ATNF News

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CSIRO Astronomy and Space Science — Undertaking world-leading astronomical research and operator of the Australia Telescope National Facility.

Editorial

Welcome to the October 2012 edition of *ATNF News*. It has been a particularly busy period since the last edition, from the announcement of the site of the Square Kilometre Array (SKA) in May and the successful landing of the Mars Science Laboratory in August, to the triennial IAU General Assembly in September and the opening of the Australian SKA Pathfinder (ASKAP) and Murchison Radio-astronomy Observatory (MRO) in early October.

We start with a photographic account of the official opening of ASKAP and the MRO, a high-profile event that took place on Friday 5 October. We also look at the latest news from the ASKAP project and provide an update on CSIRO's contribution to the international planning for the SKA.

We then feature the successful landing of 'Curiosity' on Mars and the support role played by the Parkes radio telescope in tracking the entry, descent and landing of the science laboratory.

In other news, we report on CSIRO Astronomy and Space Science participation in the IAU General Assembly in Beijing, the CASS Radio School 2012, and recent awards and appointments. We also include our regular features on new postdoctoral staff, the graduate student program and recent distinguished visitors.

It has also been a productive period for science. Four science articles give a snapshot of the latest radio astronomy research being conducted with the ATNF. These include:

- A review of the Parkes Pulsar Timing Array project by George Hobbs and Dick Manchester
- A description of fascinating jet structures in PKS B2152-699 by Diana Worrall and Mark Birkinshaw
- Catarina Ubach and coauthors' identification of signatures of grain growth in protoplanetary discs, and
- A detailed study of gas and star formation in the Circinus galaxy by Bi-Qing For, Bärbel Koribalski and Tom Jarrett.

We conclude with our regular contributions on education and outreach activities, ATNF operations and recent publications.

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

Gabby Russell and Tony Crawshaw

The *ATNF News* Editorial Team
(*newsletter@atnf.csiro.au*)

Front cover image

The majestic antennas of CSIRO's newest radio telescope, the Australian Square Kilometre Array Pathfinder (ASKAP), stand proudly against the night sky in the Mid West region of Western Australia. On 5 October, an official opening ceremony was held to celebrate the construction of ASKAP and the establishment of the Murchison Radio-astronomy Observatory on which ASKAP is sited. This image is one of 19,960 images taken by photographer Alex Cherney at the end of September 2012; it is included in a stunning timelapse video of ASKAP that can be viewed online at http://youtube/FDoDk4D2RAw. Credit: Alex Cherney/terrastro.com.

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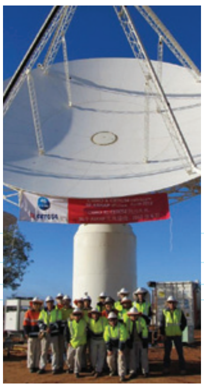
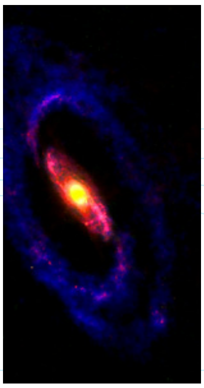
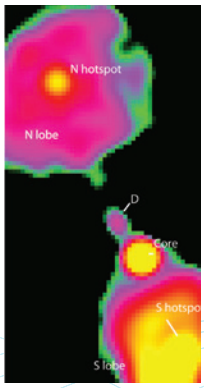






From the Chief of CSIRO Astronomy and Space Science

PHIL DIAMOND (CHIEF OF CASS)

It is with a degree of sadness that I write this final message for *ATNF News*, my last as Chief of CASS and as ATNF Director. As many in the astronomy community will be aware, I departed CSIRO on 12 October to take up the role of Director General with the international SKA Organisation based in Manchester, UK. My new role will, of course, allow me to stay in touch with CSIRO and the Australian astronomy community as the SKA telescope project begins to takes shape.

While my time with CASS has been a relatively short two-and-a-bit years, it has been personally satisfying to participate in the development and official launch of the Australian SKA Pathfinder and Murchison Radio-astronomy Observatory in Western Australia, and to lead such a talented team of scientists and engineers delivering world-class science and facilities. Other highlights of my time here have included celebrating the 50th anniversary of 'The Dish' at Parkes, being involved in the team that successfully delivered SKA co-hosting rights, and experiencing the awe-inspiring landing of the Mars rover 'Curiosity' from the CASS-operated Canberra Deep Space Communication Complex, which was responsible for tracking the spacecraft.

My thanks go to the CASS team, I will treasure and remember your ingenuity and spirit, as well as your help and advice in ensuring that the high standards expected in such a post were met.

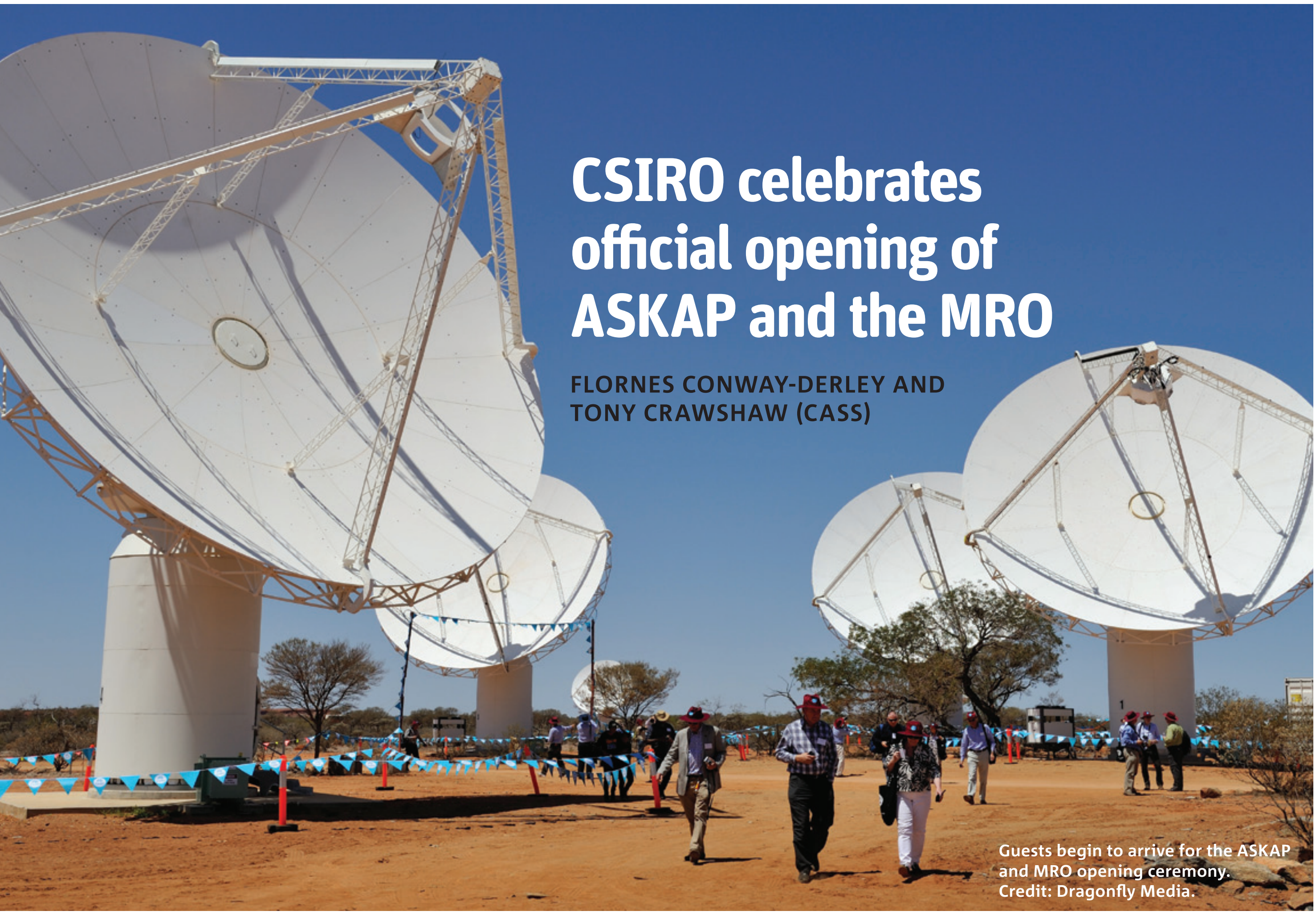
CASS has a truly outstanding heritage in radio astronomy and I'm sure will continue to deliver great things into the future. When ASKAP is operational next year, I look forward to seeing great science come from this innovative instrument along with a continuation of the excellent science that is done with the other telescopes that make up the ATNF.

Sarah Pearce, CASS Deputy Chief, has taken on the role of Acting Chief of CASS while an international search takes place for my replacement.

I wish everyone all the best for the future and depart all the richer for the experiences that I have gained here.

CSIRO celebrates official opening of ASKAP and the MRO

FLORNES CONWAY-DERLEY AND
TONY CRAWSHAW (CASS)



Guests begin to arrive for the ASKAP and MRO opening ceremony. Credit: Dragonfly Media.

Friday 5 October 2012 marked an historic occasion as, under clear blue skies, Senator the Hon. Chris Evans, Minister for Tertiary Education, Skills, Science and Research, officially opened CSIRO's newest radio telescope, the Australian Square Kilometre Array Pathfinder (ASKAP) and the Murchison Radio-astronomy Observatory (MRO) on which ASKAP is sited.

Guests transported to the remote site for the day included board members of the SKA Organisation, senior government representatives, ambassadors and high commissioners of SKA member countries, neighbouring pastoralists and traditional owners of the MRO, the Wajarri Yamatji.

CSIRO Chief Executive Dr Megan Clark addresses the audience. Credit: Dragonfly Media.

Minister John Day, Western Australian Minister for Science and Innovation (left), Minister Chris Evans, Australian Minister for Tertiary Education, Skills, Science and Research (centre), and CSIRO's Chief Executive Dr Megan Clark (right) at the official opening of ASKAP and the MRO. Credit: Dragonfly Media.

Following a 'Welcome to Country', members of the Wajarri Yamatji performed traditional dances. Credit: Dragonfly Media.

The audience at the official opening of ASKAP and the MRO on Friday 5 October 2012. Credit: Dragonfly Media.

Highlights of the ceremony included a 'Welcome to Country', traditional dancing by members of the Wajarri Yamatji, and bestowing of traditional Wajarri names to each of the ASKAP antennas. Addresses were given by Dr Megan Clark (CSIRO Chief Executive), Simon Broad (Murchison Shire President), the Hon. John Day (Western Australian Minister for Science and Innovation), Godfrey Simpson (Wajarri Yamatji) and Minister Evans. Proceedings concluded with the push of a button by Minister Evans, initiating the slewing of the ASKAP antennas to point toward Virgo A as test data began to stream in.

As part of festivities, public talks on ASKAP and the SKA were held in Geraldton, and local celebrations took place at CASS sites at

Senator the Hon. Chris Evans, Minister for Tertiary Education, Skills, Science and Research, officially opened ASKAP and the MRO. Credit: Dragonfly Media.

CSIRO ASKAP Project Director Ant Schinckel takes some of the guests and media on a tour of an ASKAP antenna.

Marsfield, Parkes, Narrabri and Tidbinbilla. A webcast of proceedings was also available to viewers from around the world and continues to be available at *http://tinyvio.com/CSIRO_ASKAP_Opening_Ceremony*.

Special thanks goes out to everyone involved in the organisation and coordination of the ceremony and supporting events. From those on the ground at the MRO, to those who joined in the local festivities, many people worked tirelessly to ensure the opening was certainly a day to remember.

ASKAP commissioning activities are currently underway, with operations due to begin in 2013.

At Narrabri, staff watched the live webcast as part of the opening ceremony celebrations.

At Marsfield, Julie Tesoriero and Graeme Carrad cut celebratory cakes while Russ Bolton looks on.

Staff at CSIRO's Marsfield site watched the live webcast of the ASKAP and MRO opening ceremony in the lecture theatre.

After the ceremony, guests were led on tours through the control building, a unique facility that will house the complex digital systems of ASKAP, termination points for approximately 7600 high-bandwidth optical fibre links from projects on the site, and the fibre link to Geraldton. Credit: Dragonfly Media.

At Parkes, staff enjoyed a barbeque before watching the live webcast.

As part of the celebrations at the Canberra Deep Space Communication Complex in Canberra, staff marked the occasion by constructing 36 paper dishes to represent ASKAP, along with a small origami kangaroo.

ASKAP and SKA news

FLORNES CONWAY-DERLEY (CASS), SARAH PEARCE (CASS), CAROLE JACKSON (CASS) AND STEVEN TINGAY (ICRAR/CURTIN)

Update from the MRO

Assembly of all 36 antennas of the Australian Square Kilometre Array Pathfinder (ASKAP) at the Murchison Radio-astronomy Observatory (MRO) was completed in May, and final site acceptance tests confirmed accuracy levels a factor of two better than the required ASKAP specification.

The ASKAP antenna reflectors were designed to a surface accuracy of 1.0 mm, to allow for astronomy-capable operation up to 10 GHz. The surface accuracy actually achieved on all 36 antennas has been close to, or better than, 0.5mm, effectively increasing the range of astronomy-capable operation up to 20 GHz.

Other essential works on site at the MRO have included the completion of the control building, and the installation and testing of bespoke ASKAP telescope operating system software into all computers on site.

FIRST EVER PHASE CLOSURE ACHIEVED WITH ASKAP PAFS

In July, a major milestone in ASKAP commissioning was achieved with the first ever successful demonstration of phase closure between three phased array feed (PAF) receivers installed on ASKAP antennas at the MRO.

There are currently four ASKAP antennas installed with PAF receivers and associated beam-forming electronics. The fit-out of the complex receiver and computing systems will enable ASKAP to survey the sky faster than any other radio telescope.

Phase closure is an important step in calibrating the antennas in preparation for interferometry with ASKAP by demonstrating the proper functioning of the antennas and their electronic systems. This was the first time the correlation has ever been demonstrated using a closed loop, three-PAF system, removing phase offsets in observations to ensure a more accurate imaging process.

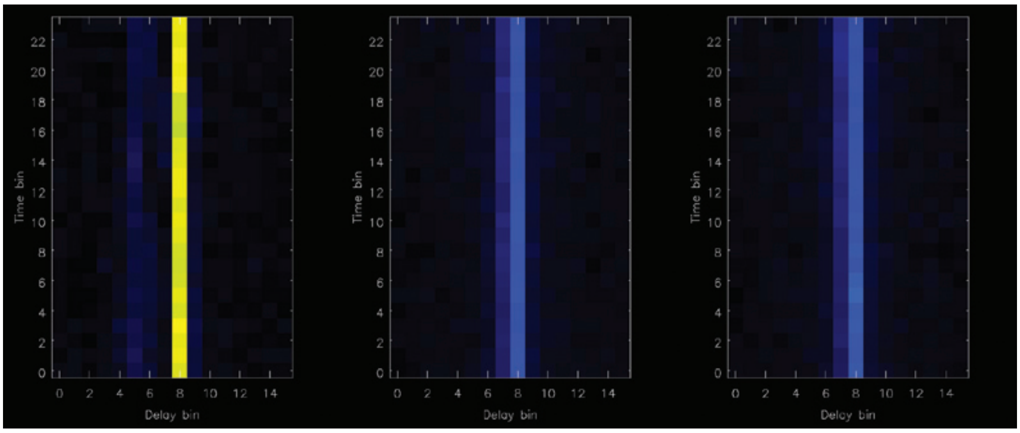
The ASKAP systems commissioning team used the strong compact astronomical source Virgo A to perform the correlations at the MRO, with data captured simultaneously from the three beamformers and processed in real time. The three baselines were then combined to form the closure phase, the results of which were encouragingly close to zero degrees.

The ASKAP team then achieved further system verification success by demonstrating simple multibeam imaging on three PAF-equipped ASKAP antennas. Several hours of observation data was then used to construct a rudimentary image of 1934-638, effectively demonstrating the full data reduction path from the software correlator to imaging in ASKAP's purpose-built software package, ASKAPsoft.

This is an essential step on the road to commissioning the Boolardy Engineering Test Array (BETA), a six-element widefield interferometer made up of the first six ASKAP antennas at the MRO to be installed with PAFs and associated electronics.

Operation of the initial BETA array will be an invaluable testbed for the ASKAP team to learn how to achieve the best possible performance from the full 36 antenna ASKAP telescope, and further develop technologies in using PAFs for radio astronomy.

First fringes achieved as part of system verification tests using three of CSIRO's PAF receivers installed on ASKAP antennas at the MRO.



The fourth phased array feed (PAF) receiver is installed on an ASKAP antenna at the Murchison Radio-astronomy Observatory.

Members of the CETC54 and ASKAP teams celebrate assembly of all 36 ASKAP antennas in May 2012. Final site acceptance tests have since confirmed reflector accuracy better than ASKAP specification, allowing for range of astronomy-capable operation up to 20 GHz.

ASKAP technologies

NEXT GENERATION PAF UNDER DEVELOPMENT

Since August 2011, development of a second generation ('Mark II') receiver chain for ASKAP has been underway through a work package known as ASKAP design enhancement (ADE).

The main focus for the team has been design optimisation of a new PAF, with an emphasis on reducing total system costs (including utilising new cost-effective technologies); design for manufacturability and testability has also been given careful consideration. By creating a highly reliable and modular design, the ADE system will also provide ASKAP with a high degree of availability, provide significant benefits in system performance, will reduce manufacture complexity and increase maintainability.

Enhancements to the system include improved performance across the ASKAP band for the PAF receiver, signal transmission using 'RF-over-fibre', direct sampling of the radio signal at the MRO control building, and hardware for digital signal processing that uses the latest in field-programmable gate array and high speed communication devices.

Continued testing of PAF data capture, beamformers and antenna drive software continues with regular observing sessions scheduled at the Parkes Testbed Facility, a 12-m testbed antenna equipped with a prototype PAF working in conjunction with the multibeam receiver installed on the 64-m Parkes radio telescope.

The testbed will remain an invaluable resource for developing new receiver technology and gaining crucial insight into PAF performance. Recently it was used to test a proof-of-concept design for the Mark II PAF, successfully demonstrating excellent performance across the entire ASKAP frequency band.

ASKAP science

ASKAP CENTRAL PROCESSOR INSTALLATION TO START IN 2013

In August, CSIRO welcomed the announcement by Senator the Hon. Chris Evans, Minister for Tertiary Education, Skills, Science and Research, of the new supercomputer to be installed at iVEC's Pawsey Centre in Perth, Western Australia.

The procurement agreement for the Pawsey Centre includes the purchase, installation, integration and commissioning of the petascale supercomputer that provides support to ASKAP and other international projects based at the MRO.

The supercomputer will be a Cray Cascade system capable of processing radio astronomy data in real time with partitions for multipurpose research. Installation of the ASKAP central processor, a 200 TFlop/s system with a 1 PByte Lustre file system, is expected to begin in 2013. Coinciding with this will be installation of the first stage of the general purpose research petascale system, the expansion of which will see increased performance to 1.2 petaflops in 2014.

The first-stage deployment of tape libraries and a HSM file system for the ASKAP central processor in 2013, with capacity up to 5 PBytes, is expected to support one year of observing with ASKAP. In 2014, this will be expanded to at least 25 PBytes for the ASKAP science data archive.

iVEC's Pawsey Centre represents the third and final phase of the Federal Government's Super Science Initiative to boost supercomputing capabilities and scientific research in Australia. The ASKAP team has been testing the processing capabilities of the first two phases of the system since July 2011 as 'early adopters', simulating how ASKAP data will be processed to create images of the radio sky.

Supercomputing resources at iVEC's Pawsey Centre will also be available for data-intensive projects across the scientific spectrum, including biotechnology, geosciences and nanotechnology.

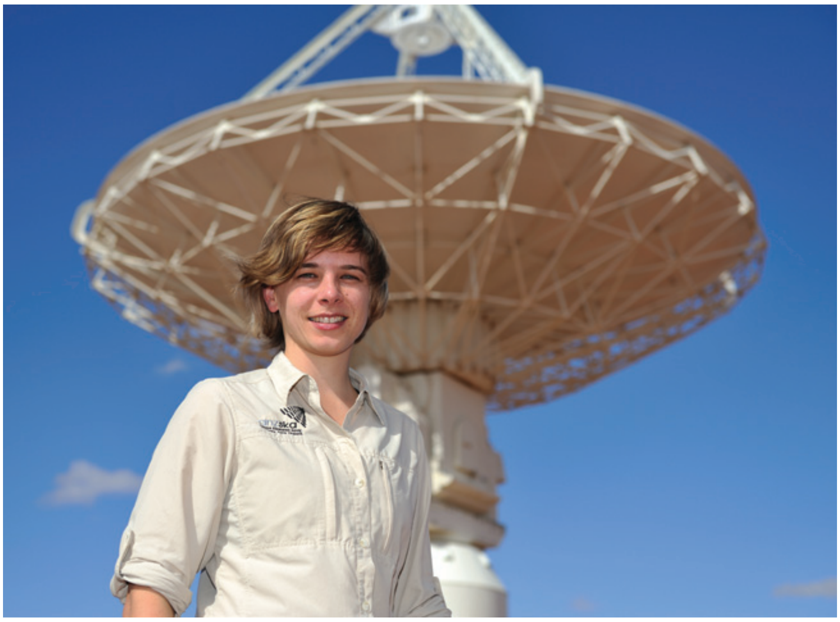
Construction activities underway at the iVEC Pawsey Centre in Perth. The supercomputer to be installed will be capable of processing radio astronomy data in real time with partitions for multipurpose research including biotechnology, geosciences and nanotechnology. Credit: Jim Masocco, Cray.

NEW PROJECT SCIENTIST FOR ASKAP

Dr Lisa Harvey-Smith was recently appointed Project Scientist for ASKAP to provide critical input and leadership in the areas of ASKAP performance, survey science team management, commissioning, and international SKA developments.

Previously CSIRO Project Scientist for the SKA, Lisa worked closely within the international SKA project and the wider astronomical community to refine the science case for the SKA with a particular emphasis on keeping technology developments aligned with science goals.

Lisa is also a member of the continuum (EMU) and polarisation (POSSUM) ASKAP survey science teams, playing a leading role in the design and verification of data catalogues. Lisa is now looking forward to working more closely with all ten ASKAP survey science teams.



ASKAP Project Scientist Lisa Harvey-Smith. Credit: Dragonfly Media.

SKA activities

SKA PRE-CONSTRUCTION PHASE UPDATE

On 25 May, the international SKA Organisation announced that the SKA radio telescope will be deployed in Australia and southern Africa. The organisation noted that a dual-site implementation model for the SKA had been agreed by the majority of its members.

Construction of the SKA Phase 1 is planned to start in 2016 with sets of antennas with complementary frequencies to be placed on each continent. In Phase 1, 60 mid-frequency SKA dishes equipped with phased array feeds, as well as an array of low-frequency antennas, will be built in Australia.

Since the announcement of the dual-site outcome, two additional countries have been admitted to the organisation — Sweden is the ninth member country, and India is an associate member.

Building on the foundation of the project execution plan, the SKA Organisation has led the development of a full work breakdown structure (WBS) covering all aspects of the first year of the pre-construction phase, which will culminate with the systems requirements reviews.

The WBS is divided into a number of major sections covering aspects such as project management, science, site, power and the technology work packages.

Critically, the impact of the dual-site implementation does not change the fundamental assumption that as much technology and infrastructure as possible should be common to all SKA systems. The expectation is that consortia of institutes, companies and other stakeholders will respond to an up-coming request for proposals from the SKA Organisation early in 2013.

Representatives from CSIRO, led by CASS Deputy Chief Sarah Pearce, continued to convene a number of Australia–New Zealand strategy discussions so that all stakeholders are ready to participate in the various consortia. These discussions included representatives from universities, research institutes, industry, the Australian Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE) and other stakeholders.

Concurrently, DIISRTE has run open briefings for industry to encourage interest in participating in the pre-construction work. An informal 'Expressions of Interest' process is being run by DIISRTE to filter companies who are pre-qualified to engage with the emerging consortia.

Within CASS we have identified which of the consortia we wish to participate in, allocated some preliminary resources and begun more detailed discussions with national and international partners. Current priorities are towards consortia for dish array (with an emphasis on receiver systems — for all feed types — and PAF systems work), computing, and site and infrastructure, with lower levels of engagement in a number of other work packages.

In September, a team of nine from CASS and the CSIRO ICT Centre attended the ICEAA conference in Cape Town, South Africa. The 'ICEAA12' event brought together three parallel conferences: the International Conference on Electromagnetics in Advanced Applications (ICEAA), the IEEE-APS Topical conference on Antennas and Propagation and the inaugural URSI Electromagnetic and Environment and Interference symposium (EEIS).

Of particular interest were day-long sessions on radio astronomy (including the SKA) and imaging arrays for radio astronomy, with CSIRO representatives presenting papers on aspects of ASKAP's ADE PAF system developments during the latter session.

An international workshop on PAFs for the SKA was also held during the conference, to take advantage of the number of engineers at ICEAA who also participate in the informal 'PAFSKA' collaboration. The workshop commenced with an overview from each institute/country on current developments, which gave an excellent snapshot of a range of PAF developments including recent work in Australia (CSIRO) on chequerboard-type PAFs, in Canada (National Research Council) and The Netherlands (ASTRON) on Vivaldi-type PAFs, and in the US (Brigham Young University and National Radio Astronomy Observatory) on crossed-dipole PAFs.

These presentations provoked discussion on the real challenges of achieving thermal noise performance in light of instrumental and sky effects (including the ever-present global positioning system signals). The afternoon of the workshop was dedicated to reviewing some of the critical issues regarding the design SKA optics, most of which are not particularly PAF-specific but impact all feed choices and the future-proofing of the SKA. The workshop was well appreciated by the attendees and identified many aspects of SKA design which the SKA dish array consortium will have to address.

INTERNATIONAL SKA ORGANISATION VISITS AUSTRALIA

CASS recently welcomed members of the SKA Organisation team to its Marsfield headquarters in Sydney and the MRO in Western Australia as part of a familiarisation visit to further explore synergies between ASKAP and the SKA project in preparation for Phase 1 of the SKA.

In Sydney, a number of workshops were convened that included discussions on system engineering and detailed presentations from the ASKAP team on the design history of ASKAP.

The following week, CASS hosted the group at the MRO for a two-day familiarisation visit. There the team learnt in further detail more about ASKAP, the MRO and the larger Murchison region, and had an opportunity to appreciate the vast, remote and radio-quiet nature of the location.

While in Western Australia, the team also visited related organisations such as the iVEC Pawsey Centre, where development of next-generation computing facilities for ASKAP and the SKA are currently underway, and the International Centre for Radio Astronomy Research in Perth.

In September, the SKA Organisation team had taken a similar trip to the SKA site in South Africa. These visits will be useful in developing an implementation plan for the integration of the SKA precursor telescopes and associated infrastructure at both locations into Phase 1 of the SKA.

The SKA Organisation team at CSIRO's Murchison Radio-astronomy Observatory in Western Australia: (from left) Wallace Turner, Andre Gunst, Kobus Cloete, Roshene McCool, Georgina Harris, Tim Stevenson, Minh Huynh, Rob Millenaar and Peter Dewdney.

Collaborator projects

MWA CLOSE TO COMPLETION: FIRST SCIENCE OBSERVATIONS BECKON

The Murchison Widefield Array (MWA) is one of three SKA precursor instruments, the only low-frequency precursor and the first SKA precursor to reach construction completion. Over the past nine months, the MWA project has completed all physical infrastructure work at the MRO, completed production of all antennas, receivers and correlator components, and has implemented a data archive.

The MWA team is now in the final stages of integrating the full facility at the MRO, with construction completion of the full instrument expected in November/ December 2012.

Engineering and science commissioning activities commenced on the partially complete instrument in September, with final commissioning of the full instrument to take place in early 2013. Science observations are expected to commence with the full instrument in mid-2013.

The MWA is an 'open skies' facility and the MWA Board has recently completed a revision of the project policies concerning time allocation on the facility and data access (available at *http://mwatelescope.org/info/documents.html*).

Before the end of 2012, the MWA project team aims to release the first call for proposals to the astronomy community, to support a time allocation process that will commence in early 2013; observing is expected to commence from approximately mid-2013. Ahead of the first call for proposals, two key publications are in the final stages of production. The first is a full technical description of the MWA system capabilities (Tingay *et al.* 2012, PASA accepted:arXiv:1206:6945). The second is a full description of the MWA science case (Bowman *et al.* 2012, PASA submitted).

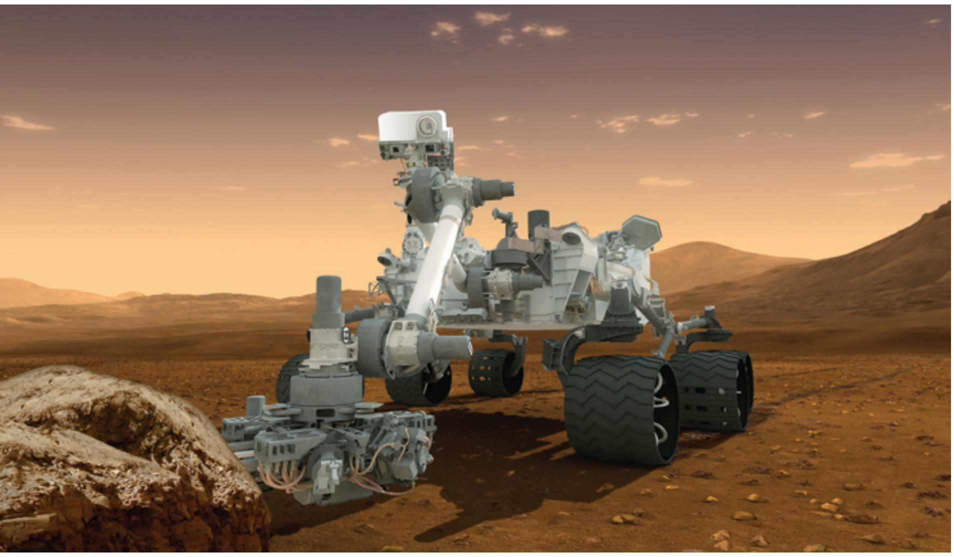
In excellent news for the MWA project, DIISRTE has recently provided initial funding (via Astronomy Australia Limited) for MWA operations, for the calendar years 2013 and 2014. This funding allows the project to open the facility for science observations on time and allows both the project and users to plan for the next few years.

To keep up-to-date with the final stages of MWA construction, and activities such as the formal launch event (which will take place on 30 November 2012), visit the MWA Facebook page at *http://www.facebook.com/Murchison.Widefield.Array*.

MWA tiles at the MRO. The final stages of integration of the facility are currently underway, with full instrument completion due in November/December 2012. Credit: Dragonfly Media.

Parkes supports Mars rover landing

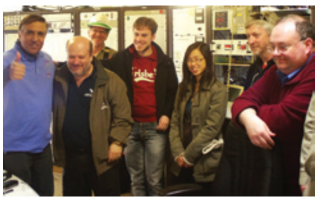
PHIL EDWARDS (CASS)



This artist's concept features NASA's Mars Science Laboratory Curiosity rover, a mobile robot for investigating Mars' past or present ability to sustain microbial life. Credit: NASA/JPL-Caltech.

Monday 6 August 2012 was a red-letter day for exploration of the red planet, with NASA's Mars Science Laboratory (MSL) successfully landing on Mars. CSIRO's Parkes radio telescope played an important support role to the Canberra Deep Space Communication Complex in tracking the entry, descent and landing of the MSL.

The complex series of manoeuvres required to land the 900-kg rover 'Curiosity' on the surface of Mars were dubbed the 'seven minutes of terror' as all actions were pre-programmed with no opportunity for manual intervention if anything went awry. The main task of monitoring Curiosity's entry, descent and landing was handled by the Canberra Deep Space Communication Complex (CDSCC), which CSIRO Astronomy and Space Science manages on NASA's behalf. CDSCC's 70-m and two 34-m antennas at Tidbinbilla received signals from the spacecraft directly at first, and then relayed through NASA's Mars Odyssey spacecraft which has been in Mars' orbit since 2001.



Happy faces in the Parkes control room as the signal from MSL is received: (from left) Sami Asmar (JPL), John Sarkissian (CASS), Brett Preisig (CASS), visiting observers Alessandro Ridolfi and Cherry Ng, John Reynolds (CASS) and Shaun Amy (CASS).

A smaller role in the monitoring of the entry, descent and landing was played by CSIRO's Parkes 64-m radio telescope. In addition to the 8-GHz band telemetry tracked by CDSCC, the spacecraft transmitted a beacon at 401.58 MHz. Although the Parkes 70-cm receiver had been retired from active service in 2003, it was able to be revived, re-tuned, and refurbished to operate at this frequency, and was installed in the focus cabin for tests and characterisation of the radio frequency environment during a two-week telescope shutdown in May–June 2012.

Monday 6 August dawned calm and clear, eliminating fears of the famous wind storm at Parkes on the day of the Apollo 11 lunar landing. With John Sarkissian at the telescope's controls, the signal was obtained on schedule and successfully tracked until the direct line-of-sight to the spacecraft was lost. Events during the descent such as the ejection of the heat shield and deployment of the parachute clearly showed up as small changes in the Doppler-shifted beacon frequency.

At Marsfield, Tidbinbilla and Parkes, staff and a huge public presence watched a direct feed of the NASA television coverage (there was surprise in some quarters when the television coverage stated that the signal had been detected at the MRO, until it was pointed out this was the 'Mars Reconnaissance Orbiter').

The Curiosity rover is designed to assess whether Mars ever had an environment suitable to support small microbial life forms. The 900 kg vehicle landed at, and will initially explore, Gale Crater, named after Australian Walter Gale (1865–1945). Gale was a keen amateur astronomer and an ardent supporter of the suggestion of possible life on Mars, and so it is quite appropriate that one of the main scientific objectives of the mission is to 'identify features that may represent the effects of biological processes' (so-called biosignatures).

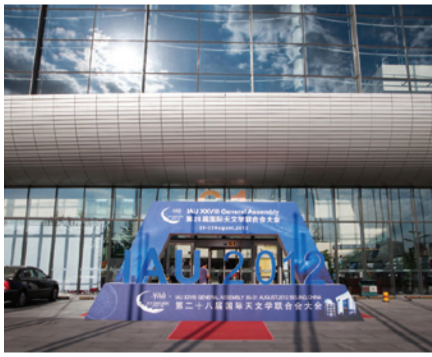
Full credit goes to the NASA Jet Propulsion Laboratory team who designed the mission and guided Curiosity to a successful landing, and to the CASS staff at CDSCC who ensured every bit was captured and relayed back to JPL.

Parkes may have had a small cameo role in the tracking support, but everything went to plan. NASA Scientist Sami Asmar, who was present at Parkes for the track, noted, "For JPL and the MSL project, the role Parkes played in support of entry, descent and landing was considered extremely important since all critical portions of the mission needed a proven and reliable back-up. Parkes performed flawlessly due to the efforts of the team in testing and preparations."

Overall, CDSCC and Parkes completed a fantastically successful double act, placing CASS into the international limelight.

On show at the IAU General Assembly

SIMON JOHNSTON AND ROB HOLLOW (CASS)



The China National Convention Center in Beijing, the venue for the IAU General Assembly 2012. Credit: IAU/F. Zhao.

The International Astronomical Union (IAU) holds its General Assembly every three years. Following the successful 2010 event in Rio de Janeiro, Brazil, the 2013 meeting was held in the imposing China National Convention Center near the Olympic precinct in Beijing, China from 20 to 31 August. CASS staff played a leading role in the management of the IAU and its divisions, running symposia, presenting talks and posters, renewing old friendships and forging new collaborations.

Highlights from the many different activities that CASS staff were engaged in included the pulsar symposium. This started in excellent fashion with a presentation by Mike Keith where he announced the discovery of a high dispersion fast transient from the latest Parkes pulsar survey, which generated a buzz that continued throughout the week. The interstellar medium meetings were well attended in the first week with the extragalactic talks given prominence in the second week.

Dave Jauncey (recently retired from CSIRO) delved into the history of radio astronomy while the ‘future facilities’ session contained a mouth-watering smorgasbord of instruments we can expect to come online over the next decade. CASS Chief Phil Diamond presented the latest news from the ASKAP project including the hot-off-the-press result of phase closure between three phased array feeds at the Murchison Radio-astronomy Observatory.

CSIRO was a sponsor of the General Assembly and CASS had an exhibition booth for the two-week event. Chinese visitors to the booth commented on the strong collaboration and links between China, Australia and CSIRO, in particular. An additional valuable role of the booth was that many Australian attendees, not just those from CSIRO, used it as a meeting point to catch up with others at the assembly, introducing them to CASS activities in the process.

The event was extremely well organised and the weekend tours allowed an excellent sampling of Chinese culture with trips to the Great Wall and the Forbidden City. The next IAU General Assembly will take place in Hawaii in 2016.

Rob Hollow (CASS), Kate Brooks (CASS), Chris Fluke (Swinburne University) and David Jauncey at the CSIRO Astronomy and Space Science stand at the IAU General Assembly in Beijing.

CASS Radio School 2012

TOM FRANZEN (CASS)

This year, the CASS Radio School took place at the Australia Telescope Compact Array (ATCA) near Narrabri, NSW, from 24 to 28 September. Thirty-eight students attended the school, including participants from New Zealand, Malaysia and Japan, and there were 19 speakers. We were fortunate to have as international speakers Ravi Subrahmanyan and Urvashi Rau from the National Radio Astronomy Observatory.

Most students had little or no knowledge of synthesis imaging before arriving at the school. Some of the participants had already attended last year's CASS radio school held at Parkes, where the focus was mainly on single dish telescopes.

The lectures were held in the visitor centre. All the presentations can now be found at *www.atnf.csiro.au/research/radio-school/2012/index.html*.

The school started with a presentation by Phil Edwards, introducing students to the facilities that make up the ATNF. Douglas Bock reviewed the basics of radio astronomy, while Ron Ekers and Ravi Subrahmanyan outlined the principles of interferometry, bringing beginner students up to speed. John Reynolds described the basics of Fourier transforms and their application to radio astronomy. In the last talk of the day, Phil Edwards took us on a whistle-stop tour of radio telescopes all over

Participants in the CASS Radio School 2012. Credit: Bruce Tough.

the world. The day ended with a 'question and answer' session which gave students the opportunity to seek clarification on any of the material presented during the day. In the evening, a dinner was held at the Seplin Estate Winery in Wee Waa. There was no shortage of entertainment: Phil ran an astronomy and general knowledge quiz, and students at each table were challenged to build their own telescope out of a bundle of wire.

On Tuesday morning, John Tuthill and Suzy Jackson covered signal processing and receiver systems. Mark Wieringa outlined the steps required to calibrate ATCA data, while Urvashi Rau went over imaging and deconvolution. The session ended with a talk on observing strategies by Shari Breen during which students were showered with chocolate-flavoured frogs if they were able to answer questions on the material just presented.

Wednesday began with Malte Marquarding demonstrating the use of various computing tools in astronomy, including the virtues of version control. There were two talks on polarimetry: the basics were covered in Jimi Green's lecture, which also included an overview of the exciting science that can be carried out from polarimetric observations; while more of the formalism and advanced calibration techniques were covered in Bob Sault's lecture. Emil Lenc discussed how different types of error, leading to image defects, may be diagnosed. The evening was spent at the observatory. Noodle dishes were served outside the lodge for dinner! This was followed by a fascinating talk by Ron on Pluto and its reclassification as a dwarf planet; it was great to hear insight from Ron, who was President of the International Astronomical Union at the time the decision to reclassify Pluto was made.

Some more advanced topics were covered on Thursday. Ravi Subrahmanyan started off with a comprehensive talk on self calibration and high dynamic range imaging. Tim Cornwell gave a talk on widefield imaging in which he included a description of the latest, cutting-edge techniques being developed to process future data from the Australian Square Kilometre Array Pathfinder. Lister Staveley-Smith covered mosaicing and explained how radio interferometer data can be combined with single dish data to fill in the shortest spacings. Finally, Aaron Chippendale reviewed the development of phased array feeds, describing the latest work being carried out at CASS.

On Friday, Andrew Hopkins gave a presentation on image analysis, with an emphasis on source finding and statistics. Steven Tingay described the technique of Very Long Baseline Interferometry and how it can be used as a tracer of the most energetic and dynamic processes in the Universe. Urvashi Rau gave another very informative talk, this time on wideband imaging, a highly relevant topic given the large instantaneous bandwidths now offered by ATCA and other instruments. The school ended again with Andrew Hopkins giving students some advice on how to write observing or funding proposals and valuable insight into the review process.

Tuesday, Wednesday and Thursday afternoons were taken up by tutorials. Students were advised to follow a tutorial on Miriad data reduction (basic continuum, advanced continuum or spectral line) during one of the afternoons, but were able to choose from a list of activities for the remainder of the time. The electives on offer were ATCA observing, advanced ATCA observing, making ATCA schedule files, Mopra observing, antenna/screen room tour, tour of the Sydney University Stellar Interferometer and the Ionospheric Prediction Service, and SIMPLE telescope demonstration. In the advanced ATCA observing tutorial, Ron asked students to apply what they had learnt in the lectures by challenging them to interpret the visibility data displayed in real time for observations of different types of sources under varying conditions. The SIMPLE telescope demonstration was oversubscribed. This was designed to demonstrate how a radio interferometer works using only a few electronic components and a computer. SIMPLE is a two-element 20-MHz interferometer used for educational purposes and is capable of detecting the Galactic plane, Centaurus A and the Sun during periods of solar activity. Students were shown how the interferometer works by Dave Brodrick, Chris Bremming and Steven Tingay.

Since many of the students were leaving by train on Saturday, several went to Sawn Rocks in Mt. Kaputar National Park, a rock formation resembling a huge wall of organ pipes, on Friday afternoon. A high note on which to end the school!

The feedback we received from the students was very positive and I would like to thank the following people for making the radio school possible: first of all, the speakers for making the trip to Narrabri and giving such great presentations; the observatory staff for running the tutorials; Margaret McFee for organising transportation, accommodation and evening functions; Robin Wark for organising the tutorials and for her advice and support during the run up to the school; Jamie Stevens for preparing the USB sticks for distribution of lecture slides and other materials; the catering staff for keeping everyone supplied with lunches and morning/afternoon coffees; Alex Hill, Phil Edwards, Naomi McClure-Griffiths and Dave McConnell who were on the scientific organising committee; and Amanda Gray for administrative support and handling student registrations.

Awards and appointments

GABBY RUSSELL (CASS)

Three CASS astronomers, George Hobbs, Bärbel Koribalski and Jill Rathborne, have recently received recognition of their research excellence. Congratulations George, Bärbel and Jill!

ARC Future Fellowship for George Hobbs

Over the four-year term of his Australian Research Council Future Fellowship, George Hobbs will aim to detect gravitational waves using precision pulsar timing observations. Direct detection of these waves is of huge international importance and will keep Australia at the forefront of the new research field of gravitational wave astronomy as it grows with the planned radio telescopes of the future. George's appointment reflects the excellent research he has been doing over the past few years in the hunt for gravitational waves and his role in the Parkes Pulsar Timing Array project (see page 19 for more information on the Parkes Pulsar Timing Array).

George joins Nick Seymour as a Future Fellow in CASS.

Bärbel Koribalski appointed OCE Science Leader

In August 2012, Bärbel Koribalski was awarded a prestigious CSIRO Office of the Chief Executive Science (OCE) Leader position.

This is a five-year position providing funding for two postdoctoral staff and two PhD students to work with Bärbel, enhancing her leading role in multiwavelength investigations into galaxy formation and evolution. Bärbel is the co-Principal Investigator, along with Lister Staveley-Smith (ICRAR/UWA), of WALLABY, one of the two high-priority ASKAP survey projects. Bärbel will use the resources from the OCE Science Leader position to strengthen her extragalactic research team working towards SKA Pathfinder HI surveys.

Julius Career Award for Jill Rathborne

A recipient of CSIRO's highly sought after Julius Career Award, Jill Rathborne will have the opportunity to continue her cutting-edge research into the formation of high-mass stars and to strengthen existing collaborations both within Australia and around the world. Over the three-year period of this award, Jill will use next-generation facilities such as the Atacama Large Millimeter/submillimeter Array (ALMA), visit key collaborators at world-leading institutes and undertake a sabbatical to work with international ALMA experts. Jill's international colleagues will also be encouraged to visit CSIRO: in doing so, Jill will help build new science networks for herself and her research group.

Welcome
to new postdoctoral staff

GABBY RUSSELL AND SIMON JOHNSTON (CASS)

Since the April 2012 edition of *ATNF News* was published, CASS has welcomed three new postdoctoral staff. We asked each of them to tell us, in their own words, about their research interests. Please join us in welcoming Yanett, Peter and Tim.

YANETT CONTRERAS

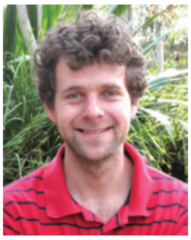
CSIRO Office of the Chief Executive Postdoctoral Fellow
PhD: Universidad de Chile, Chile, 2012

"My research interests are filamentary molecular clouds and the chemical evolution of the clumps and cores that will give rise to high-mass stars within them. For this research, the MALT90 survey (currently underway) is very important because it will allow us to establish a chemical evolution of the regions where the stars are born allowing us to understand how high-mass stars are formed."

PETER KAMPHUIS

CSIRO Office of the Chief Executive Postdoctoral Fellow
PhD: Kapteyn Astronomical Institute, University of Groningen, The Netherlands, 2008

"I am mostly interested in the formation and evolution of galaxies. My PhD work was focused on the kinematics of hydrogen in the halos of spiral galaxies in order to get a better understanding of how the gas is accreted and cycled in these galaxies. During my time as a Humboldt Fellow at the Astronomical Institute Ruhr-University-Bochum in Germany my interests were expanded to include the automated fitting of models to interferometric radio data, an approach that I'll be exploring with the aim to reliably extract kinematical parameters from the WALLABY survey. Here at CASS I hope to keep on working on both subjects as well as other projects such as LVHIS."



TIM SHIMWELL

CSIRO Office of the Chief Executive Postdoctoral Fellow
PhD: University of Cambridge, UK, 2011

"My PhD work was focused on the detection of massive galaxy clusters via their Sunyaev Zel'dovich signature. Whilst at CASS I look forward to continuing my research on galaxy clusters but also exploring new areas of research. I am pleased to be part of the ASKAP commissioning team and hope to help with this very exciting project's rapid progress."

Two postdoctoral staff, Shea Brown and Shane O'Sullivan, have recently completed their terms and taken up positions at Ohio University, USA and the University of Sydney, respectively.

Graduate student program

BÄRBEL KORIBALSKI (CASS)

Lina Levin Preston

Kate Chow (née Randall)

We would like to officially welcome the following students into the CASS co-supervision program:

- Vasaant Krishnan (University of Tasmania) – *Astrometric observation of methanol masers,* with supervisors Dr Simon Ellingsen (University of Tasmania) and Dr Shari Breen (CASS)
- Paul Brook (Oxford University) – *Variability in pulsars,* with supervisors Dr Aris Karastergiou (Oxford University) and Dr Simon Johnston (CASS)
- Guillaume Drouart (ESO) – *AGN and stellar components in HzRGs,* with supervisors Dr Brigitte Rocca-Volmerange (IAP), Dr Carlos De Breuck (ESO), Dr Joël Vernet (ESO) and Dr Nick Seymour (CASS)
- Jingbo Wang (Xinjiang Astronomical Observatory, China) – *Pulsar astronomy and gravitational wave detection*, with supervisors Dr Nina (Na) Wang (Xinjiang Astronomical Observatory) and Dr George Hobbs (CASS)
- Xinping Deng (National Space Science Center, Chinese Academic of Sciences) – *Pulsar timing and its application in spacecraft navigation,* with supervisors Dr Jianhua Zheng (NSSC, China) and Dr George Hobbs (CASS)
- Jordan Collier (University of Western Sydney) – *The history of supermassive black holes in the Universe,* with supervisors Dr Miroslav Filipovic, Dr Nick Tothill (both University of Western Sydney) and Dr Ray Norris (CASS)
- Graeme Wong (University of Western Sydney) – *Physics and chemistry of molecular gas in the Milky Way Galaxy,* with supervisors Dr Miroslav Filipovic, Dr Nick Tothill (both University of Western Sydney) and Dr Shinji Horiuchi and Dr Jimi Green (both CASS).

Congratulations on the award of their PhD and best wishes for their future career goes to the following students:

- Lina Levin Preston (Swinburne University) – *A search for radio pulsars: from millisecond pulsars to magnetars*
- Yanett Contreras (Universidad de Chile) – *The nature of filamentary structures of dense molecular gas in the Galactic plane*
- Rajan Chhetri (University of Sydney) – *Quasars, radio galaxies and gravitational lenses in the high radio frequency Universe*
- Luke Hindson (University of Hertforshire) – *The G305 star forming complex: A panoramic view of the environment and star formation*
- Kate Chow (née Randall) (University of Sydney) – *The evolution of young radio sources and the milliJansky radio source population*
- Minnie Mao (University of Sydney) – *Cosmic evolution of radio sources in ATLAS.*

Dr Lina Levin Preston is now a postdoctoral fellow at the University of West Virginia, USA and Dr Yanett Contreras has joined CASS as a postdoctoral fellow. Dr Luke Hindson recently started at the University of Victoria in Wellington, New Zealand, and Dr Minnie Mao is now a postdoctoral fellow at NRAO, USA.

To all students, well done!

A summary of the CASS graduate student program, current and past students, as well as new application forms can be found on the ATNF website at *www.atnf.csiro.au/research/graduate/scholars.*

Distinguished visitors

SIMON JOHNSTON (CASS)

Over the past six months we have enjoyed extended visits from Enno Middelberg (Bochum University, Germany), Duncan Lorimer and Maura McLaughlin (both University of West Virginia, USA), Barbara Catinella (MPIA, Garching, Germany), Luca Cortese (ESO, Garching, Germany), Grazia Umana and Corrado Trigilio (both INAF, Catania, Italy), Lukasz Stawarz and Yasayuki Tanaka (both ISAS, Japan). Current visitors include Martin Cohen (UC Berkeley, USA) and Bill Coles (UC San Diego, USA).

The distinguished visitors program remains a very productive means of enabling collaborative research projects with CASS staff, adding substantially to the vitality of the research environment. Visits can be organised for periods ranging from only a few weeks up to one year.

For more information on the distinguished visitors program see *www.atnf.csiro.au/people/distinguished_visitors.html.*

Prospective visitors should contact the local staff member with the most similar interests, or Naomi McClure-Griffiths, Chair of the Distinguished Visitors Committee.

9,000 hours of the Parkes Pulsar Timing Array

GEORGE HOBBS AND DICK MANCHESTER (CASS) ON BEHALF OF THE PPTA TEAM

In late 2003 we submitted the proposal that began the Parkes Pulsar Timing Array (PPTA) project. Now, 9,000 hours of observing time later, we have reached the stage where the goals of the project are within reach. Our data sets are the best of their type in the world with high-quality timing data for 20 millisecond pulsars (MSPs) over a more than six-year data span. Several major papers reporting on the project and describing progress on the main scientific objectives have been or soon will be published. True, we have not yet reached our major goal — the direct detection of gravitational waves — but we have started to seriously constrain the current galaxy merger and black-hole formation paradigms and are giving our Goliathan competitors in the quest for the first detection a run for their money.

We have made our data sets available to the International Pulsar Timing Array (IPTA) project and are working with colleagues from other PTAs to optimally combine the data sets and make further progress toward our goals. After the usual embargo period, our data sets are also publically available through the Australian National Data Service. The precision timing data sets of the PPTA have also been used for a wide variety of applications including investigations of the interstellar medium, detailed studies of the properties of individual pulsars and even proposed as a natural global positioning system for spacecraft navigation. Pulsars are fascinating objects, highly dynamic, continually pushing the boundaries of physical theories, and full of surprises. They have wide appeal to the general public and are a natural topic for outreach programs as testified by our highly successful 'PULSE@ Parkes' project.

The first proposal was written by researchers at CSIRO and the Swinburne University of Technology. It was led by Dick Manchester who had obtained an Australian Research Council Federation Fellowship to realise the world's first pulsar timing array (PTA). Whereas most standard pulsar observing programs are based on studies of individual pulsars or binary systems such as the double pulsar, PTA projects are based on the study of correlated timing signatures in a group of precisely timed pulsars. Foster and Backer (1990) showed that any identical signal in two or more pulsar data sets must correspond to terrestrial phenomena such as timing errors in the observatory instrumentation or irregularities in atomic time standards. Partially correlated signals with a spatially dipole signature would occur if there was an error in the Solar System planetary ephemeris used in the timing analysis and signals with a quadrupolar signature would arise from gravitational waves (GWs) passing over the Earth.

FIGURE 1: CSIRO's Parkes 64-m radio telescope.

The main goals of the PPTA were therefore defined in 2003 to be: 1) to detect the GW background; 2) to improve our knowledge of Solar System dynamics; and 3) to produce a pulsar-based timescale. It was clear that these goals could only be achieved by observing a large number of highly stable millisecond pulsars (MSPs) that provide sub-microsecond timing precision. These requirements were formalised by Jenet *et al.* (2005) who showed that, in order to detect a GW background with 95% confidence, it would be necessary to observe 20 MSPs over a period of five years with weekly observations. The rms timing residual for each pulsar over the entire data span needs to be <100 ns.

These requirements were (and still are) incredibly challenging. Van Straten *et al.* (2001) had shown that rms timing residuals <100 ns were possible for a single pulsar, PSR J0437-4715, but such timing precision had not been realised for any other pulsar. To begin the project we therefore needed new hardware, new software and new algorithms. We describe these in the next section, followed by a section on the astrophysical results that we have achieved so far and we finish this article by describing current and future work.

Systems development for the PPTA project

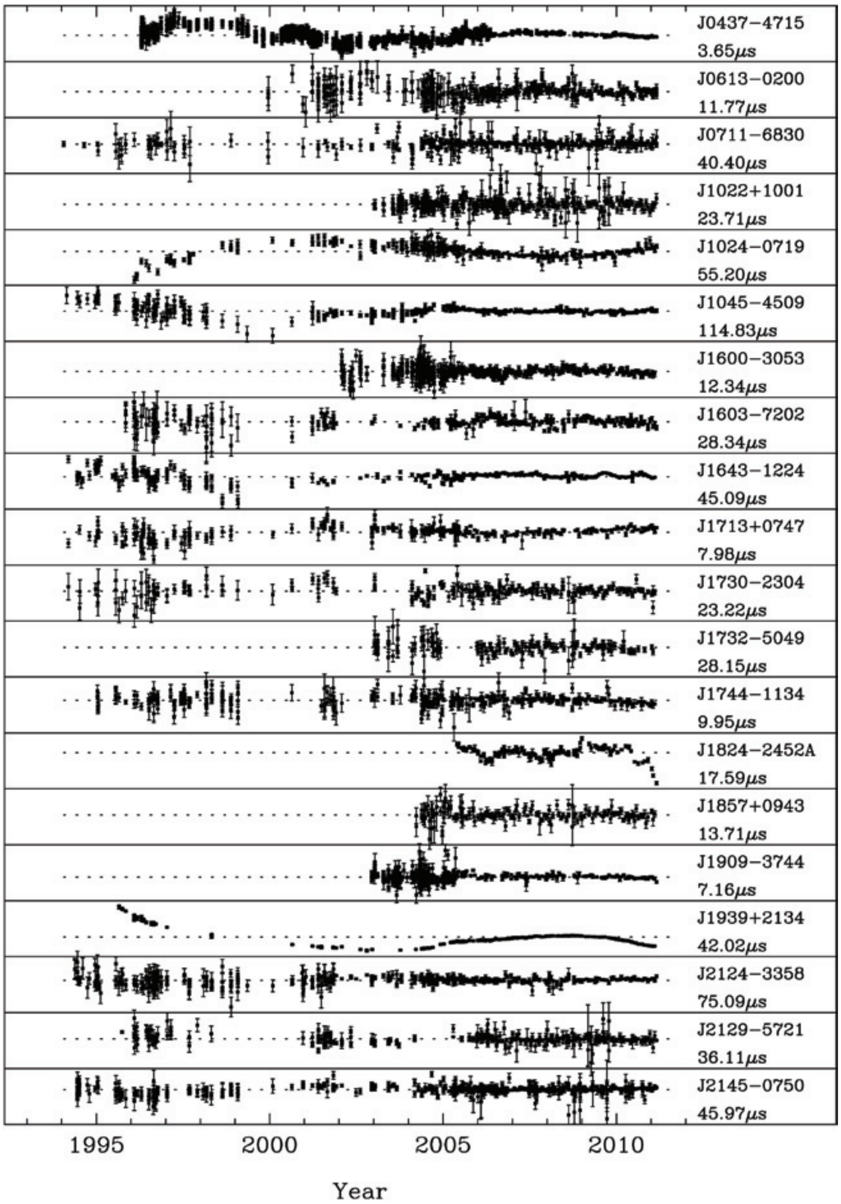
The PPTA project relies on precise measurements of pulse arrival times for approximately 20 MSPs using CSIRO's Parkes radio telescope (Figure 1). Throughout we have made observations using a 20-cm receiver (usually the central beam of the multibeam receiver, but sometimes the H-OH receiver) and the dual-band 10-cm/50-cm receiver. Initially we recorded the data using the wideband correlator (WBC) and the Caltech Swinburne Parkes Recorder 2 (CPSR2). The WBC was not adequate for high-precision measurements and a set of digital filterbank systems were designed and commissioned. The first, PDFB1, was commissioned in June 2005, which, along with CPSR2, provided our first major data set. A second digital filterbank system, PDFB2, which could process a bandwidth up to ~ 1024 MHz was commissioned in March 2007. The final filterbanks (PDFB3 and PDFB4) are based on the same hardware as the Compact Array Broadband (CABB) system and were commissioned in July 2008.

The digital filterbank systems are not ideal for low-frequency observations since they employ incoherent summing of frequency-channel data to remove the pulse sweep resulting from interstellar dispersion which is much larger at low radio frequencies. Fortunately there is another technique known as 'coherent dedispersion' which overcomes this problem. This technique is extremely computing intensive and was initially applicable only to relatively narrow bandwidths as in CPSR2. In 2009, we developed the ATNF Parkes Swinburne Recorder (APSR) which can provide 1024 MHz of coherently dedispersed data and in late 2010 we were also making use of a second coherent dedispersion system developed at Swinburne University, CASPSR, in parallel with APSR.

It was necessary to develop new software to calibrate and process these observations. Various updates (for example, van Straten 2004) have been made to the PSRCHIVE software suite to enable the necessary polarisation calibration. The resulting pulse arrival times form the basis of the PPTA project and have been published by Manchester *et al.* (2012) as two data sets. The first data set contains data from 2005 to 2011 and is our first major data release. The second combines Parkes archival data with the first data release to provide observations of the PPTA pulsars with data spans of up to 17 years. Figure 2 shows the timing residuals for the extended data sets, illustrating the high quality and good sampling of our data, particularly in the PPTA era.

The pulse arrival times are processed using the TEMPO2 software package. This software was designed to process multiple pulsars simultaneously and to deal with all known physical phenomena that will affect the timing residuals at the 1 ns level. In order to achieve the PPTA goals various algorithms have been implemented into TEMPO2 including global fitting procedures (Champion *et al.* 2010), simulation of GW signals (Hobbs *et al.* 2009), methods to deal with low-frequency noise (Coles *et al.* 2011) and routines for optimal interpolation and prediction (Deng *et al.* 2012).

FIGURE 2: Timing residuals for the extended PPTA data set (Manchester *et al.* 2012). The vertical scale for each subplot is adjusted to fit the range of the residuals. The PPTA data set extends from March 2005. Significant long-term fluctuations in the observed pulse period can be seen in most of the pulsars. The most prominent of these can be attributed to intrinsic variations in the pulsar period, but fluctuations due to gravitational waves passing over the pulsar and the Earth may also be present.



Astrophysical results from the PPTA project

A GW signal will induce long-term timing variations at the 10–100 ns level over five years. For most millisecond pulsars the dominant noise source over these timescales is caused by turbulence in the interstellar medium that leads to variations in the pulsar dispersion measures. It is therefore essential that these signals be measured and removed from the timing data. New techniques for removing the frequency-dependent variations without affecting any underlying achromatic gravitational-wave signal have been developed by Keith *et al.* (2012).

As a bonus, these measurements also provide a wealth of information about the interstellar medium. In the first study using the PPTA data, You *et al.* (2007a) analysed 20 pulsars and showed that the variations in dispersion measure were mostly consistent with an interstellar medium characterised by a Kolmogorov turbulence spectrum. However, the analysis for two pulsars, PSRs J1045-4509 and J1909-3744, provided the first clear evidence of a damping process in the turbulence spectrum, caused, perhaps, by ion-neutral collisions.

The solar wind also leads to variations in pulsar dispersion measures as Earth orbits around the Sun. In August each year, the line of sight to PSR J1022+1001 passes within 0.1 degrees of the Sun. High precision observations of this pulsar therefore provide a unique opportunity for studying the solar corona. Our results have been published in You *et al.* (2007b) who demonstrated how observations from the Wilcox Solar Observatory could be used to predict the effect of the solar wind and in You *et al.* (2012) who used PPTA observations to measure the electron density and magnetic field of the solar wind.

One of the major PPTA goals is to use pulsar timing data to detect imperfections in the planetary ephemeris that we use to correct site arrival times to the Solar System barycentre. These imperfections could come from either errors in the assumed masses of the planets or asteroids included in the ephemeris, or from other Solar System objects not currently included either because their mass is unknown or because their very existence is unknown. We currently use the Jet Propulsion Laboratory DE421 ephemeris for the barycentre corrections. Any planetary mass error, for example, will induce sinusoidal timing residuals at the orbital period of the planet and with amplitude dependent on the mass error and the ecliptic latitude of the pulsar. In our first analysis of this type, Champion *et al.* (2010) searched for errors in the masses of the known planets. Our results were consistent with, but less precise than, spacecraft measurements for all the planetary systems except for the Jovian system. Our derived mass of the Jovian system was consistent with the value assumed in DE421 (Folkner *et al.* 2009) to within 2×10^{-10} $M_\odot$, a higher precision than the published result obtained from observations of the Pioneer and Voyager spacecraft and consistent with the value obtained from Galileo. We are now continuing this research in the hope of discovering an unknown object in our Solar System.

In 2012 we achieved another of our goals: developing a timescale based on the rotational phase of the PPTA pulsars (Hobbs *et al.* 2012). This Ensemble Pulsar Scale (EPS) is analogous to the free atomic timescale, Échelle Atomique Libre (EAL), and can be used to detect fluctuations in atomic timescales, therefore leading to a new realisation of Terrestrial Time, TT. Our new realisation, TT(PPTA11), successfully follows known irregularities in the International Atomic Timescale (TAI) and has marginally significant deviations from the world's best atomic timescale TT(BIPM11). We have embarked on an IPTA project to combine our results with those from other PTAs which may confirm these deviations, thereby establishing the world's most stable timescale.

The primary aim of the PPTA project is to detect GWs. The PPTA is sensitive to GWs with periods longer than our typical sampling (approximately 3 weeks) and less than the total time span of our data (approximately 15 years for the extended data set). It is still not clear exactly what signal we should be searching for. Predictions have been made for isotropic stochastic GW backgrounds caused by oscillations of cosmic strings, fluctuations in the inflationary era and coalescing supermassive black holes in the cores of distant galaxies. It is also possible that individual supermassive black hole binary systems will lead to detectable GW radiation coming from a specific direction. The coalescence of such a system will lead to a 'GW memory event' that will be characterised in the residuals as a correlated glitch event. We have therefore developed algorithms to search for all of these possible signals.

Jenet *et al.* (2006) published the first upper bound on the GW background using the PPTA data sets. This work has now been cited more than 150 times on topics relating to inflationary models of the Universe, limiting possible cosmic-string models, close galaxy pairs, searching for dark matter halo substructure and primordial black holes. We are now preparing to publish a new limit based on the extended PPTA data set (Shannon *et al.* 2012) that is almost an order of magnitude lower than the 2006 result and three times better than recent limits from the other PTAs (van Haasteren *et al.* 2011, Demorest *et al.* 2012). Our results for the first time place significant constraints on current models for galaxy mergers and black hole coalescence in their cores (for example, Sesana *et al.* 2008).

Yardley *et al.* (2010) used PPTA data to present the first sensitivity curve of a PTA to individual sources of GW emission. This work provided a sky-averaged constraint on the merger rate of nearby ($z < 0.6$) black hole binaries in the early phases of coalescence with a chirp mass of 10^{10} $M_\odot$ of less than one merger every seven years. More recently, we have attempted to detect individual sources of GW emission, but, so far, no detection has been made.

The PPTA data sets are also being used for a diverse range of projects including studies of the polarisation properties of millisecond pulsars, studying low-frequency timing irregularities and even how millisecond pulsars may, in the near future, be used to help navigate spacecraft through the Solar System.

Any project that combines pulsars, space-time, black holes and galaxies attracts public interest. We have used such interest to develop the 'PULSE@Parkes' outreach project in which high school students from Australia and around the world are able to carry out research-quality pulsar observations using the Parkes telescope (Figure 3). It is hoped that some of these students will be inspired to continue their studies of physics, engineering and/or astronomy and may, one day, be amongst the first gravitational wave astronomers.

Future plans

With the release of our first data sets, the PPTA project is now entering a new era. Our first goal is to combine our data sets with those from the two other major PTA projects, the European Pulsar Timing Array (EPTA) and the North American NANOGrav project. Together these will form the IPTA with a larger number of pulsars, increased sampling of pulsars common to two or more of the PTAs and, for some pulsars, longer data spans. All of these factors will increase our sensitivity to gravitational waves and the other PTA goals.

We also need to continue our efforts to improve the precision and accuracy of our timing measurements. Currently, the dominant noise source for most of our pulsars is from fluctuations in interstellar dispersion. Currently we require long observations with both the 20-cm receiver and the 10-cm/50-cm dual-band receiver to correct these fluctuations and, even with that, uncertainties in these corrections are a limiting factor in the precision of our pulse times of arrival. To help overcome this limitation, we are proposing an ultra-wide bandwidth receiver covering the band from 700 MHz to 4 GHz and an associated graphics processing unit-based signal processing system. This would not only give us more accurate dispersion corrections, but it would do so in a single observation of each pulsar, saving valuable observing time. The development of this system would also fit in well with the plans to streamline operations at Parkes, since essentially all (non-multibeam) pulsar observations could be done with this one receiver. It would also benefit other observational programs such as polarisation and Faraday rotation studies of the Galactic background.

It is likely that the next low-frequency noise process that we will need to deal with is intrinsic period fluctuations. This was previously thought to be random and uncorrectable. However, recent work has suggested the possibility that timing noise is related to a two-state magnetospheric process in which the pulsar flips between well-defined states with different slow-down rates (Lyne *et al.* 2010). This leads to the exciting possibility that at least some of the intrinsic timing noise can be corrected — we are currently advertising for a postdoctoral researcher to work on this project.

One of the most effective means to improve the sensitivity of PTAs is to increase the number of high-quality MSPs that are being monitored. Ongoing searches (for example, Keith *et al.* 2010, Crawford *et al.* 2012) are finding such pulsars and several have already been added to existing PTA projects. Further into the future, large new radio telescopes such as the Chinese Five-hundred-meter Aperture Spherical Telescope (FAST) and the Square Kilometre Array will enable more sensitive surveys and precision timing of a large number of MSPs that are currently too weak for effective timing. With these developments we can confidently predict that low-frequency gravitational waves will be detected by PTAs in the next five to ten years and that, in the SKA era, detailed studies of the signal and source properties of these waves will be possible, opening up a new window on the Universe.

FIGURE 3: Students at work with PULSE@Parkes. Credit: David Crosling.

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PKS B2152-699 reveals details of its large-scale jet

DIANA M. WORRALL AND MARK BIRKINSHAW (UNIVERSITY OF BRISTOL)

PKS B2152-699, the first radio source mapped with the Australia Telescope Compact Array (ATCA) during construction (Norris *et al.* 1990), has revealed fascinating jet structures in new ATCA maps.

The radio source has been known for many years as double-lobed, extending almost 100 kpc in projection on the sky, and hosted by a bright elliptical galaxy 120 Mpc away (for example, Fosbury *et al.* 1998). Now the brightest of the two radio jets that feed the lobes has been mapped over much of its extent (Figure 1). This development has been possible thanks to the Compact Array Broadband Backend (CABB, Wilson *et al.* 2011), and an ATCA observation made as part of a comprehensive multiwavelength study of the system, for which initial results are published in Worrall *et al.* (2012).

PKS B2152-699 is of particular interest as a nearby example of the population of sources that must dominate radio-mode 'feedback'. Feedback is needed to regulate the growth of super-massive black holes (SMBHs) and their host galaxies in the Universe, so that they scale with one another, and so that galaxies have the correct mass distribution. The basic idea is that a radio source provides energy and momentum to the surrounding gas, slowing star formation. The radio source is regulated by accretion onto the SMBH in the galaxy's centre, and for feedback to work a connection must exist between heating on large scales and accretion on small scales. It is hoped that through detailed study of jet-gas interactions, the mechanisms underlying feedback will be understood.

Most radio sources for which gas heating has been studied to date are of relatively low radio power. While results have shown that radio power is a good proxy for the kinetic power responsible for boring large-scale cavities in surrounding gas (for example, Cavagnolo *et al.* 2010), the sources that dominate radio feedback overall must be of higher power than those studied so far, while not being of such high power that they are rare. PKS B2152-699 falls in the critical power range. Our key result, that most of its power goes into heating and moving of shocked gas that is measured in X-rays with the Chandra satellite, instead of into the excavation of cavities, is therefore particularly important (Worrall *et al.* 2012).

Our new ATCA observations were made at 18 GHz to give an angular resolution well matched to that of Chandra. Our measurements of the contrast between the

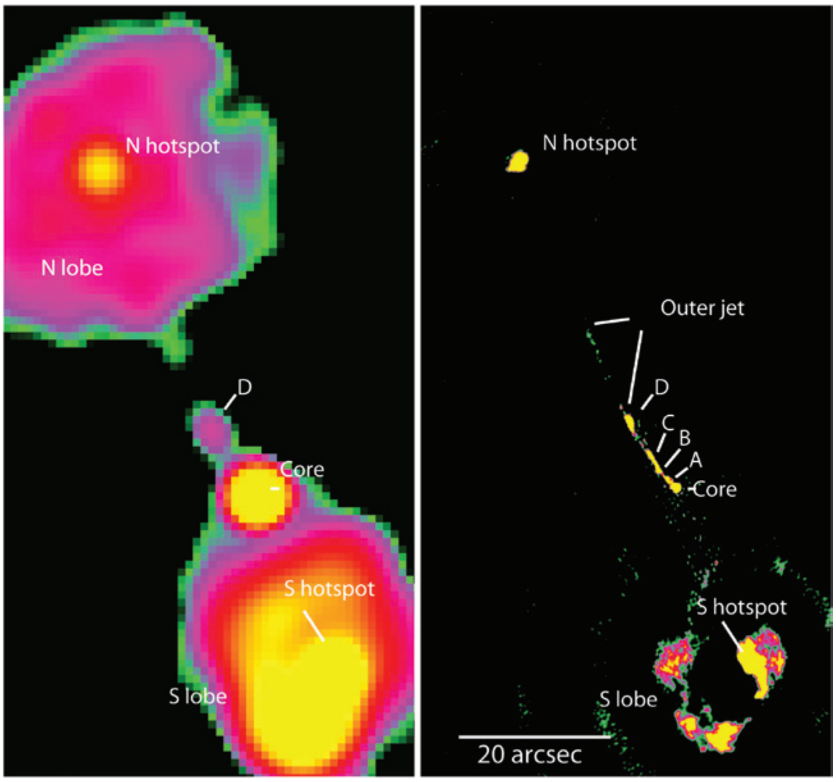

FIGURE 1: Left: 4.74-GHz ATCA map from the data of Fosbury et al. (1998) with 2.35 arcsec restoring beam. Right: 18-GHz map made from the new ATCA-CABB data with 0.35 arcsec restoring beam, revealing details of the northern jet and the two jet termination regions (hotspots). Images cover identical regions of sky.

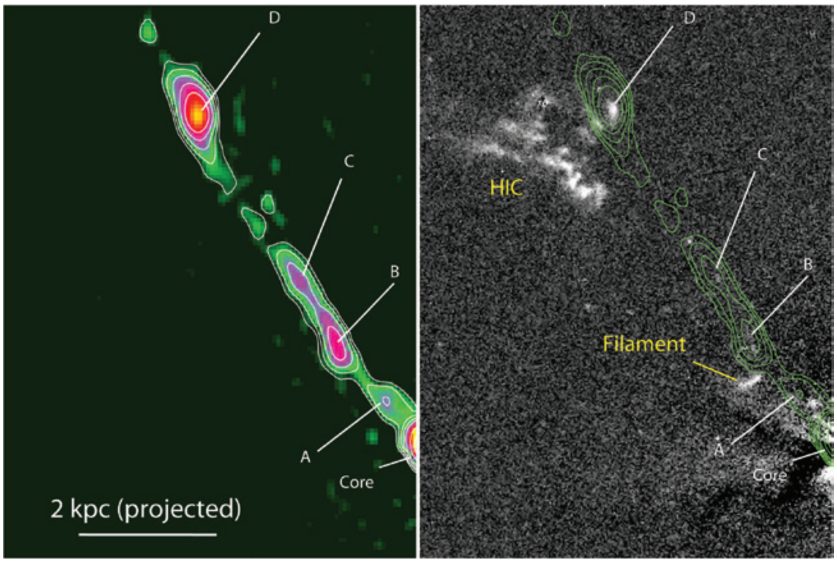

FIGURE 2: Left: Details of the inner northern jet from Figure 1 (right), showing significant wiggles. The brightest knots are labelled. Right: Radio contours from the left panel superimposed on an HST F606W image after galaxy subtraction. Note the HIC to the east of knot D and the optical filament close to the base of knot B, as well as optical emission associated with the centres of radio knots.

northern and southern jets have helped us to constrain the orientation of the source and the speed of plasma flow in the jet, after taking the effects of Special Relativity into account. PKS B2152-699 is a particularly good case to study because we can compare the power in the jet with the power integrated over the lifetime of the source, as measured from the lobe-shocked gas. We find the powers to be comparable, providing some confidence that our understanding of the source is correct.

Particularly remarkable are the jet knots and wiggles revealed in the new ATCA observations. One of these wiggles causes the jet to pass just to the west of a region which is peculiarly bright in optical emission lines, referred to as a High Ionization Cloud (HIC; Fosbury *et al.* 1998). The HIC's scar-like appearance in Hubble Space Telescope images is quite remarkable, as is the appearance of a second bright optical filament lying adjacent to another of the jet wiggles, this time closer to the nucleus (Figure 2). We have mapped the jet termination regions (the northern and southern hotspots) in intensity and polarisation in exquisite detail from the ATCA data, revealing a fascinating spiral pattern in the south, and interesting radio/optical/X-ray offsets in the north, thus providing insight into the mechanisms at play where jet plasma undergoes catastrophic deceleration. Our work continues by observing and modelling the HIC in detail, to study how jets within the important power range for feedback interact with, and are shaped by, their immediate surroundings, as they carry power to large scales. Stay tuned for updates!

Acknowledgements

We thank staff at Narrabri for help and advice before and during the ATCA observations, and the Science and Technology Facilities Council for travel support.

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Signatures of grain growth in protoplanetary discs

CATARINA UBACH (SWINBURNE UNIVERSITY/CASS), SARAH MADDISON (SWINBURNE UNIVERSITY), CHRIS WRIGHT (UNSW/ADFA), DAVID WILNER (HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS), DAVE LOMMEN (RAFFLES INSTITUTION) AND BÄRBEL KORIBALSKI (CASS)

Planet formation takes place in the dusty protoplanetary discs surrounding young stars. Multiwavelength studies of protoplanetary discs are conducted to observe the first stages of the multi-step process of planet formation as tiny grains grow in size via low-speed collisions. As submicron grains grow to millimetre and centimetre size, the grains become decoupled from the gas and settle towards the mid-plane of the discs.

Observational signatures of grain growth are probed in both the infrared and millimetre wavelengths. The infrared regime explores the hot inner upper surface of the disc (sub-micron and micron-sized grains), whereas the millimetre regime probes the cooler outer regions and mid-plane of the disc where the bulk of the dust resides (millimetre and larger grains). These wavelengths directly probe the first stages of planet formation, as tiny grains grow in size to become planetary building blocks.

The spectral slope from 1—3 mm ($\alpha_{1\text{-}3mm}$), where the flux $F \propto \nu^{\alpha}$ and ν is the frequency, can be used to estimate the dust opacity index β, where dust opacity $\kappa_{\nu} \propto \nu^{\beta}$. Assuming the continuum emission from protoplanetary discs at 1—3 mm arises from optically thin thermal dust emission, the dust opacity index can be written as $\beta \sim \alpha$-2, where $\beta \leq 1$ indicates grain growth up to the size of the observing wavelength, that is, millimetre sizes (Draine 2006).

The dust opacity index relationship can be extended to 7 mm wavelengths. However, the emission observed at 7 mm wavelengths and beyond can result from a range of physical processes present in these young stellar objects, including thermal emission from dust, free-free emission from an ionised wind, and non-thermal chromospheric emission (for example, Dullemon *et al.* 2007; Millan-Gabet *et al.* 2007). A constant spectral slope up to 7 mm and beyond indicates that thermal dust emission dominates the emission and that centimetre-sized pebbles may be present. A change in the spectral slope, combined with temporal flux variability, can be used to determine the dominant emission mechanism at centimetre wavelengths.

Utilising the Australia Telescope Compact Array (ATCA) with the new Compact Array Broadband Backend (CABB), we conducted a survey of 20 T Tauri stars at 3 and 7 mm in the Chamaeleon and Lupus southern star forming regions, with the aim of identifying protoplanetary discs with signs of grain growth. Through temporal monitoring at 7, 15 mm and 3+6 cm, we also determined the emission mechanisms present in a smaller subset of sources in Chamaeleon. These observations reached a sensitivity of ~ 0.1 mJy beam^{-1}, which allowed us to detect 90% of the sources at better than 5σ at 3 and 7 mm, 4/6 sources at 15 mm and 1/3 sources at 3+6 cm.

We found that 50% of the sources have dominant thermal dust emission up to 7 mm. Half of these have a dust opacity index $\beta < 1$, suggesting grain growth up to at least millimetre sizes, see Figure 1 for a histogram of $\alpha_{1\text{-}3mm}$ of the detected sources. The dust disc masses range from 10^{-5} to 10^{-3} $M_{\odot}$, with eight sources having a total disc mass (gas plus dust, assuming a gas-to-dust ratio of 100) above the minimum mass solar nebula of 0.01 $M_{\odot}$ (Weidenschilling 1977).

The Chamaeleon sources observed at 15 mm and beyond show the presence of excess emission from an ionised wind and/or chromospheric emission (Figure 2). Temporal monitoring on yearly timescales at 7 mm suggests that centimetre-sized pebbles are present in at least four sources, and temporal monitoring on hourly to daily timescales at 15 mm indicates the excess emission observed in the spectral energy distribution is from thermal free-free emission.

These results suggest that grain growth up to centimetre-sized pebbles are common around young discs, that excess emission at 15 mm and beyond is also common in these systems, and that temporal monitoring is required to disentangle emission mechanisms.

Further results and analysis of this work, including a comparison of the signatures of grain growth in the infrared to the millimetre wavelengths, are presented in Ubach *et al.* (2012).

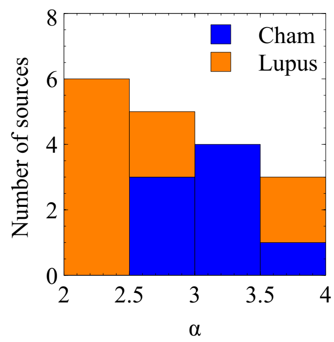

FIGURE 1: Histogram of the $\alpha_{1\text{-}3mm}$ of the detected sources, indicating that approximately 50% have an $\alpha_{1\text{-}3mm} < 3$, thus a $\beta < 1$. Original figure presented in Ubach et al. (2012).

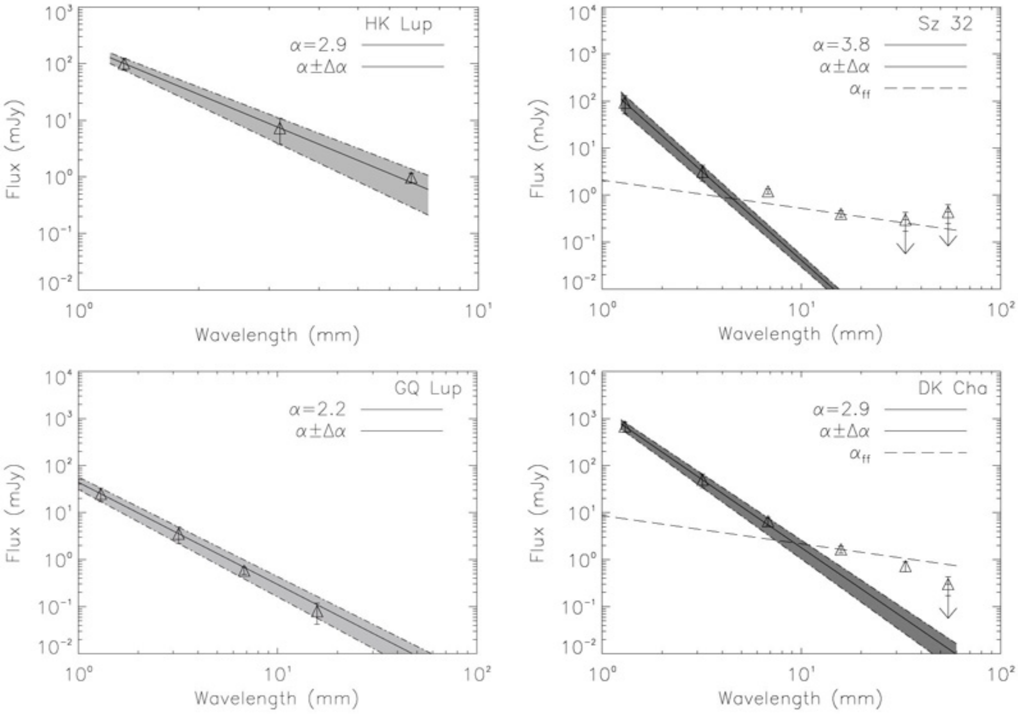

FIGURE 2: Sample results of millimetre flux versus wavelength for Chamaeleon sources. The solid line represents $\alpha_{1\text{-}3mm}$, and the dash-dotted lines are the upper and lower limits for $\alpha_{1\text{-}3mm}$ using the flux fit uncertainty and assuming a primary flux calibration uncertainty (20% for 1.2 mm, 30% for 3 mm, and 10% for 7 and 15 mm and 3+6 cm). The dashed line represents the free-free emission with α_{ff} = 0.6 anchored at the 15 mm data point for sources with centimetre data. Original results presented in Ubach et al. (2012).

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Gas and star formation in the Circinus galaxy

BI-QING FOR (ICRAR/UWA), BÄRBEL KORIBALSKI (CASS) AND TOM JARRETT (SSC/CALIFORNIA INSTITUTE OF TECHNOLOGY)

Introduction

The Circinus galaxy is a nearby, highly obscured spiral galaxy which was discovered by Freeman *et al.* (1977). It is located behind the Galactic plane, hidden by dust and high star density. It is an Sb to Sd type galaxy with a Holmberg radius of ~17' and a distance of about 4 Mpc (Freeman *et al.* 1977).

Circinus is full of interesting features. It hosts an active galactic nucleus (AGN) (Ghosh *et al.* 1992), superluminous H_2O masers (Gardner and Whiteoak 1982; Whiteoak and Gardner 1986), a recent supernova (Bauer *et al.* 2001), a star-forming nuclear ring (Marconi *et al.* 1994), a spectacular pair of radio lobes (Elmouttie *et al.* 1998; Wilson *et al.* 2011) and a gigantic hydrogen disk (Mebold *et al.* 1976; Freeman *et al.* 1977; Koribalski *et al.* 2004). Despite the richness of interesting features in the Circinus galaxy, most studies have been limited to its nuclear region. While the 2MASS Large Galaxy Atlas (Jarrett *et al.* 2003) has provided an extensive view of the stellar content of Circinus, the formidable dust opacity at 2 µm and the dense stellar foreground prevent a detailed investigation of its large scale and low surface brightness disk.

The mid-infrared (MIR) window is ideal to unveil both the old stellar disk population of the obscured Circinus galaxy as well as the interstellar emission from the newborn stars in the outer disk. The high angular resolution, sensitivity and dynamic range of the IRAC and MIPS instruments on board the Spitzer Space Telescope are suitable for this task. The IRAC 3.6 µm and 4.5 µm bands primarily trace the old stellar population in a galaxy and the 5.8 µm and 8.0 µm bands reveal polycyclic aromatic hydrocarbon (PAH) emission from the heated interstellar dust via UV photons radiating from massive young stars. The MIPS 24 µm band is dominated by thermal emission from warm (T > 120 K) dust inhabiting the molecular and neutral medium phases of the interstellar medium (ISM), while 70 µm band traces cold (T < 50 K) emitting dust.

Observations

I. SPITZER OBSERVATIONS

The MIR imaging observations of the Circinus galaxy were carried out with the IRAC (3.6, 4.5, 5.8 and 8.0 µm) and MIPS (24 and 70 µm) bands of the Spitzer telescope. The total field coverage is 50' x 50', which is large enough to cover the entire HI disk of Circinus. Two epochs of observations were carried out to improve the sensitivity and to mitigate data artefacts. The achieved 1σ sensitivity in surface brightness is 0.059, 0.045, 0.073, 0.086, 0.058 and 1.46 MJy/sr for the 3.6, 4.5, 5.8, 8.0, 24, and 70 µm bands, respectively.

II. ATCA HI OBSERVATIONS

High-resolution HI single-pointing observations of the Circinus galaxy were carried out with the Australia Telescope Compact Array (ATCA) using the 375, 750A and 1.5 array configurations (Jones *et al.* 1999). The data were used to analyse the large-scale HI distribution and kinematics of Circinus. For the purpose of studying the full HI extent of Circinus, which is much larger than the 33' ATCA primary beam, HI mosaic observations were obtained in the 375 m array (Curran, Koribalski and Bain 2008).

For this work, we used the ATCA HI data to create: (1) Galactic HI maps for removing the Galactic foreground ISM, and (2) high-resolution HI maps of the inner disk of the Circinus galaxy for comparison with Spitzer MIR data. Galactic HI emission is prominent at radial velocities between about -250 km/s and +50 km/s. As for the HI emission from Circinus, it is observed between +240 km/s and +640 km/s.

Highlights

I. GALACTIC ISM SUBTRACTION

It is crucial to separate Galactic from extragalactic (Circinus galaxy) infrared emission, which is not a trivial task. The foreground ISM contribution is negligible at the shorter wavelength bands of IRAC. Thus, we only subtracted the Galactic ISM from the IRAC 8 µm and MIPS 24 µm images. To achieve this, we processed the images in two steps: (1) removing large-scale Galactic foreground; and (2) removing small-scale filamentary structure.

To remove large-scale Galactic foreground, a correlation analysis was performed by comparing the spatial distribution of dust emission derived from Spitzer MIR maps to that of HI gas. Both single-pointing and mosaic HI data, as well as Parkes HI maps from the Galactic All-Sky Survey (McClure-Griffiths *et al.* 2009; Kalberla *et al.* 2010), were employed. We adopted the non-linear method for combining the interferometer (ATCA) and single-dish (Parkes) data (Stanimirovic 2002) with velocities ranging -88 km/s to +124 km/s. Scaled integrated Galactic HI emission maps were then subtracted from the Spitzer images.

To remove the small-scale filamentary structure that is intersecting the southwestern disk of the Circinus galaxy, we re-analysed the single-pointing ATCA data over a velocity range from -220 km/s to +220 km/s and at a range of angular resolutions. At an angular resolution of ~35", we were able to identify the spur-like filamentary structure. The bulk of the structure has a mean velocity of -45 km/s and is strongly correlated to the 8 µm PAH emission. Once we subtracted that particular small-scale structure, a much improved view of the star-forming regions in the inner spiral arms of the Circinus galaxy was achieved.

II. PHYSICAL PROPERTIES OF THE CIRCINUS GALAXY

We performed surface photometry and source characterisation for the Circinus galaxy. A visual extinction of 2.1 mag was determined with the spectral energy distribution method due to inaccurate measurement of infrared dust emission in high extinction regions (Schlegel, Finkbeiner and Davis 1998). We also derived the total stellar mass of 9.5×10^{10} $M_{\odot}$ using the IRAC 3.6 and 4.5 µm bands and total gas mass of 9×10^{9} $M_{\odot}$ using the HI map and the Swedish-ESO Submillimeter Telescope (SEST) CO(1—0) map (Curran, Koribalski and Bains 2008).

III. STAR FORMATION

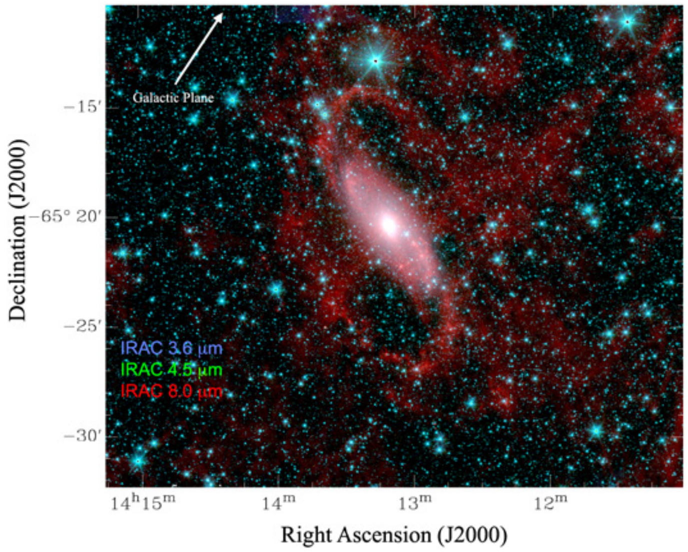
Star formation mostly occurs in the nuclear region and inner spiral arms of galaxies. Some star formation also occurs in their outer disks (for example, M 83; Thilker *et al.* 2005) and interaction zones between galaxies (for example, NGC 1512/1510 pair; Koribalski and Lopez-Sanchez 2009). The star formation activities are particularly prominent in regions of high gas density.

We used a range of star formation rate (SFR) relations to estimate the obscured global SFR of the Circinus galaxy. We note that the PAH emission in the nuclear region is not related to the AGN, as claimed in the near-infrared polarimetry study of the Circinus nucleus (Alexander, Ruiz and Hough 1999). Thus, we conclude that the obscured global SFR of the Circinus galaxy is approximately 3—8 $M_{\odot}$ per year.

We also identified 12 distinct/resolved individual star forming regions in the Circinus galaxy by using HI gas as a tracer. Multiwavelength composite images provide a powerful way to reveal the locations of star formation within the gaseous disk of Circinus. In Figures 1 and 2, we show multiwavelength colour composite images of the Circinus galaxy. The first figure shows the composite image of IRAC 3.6 µm (blue) + 4.5 µm (green) + 8.0 µm (red), without stellar foreground subtraction. The second figure shows IRAC 8.0 µm (red) + 3.6 µm (green) + high-resolution ATCA HI map (blue). Spectacular spiral arms are revealed in these composite images. In Figure 3, we overlay the high-resolution ATCA HI map in contours onto the IRAC 8.0 µm. The contours are plotted at HI gas column densities of 1.23 (thick solid), 2.45 (dotted) and 3.19 (thin solid) $\times 10^{21}$ cm^{-2}. The same contours are overlaid onto the MIPS 24 µm image near the central region in Figure 4. An additional contour of the CO (1—0) map is also shown (dashed). Ten individual star forming regions have been identified in the IRAC 8.0 µm image that are clearly associated with the high-density HI gas. Two additional resolved star forming regions are shown near the central region of the MIPS 24 µm image. They are labelled according to their relative position to the centre of the Circinus galaxy.

Summary and conclusions

We present a detailed study of the Circinus galaxy, investigating its star formation, dust and gas properties both in the inner and outer disk. We utilised the high-resolution Spitzer infrared images taken with the IRAC and MIPS instruments, ATCA and Parkes HI radio data, as well as a SEST CO map. Due to the location of Circinus behind the Galactic plane, we demonstrate that careful removal of Galactic emission from the MIR images was necessary prior to further analysis. A correlation method and structure matching based on HI gas in different velocity ranges successfully removed both large and small-scale foreground structure from the IRAC 8.0 µm and 24 µm images. We derive a visual extinction of 2.1 mag from the spectral energy distribution of Circinus, and the total stellar and gas masses are 9.5×10^{10} $M_{\odot}$ and 9×10^{9} $M_{\odot}$, respectively. Using various wavelength SFR relations, we find the obscured global star formation rates to be 3—8 $M_{\odot}$ per year. Star forming regions in the inner spiral arms of Circinus are unveiled in the Spitzer 8 µm image and rich in HI gas.



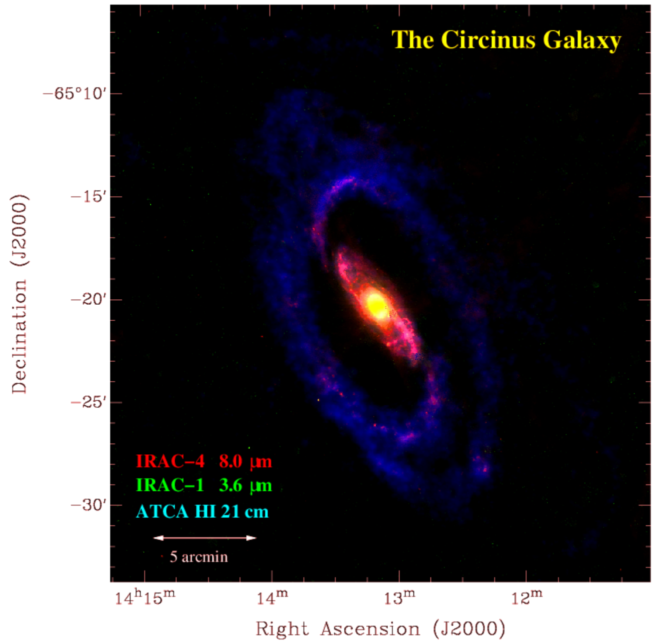
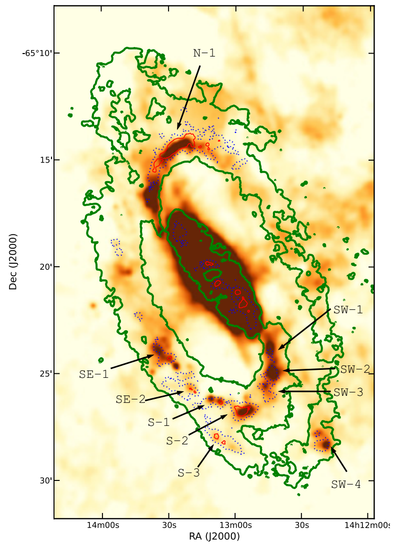


FIGURE 1: A multiwavelength colour composite image of the Circinus galaxy showing IRAC 3.6 µm (blue) + 4.5 µm (green) + 8.0 µm (red), without stellar foreground subtraction.

FIGURE 2: A second multiwavelength colour composite image of the Circinus galaxy showing IRAC 8.0 µm (red) + 3.6 µm (green) + high-resolution ATCA HI map (blue).



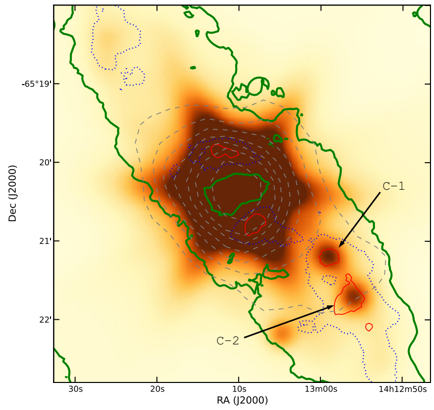


FIGURE 3: An overlay of the high-resolution ATCA HI map contours onto the IRAC 8.0 µm. The contours are plotted at HI gas column densities of 1.23 (thick solid), 2.45 (dotted) and 3.19 (thin solid) x10^{21} cm^{-2}.

FIGURE 4: The high-resolution ATCA HI map contours overlaid onto the MIPS 24 µm image near the central region. An additional contour of the CO (1—0) map is also shown (dashed).

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Education and outreach

ROB HOLLOW (CASS)

Participants in the three-day 'Astronomy from the Ground Up' teacher workshop held at Parkes Observatory in May enjoyed taking a look around the recently upgraded displays at the visitors centre.

Education and outreach activities

The Cairns – Port Douglas region will be the centre of attention for astronomers across the globe when it experiences a total solar eclipse in November 2012. In preparation for this, CASS Education Officer Rob Hollow ran a two-day astronomy workshop for teachers from across far north Queensland in Cairns in late April. The workshop, supported by Education Queensland, prepared teachers for educational activities and safe viewing of the eclipse (as well as the Transit of Venus that took place in June). Rob also visited three schools and talked to hundreds of students about the upcoming events.

The annual three-day 'Astronomy from the Ground Up' teacher workshop was held at Parkes Observatory in May, attracting teachers from three states. Several CASS staff and other presenters talked about their research and a variety of astronomy topics. Participants also learnt solar observation techniques, how to run a viewing night and had a close-up tour of 'The Dish'. Rob also presented several workshop sessions at science teacher conferences in Canberra and in Sydney.

CASS co-sponsors the annual Southern Cross Astronomy Conference. This year's event took place in the Hunter Valley and coincided with the Transit of Venus. The 100 assembled astronomers, from around the world, were fortunately able to view the event between clouds and rain with a number of telescopes operated by CASS staff.

Rob participated in the Mid West Youth Science Forum in Geraldton and gave an on-air lesson at the Meekatharra School of the Air as part of CASS engagement in the Mid West region of Western Australia.

Numerous CASS staff have also presented a wide range of talks to Australian audiences over recent months. This includes Ray Norris, who delivered popular talks on Aboriginal astronomy at the Western Australian Museum in Geraldton and the Australian Museum in Sydney.

PULSE@Parkes

PULSE@Parkes sessions for schools were held in Sydney, Melbourne and Perth duringthe current telescope observing semester. The sessions, held in collaboration with the Victorian Space Science Education Centre in Melbourne and SPICE in Perth, allowed several schools to participate for the first time in this exciting program.

The International Pulsar Timing Array Winter School for graduate students was held at the University of Sydney in June. Students from around the globe took part in a PULSE@Parkes observing session as part of the school. For some it was their first chance to actually observe with a radio telescope. The modified session ran as a masterclass with a collection of some of the finest pulsar astronomers in the world describing the nuances of pulsar observing with the participants. This was the first time we have run such a session but all involved agreed that it was a useful event and an instructional tool worth repeating in the future.

In addition, coordinator Rob Hollow presented a talk about the project at the Astronomical Society of the Pacific's education and outreach conference in Tucson, USA in August.

PULSE@Parkes has also been awarded a grant from the Australia–Japan Foundation that will see the team tour Japan in the first half of 2013 to run observing sessions for Japanese students, help train teachers and give talks about pulsar astronomy to Japanese colleagues.

With the new Science Operations Centre due to commence operations in coming months (see page 33 for more information), we look forward to adapting our Marsfield-based school sessions to utilise the new facilities and provide an even better experience for students.

Operations

DOUGLAS BOCK, PHIL EDWARDS, ERIK LENSSON AND DAVE MCCONNELL (CASS)

Over the past several years the operations team has been preparing for ASKAP to join the ATNF. The recent ASKAP opening signalled the next phase. Barry Turner's team based in Geraldton, Western Australia, will move to ATNF Operations in November as the focus for their day-to-day activities changes. At the same time, the ASKAP and existing ATNF Operations science computing teams will be merged. The Geraldton office will grow from the current 10 staff to approximately 15 staff over the next year. We will introduce you to the new faces in the next *ATNF News*.

Parkes

The Parkes maser hut has been replaced by a new environmentally controlled (temperature, vibration, humidity) enclosure. In addition to a stable environment, the new maser provides for energy efficiencies, improved monitoring and fibre connectivity for the timing chain to the tower. This work on the enclosure was led by Tim Wilson. Meanwhile, Christoph Brem led a team that reconfigured the timing signal distribution, including new line amplifiers and change from the disturbance-prone daisy chain distribution to a buffered star configuration. Work also continued on the installation of high voltage infrastructure at Parkes, with the new 750 kVA transformer kiosk and switchgear now installed near the power house.

As mentioned earlier in this newsletter (see page 12), Parkes provided support for NASA during the entry, descent and landing of the Mars Science Laboratory. Everything went smoothly on the day, thanks to the preparatory efforts of engineering and operations staff in the months leading up to the track. This included Mark Bowen, Suzy Jackson and Alex Dunning's work on re-designing the cavity-back feed and new low noise amplifiers to retune the receiver from 430 MHz to 401.58 MHz. Stacy Mader provided assistance during the test installation in the focus cabin in early June, which proved to be very useful in characterising the radio frequency environment at these frequencies. A particularly strong signal was observed on occasions at the uncomfortably close frequency of 401.58 MHz and following some detective work, the source was narrowed down to the telemetry beacons carried by Bureau of Meteorology (BoM) radiosonde on-board high-altitude weather balloons. Following discussions between Erik Lensson (Engineering Operations) and Paul Hettrick (BoM), meteorological operations staff kindly agreed to a temporary radiosonde frequency change to assist the Parkes tracking efforts.

There was no possibility of the spacecraft switching on its 401.5 MHz beacon prior to its arrival at Mars, but NASA's Jet Propulsion Laboratory realised that the same band is used by the existing rovers on the surface of Mars to communicate with the various satellites orbiting the planet. The rover team agreed to switch on the beacon on one of the rovers for 10 minutes the week before the landing to test out the Parkes system, which reassuringly resulted in a clear detection. One minor mystery remained however, in that one polarisation was found to be noticeably noisier than the other. After much head scratching, Ettore Carretti realised the noise level was changing as Brett Preisig moved around in the focus cabin... and was minimised when Brett stood in front of a particular rack of equipment! Some extra shielding was promptly installed to fix the problem.

The track itself was supported by local staff, with John Reynolds, Shaun Amy and Suzy Jackson also on site to lend a hand if required. Suzy had the foresight to buy all the Mars bars in stock at the Dish café and a celebratory chocolate was enjoyed by all present after the successful conclusion of the track!

There have been several staff changes at Parkes in recent months. Our new industrial electrician, Bob Kaletch, will be joined by electrician Alan Pieroz this month. Brett Armstrong has moved from Parkes to a new role in Geraldton supporting ASKAP.

Remote observing with Parkes

The Remote Access to the Parkes Telescope (RAPT) project team continues to work towards providing remote access to the Parkes telescope. Ultimately, this will allow completely unattended operation with observers accessing the telescope from the Science Operations Centre at Marsfield or from their home institution. The remote observing procedures will be similar to those already in use for the Compact Array and Mopra, and the RAPT project has been adapting and developing software to enable this to take place. In addition, there are special requirements for the protection of the telescope's safety — a custom-designed telescope protection system (TPS) is being built to detect adverse operating conditions. At this stage, most of the software and computing changes have been completed and are under test. The TPS, including a specialised vibration monitor, is under construction and is expected to be ready for installation and commissioning in late November or early December. At that point remote observations can commence; during the first few weeks of remote access, while trust in the TPS is established, human presence in the telescope tower will be maintained as a precaution.

Australia Telescope Compact Array

It has been a busy six months at the Compact Array, with the first two 'production' 4-cm receivers (upgraded 6-cm/3-cm receivers, which provide a band from 4 to ~10.8 GHz) joining the prototype receiver on the array. Tests have also been done with a re-designed feed for the 4-cm receivers to improve the performance above 10.8 GHz to at least 12 GHz. There has also been good progress with CABB, with the multi-zoom 64 MHz mode becoming available in September.

A trainee, Liza-Jane McPherson, started working in May to provide assistance to the administration group at Narrabri. Aaron Sanders has also moved from Marsfield to Narrabri for an extended visit to help with, and learn from, the engineering group on site. As described elsewhere in this issue (see page 14), the CASS Radio School was held at Narrabri this year, with local staff ensuring all preparations were in place for the event to run smoothly.

Mopra

Funding has been secured to operate the Mopra telescope for three years, commencing in October 2012. Mopra operations will initially be funded by the National Astronomical Observatory of Japan, the University of New South Wales, and the University of Adelaide. A majority of the observing time will be provided to the funding organisations. A portion of the time will be made available to ATNF users under the agreement. In the first year of operation under this new model, the ATNF time will be used primarily for Long Baseline Array (VLBI) observations and for the completion of current, large, Time Assignment Committee-approved projects.

The Mopra schedule for the month of October 2012 has been released (see *www.narrabri.atnf.csiro.au/observing/schedules);* more details are given in the accompanying release notes.

In the 2013 April semester, some Mopra single-dish time will be available in the LST range 2200 to 1100. The process for requesting this time will be documented in the November proposal call for the semester. The time will be available for conducting larger projects with limited support requirements. In future semesters we anticipate offering ATNF time in all LST ranges.

The new Science Operations Centre has an open meeting or 'interaction' space, seen here in the foreground; the visitors' area can be seen in the background.

Science Operations Centre

Over the past few months, the new Science Operations Centre has been taking shape at Marsfield. The SOC runs the length of F-wing, on the ground floor of the site, behind the lecture theatre. The SOC comprises four control rooms that can be linked to the four telescopes – ASKAP, Compact Array, Mopra and Parkes. The existing remote observing stations in Room 23 (currently used for remote observing with Mopra and the Compact Array) will be relocated and a similar set-up established for Parkes. ASKAP commissioning will initially use one of the larger observing rooms, with a smart board linked to a similar unit at the MRO site to ensure there is a single source of current information available to engineers and commissioning teams. The two larger rooms can be joined into one large space for group observing sessions such as LBA observing, ASKAP commissioning and 'PULSE@Parkes'.

Next to the observing rooms is an open space to encourage interactions between observers and other visitors and local staff, with comfortable seating, current periodicals, white boards and tables for discussions and small informal meetings. The area immediately behind the lecture theatre will be used for workspaces for visitors, and the librarians' desk will also be located here. The office for the Visitors Services Group is now located at the end closest to the main reception area, in an area much easier for visitors to the site to find. Finally, in the old compactus area of the library there will be a quiet reading area and shelving accommodating the collection of theses and other reference material.

October 2012 time assignment

The Time Assignment Committee (TAC) met at Marsfield on 24 and 25 July to consider the 152 proposals submitted for the 2012 October semester for observations with the Compact Array, Parkes, Tidbinbilla and Long Baseline Array.

Several cautionary tales emerged from the meeting for future proposers. For example, one team inadvertently attached the justification for one of their other projects to a proposal. The TAC was surprised to see the same justification twice, but naturally could not assess the merits of the proposal with the wrong justification. OPAL has an option to preview the complete proposal (cover sheets, observations table and justification) before submission, and it is recommended all proposers make use of this feature.

Another team completed their observations table in equatorial coordinates (right ascension and declination) but checked the box for galactic coordinates, resulting in the wrong positions being automatically transferred to the scheduling software. This was caught before the scheduling process commenced, but required some effort to undo the proposers' error.

This TAC meeting was the last for Helen Johnston, Martin Meier, and Willem van Straten, whose collective knowledge and wisdom has been greatly appreciated.

The new visitors' area provides desk space for visitors close to the observing rooms.

There are four new observing rooms: two office-type spaces and two larger rooms that can be joined into one large space for group observing sessions.

Publications

The following list of publications includes published refereed papers that use ATNF data or are by CASS authors; the list has been compiled following publication of the April 2012 issue of *ATNF News*. Papers that include CASS authors are indicated by an asterisk. Please email any updates or corrections to this list to *Julie.Tesoriero@csiro.au*.

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

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A spectacular aerial view over the Murchison Radio-astronomy Observatory in Western Australia; 19 of ASKAP's 36 antennas and the MRO control building are visible. Credit: Dragonfly Media.

CONTACT US
t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

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HEADQUARTERS
PO BOX 76
Epping NSW 1710
Australia
t +61 2 9372 4100
f +61 2 9372 4310

PAUL WILD OBSERVATORY
Locked Bag 194
Narrabri NSW 2390
Australia
t +61 2 6790 4000
f +61 2 6790 4090

PARKES OBSERVATORY
PO Box 276
Parkes NSW 2870
Australia
t +61 2 6861 1700
f +61 2 6861 1730

MURCHISON RADIO-ASTRONOMY OBSERVATORY SUPPORT FACILITY
PO Box 2102
Geraldton WA 6531
Australia
t +61 8 9923 7700

atnf-enquiries@csiro.au www.atnf.csiro.au www.outreach.atnf.csiro.au