also based at the SOC). With almost all observers now remote from the telescope site, an all-sky webcam has been installed on the control-building roof: observers now monitor conditions by opening a browser window, instead of peering through a real one in the control building.

In addition to Robin moving, Mark Wieringa relocated to Marsfield, Christoph Brem moved to Geraldton to join the ASKAP team, and Meg Rees left CSIRO after many years of making visiting observers feel right at home during their stay.

'HEAT STOWS'

November 2014 saw an early start to the summer, with several days nearing 43°C. The combination of high temperatures and strong winds led to the cryogenic-compressor units being stressed in some antenna orientations, with the hot winds negating the efforts of the compressor's internal fan to cool the unit. The only solution was to rotate the antennas in azimuth to allow the compressors to recover. A 'heat stow' command has been added to caobs to facilitate this when required.

SPLIT-RECEIVER MODE NOW AVAILABLE

A new mode now available for the Compact Array Broadband Backend (CABB) enables observers to split the array and simultaneously observe at different frequencies with different receivers. This can be valuable for studying emission processes, the interstellar medium, or source structure. Mark Wieringa and Warwick Wilson (CSIRO) implemented the new mode, and Richard Dodson (ICRAR) and Jamie Stevens (CSIRO) added the final touches to bring it into operation. The change was made specifically to facilitate simultaneous 43 and 86 GHz VLBI observations between the Compact Array and the Korean VLBI network (KVN): it makes the Compact Array the sole facility in the Southern hemisphere able to observe simultaneously at these frequencies. The lower frequency measurements can be used to correct for atmospheric disturbances to the phase at the higher frequencies, in a technique called source-frequency phase referencing. Using this technique, correlation fringes have been found between the KVN and the Compact Array.

Online software had to be modified to make the new mode easy to use, but now split-array observations can be scheduled just like any other, and can use all existing CABB modes (continuum, zooms, pulsar binning and high-time-resolution). Because CABB has only two intermediate frequencies (IFs), the array can split only in two, with one set of antennas using one receiver in IF1 and the other antennas using another receiver in IF2. There are two general rules, firstly, the 4 cm receiver can be used with any other receiver and secondly, the 15 mm receiver cannot be used with either of the 7 mm or 3 mm receivers.

There are also some restrictions in the frequencies that can be chosen together (due to constraints in the choice of LO frequencies). If you are interested in using this mode, please speak to observatory staff to ensure your observations will be possible.

Mopra

CSIRO announced in May 2014 that it will cease funding Mopra when the current agreements with the National Astronomical Observatory of Japan and the University of New South Wales finish in September 2015. As a result, the 2015APR semester is the last in which Mopra will be offered as a national facility. Discussions on the future of the telescope after September 2015 are continuing.

Mopra's 20 cm/13 cm receiver, used for VLBI observing, suffered a failure last year but was repaired and reinstalled in time for the March 2015 long-baseline-array session, during which it was put to good use.

Long Baseline Array

The reduced number of receiver changes at Parkes resulted in Parkes participating in the November 2014 VLBI session at 1.4 GHz only (using the central beam of the multibeam receiver). In fact, between the receiver change on 23 September 2014 (at the end of a long-baseline array (LBA) session) and that on 23 March 2015 (in preparation for another LBA session) Parkes went a full six months without a receiver change—possibly a record in the telescope's lifetime!

Auckland University of Technology has recently taken over use of a 30 m beam-waveguide antenna, formerly used for telecommunications, that is located on the same site at Warkworth as its existing 12 m geodetic telescope. This new antenna successfully participated in 6.7 GHz VLBI observations at the end of 2014, and first fringes at 8.4 GHz were found during the March 2015 LBA session.

Australian SKA Pathfinder

The Australian SKA Pathfinder (ASKAP) team has hit the ground running in 2015: commissioning observations have achieved great scientific results and the deployment of second-generation phased-array feeds is going well.

ASKAP COMMISSIONING

In 2014 the ASKAP Commissioning and Early Science (ACES) team ran weekly 'Busy Thursdays', days when the team members could dedicate themselves to ASKAP issues. This year the team has ramped up the activity to monthly 'busy weeks'. There have been seven 'busy weeks' to date, focused on themes such as the preparation of technical memos, imaging and beamforming. These meetings speed up the process of solving problems and are extremely helpful in making the collaboration work, particularly now that the team members are spread across the country.

Commissioning observations continue with the Boolardy Engineering Test Array (BETA), the first six ASKAP antennas installed with phased-array feed (PAF) receivers. Noteworthy findings have been the 'blind' detection of HI in absorption (reported in ATNF News issue 77), detection of an intermittent pulsar, and the discovery of 'dark', massive clouds of HI near the galaxy IC 5270 (described on page 28 of this issue).

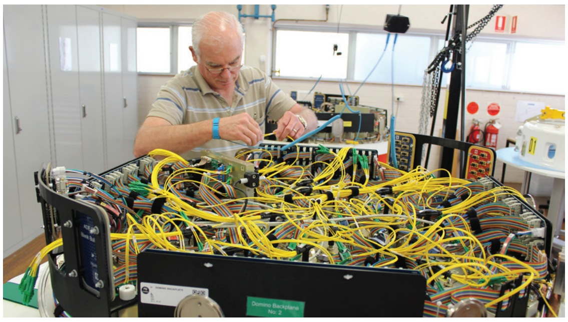
These results, two of which are now published, lay the groundwork for some of the ten Survey Science Projects (SSPs) planned for the first five years of ASKAP operation: for FLASH (the First Large Absorption Survey in HI), VAST (Variables and Slow Transients) and WALLABY (the ASKAP HI All-Sky Survey) respectively. They would not have been possible without the features that make ASKAP

unique, namely its wide-area and rapid survey capability and the radio-quiet environment of our Murchison Radio-astronomy Observatory (MRO).

The previous issue of ATNF News (no. 77) featured an ASKAP image of a 50-square-degree field in Tucana. This new image of the Tucana field covers 150 square degrees, and reached a (1-σ) depth of below 1 mJy in only 12 hours of observing.

The field was observed three times, over a period of a month. During each 12-hour observation the telescope, with its nine beams arranged to create a square 'footprint', cycled around 12 different points in the field. Each epoch contains approximately 2000 sources above 5σ.

Andrew Brown packing four ASKAP beamformers for shipping to the MRO.



Les Reilly working on one of the first production PAFs in the Marsfield workshop.

David Chandler installing fans on a PAF casing in the assembly area at Marsfield.

SKA Organisation Director General Phil Diamond inspecting a Mk II production PAF during his recent visit to Marsfield.

We tested the telescope's stability by rendering each day's image a different colour (red, green or blue), then combining the coloured images to form a three-colour image. Fading sources would appear red in the image and brightening ones blue. But all sources in the final image are white, showing that BETA is extremely stable (and that these observations did not capture any transients).

Credits: observations, Keith Bannister (CSIRO); calibration and imaging, Ian Heywood (CSIRO); system stability, the ASKAP and ACES teams.

MK II PAF DEPLOYMENT

In late 2014 the ASKAP team carried out ground-based tests of a second-generation (Mk II) phased-array feed (PAF) at the MRO (as described in issue 77 of ATNF News). Since then the ASKAP team has successfully performed on-dish measurements of the Mk II system, confirming its low-noise performance across the entire ASKAP frequency band. Above 1,400 MHz the new PAFs are twice as sensitive as the first-generation ones, and have four times the survey speed. The minimum T_{sys}/η is 78 K at 1230 MHz, and T_{sys}/η is 95 K or better across the 835–1800 MHz range. This is a preliminary result that we continue to refine.

The first eight production Mk II PAFs have been assembled and tested at Marsfield. Four PAFs are now installed on ASKAP antennas on site, with four more now undergoing vital system testing prior to deployment to the MRO. Meanwhile the correlator room in the control building at the MRO is being fitted out with 30 antennas' worth of hardware, readying it for the imminent arrival of the PAFs.

VIP group visits the MRO

In April the Murchison Radio-astronomy Observatory (MRO) again hosted a group of distinguished visitors. The delegation, jointly arranged and supported by Curtin University and the CSIRO, included Mr Sem Fabrizi, the European Union Ambassador to Australasia; Ms Annemieke Ruigrok, the Ambassador for the Netherlands; Professor Deborah Terry (Vice-Chancellor of Curtin University); Curtin University Professors Steven Tingay and Peter Hall; and CASS's Assistant Director for Western Australia, Dr Phil Crosby.

The group flew directly from Perth to Boolardy Station. Once on site they met the MRO personnel and inspected the instruments being developed and commissioned: the Australian SKA Pathfinder, the Murchison Widefield Array (MWA), and the Aperture Array Verification System experiment (part of the MWA) that is providing information for SKA1 Low. The Ambassador for the Netherlands later remarked on her delight at visiting the MRO, "*not only because it is a spectacular sight, but also because it is such an important example of scientific cooperation between Australian and Dutch institutions*".

The visitors ate lunch and toured the MRO control building before enjoying the scenic flight back to Perth, covering the 5-hour road trip in just 90 minutes. As a result of the rain in recent weeks they were treated to the rare sight of flowing creeks and an unusually green Mid-West region.

CSIRO engineer Suzy Jackson explains ASKAP's digital signal processing system to the visitors.

Square Kilometre Array

CSIRO engages with the international Square Kilometre Array (SKA) project through seven of the 11 SKA research and development consortia, particularly as lead of the *Dish* and *Infrastructure-Australia* consortia and as a key partner in *Assembly, Integration and Verification*.

RE-BASELINING

In 2013 the SKA Board of Directors set a cost cap for the project's first phase, SKA1, of €650 m. This was lower than the estimated cost to build the design and made it necessary to re-baseline the project. Input into the form the re-baselining should take was provided by an ad hoc Science Review Panel, the SKA Science and Engineering Advisory Committee, staff of the SKA Office and, importantly, by SKA consortia teams from around the world.

When the group met in March this year the Board discussed and noted the resulting recommendation for re-baselining. This is a major step in moving SKA1 into its final pre-construction phase. Aspects of the recommendation with implications for Australia were that:

- SKA1 Low in Australia should be built, with the planned frequency range (50–350 MHz) and baseline lengths (~80 km) but only 50% of the planned 262,144 low-frequency dipoles; and that the inclusion of a pulsar-search capability should be actively explored
- SKA1 Survey in Australia should be deferred
- a development program for phased-array feeds for the SKA should be started, as part of a broader Advanced Instrumentation Program
- with Australia's agreement, the Board should approve funding for ASKAP to be operated as an integral component of SKA1. This would allow ASKAP to provide SKA1 with an early survey capability and serve as a platform for the development of next-generation phased-array feeds.

Following this recommendation, the SKA Organisation will formally negotiate with the governments of countries involved, such as Australia.

PRELIMINARY DESIGN REVIEWS

Preliminary design reviews (PDR) for the SKA were held in early 2015. CSIRO staff involved in the SKA R&D consortia contributed to them by preparing documents and slides for presentation to the PDR panels, and responding to comments made by the review panels in the lead-up to and during the PDR process.

When all work on the PDRs has been completed, the SKA project will enter Stage 2 of its pre-construction phase: detailed design work leading to the Critical Design Reviews (CDRs) in 2016 and 2017.

Further information on the progress of SKA R&D Consortia work can be found in the SKA Monthly Bulletin, at www.skatelescope.org/skao-monthly-bulletin/.

MARK MCKINNON LEAVES CSIRO

Mark McKinnon, leader of the SKA Dish consortium, joined CSIRO in September 2013 on secondment from the US National Radio Astronomy Organisation (NRAO): he left CSIRO in March this year to return to NRAO. Mark's experience in radio astronomy, international collaboration and industry engagement was invaluable for our involvement in the Dish consortium, and was much appreciated by all who worked with him.

BRIAN BOYLE STEPS DOWN

In another departure, Professor Brian Boyle has stepped down from his role as Australian SKA Project Director, a position he held since 2009. Prior to that he was Director of the ATNF.

During his 12 years with CSIRO Brian made extraordinary contributions to the SKA project: he obtained funding to build the Australian SKA Pathfinder, established the Murchison Radio-astronomy Observatory, secured Commonwealth Government support for Australia's involvement in the SKA, led the bid that saw Australia named as co-host of the SKA, and represented the country as Australia's science member on the international SKA Board. (Somehow he also found time to lead the development of the National Committee for Astronomy's Decadal Plan for 2006–2015.) After becoming Australian SKA Director he continued to work for Australia's involvement in the SKA, and for the success of the overall project, with dedication and professionalism.

In recognition of his outstanding work for the Australian astronomical community, and leadership of the Australian SKA team, Brian was awarded the Public Service Medal in 2013.

He was farewelled from the Australian SKA Office in style on 8 April, at a dinner in Canberra attended by colleagues past and present from the Office, CSIRO, and other areas of the scientific community. We wish Brian all the best in his future endeavours.

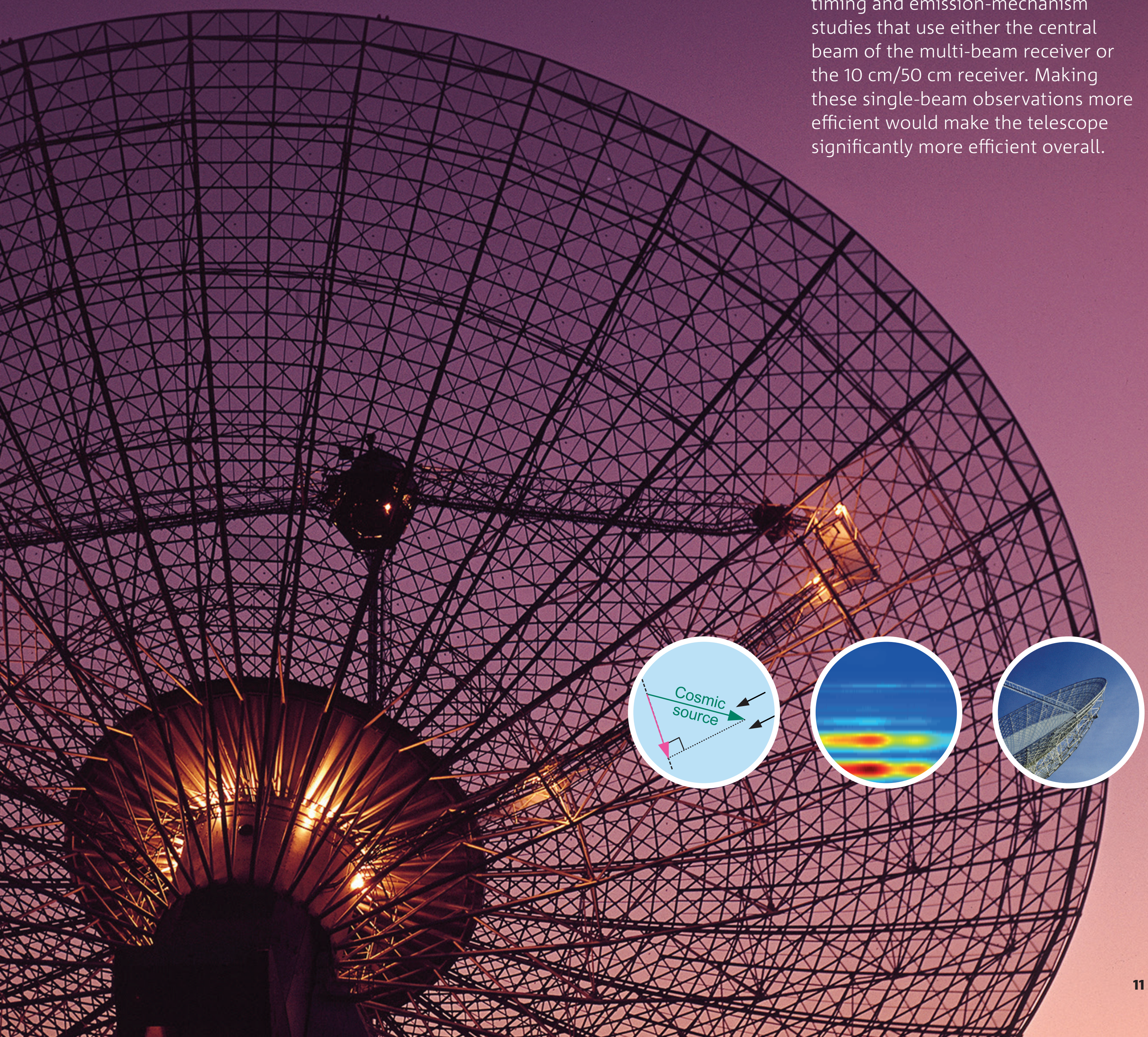
Brian Boyle holding a historic map of Western Australia presented to him at his farewell from the SKA Office. Photo: Hank Scorpio

Technology development

An ultra-wideband receiver for Parkes

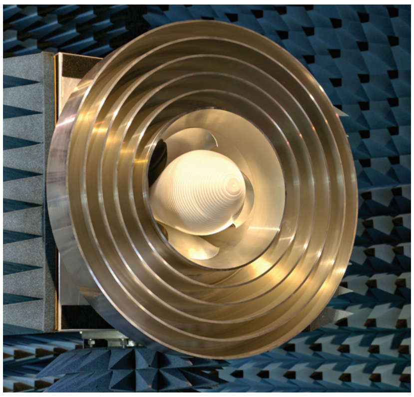
Dick Manchester (CSIRO)

The Parkes radio telescope is an icon of Australian science, not only because of its imposing physical stature but also because it produces some of the highest-impact science of any Australian research facility. Pulsar science dominates the Parkes telescope's workload, accounting for more than three-quarters of scheduled observations over the past year. Of these, nearly two-thirds are pulsar-timing and emission-mechanism studies that use either the central beam of the multi-beam receiver or the 10 cm/50 cm receiver. Making these single-beam observations more efficient would make the telescope significantly more efficient overall.



To do this and, importantly, to improve the sensitivity and precision of low-frequency observations, the team are designing and constructing an ultra-wideband (UWB) receiver that covers the band 0.7–4.0 GHz. Alex Dunning (CSIRO) has designed a new feed with exceptional polarisation properties and nearly constant beamwidth (that is, dish illumination) and focal position over this nearly 6:1 frequency range. CSIRO has applied for a patent for this new design.

To complement the feed and associated receiver, CSIRO and Swinburne University are developing a new digital signal processing system. The RF signals will be digitised in the focus cabin and then put through a powerful FPGA-based pre-processor and CPU/GPU cluster in the tower receiver room. We plan to use this signal processor to support all single-beam observations (including pulsar-timing and polarisation studies, spectral-line observations and VLBI) and a future phased-array feed on Parkes.



The Parkes ultra-wideband feed undergoing performance testing at the CASS anechoic chamber. This is an ambient temperature version of the feed. In the final version, the horn and dielectric insert will be cooled to 70K and covered by a vacuum window, while the outer rings remain at ambient temperature.

The project has received cash support from an Australian Research Council LIEF grant ($370k), six Australian universities ($195k), the Max Planck Institute for Radio Astronomy ($150k) and the National Astronomical Observatories of China ($100k), thanks particularly to the efforts of Matthew Bailes (Swinburne University), Michael Kramer (MPIfR) and Jinlin Han (NAOC). Xinjiang Astronomical Observatory (led by Nina Wang) is currently negotiating to enter the collaboration with a contribution similar to that of the NAOC. CSIRO has committed in-kind support to the value of just under $1.5m; several of the collaborating institutions have also promised in-kind support.

The UWB receiver's very wide bandwidth and relatively low frequency make radio-frequency interference (RFI) a major concern. The 0.7–4.0 GHz band contains mobile phone and aircraft transmissions that can be more than 40db above the noise floor. The UWB system has been designed to ensure that its response remains linear in the presence of these strong signals. This will allow RFI to be rejected in the digital domain; for instance, by adaptive filtering using up to three reference signals to identify the RFI. It is also critical that we reduce locally generated RFI, particularly from digital systems, to levels well below system noise.

Construction of the feed is complete and laboratory tests (at ambient temperature) have shown that the feed performs according to the design specifications. We aim to start commissioning observations with the receiver and signal processor at the telescope in late 2016 or early 2017. This system will usher in a new regime of very wideband and largely digital receivers, keeping Parkes at the forefront of radio astronomy into the SKA era.

Spatial filtering for RFI mitigation

Gregory Hellbourg (CSIRO)

The sensitivity required for radio-astronomy observations makes instruments very vulnerable to interfering sources. Most sources of radio-frequency interference (RFI) are much stronger than cosmic sources of interest for astronomers, even when they appear in far sidelobes. A corrupted observation makes the source of interest hardly detectable and the data unusable. There are many sources of RFI: active users of the spectrum, unshielded equipment at the observatory itself or further afield, and natural phenomena.

Passive mitigation measures such as 'radio quiet zones' are extremely important; however, they cannot counter RFI from moving sources such as aeroplanes or satellites. Protected windows of radio spectrum are also very valuable, but they are sparse on the table of frequency allocations, and observers are increasingly interested in using wider continuous regions of the spectrum (for instance, for high-redshift studies). So we must add active RFI mitigation to the weapons in our armoury.

ACTIVE RFI MITIGATION

Active RFI mitigation involves processing the data before using it in a scientific context, to reduce the RFI contribution to the astronomical observation. Astronomers commonly flag and excise corrupted time and frequency slices of observed data before further processing: this can be done manually or automatically. This approach is very efficient in most situations, but the loss of data can be significant at much-used frequencies. Also, the detection step is very sensitive to the interference-to-noise ratio, and detection errors are likely to occur.

Other forms of active RFI-mitigation studied in the past decades include adaptive filtering in the frequency domain, and spatial signal processing such as adaptive beamforming, deep nulling, and subtraction techniques. The spatial approach is particularly attractive for astronomers because the data is processed in a domain they do not exploit, and it theoretically leads to the recovery of uncorrupted time-frequency data. Figure 1 shows an example of real data processed spatially.

The choice of the type of processing and algorithm to use is dictated by the right balance between the achievable performance and the overall computational cost of the technique. An important part of research in algorithmic RFI mitigation focuses on lowering the computational cost of efficient algorithms.

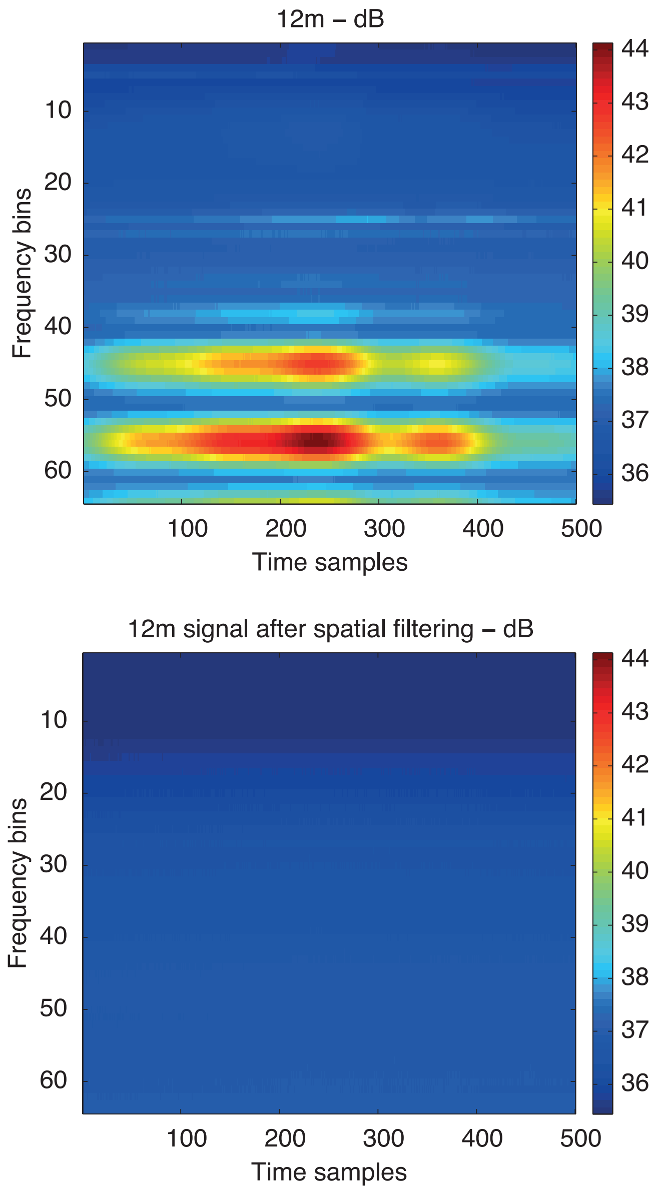


FIGURE 1: Example of spatial filtering applied to ASKAP data. (a) Observation corrupted by a Galileo navigation satellite (ASKAP testbed at the Parkes Observatory, NSW). (b) Same observation after applying a spatial filter.

THE SPATIAL APPROACH

In most sensing systems, the signals acquired can be represented and processed in either the time or the frequency domain. Array-based radio telescopes (such as phased-array feeds, aperture arrays, or a reference antenna coupled to single dish) also provide spatial information about the observed sources.

In the spatial framework, the different sources (cosmic or RFI) are represented in an abstract spatial vector space. Because of their physical spatial diversity (that is, having different locations relative to the instrument), each source lies in a separate subspace. The sources are identified, not by classical Euclidean coordinates, but according to their spatial signatures. This signature represents the physical response of the radio-telescope array to the source location, expressed in a vector form. It is assumed that each source possesses instantaneously its own unique spatial signature.

Two types of RFI mitigation can be applied to such spatial data. The first is commonly called the estimation and subtraction technique. The idea here is to find a way to estimate the content of the subspace of the whole observational vector space corresponding to the RFI. Once estimated, this content is simply subtracted from the data. (See Figure 2.) The second type of technique is based on mathematical operators called projectors. In this case, the processing makes the observational vector space virtually collapse along the RFI subspace in order to null its contribution. (See Figure 3.)

Because these techniques are based on simple geometrical concepts, it is easy to formulate and apply corrections to the post-processed data to recover the integrity of the signal of interest.

LIMITATIONS

To apply any spatial RFI-mitigation algorithm one must have accurate information about the RFI subspace. Although we may have some a priori knowledge of the interferers, such as their location, frequencies or modulation, it is common to estimate the RFI subspace from the data provided by the instrument, to limit the propagation of errors in the signal-processing chain. But noisy data and finite-sample effects can introduce errors into the estimate, and may strongly influence the quality of the processing. Also, the relative movement between the interferer and the instrument over the data-integration time complicates the model, and therefore the algorithm design. Instead of nulling a single direction in the sky, a good mitigation algorithm is supposed to remove a wider area where the interferer is likely to be found. But a portion of sky is not easily expressed algebraically, again limiting the achievable performances of spatial processing.

It may be difficult to implement spatial RFI-mitigation algorithms on current systems, because of their high computational cost. Even if this can be greatly reduced, processing resources at the instrument backend have to be allocated for the task. Luckily, most algorithms are versatile enough to be applied in different ways or at different stages of the processing chain (in real time or offline, pre- or post-correlation, in hardware or software).

A final, important limitation to these approaches is the willingness of end-users to adopt them, and to move away from tried and true solutions. But new science cases are pushing us to adopt new approaches, and should lead to them being incorporated into standard data processing in the near future.

FIGURE 2: The estimation and subtraction approach: after estimating the RFI subspace, its contribution is subtracted from the data.

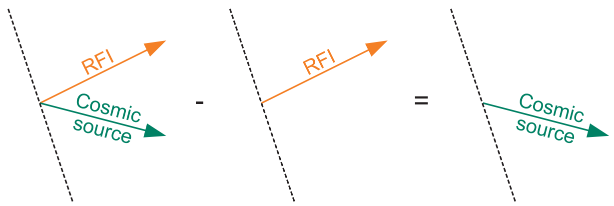
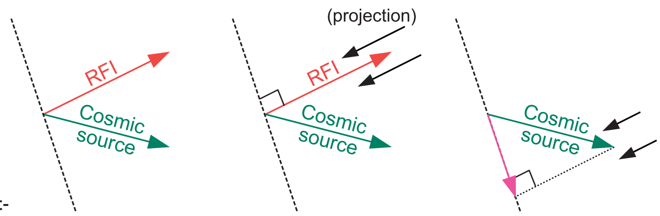


FIGURE 3: The projection approach: the data vector space is projected onto a subspace orthogonal to the RFI subspace, nulling the RFI contribution and attenuating the cosmic-source contribution.



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RFI monitors at Narrabri and Parkes

Christoph Brem and Jamie Stevens (CSIRO)

In yet another move to counter radio-frequency interference (RFI), an RFI monitoring system was installed on the roof of the ATCA control building in November 2014, and an identical system was installed at Parkes a month later. Each system is made up of two antennae mounted on a rotatable pole, and two monitoring receivers, and is capable of surveying the RFI environment in two frequency ranges.

The high-frequency system consists of a log-periodic dipole array and a mast-mounted broadband low-noise amplifier connected to a Rohde & Schwarz EB500 monitoring receiver, spanning the range 400 to 3500 MHz. This frequency range matches most of the observing that may be badly affected by terrestrial RFI, and the monitor is designed to give observers a view of the RFI 'weather' at any moment without having to use the telescope.

Observers can view the output from the RFI monitors online, at

www.narrabri.atnf.csiro.au/observing/rfi/weathermap/ (Narrabri) and **www.narrabri.atnf.csiro.au/observing/rfi/weathermap_parkes/** (Parkes).

Each page displays three plots. Two show the RFI intensity with frequency over the past hour, while the third shows how the RFI is distributed around the horizon. To make this latter plot, the log-periodic antenna is rotated through 360 degrees once every 20 minutes, in 10 degree steps. Although the antenna will see intense RFI regardless of where the transmitter is with respect to the observatory, the direction of the interference is usually discernible from the maximum intensity shown in the azimuthal plot.

The low-frequency setup, which uses a loop antenna and an EM100 monitoring receiver, has not yet been commissioned for automated monitoring of the RFI weather, but can be used independently of the high-frequency system in real time to find interferers such as air conditioners and electric fences.

The monitors alert observers to the presence of 'mid week' RFI (which is generally fatal to observing at these frequencies), and locally generated signals from WiFi devices and mobile phones. Local staff can then investigate such signals and shut them off if possible, and observers can change their plans if necessary. The Parkes monitor has already proved its worth making it possible to track down the cause of the mysterious 'peryton' radio bursts (Petroff *et al*. 2015).

A monitoring system of similar design will soon be installed at the Murchison Radio-astronomy Observatory.

The RFI monitor installed at Narrabri.

Awards and appointments

ASKAP wins national innovation award

On 26 November last year CSIRO's Australian SKA Pathfinder (ASKAP) telescope took out the top prize in the national Australian Innovation Challenge Awards, with judges recognising the telescope as "one of those advances that keeps Australia on the global innovation map".

The telescope's revolutionary phased-array feed receivers and associated digital systems were the key technologies leading to the win. ASKAP also topped the awards' Manufacturing, Construction and Infrastructure category.

...one of those advances that keeps Australia on the global innovation map ...

The Australian Innovation Challenge awards are run by The Australian newspaper in association with Shell, and with the support of the Commonwealth Department of Industry.

This is not ASKAP's first national award. In 2013 its phased-array feeds received a national Engineering Excellence Award – given to recognise world-class expertise and innovation – from Engineers Australia.

ASKAP Project Director Ant Schinckel with the Australian Innovation Challenge Award. Photo: Wheeler Studios

Pleiades Award for CASS

CSIRO Astronomy and Space Science has received a bronze award in the first year of a new national scheme to improve gender equity in Australia's astronomy departments and research institutes.

Inspired by the United Kingdom's Athena SWAN scheme, the Pleiades Awards have been created by the Astronomical Society of Australia to recognise organisations that take active steps to advance the careers of women.

We have established the structures and clearly demonstrated the intent to deliver improvements in diversity. While there is room for substantial improvement, we're very proud of this external recognition of our efforts to build a better working environment,

said Dr Jill Rathborne, Chair of CASS's Diversity Committee.

Organisations had to submit a case to be judged, and were assessed against criteria that involved monitoring the conduct of the organisation, making plans for improvement, and publicly demonstrating a commitment to best practice in the field.

The awards take their name from the constellation of the Pleiades, which is also known as 'the seven sisters'.

Inaugural scholarship for CASS student

CASS PhD student Claire-Elise Green has won the inaugural CSIRO Alumni Scholarship in Physics.

Co-supervised by Dr Maria Cunningham (UNSW) and Dr Joanne Dawson (CSIRO/Macquarie University), Claire-Elise is studying the dynamics and structure of the Milky Way, specifically gaseous filaments within molecular clouds and their role in the formation of new stars.

The $5000 scholarship will help her to travel to Bonn, Germany, where she will work with the millimetre and sub-millimetre astronomy group of the Max Planck Institute for Radio Astronomy, under the supervision of Professor Karl Menten.

This experience will not only benefit her research but will also build collaborative relationships within her field, Claire-Elise says.

"The team in Bonn has direct access to the Atacama Pathfinder EXperiment (APEX) telescope in Chile."

"APEX can study cold dust and gas in the Milky Way and in distant galaxies. The APEX data will be invaluable to my research, as will the expertise Professor Menten and his team have in reducing and analysing the data."

CSIRO Chief Executive Dr Larry Marshall presented Claire-Elise with her award at CSIRO's laboratory in Lindfield, in NSW, on 20 March.

The CSIRO Alumni Scholarship in Physics was established to commemorate the contributions of CSIRO scientists John Dunlop, Tony Farmer, Gerry Haddad and Don Price, who died in a helicopter crash in March 2013.

The scholarship is intended to help postgraduate students visit and/or conduct research in an overseas or interstate institution such as a University or any other research establishment of international standing. Funding for the scholarship has been provided by friends and colleagues of Dunlop, Farmer, Haddad and Price; CSIRO Alumni; and the Laboratories Credit Union. All donations to the CSIRO Alumni in Physics appeal (givenow.com.au/csiroalumni) are appreciated.

(L-R) Director of CSIRO Manufacturing Science, Dr Cathy Foley; Scholarship in Physics winner Claire-Elise Green; and CSIRO Chief Executive, Dr Larry Marshall.

APEX can study cold dust and gas in the Milky Way and in distant galaxies. The APEX data will be invaluable to my research, as will the expertise Professor Menten and his team have in reducing and analysing the data.

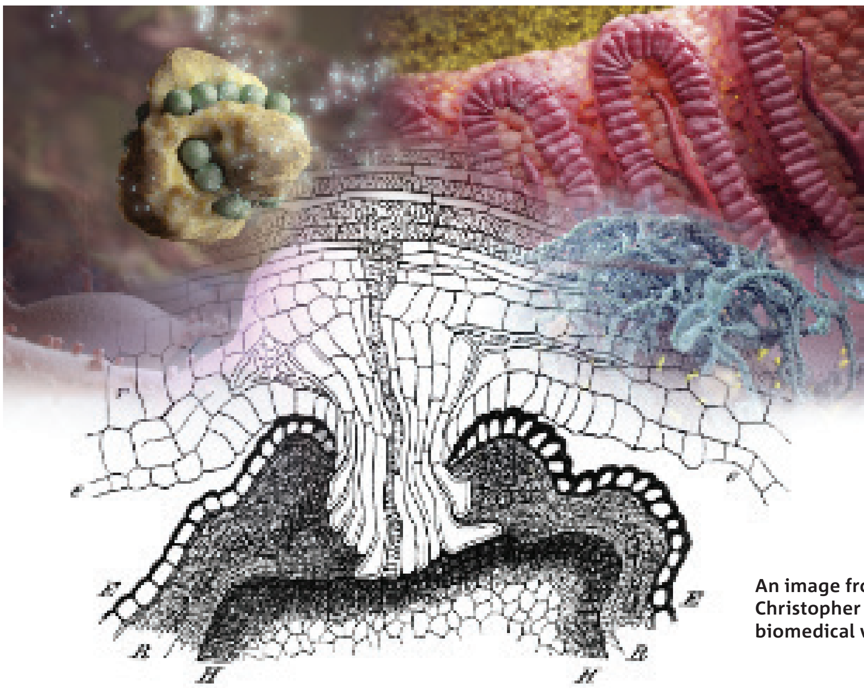
OCE Science Leaders' award for visualisation

'Dark matter' is one of the topics to be explored in new CSIRO science visualisations funded by the Office of the Chief Executive's (OCE) Science Team.

A few years ago CSIRO's Digital Productivity Flagship began to create world-class, scientifically accurate science animations. Two examples of these, created for CSIRO by animator Christopher Hammang, can be seen at vizbi.org/plus/, the website for the vizbi (visualizing biological data) project.

The OCE Science Team has now funded four OCE Science Leaders (Bärbel Koribalski of Astronomy and Space Science; Peter Dodds of Food Futures; Seán O'Donoghue of Digital Productivity and Susie Nilsson of Manufacturing) to build on the expertise developed in Digital Productivity and create three new animations that will showcase recent, cutting-edge research outcomes from four CSIRO flagships. The topics to be covered include blood stem cells, and leukemia and related disorders; plant rust and how plants defend themselves against it; and a comparison of two perplexing scientific mysteries being studied in CSIRO – 'dark matter' in astronomy and 'dark proteins' (which 'hide' from researchers) in biology.

Bärbel will participate in all three projects and will work with OCE Science Leader Seán O'Donoghue and animator Christopher Hammang for the 'dark matter–dark proteins' animation. The work will include and expand on her previous 3D visualisations of gas and stars in galaxies, which are based on multi-wavelength data (optical, UV and ATCA HI data at different angular resolutions to show emission at a range of scales). As part of the project Bärbel hopes to invite two collaborators from Europe to work with the team on these animations for both outreach and professional use.



An image from one of Christopher Hammang's biomedical visualisations.

New postdoctoral staff

Since the last issue, we have welcomed a new postdoctoral fellow, Helga Dénes. Helga describes her background and work below.

Helga Dénes

Office of the Chief Executive Postdoctoral Fellow

PhD: Swinburne University of Technology, Australia, 2015

For my PhD I investigated scaling relations between the neutral hydrogen (HI) content of galaxies and their optical properties. At CASS, I will be working on determining the nature of 'dark gas' in the Milky Way. The current thinking is that this gas is probably partly optically thick atomic hydrogen and partly molecular hydrogen that is not traced by CO emission.

Outreach and engagement

Science Meets Parliament 2015

Kate Chow (CSIRO)

Science meets Parliament (SMP) is an annual two-day event in Canberra, organised by Science and Technology Australia, that puts scientists face-to-face with politicians. About 200 scientists took part in this year's SMP, which was held on 24 and 25 March. James Allison, Daniel Mitchell and I were there to represent CASS.

On the first day we were given advice on how to interact with politicians, by people who do it often: political lobbyists, journalists, policy makers, and Australia's own Nobel-Laureate astronomer, Brian Schmidt. In addition, the SKA Board Member for Australia, Martin Hoffman, who is also Deputy Secretary for the Department of Industry and Science, spoke to us about the nature of policy-making.

That evening we attended a wonderful gala dinner at Parliament House, complete with speeches from Ian Macfarlane (Minister for Industry), Bill Shorten (Leader of the Opposition) and Catherine Livingstone (President of the Business Council of Australia and former Chair of CSIRO). We were also able to have informal discussions with politicians. My table hosted Alan Griffin (ALP), who regaled us with tales of politicians playing soccer and details of what life is like for a politician, particularly during a Parliamentary sitting week.

The second day of SMP was the 'pointy end' of the event, when we met with politicians to discuss our science – in my case, the Square Kilometre Array. About 65 MPs met individually with small groups of scientists: several scientists were chosen to speak with Prime Minister Tony Abbott. The politicians appeared to be genuinely engaged, and several groups of scientists spent an hour or two in discussion with their MPs.

I met with Senator Kim Carr (Shadow Minister for Higher Education, Research, Innovation and Industry and Shadow Minister Assisting the Leader for Science) for about half an hour, along with two other scientists. Daniel Mitchell spoke with the Hon Anthony Albanese (Shadow Minister for Infrastructure and Transport and Shadow Minister for Tourism), while James Allison spoke with Paul Fletcher (MP and Parliamentary Secretary to the Communications Minister). We all had short, positive chats with these politicians about matters related to CASS, the Australian SKA Pathfinder, and the Murchison Radio-astronomy Observatory.

The second day also saw the well-timed launch of "The Importance of Advanced Physical and Mathematical Sciences to the Australian Economy", a report from the office of the Chief Scientist, Professor Ian Chubb. The new report (which can be found via www.chiefscientist.gov.au) asserts that science directly contributes $145 billion dollars to the national economy each year.

I would highly recommend *Science Meets Parliament* to other scientists and would encourage anyone interested to attend next year. The presentations and workshops were valuable, as was the chance to speak with scientists from other fields, and I gained further insight into how policy is made. Overall, *Science meets Parliament* was a great event, and I thoroughly enjoyed it.

Kate Chow explaining the SKA and her role in 60 seconds. Photo: Lorna Sim

Astronomers at the formal dinner for Science Meets Parliament 2015 (l-r): Daniel Mitchell (CSIRO), Alan Duffy (Swinburne University of Technology), Brian Schmidt (Australian National University), James Allison (CSIRO), Kate Chow (CSIRO). Photo: Lorna Sim

Education and outreach

ASKAP AND SKA OUTREACH

CSIRO staff have run three outreach activities in Western Australia in the last six months. Last November, students from the Pia Wadjarri Remote Community School toured the Murchison Radio-astronomy Observatory, as part of an ongoing series of 'mentoring visits' by CSIRO staff. In March, students and teachers from the Meekatharra School of the Air visited the Murchison Support Facility in Geraldton to learn more about astronomy and the Australian SKA Pathfinder (ASKAP) through hands-on activities and talks from local staff Mary D'Souza, Tom Cox and Christoph Brem (assisted by Rob Hollow from Marsfield). Also in March, Mary, Rob and Perth-based staff Phil Crosby and Aidan Hotan manned the CASS display at the 2015 Perth Astrofest, helping children build dishes out of Lego and talking with visitors about ASKAP and the SKA – activities that kept them fully occupied all evening! CASS's Ray Norris gave a public talk on Aboriginal astronomy at the event as well. Organised by ICRAR (the International Centre for Radio Astronomy Research), Astrofest drew about 3,500 visitors.

CASS has also conducted outreach at professional-level events. Rob Hollow and Flornes Yuen (CASS SKA Information Officer) staffed a display of art by Wajarri Yamatji artists at the Australian Institute of Physics Congress in Canberra in December. (In addition, our ASKAP Project Scientist, Dr Lisa Harvey-Smith, gave an invited address at the Congress that was very well received.) In January, Flornes ran the CASS display booth at the winter meeting of the American Astronomical Society in Seattle: this attracted significant interest.

CSIRO staff with students and teachers from Meekatharra School of the Air during their visit to the Murchison Support Facility.

PULSE@PARKES

PULSE@Parkes is an education program in which high-school students control the Parkes telescope and use it to observe pulsars. Ryan Shannon and Rob Hollow had taken the program to Japan in 2013: last November they did so again, funded by a grant from the Australia-Japan Foundation. They ran observing sessions in Kagoshima, Yamagata, Tokyo and Sendai; Ryan also gave talks on pulsars at Yamagata and Kagoshima. The final session, at Sendai Astronomical Observatory, had 25 high-school students participating and 20 students from Tohoku University assisting, and was also open to the public. One of the school students travelled for 14 hours across Japan to take part in the session, then turned around and travelled back overnight for school the next day!

The PULSE@Parkes team ran two special observing sessions at the Canberra Deep Space Communication Complex in January, as part of a new education program, STARS (Space, Technology, Astronomy, Research Students). The first involved 50 teachers from across Australia participating in the National Science Teacher Summer School. They loved the opportunity to control the Dish, leading to requests for sessions with many schools, including one in Woomera, South Australia. The following week 30 students from the

The PULSE@Parkes observing session at Sendai Astronomical Observatory.

National Youth Science Forum visited for a hands-on observing session.

Last December the PULSE@Parkes team tested a new approach to sessions, with students from St Ursula's College in Toowoomba, Queensland, being the first to try it. The students controlled the telescope directly from their school, guided by PULSE@Parkes team members in the science operations centre at Marsfield: a video link allowed each group to see what the other was doing. The session worked well, meaning that we can now offer PULSE@Parkes to students in remote locations.

In February, girls from Danebank Anglican School came to Marsfield for a PULSE@Parkes session. Danebank was the school where pioneering radio astronomer Ruby Payne-Scott taught after leaving CSIRO, so the visit made an exciting historical connection.

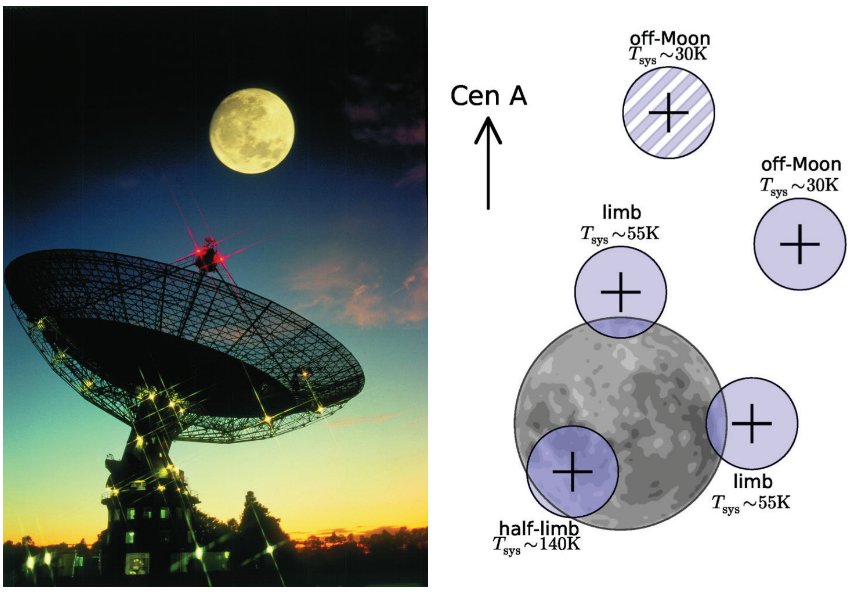
TEACHER WORKSHOPS

Rob Hollow presented workshop sessions for teachers at STAVCON (Science Teachers Association of Victoria Congress) in Melbourne last November, the STAV/AIP VCE Physics Teacher Conference in Melbourne in February, and the STAQ (Science Teachers Association of Queensland) 'Science is Primary' workshop in Brisbane in March.

ATNF Daily Astronomy Picture

Did you know that ATNF issues a Daily Astronomy Picture? We started doing this in December last year and have now presented over 100 images. They show our science and engineering results, and our telescopes, along with research highlights from recent publications and conferences, and technical updates. You can find the daily images on Twitter under the @CSIRO_ATNF account and online via www.atnf.csiro.au/ATNF-DailyImage/. Past images can be found in an archive linked to the same page, or in the form of monthly collages, for example at www.atnf.csiro.au/ATNF-DailyImage/archive/2015/02-Mar-2015.html.

All pictures have been contributed by ATNF staff and users, and we invite everyone to submit an image (< 2 Mb) related to our facilities (Parkes, the Compact Array, Mopra, ASKAP and the Long Baseline Array), together with a brief description and credits. You can use the submission form at www.atnf.csiro.au/ATNF-DailyImage/contribute.html or just email Bärbel Koribalski (Baerbel.Koribalski@csiro.au). Your submission will be added to a queue, to await review. We've had everything from a coffee-cup full of galaxies to people wearing rabbit ears (all relevant, of course), so the sky's the limit!



An ATNF Daily Astronomy Picture explaining observations designed to detect evidence of ultra-high-energy cosmic neutrinos.

Undergraduate Vacation Scholarship Program

As in previous years, CASS hosted eight students for the 2014–2015 Undergraduate Vacation Scholarship program, giving them the opportunity to work on engineering and astrophysics research projects under the supervision of CSIRO staff.

The students were introduced to radio-astronomy techniques and fields of research through talks from CSIRO staff. In January they put this knowledge into practice, visiting the Compact Array and using it to observe for group projects of their choosing: they also observed with Parkes by taking part in a special PULSE@Parkes session in December. The results of their projects were revealed to a wider audience at a student symposium held in February. That event marked the end of the summer program, but we look forward to seeing some of the students in Marsfield again as they continue their studies. (Claire-Elise Green, a co-supervised PhD student who recently received the inaugural CSIRO Alumni Scholarship in Physics (page 17), first came to CASS as an Undergraduate Vacation Scholar.)

CASS Education and Outreach Officer Rob Hollow coordinated the overall program for the students, while CASS postdoc Josh Marvil handled the astronomy talks and the observing trip to Narrabri. Many other CASS staff contributed to the program's success also, generously giving their time as supervisors, as speakers, or in helping the students with their observations.

Student	CASS supervisor(s)	Project
Alexandra Ryan (Monash University)	Paolo Serra Ian Heywood	Measuring the spectral response of the BETA (Boolardy Engineering Test Array) telescope
Sarah Hegarty (University of Queensland)	Aidan Hotan Keith Bannister	Determining optimal beamforming methods for ASKAP science
Daniel George (University of Wollongong)	John Tuthill	Development of ten-gigabit Ethernet for DSP systems
Annabelle Austin (University of Tasmania)	Joanne Dawson Shari Breen	Hydroxyl as a probe of star formation and the Milky Way's hidden gas
Upadhya Avinash (Australian National University)	Gregory Hellbourg	Spatial calibration of a reference antenna for interference mitigation
David Batt (University of Melbourne)	Keith Bannister	Finding cosmic clouds in wideband radio data
Charlotte Ward (University of Sydney)	George Hobbs	Studying the intermittent radio emission from pulsars
Timothy Hansen (Macquarie University)	Alex Dunning	Receiver development for an Epoch-of-Reionisation experiment

The Undergraduate Vacation Scholars at the Compact Array.

Graduate Student Program

The CASS Graduate Student Program continues to attract high-quality students from around the world to study a huge array of different astrophysical problems. We congratulate the following students who have recently completed their projects:

Tiffany Day, MSc (Macquarie University): “The flows of neutral hydrogen in the grand-design spiral galaxy M83”

Helga Dénes, PhD (Swinburne University of Technology): “Global HI properties of galaxies in the southern sky”

Vicki Lowe, PhD (University of New South Wales): “The environment of high-mass star formation”

Vanessa Moss, PhD (The University of Sydney): “The Galactic ecosystem: outflow and infall in the halo of the Milky Way”

Nipanjana Patra, PhD (Raman Research Institute): “Measurement of spectral features in the cosmic radio background”

Hayden Rampadarath, PhD (Curtin University): “Wide-field VLBI”.

Vikram Ravi, PhD (Melbourne University): “Evolving the history of massive black hole and galaxy populations with gravitational waves”

Kathrin Wolfinger, PhD (Swinburne University of Technology): “The effect of environment on the evolution of nearby gas-rich spiral galaxies”

Peter-Christian Zinn, PhD (Ruhr University Bochum): “Lighting the Universe – active galactic nuclei, star formation and their interplay”.

We have recently welcomed the following students into the program:

Shaila Akhter (University of New South Wales): “Turbulence in the interstellar medium and its relationship to massive star formation”

Alessandro Maini (Macquarie University): “Modelling the faint radio sky: the pathway to the SKA”

Jesse Swan (University of Tasmania): “The evolution of star formation and black-hole activity across cosmic time”

Mustafa Yildiz (University of Groningen): “Star formation in the outer regions of early-type galaxies”.

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

CASS graduate students on a visit to the Blue Mountains: (L-R) Steve Goldman (a CSIRO visitor), Alessandro Maini, Shi Dai, Jumei Yao, Qing Qing (friend of Jumei Yao), Francesco Cavallaro, Laura Gomez, Elise Servajean. Photo: Andreas Herzog

Scientific Visitors program

CSIRO welcomes applications to our Scientific Visitors program for visits of between two weeks and one year. Financial support typically covers the cost of on-site accommodation at CASS headquarters in Marsfield, or its equivalent. Visitors are expected to deliver at least one colloquium or seminar during their stay.

Scientific visitors to Marsfield since November 2014 have included:

Jillian Bellovary (Vanderbilt University)

David Blair (University of Western Australia)

Steve Croft (University of California Berkeley)

Helmut Dannerbauer (University of Vienna)

Huib Intema (National Radio Astronomy Observatory)

David Kaplan (University of Wisconsin–Milwaukee)

Jean-Pierre Macquart (Curtin University)

Wayne Orchiston (National Astronomical Research Institute of Thailand)

Rick Perley (National Radio Astronomy Observatory)

Norbert Werner (Stanford University)

David Wilner (Harvard University).

Visitors are also welcome to stay for longer periods, such as six or twelve months. Significant funds can be obtained for these longer visits from CSIRO, through a competitive process.

For more on the Scientific Visitors program see **www.atnf.csiro.au/people/scientific_ visitors.html** or contact Simon Johnston (Simon.Johnston@csiro.au).

Other news

Cutting the ribbon at the CASS Perth office

Dr David Williams, Executive Director of CSIRO's National Facilities and Collections, formally opened the new CASS Office at the Australian Resources Research Centre (ARRC) in Perth, Western Australia, on 21 January.

While CASS remains headquartered in Marsfield, and now has several sites in both the eastern States and in Geraldton, Western Australia, there was a clear need for an Executive presence in Perth to manage local interactions, and for a facility to offer technical support, remote observing and workspace for visitors.

Sydney-sider Dr Phil Crosby pioneered the move to Western Australia, and has spent the past year busily building CASS's Perth base and WA presence. But his 'lone ranger' days are now over, as others have also heard the call and made the move West. Kate Brooks, Juan-Carlos Guzman, and Aidan Hotan joined Phil at the beginning of 2015, providing a mix of management, science, and engineering capability. Tony Ambaum and Craig Haskins arrived mid 2015 to strengthen the team.

To celebrate the new Perth team and officially open the offices, David Williams performed a ribbon-cutting ceremony. Taking part in the special occasion were local guests from CSIRO Communications, Business Development and Commercial, and from CASS's new neighbour, Curtin University.

Perth team members are excited about the possibilities Western Australia holds for CASS expansion and look forward to others joining them and strengthening the astronomy and space-science bonds in the West.

Dr David Williams formally opening CASS's Perth office.

A tribute to James Caswell (1940 to 2015)

Simon Johnston, Jessica Chapman and Shari Breen (CSIRO)

It is with great sadness that we note the passing of Dr James (Jim) Leslie Caswell on 14 January 2015 in Sydney. In this tribute we review Jim's career and scientific achievements and give some recollections from close colleagues.

JIM'S CAREER

Jim was born in England in 1940. After completing high school in Thornbury, near Bristol, he went to St John's College, Cambridge, where he obtained his undergraduate degree in 1962. He then joined the Radiophysics group of Professor (later Sir) Martin Ryle at the Cavendish Lab in Cambridge, where he was awarded his PhD in 1967 for Astronomy studies using a large-aperture synthesis radio telescope operating at 178 MHz.

He was awarded a Canadian Research Council fellowship and took up at postdoctoral position at the Dominion Radio Astrophysical Observatory (DRAO) in Penticton, Canada, from 1967 to 1969. He subsequently moved to Sydney and started at the (then) CSIRO Division of Radiophysics (now CSIRO Astronomy and Space Science) on 6 January 1970.

Jim remained at CSIRO from then on, apart from sabbaticals in Cambridge in 1976 and at DRAO in 1983–84. Although Jim retired several years ago he continued his highly productive research career at CASS until being admitted to hospital, shortly before he died.

Jim had more than 200 papers in the refereed literature: his first (published in Nature!) appeared in 1965 and he was still publishing major papers on methanol-maser surveys in 2013 and 2014. It is difficult to pick out the highlights from such a large body of work. Here we mention just three of his highly cited papers, one each from the 1970s, 80s and 90s, which represent different facets of his career.

Clark & Caswell, 1976, A study of Galactic supernova remnants, based on Molonglo-Parkes observational data, MNRAS, 174, 267–305

This paper used observations made with the Molonglo and Parkes telescopes to investigate the evolutionary properties of supernova remnants (SNRs). It identified adiabatic expansion as important in the latter stages of SNRs, estimated a birthrate of one per 150 years, and showed the concentration of SNRs in the spiral arms.

Caswell & Haynes, 1987, Southern HII regions: an extensive study of radio recombination line emission, A&A, 171, 261–276

This paper provided velocities and distances for over 300 HII regions in the southern Galaxy and is a go-to paper for any discussion on Galactic structure. Observations were made with the Parkes telescope of recombination lines at frequencies around 5 GHz.

Caswell et al., 1995, Galactic methanol masers at 6.6 GHz, MNRAS, 272, 96–138.

Following the discovery of the 6.6 GHz methanol masers in 1991, Jim and colleagues carried out a major survey with the Parkes radio telescope and catalogued more than 200 sources. This paper laid the groundwork for the future multibeam survey with the Parkes telescope.

Jim also made significant contributions to the development of the Australia Telescope National Facility, for instance during the construction of the Australia Telescope Compact Array (ATCA) and as Project Scientist for the Compact Array Broadband Backend upgrade on the ATCA.

Jim's scientific passion was masers and Galactic structure; some 90 of his papers have 'maser' in the title. Most recently, he led the Parkes Methanol Multibeam (MMB) survey and subsequent follow-up studies with the Compact Array, observations that discovered hundreds of methanol masers associated with high-mass star-forming regions. The sequence of papers arising from the MMB are typical of Jim's output: they are defined by scientific excellence, integrity, and attention to detail, and have not a comma out of place or a dangling participle to be seen!

SOME RECOLLECTIONS

Raymond Haynes worked with Jim at CSIRO for nearly 30 years. He recalls:

Jim and I worked together on many projects related to radiation from the Galaxy, Galactic structure, and molecules in our Galaxy and other nearby galaxies. Our preference was always to undertake major surveys that had not been done, both molecular-line studies and continuum-radiation studies, Jim's argument being that 'picking the eyes' out of science did not make major scientific breakthroughs. I concurred, in that in-depth studies were needed to discover the unknowns. Take a good instrument and use it to its full capacity and one is guaranteed to make new and often surprising discoveries.

Jim and I formed a close professional working and personal friendship. These were fun and productive years and we shared the exhilaration of scientific success, international recognition and the successes of CSIRO. Fourteen years after retiring from CSIRO, I look back at the times I worked with Jim Caswell as the highlight of my working life.

Colleagues from the Methanol Multibeam Survey have contributed these memories:

JIMI GREEN: *My first observing run, the installation and commissioning of the 7-beam receiver on the Parkes telescope as part of the Methanol Multibeam Survey, was my initial introduction to the greatness of Jim Caswell—identifying masers by eye, and recounting the history and variability from memory. Jim set amazing standards and provided invaluable guidance, which will always remain.*

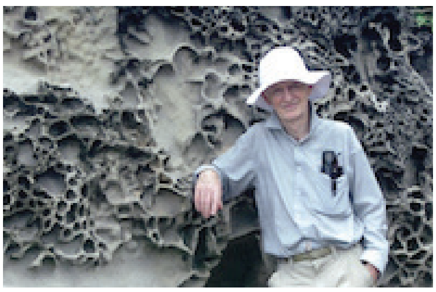
MAXIM VORONKOV: *As a maser person, I knew Jim's papers well before I met him for the first time in March 2001. In fact, working as a student on my first contribution to an observational paper, I was tasked with writing a Caswell-style review of observed sources. Later on, Jim became a very valuable collaborator of mine. I was always amazed by his attention to details and the overall quality of results. If I ever have to rate experimental astronomers by the quality and completeness of the analysis they produce, it would be fair to assign the 100% mark to Jim.*

SHARI BREEN: *The photo (shown below) is from one of our many observing trips to Parkes for the Methanol Multibeam Survey. These trips were usually fairly gruelling, often two or more weeks of 24-hour observations, not that you'd know it from the smiles on our faces! Observing trips with Jim were always fun. He was so generous with his time and his knowledge, instilling in us an appreciation of observing, telescopes and masers that far surpassed the facts. Jim and I used to play a game that we called maser roulette. I would send the telescope off to a maser, Jim would be able to see out the window the rough direction the telescope was pointing as well as a spectrum on the display. When he'd see the spectrum he would inevitably smile and say "oh, this is a lovely one" and name the maser with ease, recounting the detailed history of each source with an infectious love that he passed onto all of us that were lucky enough to work closely with him.*

SIMON ELLINGSEN: *In the early 1990s, when I was a PhD student, I was lucky enough to be involved in the first Parkes search for 6.7-GHz methanol masers and spent a number of extended sessions at Parkes with Jim Caswell assisting with the observations. During those trips to Parkes I learned a huge amount about spectral-line radio observing and other aspects of radio astronomy, knowledge that has served me well throughout my career. His knowledge of masers was unparalleled. However, what I personally will miss most is the opportunity to get his take on anything and everything in astrophysics. He was generous with his time and would always give you a carefully considered, ego-free opinion. I can't think of any better way to describe Jim Caswell than the one used by Jim Lovell: "He was one of the good guys". Astronomy would be better and richer if more of us were more like Jim Caswell.*

Jim was, at his core, a research scientist whose passion was solving problems and understanding the Universe. He was always a loyal and kind-hearted colleague, encouraging to others and a patient teacher and mentor. Jim is survived by his wife Sheena and three children. He will be sorely missed by his family, colleagues and friends.

Jim with Maxim Voronkov, Lyshia Whitworth-Quinn and Shari Breen in 2009, during one of many observing trips to Parkes for the Methanol Multibeam Survey. Photo courtesy of Lyshia Whitworth-Quinn



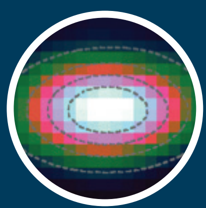
Jim Caswell. Photo: Sheena Caswell

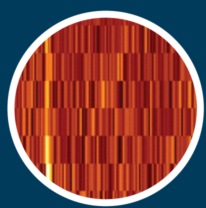
Southern Cross Astrophysics Conference

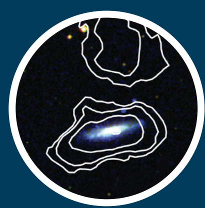
The Southern Cross Astrophysics Conferences, which are jointly supported by CASS and the Australian Astronomical Observatory (AAO), are annual meetings designed to attract international experts for discussions on a topic of interest to the Australian astronomical community. The eighth of these meetings, "Multiwavelength dissection of galaxies", was held in Sydney during 24–29 May, and focussed on galaxy evolution; in particular, what we can learn by combining resolved optical/near-infrared integral field spectroscopy (IFS) data with other multiwavelength properties (from X-ray to radio). This conference brought together observations and theoretical models to create a more complete picture of how galaxies, the Milky Way in particular, formed and evolved.

Participants of the Multiwavelength Dissection of Galaxies conference.
For details, see www.aao.gov.au/conference/multiwavelength-dissection-of-galaxies

Science reports







ASKAP spies dark HI clouds

PAOLO SERRA (CASS)

Galaxies move through space at high speed and their journeys involve spectacular encounters, collisions and occasional mergers with one another. Furthermore, the space between them, far from being empty, is filled with a tenuous medium whose pressure is felt by galaxies as they travel through it. This interaction between galaxies and their environment is a key driver of their evolution across cosmic time. It can result in galaxies changing shape and size as they age; it can make them acquire fresh gas (for example, by stealing it from nearby galaxies) and later turn it into new stars; or it can strip galaxies of their own gas (for example, through pressure from the surrounding medium), shutting down star formation and, therefore, inhibiting further growth.

The single most powerful probe of these processes, and the only one which allows us to observe them in action, is the direct imaging of gas – in particular neutral hydrogen gas (HI), the fuel for star formation – using radio telescopes. The images must have a sufficiently high spatial resolution for us to see how the hydrogen is distributed and moves around in galaxies, so that we can determine if the galaxy is accreting or losing gas. We also need a large enough field of view to observe galaxies and their environment simultaneously, to understand their interplay on large spatial scales. Making high-resolution images of HI over a wide field has been extremely challenging in the past, but with ASKAP (the Australian Square Kilometre Array Pathfinder) it is straightforward.

As part of the commissioning process for ASKAP-BETA (the first six antennas of the Australian SKA Pathfinder outfitted with phased-array feeds), we have started to search for evidence of the interaction between galaxies and their environment in the nearby Universe. Our first observation targeted the galaxy group IC 1459 (at a distance of 30 Mpc) and rewarded us with the detection of HI in 11 galaxies inside the group. For six of them this is the first high-resolution hydrogen image ever taken, and our data reveal new clues about the dynamic environment in which they live. The most exciting of these systems is IC 5270, a spiral galaxy living at the northern outskirts of the galaxy group. This galaxy is forming stars at a relatively high rate and so finding HI within its stellar disc was not a surprise.

But what we did not expect was the presence of two gas clouds near IC 5270 (30 and 60 kpc from it, respectively; Figure 1), each with more than a billion solar masses of HI. The clouds are ‘dark’: that is, they appear to contain no stars, making it unlikely that they are dwarf galaxies orbiting IC 5270. Indeed, further analysis suggests that the two clouds are just the tip of the iceberg – the densest, brightest gas clumps – of a larger hydrogen tail that may be connected to IC 5270. The tail may be tracing gas stripped from the galaxy as it makes its way to the centre of the group; if so, it would show that the galaxy has recently lost about a third of its initial gas content.

WALLABY (the ASKAP HI All-Sky Survey) will make such images at twice the resolution, over three-quarters of the sky. Although our present ASKAP observations alone are not sufficient to fully understand the origin of the gas tail in IC 5270, they do offer a rich appetiser of what is to come as the commissioning of ASKAP continues and then its full operation begins.

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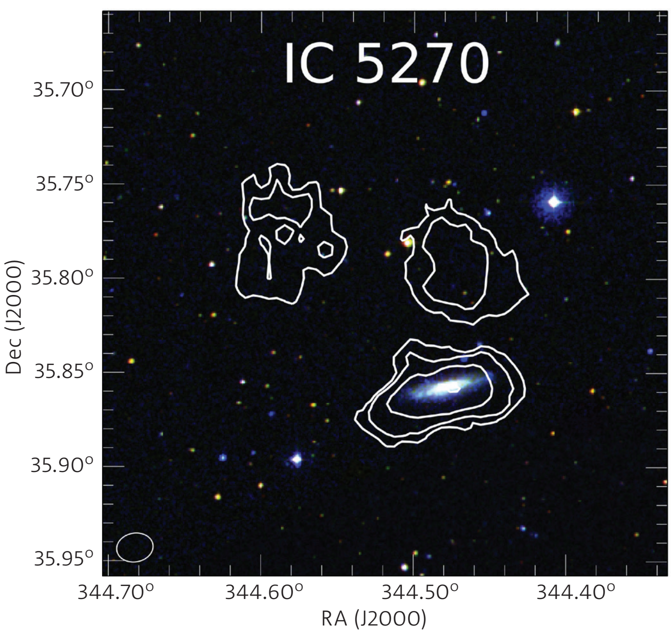


HI emission (shown as white contours lines) overlaid onto an RGB optical image of IC 5270. Neutral hydrogen was detected within the galaxy as well as in two clouds in its proximity. The clouds near IC 5270 have each an HI mass of ~109 M and, together, account for ~1/3 of the gas in and around this galaxy. Their detection provides an explanation of the strong asymmetry of the Parkes HI spectrum of IC 5270. Credit: Serra *et al.*

The first 'fast radio burst' seen in real time

EMILY PETROFF (SWINBURNE UNIVERSITY)

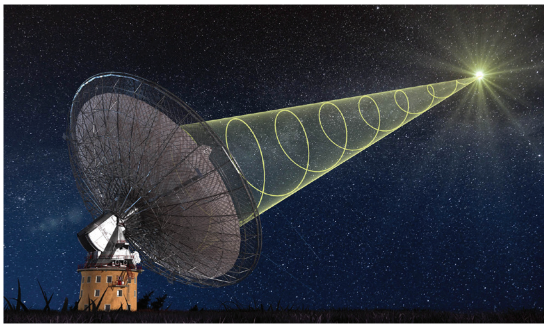
In the last decade radio pulsar surveys at Parkes and Arecibo have revealed a new class of objects: 'fast radio bursts' or FRBs (Lorimer *et al*. 2007; Thornton *et al*. 2013; Spitler *et al*. 2014; Burke-Spolaor & Bannister 2014). All FRBs discovered to date have been single radio events lasting about a millisecond. The electron column density (dispersion measure or DM) towards the sources is high, suggesting that FRBs originate at cosmological distances (Thornton *et al*. 2013) and/or in extreme environments (Katz 2014; Lyubarsky 2014). Although relatively few FRBs have been found (there are ten in the literature at the time of writing), they appear to have a dependence on Galactic latitude, shying away from the Galactic Plane (Petroff *et al*. 2014; Burke-Spolaor & Bannister 2014). FRBs have been the topic of considerable discussion, both as to their origins and their potential use as cosmological tools (Loeb *et al*. 2014; Kulkarni *et al*. 2014; Deng & Zhang 2014; Gao *et al*. 2014).

We recently investigated another class of radio bursts, perytons, which had also been detected with Parkes: these turned out to be terrestrial in origin (from microwave ovens, in fact: see Petroff *et al*. 2015b). However, unlike the perytons, FRB detections to date faithfully follow cold-plasma dispersion; some have shown clear scattering tails whose frequency-dependent width follows a Kolmogorov spectrum. We remain convinced that FRBs are of cosmic origin, although their progenitors are unknown.

One approach to understanding FRBs is to make sufficient detections to deduce the characteristics of the population. Another is to detect them in real time and make rapid follow-up observations at other wavelengths. We have taken this second path, using a real-time transient pipeline at the Parkes telescope. Our observing instrumentation is described in Petroff *et al*. (2015a), and is identical to that used for the High Time Resolution Universe (HTRU) survey and the FRB discoveries reported in Thornton *et al*. (2013).

Some theorists have posited that FRBs arise from flare stars or flaring magnetars (Loeb *et al*. 2014; Kulkarni *et al*. 2014): if so, FRBs should repeat. In any case, the discovery of repeating FRB sources would strongly constrain emission mechanisms and possible progenitors, and so last year we began using Parkes to search the fields of previous FRB events for repeating bursts. On 14 May UTC we were observing the field of FRB 110220 when at 17:14:11.06 UTC an FRB appeared in the central beam of the Parkes multibeam receiver. The pipeline identified the burst within 10 seconds and 2.22 seconds of data around the event were recorded to disk in 8-bit dual polarisation for all 13 beams of the Parkes multibeam receiver. An FRB alert email was sent to project observers at 17:14:30 UTC.

If the burst occurred at the beam's centre, the detection corresponds to a peak flux density of ~ 0.47 Jy and a fluence of ~1.3 Jy ms. The dispersion index, α, was −2.000(4), meaning that $\delta t \propto$ DM $\nu\alpha$, in agreement with the ν−2 expected for cold plasma. The scattering timescale was found to be τ1GHz = 5.4(1) ms. We calculate the upper limit on the redshift to be 0.4(1). This clearly sets the burst apart from its predecessor in the same field, FRB 110220, for which z < 0.81.



A schematic illustration of CSIRO's Parkes radio telescope receiving the polarised signal from the new 'fast radio burst'.

This observation was not only the first real-time detection of an FRB but also the first to record the polarisation of the signal. We saw 21 ± 7% (3-σ) circular polarisation averaged over the whole pulse. On the leading edge of the pulse, however, the pulse was 42 ± 9% circularly polarised, a 5-σ detection. No linear polarisation was detected and we place a 1-σ upper limit of 10% of the total intensity. It would require a very rare and specific feed rotation to result in high fractional circular polarisation with no linear detection. Such a configuration would also result in a high correlation between Stokes V and I, and we do not see the circular polarisation tightly following the total intensity. It appears, therefore, that the measured circular polarisation is intrinsic to the observation, not a calibration artefact.

Detecting FRB 140514 in real time allowed us to immediately pursue it with a dozen telescopes, working at many wavelengths. This was the fastest and largest follow-up effort ever undertaken for an FRB: it began within a few hours of the alert going out and continued over the subsequent weeks and months.

Radio observations were made with four telescopes (Parkes itself; CSIRO's Australia Telescope Compact Array; the Giant Meterwave Radio Telescope in India; and the Effelsberg Radio Telescope in Germany) and optical observations with six (the Swope and Baade telescopes at Las Campanas observatory in Chile; the Samuel Oschin Telescope at Palomar Observatory in the USA; the ANU's SkyMapper telescope in Australia; the Nordic Optical telescope in La Palma; one of the Magellan telescopes in Chile; and the Keck I telescope in Hawaii). The MPI-ESO telescope at La Silla in Chile made both optical and near-infrared observations of the field, and NASA's Swift X-ray space telescope studied it at X-ray and ultraviolet wavelengths.

In explosions such as supernovae (SNe) and superluminous supernovae (SLSNe), or in long gamma-ray bursts (GRBs), a counterpart is detectable as an object of varying brightness in subsequent observations. Variations in brightness would be observable on timescales of hours (for a long GRB), days (for typical SNe) or weeks (for SLSNe). The search for a counterpart focused on identification of any variable slow transients in the field that either brightened or dimmed by more than two magnitudes between epochs. We did not see such variations in the X-ray, near-infrared, optical, or radio regimes. Additionally, the interplanetary network (IPN) observed no gamma-ray emission from the field in either the hard or soft gamma-ray energy bands, ruling out all GRB progenitors except soft, short gamma-ray bursts.

From these follow-up observations we were able to place limits on the magnitude of any potential afterglow for FRB 140514, and compare these limits to light curves of known variable supernovae and gamma-ray bursts. The comparison shows that many nearby sources would have been detected (Evans *et al*. 2007; Rest *et al*. 2011; Kulkarni *et al*. 1998; Galama *et al*. 1998). So we have been able to rule out a local superluminous supernova and a nearby ($z < 0.3$) type Ia supernova as the progenitor of FRB 140514, as well as a slow transient with variations greater than 2 mag AB between our epochs of observation. We can also rule out an FRB association with long GRBs. The mystery of FRBs continues, but any hypotheses about their origin must take account of our polarisation data and the limits we have placed on their afterglows.

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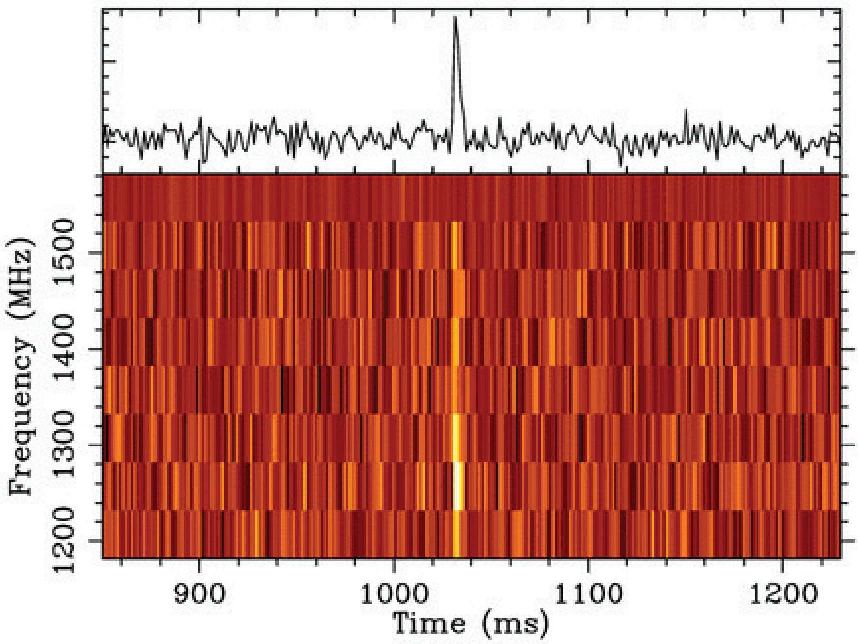

The pulse profile and dynamic spectrum of FRB 140514, the first 'fast radio burst' observed in real time, which was discovered using the Parkes radio telescope. (From Petroff *et al*., 2015a)

Searching the depths of the radio sky

MARTIN BELL (CSIRO)

With the recent advent of widefield radio telescopes, the dynamic radio sky has become a new frontier in astrophysics. A vast amount of parameter space can be searched for transient and variable radio sources. We hope to elucidate the physical mechanisms driving dynamic radio emission, which are still poorly constrained as a function of frequency and flux density. This is especially true at higher frequencies (above 5 GHz) where the field of view and survey speed of radio interferometers decreases.

We have just finished a survey with the Australian Telescope Compact Array (ATCA) that targets an extremely deep part of the time-domain radio sky: the Chandra Deep Field South (CDFS). This is a 0.3 deg^2 region favoured for its low optical and HI extinction. A plethora of multiwavelength data from both space- and ground-based facilities is available for this region.

In late 2009, Huynh *et al.* (2012) observed the CDFS at 5.5 GHz for 144 hours, creating a map of the region with a noise limit of ~10 microjanskys. Our survey was designed to obtain a further two epochs of observations (100 hours) of the CDFS that could be compared with those of Huynh *et al.*, so that we could search a specific region of parameter space (5 GHz and < 1 mJy) for signatures of dynamic radio emission over timescales of months to years. Our survey is the deepest search ever made for transient and variable sources at 5 GHz. By surveying a region that had already been observed at many wavelengths, we avoided having to make potentially lengthy follow-up observations. The multiwavelength data give us accurate source identifications, the lack of which has hampered the interpretation of discoveries in previous surveys for variables.

We found a total of 124 sources in the field, of which four were variable, one showing variations greater than 50 per cent. Nearly all of the sources in the field were cross-matched with AGN or QSOs: we had complete spectral information for all the objects, including optical and X-ray identifications. Remarkably, all the variables we found were inverted-spectrum radio sources. We think that these objects are young gigahertz-peaked spectrum sources, and that their variability and spectra indicate fairly recent activity within their radio jets. Our finding has an implication for future blind radio surveys, such as those to be done at 1.4 GHz with ASKAP: because of their inverted spectra, such sources will be difficult to detect.

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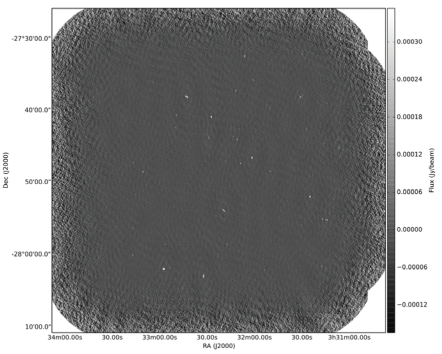

Figure 1: An image of epoch 2. A total of ~0.3 deg^2 was imaged, using 42 separate pointings: 82 sources were detected. The sensitivity achieved in the centre of the map was 17.1 μJy per beam.

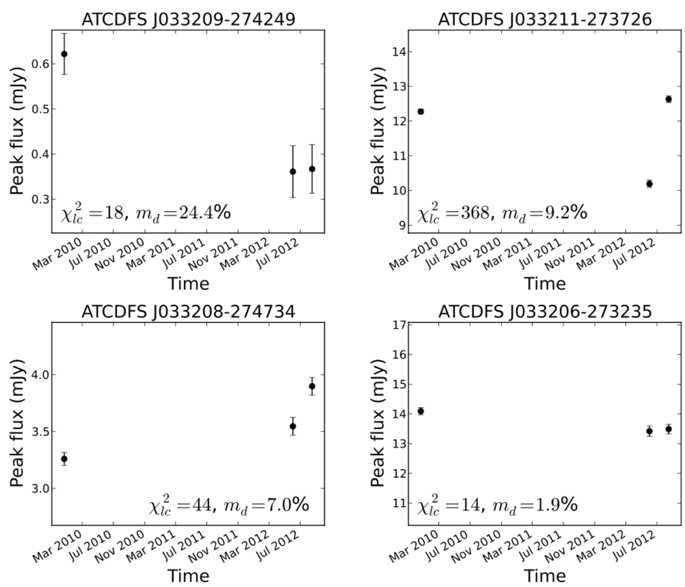

Figure 2: Light curves of the variable sources detected.

The host galaxy of an extreme quasar

AMY KIMBALL (CSIRO)

Quasars – actively accreting supermassive black holes– are the most powerfully emitting objects in the Universe, outshining even the most luminous galaxies. They probably played an important role in the evolution of massive galaxies in the early Universe, generating powerful jets and winds of ionising radiation that might have disrupted star-formation processes near the quasars themselves and perhaps even throughout their host galaxies. Studying the most powerful quasars is a way to probe massive galaxies in their most dynamic growth phases.

By combining publicly available data across a large range of frequencies, we have identified a handful of quasars with luminosities trillions of times greater than that of the Sun. We have started a campaign to study the host galaxies of these quasars, to investigate their properties and evolutionary phase. Until recently, the time required for detailed follow-up of the host galaxies would have been prohibitive. However, the ALMA (Atacama Large Millimeter/submillimeter Array) telescope has made these distant objects accessible with unprecedented resolution and observing sensitivity.

We were awarded observing time in Cycle 1 of ALMA operations to target a handful of the most luminous quasars known, looking for the ionised-carbon [C II] line at 158 µm. As the strongest cooling line of the interstellar medium, the [C II] line is a very effective dynamical tracer of star-forming gas. In our first observation, we detected a remarkable instance of this line from the host galaxy of one quasar, J1554+1937, at a redshift of 4.6. We targeted this quasar both for its extreme luminosity (> 10^{14} $L_\odot$) and its very high central black-hole mass (>10^{10} $M_\odot$). Its [C II] line was detected with high signal-to-noise in just five minutes of observing! The question arises: where does this line originate?

Figure 1a shows a map of the [C II] emission. The emission region is marginally resolved, with a physical diameter of 1.6 kpc. An intensity-weighted velocity map (moment–1 map) is shown in Figure 1b. Here we see a large velocity gradient from the northeast to the southwest side of the source. This type of gradient can indicate large-scale rotation, such as from a disc of star-forming material.

For more information about the origin of the line we look to the line profile, shown in Figure 2. This line is remarkable for both its profile shape and its extreme width. The profile shape is double-peaked, similar to lines that are seen, for example, from HI discs of massive galaxies (Koribalski *et al*. 20014). Only one similar [C II] line profile has been observed at high redshift, in a young starburst galaxy at z = 4.8 (De Breuck *et al*. 2014): that had a line width of 350 km/s. The line shown here has an incredibly broad FWHM (full width at half maximum) of 740 km/s.

This width suggests a very high rotation rate, if the line truly originates in a rotating disc. Fitting a rotating disc model (the black line in Figure 2) to the line profile, we find that the best fit corresponds to a maximum circular velocity of 480 km/s. Using this value and the physical size of the emission region, we estimate a dynamical mass for the host galaxy of ~10^{11} $M_\odot$ (with an uncertainty of a factor of two, because of the galaxy's unknown inclination to the line of sight).

We can estimate other properties of the quasar host galaxy using relationships observed in other galaxies. From the disc-rotation velocity (determined by fitting the line profile), and an empirical correlation between galaxy discs and their central bulges (Pizzella *et al*. 2005), we

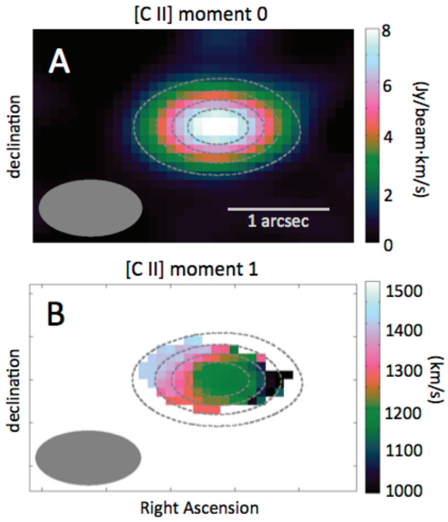

Figure 1: (a) Map of the [C II] 158 µm line emission for quasar J1554+1937. The grey ellipse shows the synthesised beam size and orientation. The deconvolved source size is estimated to be 250 mas in diameter. The contours correspond to the continuum emission. (b) Intensity-weighted velocity map of the [C II] emission. Only pixels with S/N > 4 from the Moment 0 map are shown. (From Kimball *et al*. 2015)

estimate a bulge velocity dispersion of about 400±100 km/s, where the uncertainty is due to the unknown disc inclination. Using this, we can compare this host galaxy to the local M–σ relation, a tight correlation between central black hole mass and bulge velocity dispersion that has been observed for a range of galaxy types and over many orders of magnitude in black-hole mass (Gültekin *et al*. 2009; Kormendy & Ho 2013). Because its disc inclination is unknown, we cannot be sure how well this quasar host galaxy conforms to the local M–σ relation. However, the estimated velocity-dispersion range suggests that the galaxy is either consistent with the relation or has a slightly over-massive black hole. In this, it appears to differ from other high-redshift quasar host galaxies, whose black holes are generally found to be much more massive than the local M–σ relation suggests (see, for example, Willott *et al*. 2013).

If its disc is indeed massive and rapidly rotating, then this galaxy seems to have evolved more quickly than other high-redshift galaxies. Galaxy morphology studies with HST suggest that well-ordered discs are not generally seen at redshifts above z~2 (for example, Ferguson *et al*. 2004; Papovich *et al*. 2005). Furthermore, typical galaxies have circular velocities in the range 200–400 km/s (for example, Pizagno *et al*. 2007; Cattaneo *et al*. 2014), lower than we have estimated for J1554+1937. While the velocity map and the line profile for this source suggest disc rotation, we cannot currently rule out another cause for the width of the line, such as fast outflows, or dynamics disrupted by a galaxy merger.

Of course, the analysis we have presented only applies if this galaxy has properties similar to those of other galaxies. As it is the host of such a luminous quasar, it is not a typical galaxy, but using those empirical relationships was a good place to start, since we don't yet know very much about this galaxy. We are in the process of obtaining follow-up observations to learn more about it, which will allow us to better understand what its properties are in relation to other galaxies. In the upcoming ALMA proposal cycle we will request time for making higher-resolution observations, with the goal of confirming or refuting the hypothesis that the [C II] line truly originates from the host galaxy disc.

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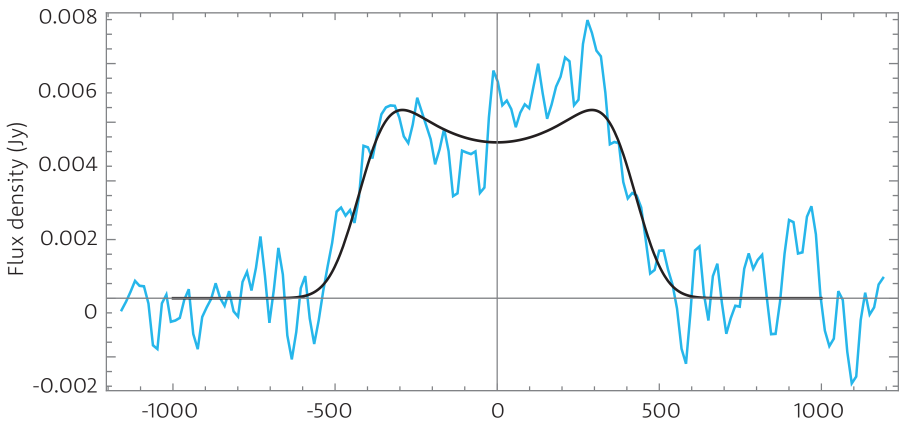

Figure 2: The profile of the [C II] 158 μm line, integrated over the entire source. The observed data are shown in purple. The black solid line represents a model of a rotating disc with maximum rotation velocity of 480 km/s, intrinsic velocity dispersion of 75 km/s, and an inclination to the line of sight of 60°. (From Kimball *et al*. 2015)

Publications

Publications lists for papers that include ATNF data or CASS authors are available on the web at **www.atnf.csiro.au/research/publications**.

This list includes refereed papers published between October 2014 and April 2015. Papers which include CASS authors are indicated by an asterisk.

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