CAASTRO

ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

FOUR

ANNUAL REPORT 2014

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INTRODUCTION FROM THE CHAIR

DR ALAN FINKEL AM FTSE
CHAIR, CAASTRO ADVISORY BOARD

If science is a race and CAASTRO an entrant I am pleased to report that its competitive rate of laps is made possible by skilled drivers and a support crew that constantly monitors performance and tweaks parameters. A high volume of quality research is constantly underway and the KPIs are being met.

The big change this year was the departure of the founding Director, Professor Bryan Gaensler, to head the Dunlap Institute at the University of Toronto. My colleagues on the Advisory Board join me in wishing Bryan much success in this new role and we are pleased to note that Bryan will continue his relationship with CAASTRO as a Partner Investigator. I already knew Bryan for several years before CAASTRO was conceived but it was only after the CAASTRO bid got underway that I became familiar with his prodigious capacity for multitasking and hard work that complements his academic expertise. Together, these skills enabled him to conceive of and build CAASTRO into a world-class organisation.

The heartbeat of the organisation hesitated when Bryan announced his intention to resign but I am pleased to report that it continues to beat strongly. Our current Director, Professor Elaine Sadler brings her own style and academic experience. Elaine is a high achiever in international astronomy and is well known inside CAASTRO as the head of the team studying extragalactic hydrogen absorption. Elaine has a superb research record in widefield astronomy combined with leadership experience that makes her eminently suited to lead CAASTRO across its range of activities.

CAASTRO was reviewed twice this year. The first was an internally initiated, mini science review undertaken by our own Advisory Board members Kenneth Freeman, Ron Ekers, Martha Haynes and Garth Illingworth. This was of enormous value because it led to acknowledgement of our strengths, areas that needed development and several opportunities. I thank Ken, Ron, Martha and Garth for their effort, which was enthusiastically offered by them and was above and beyond the call of duty.

The second was the Mid-Term Review by the ARC. The results from the ARC were very positive, and I can say that participating in the review reinforced for my colleagues and me the breadth of fronts across which the organisation is operating, while always maintaining efficiency and good humour.

Australia is well positioned in astronomy and has made major investments in telescope infrastructure, but the rest of the world is making even bigger investments. Nevertheless, we have our own competitive advantage in our instruments and our talent. That talent is publicly evident in the CAASTRO scientific staff, but is also abundantly evident in 'the A team' of administrative staff that ensure that everything works all the time, with a minimum of fuss.

From my amateur perspective, astronomy is about to enter a golden age of telescope development with huge optical and radio telescopes coming on line that will deliver major increases in sensitivity and resolution. If I were to be reborn, one of the requests on my wish list would be to be an astronomer, ideally working at CAASTRO.

It's not just about science. CAASTRO is actively committed to improving gender balance through providing a conducive workplace and promotional opportunities. We have an ever growing outreach program for schools and communities. And we provide mentoring programs and workshops for early career scientists in our organisation.

Finally, on behalf of all of us on the Advisory Board I offer my gratitude to those colleagues who retired during the year for various personal and work-related reasons. Alistar Robertson, Guy Robinson and Tanya Monro, you participated actively around the table and made a real difference. Our ongoing Board members (profiled elsewhere in this report) are fabulous contributors and I look forward to the participation of our incoming Board members Hugh Durrant-Whyte, Rachel Nowak, and Bronwyn Evans.

Astronomers look into the past. As Chair of the CAASTRO advisory board I'm in a position to look to the future. There is a lot to be done, and at CAASTRO we have the scientists and staff to do it well.

Credit: Steven Tingay

Professor Steven Tingay (centre) hosts Australia's Foreign Minister The Hon Julie Bishop MP (right) and the UK Science Minister (left) on a visit to the MWA.
Credit: Steven Tingay

The CAASTRO Vision

CAASTRO aims to be an international leader in wide-field astronomy, positioning Australia to address fundamental unsolved questions about the Universe with the dramatic capabilities of next-generation telescopes and advanced instrumentation.

The CAASTRO Mission

CAASTRO is carrying out key science with 21st century telescopes. Our underlying goals are:

DISCOVER To make ground-breaking advances in our understanding of the Universe, thereby cementing Australia's reputation as a world leader in astrophysical research;

INNOVATE To develop innovative new ways of surveying the entire sky, of processing enormous volumes of astronomical measurements, and of visualising complex data sets, so as to build unique expertise in wide-field radio and optical astronomy;

PERFORM To make high-impact discoveries using Square Kilometre Array pathfinder telescopes, thus positioning Australia to lead the science programs planned for the SKA;

EDUCATE To provide compelling new opportunities for students and early-career researchers and exciting stories to inform the public; and

UNITE To bring the top astronomers from Australia and around the world together into a focused collaborative environment.

About CAASTRO

Astronomy is entering a golden age, in which we seek to understand the complete evolution of the Universe and its constituents. But the key unsolved questions in astronomy demand entirely new approaches, requiring enormous datasets covering the entire sky.

In recent years, Australia has invested more than $400 million both in innovative wide-field telescopes and in the powerful computers needed to process the resulting torrents of data. Using these new tools, Australia now has the chance to establish itself at the vanguard of the upcoming information revolution centred on all-sky astrophysics.

The ARC Centre of Excellence for All-sky Astrophysics (CAASTRO) has assembled the world-class team who now lead the flagship scientific experiments on these new wide-field facilities. CAASTRO is delivering transformational new science by bringing together unique expertise in radio astronomy, optical astronomy, theoretical astrophysics and computation, and by coupling all these capabilities to the powerful technology in which Australia has recently invested.

CAASTRO is pursuing three interlinked scientific programs, each of which can be addressed only with the all-sky perspective provided by wide-field telescopes:

- The Evolving Universe: When did the first galaxies form, and how have they evolved since?
- The Dynamic Universe: What is the high-energy physics that drives change in the Universe?
- The Dark Universe: What are the Dark Energy and Dark Matter that dominate the cosmos?

All CAASTRO activities are based on the principle that international leadership comes from commensurate investment in cutting-edge facilities and human capital. In particular, the CAASTRO research program is underpinned by a strong focus on training and enabling the next generation of scientists, thus providing a legacy extending well beyond the Centre's lifetime. The students we mentor and inspire will lead the scientific discoveries made on future wide-field facilities, culminating in the ultimate all-sky telescope, the Square Kilometre Array. CAASTRO is further motivated by the belief that science is a passionate undertaking and this passion should be contagious. We aim to leverage the high impact and strong public interest in our discoveries to highlight Australian innovation to the general public, and to inspire students to consider careers in science and engineering.

CAASTRO is receiving more than $30 million in funding over the period 2011–2018. CAASTRO is led by The University of Sydney, in conjunction with The University of Western Australia, The University of Melbourne, Swinburne University of Technology, The Australian National University, Curtin University and The University of Queensland, complemented by a group of world-class Australian and international partners.

A Universal Perspective

A universal perspective of the cosmos, exploring the sky in its entirety not just section by section.

A universal perspective of science, engaging teams, scientists and the public in an inclusive and egalitarian way.

A universal perspective of insight and discovery, understanding how knowledge can be used practically in the wider world.

DIRECTOR'S REPORT

PROF ELAINE SADLER FAA
CAASTRO DIRECTOR

2014 has been a very successful year for CAASTRO, as well as a year of changes. CAASTRO's founding Director, Professor Bryan Gaensler, announced in June 2014 that he would be stepping down before the end of the year to take up a new position as Director of the Dunlap Institute for Astronomy and Astrophysics at The University of Toronto. I took over from Bryan as CAASTRO Director on 15 September 2014, and I am enormously grateful to everyone who helped to make this transition a smooth one. I have been involved in CAASTRO since its inception, and am delighted to have the chance to serve as the new CAASTRO Director. Bryan has left the Centre in fantastic shape, and will continue to be part of CAASTRO in his new role as an overseas Partner Investigator.

I hope you will enjoy reading about the great range of CAASTRO activities presented in this latest Annual Report. 2014 was another bumper year for our Centre, with new successes in our research and collaborative activities as well as our innovative outreach programs. Two of CAASTRO's flagship facilities, the Murchison Widefield Array (MWA) radio telescope and the Sydney-AAO Multi-object Integral field spectrograph (SAMI) are now in full scientific operation and already producing some outstanding science results.

Our research highlights for 2014 include some notable firsts: the first real-time detection of a fast radio burst (by CAASTRO student Emily Petroff), the first public data release from the SAMI survey, and the first ASKAP detections of neutral hydrogen in the distant Universe. Our research publications continue to increase in number each year, and we are continuing to build new research links both within CAASTRO and more widely around Australia and across the world. All CAASTRO's research themes and projects involve research collaborations across multiple nodes and institutions, and in 2014 we also held joint workshops with the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP) and training with the ARC Centre of Excellence for Ultrahigh bandwidth Devices for Optical Systems (CUDOS). This year we have developed new collaborations with the eRosita group at the Max Planck Institute in Germany and the US-led Large Synoptic Survey Telescope (LSST) project.

CAASTRO now has 178 members, including 25 postdoctoral research scientists and 40 students. Following our most recent hiring round, a number of new postdocs will also be joining us in 2015.

This year Tara Murphy joined the ranks of CAASTRO's Chief Investigators, and we also welcomed Lisa Fogarty as the Theme Scientist for the Evolving Theme, Evan Keane as the Theme Scientist for the Dynamic Universe Theme and Michael Childress as the Theme Scientist for the Dark Theme. Our major research conference for 2014, 'Supernovae in the Local Universe: Celebrating 10,000 Days of Supernova 1987A', was attended by around 150 people, including many of the world's leading experts in this research area.

Our education and outreach programs continue to thrive. This year saw the establishment of a new 'Uluru Astronomer in Residence' program in central Australia, in which CAASTRO scientists each spend two weeks interacting with visitors and conducting night-time sky viewing at the Voyages resort at Uluru. Our 'CAASTRO in the Classroom' program received a $195,000 grant from the Federal Government this year, which will allow us to extend these activities to many more schools across the country.

The 2014 CAASTRO Annual Retreat took place in relaxing surroundings at Twin Waters, Queensland, over 19–21 November, and was attended by almost 100 members of CAASTRO. As usual it was a great opportunity for all of us to meet and talk about our work. We enjoyed a stimulating program of science talks and networking activities, including invited talks from overseas visitors Professor Volker Springel (Heidelberg) and Dr Huib Intema (NRAO). The retreat also gave as an opportunity to farewell Bryan Gaensler in a formal way at our annual dinner, and to acknowledge his tremendous contributions to CAASTRO.

In November, we were delighted to hear that the 2015 Breakthrough Prize in Fundamental Physics had been awarded to CAASTRO Chief Investigator Brian Schmidt. The prize was also shared with CAASTRO Partner Investigators Warrick Couch and Reynald Pain, and Associate Investigators Brian Boyle and Chris Lidman.

CAASTRO's long-standing commitment to gender equity was recognised in December this year, when we were one of only two organisations awarded an inaugural 2014 Silver Pleiades award from the Astronomical Society of Australia. The Pleiades Awards recognise groups who take active steps to advance the careers of women in Australian astronomy and strive for sustained improvement in providing opportunities for women to achieve positions of seniority, influence and recognition.

The awards committee noted that: "We consider CAASTRO to be a leader in encouraging greater gender equity in astronomy in Australia, and many of the initiatives taken up by the project, such as encouraging flexible and part-time working, have been picked up by other astronomy groups." This outstanding result is a tribute to the efforts of Bryan Gaensler, Kate Gunn and the CAASTRO Executive over the past three years, as well as the work of CAASTRO's new Gender Action Committee, chaired by Brian Schmidt.

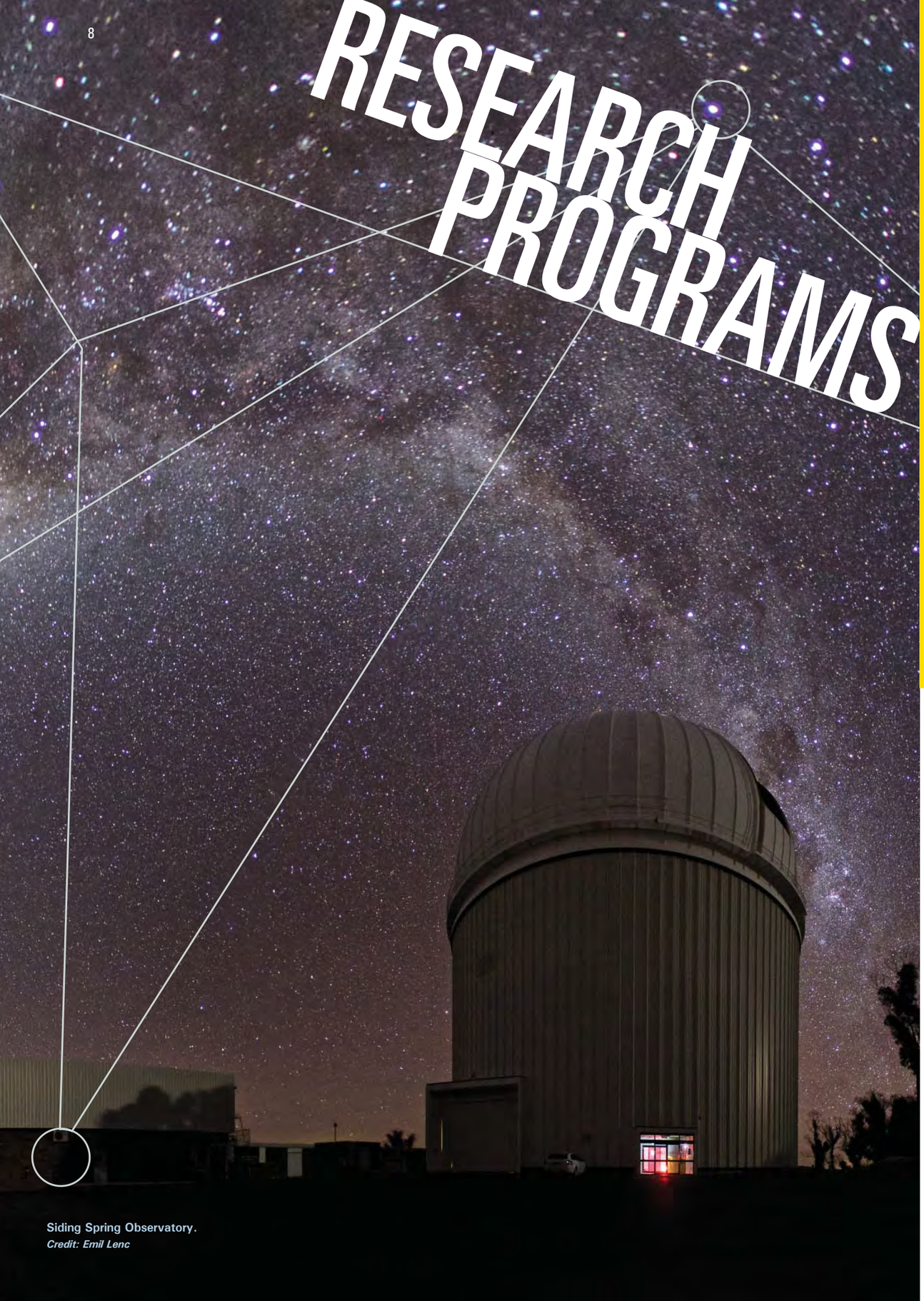
The last few months of 2014 also saw us busy with preparations for the ARC's Mid-Term Review of CAASTRO, which took place in Sydney on 12 November. The feedback we received from the review panel was extremely positive, and the panel members were enthusiastic about all aspects of CAASTRO's activities, including the excellent collaboration between nodes, the enthusiasm of our students and researchers, and the success of our mentoring and outreach program. They also commended CAASTRO's gender equity activities, saying that our work in this area was a model for other organisations to emulate.

I am grateful to all those who came to Sydney for this review, and to Kate Gunn and our administration team for ensuring that the day ran like clockwork. Warmest thanks are also due to the CAASTRO Advisory Board members and Board Chair, Dr Alan Finkel, both for their valuable support in preparing for the review and for travelling to Sydney to meet with the review panel.

The Mid-Term Review gave us an excellent opportunity to look back over the past three years and forward to the future. We were able to show that CAASTRO has robust governance and decision mechanisms that have allowed us to respond to external challenges, and that the CAASTRO 'brand' is internationally recognised and our scientific productivity is high.

Our goal now is to ensure that we translate the hard work of our first three years into ground-breaking science results. I hope that we can continue to strengthen the linkages between projects, increase our student numbers, and build new links with our international partners. We should all feel immensely proud of what CAASTRO has achieved so far, and excited by what is still to come.

RESEARCH PROGRAMS



Siding Spring Observatory.
Credit: Emil Lenc

THE EVOLVING UNIVERSE

Theme Leader: Professor Stuart Wyithe | The University of Melbourne

Theme Scientist: Dr Lisa Fogarty | The University of Sydney

When in the Universe's history did the first galaxies form? How have gas, stars and galaxies subsequently evolved over cosmic time? These are two core questions in our understanding of the Universe, and the questions on which CAASTRO's Evolving Universe theme is focused.

After years of planning and preparation, in 2014 we have seen major new Australian instruments start to produce exciting scientific results. Researchers using the Murchison Widefield Array (MWA) in Western Australia this year collected most of the data they will analyse in the search for the 'Epoch of Reionisation', the period in the Universe's history when the first stars began to shine. BIGHORNS, a smaller project to search for the Epoch of Reionisation also led by CAASTRO researchers, was set up alongside the MWA this year. In addition, the MWA substantially completed a low-frequency survey of the southern sky, GLEAM, which will be a rich resource for many astrophysical studies. These three projects are described from page 10.

Another radio telescope, CSIRO's Australian SKA Pathfinder (ASKAP), is currently being commissioned in Western Australia. This year CAASTRO researchers led a groundbreaking 'blind' detection of neutral hydrogen gas in absorption with ASKAP. The result shows for the first time that astronomers will be able to use the technique to detect gas in galaxies at epochs critical for understanding the history of star formation. In a second development, a CAASTRO student has explored a technique that will allow more information to be extracted from ASKAP survey data. These projects are covered on pages 11–12.

At optical wavelengths, the CAASTRO-funded SAMI instrument, which uses revolutionary optical-fibre technology, is well under way in its survey of thousands of galaxies. The SAMI team made its first public release of data in the middle of the year and has started to publish science results. SAMI developments are discussed on page 13.

Searching for the Epoch of Reionisation

The earliest period of the Universe we can see is the cosmic microwave background: a hot, glowing screen of gas, which we see as it was some 380,000 years after the Big Bang. Between that time and the time of the earliest stars and galaxies is a gap of about half a billion years, a period dubbed 'the Dark Ages'. This is the last major unstudied epoch of the Universe's history.

In the period immediately after the Big Bang, the hydrogen gas that filled the Universe was hot and ionised, having had its electrons stripped off by the radiation that also filled the Universe. As the Universe expanded and cooled, this gas assumed its neutral, un-ionised state, and the Universe entered the Dark Ages. Towards the end of this period, collapsing matter formed the first entities that later generated ionising radiation (ultraviolet or X-rays); this radiation created bubbles of ionised hydrogen gas in the neutral hydrogen, like the bubbles in Swiss cheese. Carried to completion, the process led to today's Universe, in which the gas between galaxies is fully ionised. Researchers wish to understand the astrophysics (and cosmology) underlying this Epoch of Reionisation (EOR). When did the process take place, and how rapidly? How was matter distributed at this time? And, in particular, what were the first 'ionisers': were they the first stars, or black holes born from the violent collapse of those stars?

The ionising radiation from the first entities not only created bubbles of ionised hydrogen (HII) but also triggered the emission of specific radiation from the surrounding neutral hydrogen (HI): radio waves with a (rest-frame) wavelength of 21 centimetres. This HI emission is currently the only tool we have for exploring the Epoch of Reionisation. The future Square Kilometre Array radio telescope will directly image the distribution of the HI emission. Meanwhile, other attempts are being made to detect the EOR signal. The simplest detection would be of a 'global' signal, averaged over the whole sky: this would allow us to date the onset of the EOR and measure its duration. Researchers are also attempting to learn about the 'bubbles' of the EOR by measuring the HI power spectrum (the variation in signal strength by spatial scale). The shape of the power spectrum is predicted to change markedly as the ionisation of the intergalactic medium proceeds. This changing shape could indicate the nature of the first 'ionisers'.

Attempts to detect the EOR signal face many challenges. During its long journey the signal is redshifted, arriving on Earth as low-frequency radiation that can be distorted by its passage through the Earth's ionosphere. Even more significantly, the EOR signal is predicted to be extremely weak, and must be distinguished from far stronger foreground cosmic sources (both Galactic and extragalactic), man-made radio interference, and subtle effects generated by the observing instruments themselves. Researchers must understand well all these possible sources of contamination.

PERFORM

BIGHORNS

Theorists predict that the 'global' EOR signal will lie in the range 50–200 MHz and that its main features will appear around 70 and 100 MHz. In principle this signal could be detected by a single antenna. Several groups are planning or operating such experiments: one, led by CAASTRO researchers, is BIGHORNS (the Broadband Instrument for Global HydrOgen ReioNisation Signal). BIGHORNS is distinguished by its bandwidth, 50–350 MHz, the broadest of any of the global EOR experiments, which will make it easier to distinguish the EOR signal from foreground or instrumental effects. BIGHORNS also has an unusual 'backend' processing system, which processes data with extremely high time resolution: in effect, it captures data continuously, making the system highly sensitive to weak signals.

During 2012–2014 a preliminary version of BIGHORNS using an off-the-shelf antenna was deployed for short periods at three locations in Western Australia. In 2014 the BIGHORNS team replaced the system's antenna with a custom-designed conical log-spiral antenna, better matched to the BIGHORNS receiver system, and made other improvements; in October the team installed the instrument at CSIRO's Murchison Radio-astronomy Observatory (MRO), also in Western Australia, which is an extremely radio-quiet site. BIGHORNS now runs continually, collecting about 30 GB of data each day. As well as 'listening' for the EOR signal the instrument is also being used to measure the (changing) temperature of the electrons in the ionosphere and monitor both the Sun and any radio-frequency interference at the MRO. The BIGHORNS team will publish its initial science results in 2015.

The new BIGHORNS antenna at Curtin University prior to its completion and deployment.
Credit: Randall Wayth (Curtin University)

The Murchison Widefield Array EOR experiment

While BIGHORNS is intended to detect the global EOR signal, the Murchison Widefield Array (MWA) was designed to detect the EOR power spectrum (the variation in signal strength by spatial scale). The MWA is a radio interferometer, a set of 2,048 antennas acting as one instrument; it operates at low frequencies (80–300 MHz). The compact antenna 'tiles' (groups of 16 antennas) give it a very wide field of view, which makes it a superb survey instrument. The MWA is one of three official 'precursor' instruments for the future Square Kilometre Array telescope and is operated by an international partnership.

In its search for the EOR signal, the MWA will collect more than 1000 hours of data: this volume is required to separate the weak EOR signal from contaminating signal from foreground galaxies (including our own) and noise in the data. Three fields are being observed: these are regions where the combined characteristics of sky and instrument are such that foreground contamination will be at a minimum.

Two main algorithms ('pipelines') have been developed to calibrate the data, and two to measure the signal. One pair has been developed at CAASTRO nodes: the Universities of Melbourne and Sydney have developed one of the calibration pipelines, and Curtin University has developed one of the signal-processing (power spectrum) pipelines. The other two pipelines have been created by US partners in the EOR collaboration. Using multiple pipelines with different approaches provides a necessary cross-check on results.

In 2014 the MWA team produced trial power spectra from some of its collected data. As expected, most of the signal was due to contamination from foreground sources. CAASTRO researchers are devoting considerable effort to understanding the features of these sources, so that they may be removed from the data.

By the end of 2014 the MWA team had acquired 75 per cent of the data that it will use for analysis. This massive dataset, running to several petabytes, is stored at the Pawsey Supercomputing Centre in Perth, Western Australia; this is also where the data are processed. The project has been awarded half a million hours of computing time: most of the processing will be done in 2015.

These projects are described in the papers "BIGHORNS – Broadband Instrument for Global HydrOgen ReioNisation Signal" (*Publications of the Astronomical Society of Australia*, February 2015) and "Science with the Murchison Widefield Array" (*ibid.*, April 2013).

GLEAM

As described on page 10, researchers using the Murchison Widefield Array are searching for the signal from the Epoch of Reionisation (EOR). To them, the foreground radio sources in our Galaxy and other galaxies are a nuisance to be removed from their data. But one researcher's obstacle is another's observable. In parallel with the EOR experiment, the MWA has been carrying out a low-frequency survey of the entire southern radio sky: the GaLactic Extragalactic All-sky MWA (GLEAM) survey.

GLEAM will be used to characterise foreground sources for both the MWA EOR experiment and low-frequency observations by the future Square Kilometre Array. But it provides much more than that. The detectability of radio sources depends on the frequency at which they are observed: sources detectable at high frequencies may not be so at low ones, and vice versa. GLEAM is the first survey of the southern sky at its frequency range, 73–230 MHz, and complements other southern surveys made at different wavelengths. It will also dovetail with a low-frequency radio survey of the northern sky, the Multifrequency Snapshot Sky Survey (MSSS) currently being made with the LOFAR telescope in Europe: together, GLEAM and MSSS will create an unprecedented low-frequency survey of the entire sky.

GLEAM will produce a rich dataset, useful for studying a myriad of subjects: radio galaxies and active galactic nuclei, galaxy clusters, the Magellanic Clouds (small galaxies, near neighbours to our own Milky Way), diffuse Galactic emission, the Galaxy's magnetic field, spectral lines, supernova remnants, star-forming regions, pulsars and their wind nebulae, and cosmic rays. The MWA is extremely sensitive to large-scale structures such as radio relics and radio halos—arcs of radio-emitting charged particles that signpost where galaxies or clusters of galaxies have collided. Similarly, it is ideally suited to detecting older radio galaxies that are fading away after losing their central sources of power: these objects are invisible at high radio frequencies. Low-frequency observations give a truer estimate of the power from radio galaxies than high-frequency ones do. And they provide a means of observing young radio galaxies in the early (distant) Universe whose radio emission arrives on Earth significantly redshifted.

GLEAM began in 2013 and by the middle of 2015 will have gathered 814 hours of MWA data, a total volume of about a petabyte. The GLEAM extragalactic catalogue, which will be based on the first year of data, will be ready in 2015, and is expected to contain around 500,000 sources.

The project is described in "GLEAM: the GaLactic and Extragalactic All-sky MWA survey" (*Publications of the Astronomical Society of Australia*, in press).

Extending the reach of HI surveys

Another major Australian radio telescope is coming to fruition in Western Australia: CSIRO's Australian SKA Pathfinder. As the name indicates, this is one of the designated 'pathfinder' instruments for the future Square Kilometre Array. Like the MWA, is located at the Murchison Radio-astronomy Observatory; however, it operates at higher frequencies (700 MHz–1.8 GHz) and rather than dipole antennas it has dishes, each 12 m in diameter. In its final form, ASKAP will have a complement of 36 dishes: it is currently being commissioned with the first six, in a configuration called the Boolardy Engineering Test Array (BETA).

ASKAP is designed to be an extremely fast survey instrument, with a large field of view. During its first five years of operation most of its observing time will be used for ten large Survey Science Projects. Two of these, WALLABY and DINGO, will find galaxies through the radio waves emitted by the neutral hydrogen gas (HI) that they contain. A third, FLASH (the First Large Absorption Survey in HI), led by CAASTRO Director Professor Elaine Sadler, will seek to detect galaxies by looking for signs that they are absorbing HI emission from background sources. Two developments this year hold promise for these surveys. A 'blind' search for HI in absorption with the first six ASKAP antennas detected a signal: this is the first step towards FLASH. And a new way was found to use the data that WALLABY and DINGO will collect.

Venturing into the 'HI desert'

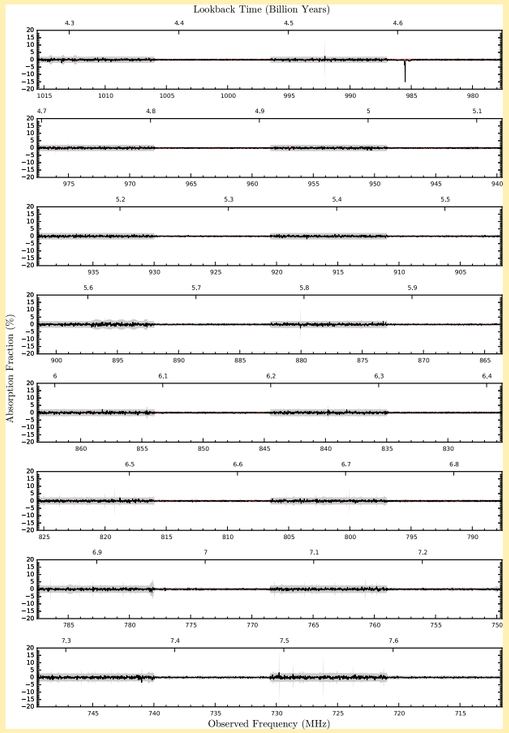
Ten billion years ago galaxies were making stars ten times faster than they are today. To understand why, we need to understand the history of the gas, mainly hydrogen, that stars form from: how much there was, and where it was found, at different times in the Universe's history.

For six decades astronomers have mapped the distribution and movement of neutral (un-ionised) hydrogen gas in galaxies by detecting the characteristic radio waves it produces, waves that are 21 cm long. But direct detection has only been possible for nearby galaxies, because the signal of neutral hydrogen (HI) is relatively weak. Optical astronomers have a way to detect this gas in galaxies in the early Universe. But the two techniques still leave a gap of some seven billion years, half the Universe's history, in which astronomers have struggled to detect HI. (This 'HI desert' extends between redshifts of 0.3 and 2.0.) Fortunately, HI can also reveal its presence by absorbing radio waves coming from a background galaxy. This manifests as a dip in the radio signal a telescope receives. By looking for absorption, astronomers can detect HI out to much greater distances than by looking for the emitted radiation.

However, attempts to use this technique have been hindered by the limited bandwidth, frequency range and sensitivity of the radio telescopes available, and by man-made radio signals that can swamp the effects astronomers are looking for. As a result, most HI-absorption surveys have been able to target only sources for which there is already information about the source's distance (redshift): this tells astronomers which part of the radio spectrum the telescope should be tuned to.

This year CAASTRO Affiliate James Allison (CSIRO) and his colleagues used the new ASKAP telescope to make the first 'blind' search for HI in absorption: that is, one without using a pre-existing redshift. This search turned up a previously undetected signal from the galaxy PKS B1740-517; a signal which left that galaxy about five billion years ago, before the Earth formed.

The signal was tiny, but it stood out clearly in the ASKAP data, thanks to the extremely low levels of man-made radio interference at the telescope site. It is a sign that the FLASH survey planned for ASKAP is likely to achieve its goals. FLASH will target galaxies that are five to eight billion years old, a timespan that represents a fifth of the Universe's history. Following this first ASKAP detection, the FLASH team is now confident of detecting hundreds of new galaxies, learning more about how galaxies have evolved over time, and filling in another piece of the Universe's story.



An ASKAP-BETA spectrum, showing the 'search space' for HI detection. The new detection of HI in absorption can be seen at a frequency of 985.5 MHz (equal to a redshift of 0.44).
Credit: James Allison (CSIRO)

Extending Tully-Fisher relations using HI stacking

The Tully-Fisher relation (TFR) is an empirical relationship between the mass of a spiral galaxy and its rotational velocity. In practice, luminosity is usually used as a proxy for mass. Astronomers use the TFR to calculate galaxy distances. But the TFR also shows something fundamental; namely, that at a given redshift, there is an essentially fixed ratio of dark to luminous matter in a spiral galaxy, regardless of its size. This means that studying how the TFR of galaxies changes over the Universe's history gives us information about how those galaxies grow and change. To track this evolution, we need to measure the TFR at a range of redshifts.

A galaxy's rotational velocity is most accurately measured using the 21-cm radio emission from the galaxy's neutral hydrogen gas (HI): the width of the HI line profile gives the rotational velocity. But the HI signal is weak, and so TFR studies have been limited to relatively nearby galaxies.

CAASTRO PhD student Scott Meyer (University of Western Australia) and his colleagues have now found a way to extend the TFR to higher redshifts. They used *stacking*, a process of combining the weak signals of many individual galaxies so as to increase the signal-to-noise ratio. Even when an individual galaxy's HI signal is too weak to detect, a stacked HI spectrum gives information about the average HI properties of an ensemble of galaxies.

Meyer and his colleagues tested whether a stacked HI spectrum could be used to establish a reliable TFR. They approached the problem in stages, first using samples of simulated galaxies that became progressively more realistic, and then a catalogue of galaxies whose individual TFRs were known.

Two surprising and important findings emerged. First, including elliptical galaxies in the sample made very little difference to the TFR. This is significant because the TFR has traditionally been limited to spiral galaxies. Second, with stacking it was unnecessary to correct for a galaxy's inclination (angle), or to exclude galaxies that were too face-on; again, this is a departure from past TFR studies.

The next step is to test the technique at higher redshifts. If validated, stacking holds promise for establishing Tully-Fisher relations from the planned ASKAP surveys WALLABY and DINGO. These surveys are expected to net around 600,000 galaxies. Stacking their observations should allow HI to be detected out to redshifts around 0.4.

The papers describing these two projects are "Discovery of HI gas in a young radio galaxy at z = 0.44 using ASKAP" and "Extended Tully-Fisher relations using HI stacking". Both have been submitted for publication in *Monthly Notices of the Royal Astronomical Society*.

The first science from SAMI

Galaxy evolution is complex: gas, stars, dust, supernovae and super-massive black holes all play a part. Over the last 15 years much has been learned about the process from surveys of hundreds of thousands of galaxies, which have been large enough to allow astronomers to establish statistically robust relationships between different galaxy properties. But, while capturing huge numbers of galaxies, these surveys have been unable to study each galaxy in detail. What astronomers have wanted is a way to do both. With SAMI, the Sydney University–AAO Multi-object Integral field spectrograph instrument, they now have it.

Developed through a collaboration of the University of Sydney and the Australian Astronomical Observatory, and funded by CAASTRO, SAMI can sample the light from up to 61 points in a galaxy, for thirteen galaxies at a time. The spectrum of each sample reveals how the stars and gas at that location are moving. What makes this possible is a new technology developed by the astrophotonics group at the University of Sydney: the 'hexabundle', a bundle of 61 optical fibres close-packed and fused together.

In 2013 SAMI was installed on the 4-m Anglo-Australian Telescope and began taking data for the SAMI Galaxy Survey, a study of around 3,400 local galaxies, mostly in the fields covered by the multi-wavelength Galaxy And Mass Assembly (GAMA) project. The survey has been awarded 150 observing nights over three years: 71 nights had been completed by the end of 2014. The key science goals of the SAMI Survey are to determine the role of the environment in galaxy evolution; to study the relationship between the growth of stellar mass and changes in angular momentum in galaxies; and to investigate the flow of gas in and out of galaxies, and the effect of these flows on star formation.

Data, and publications derived from them, began to emerge this year. The SAMI team presented its Early Data Release for the general astronomical community in July: this comprised fully calibrated datacubes for a selection of 107 galaxies that represented the full survey sample in its range of redshifts, stellar masses and galaxy morphologies. The data-release paper also demonstrated the SAMI data-processing pipeline's high level of performance.

Science results from SAMI published this year were:

- a study of the relationship between the kinematic morphology of galaxies in three clusters and the density of their surrounding environments, using data on 79 early-type galaxies from the SAMI Pilot Survey (a forerunner of the SAMI Galaxy Survey). This investigation, led by CAASTRO Evolving Theme Scientist Lisa Fogarty, examined two sub-classes of these galaxies, 'fast rotators' and 'slow rotators', and whether they were found preferentially in different environments. The work suggested that at least some of the slow rotators have migrated to where they're now found (at the centres of galaxy clusters) rather than having been formed there
- the discovery of a 'galactic wind' (a stream of charged particles travelling at up to 3,000 km a second) from the centre of a galaxy (SDSS J090005.05+000446.7). Such large-scale galactic outflows have been studied in nearby galaxies, but how common they are is unknown, as astronomers have lacked a way to search for them systematically. This study, led by I-Ting Ho (University of Hawai'i), shows that the SAMI Galaxy Survey is likely to give astronomers a much better understanding of their prevalence and cause
- observations of a luminous star-forming region in a dwarf galaxy, GAMA J141103.98-003242.3, by a team led by CAASTRO students Samuel Richards and Adam Schaefer (both of the University of Sydney). The region appears similar to the 30 Doradus region in the Large Magellanic Cloud (a dwarf satellite of our Milky Way Galaxy) but, unlike that galaxy, the dwarf in question is isolated, suggesting that the star formation must arise intrinsically rather than being externally triggered. The SAMI Galaxy Survey will study about 400 dwarfs (the most numerous type of galaxy) in the local Universe, allowing us to learn much more about their star-formation histories
- a unified *scaling relation* for galaxies of all types. A scaling relation links different physical properties of a galaxy, such as mass and rotational velocity. Scaling relations are used both to determine galaxy distances and to study galaxy evolution. Two of the most important date from the mid 1970s. One uses the velocity dispersion of a galaxy's stars; the other, a galaxy's rotational velocity: they apply to elliptical and spiral galaxies, respectively. Using data from the SAMI Galaxy Survey, a team led by Luca Cortese (Swinburne University) has shown that there is a new scaling relation, incorporating both dispersion and rotational velocity, that all types of galaxies conform to. Furthermore, it can be derived from observations of either gas or stars. This more general relation does away with the need to carefully select galaxy samples. It could also become an important tool for estimating galaxy distances.

The publications covering this work are "The SAMI Galaxy Survey: Early Data Release" (*Monthly Notices of the Royal Astronomical Society*, November 2014 (online)); "The SAMI Pilot Survey: the kinematic morphology–density relation in Abell 85, Abell 168 and Abell 2399" (*ibid.*, September 2014); "The SAMI Galaxy Survey: shocks and outflows in a normal star-forming galaxy" (*ibid.*, November 2014); "The SAMI Galaxy Survey: the discovery of a luminous, low-metallicity HII complex in the dwarf galaxy GAMA J141103.98-003242.3" (*ibid.*, December 2014); and "The SAMI Galaxy Survey: towards a unified dynamical scaling relationship for galaxies of all types" (*The Astrophysical Journal Letters*, October 2014).

THE DYNAMIC UNIVERSE

Theme Leader: Professor Matthew Bailes | Swinburne University of Technology

Theme Scientist: Dr Evan Keane | Swinburne University of Technology

For millennia people thought of the heavens as largely unchanging, the realm of the fixed, eternal stars. But we now know the Universe to be extraordinarily dynamic and violent, with change taking place not just over millions or billions of years but also within days, hours, seconds, and even fractions of a second.

CAASTRO's Dynamic Universe theme is focused on all-sky surveys for variable and transient objects. In particular, we are making radio observations with the Murchison Widefield Array, CSIRO's Parkes radio telescope and the University of Sydney's upgraded Molonglo Observatory Synthesis Telescope. With their wide fields of view, frequency ranges and time resolution, these surveys are allowing us to reach into new 'discovery space'. One such survey, begun this year, is SUPERB (the SUrvey for Pulsars and Extragalactic Radio Bursts), described on page 14. In another project, the low-frequency capability of the Murchison Widefield Array was turned to hunting for extrasolar planets (page 17).

Future surveys with telescopes such as the Square Kilometre Array and the Large Synoptic Survey Telescope will generate vast volumes of data to be mined for signals of interest. Two projects this year explored the use of automated classifiers for dealing with voluminous data, one dealing with variable sources (described on page 15) and one with pulsars (page 16).

SUPERB: a survey for fast radio bursts

'Fast radio bursts' (FRBs) are fleeting cosmic radio signals, lasting just a few milliseconds. The first FRB was discovered in 2007: to date, seven have been discovered in archival data taken with CSIRO's Parkes radio telescope, and an eighth in the archive of the Arecibo telescope in Puerto Rico. One further burst was discovered in 'real time' with Parkes in 2014 by CAASTRO student Emily Petroff: this work is described on page 32.

The bursts are strong for cosmic radio signals, around a jansky (the radio astronomers' standard unit for flux measurement). All of them show a large frequency-dependent time delay ('dispersion measure'), caused by free electrons in interstellar and intergalactic space, meaning that they must have originated billions of light-years away. For the bursts to be so strong even when coming from such distances, their sources must emit in a few milliseconds enormous amounts of energy.

The bursts' combination of characteristics could make them important tools for probing the cosmos. They could, for instance, locate the 'missing cosmic baryons': matter, so far undetected, that may lie in the outermost regions of galaxies or in intergalactic space. Unlike any other observational technique, the dispersion measure of an FRB is sensitive to the number of the baryons along the line of sight. Finding around a hundred FRBs would give us useful information about the baryonic mass of the Universe. By contrast, just a single FRB might allow us to measure the magnetic field in the space between galaxies: if it were linearly polarised, the magnetic fields in space would change the direction of this polarisation, in a measurable way. With many such FRBs, lying in different directions, we could map the magnetic field of intergalactic space.

But above all, astronomers wish to determine the phenomenon that generates the FRBs. This will require the FRBs to be detected in real time, so that rapid follow-up observations can be made at many wavelengths, by several telescopes. A survey to do just that began on CSIRO's Parkes radio telescope this year: SUPERB, the SUrvey for Pulsars and Extragalactic Radio Bursts, led by Evan Keane (Swinburne University), Theme Scientist for CAASTRO's Dynamic theme. As its name indicates, SUPERB is a (real-time) survey for pulsars as well as for fast radio bursts: although the scientific goals for detecting pulsars differ from those of FRBs, both can be accomplished in the one survey.

SUPERB extends the successful HTRU (High Time Resolution Universe) survey carried out at Parkes since 2008. It targets Galactic latitudes (angles up and down from the Galactic plane) in which previous FRBs have been found, and uses the SPINN neural network (described on page 16) and other data-processing techniques that allow pulsars and FRBs to be identified in real time and followed up immediately. Importantly for FRB studies, SUPERB captures the polarisation information of signals it detects. Ten other telescopes, working at wavelengths from radio to X-rays, are poised to respond to a detection by SUPERB on Parkes; data from the gravitational wave experiment LIGO will also be searched for traces of the FRB after the exact time the burst occurred is pinpointed.

SUPERB is expected to discover approximately 20 of the super-fast millisecond pulsars and about 100 'normal' ones. By the end of 2014, the survey had detected a 'millisecond' pulsar with a period of 6.38 milliseconds, and two slower ones—one that scintillates strongly and a second that turns its pulses 'on' and 'off' every few minutes. SUPERB is intended to take 1000 hours of data, and will run until 2016.

CSIRO's Parkes radio telescope, which is being used for the SUPERB survey.
Credit: CSIRO

An automated classification system for X-ray sources

Future telescopes such as the Large Synoptic Survey Telescope and the Square Kilometre Array will generate terabytes of sky-survey data each day. Buried within that data will be transient signals from gamma-ray bursts, gravitational wave sources, coalescing neutron stars, exoplanets—and from totally new, unexpected phenomena. Identifying such signals will be beyond the capacity of human observers: automatic classification is required. One of the most accurate classification algorithms, Random Forest, has already been used successfully with variable stars and supernovae. In 2014 CAASTRO PhD student Kitty Lo and her colleagues assessed its performance in classifying variable and transient X-ray sources.

A 'random forest' is an ensemble of decision trees, all different. Each tree is presented with an unclassified object; the tree allocates it to a class, effectively 'voting' for it; and the most common vote from the forest is the classification. The algorithm's probability of the classification being correct is the fraction of 'votes' cast for that class.

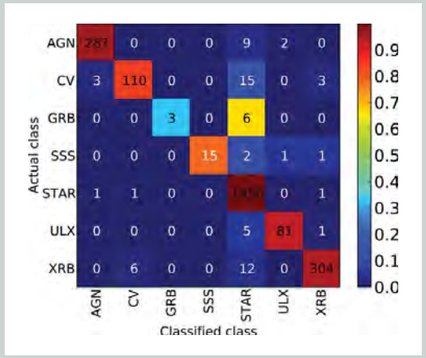
The decision trees are built from a set of training data and set of relevant features (for instance, luminosity). To build one, objects are chosen at random from the training set. Then for each node (decision point) on the tree, the algorithm randomly picks a subset of features and selects the best for splitting the tree into branches, the 'best' being the one that most reduces the chance of the item being incorrectly classified. Each object presented to the tree passes through a series of nodes until it is given a final classification and arrives in a 'leaf' on the tree.

Finding rare and novel objects is an important goal for future transient surveys. A Random Forest classifier cannot correctly label sources of a kind that it has not been trained on; nevertheless, it can reveal novel sources. They show up widely separated on the 'leaves' of the tree from other objects of the same class: that is, they are outliers.

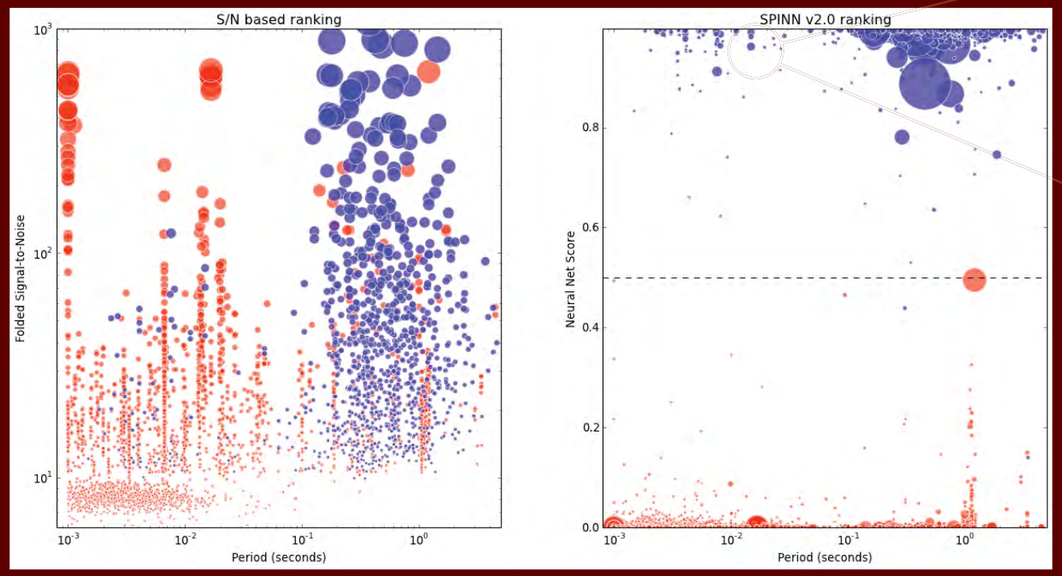
To train and test their Random Forest classifier, Lo and her colleagues used 873 sources from the X-ray Multi Mirror Mission – Newton (XMM-Newton), sources whose classification was already known. They evaluated the classifier's accuracy using '10-fold cross-validation', alternately training and testing on subsets of the training set.

In their first round of tests, Lo *et al*. used only time-series features, such as the duration of the strongest flare—27 features in all. With these, the classifier was able to correctly identify 77 per cent of sources, which is not enough to be practical. But adding a further 22 'contextual' features, such as proximity to galaxies and cross-matches with sources at other wavelengths, boosted the accuracy to 97 per cent. Lo and her colleagues concluded that, to perform well, classifiers hunting for variables and transients will need more to work with than just temporal flux measurements.

The paper by Lo *et al*., "Automatic Classification of Time-variable X-Ray Sources", appeared in *The Astrophysical Journal* in May 2014.



Test results from the Random Forest classifier. The colour bar represents the true positive rate. The overall accuracy is 97%.
Credit: Kitty Lo (University of Sydney)



Pulsar candidates ranked by their signal-to-noise ratio (left panel) and by SPINN (right panel). Known pulsars are in blue, radio-frequency interference or noise candidates are in red. SPINN ranks the candidates much more accurately than the older signal-to-noise method.

Credit: Vincent Morello (Swinburne University of Technology)

Pulsar identification using neural networks

Like the transient and variable sources discussed on the previous page, the compact, rapidly rotating stars called pulsars are relatively rare objects, and notoriously difficult to discover. Nevertheless, modern searches for pulsars generate millions of pulsar candidates, most of which are not pulsars, but 'noise' or radio-frequency interference. Each candidate must be inspected by an astronomer to determine if it is indeed likely to be a pulsar, and re-observed: only then can it be confirmed as a pulsar. Future surveys will present an even greater challenge: the Square Kilometre Array telescope is expected to find 20,000 pulsars, but only after 200 million candidates have been correctly classified. So, like astronomers searching for transients, pulsar astronomers are turning to automated classification.

Pulsars are distinguished by their regularly pulsed signals, and searching for them requires large-scale data mining. Once periodic signals are identified, the data can be 'folded' (coherently stacked) to reveal the pulse profile of a potential pulsar—a candidate. Each candidate has a set of diagnostic information or features, such as the signal-to-noise ratio of the pulse profile.

A few attempts have been made to classify pulsar candidates automatically. CAASTRO PhD student Vincent Morello (Swinburne University) and his colleagues have built on this work to create a new classifier employing a small number of information-rich features, dubbed SPINN (Straightforward Pulsar Identification using Neural Networks). As its name indicates, SPINN is based on a network of computational models called *artificial neurons*.

Morello and his colleagues trained and tested SPINN on data from the southern High Time Resolution Universe (HTRU) survey, carried out with CSIRO's Parkes radio telescope. The training set contained 90,000 non-pulsar candidates chosen at random, and 542 confirmed pulsars found in HTRU data that had been re-processed with a new pulsar-searching pipeline, PEASOUP. Following training, SPINN was used to classify all 4.35 million pulsar candidates generated by PEASOUP. This process took only 400 CPU hours, and could be accomplished overnight on Swinburne University's gSTAR cluster.

The goal of an automated classifier is to maximise 'recall' (that is, the fraction of pulsars labelled as such) while minimising 'false positives' (noise or RFI mislabelled as pulsars). SPINN can be tuned to optimise one of these factors or the other. At 100% recall, its false-positive rate was 0.64%; at 95% recall, it was 0.01%. While SPINN is successful in finding new pulsars, its false-positive rate is still two orders of magnitude higher than that of an experienced pulsar astronomer. However, SPINN can reduce the number of candidates that have to be inspected by eye, by up to four orders of magnitude. Overall, SPINN is a significant improvement on previous classifiers.

The performance of automated classifiers depends strongly on the properties of the data they are trained on and evaluated with. Morello *et al*. have made publicly available the dataset they used for this project, so that other classifiers—perhaps including ones generated outside astronomy—can be compared with SPINN. As yet, none has bettered SPINN's performance.

This work was described in "SPINN: a straightforward machine learning solution to the pulsar candidate selection problem", published in *Monthly Notices of the Royal Astronomical Society* in September 2014.

Searching for exoplanets with the MWA

In 1995 astronomers found the first planet outside our solar system that orbited a Sun-like star. Today there are more than 1,000 exoplanets known, with a further 3,000 or so candidates awaiting confirmation. Almost all have been discovered indirectly, most often through effects a planet can have on the light of its parent star. Only a few exoplanets have been found by direct imaging at optical or infrared wavelengths.

But direct radio detection may also be possible. Large, Jupiter-like planets with strong magnetic fields (and a source of energetic electrons) should emit low-frequency radio waves, as Jupiter does. While at optical wavelengths the parent star can be a million times brighter than its planet(s), at radio wavelengths the two can be of comparable strength.

Radio searches for exoplanets are part of the program for the low-frequency component of the forthcoming Square Kilometre Array radio telescope. To verify the validity of this approach, CAASTRO Chief Investigator Tara Murphy (University of Sydney) and colleagues have begun a systematic search for exoplanetary emission with the Murchison Widefield Array (MWA), which operates at 80–300 MHz. This search is a component of the larger MWA Transients Survey (MWATS), which will cover the southern sky at 154 MHz, looking for radio sources that vary over months, hours and minutes.

Of the 1,110 exoplanetary systems confirmed at the time the work began, 347 fall within the region that MWATS had covered by mid 2014. Murphy and her colleagues calculated the expected maximum emission frequency and flux density for these sources, and selected those for which these parameters were close to or above the MWA's detection capabilities. They also included ten sources that had been identified as the most likely candidates for radio emission generated by magnetosphere–ionosphere coupling. This resulted in a sample of 17 candidates, 13 of which had not previously been observed at radio wavelengths.

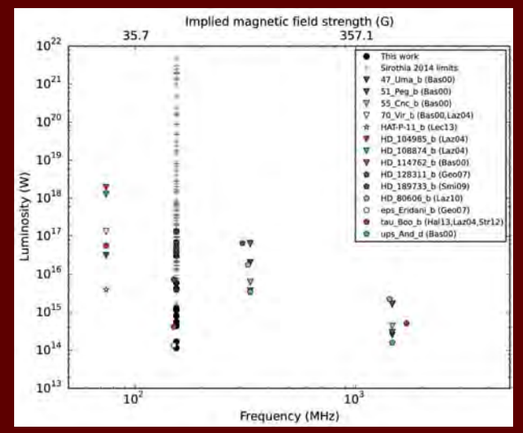
Murphy and her colleagues detected no radio emission from a band of radio emission at a centre frequency of 154 MHz, and put 3σ upper limits in the range 15.2–112.5 mJy on this emission. They also searched for circularly polarized emission and made no detections, obtaining 3σ upper limits in the range 3.4–49.9 mJy. These limits are comparable with the best limits from other low-frequency surveys. If the emission is assumed to be completely circularly polarized, they translate to luminosity limits of between 1.2×10^{14} and 1.4×10^{17} W—at least three orders of magnitude greater than the luminosity of Jupiter.

Why was no emission detected? There are a few possible reasons. More sensitive observations may be needed. The observing frequency, while lower than that of previous studies, was still higher than the predicted maximum emission frequency for many systems in the sample. And radio emission from exoplanetary systems is likely to be 'beamed' in the plane of the planet's orbit, and also sporadic. Future work with the MWA will use lower-frequency (90 MHz) observations and cover the full orbital period of several known systems to increase the probability of detection.

The paper describing this work, "Limits on low-frequency radio emission from southern exoplanets with the Murchison Widefield Array", was published online by *Monthly Notices of the Royal Astronomical Society* in November 2014.

Luminosity limits on radio emission from exoplanets. The limits obtained with the MWA are shown as black dots.

Credit: Tara Murphy (University of Sydney) et al.



THE DARK UNIVERSE

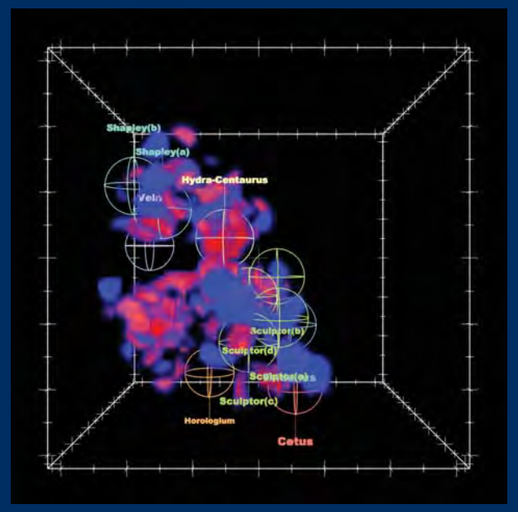
Theme Leader: Professor Tamara Davis | University of Queensland
Theme Scientist: Dr Michael Childress | Australian National University

Our current 'standard model' of the Universe, which is our best description of how it works, is a model that contains dark energy (designated by the Greek letter Λ, Lambda) and cold dark matter: it is therefore known as the ΛCDM (Lambda cold dark matter) model. This model accounts well for our observations of the cosmic microwave background; the large-scale structure of the Universe (how galaxies are distributed on large scales); how much hydrogen, helium and lithium the Universe contains; and the accelerating expansion of the Universe, discovered in the late 1990s, which is attributed to 'dark energy'. The ΛCDM model also assumes that general relativity is the correct theory of gravity governing the cosmos.

However, the dark-energy term, Λ, is open to question. Lambda is the 'cosmological constant' that Einstein inserted into his equations for general relativity. It is by no means established that dark energy is of this nature: there are other candidates, and they would produce observable differences from the cosmological constant. It is also possible that, on the large scales, gravity is better described by a theory other than general relativity. Much of the work in CAASTRO's Dark Universe theme in 2014 has involved testing these possibilities.

This year a CAASTRO-led team released the final sample of the 'peculiar velocities' of galaxies (galaxy movements resulting from gravitational attraction) from the 6dF Galaxy Survey. This is the largest such survey ever made; large enough to allow researchers to check if the local Universe is consistent with ΛCDM. CAASTRO researchers used the dataset to make two such consistency tests, by calculating the 'bulk flow' of the local Universe and, for the first time, measuring the rate of growth of structure on scales larger than 300 million light-years. (These projects are described on page 19.) The peculiar-velocity data was also used to test for one of the modified versions of general relativity (page 20). While some CAASTRO researchers were using peculiar velocities as tools, others were correcting for their effects in the data from the WiggleZ galaxy survey, allowing them to make a more precise determination of the 'baryonic acoustic feature' (a measure of galaxy clustering) and from that, a value for the parameter *w*, which describes how dark energy reacts to the expanding universe. This work is discussed on page 21.

Measuring the effects of dark energy is the aim of another long-term project, the Dark Energy Survey (DES). A number of CAASTRO researchers are contributing to this through OzDES, an Australian observing program that aims to measure for DES the redshifts of around 3,000 Type Ia supernovae. OzDES began in 2013 and by the end of 2014 had completed its second season of observing: its progress is discussed on page 22. Meanwhile, other CAASTRO researchers have had a look 'under the bonnet' of Type Ia supernovae, the 'standard candles' on which many dark-energy studies rely. These findings are discussed on page 23.



The 3D map of galaxy peculiar velocities in the nearby Universe, as observed by the 6-degree Field Galaxy Survey (6dFGS). Our own Galaxy lies at the centre of the map. Red indicates regions where galaxies are moving away from us, blue the regions where galaxies are moving towards us. Nearby 'superclusters' of galaxies are labelled. The cube measures about 1.5 billion light-years on each side.
Credit: Chris Fluke (Swinburne University)

Cosmological tests with peculiar velocities

In general, galaxies 'go with the flow': they move further apart as the Universe expands. But this is not the whole story. Galaxies are also drawn together by their mutual gravitational attraction. And this gives them an additional component of motion: their 'peculiar velocities'. By measuring the speed and direction of these individual movements, researchers can map the gravitational forces that are tugging on the galaxies, and so determine how matter, seen and unseen, is distributed.

This year, CAASTRO Research Staff member Christopher Springob (University of Western Australia) and colleagues have publicly released data on the movements of 8,885 galaxies, almost double the number measured by the largest previous study of this type. This new set of peculiar velocities was derived from the 6-degree Field Galaxy Survey (6dFGS), which was carried out with the 1.2-m UK Schmidt Telescope at Siding Spring Observatory in northwest NSW. The survey recorded redshifts for more than 110,000 galaxies over 80 per cent of the Southern sky. The galaxies in the peculiar-velocities sample are spread over a region 1.5 billion light-years across, the largest volume ever covered by such a survey. The size of this survey has allowed researchers to test for the first time if our local region is representative of the Universe as a whole, and whether our standard cosmological model, ΛCDM, correctly predicts galaxy movements.

A number of peculiar-velocity surveys carried out in recent years suggested that the 'bulk flow' of galaxies in the nearby Universe (their movement *en masse* under the influence of gravity) was *not* consistent with the predictions of the ΛCDM model (in fact, faster). But yet other studies suggested that it *was*. CAASTRO PhD students Morag Scrimgeour and Christina Magoulas are contributing to the debate, using the 6dFGS peculiar velocities to calculate the bulk flow of local galaxies. They used different methods, but both found the bulk flow to be consistent with the ΛCDM model, although greater than one would expect from the large-scale structure we observe in the nearby Universe.

CAASTRO student Andrew Johnson (Swinburne University) and his colleagues have used the 6dFGS peculiar velocities to carry out another kind of test, a test of our model of gravity. The cosmic microwave background reveals very slight fluctuations in the density of matter in the Universe. Over time, the slightly denser regions accumulated more and more matter, leading to the large-scale distribution of galaxies that we see today. General relativity predicts that the rate at which this large-scale structure has grown depends only on time. But some other theories of gravity predict that the rate of growth differs on different spatial scales. Of the various techniques that can be used to constrain theories of gravity in this way, peculiar velocities are uniquely able to probe the growth rate of structure on scales greater than 300 million light-years.

Johnson *et al*. have made the first test of the growth of structure on this scale, using the peculiar velocities from 6dFGS and a sample of low-redshift ($z < 0.07$) Type Ia supernovae (another means of tracing the peculiar velocities of galaxies). They found that the growth of structure is consistent with the standard model's prediction (although slightly higher than expected), with no evidence for scale-dependence in the growth rate. The growth rate they calculated was also consistent with one previously derived from redshifts from the 6dFGS sample by Beutler *et al*. (2012).

Two future Australian peculiar-velocity surveys, TAIPAN (to be carried out on the 1.2-m UK Schmidt Telescope) and WALLABY (to be done with the Australian SKA Pathfinder radio telescope), will measure the rate of growth of structure even more precisely, to within three per cent (at $z \sim 0.025$). Both will involve many members of CAASTRO.

The peculiar-velocities work described here was reported in "The 6dF Galaxy Survey: peculiar velocity field and cosmography" (*Monthly Notices of the Royal Astronomical Society*, December 2014) and "The 6dF Galaxy Survey: cosmological constraints from the velocity power spectrum" (*ibid*., November 2014). As of the end of 2014, the work of Scrimgeour was under review.

Testing a modified theory of gravity

As mentioned on page 18, our current standard model of the Universe, the ΛCDM model, posits the existence of both dark matter and dark energy. In fact, the existence of both dark matter and dark energy follow from assuming that general relativity is the correct description of gravity.

ΛCDM has many successes. But it also has a few problems. The most striking is that the energy density of Λ appears from observation to be about 120 orders of magnitude smaller than would be expected from quantum theory. Moreover, the energy density of Λ (dark energy) is of the same order of magnitude as the average matter density in the Universe today. These two quantities scale with the size of the Universe in very different ways, and so their similarity at the present time is an unsettling coincidence. The energy density of dark matter is very close to the energy density of baryons (non-dark matter): as the two are thought to have different production mechanisms, this also is surprising. Several kinds of observations have suggested that dark matter does not behave as predicted (although some of these discrepancies may be resolvable). All this may signal that we need to go beyond general relativity in describing gravity.

Extending general relativity began as early as 1918, and there are now many 'modified' theories of gravity. As a group, they differ from general relativity in their predictions for how matter will cluster and grow into large-scale structures. The predictions also differ from model to model. Growth-of-structure observations can therefore be used as a discriminator.

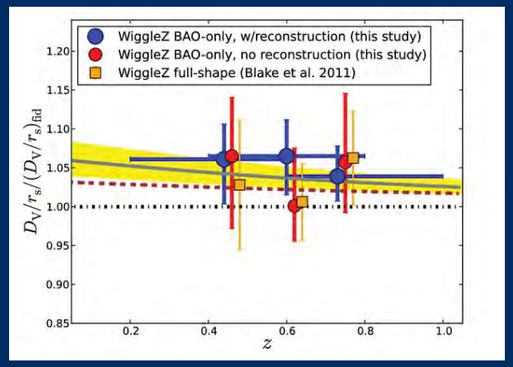
This year, CAASTRO Associate Investigator David Parkinson and his colleagues have tested f(R) models of gravity: extensions of general relativity that include a more general function of R (the Ricci scalar, a term representing the curvature of spacetime) than do Einstein's equations. Parkinson and his colleagues created predictions of the growth of structure for f(R) and compared them to measurements of the cosmic microwave background from the Planck space telescope, combined with observations made by the WiggleZ galaxy redshift survey (described on page 21) of large-scale structure.

f(R) models contain a scalar field, the *scalaron*, not present in general relativity, which is a candidate for dark energy. The mass of this field depends on the local matter density (it will be high where the local matter density is high, for instance). The mass of the scalaron in the local Universe is represented by a parameter, B_0:

Parkinson and his colleagues looked for evidence of a non-zero value of B_0.

Previous work had placed upper bounds on B_0. Observations of the cosmic microwave background with the Planck satellite had given $B_0 < 0.1$. Combining tracers of large-scale structure with data from the WMAP (Wilkinson Microwave Anisotropy Probe) satellite had given an even more stringent constraint, of 1.1×10^{-3} (both figures are at the 95% confidence limit). By adding WiggleZ observations to the Planck data, Parkinson's team improved the previous best limit for B_0 by another order of magnitude, to $\log10(B_0) < -4.07$ ($= 8.5 \times 10^{-5}$). This represents one of the tightest constraints on B_0, and thus on f(R) models, to date.

This work was described in the paper "Constraining models of f(R) gravity with Planck and WiggleZ power spectrum data", published in the *Journal of Cosmology and Astroparticle Physics* in March 2014.



The distance-redshift relation obtained using the 'reconstruction' technique (blue points), with the previous analysis (red points) shown for comparison.
Credit: Eyal Kazin (Swinburne University of Technology) et al.

Sharpening the WiggleZ

One way to investigate the nature of dark energy relies on detecting a pattern in how galaxies are distributed in space. Pairs of galaxies have a slight 'preference' for being a certain distance apart. When measured in today's Universe, that distance is 490 million light-years.

Where does this pattern come from? It was created by pressure waves (sound waves) that existed in the Universe when it was very young, no more than a few hundred thousand years old, and very hot. As the Universe cooled, the sound waves became 'frozen' and the signature of that pattern can still be seen in the distribution of matter; it is known as the 'baryon acoustic feature'.

As the Universe has expanded over its lifetime, the galaxy-clustering pattern has stretched accordingly. Measuring the preferred distance of galaxies at several stages of the Universe's history is a way to track the rate of expansion of the Universe and how that has changed over time. Importantly, this method is completely independent of the measurements of the expansion made using Type Ia supernova (such as those the OzDES project, described on page 22, will contribute to). Measuring the galaxy-clustering pattern is one way to determine the parameter *w*, which characterises dark energy. If *w* can be measured with sufficient certainty, it will rule out some candidates for dark energy.

Several projects have been carried out to measure the preferred spacing of galaxies. The first one to produce significant results for high redshifts (that is, for much earlier in the Universe's life) was WiggleZ, a survey we carried out with the 4-m Anglo-Australian Telescope. The WiggleZ team measured the preferred spacing of galaxies when the Universe was about 8 billion years old (corresponding to a redshift of 0.6), and published its results in 2011.

However, the signature of the 'preferred spacing' is not sharp. As discussed on page 19, galaxies aren't just carried along by the expansion of the Universe, but also have their own, 'peculiar', velocities, that arise from gravitational attraction. In fact today the galaxies are displaced, on average, by some 16 million light-years from where they'd be if they weren't influenced by gravity. The effect is to 'blur' the spacing of the preferred separation. It's like looking at a car's headlights at night: if the night is clear, the spacing between them is easy to see and measure, but if the night is foggy, equivalent to the galaxies having been moved by gravity, then the spacing is harder to measure.

This effect has been understood for a long time, and in 2007 Eisenstein *et al*. suggested a way to correct for it: use the density field (that is, a map of gravitational potential) to work out how much the galaxies have been displaced; in effect, put them back in their original positions; and then re-calculate their preferred spacing. The technique has been successfully applied to galaxy samples obtained by the Sloan Digital Sky Survey. But it was not clear if it would work for WiggleZ, which had been carried out over several non-contiguous volumes, meaning that there are 'edge effects'; also, the WiggleZ data was patchy in some areas and inherently sparse at higher redshifts.

To learn if 'reconstruction' could be usefully applied to the WiggleZ data, CAASTRO Research Associates Eyal Kazin and Jun Koda (Swinburne University) and their colleagues created 600 simulated catalogues of galaxies and tested the procedure on those. In two-thirds of the cases this yielded a better-defined baryonic acoustic feature. When applied to the WiggleZ data itself, the technique decreased the uncertainties of the measurement from 4.5–7.5% (the figures vary by redshift) to 3.4–4.8%. This is a significant improvement, effectively equivalent to the result expected from a survey with up to 2.5 times the volume of WiggleZ.

Combining their new measurement with others from the Six-Degree Field Galaxy Survey (6dFGS) and observations of the cosmic microwave background, the researchers calculated a value for *w* of -1.08 ± 0.14, which agrees well with others in the literature reached through different techniques, and also with the standard 'flat ΛCDM' cosmological model that predicts *w* of −1. Their calculated values for other cosmological parameters were, reassuringly, also in line with the standard 'flat ΛCDM' cosmological model.

This work appeared in the paper "The WiggleZ Dark Energy Survey: improved distance measurements to z = 1 with reconstruction of the baryonic acoustic feature", published in *Monthly Notices of the Royal Astronomical Society* in July 2014.

DISCOVER

OzDES and the Dark Energy Survey

Is dark energy the 'cosmological constant' that Einstein built into his general theory of relativity, or a sign that that theory is incomplete? One of the largest attempts so far to answer that question is the Dark Energy Survey (DES), a 5-year international project led from the USA and UK.

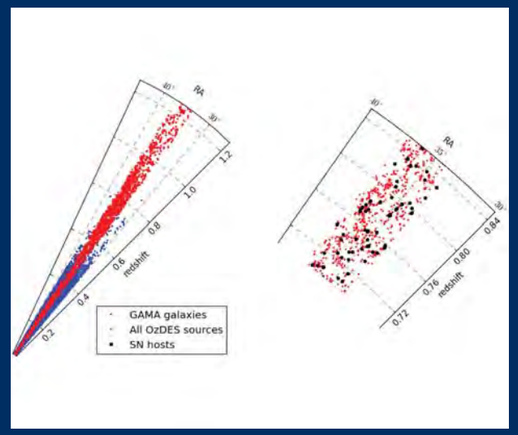
DES is measuring the effects of dark energy in four ways. One of them involves determining the brightness of Type Ia supernovae. This was the technique that originally uncovered dark energy: DES aims to improve its precision by finding thousands of new supernovae between redshifts of 0.2 and 1.2. To this end, a 570-megapixel 'dark energy camera', DECam, is now surveying the southern sky from the Chilean Andes.

Having found the supernovae, DES needs their redshifts. These were traditionally obtained one supernova at a time, by taking a spectrum of each exploded star before its light had faded. But with so many supernovae being found, it's impractical to follow each one up while it is still bright. In most cases, therefore, the strategy is to obtain a redshift for the supernova's host galaxy, which can be done at leisure.

The 2dF instrument on the 4-m Anglo-Australian Telescope (AAT) in eastern Australia has a field of view exactly the same as that of DECam, and the combination of 2dF (which positions optical fibres for capturing light) and the AAOmega spectrograph (which analyses the light) allows almost 400 redshifts to be measured simultaneously. Using these instruments, OzDES, the Australian Dark Energy Survey to measure redshifts for DES, began in 2013. OzDES involves 10 Australian institutions and 30 Australian researchers, including many affiliated with CAASTRO; CAASTRO also provides postdoctoral support for the project. The survey has received an allocation of 100 nights on the AAT, spread over five years.

By the end of 2014, OzDES had completed its second season of observing, 26 nights in total. It has obtained redshifts for 11,000 targets, of which 1,200 are the host galaxies of transients, mostly supernovae. Of these galaxies, about 240 have been confirmed as the hosts of Type Ia supernova that will be useful for cosmological studies. OzDES is well on the way to meeting its target of about 3,000 such redshifts after five years' observing.

The first scientific papers from OzDES will be published in the first half of 2015.



Galaxies observed with OzDES (in red) in a 3°-wide slice centred on the XMM-LSS 2hr field. Galaxies in the Galaxy and Mass Assembly (GAMA) survey are shown for comparison in blue. Not shown are the active galactic nuclei (AGN), which go out to redshift 4. The right-hand plot shows part of the region in more detail: galaxies shown in black hosted a supernova in the first two years of the Dark Energy Survey.

Credit: Chris Lidman (AAO)

Type Ia supernovae have varied progenitors

Type Ia supernovae (SNe Ia) have been used for decades as 'standard candles', objects of known luminosity. They were the key tool for uncovering the acceleration of the expansion of the Universe, and for many subsequent attempts to refine the measurement of the acceleration and determine its cause. (One such project, OzDES, is discussed on page 22.) However, there were hints that SNe Ia are produced by more than one mechanism. Now CAASTRO researchers have found more evidence that this is so.

SNe Ia vary widely in peak brightness and the rate at which they fade. Using correlations between their luminosity, colour, and the width of their light-curve (how fast they brighten then fade), the luminosities of different SNe Ia can be standardised to within about 10% (~0.15 magnitude). But in 2013 CAASTRO Postdoctoral researcher Michael Childress (Australian National University) and colleagues showed that, even after making such corrections, another bias remains: SNe Ia supernovae at higher redshifts are on average fainter than their counterparts in the local Universe. This trend is not strong enough to negate the evidence for the accelerating expansion of the Universe, but it could bias measurements aimed at discriminating between different 'dark energy' candidates. The researchers identified the age of the Type Ia progenitor as the most probable cause of the bias.

This year Childress and his colleagues looked further into the ages of SNe Ia progenitors. They considered how the age of the progenitors coupled with the star-formation history of galaxies, and found that this coupling naturally explains a bimodality in SNe Ia ages revealed by previous studies. More importantly, they found that the young (or 'prompt') SNe Ia consistently arise from progenitors of the same age at all redshifts, while the progenitors of old (or 'tardy') SNe Ia have different average ages at different redshifts. They also found that this age bimodality evolves with redshift in a way currently not accounted for in cosmological studies.

In two studies this year, CAASTRO Associate Investigator Richard Scalzo (Australian National University) probed another aspect of Type Ia supernovae: their progenitor masses.

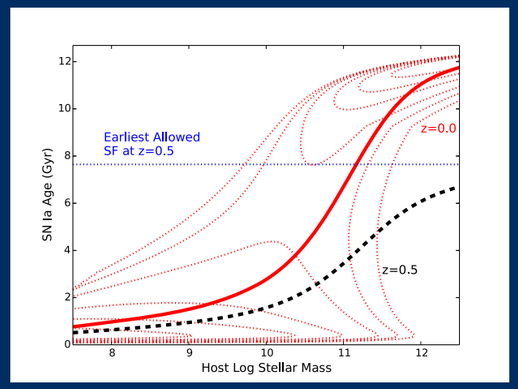
For many years SNe Ia were thought to result from a carbon/oxygen white-dwarf star in a binary orbit with another star, the dwarf triggered to explode by accreting material from its companion that put it over the Chandrasekhar limit (1.4 solar masses). This is the *single-degenerate* scenario. In recent years, detailed observations of the explosions have suggested that there might be additional mechanisms at work, including white-dwarf mergers or collisions (the *double-degenerate* scenario).

Scalzo and his colleagues initially examined 19 low-redshift SNe Ia. They used the characteristics of the supernovae's light-curves to calculate the mass of the ejecta (the debris) from each explosion: this is exactly the mass of the progenitor, which is totally destroyed by the explosion. In the single-degenerate scenario, it is assumed that the single white dwarf must explode near the Chandrasekhar limit. But in a finding at odds with this, the progenitors of the 19 objects in this study appeared to have masses from 0.9 to 1.4 solar masses (with about 15% uncertainty). Scalzo *et al*. also discovered a very strong correlation of the ejecta mass with the width of the SN Ia lightcurve.

In a subsequent study, Scalzo, along with CAASTRO Associate Investigators Ashley Ruiter and Stuart Sim, used the correlation of light-curve width with ejecta mass to derive the ejected masses of 337 SNe Ia, all at a redshift of less than 0.7. They found that 25-50% of SNe Ia *cannot* have 1.4 solar-mass progenitors. Almost all of these progenitors must have masses below the Chandrasekhar mass; less than 1% of SNe Ia (with the exception of some spectroscopic oddities) have masses significantly exceeding the Chandrasekhar mass. Scalzo and his collaborators found that the mass distribution, while not obviously bimodal, cannot be described by any single explosion model. SNe Ia must be produced by more than one process.

SNe Ia are powerful tools for characterising the contents of our Universe. Careful probing of the phenomena that underlie them will help us to use them with greater precision.

This research appeared in three papers: "Ages of Type Ia supernovae over cosmic time" (*Monthly Notices of the Royal Astronomical Society*, December 2014), "Type Ia supernova bolometric light curves and ejected mass estimates from the Nearby Supernova Factory" (*ibid.*, May 2014), and "The ejected mass distribution of type Ia supernovae: a significant rate of non-Chandrasekhar-mass progenitors" (*ibid.*, December 2014).

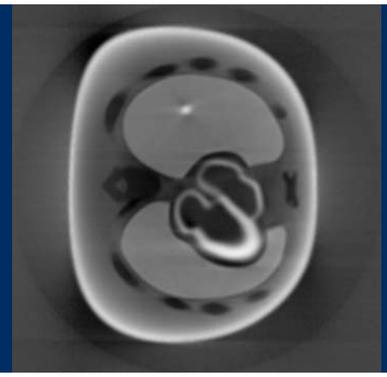


Mean ages of Type Ia supernovae as a function of their host galaxy mass in the local (z = 0, solid red curve) and distant (z = 0.5, dashed black curve) Universe. Dotted red lines show the full contours for SN Ia age distributions in the local Universe.

Credit: Michael Childress (ANU) et al.

CASE STUDIES

The Murchison Widefield Array, Western Australia
Credit: Steven Tingay



A simulated slice through the body, with a lesion present in the lung.
Credit: Cathryn Trott (Curtin University)

Interdisciplinary Research Case Study

DESIGNING AN ALGORITHM TO DETECT TUMOURS

Cathryn Trott (Curtin University)

When new techniques are created for acquiring or processing medical images, they have one goal: to improve image quality. That is, to make it easier for a radiologist to spot what he or she is looking for, a tumour, for instance.

The ultimate arbiter of image quality is the trained radiologist. But this means that new imaging techniques have to be assessed by trained radiologists, and that is a lengthy (and expensive) process.

To carry out such tests on new techniques, it is useful to have reliable mathematical algorithms that can mimic the lesion-detecting skills of a trained person. Algorithms have been developed for this purpose, but they still fall short of human abilities.

Source recognition is a major issue in astronomy too. The human eye and brain are excellent at pattern recognition and, therefore, in finding sources in data. But the volume of data from telescopes such the future Square Kilometre Array and its precursors, such as the MWA and ASKAP, makes automated source recognition a must.

CAASTRO Affiliate Cathryn Trott (Curtin University) is a specialist in extracting information from astronomical data. Like medical images, astronomical images are filled with extraneous signals and noise, and detecting an object within these complex datasets requires optimal methods. In an interdisciplinary project, Trott worked this year with the Positron Emission Tomography (PET) Imaging Physics team at Massachusetts General Hospital in Boston, USA, to design a new algorithm that more closely mimics a trained radiologist.

PET imaging is used extensively to measure glucose use in the body, and is a principal tool used by oncologists to detect cancerous tumours. Detecting a tumour involves distinguishing between normal and diseased tissue in images with complicated backgrounds and/or 'noise'. Motion from the patient's breathing significantly degrades images.

The team's starting point was previous 'numerical observers' (algorithms), such as the *channelized Hotelling observer* (CHO). The CHO uses a template to decorrelate the noise in the image, and also applies linear filters ('channels'), which mimic the human visual system. It performs well compared to radiologists when assessing medical images.

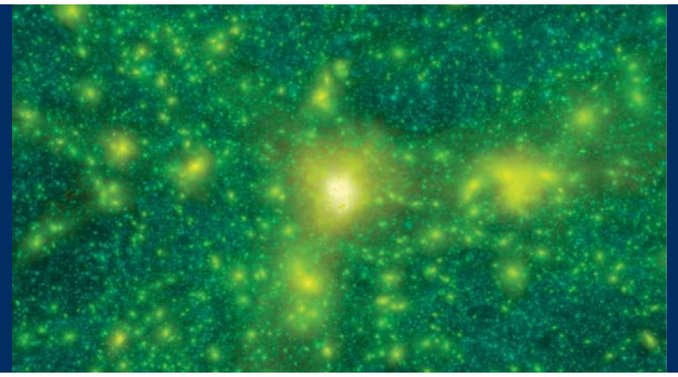
However, radiologists also look for the way the image varies in time to help them determine if a tumour is present. In this study, Trott and her colleagues developed a way for their algorithm to make use of time-variation in the images. It is thus referred to as a '4D model', using the three spatial dimensions plus time.

Importantly, the team incorporated 'respiratory gating' into their algorithm. The motion from a patient's breathing significantly degrades the quality of a diagnostic image. Respiratory-gated imaging uses a signal from breathing to time when the image data are collected (typically at the end of exhalation): the resulting images are of higher quality than images made without gating.

The researchers created a set of realistic simulated PET images with a range of lesion sizes, severities, locations and degree of respiratory motion. To this they applied their new 4D algorithm, using gated imaging; the standard CHO algorithm, on non-gated images; and the CHO algorithm on motion-corrected images. The 4D algorithm, using gated imaging, proved superior to the other two techniques: on average, it improved the signal-to-noise ratio of the image by 48.6%, as compared to the non-gated method, while the 3D methods on motion-corrected images showed a corresponding improvement of 31.0%. (The 4D method avoids registration and interpolation inaccuracies that can occur in the motion-corrected imaging, effects that lead to lower contrast and poorer spatial resolution.) These results are encouraging. The next step will be to test the 4D model against the performance of real radiologists with real patient images.

In a related project, Trott has begun working with physicists in the Radiation Physics Laboratory at the University of Sydney who are developing a low-cost computed tomography (CT) radiotherapy scanner. She is helping them design methods for rapidly imaging a tumour and tracking its motion and deformation so that radiotherapy can be optimally timed.

CAASTRO CoEPP
Workshop Participants
Credit: Caroline Hamilton



A simulation of the Universe, generated from data from the WiggleZ survey.
Credit: Gregory Poole

Interdisciplinary Research Case Study

COEPP-CAASTRO JOINT WORKSHOP

Katherine Mack (University of Melbourne)

Dark matter, dark energy, neutrinos and theories of gravity: all are areas in which the work of particle physicists complements that of astrophysicists. The ARC Centre of Excellence for Particle Physics on the Terascale (CoEPP) and the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO) held their first joint workshop in 2012, to explore their common interests. The second joint workshop, run over 28–30 September 2014, was held to make concrete plans for an exciting new opportunity in dark-matter research.

The workshop was held in the town of Great Western in rural Victoria. As well as bringing together local and international experts on all aspects of dark matter research, the workshop was also designed around introducing the scientific community to a proposal for a dark-matter detector in the Stawell gold mine, close to Great Western. Attendees at the workshop included scientists from Italy's Istituto Nazionale di Fisica Nucleare (INFN), a research agency dedicated to the study of the fundamental constituents of matter, and the Science Attaché for the Italian Embassy in Canberra.

Members of CAASTRO and CoEPP from Melbourne and Swinburne Universities had began talks with the managers of the Stawell mine in 2013, to explore the possibility of using a portion of the mine as an underground physics laboratory. While dark-matter detectors are already operating underground in many locations in the northern hemisphere, this will be the first such detector in the southern hemisphere, and will help us to confirm possible dark-matter signals found at other sites (such as INFN's laboratory at Gran Sasso in central Italy). Having our own dark-matter detector will give Australia much greater involvement in the worldwide endeavour to identify dark matter and study its properties.

Discussions at the CoEPP-CAASTRO workshop touched upon the radiation and cosmic-ray-shielding conditions at the Stawell mine, both of which appear to be acceptable. The next steps will be to form an official collaboration and secure funding for equipment and researchers. Both the local council and the community of Stawell have shown their support for the enterprise.

Research talks at the workshop made it clear that there is still a lot of work to be done in our understanding of dark matter. On the observational side, inconsistencies between models and observed properties of small-scale dark-matter systems (such as dwarf galaxies) are still vexing, as pointed out by invited speaker Manoj Kaplinghat (University of California Irvine). Geraint Lewis (University of Sydney) described an even more puzzling problem: the discovery of great co-rotating planes of satellite galaxies around the Milky Way and Andromeda, in apparent disagreement with expectations of dark-matter behaviour. Other researchers spoke about work to study dark matter in the cosmic microwave background, and prospects for detecting dark matter indirectly, through neutrino and gamma-ray signals.

On the theoretical side the field is still open for new ideas about dark matter's fundamental nature. Several speakers discussed dark-matter models beyond the 'supersymmetric neutralino', which is looking less and less favoured due to the failure of the Large Hadron Collider to detect signatures of other 'supersymmetric' particles.

The second day of the workshop was devoted mainly to the nuts and bolts of designing and building a dark-matter detector, and highlighted the opportunities for CoEPP and CAASTRO researchers to be part of this emerging collaboration between Italy and Australia. This prospect of direct detection, coupled with the prospects of indirect detection via cosmic rays, gamma rays or neutrinos, makes it an exciting time to be studying dark matter in Australia.

Interdisciplinary Research Case Study

PAINTING NEUTRINOS INTO A CORNER

Signe Riemer-Sørensen (University of Oslo)

As elementary particles go, neutrinos—'little neutral ones'—are not newcomers: they were proposed by physicist Wolfgang Pauli in 1930 and revealed by experiment in 1956. The 'Standard Model' of particle physics says they are massless; however, experiments and observations have shown otherwise. This makes the neutrino the only confirmed particle that doesn't fit the Standard Model (which is otherwise extremely successful).

The neutrino mass is not well constrained, either. Pinning it down would help us to better understand how neutrinos fit into the family of fundamental particles.

But even talking of 'the' neutrino mass is misleading. Neutrinos come in at least three kinds, or 'flavours', which can transform into each other. Experiments show that there are mass differences between them. Current particle-physics experiments can only measure the mass differences, not the masses themselves. Cosmology, however, is sensitive to the combined mass of the neutrinos, because that affects the formation of large-scale structure (the distribution of galaxies).

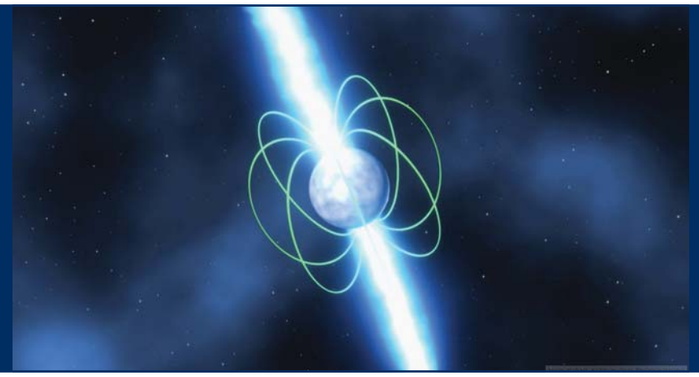
Observations of neutrinos from the Sun, the atmosphere, and nuclear reactors have put the lower limit for the combined mass at 0.05 eV, an amount equivalent to a tenth of a millionth of the (already tiny) mass of the electron.

The strongest upper limits come from cosmology. Until recently, the best figure was 0.23 eV. That was obtained from the measurements of the cosmic microwave background by the Planck spacecraft, coupled with information about the patterns in which galaxies are clustered from four galaxy redshift surveys. Two of those surveys were done in Australia: the 6dF Galaxy Survey of more than 125,000 galaxies, made with the 1.2-m UK Schmidt Telescope, and the WiggleZ survey of almost 240,000 galaxies, carried out with the 4-m Anglo-Australian Telescope.

Now CAASTRO affiliate Signe Riemer-Sørensen (University of Oslo), CAASTRO Associate Investigator David Parkinson (University of Queensland), and the leader of CAASTRO's Dark theme, Tamara Davis (University of Queensland), have painted neutrinos even further into a corner. By adding extra data from the WiggleZ survey to the dataset used by the Planck team, they have pushed the upper mass limit down to 0.18 eV—an improvement of over 25%. This limit is an order of magnitude better than laboratory experiments will be able to obtain in the next decade.

The additional data was the 'matter power spectrum' from WiggleZ—a function that captures information about the distribution of matter on different scales. This function contains significant information on the neutrino mass. This is because when large-scale structures, clusters, sheets and filaments of galaxies, formed in the early Universe, neutrinos would have slowed down the formation of the smaller features of that structure, 'washing out' the smaller scales in the matter power spectrum that we observe today. They also affect the growth of structure by altering how the expansion rate of the universe changes with time. So from the details of the matter power spectrum we can infer an upper limit for the sum of neutrino masses.

Using the matter power spectrum is complex: Riemer-Sørensen and her colleagues used only the part of it that applies to matter forming structures on very large scales (much larger than clusters of galaxies, $k < 0.2\ h\ \mathrm{Mpc}^{-1}$). When matter begins to condense to form 'small' structures (such as a cluster of galaxies), the physics becomes complicated. We could obtain a tighter constraint on the neutrino mass, even from existing data, if there were better simulations of how this small-scale structure grows: this is something CAASTRO researchers are also working on. Looking forward, astronomers expect to obtain tighter limits on the neutrino mass from the Euclid spacecraft (scheduled to launch in 2020) and the Square Kilometre Array radio telescope (to be built in Australia and South Africa from 2018), both of which will detect tens of millions of galaxies.



An illustration of a pulsar showing its beam (blue) and magnetic field lines (green).
Credit: Swinburne Astronomy Productions

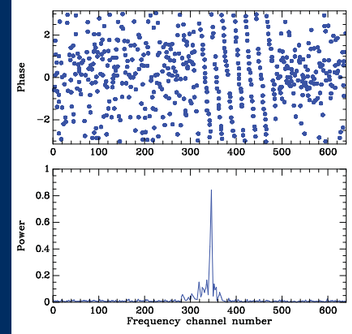


Figure 1: the signal from a quasar, lurking in the foothills of a spike generated by mobile-phone calls.
Credit: Chris Flynn

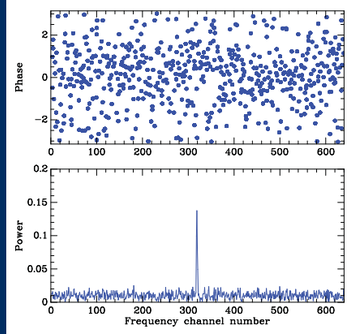


Figure 2: the same data, processed after the phone calls interference has been reduced. The quasar signal stands out more clearly.
Credit: Chris Flynn

National Innovation Priority Case Study: Smart Information Use

'EXTREME IMAGING' OF A PULSAR

Ue-Li Pen (University of Toronto)

Radio pulsars are a form of neutron star, a ball of condensed 'neutron matter' only a few tens of kilometres in diameter that is formed by the explosion of a 'regular' star. They possess a strong magnetic field and emit a beam of radio waves along the axis of that field. If the magnetic axis is not aligned with the pulsar's rotation axis, as the pulsar spins we may detect the beam of radio waves flashing periodically over the Earth. This is the pulsar's 'pulse'.

Forty-five years after pulsars were discovered, astronomers are still debating the exact mechanism by which a pulsar produces its radio beam. In part that is because, as pulsars are small and distant, we have not been able to measure the size of the emission region that generates the radio beam or its altitude above the pulsar surface. CAASTRO Partner Investigator Ue-Li Pen (University of Toronto) and Associate Investigator Jean-Pierre Macquart (Curtin University), along with their collaborators, have now invented a new technique for measuring the location of the pulsar emission with extraordinary accuracy. They have, for the first time, been able to directly and precisely detect the motion of the emission region as the pulsar rotates.

The basis of their technique is something that would often be considered a problem: the 'interstellar medium', the extremely thin gas that lies in space between the stars. The gas is ionised (the electrons and their parent atoms have been separated) and the radio signal from the pulsar interacts with this charged material. The gas is also irregular and turbulent, and causes the image of the pulsar's radio beam to scintillate (twinkle) and break up, just as the Earth's atmosphere does to the image of a star.

In 2010 Brisken *et al*. used the irregularities of the interstellar medium to learn about the medium itself, for instance, its velocity. For that work, they made observations of the pulsar B0834+06 with four large radio telescopes in the USA and Europe. Rather than making observations with each telescope separately, they used the telescopes as a single instrument, in a technique called Very Long Baseline Interferometry, which makes images of extremely high resolution.

For their new work, Pen and his collaborators used a subset of the data taken by Brisken *et al*. This time the focus of the investigation was not the interstellar medium but the pulsar itself. To study it, Pen *et al*. used the fact that radiation scattered by the interstellar medium enables us to see many thousands of images of the same pulsar, all at once. The radiation from each image interferes with that from every other image across the entire scattering region. The interstellar medium operates as a giant telescope, albeit one with imperfect optics, whose diameter is comparable to the maximum distance between images across the scattering region, which in this case was ten times the distance between the Earth and the Sun.

Even with such an enormous telescope, the emission region itself was too small to image. But what the researchers could determine was the exact position of the pulse during the pulsar's rotation: effectively, they measured the speed at which the emission region appeared to move as the pulsar turned.

The pulse deflection Pen *et al*. measured was less than 30 km, two orders of magnitude smaller than some previous estimates. The pulse appears to travel at about 1000 kilometres a second as the pulsar rotates. The results imply that the emission region is small, and only a few hundred kilometres above the pulsar surface—much less than some previous estimates. This work has increased a million-fold the precision with which pulsars can be imaged, from the 50 milliarcseconds attainable with Very Long Baseline Interferometry to the 50 picoarcseonds attained here. In fact, this is the highest-resolution measurement ever achieved, equivalent to being able to resolve a single viral particle from the Moon.

The new technique could be used to measure the parallax of pulsars in binary systems, giving us new, precise measurements of their distances. That in turn would increase the sensitivity and angular resolution of the pulsar-timing arrays that are now being used to hunt for gravitational waves, the last unconfirmed prediction of Einstein's general theory of relativity.

National Innovation Priority Case Study: Frontier Technologies

REMOVING RADIO-FREQUENCY INTERFERENCE IN REAL TIME

Chris Flynn (Swinburne University)

In 2007 astronomers noticed the Universe doing something completely new and unexpected: producing very short radio bursts, each lasting for a few milliseconds. These signals have no known counterparts at other wavelengths, and their characteristics suggest that they have travelled a long way through space: billions of light-years, in fact.

To date nine of these 'fast radio bursts' have been found, mostly in archival data. In 2014, CAASTRO PhD candidate Emily Petroff (Swinburne University) became the first person to detect a fast radio burst in 'real time'. (See page 32 for more details.)

Finding more fast radio bursts, and, ultimately, determining what they are, has been a key science driver behind the upgrade of the University of Sydney's Molonglo Observatory Synthesis Telescope (MOST), carried out with the help of Swinburne University and the Australian National University, in a project facilitated by CAASTRO.

The telescope has kept its basic structure, a 1600-m 'trough' of wire mesh that captures radio waves. However, it has a new 'backend': a cluster of signal-processing computers that incorporate off-the-shelf graphics processing cards (GPUs). These cards have become very cheap because of their wide use in the gaming industry. The backend can handle up to 22 gigabytes of data per second, and in the course of a year will process almost an exabyte (10^{18} bytes).

As well as entering the era of 'big data', the telescope has also had a change of name, going from MOST to (appropriately) UTMOST.

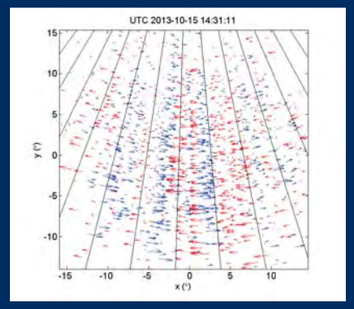
UTMOST is well suited to doing widefield, high-time-resolution searches for fast radio bursts. The FRB search program is set up to operate at the same time as every other program being run on the telescope so that, for instance, while the telescope is looking for fast radio bursts, the same set of data is being combed through for pulsars. Future radio telescopes will have to carry out such simultaneous searches: UTMOST demonstrates how that requirement can be met.

A fast radio burst could easily be confused with, or obscured by, an unwanted man-made radio signal, radio-frequency interference or RFI. Being only 50 km from Canberra, UTMOST receives RFI from several sources, including discharges from electric fences, vehicles, and electrical equipment operating on farms. One of the most prominent sources is mobile-phone calls, which are present about 5–10 per cent of the time and which can affect up to half of the region of spectrum over which the telescope observes (currently, 836–850 MHz).

Fortunately, mobile-phone signals have a characteristic appearance: they are bright, come from directions that clearly indicate their terrestrial origin, and fall into a well defined frequency range, so they are easily distinguished from the radio waves the telescope receives from the cosmos.

Because the telescope captures so much data, storing it all is impractical. The backend that processes it does so in real time, reducing its volume by a factor of a thousand, a million or even a billion, depending on the type of observation being made. So the RFI needs to be recognised and excised from the data in real time too.

This process works extremely well, as the Figures show. The RFI thus removed, UTMOST has a clearer view of the Universe, and will have a better chance of detecting fast radio bursts.



One of the MWA 'snapshots' from the dataset EoR 2013-10-15. The Earth's magnetic field lines are in black. Red and blue vectors show the position offsets of the radio sources, red to the east and blue to the west.

Credit: Cleo Loi (University of Sydney)

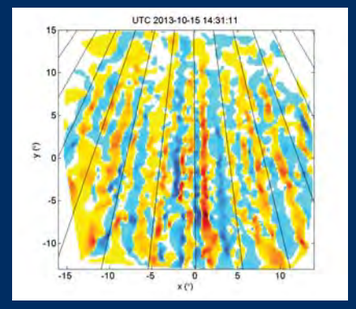


Figure 2: The pattern of over- and under-density in ionospheric plasma, derived from Figure 1. Over-densities are in red and yellow, under-densities in blue and cyan. The Earth's magnetic field lines are in black.

Credit: Cleo Loi (University of Sydney)

National Innovation Priority Case Study: Smart Information Use

PROBING THE IONOSPHERE WITH THE MURCHISON WIDEFIELD ARRAY

Cleo Loi (University of Sydney)

The MWA is not just a tool for investigating the cosmos: it is the first radio telescope able to image the Earth's ionosphere. MWA observations have revealed large-scale, periodic, banded plasma structures strongly elongated along the Earth's magnetic field that appear to be 'whistler ducts'— structures never imaged before.

Some of the gas molecules in the Earth's atmosphere are ionised, having had one or more of their electrons stripped away. Most commonly this is caused by the Sun's radiation. At an altitude of 100 km, less than one molecule in a million is ionised; at 1000 km, it's one in ten. The ionised component of the atmosphere is known as the ionosphere. At its outer edge (around 1000 km) it merges into the plasmasphere, a region of cold, dense plasma in the innermost part of the Earth's magnetosphere.

The ionosphere affects low-frequency radio-astronomy observations, those below 1 GHz. This was noticed at the very beginnings of the science: Hey *et al*. (1946) observed the radio source Cygnus A scintillating at 60 MHz. The ionosphere is opaque to radio waves of the lowest frequencies. At the Murchison Radio-astronomy Observatory (MRO) in Western Australia (lat -27°, lon 116°) the cut-off frequency is about 10 MHz for observations at the zenith.

The ionosphere also produces refraction (shifting the positions of celestial radio sources), dispersion (where signals of different frequencies experience different signal delays), and Faraday rotation (twisting a cosmic radio signal's plane of polsarisation). Other effects include signal scintillation (rapid changes in brightness); decoherence of a common signal over an extended baseline; and phase instability (where signal phases vary over an extended wavefront). Refraction, which alters the apparent position of radio sources, could potentially play havoc with automated cross-matching (with sources from other surveys), while scintillation could hinder classification of the light curves of transient sources.

Such problems made low-frequency radio astronomy seem extremely challenging for many decades. Indeed, the stability of the ionosphere was a consideration in choosing the site for the MRO, which is currently home to the Murchison Widefield Array, and the future site of the low-frequency component of the Square Kilometre Array. For her Honours thesis in 2014 CAASTRO student Cleo Loi (University of Sydney) investigated how ionospheric distortions would affect the science goals of the MWA surveys.

Reassuringly, Loi found that typical levels of plasma fluctuation in the ionosphere produce angular offsets smaller than the telescope's resolution, and so are not large enough to affect cross-matching. And the MWA's compact size (its maximum baselines are only three kilometres long) reduces the risk of decoherence, and so measured variations in flux density are dominated by the 'noise' in the image. But as well as drawing these conclusions, Loi made a major, serendipitous, finding.

Near local midnight on 15 October 2013, a series of 46 snapshots was taken as part of the MWA's Epoch of Reionization Transients Survey. The telescope tracked a patch of sky centred on $(\alpha, \delta) = (0°, -26.7°)$ near zenith, taking snapshots every 2 minutes. The data were obtained over a 30.72-MHz band centred at 183 MHz. The observations followed moderate geomagnetic storm activity that had occurred about 12 hours earlier.

A member of the MWA Collaboration who reduced the data noticed a high amplitude of oscillatory motion, shape distortions and scintillations of the point sources in the images. Some sources were observed occasionally to split into two, suggesting multipath propagation. In terms of the level of distortions observed, this dataset (hereafter referred to as EoR 2013-10-15) is one of the most extreme so far imaged with the MWA. Loi decided to investigate it.

EoR 2013-10-15 displays a striking pattern of fluctuations in the rdio-source positions that appear as a series of radial spokes fixed in the terrestrial sky. The pattern appears to be symmetric about the meridian, and the convergence point of the spokes lies on the meridian or close to it. The high spatial organisation of the pattern and its strong resemblance to source sidelobes, which often appear as radial spokes, raised concerns from MWA personnel that this was some form of artefact. However, careful investigation ruled that out.

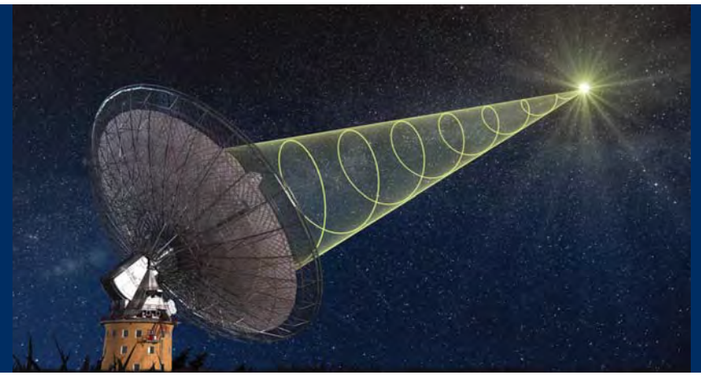
At the site of the MWA, the magnetic declination is close to 0°, while the magnetic inclination (the angle of the field lines to the horizontal) is around −60°. Figure 2 shows the divergence (magnitude) of the vector field of position offsets for EoR 2013-10-15, overplotted with the geomagnetic field lines. The alignment between the structures in EoR 2013-10-15 and the geomagnetic field is extremely good, and strongly suggests that we are looking at a plasma phenomenon, not an instrumental artefact. Loi and her colleagues measured some components drifting in an easterly direction and others to the west, at a low speed (around 10 m s^{-1}).

Many kinds of disturbance rumble through the ionosphere. Two of the best investigated are plasma bubbles and 'travelling ionospheric disturbances' or TIDs, of which there are three classes. Could one of these phenomena be behind EoR 2013-10-15? It seems very unlikely. The instability that leads to plasma bubbles is known to develop only in equatorial regions, not at mid latitudes. And TIDs ordinarily have speeds of more than 100 m s^{-1}, which is not compatible with the slow drift observed.

What, then, could the structures be? The best interpretation at present is that they are *whistler ducts*. A *whistler* is a very-low-frequency electromagnetic wave (1–30 kHz), generated by lightning, that travels through the Earth's magnetosphere. Its path can be 'ducted' or 'un-ducted', the ducts being field-aligned density irregularities. Evidence for these structures—that is, variations in plasma density—have been observed by satellites; the structures were also detected with the Very Large Array radio telescope in the 1990s. But this is the first time they have been imaged.

Using the MWA in a novel and unconventional way, Loi and her colleagues measured the altitude of these density ducts. Essentially using the array as a stereo camera, they divided it east-west and used the two groups of antenna 'tiles' to make separate images of the density ducts. This enabled them to measure a parallax shift that implied an average altitude for the ducts of 570 ± 40 km over the period of observation (1.5 hours). Computing the parallax separately over the first and second halves of the interval showed that the structures had drifted downward over time, from 720 ± 90 km to 470 ± 40 km. Splitting the data into northern and southern halves of the field of view revealed higher altitudes to the north, which is consistent with the steep magnetic inclination at the MWA site. From the altitude of the ducts, Loi and her colleagues calculated their physical spacing to be 10–50 km.

These are the first direct wide-angle observations of these structures. This groundbreaking work shows that the MWA is an outstanding instrument for probing the ionosphere.



An illustration of CSIRO's Parkes telescope detecting the new 'fast radio burst'.
Credit: Swinburne Astronomy Productions

The upgraded Molonglo Observatory Synthesis Telescope, ready to hunt for fast radio bursts.
Credit: Chris Flynn

National Innovation Priority Case Study: International Collaborations

FIRST REAL-TIME DETECTION OF A 'FAST RADIO BURST'

Emily Petroff (Swinburne University)

They last just a few milliseconds, but in that brief time they give out the energy the Sun does in a year. 'They' are 'fast radio bursts' or FRBs, first detected in 2007 in archival data from CSIRO's Parkes radio telescope in New South Wales. As of the end of 2014, nine FRBs had been reported in the scientific literature: eight were found with Parkes, and the ninth with the Arecibo radio telescope in Puerto Rico.

FRBs manifest as a single spike of radio waves. Like signals from the radio-emitting stars called pulsars, the FRB signal is dispersed in frequency as it interacts with electrons in the space through which it travels. The radio waves at lower frequencies are slowed down more than the ones at higher frequencies, so they reach us later: the further the radio waves travel, the greater this time delay becomes. Expressed as a 'dispersion measure', the delay is used to calculate the distance of the source. All nine published FRBs appear to come from far beyond our Galaxy, perhaps as much as seven billion light-years away.

The recorded FRB signals are generally of the order of a jansky, which is fairly strong for a cosmic radio signal. Given their distances, this means that FRBs have huge energies: Dolag et al. (2014) put their minimum energy at 10^41 erg (10^{34} J), equivalent to the Sun's output over a year. And although we have only a small sample of FRBs to work with, the implied rate at which they 'go off' all over the sky is enormous: about 10,000 a day, or once every ten seconds.

Despite these intriguing characteristics, we still don't know what phenomenon produces FRBs. Astronomers are approaching the problem in two ways. The first is to detect as many FRBs as possible and then compare their population characteristics with those of simulated populations of different FRB candidates. The second is to try to detect individual FRBs in real time and obtain rapid follow-up observations at other wavelengths, as is done with another high-energy phenomenon, gamma-ray bursts.

On 14 May this year, a team led by Emily Petroff, a CAASTRO PhD candidate at Swinburne University, made the first real-time detection of an FRB. The finding was made with the Parkes radio telescope while Petroff and her colleagues were re-observing a field containing a known FRB, as part of an observing campaign to see if bursts repeat: however, the burst of 14 May (FRB 140514) has a dispersion measure significantly different from that of the earlier burst (FRB 110220), so the researchers were sure they were looking at a new object. The new burst's dispersion measure suggested that its source was up to 5.5 billion light-years away.

Petroff and her colleagues were using observing instrumentation developed for the High Time Resolution Universe survey, which had been operating successfully at Parkes since 2008. This allows pulsars, and now FRBs, to be detected in real time. The data-processing pipeline identified the incoming signal as an FRB within 10 seconds of its arrival, and immediately sent an alert email to observers associated with the project.

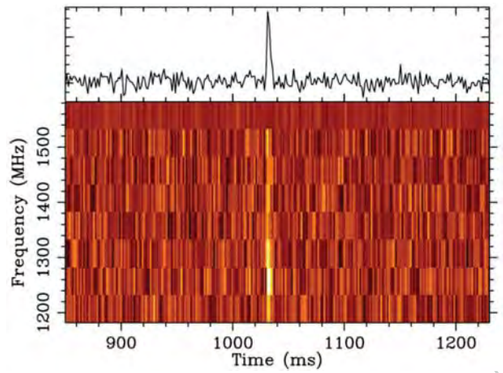
Over the next few hours, telescopes around the world swung into action. Follow-up radio observations were made with four telescopes (Parkes itself; CSIRO's Australia Telescope Compact Array; the Giant Meterwave Radio Telescope in India; and the Effelsberg Radio Telescope in Germany) and optical observations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

This intense scrutiny revealed no optical, infrared, ultraviolet or X-ray counterparts to the radio burst. That in itself rules out some possible FRB mechanisms: long gamma-ray bursts and nearby ($z < 0.3$) supernovae.

However, short gamma-ray bursts could still be contenders, as could giant flares from magnetars (neutron stars with extremely strong magnetic fields) or 'blitzars', neutron stars collapsing to form black holes.

Importantly, this Parkes observation was the first to measure an FRB's polarisation, a parameter not recorded in the archived data in which all previous FRBs had been found. The radio emission from the new burst was more than 20% circularly polarised; no linear polarisation was detected. Petroff and her colleagues think that this polarisation is likely to be intrinsic to the source, rather than being created by an external mechanism such as scintillation. Its presence does not tip the scales in favour of any of the possible FRB progenitors, but it does suggest that there were magnetic fields near the burst's source.

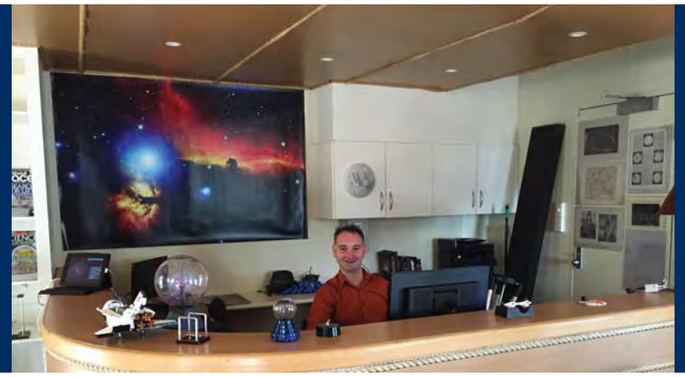
The way forward for FRB studies is to find more FRBs. CAASTRO has two projects to do so: SUPERB, the SUrvey for Pulsars and Extragalactic Radio Bursts (described on page 14), which began on the Parkes telescope in 2014, and a similar survey that will run on the upgraded Molonglo Observatory Synthesis Telescope (described on page 29). On the theory side, any hypotheses about the origin of FRBs must now take into account the polarisation data from Petroff *et al.*'s study, and the limits the follow-up observations have placed on the FRB's multi-wavelength 'afterglow'.



The pulse profile and dynamic spectrum of FRB 140514, the first 'fast radio burst' observed in real time.
Credit: Emily Petroff (Swinburne University) et al.

INNOVATE

MWA upgrade session at the 2014 MWA conference in Tempe.
Credit: Emil Lenc



CAASTRO Affiliate Mike Dalley (Voyages) works closely with the Astronomers in Residence
Credit: Kate Gunn

National Innovation Priority Case Study: Developing a Strong Base of Skilled Researchers

MWA BUSY WEEKS FOR KNOWLEDGE TRANSFER

Randall Wayth (Curtin University)

The Murchison Widefield Array (MWA) has been developed by an international collaboration of 15 institutions (many of them CAASTRO nodes and partners) in Australia, India, New Zealand, and the United States. One hundred and eighty researchers take part. Just bringing the telescope into operation in 2012–2013 involved two dozen researchers, in three countries. How could the efforts of this large, distributed team best be harnessed? One answer was Busy Weeks: week-long meetings dedicated to making rapid progress on problems.

A Busy Week brings as many MWA researchers as possible together in a single room. Those who can't be there join the meeting via CAASTRO's videoconferencing system. Participants dedicate themselves to the task in hand: there are no distractions. MWA Busy Weeks originally focused on problems associated with commissioning the telescope, but they now deal mostly with the major MWA projects, such as the Epoch of Reionisation experiment (page 10), the GLEAM survey (page 11), and the MWA Transients Survey.

The specific topics for a Busy Week are pre-determined through a teleconference. Meetings are held every few months: there were seven in 2014. They move around the country, so as to spread the burden of travel across institutions. International participants join in at least every six months, at Busy Weeks that are scheduled to dovetail with MWA project meetings.

Busy Weeks provide rapid communication and immediate feedback, speeding up the process of solving problems. They particularly help to bring new team members 'up to speed' about the status of projects; they are also the quickest way for participants to identify who in the large MWA team holds the knowledge and experience needed to solve a problem. In addition, they foster broader discussion and let participants make serendipitous connections, links that would probably not have been made any other way.

The value of the Busy Weeks is shown by an example. At one of these meetings participants were discussing a long-standing, vexatious issue: how the ionosphere affects the MWA's observations, and how best to correct for this. Plots of the effects were shown, and an idea proposed for dealing with them. Within 24 hours the team had made simulations showing how well this solution would work. The proposed solution was adopted and has been used across the board by the MWA team ever since. The case is closed, thanks to a Busy Week.

MWA Busy Week.
Credit: Emil Lenc

National Innovation Priority Case Study: Collaboration with Business

ASTRONOMER IN RESIDENCE, ULURU

Kate Gunn (University of Sydney)

One of CAASTRO's key industry collaborations is with Voyages Indigenous Tourism Australia, which operates the Ayers Rock Resort at Uluru. The Indigenous Land Corporation (ILC) owns Voyages, and handles tourism and resorts on its behalf. Voyages has a strong commitment to social responsibility, and all profits from its business activities go towards supporting the ILC's Indigenous programs across Australia.

From March to November 2014 a CAASTRO Astronomer in Residence was based at Uluru on a fortnightly roster. Astronomers at all levels, from most of our nodes and partner organisations, participated.

Each fortnight, a new astronomer resided at Uluru sharing their knowledge and enthusiasm for astrophysics with the locals and tourists, and on the @CAASTROatUluru Twitter account. The astronomer works closely with Mike Dalley, Voyages' 'Head SkyTalker', who manages the astronomy components of the tourism offerings at the resort. Mike is a CAASTRO Affiliate member. Two of the tours offered by Voyages are about experiencing the night sky: one is for families and the other is aimed at people who are looking for more of that 'wow' factor.

The flagship event at Uluru is the Sounds of Silence dinner, where the audience sips sparkling wine while watching the sunset over Uluru to the sound of a didgeridoo, and then sits down to a buffet dinner. The after-dinner entertainment is a tour of the sky, guided by laser pointer. There is also the Tali Wiru fine dining experience that involves a sky tour with a more Indigenous focus. The astronomer's role at these events is to field questions of a deeper scientific nature, as well as to help the team with tasks such as setting up and packing down the telescopes.

Each afternoon the astronomers and Sky Talkers man a stall in the resort's town square, where they talk to both guests and locals about the tours and about astronomy in general. Every day they train a small solar telescope with an H-alpha filter on the Sun, and point another 9-inch telescope towards Venus (when it can be found). On average the team speaks to 70–100 people per session.

The Uluru Astronomer in Residence program is a unique experience for all involved. The astronomers spend two weeks in an amazing part of Australia under the darkest skies most have ever seen, talking to a large number of people who have a real curiosity and interest in our research.

The astronomers who participated in 2014 were: Dr Tara Murphy, University of Sydney; Professor Ray Norris, CSIRO; Dr Sean Farrell, University of Sydney; Dr David Lagattuta, Swinburne University; Mr Joe Callingham, University of Sydney; Dr Ned Taylor, University of Melbourne; Mr Syed Ashraf Uddin, Swinburne University; Dr Iraklis Konstantopoulos, Australian Astronomical Observatory; Dr Richard Scalzo, Australian National University; Dr Anna Kapinska, University of Western Australia; Ms Emily Petroff, Swinburne University; Dr Jamie Farnes, University of Sydney; Dr Martin Bell, CSIRO; and Ms Jessica Bloom, University of Sydney.

In August 2014 CAASTRO and Voyages also hosted the inaugural 'Uluru Astronomy Weekend', as part of National Science Week.

ACTIVITY PLAN FOR 2015

CAASTRO expects to have another enriching and rewarding 12 months with many stimulating activities and research discoveries.

Hands-on Astronomy, Uluru Outreach.
Credit: Voyages.

CAASTRO RESEARCH PROGRAM

Evolving Theme

2015 promises to be another very exciting year for science in the Evolving Theme, as we build on work done in 2014.

The SAMI Galaxy Survey is now in full operation. More than 70 nights of observations have resulted in spatially resolved spectra of over 1000 galaxies. Following the project's 'early data release' in 2014, the astronomical community is now analysing the richness of the SAMI data.

During 2014 over 350 hours of observing were completed for the MWA Epoch of Reionisation (EoR) survey, generating some 467 TB of data. The MWA EoR collaboration has developed three independent and parallel data-reduction pipelines, two for the targeted EoR fields and one for the driftscan observations. CAASTRO researchers are leading the development of a pipeline for the MWA Realtime System. This pipeline, now operational, will be applied to the MWA EoR survey data during 2015, with the goal of measuring the power spectrum of redshifted 21-cm intensity fluctuations.

2015 will see the first results from CAASTRO's new intensity-mapping project, which is designed to study the HI content of the Universe at a wide range of cosmic times. Intensity mapping involves averaging together the neutral hydrogen (HI) emission from large numbers of galaxies observed in a wide-area survey. The radio-survey data are then combined with additional information from optical redshift surveys and from galaxy simulations. The cross-correlation of redshifted 21-cm intensity with galaxies identified optically will allow us to measure HI at high redshift and study its distribution in galaxies. The first phase of the project will include observations and modelling of these datasets. There is currently a gap in our knowledge of how gas evolves in galaxies in the crucial redshift range of 0.1 to 1; intensity mapping will enable CAASTRO researchers to bridge this gap. The project will have implications for the science goals and design of the Square Kilometre Array radio telescope.

Dynamic Theme

In 2015 researchers in the Dynamic Theme are looking to regularly detect 'fast radio bursts' with a combination of telescopes, including the Parkes 64-m telescope, the new UTMOST facility (the upgraded Molonglo Observatory Synthesis Telescope), the Murchison Widefield Array, and the Giant Metrewave Radio Telescope in India.

This expectation is grounded in a key result of 2014: the first detection of a fast radio burst in real time, with the Parkes radio telescope. The real-time nature of the detection allowed 12 telescopes, including NASA's Swift X-ray space telescope, to make follow-up observations. This work was published in Petroff *et al*. (2015). In some ways it was a 'dress rehearsal' for what is to come in 2015 as new facilities to detect FRBs more regularly come online.

The pipelines of the Murchison Widefield Array are now creating very widefield maps for projects such as the Epoch of Reionisation survey. These observations can also be searched for low-frequency radio transients. The challenge for these transient searches is not so much finding things that vary as determining which signals are worth further attention: 'sorting the wheat from the chaff'. With petabytes of data to be sifted through, this is really a search for 'needles' in a cosmic 'haystack'.

Starting in early 2015, the SkyMapper Supernova Survey will run in parallel with the SkyMapper Main Survey. The rolling search is expected to find 100 SNe Ia per year by monitoring about 1000 square degrees every three to four days. The survey kicks off in March, with a live presence on the BBC Stargazing Live series, when millions of viewers of the program will be asked to identify transient objects from streams of survey data. Target-of-opportunity observations for fast radio bursts and gamma-ray bursts will continue to override other SkyMapper observations. In addition, SkyMapper will spend some time shadowing the Parkes telescope with the hope of catching fast radio bursts in real time.

Dark Theme

During 2015 the Dark Theme will be advancing some of its newer projects as datasets build up and we welcome new postdoctoral fellows.

The peculiar-velocity surveys should result in a series of papers this year, and the 2MASS Tully-Fisher (2MTF) cosmographic survey of the local Universe will be completed (including estimations of cosmological parameters from that data). The 6-degree Field Galaxy Survey (6dFGS) peculiar-velocity results for measuring bulk flows should be finalised, and we will start modelling the local dark-matter distribution using both 2MTF and 6dFGS data. We also expect that the 2MTF dataset will be enhanced by newly released observations from the Arecibo Legacy Fast ALFA Survey (ALFALFA).

Supernovae will continue to be an important topic of study. SkyMapper will undertake regular observations for the purposes of cosmology: these will be followed up with spectroscopy with the WiFES instrument. CAASTRO members will also carry out an important program of precision calibration of SkyMapper, cross-calibrating the telescope's observations with results from the Dark Energy Survey and recalibrating SkyMapper's SkyDICE instrument, which was damaged in the 2013 bushfire at Siding Spring Observatory.

One of the new postdocs in the Dark Theme has started measuring the lensing magnification of supernovae in OzDES. This will allow us to remove the effect of lensing from the data, thus 'sharpening' the resulting Hubble diagram, and use the correlation between supernova magnitude and density to test cosmology. A second supernova postdoc will begin at the Australian National University this year to work on SkyMapper and OzDES science. OzDES is proceeding apace, with many supernovae now confirmed and the first-year paper almost complete.

Within the large-scale-structure project we now have access to a number of new datasets. In 2015 we will add value to existing survey results from projects such as WiggleZ and the 6dFGS peculiar-velocity survey by combining datasets in innovative ways. One project is a joint cosmological measurement using both peculiar velocities and the density field of the 6dFGS. Another is using the overlap region of the two largest galaxy redshift surveys, WiggleZ and the Baryon Oscillation Spectroscopic Survey, to test for new physics (and systematic errors) by measuring the baryon acoustic peak and redshift-space distortions through cross-correlation between the two surveys. Meanwhile, we are continuing to analyse the previous datasets. This analysis includes improving the 'reconstruction' technique that we used in 2014 to 'sharpen' the baryon acoustic oscillation 'standard ruler'.

Extending the search for evidence for beyond-standard gravitational physics, we are using a combination of cosmological observations to examine scale-dependent and redshift-dependent variations of general relativity. We are also working to predict the formation of large-scale structure in Galileon models of gravity and test the predictions against the latest cosmological datasets.

Finally, there are a few papers in train that look at other types of new physics, such as new types of particles and unexpected initial conditions. This year we intend to publish our constraint on the neutrino mass derived from Planck data and large-scale-structure data. We will also release a study of how well our radio telescopes will be able to measure primordial non-Gaussianity using the integrated Sachs-Wolfe effect.

Education and Outreach

The breadth and depth of CAASTRO's Education and Outreach program received very positive feedback at the Mid-Term Review in late 2014. The coming year will see more of our successful projects, but also a number of major unique offerings. The continuing CAASTRO classics are our High School support through 'CAASTRO in the Classroom' and 'Telescopes in Schools', our public outreach efforts at Perth Astrofest and Mount Burnett Observatory, and our partnership with Voyages Indigenous Tourism Australia for the 'Astronomer in Residence' and 'Astronomy Weekend' activities.

In 2015, our collaboration with Museum Victoria for the production of a Planetarium show will intensify as visuals are being created to tell the story of the new golden age of astronomy. This show is an exciting project for CAASTRO Education and Outreach to complete in the second half of our funding period, with the prospect of national and international distribution. We will also be deploying more 'antenna tile' displays of the Murchison Widefield Array (MWA) at various Australian locations, along with new signage. Further plans for activities in 2015 include an even stronger engagement in schools through fine-tuning and distributing the MWA classroom tool and through curriculum-specific research stories and career advice.

The Australia Telescope Compact Array.
Credit: Emil Lenc

Commercialisation and Knowledge Transfer

Given CAASTRO's primary focus on pure research, in 2015 we will approach commercialisation and knowledge transfer in innovative ways.

In 2015 CAASTRO will develop an e-book to educate and assist researchers in identifying and protecting intellectual property, engaging with industry, and transferring knowledge. CAASTRO's key strength is in knowledge distribution through formal and informal networks, which is an essential part of Australia's economic performance. Innovation is driven by the interaction of producers and users in the exchange of both codified and tacit knowledge. The flow of information between industry, government and academia in the development of science and technology is an important economic determinant and in 2015 CAASTRO will continue to provide leadership in this area.

Joint China-Australia Astronomy Research Centre

In February 2013, the Chinese Academy of Sciences (CAS) and the Australian Department of Industry, Innovation, Science, Research and Tertiary Education (Industry) signed a Memorandum of Understanding (MoU) to collaborate on areas of common interest within astronomy, astrophysics and cosmology. The MoU required the establishment of a joint CAS/Industry working group, to monitor and encourage proposed areas of collaboration.

The first meeting of the joint CAS/Industry working group took place in Nanjing, China, on 11th November 2013. At this meeting, it was resolved to establish a joint China-Australia research centre in astronomy. This was envisaged as a 'virtual' centre, to serve as an umbrella and coordination point for bilateral astronomical collaborations. The proposed title for the centre is the Australia-ChinA ConsortiuM for Astrophysical Research (ACAMAR). Acamar (θ) Eridani, (天園六) is a bright naked-eye star visible from both Australia and China.

It is currently proposed that CAASTRO will host the ACAMAR secretariat at The University of Sydney, and that the first joint Director will be Professor Brian Schmidt. There will be a Chinese Director as well.

The specific opportunities that the Centre seeks to implement or facilitate are:

- Exchange of astronomical research staff and students between research organisations and projects in order to best engage available skills or to facilitate the development of human capital;
- The cooperative operation of telescopes whose observations may complement one another including telescopes based in Antarctica, Australia, China and other international telescopes to which Australia and China may have access;
- Joint operation of radio telescopes that may be linked as interferometers;
- The coordination and sharing of observations and related data products that will contribute to large-scale sky surveys in the optical, infrared and radio wavebands;
- The coordination of future instrumentation and telescope development programs to ensure the most efficient use of available infrastructure investment; and
- Coordination of efforts in designing and engineering the Square Kilometre Array (SKA), including pathfinders, in conjunction with and through the SKA Organisation and associated processes.

We are looking forward to seeing these plans come to life in 2015.

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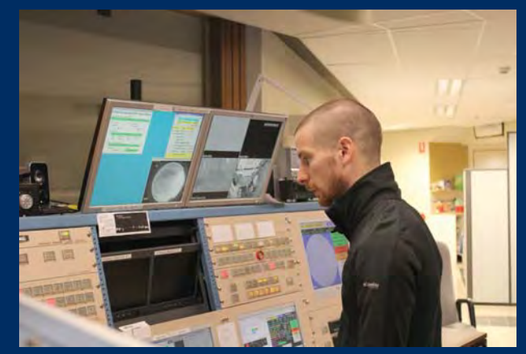


CAASTRO PhD student Samuel Richards at the control desk of the Anglo-Australian Telescope during a SAMI run.
Credit: Helen Sim

STUDENT LIFE

Steven Murray

UNIVERSITY OF WESTERN AUSTRALIA

I am a PhD student in my third year at ICRAR at the University of Western Australia (UWA), under the supervision of Chris Power and Aaron Robotham. I have been involved in CAASTRO for the duration of my PhD, working under the Dark theme.

I did my time in undergraduate studies at the University of Queensland, before moving to the UWA to complete my Honours year, studying large-scale structure in the SDSS and GAMA surveys. Having been connected to world-class researchers at ICRAR in this time, I decided to stay for my postgraduate research.

My work is all about making predictions and developing tests for the nature of dark matter. I use a combination of theory and statistics to create models for the observed large-scale structure of the Universe, given different candidates for the dark matter particle. In this way, we can hope to begin to observe the different effects in large galaxy surveys, and pin down what dark matter really is.

Along with learning and applying the theory, my PhD has taught me valuable lessons like how to code up functional web applications. My first such application is now public and is being used by researchers across the globe to calculate theoretical halo mass functions for their work. I hope to release a second, more involved, web application in the near future.

Being a part of CAASTRO has significantly enhanced my study, both in the special training events that are available, but especially by exposing me to the broader context of the leading-edge of astronomy, and my role in it. I am currently Chair of the CAASTRO Student Committee.

Anthea King

UNIVERSITY OF QUEENSLAND

I am a joint PhD student between the University of Queensland (UQ) and the Dark Cosmology Centre of the University of Copenhagen (UC) under the supervision of Tamara Davis (UQ), Darach Watson (UC) and Marianne Vestergaard (UC). I completed my undergraduate degree in Physics at the University of Queensland, where I developed my interest in astronomy. Due to Tamara's close involvement with the Dark Cosmology Centre in Copenhagen, the opportunity arose for me to do a joint PhD between the two Universities and I jumped at the chance. As a consequence, my time has been shared between Brisbane and Copenhagen over the last three years. I joined CAASTRO at the start of the year and have been involved with the OzDES survey.

My PhD broadly concentrates on investigating whether active galactic nuclei (AGN) are useful and viable standard-candle candidates. My initial work in this topic, investigated whether high-redshift standard candles are useful probes of dark energy. At present, I am involved in the OzDES reverberation mapping project, which is working in conjunction with the Dark Energy Survey (DES) to monitor 500 AGN. This project will not only provide black-hole mass measurements in a broad AGN population over a large redshift range, giving important insight into black-hole-galaxy co-evolution, but could potentially provide standard candle measurements out to a redshift of four. I have been working on predicting the efficiency of the OzDES reverberation mapping campaign, how to optimally select the sample and the most efficient ways to improve the survey.

Joe Callingham

UNIVERSITY OF SYDNEY

I am a second year PhD student at the University of Sydney, jointly supervised with CSIRO Astronomy and Space Science. The main focus of my PhD is contributing to the development of the Murchison Widefield Array (MWA) all-sky radio catalogue and studying the environments of young radio galaxies at low radio frequencies. The MWA is a new radio telescope that has four main science areas: study of extragalactic and Galactic sources through an all-sky survey, a transient survey, heliographic and ionospheric studies, and the search for the 21-cm signal of the Epoch of Reionisation. I am jointly supervised by Bryan Gaensler, Ron Ekers, Randall Wayth and Elaine Sadler.

I completed my undergraduate degree at The University of Sydney in 2012. I elected to remain at The University of Sydney after being offered the fantastic opportunity of being part of a team establishing a new radio telescope. My PhD work is evenly split between instrumentation and science. I have largely focussed on constraining the primary beam of the MWA, setting the low-radio-frequency flux scale for the southern hemisphere, and spectral modelling of young radio galaxies. We are entering a new era of radio astronomy with the MWA, and the wideband receivers on the back of such as the Australia Telescope Compact Array, coming online. We are moving from an era where we only had a handful of flux measurements at different frequencies to model the spectra of sources to having thousands of independent measurements. Therefore, we will soon be able to conduct one of the most comprehensive studies of the physics of radio sources.

CAASTRO has played an integral role in facilitating my PhD. Without the video-conferencing system, the fortnightly meetings that occur between the different MWA teams would be not be as successful as they are now. The video-conferencing system allows me to stay up to date with any developments with the MWA even though the operations team is based out of Curtin University. As part of the Evolving theme, I have been able to travel to conferences and busy weeks. I am very grateful to be part of CAASTRO as it has provided me access to resources and exposure to different ideas that wouldn't have been possible without being a part of it.

Bonnie Zhang

AUSTRALIAN NATIONAL UNIVERSITY

I am a first year PhD student at the Australian National University (ANU), supervised primarily by Brian Schmidt. I also work under the supervision of Chris Lidman (AAO), Tamara Davis (University of Queensland) and Richard Scalzo, Fang Yuan and Michael Childress in the ANU supernova group. My work is in supernova cosmology, in particular as part of OzDES (the Australian team collaborating with the Dark Energy Survey), and the SkyMapper Supernovae Survey.

In 2012 I completed my undergraduate degree, a Bachelor of Philosophy (Science) with Honours in pure mathematics. The PhB is a research-intensive science degree that enabled me to explore several areas of research including astrophysics, physics and mathematics. After spending 2013 travelling, I began my PhD and joined CAASTRO in early 2014.

The broad aim of my PhD research is to improve constraints on dark energy through observations of Type Ia supernovae. Over the next few years, SkyMapper is expected to measure hundreds of supernovae, forming the largest uniform sample to date at low redshift, while the Dark Energy Survey will discover an order of magnitude more at high redshift. As our sample size increases and statistical errors decrease, a major challenge is to reduce systematic errors. A dominant systematic is photometric calibration; this is an area I will focus on, particularly in relation to SkyMapper and the Dark Energy Survey.

Over the past year I have already had the opportunity to travel to conferences, workshops and telescopes, with the support of CAASTRO. I look forward to my involvement with CAASTRO over the next year, which will include spending time as an Uluru Astronomer in Residence and on the newly formed CAASTRO Student Committee.

CAASTRO STUDENTS

In 2014 the CAASTRO Executive decided, in agreement with CAASTRO students, to create the CAASTRO Student Committee. This committee was established with the purpose of increasing interaction between students and the Executive, and thereby improving the overall outcomes for CAASTRO students.

The Committee consists of a member from each Node, and represents the full diversity of CAASTRO membership. This means that every student has a local representative to whom they can relate their concerns or ideas, and that the full range of values and perspectives is represented.

The first meeting of the Committee was held in October, under the Chair of COO Kate Gunn, and established the Terms of Reference and elected the first student Chair. We have established two broad objectives, namely the promotion of student involvement, and the representation of student concerns to the CAASTRO Executive.

In its first few months, the Committee has agreed on several initiatives. These include holding annual sessions with third-year and new postgraduate students to advertise the work of CAASTRO and inform students about the role they can play; the development of a student 'cheat sheet' to bring students up to speed on their role and the benefits of being in CAASTRO (housed on a dedicated web page); and monthly local-area gatherings for all CAASTRO students for the purpose of networking and brainstorming ideas. We look forward to a productive first year for the Committee, with clear benefits for the students of CAASTRO.

Steven Murray, University of Western Australia
Chair, CAASTRO Student Committee

2014 NEW CAASTRO STUDENTS

University of Sydney

Loi, Ms Cleo, *Dynamic, Student (Honours)*
SUPERVISORS Tara Murphy (USyd)
THESIS TITLE Waves in the sky: Probing the ionosphere with the Murchison Widefield Array

McElroy, Ms Rebecca, *Evolving, Student (PhD)*
SUPERVISORS Scott Croom (USyd) Michael Pracy (USyd)
THESIS TITLE The host galaxies of luminous type II AGN

University of Melbourne

Ozbilgen, Ms Sinem, *Dark, Student (PhD)*
SUPERVISORS Rachel Webster (MEL) Jeremy Mould (SWIN)
THESIS TITLE Is there a third parameter in the Tully-Fisher Relation?

Australian National University

Sathyanarayana Rao, Ms Mayuri, *Evolving, Student (PhD)*
SUPERVISORS Frank Briggs (ANU) Ravi Subrahmanyan (RRI) Charley Lineweaver (ANU) Brian Schmidt (ANU)
THESIS TITLE On the detection of spectral ripples from the epoch of recombination

Zhang, Ms Bonnie, *Dark, Dynamic, Student (PhD)*
SUPERVISORS Brian Schmidt (ANU) Chris Lidman, Tamara Davis, Richard Scalzo, Fang Yuan and Michael Childress,
THESIS TITLE Joint photometric calibration and cosmology analysis of Type Ia supernovae in the SkyMapper and Dark Energy Survey samples

ICRAR | Curtin University

Rogers, Ms Seonaid, *Outreach, Student (undergrad)*
SUPERVISORS Wiebke Ebeling (CUR) Steven Tingay (CUR)
THESIS TITLE Visualisations of astronomical all-sky data sets for researchers and public audiences

Swinburne University of Technology

Bhandari, Ms Shivani, *Dynamic, Student (PhD)*
SUPERVISORS Matthew Bailes, Willem van Straten, Evan Keane (SWIN)
THESIS TITLE The radio Universe at 1000 frames/sec

2014 CAASTRO Students

Codoreanu, Mr Alexandru, Evolving, *Student (PhD)*
SUPERVISORS Emma Ryan-Webber (SWIN) Michael Murphy (SWIN) and Neil Chrighton(SWIN)
THESIS TITLE Chemical fingerprints in the highest-redshift quasar absorption systems: Probing the epoch of hydrogen reionisation

Garcia, Miss Angela, *Evolving, Student (PhD)*
SUPERVISORS Emma Ryan-Webber (SWIN) Edoardo Tescari (MEL) Stuart Wyithe (MEL)
THESIS TITLE Diagnosing Hydrogen Reionization with metal absorption line ratios.

Morello, Mr Vincent, *Dynamic, pre-PhD Student,*
SUPERVISORS Willem van Straten, Matthew Bailes (SWIN)
THESIS TITLE Mining the Radio Sky for Pulsars and Transients

Venkatraman, Mr Vivek, *Dynamic, pre-PhD Student,*
SUPERVISORS Matthew Bailes, Willem van Straten, Evan Keane (SWIN)
THESIS TITLE Next generation Instrumentation for studies of Pulsars and Fast Transients with the SKA

Poruri, San-Rahul, *Evolving, Pre-PhD Summer Student,*
SUPERVISORS Jeremy Mould (SWIN)
THESIS TITLE SAMI

Tabbara, Ms Dana , *Dynamic, Student (undergrad)*
SUPERVISORS Matthew Bailes (SWIN)
THESIS TITLE FRB calculations

University of Queensland

Hinton, Mr Samuel, *Dark, Pre-PhD Summer Student,*
SUPERVISORS Tamara Davis (UQ)
THESIS TITLE Measuring 2D BAO with WiggleZ

King , Ms Anthea, *Dark, Student (PhD)*
SUPERVISORS Tamara Davis (UQ) Darach Watson (UCPH) Marianne Vestergaard (UCPH)
THESIS TITLE Active Galactic Nuclei as high-redshift standard candles

O'Neill, Mr Conor, *Dark, Student (Honours)*
SUPERVISORS Tamara Davis (UQ) Chris Lidman (AAO)
THESIS TITLE Cosmological Investigations: Optimising novel observation techniques in OzDES and examining the precision of cosmological probes

Thomas, Mr Adam, *Evolving, Student (Hons)*
SUPERVISORS Michael Drinkwater (UQ)
THESIS TITLE Searching for ram-pressure stripping in galaxy clusters with the SAMI Galaxy Survey

Thomson, Ms Sarah, *Dark, Student (Honours)*
SUPERVISORS David Parkinson (UQ) Ray Norris (CSIRO)
THESIS TITLE Probing the Early Universe with Large Area Radio Surveys

ICRAR | University of Western Australia

Valcin, Mr David, Evolving, *Dark, Student (pre-PhD)*
SUPERVISORS Chris Power (UWA)
THESIS TITLE Supercomputer simulations of galaxy formation to make predictions for the SAMI (Sydney AAO Multi-object IFU) Galaxy Survey

CONTINUING CAASTRO STUDENTS

University of Sydney

Eromanga Adermann, *Evolving, Honours*
SUPERVISORS Sean Farrell, Anne Green
THESIS TITLE A Population Study of Ultra-Luminous X-Ray Sources

Jessica Bloom, *Evolving/Dark, PhD*
SUPERVISORS Joss Bland-Hawthorn, Scott Croom, Lisa Fogarty
THESIS TITLE Dynamical Interactions in Nearby Galaxies

Joseph Callingham, *Evolving, PhD*
SUPERVISORS Bryan Gaensler, Sean Farrell, Randall Wayth, Ron Ekers
THESIS TITLE An MWA Source Catalogue: Compact Steep Spectrum and Gigahertz Peaked Spectrum Sources at Low Radio Frequencies

2014 CAASTRO Post Doctoral Researchers

Marcin Glowacki, *Evolving, PhD*
SUPERVISORS Elaine Sadler (USyd) James Allison (USyd/ CSIRO)
THESIS TITLE Studies of HI Absorption Against Distant Radio Sources with ASKAP

Fabian Jankowski, *Dynamic, PhD*
SUPERVISORS Matthew Bailes, Willem van Straten
THESIS TITLE The Radio Universe at 1000 frames per second

Aina Musaeva, *Evolving, PhD*
SUPERVISORS Elaine Sadler, Sean Farrell, Bärbel Koribalski
THESIS TITLE Intermediate Mass Black Holes in Dwarf Galaxies

Samuel Richards, *Evolving, PhD*
SUPERVISORS Joss Bland-Hawthorn, Julia Bryant
THESIS TITLE Novel new astrophotonic technologies and telescope instruments to address the role of star formation as a function of galaxy environment.

Adam Schaefer, *Evolving, PhD*
SUPERVISORS Scott Croom, James Allen
THESIS TITLE The modulation of star formation by galaxy environment using the Sydney-AAO Multi-object Integral Field Spectrograph (SAMI)

Sarah Reeves *Evolving, PhD*
SUPERVISORS Elaine Sadler, Tara Murphy, Bärbel Koribalski
THESIS TITLE HI and OH absorption line studies of nearby galaxies

University of Melbourne

Loren Bruns Jr *Evolving, PhD*
SUPERVISORS Stuart Wyithe, Rachel Webster
THESIS TITLE Lyman alpha emitters as a probe of galaxy formation and ionisation history

Catherine De Burgh-Day *Dark, PhD*
SUPERVISORS Rachel Webster, Ned Taylor, Andrew Hopkins
THESIS TITLE Direct Shear Mapping

Antonios Katsianis *Evolving, PhD*
SUPERVISORS Stuart Wyithe, Edoardo Tescari
THESIS TITLE Feedback and Evolution of High Redshift Galaxies

Jack Line, *Evolving, PhD*
SUPERVISORS Rachel Webster, Daniel Mitchell
THESIS TITLE Detecting the Power Spectrum of the 21-cm Emission of Hydrogen from the Epoch of Reionisation

Sinem Ozbilgen *Dark, MSc*
SUPERVISORS Rachel Webster, Jeremy Mould
THESIS TITLE Calibrating the Tully-Fisher Relationship

Tristan Reynolds, *Evolving, Honours*
SUPERVISORS Rachel Webster
THESIS TITLE Detection of EoR

Nastaran Rezaee *Evolving, MPhil*
SUPERVISORS Stuart Wyithe, Daniel Mitchell
THESIS TITLE Simulations of Foregrounds in MWA Epoch of Reionisation Observations

ennifer Riding *Evolving, PhD*
SUPERVISORS Rachel Webster, Daniel Mitchell
THESIS TITLE Extremely Low Frequency Radio Astronomy Techniques to Confirm Epoch of Reionisation Theories

Australian National University

Manisha Caleb, *Dynamic, PhD*
SUPERVISORS Frank Briggs, Matthew Bailes, Brian Schmidt
THESIS TITLE A Pursuit for Celestial Radio Sources

Sarah Leslie, *Evolving, Pre-PhD*
SUPERVISORS Elaine Sadler, Scott Croom, Julia Bryant, Lisa Kewley
PROJECT TITLE A radio continuum study of SAMI galaxies

Benjamin McKinley *Evolving, PhD*
SUPERVISORS Frank Briggs, Brian Schmidt, Randall Wayth
THESIS TITLE A multifrequency, spatially resolved study of nearby radio galaxies at low frequencies

Sharon Rapoport *Dynamic, PhD*
SUPERVISOR Brian Schmidt
THESIS TITLE Gamma Ray Bursts and Exploding Stars

Jonghwan Rhee *Evolving, PhD*
SUPERVISORS Frank Briggs, Philip Lah, Jayaram Chengalur, Brian Schmidt
THESIS TITLE Cosmic Hydrogen – Fuel for Star Formation and Tracer of Baryon Flow

ICRAR | Curtin University

Mehran Mossammaparast *Evolving, MSC*
SUPERVISORS Steven Tingay, Randall Waythe, Peter Hall at ICRAR, Curtin.
THESIS TITLE Radiometric Receiver for Measuring Red-shifted 21-cm Hydrogen Monopole during EoR

Samuel Oronsaye *Dynamic, PhD*
SUPERVISORS Steven Tingay, Steve Ord, Ramesh Bhat, Steven Tremblay
THESIS TITLE Survey for Pulsars with the MWA

ICRAR | University of Western Australia

Scott Meyer, *Evolving/Dark, PhD*
SUPERVISORS Martin Meyer, Danail Obreschkow
THESIS TITLE Investigating the Tully-Fisher relation and galaxy kinematics through neutral Hydrogen spectral line stacking techniques

Steven Murray *Evolving/Dark, PhD*
SUPERVISORS Chris Power, Aaron Robotham, Simon Driver, Lister Staveley-Smith
THESIS TITLE Non-Parametric Descriptions of Dark Matter Haloes

Paul Scott-Taylor, *Evolving/Dynamic, PhD*
SUPERVISORS Danail Obreschkow
THESIS TITLE Large-scale computer simulation of radio continuum emission

Swinburne University of Technology

Andrew Johnson *Dark, PhD*
SUPERVISORS Chris Blake, David Wiltshire and Tamara Davis
THESIS TITLE Testing Non-Standard Cosmological Models with Galaxy Surveys

Emily Petroff *Dynamic, PhD*
SUPERVISORS Willem van Straten, Matthew Bailes, Simon Johnston
THESIS TITLE Our Dynamic Galaxy

Syed Uddin *Dark, PhD*
SUPERVISORS Jeremy Mould, Chris Lidman and Karl Glazebrook
THESIS TITLE Improved Constraints on Cosmology from Type Ia Supernovae Hosted in Early-Type Galaxies

ICRAR | UWA | NAOC, China

Tao Hong *Dark, PhD*
SUPERVISORS Jin Lin Han, Lister Staveley-Smith
THESIS TITLE Cosmological Structure and HI Observations

An MWA Busy Week (UWA, Perth)
Credit: Emil Lenc

CAASTRO GOVERNANCE

CAASTRO is a collaboration between The University of Sydney, The Australian National University, The University of Melbourne, Swinburne University of Technology, The University of Queensland, The University of Western Australia and Curtin University, the latter two participating together as the International Centre for Radio Astronomy Research (ICRAR). CAASTRO is funded under the Australian Research Council (ARC) Centre of Excellence program, with additional funding from the seven participating universities and from the NSW State Government's Science Leveraging Fund.

As the Administering Organisation, The University of Sydney manages the ARC grant and distributes funds in accordance with the signed Collaboration Agreement. This agreement covers how the Centre is managed, and how collaboration and intellectual property agreements are managed.

The seven collaborating universities are represented on the CAASTRO Executive, which meets every six weeks via video-conference, and twice a year at face-to-face meetings. The Centre also has an Advisory Board that meets twice per year via video-conference and annually face-to-face.

Centre Management

The CAASTRO Executive team is responsible for the administration of the Centre, including research output, research training, partnerships, national and international liaison, policies, performance, financial management, commercialisation and outreach. CAASTRO staff and activities at each Collaborating Organisation are supported by a dedicated administrative officer.

The Management Team is:

Professor Elaine Sadler
Centre Director

Professor Lister Staveley-Smith
Deputy Director

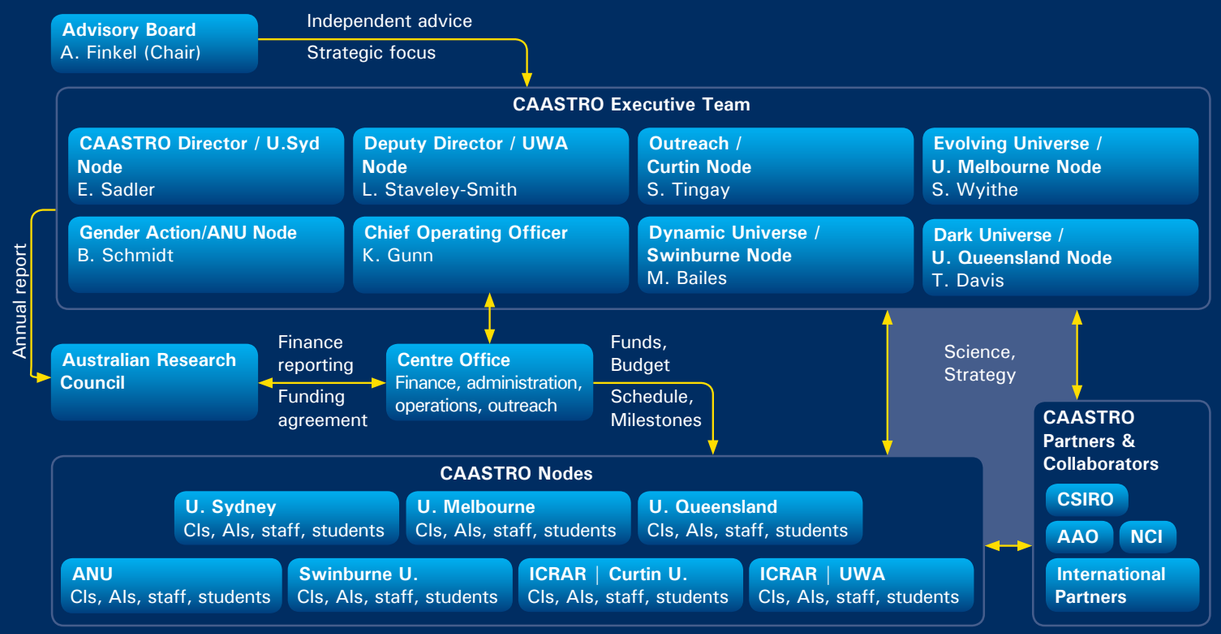
Ms Kate Gunn
Chief Operating Officer

During late 2014, the ARC undertook its Mid-Term Review of CAASTRO, culminating in a Panel Visit on 12 November 2014. CAASTRO was delighted to be able to share its achievements with the panel, and was very comfortable with the feedback and recommendations it received.

In 2014, the CAASTRO Executive met 9 times, including face-to-face meetings at Swinburne, the University of Melbourne, ICRAR University of Western Australia and ICRAR Curtin University. During 2014 areas meetings were held in Sydney, Canberra, Brisbane, Melbourne and Perth.

In 2014 CAASTRO's Theme Scientists continued to add value to the research program, and gain leadership experience and new skills during this time. Thanks must go to Dr Lisa Fogarty (Evolving), Dr Andre Offringa (Dynamic), Dr Evan Keane (Dynamic) and Dr Michael Childress (Dark) for their hard work as CAASTRO Theme Scientists in 2014. Their assistance in maintaining the Research Project Plans and organising the Theme Meetings has been invaluable.

The following diagram shows the CAASTRO Governance structure:



CAASTRO Advisory Board

The CAASTRO Advisory Board met three times in 2014, including a two-day planning meeting held in Sydney in November. At this meeting the Board assisted the CAASTRO Executive in its preparation for the ARC Mid-Term Review. It also took time to farewell Professor Bryan Gaensler, who was a tireless foundation Director of CAASTRO. In 2014, the Advisory Board conducted a Mini-Review of the CAASTRO Science Program utilising the skills of Professors Haynes, Illingworth, Ekers and Freeman. This review was very useful, and provided clarity around a number of science program items. The Board has also considered matters of strategy, responding to the changing external environment, collaboration across distances, community outreach, intellectual property and industry engagement. They have also met with students, researchers and professional staff, as well as participating in the ARC Mid-Term Review.

CHAIR
Dr Alan Finkel AM
Chancellor
Monash University

MEMBER
Ms Soula Bennett
Director
Quantum Victoria

MEMBER
Prof Elaine Sadler
CAASTRO Director

MEMBER
Prof Martha Haynes
Goldwin Smith Professor of Astronomy
Cornell University

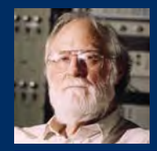
MEMBER
Prof Garth Illingworth
Professor of Astronomy & Astrophysics
University of California Santa Cruz

MEMBER
Prof Tanya Monro
Deputy Vice-Chancellor (Research),
University of South Australia
(January – December 2014)

MEMBER
Mr Guy Robinson
Systems Architect
Pawsey Supercomputing Centre, CSIRO
(January – August 2014)

MEMBER
Prof Alistar Robertson
(January – October 2014)
Emeritus Professor/
Senior Honorary Research Fellow, UWA

MEMBER
Prof Kenneth Freeman
Duffield Professor of Astronomy, Australian National University



MEMBER
Prof Ron Ekers
CSIRO Fellow

CAASTRO Executive

Steven Tingay, Lister Staveley-Smith, Bryan Gaensler, Elaine Sadler, Tamara Davis, Kate Gunn, Stuart Wyithe.

Absent: Brian Schmidt, Matthew Bailes

CAASTRO MEMBERSHIP

The University of Sydney	Administering Organisation
ICRAR | The University of Western Australia	Collaborating Organisation
The University of Melbourne	Collaborating Organisation
Swinburne University of Technology	Collaborating Organisation
The Australian National University	Collaborating Organisation
ICRAR | Curtin University	Collaborating Organisation
The University of Queensland	Collaborating Organisation
CSIRO	Partner Organisation
Australian Astronomical Observatory	Partner Organisation
Max Planck Institute for Radio Astronomy	Partner Organisation
California Institute of Technology	Partner Organisation
The University of Oxford	Partner Organisation
Durham University	Partner Organisation
Max Planck Institute for Extraterrestrial Physics	Partner Organisation
The University of Arizona	Partner Organisation
The University of Toronto	Partner Organisation
Laboratoire de Physique Nucléaire et de Hautes Energies	Partner Organisation
Raman Research Institute	Partner Organisation
National Computational Infrastructure	Partner Organisation

All members of CAASTRO agree to:

- Support the goals, objectives and research of CAASTRO.
- Accept the processes and procedures for joining, maintaining and leaving CAASTRO.
- Allow the CAASTRO Executive the right to refuse membership to any organisation or person at any time.
- Accept the legal obligations that the Administering Organisation has with the ARC.
- Accept the intellectual property policy of CAASTRO.
- Accept that all disputes regarding membership will be referred to the Research Director.
- Accept that membership is not transferable between individuals.

CAASTRO has defined categories of membership, and individuals and organisations must apply to the CAASTRO Executive addressing certain defined criteria to make their case for membership. The CAASTRO Membership categories are:

Chief Investigators

Chief Investigators (CIs) are senior researchers employed by collaborating organisations named in the CAASTRO Collaborators' Agreement. CIs are responsible for making a substantial intellectual and strategic contribution to CAASTRO, and for supervising CAASTRO research staff, CAASTRO professional staff and CAASTRO students.

Partner Investigators

Partner Investigators (PIs) are senior researchers employed by partner organisations named in the CAASTRO Multi-Institute Agreement. PIs are responsible for making a substantial intellectual and strategic contribution to CAASTRO. Where appropriate, they may also co-supervise CAASTRO students.

Associate Investigators

Associate Investigators (AIs) are scientists who are funded from a Collaborating Organisation, Partner Organisation or other source, and who are participating in CAASTRO research projects with specific deliverables. Associate Investigators are responsible for making an intellectual and strategic contribution to CAASTRO in their specific area(s) of expertise. AIs are typically researchers for whom membership at the CI or PI level is not suitable for logistical or strategic reasons.

Research Staff

CAASTRO Research Staff are employees of a CAASTRO collaborating organisation, who are classified on the academic pay scale, and are funded at FTE 0.2 or higher from the CAASTRO budget. Research staff are responsible for producing the research, technical and outreach results associated with the CAASTRO milestones and, where appropriate, may also co-supervise CAASTRO students. All CAASTRO Research Staff must have a CAASTRO CI as their line manager.

Professional Staff

CAASTRO Professional Staff are employees of a CAASTRO collaborating organisation who are classified on the professional/general pay scale, or are working in a professional role, and are funded from the CAASTRO budget or as an in kind contribution to CAASTRO. Professional staff are responsible for coordinating the administrative, financial, educational and outreach activities within CAASTRO. All CAASTRO Professional Staff must have a CAASTRO CI or the CAASTRO Chief Operating Officer as their line manager.

Affiliates

CAASTRO Affiliates are researchers who have a scientific association with CAASTRO, but who are not CIs, PIs, AIs or staff. CAASTRO Affiliates include independently funded researchers (e.g., Future Fellows, DECRAs working alongside CAASTRO researchers at CAASTRO nodes), or researchers who have an involvement in CAASTRO not warranting membership at the CI, PI or AI levels. Affiliates are not responsible for any CAASTRO research deliverables.

Students

CAASTRO students are postgraduate, honours, masters or Pre-PhD students whose research projects make a substantial intellectual contribution to CAASTRO. A CAASTRO student can be enrolled at any higher degree granting institution, but must have a CAASTRO CI as an official supervisor or co-supervisor.

Visitors

Visitors are academics from outside Australia who spend time working at one or more CAASTRO nodes on a research project with CIs and other research staff. A CAASTRO PI may also be a CAASTRO Visitor during time spent working at a CAASTRO node.

AWARDS & HONOURS

External recognition for the CAASTRO team continued in 2014 with a number of team members receiving awards and honours for their achievements.

Brian Schmidt was awarded the 2015 Breakthrough Prize for Fundamental Physics, which was presented at a ceremony in California in November 2014. The prize was shared with a larger team, including CAASTRO PIs Warrick Couch and Reynald Pain, and AIs Brian Boyle and Chris Lidman. The Breakthrough Prize in Fundamental Physics was founded in 2012 by Yuri Milner to recognize those individuals who have made profound contributions to human knowledge. It is open to all physicists, theoretical, mathematical, experimental, working on the deepest mysteries of the Universe.

Aina Musaeva received a 2014 Australia Day Award from the National Council of Women (NSW). Aina was one of eleven young women from across NSW (in fields as diverse as history, graphic design, science and law) chosen to receive a cash award to assist with her PhD studies. Aina received her award at an Australia Day reception and lunch held at NSW Parliament House.

L to R: Adam Riess, Saul Perlmutter, Eddie Redmayne, Brian Schmidt

Credit: Breakthrough Prize

Left to right: Anne Sheehan, President, Soroptimist Region of NSW; Doreen Todd, Awards Committee member, NCW NSW; Aina Museva and Professor Elaine Sadler

Credit: National Council of Women (NSW)

Samuel Hinton, a CAASTRO student, made many astronomers' work lives a whole lot easier and also won an award for his efforts. Samuel, a software engineering student at the University of Queensland, has received the 2014 Student Thesis prize given by the Queensland chapter of the Institute of Electrical and Electronics Engineers (IEEE). For his thesis Samuel developed new software for a CAASTRO project, the OzDes redshift survey. Called *Marz*, the software greatly speeds up the process of obtaining redshifts from the OzDes observations. Samuel's thesis also won the GroundProbe Prize ('Best in microwave, photonics and communications') at the UQ Innovation Showcase event in November.

CAASTRO was delighted to receive a Silver Pleiades Award in 2014. The awards were launched in August 2014 during the Australian Women in Astronomy workshop. Inspired by the UK's Athena Swan program, they are given by the Astronomical Society of Australia (ASA) to organisations that take steps to improve gender equity in the workplace. CAASTRO was one of only two organisations to win a Silver Pleiades award. It was also gratifying that all our Collaborating Universities also all achieved Bronze Status, and CAASTRO's two Australian Partner Organisations also gained awards with a Silver award to AAO and Bronze to CSIRO Astronomy and Space Science.

Anthea King and Emily Petroff, both were student prize winners at the Astronomical Society of Australia (ASA) scientific meeting in July 2014.

Ken Freeman, a member of the CAASTRO Advisory Board, was awarded the 2014 Gruber Foundation Cosmology Prize for his work in Near Field Cosmology.

Professor Tapan Saha (UQ), Chair of IEEE Queensland, presents Samuel Hinton with his award at the IEEE Queensland 2014 Annual General Meeting on 3 December.

Credit: IEEE Queensland

GENDER ACTION COMMITTEE

By Professor Brian Schmidt, CAASTRO Gender Action Committee Chair

From its establishment in early 2011, the CAASTRO Executive has considered itself a force for gender equality and has had strong oversight of gender initiatives and the monitoring of Key Performance Indicators (KPIs) and outcomes. For example we have offered all positions part-time in CAASTRO since 2011.

In 2013 the CAASTRO Executive considered its KPIs in relation to its gender program and decided that it was falling short in a number of desired outcomes. The CAASTRO Executive decided to form the CAASTRO Gender Action Committee to address these issues and Professor Brian Schmidt agreed to lead the Committee. 2014 saw the Gender Action committee undertake its first activities, with its remit to contribute to the development of strategies to meet Gender Action challenges to maximise the proposed goals and objectives of the Centre. This includes making recommendations on ways in which CAASTRO can balance its gender representation, and boost opportunities for our female staff and students, and monitor progress.

The Gender Action Committee provides broad representation from its membership and different levels within the centre, including members from different member organisations, different genders and nationalities. The committee is made up of Elaine Sadler (USyd), Rachel Webster (UMelb), Cathryn Trott (ICRAR/Curtin), Fang Yuan (ANU), Evan Keane (Swinburne), Iraklis Konstantopolous (AAO), Jessica Bloom (USyd), Kate Gunn (USyd) and Brian Schmidt (ANU, Chair). The Committee met face to face for half a day, and then three times during the year for a two hour videoconference. The creation of the CAASTRO Gender Action Committee has fast-tracked many of our gender initiatives.

CAASTRO has gender KPIs which have been set and are measured. These include the number of women at various levels within CAASTRO, the number of female-led CAASTRO sponsored workshops, the number of female CAASTRO visitors, gender targets for speakers and SOC roles in conferences and workshops, the number of females who apply for jobs and those who are short-listed. Gender-based metrics are compiled every 6 months for consideration by the Gender Action Committee.

Despite many innovative ideas surrounding Gender Equity having been incorporated into CAASTRO, the committee was confronted with the fact that overall participation rates within several categories of CAASTRO membership were not representative of the broader community, and were skewed male. Specifically, the number of funded researchers, Partner Investigators (PIs) and Associate Investigators (AIs) all are below reasonable expectations based on the percentage of women who fill that level within astronomy.

To this end, the committee recommended to the CAASTRO executive that we could improve the representation of women in CAASTRO by:

- asking all CAASTRO nodes to think about how to attract strong female candidates for positions, and to report on their efforts and outcomes in upcoming advertisements
- to put effort in progressing outstanding female Partner Investigator memberships
- to consider whether any female CAASTRO affiliates members could be considered for Associate Investigator status
- to ask Theme Leaders if there are appropriate female researchers to bring in as Partner Investigators, Associate Investigators or Affiliate members emphasising the lack of women in these roles currently.

The committee also considered the appropriate role for the Gender Action Committee, given that each institution serves as the legal employer for CAASTRO members and has their own regulations. The committee decided that it could best serve CAASTRO by helping improve the prospects for women to navigate the leaky pipeline between PhD and tenured researcher. Initiatives that recommended and in various stages of being implemented include:

- offering programs to CAASTRO members about leadership, focusing on women
- improving and finalising CAASTRO's diversity policy
- offering a 'I need support now!' program for CAASTRO members including students
- holding a CAASTRO Women's day
- having a CAASTRO Women's lunch at each node each year
- ensuring that CAASTRO engages with the Women in Astronomy Chapter of the Astronomical Society of Australia and continues to network with similar groups about novel ideas for CAASTRO implementation
- being an active contributor to the Australian Women in Astronomy Workshop each year.

The ARC Mid-Term Review of CAASTRO commented that our gender initiatives were changing the culture of not only CAASTRO but also our member organisations. Currently 90% of professional staff and 17% of research staff have taken up the option of part-time work, and recent gender statistics from the Supernovae Science Conference held in August show a positive impact and improvement on female participation at all levels. Female representation at this conference on the SOC was 34%, the LOC 50%, invited speakers 30%, 48% of contributed talks and 42% of female chairs. CAASTRO also provided free childcare at this conference.

Since inception the number of women on the CAASTRO Executive has grown from zero to 14% during 2011–2013, then to its current 38%. CAASTRO now has a female Director, Professor Elaine Sadler. In addition our female Chief Investigators have increased from 16% to 28%.

The Gender Action Committee was very pleased that CAASTRO was awarded an Astronomical Society of Australia's Pleiaides award at the level of Silver in recognition of our Gender Diversity Activities. We were one of only two organisations to receive such a distinction. In 2015, in addition the implementation of these ideas, the Gender action committee will monitor the impact of our work, and continue to update and create new programs in response to our observations.

Dr Ivo Seitenzahl and Dr Ashley Ruiter are CAASTRO members and Post Doctoral researchers at ANU.
Credit: Dr Ashley Ruiter

CAASTRO Annual Retreat 2014
Credit: Jacinta Den Besten

PRESENTATIONS

INVITED TALKS 2014

Major Conferences

**this list does not include public talks or school talks*

Invited Talks 2014

(Conferences, workshops, colloquia, projects and collaborations)

Establishing the robustness of cosmological tests of general relativity to dark energy perturbations
Jason Dossett, 223rd Meeting of the American Astronomical Society, USA, January 2014

Cosmology - The next frontier - "Big Data or Big Ideas: What is the future of observational cosmology
Brian Schmidt, Is the Universe Necessary, Arizona, USA, January 2014

The State of the world with Nobel Laureates in science
Brian Schmidt, World Economic Forum, Davos, Switzerland, January 2014

The Universe Unveiled - with Chris Lintott
Brian Schmidt, World Economic Forum, Davos, Switzerland, January 2014

SkyMapper and the Extragalactic Distance Scale
Brian Schmidt, The Extragalactic Distance Scale, Munich, Germany, January 2014

Hunting pulsars and fast transients with the SKA
Ewan Barr, Multicore World 2014, New Zealand, February 2014

Large Scale Structure
Tamara Davis, TIARA Winter School on Cosmology, Taiwan, February 2014

The SAMI Galaxy Survey
Lisa Fogarty, 3D2014: Gas and Stars in Galaxies: A multi-wavelength 3D perspective, ESO, Garching, Germany, March 2014

An example of the process of discovery
Brian Schmidt, 6th HOPE Meeting with Nobel Laureates, Tokyo, Japan, March 2014

HI absorption-line science – current results and plans for ASKAP
Elaine Sadler, 7th International PHISCC Workshop - The Challenges of the Upcoming HI Surveys, ASTRON, The Netherlands, March 2014

Science with the MWA
Lister Staveley-Smith, 7th International PHISCC Workshop - The Challenges of the Upcoming HI Surveys, ASTRON, The Netherlands, March 2014

WALLABY/DINGO kinematic parameterisation: a new Bayesian MCMC tilted-ring fitter
Se-Heon Oh, 7th International PHISCC Workshop - The Challenges of the Upcoming HI Surveys, ASTRON, The Netherlands, March 2014

OzDES multi-fibre spectroscopy for the Dark Energy Survey: first-year operation and results (OzDES first year paper plan)
Fang Yuan, Dark Energy Survey Collaboration Meeting, University of Illinois, USA, May 2014

Galaxy formation with SPHS
Chris Power, nIFTy cosmology workshop, Madrid, Spain, June 2014

Cosmology: An example of the process of discovery
Brian Schmidt, 64th Lindau Nobel Laureate Meeting, Germany, June 2014

A cosmic census of radio pulsars
Evan Keane, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

Connecting the baryons: Multiwavelength data for HI surveys
Martin Meyer, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

The astronomical revolution
Brian Schmidt, Euroscience Open Forum 2014, Denmark, June 2014

Different manifestations of neutron stars
Evan Keane, Extreme Astrophysics in an Ever-Changing Universe, Crete, Greece, June 2014

The local velocity field and the Hubble Constant
Jeremy Mould, MIAPP Workshop Extragalactic Distance Scale, Garching, Germany, June 2014

SkyMapper science
Brian Schmidt, Astronomical Society of Australia Annual Scientific Meeting 2014, Sydney, Australia, July 2014

The lives of active galactic nuclei and the evolving Universe
Dr Anna Kapinska, Astronomical Society of Australia Annual Scientific Meeting 2014, Sydney, Australia, July 2014

The SkyMapper Southern Survey
Chris Wolf, European Week of Astronomy and Space Science (EWASS) 2014, Geneva, Switzerland, July 2014

High-time resolution radio astronomy with low-frequency interferometric arrays
Ramesh Bhat, 31st International Union of Radio Science (URSI) General Assembly and Scientific Symposium, Beijing, China, August 2014

Variation in the escape fraction of ionizing photons from galaxies and the redshifted 21-cm power spectrum during reionization
Hansik Kim, Lyman Continuum Leakage and Cosmic Reionization, Stockholm, Sweden, August 2014

SKA and HI lectures (a series of 6 lectures)
Lister Staveley-Smith, SKA Radio Astronomy School, China, August 2014

Locations of peculiar supernovae as a diagnostic of their origins
Fang Yuan, Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A, Coffs Harbour, Australia, August 2014

The Zoo of AGNs in the context of clustering and a coherent picture of AGN clustering
Scott Croom, Clustering Measurements of Active Galactic Nuclei, Garching, Germany, September 2014

The SAMI Galaxy Survey
Scott Croom, Galaxy Masses as Constraints of Formation Models, Oxford, UK, September 2014

Gender and diversity in astronomy
Bryan Gaensler, Greater Diversity Forum, Australia, September 2014

Optical and infrared astronomy
James Allen, Looking Up, Looking Down: Interdisciplinary Approaches to Remote Sensing, Image Analysis, and Data Visualisation, Sydney, Australia, September 2014

The fundamental plane and stellar populations of early-type galaxies from low redshift surveys
Matthew Colless, The Life and Times of Galaxies, Utah, USA, September 2014

Ages of type Ia Supernovae over cosmic time
Mike Childress, Type Ia supernovae: progenitors, explosions, & cosmology conference, Chicago, USA, September 2014

AGN reverberation mapping simulations
Anthea King, Dark Energy Survey Collaboration Meeting, Brighton, UK, October 2014

The Accelerating Universe
Brian Schmidt, 2014 General Assembly of The International Union of Pure and Applied Physics, Nanyang Technological University, Singapore, November 2014

Cosmology as an example of how science works
Brian Schmidt, 5th International Conference on Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia, November 2014

The Accelerating Universe
Brian Schmidt, 5th International Conference on Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia, November 2014

SAMI and HECTOR
Julia Bryant, Astrophotonica Australis, Sydney, Australia, November 2014

Everything about cosmology but were afraid to ask
Brian Schmidt, State of the Heart 2014 High Blood Pressure Research Council of Australia, Adelaide, Austin Doyle Lecture 2014, Australia, November 2014

The structure of reionization in hierarchical galaxy formation models
Hansik Kim, The 6th KIAS Workshop on Cosmology and Structure Formation, South Korea, South Korea, November 2014

Observational dark energy
Brian Schmidt, 10th Asia-Pacific Symposium on Cosmology and Particle Astrophysics, University of Auckland, New Zealand, December 2014

The dark side of astronomy
Brian Schmidt, 10th Asia-Pacific Symposium on Cosmology and Particle Astrophysics, University of Auckland, New Zealand, December 2014

Cosmological constraints on dark energy
Tamara Davis, 10th Asia-Pacific Symposium on Cosmology and Particle Astrophysics, University of Auckland, New Zealand, December 2014

Watching galaxies fall: testing theories of gravity using large galaxy redshift surveys
David Parkinson, Australian Institute of Physics Congress "The Art of Physics", Australia, December 2014

Everything you wanted to know about diffuse polarisation but were afraid to ask
Emil Lenc, Early Science from Low-Radio Frequency Telescopes, Arizona, USA, December 2014

From earth rotation aperture synthesis to patient rotation computed tomography
Ilana Feain, Edges of Universe Academy of Science Frontiers of Science Meeting, Canberra, Australia, December 2014

What is a decadal plan?
Stuart Wyithe, Edges of Universe Academy of Science Frontiers of Science Meeting, Canberra, Australia, December 2014

The edges of cosmology
Tamara Davis, Edges of Universe Academy of Science Frontiers of Science Meeting, Canberra, Australia, December 2014

Public Lectures 2014

Dark Matter
Astronomy Society of Victoria, Alan Duffy, January 2014

Education, Discovery, and Translation: The Cycle of Science – Part 1
ANU Indonesia Initiative, Bogor, Indonesia, Brian Schmidt, February 2014

Education, Discovery and Translation: The Cycle of Science - Part 2
ANU Indonesia Initiative, Bogor, Indonesia, Brian Schmidt, February 2014

Public event with Anant Agarwal Founder/CEO TedX (MOOC),
Brian Schmidt, February 2014

Science Policy
ANU Policy Launch, Canberra, Brian Schmidt, February 2014

Magnets in the Sky
Science Stars of the Future Lecture, Australian Academy of Science, Canberra, Bryan Gaensler, February 2014

The Accelerating Universe
University of Western Sydney, Brian Schmidt, February 2014

The Creation of the Universe
The Australian Museum, Tamara Davis, February 2014

A Nobel Prize Winner's Ponderings on Planets, Pinot and Prosperity
Rotary Club of Canberra, Canberra, Brian Schmidt, March 2014

Astronomy in Australia: Our Part in the Big Picture
University of Melbourne, Rachel Webster, Melbourne, March 2014

Gender Equity within the research sector
International Women's Day, Australian National University, Canberra, Brian Schmidt, March 2014

Seeing back to the Big Bang – the SKA telescope's unlimited potential
National Library, Canberra, Brian Schmidt and Brian Boyle, March 2014

Space and wonder
Sunday Assembly, Brisbane, Tamara Davis, March 2014

The Circle of Innovation: Making it work here in Australia
Rotarian Talk, Canberra, Brian Schmidt, March 2014

An astronomer's introduction to databases and SQL
ANITA lecture series, Perth, Paul Hancock, April 2014

My Life, the Universe, and Everything about the discovery of Cosmic Acceleration
Gates Cambridge Scholarship, Brisbane, Brian Schmidt, April 2014

Public Lecture
National Youth Science Forum, Brisbane, Tamara Davis, April 2014

Space 2014
TEDxNoosa, Noosa,Tamara Davis, April 2014

The Accelerating Universe
Charles Sturt University, Orange, Brian Schmidt, April 2014

The challenges facing research in Australia
QUT Gardens Point Campus VC Forum Address, Brisbane, Brian Schmidt, April 2014

Written in the Stars
QUT gardens Theatre, Brisbane, Brian Schmidt, April 2014

Murchison Widefield Array - Big Data Precursor to the Square Kilometre Array
Scitech Planetarium Big Data Week, Perth, Steven Tingay, May 2014

Public Lecture
Mandelbaum House, Sydney, Bryan Gaensler, May 2014

Public Schooling
Australian Education Union Public Education Celebratory Dinner address, Canberra, Brian Schmidt, May 2014

Public Lecture and Discussion
Women in Science Breakfast, Brisbane, Tamara Davis, May 2014

Public Lecture
Booragoon Rotary Club, Perth, Steven Tingay, May 2014

Science today for outcomes tomorrow
Defence Science and Technology Organisation Strategic Context Seminar 2014, Canberra, Brian Schmidt, May 2014

The Circle of Prosperity: Education, Science and Innovation
Royal Society of Victoria, Melbourne, Brian Schmidt, May 2014

What are dark energy and dark matter?
Diurnals Society, Melbourne, Chris Blake, May 2014

Neutral Hydrogen in the Universe
Northern Sydney Astronomical Society, Sydney, Sarah Reeves, June 2014

Spectroscopy and spectroscopic surveys
Sutherland Astronomical Society, Sydney, James Allen, June 2014

The Accelerating Universe
Johannes Gutenberg-Universität Mainz, Germany, Brian Schmidt, June 2014

Mapping the invisible gas in the Milky Way using the Murchison Widefield Array
Astronomical Society of Western Australia, Perth, Paul Hancock, July 2014

Public Lecture
Neighbourhood Fellowship, Canberra, Brian Schmidt, July 2014

Science and Society
Kenneth Myer Lecture, National Library of Australia, Canberra (also filmed for ABC Big Ideas Program), Brian Schmidt, July 2014

Square Kilometre Array
Linux Users Victoria, Melbourne, Ewan Barr, July 2014

The Path to Winning a Nobel Prize
China Scholarship Council Program, Canberra, Brian Schmidt, July 2014

A Tour of the Universe
Imperial College London, UK, Katie Mack, August 2014

A Tour of the Universe
World Science Fiction Convention, UK, Katie Mack, August 2014

Creating the Universe in a computer
Stars in the Yarra Ranges, National Science Week, Vic, Chris Power, August 2014

Galaxy Information
Stars in the Yarra Ranges, National Science Week, Vic, Karl Glazebrook, August 2014

Pulsars and fast radio bursts
Stars in the Yarra Ranges, National Science Week, Vic, Emily Petroff, August 2014

The Square Kilometre Array Telescope
Stars in the Yarra Ranges, National Science Week, Vic, Ewan Barr, August 2014

Type 1A Supernovae and Cosmology
Stars in the Yarra Ranges, National Science Week, Vic, Syed Uddin, August 2014

The cosmic microwave background
Stars in the Yarra Ranges, National Science Week, Vic, Pietro Procopio, August 2014

Paving the way with the MWA
Scitech Planetarium, Perth, Steven Tingay, August 2014

When Does Science Matter?
Public Lecture, The Australian National University, Canberra, Brian Schmidt, August 2014

Public Lecture
Astronomical Group of WA, Perth, Chris Power, August 2014

Public Lecture
Uluru Astronomy Weekend, NT, Rachel Webster, August 2014

Public Lecture
Uluru Astronomy Weekend, NT, Steven Tingay, August 2014

Public Lecture
Uluru Astronomy Weekend, NT, Ray Norris, August 2014

Public Lecture
Uluru Astronomy Weekend, NT, Bryan Gaensler, August 2014

The Accelerating Universe
University of Launceston, Hobart, Brian Schmidt, August 2014

The Accelerating Universe
University of Tasmania, Sandy Bay, Brian Schmidt, August 2014

The history of physics and astronomy in Australia
Science at the Shine Dome, Canberra, Brian Schmidt, August 2014

What will you do when your doctorate is done?
PhD to Present: a day dedicated to the career pathways of those who have gone before you, Australian National University, Canberra, Brian Schmidt, August 2014

Brief remarks on career, future of astronomy, role of GMT
Giant Magellan Telescope Dinner, USA, Brian Schmidt, September 2014

In Search of the Ultimate Fate of the Universe: Some reflections on my life as a Postdoc managing an international team, and trying to balance career and family
University of New South Wales, Brian Schmidt, September 2014

Public talk on a career in science
The Science Career Carousel, Karratha, WA, Alan Duffy, September 2014

Science and Society
National Library of Australia, Melbourne, Brian Schmidt, September 2014

The Universe as we know it
St Paul's College, The University of Sydney, Brian Schmidt, September 2014

Universe from Beginning to End: Learn everything we know about the Universe from its beginning to its end and the bits in between
Mt Stromlo Observatory public Observing nights, ACT, Brian Schmidt, September 2014

A Starry Night
Milroy Observatory, ACT, Brian Schmidt, Fred Watson and David Malin, October 2014

A strange world! Interactive role-playing activity to decipher the Universe from observations.
Universe from A-Z
Mt Stromlo and Regional Partnership School student activities and presentation, ACT, Brian Schmidt, October 2014

Bright things in the night sky
StarFest SSO 50th Birthday celebrations & Open Day children's' talk, Siding Springs Observatory, ACT, Brian Schmidt, October 2014

The big questions: How Researchers are Unlocking the Mysteries of the Universe
StarFest, Siding Springs Observatory, 50th Birthday Celebrations and Open Day, ACT, Brian Schmidt, October 2014

How a normal person helped discover 70% of the Universe: Or, a Nobel Prize Winner's Guide to Leadership
Attorney-General's Department & Ministry of the Arts 'Talking Heads' series address, Canberra, Brian Schmidt, October 2014

Leading a Revolution in Radio Astronomy with the ASKAP and MWA
Western Sydney Amateur Astronomy Group, Sydney, Emil Lenc, October 2014

Spinning the Cosmic Web in a Supercomputer
Scitech Horizon Dome, Perth, Chris Power and Paul Scott-Taylor, October 2014

The Dark Side of Astronomy
University of Auckland, New Zealand, Brian Schmidt and Tamara Davis, October 2014

The Path to winning a Nobel Prize
ANU Edge 2014 China Scholarship Council Programme, Canberra, Brian Schmidt, October 2014

Examining Gas from Galaxies Billions of Years Old
Inspiring Science, Ultimo Community Centre, Sydney, Vanessa Moss, November 2014

Public Lecture
Elemental at Melbourne Planetarium, Melbourne, Alan Duffy, November 2014

It's a Wonderful World
Woodford Folk Festival – Green Forum, Queensland, Tamara Davis with Ian Lowe, December 2014

The Dark Side
Woodford Folk Festival, Queensland, Tamara Davis, December 2014

A Tour of the Universe
Swinburne University, Melbourne, Katie Mack, December 2014

Cosmology
Australia/New Zealand Physics Summer School "Frontiers in Physics", Australian National University, Canberra, Brian Schmidt, December 2014

Public talk about SKA
University of the 3rd Age, Science and Technology Division, Sydney, Anne Green, December 2014

The Dark Side of Astronomy
Auckland, New Zealand, Brian Schmidt, December 2014

Other Presentations 2014

(Conferences, workshops, colloquia, projects and collaborations)

Inferring Ejected Masses of Type Ia Supernovae from Nearby Supernova Factory Data
Richards Scalzo, 223rd Meeting of the American Astronomical Society, Washington DC, USA, January 2014

SN 2012fr: A Type Ia Supernova with Extreme High Velocity Features and Stratified Eject
Mike Childress, 223rd Meeting of the American Astronomical Society, Washington DC, USA, January 2014

Great Debate: Parallel Realities: Probing Fundamental Physics (PANEL)
Brian Schmidt, Is the Universe Necessary, Arizona, USA, January 2014

Polarisation with the Murchison Widefield Array (There and Back Again)
Emil Lenc, SKA Science Assessment Workshop – Magnetism, Manchester, UK, January 2014

Curtin Update
JP Macquart and Cath Trott, SKA Science Assessment Workshop – Transients, Manchester, UK, January 2014

Radio Polarimetry and the Magnetic Universe
Bryan Gaensler, University of Toronto, Colloquia, Canada, January 2014

The SAMI Galaxy Survey: First Results
Lisa Fogarty, AAO Colloquium, Sydney, Australia, February 2014

Constant vs. variable winds: effect on high-z galaxies
Edoardo Tescari, ANITA 2014 Workshop and Informatics School, Sydney, Australia, February 2014

How should we observe the Epoch of Reionisation
Cath Trott, ANITA 2014 Workshop and Informatics School, Sydney, Australia, February 2014

New Constraints on f(R) gravity using ISiTGR and the WiggleZ power spectrum
Jason Dossett, ANITA 2014 Workshop and Informatics School, Sydney, Australia, February 2014

Ran N-body school
Chris Power, ANITA 2014 Workshop and Informatics School, Sydney, Australia, February 2014

The WiZ-COLA simulation: many many simulations for the WiggleZ survey
Jun Koda, ANITA 2014 Workshop and Informatics School, Sydney, Australia, February 2014

Supernova Science in Australia
Mike Childress, Gaia-PESSTO Workshop Belfast, Ireland, February 2014

Radio Polarimetry and the Magnetic Universe
Bryan Gaensler, NOVA Lecture, Leiden University, The Netherlands, February 2014

Radio Polarimetry and the Magnetic Universe
Bryan Gaensler, NOVA Lecture, Radboud University Nijmegan, Groningen, The Netherlands, February 2014

Radio Polarimetry and the Magnetic Universe
Bryan Gaensler, NOVA Lecture, University of Amsterdam, The Netherlands, February 2014

Radio Polarimetry and the Magnetic Universe
Bryan Gaensler, NOVA Lecture, University of Groningen, Groningen, The Netherlands, February 2014

Some Big Questions in Cosmology
Brian Schmidt, Physics Teachers Conference, Opening Address, Melbourne, February 2014

Bias and Gender in Science and Academia
Bryan Gaensler, Seminar, University of Amsterdam, The Netherlands, February 2014

First Galaxies and DRAGONS
Alan Duffy, Seminar, CSIRO; University of Queensland; University of Sydney, Australia, February 2014

Progenitors of Type Ia Supernovae
Mike Childress, Southampton University, UK, February 2014

Tracing the cosmic web with velocity tensor
Weiguang Cui, Tracing the Cosmic Web, Leiden, The Netherlands, February 2014

Searching for the Synchrotron Cosmic Web with the Murchison Widefield Array
Bryan Gaensler, Tracing the Cosmic Web, Leiden, The Netherlands, February 2014

The Fundamental Plane in 3D from 6dF and SAMI
Matthew Colless, 3D2014: Gas and Stars in Galaxies: A multi-wavelength 3D perspective, ESO, Garching, March 2014

The Fundamental and Mass Planes for three nearby clusters from the SAMI Pilot Survey
Nic Scott, 3D2014: Gas and Stars in Galaxies: A multi-wavelength 3D perspective, ESO, Garching , Germany, March 2014

Large surveys for 21-cm HI absorption
Elaine Sadler, 3D2014: Gas and Stars in Galaxies: A multi-wavelength 3D perspective, ESO, Garching, Germany, March 2014

Signatures of quenching in SAMI cluster galaxies
James Allen, 3D2014: Gas and Stars in Galaxies: A multi-wavelength 3D perspective, ESO, Garching , Germany, March 2014

Angular Momentum in the Era of the SKA
Danail Obreschkow, 7th International PHISCC Workshop - The Challenges of the Upcoming HI Surveys, ASTRON, The Netherlands, March 2014

Cosmology with 4MOST
Chris Blake, AAO Workshop on science with 4MOST spectrograph, Australia, March 2014

A large number of fast cosmological simulations for the revised WiggleZ BAO measurement
Jun Koda, Kavli Institute for the Physics and Mathematics of the Universe, Tokyo, Japan, March 2014

Plenary panel: Time to rethink: Learning for a changing world
Brian Schmidt, Science World Summit 2014, Belgium, March 2014

Advanced MWA primary beam models
Randall Wayth, SKA Calibration and Imaging Workshop (CALIM) 2014, Kiama, Australia, March 2014

Polarisation with the Murchison Widefield Array (There and Back Again)
Emil Lenc, SKA Calibration and Imaging Workshop (CALIM) 2014, Kiama, Australia, March 2014

RTS Processing and Calibration
Jack Line, SKA Calibration and Imaging Workshop (CALIM) 2014, Kiama, Australia, March 2014

4MOST/WAVES, eROSITA and CAASTRO-2
Bryan Gaensler, The WAVES survey on 4MOST, Sydney, Australia, March 2014

MWA Polarisation for Transient Astronomers
Emil Lenc, Transient Busy Week at Sydney University, Sydney, Australia, March 2014

DARK Lizards Informal workshop discussing the future of simulation work on alternative gravity models
Jason Dosett, Alternative Gravity Workshop, Brisbane, Australia, April 2014

Detector array Cosmetics
Fang Yuan, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

History & future, Photometry & calibration
Brian Schmidt, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

Parkes: pulsars and radio transients
Matthew Bailes, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

SkyMapper and CAASTRO
Bryan Gaensler, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

SkyMapper supernova survey
Richard Scalzo, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

SkyMapper ToO programmes
Fang Yuan, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

System performance & stats, eROSITA, Photometric redshifts
Chris Wolf, SkyMapper: Everything you need to know to use the Terabytes, Australia, April 2014

Dark matter cores in dwarf galaxies
Se-Heon Oh, CAASTRO PAM, Perth, May 2014

Fast Radio Bursts
Evan Keane, Curtin University/University of Western Australia Colloquia, Australia, May 2014

2dFLenS
Tamara Davis, Dark Energy Survey Collaboration Meeting, University of Illinois, USA, May 2014

Baryon acoustic peak reconstruction in WiggleZ
Chris Blake, Dark Energy Survey Collaboration Meeting, University of Illinois, USA, May 2014

OzDES Reverberation Mapping Campaign Simulations
Tamara Davis, Dark Energy Survey Collaboration Meeting, University of Illinois, USA, May 2014

OzDES Global redshift Catalog
Syed Uddin, Dark Energy Survey Collaboration Meeting, University of Illinois, USA, May 2014

Study of SNe Ia in Host Galaxy Environments
Syed Uddin, Dark Energy Survey Collaboration Meeting, University of Illinois, USA, May 2014

Absorption line indices
Jeremy Mould, OzDES Busy Week, Ballina, Australia, May 2014

OzDES Global redshift Catalog
Syed Uddin, OzDES Busy Week, Ballina, Australia, May 2014

Dropping Targets in OzDES
Conor O'Neill, OzDES Busy Week, Ballina, Australia, May 2014

Peculiar velocities and Lensing
Tamara Davis, OzDES Busy Week, Ballina, Australia, May 2014

Practical Statistics for Astronomers
Tamara Davis, OzDES Busy Week, Ballina, Australia, May 2014

Redshifting pitfalls
Tamara Davis, OzDES Busy Week, Ballina, Australia, May 2014

Improving distance measurements to z = 1 by reconstructing the WiggleZ Dark Energy Survey baryonic acoustic feature
Eyal Kazin, Statistical Challenges in 21st Century, Lisbon, Portugal, May 2014

Space Situational Awareness with the Murchison Widefield Array
Benjamin McKinley, 2nd Australian Workshop on Space Situational Awareness, Canberra, Australia, June 2014

MWA and AST3 Collaboration opportunities
Paul Hancock, 3rd international collaboration meeting on Antarctic Survey Telescopes, Nanjing, China, June 2014

Cosmology with Fast Radio Bursts
Cathryn Trott, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

Broadband polarimetry with the Square Kilometre Array
Bryan Gaensler, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

The Intergalactic medium and the Cosmic Web
Attila Popping, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

The Lifecycles of radio-loud AGN
Anna Kapinska, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

The SKA view of gamma-ray bursts
Davide Burlon, Advancing Astrophysics with the Square Kilometre Array, Giardini Naxos, Italy, June 2014

Wide-Field Polarimetry: A Unique Probe of Interstellar Turbulence
Bryan Gaensler, Cosmic Rays and their Interstellar Environment, Montpellier, France, June 2014

Panel Discussion: Fostering Academic Excellence in a Changing
Brian Schmidt, Euroscience Open Forum 2014, Denmark, June 2014

Massive scale pulsar observations with the Molonglo telescope
Fabian Jankowski, International Pulsar Timing Array 2014 Meeting, Banff, Canada, June 2014

An Initial Bayesian Cross Matched Catalogue
Jack Line, MWA EoR Busy Week Meeting, San Francisco, USA, June 2014

Cosmological HI Power spectrum
Cathryn Trott, MWA EoR Busy Week Meeting, San Francisco, USA, June 2014

A Study of Gigahertz-Peaked Spectrum and Compact Steep Spectrum Sources with the MWA
Joe Callingham, Powerful AGN and their Host Galaxies Across Cosmic Time, Port Douglas, Australia, June 2014

Complete Ionisation of the Neutral Gas in the Hosts of High Redshift AGN
Steve Curran, Powerful AGN and their Host Galaxies Across Cosmic Time, Port Douglas, Australia, June 2014

Feedback in Luminous Type II AGN: Winds, star formation, and formation
Rebecca McElroy, Powerful AGN and their Host Galaxies Across Cosmic Time, Port Douglas, Australia, June 2014

HI Absorption in the host galaxies of AGN
James Allison, Powerful AGN and their Host Galaxies Across Cosmic Time, Port Douglas, Australia, June 2014

The hosts of hybrids: How do peculiar radio galaxies shake our unification schemes?
Anna Kapinska, Powerful AGN and their Host Galaxies Across Cosmic Time, Port Douglas, Australia, June 2014

Data reduction update
James Allen, SAMI Busy Week, Sydney, Australia, June 2014

Multiple Component Spectral Line Fitting
Rebecca McElroy, SAMI Busy Week, Sydney, Australia, June 2014

Star Formation Gradiants and Galaxy Environments
Adam Schaefer, SAMI Busy Week, Sydney, Australia, June 2014

The MWA All-Sky Survey and its first science
Anna Kapinska, SPARCS (SKA Pathfinders Radio Continuum Surveys) 2014 meeting, Catania, Italy, June 2014

Infall and outflow in the halo of the Milky Way
Vanessa Moss, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Low-frequency radio emission from ultracool dwarfs
Cleo Loi, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Spectral Modelling of an Extreme Gigahertz-Peaked Spectrum Source PKS 0008-41
Joe Callingham, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

SN 2012fr and High-Velocity Features in Type Ia Supernovae
Mike Childress, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Is the best distance indicator a tape measure?
Jeremy Mould, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

The first real-time FRB
Emily Petroff, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Modelling of the Spectral Energy Distribution of Fornax A: Leptonic and Hadronic Production of High Energy Emission from the Radio Lobes
Benjamin McKinley, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Origin of cosmic chemical abundances
Edoardo Tescari, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Properties of z ~ 1-4 Galaxies
Antonios Katsianis, Astronomical Society of Australia Annual Scientific Meeting, Sydney, Australia, July 2014

Resolving The Signatures of Environmental Quenching With SAMI
Adam Schaefer, Durham University, Durham, UK, July 2014

Complete Ionisation of the Neutral Gas in the Hosts of High Redshift
Steve Curran, European Week of Astronomy and Space Science, Geneva, Switzerland, July 2014

Complete ionisation of the star-forming reservoir in high redshift active galaxies
Steve Curran, European Week of Astronomy and Space Science, Geneva, Switzerland, July 2014

What I'd be doing if I were a PhD Student right now
Brian Schmidt, Harley Wood Winter School, Sydney, Australia, July 2014

The first 1000 galaxies of the SAMI Galaxy Survey
James Allen, IAUS309: Galaxies in 3D across the Universe, Vienna, Austria, July 2014

The Formation of Slow Rotating ETGs
Lisa Fogarty, IAUS309: Galaxies in 3D across the Universe, Vienna, Austria, July 2014

Dynamical modelling of SAMI galaxies
Nic Scott, IAUS311: Galaxy masses as constraints of formation models, Oxford, UK, July 2014

HI Stacking & the Tully-Fisher Relation
Scott Meyer, ICRAR Student Day, Perth, Australia, July 2014

PST: Status, Review, Discussion
Willem van Straten, SKA CSP TIM#3, Florence, Italy, July 2014

Large Gpc Volume Simulations of Reionization Based on Semi-Analytic Galaxy Formation Models
Hansik Kim, 12th Asia-Pacific Regional IAU Meeting (APRIM) 2014, Daejeon, South Korea, August 2014

Simulated star formation rate functions at z ~ 4–7, and the role of feedback in high-z galaxies
Edoardo Tescari, 12th Asia-Pacific Regional IAU Meeting (APRIM) 2014, Daejeon, South Korea, August 2014

The Taipan Survey: Cosmology from the Nearby Universe
Matthew Colless, Asia-Pacific Regional IAU Meeting, Daejeon, Korea, August 2014

Space Situational Awareness with the Murchison Widefield Array
Benjamin McKinley, Defence Science and Technology, Melbourne, Australia, August 2014

SAMI-Sydney AAO Integral Field Spectrograph
Julia Bryant, Fibre Optics in Astronomy IV, Harvard, USA, August 2014

The Other 95% (Of the Universe)
Katie Mack, Science Foo Camp, USA, August 2014

The Range of Ejected Masses in Type Ia Supernovae
Richard Scalzo, Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A, Coffs Harbour, Australia, August 2014

A pursuit of transient radio sources
Manisha Caleb, Women in Astronomy Workshop, ANU Canberra, August 2014

Cosmological constraints on dark energy
Tamara Davis, CoEPP/CAASTRO Joint Workshop 2014, Australia, September 2014

Dark Matter Halos and Cosmic Evolution
Katie Mack, CoEPP/CAASTRO Joint Workshop 2014, Australia, September 2014

The impact of space activities on science
Brian Schmidt, European Space Agency (ESA) 50 Years Scientific event, Geneva, Switzerland, September 2014

BIGHORNS – Broadband Instrument for Global HydrOgen ReioNisatioN Signal
Marcin Sokolowski, ICRAR-CON, Perth, Australia, September 2014

Detecting Neutral Hydrogen in really high redshift galaxies with the MWA
Randall Wayth, ICRAR-CON, Perth, Australia, September 2014

Detecting Variables with MWA
Paul Hancock, ICRAR-CON, Perth, Australia, September 2014

The Fast Radio Burst Hunter
Steven Tremblay, ICRAR-CON, Perth, Australia, September 2014

The simulated cluster project
Weiguang Cui, ICRAR-CON, Perth, Australia, September 2014

Black Holes meet Cancer Therapy: Supernovae meets Diabetes
Ilana Feain, Ingham Institute, Sydney, Australia, September 2014

The neutral hydrogen content of galaxies in the GAMA survey: an HI stacking experiment
Attila Popping, The role of Hydrogen in the Evolution of Galaxies, Malaysia, September 2014

The SAMI Galaxy Survey: the origin of gas in galaxies
Julia Bryant, The role of Hydrogen in the Evolution of Galaxies, Malaysia, September 2014

The Range of Ejected Masses in Type Ia Supernovae
Richard Scalzo, Type Ia supernovae: progenitors, explosions and cosmology conference, Chicago USA, September 2014

Polarisation with the Extended MWA
Emil Lenc, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Searching for the Synchrotron Cosmic Web with the Murchison Widefield Array
Bryan Gaensler, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Measuring the Global EoR Signal Using the Moon and an Extended MWA
Ben McKinley, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Processing (Future) MWA Data with the (Future) RTS
Bart Pindor, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Implications of MWA extensions for estimation of the EoR signal
Cathryn Trott, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Science case for higher time resolution than the current voltage capture system
Ramesh Bhat, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Workshop summary
Randall Wayth, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Extended MWA capabilities for transients and variability
Tara Murphy, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Options for GLEAM2
Lister Staveley-Smith, Extended Capabilities for the Murchison Widefield Array, Sydney, Australia, October 2014

Complementary infrared surveys
Jeremy Mould, Large Synoptic Survey Telescope meeting, Melbourne, Australia, October 2014

Young and Frustrated: Studying GPS/CSS sources with the MWA
Joe Callingham, MWA Radio Galaxy Workshop, Perth, Australia, October 2014

Real time discovery of Fast Radio Bursts
Emily Petroff, Transient Phenomena in Astronomy and Astrophysics, Washington, USA, October 2014

The Demography of Fast Radio Bursts from Cosmological Simulations
Bryan Gaensler, Transient Phenomena in Astronomy and Astrophysics, Washington, USA, October 2014

Everything you wanted to know about diffuse polarisation but were afraid to ask
Emil Lenc, Bolton Symposium, Sydney, Australia, November 2014

The True Nature of offset AGN
James Allen, Bolton Symposium, Sydney, Australia, November 2014

CAASTRO Research – The Evolving Universe Overview
Stuart Wyithe, CAASTRO Annual Retreat 2014, Australia, November 2014

Creating a Radio Source Catalogue for Calibration and Peeling
Jack Line, CAASTRO Annual Retreat 2014, Australia, November 2014

Dark Matter in the Cosmic Context
Katie Mack, CAASTRO Annual Retreat 2014, Australia, November 2014

Gender Action Committee Overview and activities
Rachel Webster, CAASTRO Annual Retreat 2014, Australia, November 2014

OzPipe: The Australian MWA EoR Power Spectrum Pipeline
Bart Pindor, CAASTRO Annual Retreat 2014, Australia, November 2014

All you need to know about the MWA … but were afraid to ask
Emil Lenc, CAASTRO Annual Retreat 2014, Australia, November 2014

Studying GPS/CSS sources with the MWA
Joe Callingham, CAASTRO Annual Retreat 2014, Australia, November 2014

The Demography of Fast Radio Bursts from Cosmological Simulations
Bryan Gaensler, CAASTRO Annual Retreat 2014, Australia, November 2014

Waves in the sky: Probing the ionosphere with the Murchison Widefield Array
Cleo Loi, CAASTRO Annual Retreat 2014, Australia, November 2014

Parkes HI intensity mapping experiment
Jonghwan Rhee, CAASTRO Annual Retreat 2014, Australia, November 2014

Active galactic nuclei as powerful cosmic probes and the role of OzDES
Anthea King, CAASTRO Annual Retreat 2014, Australia, November 2014

Lessons from BICEP2
David Parkinson, CAASTRO Annual Retreat 2014, Australia, November 2014

Theoretical Modelling of the WiggleZ Galaxy Power Spectrum
Caitlin Adams, CAASTRO Annual Retreat 2014, Australia, November 2014

CAASTRO Research – The Dark Universe Overview
Tamara Davis, CAASTRO Annual Retreat 2014, Australia, November 2014

Background and Noise Estimation
Paul Hancock, CAASTRO Annual Retreat 2014, Australia, November 2014

BIGHORNS: Broadband Instrument for the Global HydrOgen Reionisation Signal
Marcin Sokolowski, CAASTRO Annual Retreat 2014, Australia, November 2014

Comparing the 2MTF and 6dFGS Peculiar Velocity Surveys to models from redshift surveys
Christopher Springob, CAASTRO Annual Retreat 2014, Australia, November 2014

How do you do Slow transients?
Tara Murphy, CAASTRO Annual Retreat 2014, Australia, November 2014

Outreach and Education in CAASTRO
Steven Tingay, CAASTRO Annual Retreat 2014, Australia, November 2014

CAASTRO Research – The Dynamic Universe Overview
Evan Keane, CAASTRO Annual Retreat 2014, Australia, November 2014

How do you do fast transients?
Evan Keane, CAASTRO Annual Retreat 2014, Australia, November 2014

Supernovae and FRBs
Evan Keane, CAASTRO Annual Retreat 2014, Australia, November 2014

SUPERB
Evan Keane, CAASTRO Annual Retreat 2014, Australia, November 2014

High z (z = 20) GRBs
Jeremy Mould, CAASTRO Annual Retreat 2014, Australia, November 2014

The Range of Ejected Masses in Type Ia Supernovae
Richard Scalzo CAASTRO Annual Retreat 2014, Australia, November 2014

OzDES: early results and progress
Fang Yuan, CAASTRO Annual Retreat 2014, Australia, November 2014

Photometric Calibration in Supernova Surveys
Bonnie Zhang, CAASTRO Annual Retreat 2014, Australia, November 2014

Population studies of Fast Radio Bursts using Monte Carlo simulations
Manisha Caleb, CAASTRO Annual Retreat 2014, Australia, November 2014

Cosmological covariance with the Halo model
Steven Murray, CAASTRO Annual Retreat 2014, Australia, November 2014

The neutral hydrogen content of galaxies in the GAMA survey: an HI stacking experiment
Attila Popping, CAASTRO Annual Retreat 2014, Australia, November 2014

The galaxy clusters from hydro-dynamical simulations
Weiguang Cui, CAASTRO Annual Retreat 2014, Sydney, Australia, November 2014

Kinematically offset AGN: Binary supermassive black holes
James Allen, CAASTRO Annual Retreat 2014, Australia, November 2014

Better galaxy scaling relations with SAMI
Nicholas Scott, CAASTRO Annual Retreat 2014, Australia, November 2014

Exploring 7.7 billion years of HI with ASKAP
James Allison, CAASTRO Annual Retreat 2014, Australia, November 2014

Complete Ionisation of the Neutral Gas in the Hosts of High Redshift AGN as traced through HI and MgII Absorption
Stephen Curran, CAASTRO Annual Retreat 2014, Australia, November 2014

Exploring the Dynamic Universe with the SKA and its pathfinders
Tara Murphy, CAASTRO Annual Retreat 2014, Australia, November 2014

The first real-time fast radio burst detection: polarization and multi-wavelength follow-up of a radio transient
Emily Petroff, CAASTRO Annual Retreat 2014, Australia, November 2014

Taking the pulse of the cosmos with Molonglo
Chris Flynn, CAASTRO Annual Retreat 2014, Australia, November 2014

The Molonglo pulsar timing programme
Fabian Jonkowski, CAASTRO Annual Retreat 2014, Australia, November 2014

The SAMI Galaxy Survey: finding and classifying kinematically perturbed galaxies
Jessica Bloom, CAASTRO Annual Retreat 2014, Australia, November 2014

A Novel Data Archive for SAMI
Iraklis Konstantopoulos, CAASTRO Annual Retreat 2014, Australia, November 2014

The SKA view of Gamma-ray Bursts
Davide Burlon, Italian Scientists Down Under, Italian Embassy, Canberra, Australia, November 2014

Using the FAST Radio Telescope to Detect Quasar HII Regions during the EoR
Tristan Reynolds, Mt Stromlo Christmas Seminars, Australia, November 2014

Large Scale Pulsar Timing
Fabian Jankowski, The 2014 Orange Pulsar meeting, Melbourne, Australia, November 2014

Searching for fast radio bursts in pulsar surveys
Emily Petroff, The 2014 Orange Pulsar meeting, Melbourne, Australia, November 2014

SUPERB
Evan Keane, The 2014 Orange Pulsar meeting, Melbourne, Australia, November 2014.

High time resolution science with the Murchison Widefield Array
Ramesh Bhat, The 2014 Orange Pulsar meeting, Melbourne, Australia, November 2014

Galaxy haloes at high redshift: outflow vs pre-enrichment
Emma Ryan-Weber, The Periphery of Disks, Australia, November 2014

Environmental Effects in Overdense Regions
Lister Staveley-Smith, The Periphery of Disks, Sydney, Australia, November 2014

Inferring Explosion Properties of Type I Supernovae
Richard Scalzo, Australian Frontiers of Science, CBR Australia, December 2014

Panel discussion and interview with Dr John O'Sullivan
Brian Schmidt, Australian Frontiers of Science, Canberra, Australia, December 2014

The Cosmological HI Power Spectrum Estimator
Cathryn Trott, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

Modelling the Spectral Energy Distribution of Fornax A
Ben McKinley, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

Processing MWA EOR Data with the RTS
Bart Pindor, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

Waves in the sky: Probing the ionosphere with the Murchison Widefield Array
Cleo Loi, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

Young and Frustrated: Studying GPS/CSS sources with the MWA
Joe Callingham, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

Radio Galaxy Zoo – Part II: The users
Anna Kapinska, EMU/POSSUM/GALFACTS meeting 2014, Australia, December 2014

Polarimetry with ASKAP and BETA (II) - A secondee's perspective
Emil Lenc, EMU/POSSUM/GALFACTS meeting 2014, Australia, December 2014

Positional Updating and Matching Algorithm (PUMA)
Jack Line, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

SUPERB
Evan Keane, FRB Workshop, Melbourne, Australia, December 2014

The first Real-time FRB
Chris Blake, Frontiers of Science, Australia, December 2014

Polarisation Update
Emil Lenc, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

The Brilliance of GLEAM: NGC253 and the Sculptor Group
Anna Kapinska, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

The MWA Exoplanet Survey
Tara Murphy, Early Science for Low Frequency Telescopes, Tempe, Arizona, USA, December 2014

Balmer decrements, binning and star formation rates with SAMI
Adam Schaefer, SAMI Busy Week, Melbourne, Australia, December 2014

Gas alignment in galaxies
Julia Bryant, SAMI Busy Week, Melbourne, Australia, December 2014

Probing Hα Aperture Correction with SAMI
Samuel Richards, SAMI Busy Week, Melbourne, Australia, December 2014

The True Nature of offset AGN
James Allen, SAMI Busy Week, Melbourne, Australia, December 2014

Everything you wanted to know about the Universe but were afraid to ask
Brian Schmidt, STEMFest 2014, Adelaide Roma Mitchell Secondary College , Adelaide, December 2014

CAASTRO Annual Retreat 2014
Credit: Jacinta Den Besten

International Visitors to CAASTRO in 2014

Simona Bekeraite
Leibniz Institute for Astrophysics Potsdam, Germany

Jamie Bolton
University of Nottingham, UK

Steve Curran
University of Victoria, New Zealand

Roger Davies
University of Oxford, UK

Julius Donnert
Istituto di Radioastronomia, Bologna, Italy

Richard Easther
University of Auckland, New Zealand

Bjorn Emonts
CSIC-NTO (Centro de Astrobiologica), Madrid, Spain

Stephen Fine
University of Western Cape in South Africa, South Africa

Martha Haynes
Cornell University, USA

George Heald
ASTRON, Amsterdam, The Netherlands

John Hillier
University of Pittsburgh, USA

Assaf Horesh
Weizmann Institute of Science, Israel

Jeremy Howard
University of San Francisco, USA

Garth Illingworth
University of California Observatories, USA

Huib Intema
National Radio Astronomy Observatory, New Mexico, US

David Kaplan
University of Wisconsin, USA

Wolgang Kerzendorf
University of Toronto, Canada

Robert Kirschner
Harvard-Smithsonian Center for Astrophysics, USA, USA

Roland Kothes
National Research Council, Canada

Tom Landecker
Dominion Radio Astrophysical Observatory, Penticton, Canada

Bruno Leibundgut
ESO Office for Science, Germany

Nicholas Mahany
Franklin & Marshall College, USA

Raffaella Margutti
Harvard-Smithsonian Center for Astrophysics, USA

Paolo Mazzali
Astrophysics Research Institute, John Moores University, Liverpool, UK

Fulvio Melia
University of Arizona, USA

Kunal Mooley
California Institute of Technology, USA

Cherry Ng
Max Planck Institute for Radio Astronomy, Germany

Ken'ichi Nomoto
University of Tokyo, Japan

Elena Pian
INAF Institute of Space Astrophysics and Cosmic Physics, Italy

Amrita Purkayastha
Istituto di Radioastronomia, Bologna, Italy

Kevin Schawinski
ETH Zurich, Switzerland

Volker Springel
Heidelberg Institute for Theoretical Studies, Germany

Ravi Subrahmanyan
Raman Research Institute, India

Nathan Tehrani
West Virginia University, USA

Caterina Tiburzi
Osservatorio Astronomico di Cagliari, Italy

Tony Willis
Dominion Radio Astrophysical Observatory, Penticton, Canada

Tim de Zeeuw
European Southern Observatory, Garching, Germany

Visits to overseas laboratories and facilities in 2014

Martin Bell
Arizona State University, USA

Joe Callingham
Arizona State University, USA

Bryan Gaensler
Arizona State University, USA

Jack Line
Arizona State University, USA

Cleo Loi
Arizona State University, USA

Ben McKinley
Arizona State University, USA

Tara Murphy
Arizona State University, USA

Pietro Procopio
Arizona State University, USA

Brian Schmidt
Arizona State University, USA

Rachel Webster
Arizona State University, USA

Danail Obreschkow
ASTRON, The Netherlands

Se-Heon Oh
ASTRON, The Netherlands

Lister Staveley-Smith
ASTRON, The Netherlands

Attila Popping
ASTRON, The Netherlands

James Allison
ASTRON, The Netherlands

Ewan Barr
Auckland University of Technology, New Zealand

Willem van Straten
Auckland University of Technology, New Zealand

Matthew Bailes
California Institute of Technology, USA

Brian Schmidt
California Institute of Technology,

Bryan Gaensler
Canadian Institute for Theoretical Astrophysics, Toronto, Canada

Richard Scalzo
Carnegie Observatories in Pasadena, USA

Anna Kapinska
Catania Observatory, Catania, Italy

Stuart Wyithe
Catania Observatory, Catania, Italy

Jonghwan Rhee
Center for Astronomy & Astrophysics, Shanghai Jiao Tong University, China

Lister Staveley-Smith
Center for Astronomy & Astrophysics, Shanghai Jiao Tong University, China

Bryan Gaensler
Centre d'Etudes de Saclay, Paris, France

Attila Popping
Columbia University, New York, USA

Brian Schmidt
Dark Cosmology Centre, The Niels Bohr Institute, Denmark

Bryan Gaensler
Dunlap Institute for Astronomy and Astrophysics, Toronto, Canada

James Allen
European Southern Observatory, Garching, Germany

James Allison
University of Oxford, UK

Ramesh Bhat
Giant Meterwave Radio Telescope, India

Ramesh Bhat
International Union of Radio Science, Beijing, China

Chris Blake
University of California (Berkeley), USA

Chris Blake
University of Canterbury, New Zealand

Chris Blake
University of Illinois, USA

Davide Burlon
University of Trieste – INAF Trieste Astronomical Observatory, Italy

Mike Childress
Keck Telescope, Hawai'i, USA

Mike Childress
Queen's University Belfast, Ireland

Mike Childress
Southampton University, UK

Mike Childress
University of Hawai'i, USA

Matthew Colless
European Southern Observatory, Garching, Germany

Weiguang Cui
Leiden University, The Netherlands

Tamara Davis
Institute of Astronomy and Astrophysics, Taiwan

Tamara Davis
Lawrence Berkeley National Laboratory, USA

Tamara Davis
University of Auckland, New Zealand

Tamara Davis
University of Hawai'i, USA

Tamara Davis
University of Illinois, USA

Alan Duffy
University of Manchester, UK

Alan Duffy
University of Nottingham, UK

Lisa Fogarty
European Southern Observatory, Garching, Germany

Lisa Fogarty
Gemini South, La Serena, Chile

Lisa Fogarty
Institute of Astronomy, Cambridge, UK

Lisa Fogarty
University of Oxford, UK

Bryan Gaensler
École Normale Supérieure, Paris, France

Bryan Gaensler
Institut d'Astrophysique Spatiale, Paris, France

Bryan Gaensler
Leiden University, The Netherlands

Bryan Gaensler
Observatoire de Paris, Paris, France

Bryan Gaensler
Radboud University Nijmegen, Nijmegen, The Netherlands

Bryan Gaensler
Square Kilometre Array Office, Jodrell Bank, UK

Bryan Gaensler
Université Paris Diderot, Paris, France

Bryan Gaensler
Université Pierre et Marie Curie, Paris, France

Bryan Gaensler
University of Amsterdam, The Netherlands

Bryan Gaensler
University of Groningen, The Netherlands

Anna Kapinska
Institute of Cosmology and Gravitation, University of Portsmouth, UK

Anna Kapinska
Texas Tech University, USA

Antonios Katsianis
Laboratoire d'Astrophysique de Marseille, Université d'Aix-Marseille, France

Eyal Kazin
Kavli Institute for the Physics and Mathematics of the Universe, Tokyo, Japan

Eyal Kazin
University of Oslo, Norway

Evan Keane
SKA Project Office, Manchester, Jodrell Bank, UK

Hansik Kim
Korea Institute for Advanced Study, South Korea

Hansik Kim
Kyungpook National University, South Korea

Anthea King
Royal Observatory, University of Edinburgh, UK

Anthea King
University of St Andrews, UK

Anthea King
University of Sussex, UK

Jun Koda
Kavli Institute for the Physics and Mathematics of the Universe, Tokyo, Japan

Emil Lenc
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Emil Lenc
University of California (Berkeley), USA

Jack Line
Penn State University, USA

Jack Line
University of California (Berkeley), USA

Jean-Pierre Macquart
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Felipe Marin
Fundación Centro de Estudios de Física del Cosmos de Aragón, Spain

Felipe Marin
Max Planck Institute for Astronomy, Heidelberg, Germany

Felipe Marin
University of Bologna, Italy

Jeremy Mould
Munich Institute for Astro- and Particle Physics, Germany

Se-Heon Oh
Universidad Autónoma de Madrid, Spain

Pietro Procopio
University of California (Berkeley), USA

Mayuri Rao
Raman Research Institute, Bangalore, India

Jonghwan Rhee
Korean Astronomy and Space Science Institute, Korea

Jonghwan Rhee
National Astronomical Observatories, Chinese Academy of Sciences, China

Jonghwan Rhee
Shanghai Astronomical Observatory, China

Jennifer Riding
Penn State University, USA

Jennifer Riding
University of California (Berkeley), USA

Ashley Ruiter
University of Illinois at Urbana-Champaign, USA

Elaine Sadler
European Southern Observatory, Garching, Germany

Richard Scalzo
Harvard-Smithsonian Center for Astrophysics, USA

Richard Scalzo
Stony Brook University, USA

Richard Scalzo
University of Pittsburg, USA

Adam Schaefer
Durham University, Durham, UK

Brian Schmidt
Institut Teknologi Bandung, Indonesia

Brian Schmidt
Johannes Gutenberg–Universität Mainz, Germany

Brian Schmidt
Kapteyn Astronomical Institute, Groningen, The Netherlands

Brian Schmidt
Munich Institute of Astro- and Particle Physics, Germany

Brian Schmidt
Miraikan National Museum of Emerging Science and Innovation, Japan

Brian Schmidt
Nanyang Technological University, Singapore

Brian Schmidt
Queen's University Belfast, Ireland

Brian Schmidt
Queen's University Kingston, Canada

Brian Schmidt
Radboud University Nijmegen, The Netherlands

Brian Schmidt
University of Auckland, New Zealand

Brian Schmidt
University of Southampton, UK

Brian Schmidt
University of Toronto, Canada

Nic Scott
European Southern Observatory, Garching, Germany

Nic Scott
University of Oxford, UK

Ivo Seitenzahl
University of Illinois at Urbana-Champaign, USA

Lister Staveley-Smith
National Astronomical Observatories Chinese Academy of Sciences, China

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Edoardo Tescari
Korea Institute for Advanced Study, South Korea

Edoardo Tescari
University of Trieste – INAF Trieste Astronomical Observatory, Italy

Cath Trott
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Syed Uddin
University of Illinois, USA

Rachel Webster
University of Auckland, New Zealand

Rachel Webster
University of California (Berkeley), USA

Chris Wolf
European Southern Observatory, Garching, Germany

Chris Wolf
Max-Planck-Institut für Astronomie, Heidelberg, Germany

Chris Wolf
University of Oxford, UK

Stuart Wyithe
Harvard-Smithsonian Center for Astrophysics, USA

Bonnie Zhang
Keck Telescope, Hawaii, USA

WORKSHOPS

CAASTRO hosted a number of interesting, well attended and stimulating workshops during 2014.

SkyMapper Workshop

In April 2014, almost fifty people came together for three days in the Commonwealth Solar Observatory Building at Mt Stromlo outside Canberra, to attend a CAASTRO workshop on the SkyMapper telescope. There has been high expectation of SkyMapper for several years, however a diverse range of challenges had delayed it. The telescope started its long-awaited survey only weeks before the workshop, so it was a good time to bring together the builders and users of the survey.

Starting the workshop, the then CAASTRO Director, Bryan Gaensler, reminded attendees of SkyMapper's cornerstone role in CAASTRO and its synergy with a host of other Australian all-sky projects. Brian Schmidt ran through SkyMapper's history, which brought back memories of bushfires, broken filters and ladybug invasions. Christian Wolf updated attendees on the current plan and progress with the telescope, now commissioned, and the survey strategy, the progress of projects, and updated science priorities.

The afternoon of the workshop was dedicated to technical and performance aspects of SkyMapper, including ideas for maximising the quality of data distributed to the community. The highlight of this session was a demonstration by Simon Murphy (formerly ANU, now at the University of Heidelberg) of how the SkyMapper data will be accessed through the Virtual Observatory. This facility now offers powerful and versatile tools.

On the morning of the second day, SkyMapper's work on variable phenomena was discussed, including the supernova survey, target-of-opportunity alerts, GRBs, FRBs, and the potential to look for gravitational waves. Brad Tucker (ANU) introduced a session on SkyMapper's support for the extended mission of the Kepler Space Telescope, the world's most powerful tool for the study of micro variability. This session had a focus on initiatives for exploiting synergies between SkyMapper and Kepler.

The afternoon was devoted to the subject of galaxy evolution, with a focus on a holistic approach to understanding all the components that contribute to a galaxy's evolution. This included presentations on active nuclei, the fate of gas in light of feedback, and the complications introduced by dust. The session also covered multi-wavelength approaches, as well as combining SkyMapper observations with data from the Australian SKA Pathfinder, spectroscopic instruments, and from the German-Russian eROSITA mission.

The final day of the workshop brought the focus back to one of SkyMapper's core strengths: the mapping of stars and the structure of the Milky Way. A report on the early discovery of the most metal-poor and pristine star known in the Universe found in early observations of SkyMapper was a highlight.

There is strong support for the SkyMapper team to focus on an early data release in 2015 (a preliminary calibration, but it will cover the whole sky to shallow limits), before progressing to implement the longer-term strategy. SkyMapper is now an Australian national facility, with an ARC LIEF grant led by CAASTRO paying for its operation over the next five years. The workshop was also an opportunity for the new SkyMapper Executive Committee to meet for the first time. Overall, the workshop made clear that the community's commitment to SkyMapper is strong and that there is a growing interest in the science opportunities that it offers.

LSST Workshop, AAO, Sydney
Credit: Andy Green

The Stawell mine.
Credit: Jeremy Mould

Large Synoptic Survey Telescope (LSST) Roadshow

The Large Synoptic Survey Telescope (LSST) is an 8.4-m optical and infrared telescope about to commence construction on Cerro Pachón, Chile. CAASTRO, in conjunction with AAO, ANU, Swinburne and ICRAR hosted an LSST roadshow in Sydney, Canberra, Melbourne and Perth during 27–31 October 2014.

LSST offers many scientific opportunities and synergies for Australian astronomers. The aim of the roadshow was to initiate discussion about Australian participation in LSST. Our special guests for these events were Professor Steven Kahn (LSST Director) and Professor Željko Ivezić (LSST Project Scientist).

Each workshop featured LSST overviews from Professors Kahn and Ivezić, and contributed talks from Australian astronomers on proposed LSST science. There was strong and positive discussion about LSST and Australian participation at each location.

LSST as an all-southern-sky, imaging survey, is highly complementary to the Australian community's interest in large-scale radio and spectroscopic surveys. At present Australia does not have access to contiguous digital optical imaging in the southern hemisphere (Sloan Digital Sky Survey, SDSS, only covers 2200 square degrees south of +10 deg declination). While SkyMapper improves this situation, in terms of the static sky, the main advantage of LSST over other large area surveys is in the expected average seeing of 0.7 arcsecond which allows better star-galaxy separation.

Over the 10-year period 2022 to 2032, LSST will image 18,000 deg^2 of the sky in six bands, visiting every position about 800 times to reach a final co-added magnitude limit r = 27.5. LSST will be transformational for a wide range of topics in astronomy, including weak lensing, baryon accoustic oscillation studies, supernovae, near-Earth objects, stellar astronomy, galaxy evolution, Galactic structure and transients. LSST will also explore new frontiers in astronomy data management, producing 30 TB of data and approximately one million transient alerts per night.

ASKAP Commissioning & Early Science (ACES) Busy Weeks

Over the past year the ASKAP Commissioning and Early Science (ACES) Team has been holding regular busy weeks to combine in-house CSIRO expertise with University researchers from across Australia. Led by Dave McConnell, the team includes CAASTRO research fellows Emil Lenc, Attila Popping and Pietro Procopio, and affiliates James Allison, Keith Bannister and Martin Bell. The novel phased-array feed technology, already being used with the 6-antenna test array, enables astronomers to produce a single image that would normally take multiple observations with a traditional interferometer. These activities have produced impressive results, with fantastic images of the radio sky, containing thousands of distant active galaxies. Stay tuned in 2015 for a number of early science papers, including discoveries of jet-gas interactions in young radio galaxies (Allison *et al.*, submitted to MNRAS), wide-field imaging and kinematics of HI gas in galaxy groups (Serra *et al.*, in prep.) and monitoring of intermittent pulsars (Hobbs *et al.*, in prep.).

Members of the ASKAP Commissioning and Early Science Team during one of their busy weeks.
Credit: CSIRO

MWA Workshop

The MWA expansion workshop was held at CAASTRO headquarters at the University of Sydney during 15–16 October. The purpose of the workshop was to share the MWA Director Steven Tingay's vision for future phases of expansion for the MWA and for science teams to discuss new science programs that could be supported by an enhanced MWA.

The workshop was well attended with representatives from all the MWA key science programs and from CSIRO, CAASTRO and the MWA Board. The presentations covered a myriad of topics, from ambitious new science like detecting the cosmic web to practical issues of maintaining radio-quietness at the Murchison Radio-astronomy observatory.

The meeting concluded with MWA Staff Scientist Randall Wayth presenting a proposed timeline for concluding array configuration discussions and the Director's plan for securing funding and expansion in 2015. The MWA is an active and productive telescope, and its future is exciting.

Early Science from Low-Frequency Radio Telescopes meeting in Tempe Arizona.
Credit: Emil Lenc

CoEPP/CAASTRO Joint Workshop

In February 2013, CAASTRO and the ARC Centre of Excellence of Particle Physics at the Terrascale (CoEPP) held their first joint Dark Universe meeting at The University of Melbourne. One of the outcomes of that meeting was a decision to pursue an Australian dark-matter direct detection experiment. Towards the end of 2013, the Northern Grampians Shire Council contacted CAASTRO's Katie Mack, interested in her description of direct detection experiments overseas. This idea was progressed by CoEPP, and members of the Melbourne and Swinburne Physics groups began talks with the managers of the mine to discuss the possibility of using a portion of the mine as an underground physics lab.

The 2nd CAASTRO CoEPP joint workshop, which occurred at the Seppelts Winery in the rural Victorian town of Great Western over 28–30 September 2014, was an opportunity to build on those collaborations and to make concrete plans for an exciting new opportunity in dark-matter research. In addition to bringing together local and international experts on all aspects of dark-matter research, the workshop was also designed around introducing the scientific community to a proposal for the dark-matter detector in the Stawell gold mine.

Attendees at the workshop included members of a preliminary collaboration with scientists at the INFN in Italy, as well as the Science Attaché for the Italian Embassy. Discussions at the workshop touched upon the radiation and cosmic-ray-shielding conditions at the Stawell mine, both of which appear to be acceptable. CoEPP has already received encouragement from the local Stawell council, and several public meetings have shown a great deal of community support.

Women in Astronomy Conference, ANU
Credit: Ruth Maddison

2014 Women in Astronomy Workshop

In 2014 CAASTRO supported the annual Astronomy Society of Australia Women in Astronomy workshop held in Canberra during 28–29 August 2014. Over the past three years the workshop has explored the important issues of unconscious biases and leadership development for women. The theme this year was "We are all made of stars: establishing equity and diversity within Australian Astronomy".

Attendees at the Workshop included astronomers, scientists, engineers, technical and administrative staff, who examined what we as a profession can do to improve gender, racial and sex-based equity within our field.

Some high-profile speakers inspired, and encouraged change for the audience. Elizabeth Broderick, Australia's Sex Discrimination Commissioner and a highlight speaker at the conference, presented the outcomes of the "male champions of change" initiative. Gender equity does not come about by women working alone. Male champions, in their positions of influence, are standing up alongside women to give voice to gender and equity issues.

The Hon Michaelia Cash MP, Minister Assisting the Prime Minister for Women, opened the conference and said "75% of astronomers are men, so 75% of the solutions on gender in your field need to be coming from men [...] because women's issues are men's issues and in the end, they are just people issues."

Dr Cordelia Fine, an academic psychologist and Associate Professor at the Melbourne Business School, University of Melbourne, introduced us to the term 'neurosexism'. She explained how scientific studies on brain functionality have been used to reinforce gender stereotypes in ways that are often not scientifically justified.

Dr Megan Clark, Chief Executive of CSIRO, summarised the Workshop by saying that that every leader needs to be responsible for ensuring diversity within their team and setting targets to achieve this.

ASA Early Career Researcher Mentoring Workshop 2014

CAASTRO also supported the Astronomical Society of Australia (ASA) second Early Career Researcher Mentoring Workshop in 2014. The workshop took place over 2–3 June at Cedar Creek Lodges on Tamborine Mountain in the Gold Coast hinterland close to Brisbane, QLD. The purpose of the workshop was to address topics related to career progression for the future leaders in our astronomy community.

The workshop was aimed at postdocs, finishing PhD students, very junior faculty, and anyone beginning to establish themselves and looking for career guidance. The sessions included presentations and also discussions and other thought-provoking activities with participation and interaction.

CAASTRO students inspecting the ATCA dishes during the ATNF Summer School.
Credit: Emil Lenc

CONFERENCES

Supernovae in the Local Universe conference attendees
Credit: Coffs Harbour Advocate

SUPERNOVAE IN THE LOCAL UNIVERSE

Coffs Harbour NSW, 10-15 August 2014

CAASTRO's "Supernovae in the Local Universe" was held during 10–15 August 2014 at Coffs Harbour in NSW and was the second in the annual series of CAASTRO conferences in wide-field astronomy. The meeting was successful attracting over 140 professional astronomers from 24 countries to Coffs Harbour to celebrate the life and death of an exploding star.

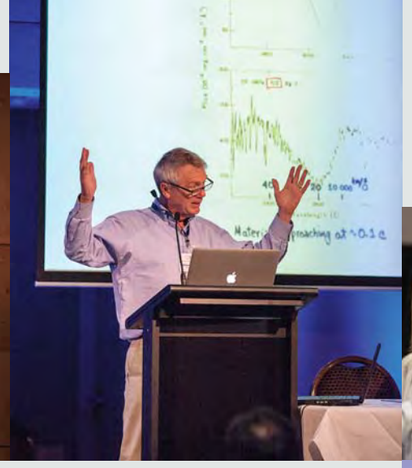
Exploding stars, supernovae, are not just a curiosity: they made all the gold, platinum, cobalt, nickel, and lead we have on Earth. With his colleagues, Brian Schmidt used exploding stars to measure the expansion of the universe, for which he was awarded the Nobel Prize in Physics in 2011.

The week-long conference particularly celebrated one star seen exploding in 1987 — 10,000 days ago.

Called supernova 1987A, it was the brightest exploding star seen since telescopes were developed, and the one that most changed our understanding of what happens in these events.

SN 1987A was a supernova in the outskirts of the Tarantula Nebula in the Large Magellanic Cloud, a nearby dwarf galaxy. It occurred approximately 160,000 light-years from earth, close enough that it was visible to the naked eye in the southern hemisphere. It was the closest observed supernova since SN 1604, which occurred in the Milky Way itself.

The light from the new supernova reached earth on February 23, 1987. As it was the first supernova discovered in 1987, it was labelled '1987A'. It was the first opportunity for modern astronomers to see a supernova up close, and observations have provided much insight into core-collapse supernovae.



Supernovae in the Local Universe Conference.
Credit: CAASTRO

Participants included Kate Scholberg (neutrino hunter from Duke University, USA) and the renowned amateur supernova hunter, the Reverend Bob Evans. Dick McCray gave an excellent overview of the remnant around SN 1987A. The conference also marked the 65th birthday of supernova supremo Professor Robert (Bob) Kirshner of Harvard University.

Science highlights from the conference include the discovery that a very high fraction of massive stars have companions, as well as the very first detection by the Hubble Space Telescope of a star whose white dwarf companion exploded as a faint thermonuclear supernova. Scientists at the conference also presented an array of novel techniques for finding and studying supernovae, such as the Gaia and Kepler satellites, massive neutrino detectors, and new facilities hunting for elusive gravity waves.

SN 1987A itself was the focus of many science talks at the conference, with astronomers presenting observations spanning from ultra-high-energy gamma-rays and X-rays, through visible and infrared light, down to the lowest-energy radio wavelengths. After nearly thirty years, this unique event continues to inspire and inform astronomers about the fundamental nature of exploding stars.

This conference received a large amount of media interest, with two articles in the local newspaper *Coffs Harbour Advocate*, a segment on both the Prime and NBN TV News, and a number of foreign language SBS radio appearances from the conference's invited speakers. It was a very successful week of science and networking.

CAASTRO ANNUAL RETREAT

The 2014 CAASTRO Annual Retreat took place in relaxing surroundings at Twin Waters, on the Sunshine Coast in Queensland, over 19–21 November, and was attended by almost 100 members of CAASTRO. Attendees enjoyed a stimulating program of science talks and networking activities, including invited talks from overseas visitors Professor Volker Springel (the University of Heidelberg) and Dr Huib Intema (National Radio Astronomy Observatory). Volker Springel spoke on hydrodynamical simulations of galaxy formation, and in particular how they have progressed in the last few years; Huib Intema spoke on how to correct for ionospheric distortions when making low-frequency radio observations.

The program packed in overviews of the CAASTRO themes, detailed talks on projects within the themes, and free-ranging panel discussions, including an overview of the opportunities in Australian astronomy. Although the program had a focus on science, time was also found for a speed mentoring session and, on the Friday, an informal breakfast for women in CAASTRO. In another step forward for gender equity, the prizes for best poster, best talk, best student talk and best student poster were all won by women: Rebecca McElroy, Emily Petroff, Cleo Loi and Mayouri Rao.

There was also a session that allowed teams to create short videos to highlight their science. The end result (of eight short video entries) was a great success. (As)tropfrest is available for viewing on the CAASTRO YouTube channel.

Many of the projects discussed at the meeting, such as SAMI, some of the MWA projects, and the upgrade of MOST, were still being planned at the time of previous CAASTRO retreats, but are now beginning to produce results, to the clear satisfaction of both speakers and listeners.

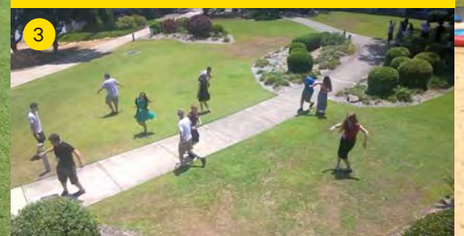
Now former CAASTRO Director Bryan Gaensler was farewelled in style at the conference dinner, with Lister Staveley-Smith (UWA), Anne Green (Sydney), Steven Tingay (Curtin), Kate Gunn (Sydney) and new Director Elaine Sadler (Sydney) all praising his leadership.

The Annual Retreat ran very smoothly, thanks to the hard work of the CAASTRO A-team. Special thanks are due to Kylie Williams for planning and running many excellent CAASTRO events during 2014.

Images from the Science in a Minute smartphone video competition.

1. **Black Holes**
2. **FRB Assault**
3. **The CAASTROic times of SAMI (ScreenShot Galaxy)**
4. **Stacking on the Beach**
5. **MWA (which took out the award for most popular movie).**

All of the movies can be found on the CAASTRO YouTube Channel



EDUCATION & OUTREACH

PhD student Jennifer Riding (Swinburne) attended a "Telescopes in Schools" observing night.
Credit: Jacinta den Besten

Visitors of "Stars in the Yarra Ranges" were well looked after by Mount Burnett Observatory members.
Credit: Roslyn Gupta

CAASTRO Voyages to the Red Centre

This year saw the start of our 'Uluru Astronomer in Residence' program with industry partner, Voyages Indigenous Tourism Australia. This program saw fourteen CAASTRO members spend two weeks each at Uluru as the CAASTRO 'Astronomer in Residence'. Under the leadership of Mike Dalley, Ayers Rock Resort Stars Department Manager, each of these astronomers spoke to the public on a daily basis in the town square about their research and CAASTRO, as well as doing some solar observing. In the evenings, the astronomers helped out with star tours and the renowned 'Sounds of Silence' dinner. This has been a fantastic experience for both astronomers and the tourists alike and the program will expand in 2015. The astronomers' adventures can be followed on the new @CAASTROatUluru Twitter account. This year's highlights included plenty of photography from Dr Sean Farrell and Dr Iraklis Konstantopoulos, Dr Richard Scalzo's visit to Yulara School, and the fantastic questions from all of the children.

The expert panel discussion with Dr Karl during the Uluru Astronomy Weekend.
Credit: Voyages

As a special signature event, National Science Week was celebrated with the Uluru Astronomy Weekend. The weekend was hosted by Dr Karl Kruzselnicki, and four prominent Australian astronomers and CAASTRO members (Professors Bryan Gaensler, Ray Norris, Steven Tingay and Rachel Webster) gave talks, demonstrations, a panel session and conversed with attendants. The weekend was very well attended with all activities well received as participants combined their interest in astronomy with the spectacular backdrop of the Australian outback.

Dr Richard Scalzo (ANU) enjoyed a visit to Yulara School in the Northern Territory.
Credit: Yulara School

Planetarium show

Our collaboration with Museum Victoria is progressing towards the production of the planetarium show "A new era of astronomy", featuring key CAASTRO projects and telescope facilities. The show will introduce the public to the concept of all-sky astrophysics as the new and unique approach that will take astronomy into the next golden age. In 2014, the collaboration's management team discussed and decided on a production script, based on which a few scenes were developed and are being reviewed by selected CAASTRO researchers who are experts on the particular topic in question. We are very excited about the previews and are looking forward to more sequences being produced and to live action filming at the two nominated telescopes sites, Siding Spring Observatory and the Murchison Radio-astronomy Observatory (MRO).

Telescopes in Schools

The University of Melbourne's "Telescope in Schools" (TiS) program just completed its third year and now boasts 11 schools and well over 3000 students having looked through the telescopes. CAASTRO has continued our proud support of this program with regular visits from members to the schools. PhD students Jennifer Riding and Antonios Katsianis are regular attendees at Gisborne Secondary College and Northcote High School, respectively. The TiS program coordinator and temporary 2014 CAASTRO outreach officer, Jacinta den Besten, always attends the school observing sessions armed with CAASTRO rulers, balls and copies of the "CAASTRO Readers Digest".

The students and teachers alike love receiving their CAASTRO merchandise and often come back asking questions about something they read in the booklet.

2015 will be an opportunity for CAASTRO to continue our connections with these schools in Melbourne's northern suburbs as the TiS program expands into more schools and the second Astrophotography competition is launched for National Science Week.

Astronaut Chris Hadfield presented at our co-sponsored "Space Oddity" event.
Credit: ScienceAlert

A Space Oddity

The team from Science Alert organized NASA Astronaut, Commander Chris Hadfield, to come out to Australia for National Science Week. Famous for his rendition of David Bowie's "A Space Oddity" in zero-G while on the International Space Station, Commander Hadfield took to the stage in sell-out shows in Sydney and Canberra to talk about his experiences and sing a song. CAASTRO Affiliate Dr Katie Mack shared the stage with the famed astronaut for all three shows talking to audiences about dark matter. Chief Investigator Professor Brian Schmidt joined the tour for the Canberra leg, taking the Commander out to Mt Stromlo and participating in the show in the evening. CAASTRO was a proud sponsor of this overwhelmingly successful event, wrapping up a huge National Science Week for 2014.

Stars in the Yarra Ranges

Our continued support for the Mount Burnett Observatory in the Yarra Ranges, north-east of Melbourne, saw six members of CAASTRO present short talks on their research to over 400 members of the public over four nights during National Science Week. The members of the amateur astronomy group organised the week-long event at various venues throughout the Yarra Ranges including local schools and the Yarra Ranges Museum. Along with telescope observing, hands-on activities and live feeds from extra-terrestrial telescopes, Dr Pietro Procopio, Mr Syed Uddin, Professor Chris Power, Professor Karl Glazebrook, Ms Emily Petroff and Dr Ewan Barr all gave very well received talks about current CAASTRO research. Each of the talks was recorded, and an overview of the week was created and can now be viewed on the CAASTRO YouTube channel. In addition to National Science Week, regular guest speakers from CAASTRO attended the Mount Burnett Observatory meetings, sharing their research and knowledge. Thanks are due to the organisation and enthusiasm of Dr James Murray, past Outreach Officer and new President, and his team at Mount Burnett as the partnership continues to flourish and CAASTRO's outreach to a wider community grows.

Public Outreach

Our researchers continue to give public talks both throughout Australia and internationally discussing their research, astronomy in general, the future of science, and equality in astronomy. We are particularly pleased that both our senior and junior members actively engage in public outreach. Ten Perth-based members offered their expertise to the around 3,000 visitors of the CAASTRO booth at the 2014 Astrofest which featured a live waterfall plot of the radio frequencies as received by a single dipole antenna of the Murchison Widefield Array. CAASTRO Partner Investigator Professor Ray Norris, CSIRO, gave a lecture on "Indigenous Astronomy and Navigation".

Professor Tamara Davis spoke at TEDxNoosa and the BrisScience Event in Brisbane before heading over to Auckland, New Zealand, to share the stage with Professor Brian Schmidt to showcase "The Dark Side of Astronomy". Naturally, Professor Schmidt's schedule is difficult to sum up briefly but he also spoke at the Universities of Western Sydney and Tasmania, took part in video broadcast panel discussions at the ANU ("The Future of Education in an Online World") and the National Library ("Seeing back to the Big Bang"), appeared at the Royal Society of Victoria fundraiser lunch, contributed to "Science at the Shine Dome", spoke in Toronto, attended the Nobel Prize Awards, and was a key presenter at the inaugural SAGE (Science in Australia Gender Equity) workshop at the Australian Academy of Science.

Nobel Laureate Prof Brian Schmidt (ANU) participated in "CAASTRO in the Chinese Classroom".
Credit: Lan Lin

PhD Student Aina Musaeva (University of Sydney) ran a "Spaceday" for four New South Wales schools.
Credit: Hill End Public School

Dr Vanessa Moss (University of Sydney) took students on a guided tour of the Universe.
Credit: Bridges to Higher Education

Dr Phil Crosby (CSIRO) ran the Professional Training workshop for CAASTRO students and postdocs.
Credit: Kate Gunn

Dr Katie Mack headed all over the world, both physically and virtually giving public talks both in person and through various podcasts, including one to India. She also explored the sounds of the Big Bang as a part of Melbourne Knowledge Week. "Pint in the Sky", hosted by her and Dr Alan Duffy, also released new podcast episodes with many more to come in 2015. Dr Duffy was also busy with regular TV spots on ABC News commenting on the latest astronomy news, and he took part in the "Science of Dr Who" tour. In addition to Professor Bryan Gaensler continuing with his regular weekly Q&A session with Linda Mottram on 702 ABC Sydney, there were many other radio spots with participation by CAASTRO members.

School Engagement

In mid 2014, local coordination of our seminar program "CAASTRO in the Classroom" (CitC), linking researchers from across Australia to schools in metropolitan and regional areas via video-conferencing technology, changed hands as we thanked Dr Jamie Farnes and Dr Shane O'Sullivan for their efforts and welcomed the University of Sydney's Dr Nicholas Scott and Dr Vanessa Moss into their new roles. The program was re-launched in a modified structure in 2014 to align sessions more closely with the science curriculum. This led to a decrease in the total number of sessions offered but the dial-up rate of schools increased, and the program ran six CitC PLUS Curriculum Revision Lectures that were attended by almost 1,000 students. In addition, the CitC Virtual Classroom allowed us to record and store sessions such that schools can include the lectures in their teaching at their convenience. Preliminary statistics from the Department of Education suggested that each lecture had been viewed more than 50 times, in particular by schools in remote New South Wales locations. We also partnered up with the Queensland Government's education service OneChannel to broadcast lectures.

Our program extension "CAASTRO in the Chinese Classroom", with enthusiastic support from Dr Fang Yuan at the ANU in Canberra, saw two sessions in 2014: on 30 May, there was a joint session by Dr Brad Tucker ("Distances across the Universe") and Dr Fang Yuan ("Dark Energy Survey and OzDES") with Guangdong Experimental High School and Hangzhou No.1 High School, which approximately 50 students attended. On 21 October, it was our Nobel Laureate Professor Brian Schmidt who took time out of his busy schedule to present "The Universe from Beginning to End" to Hangzhou No.1 and Beijing No. 57 High Schools, reaching approximately 100 students.

Professor Tamara Davis (UQ) conveyed her enthusiasm for astronomy at TEDxNoosa.
Credit: TEDx

In addition to our "CAASTRO in the Classroom" program, we are very appreciative of our individual superstars who dedicate their time to talk to school students about their astronomy research and about careers in science. Two of these superstars to highlight in 2014 were University of Sydney PhD student Aina Musaeva who single-handedly organised a "Spaceday" at Hill End Public School in New South Wales. The event was joined by three more local schools, Hargraves, Wollar, and Glen Alice Public Schools, and reached around 60 students. In the evening, Hill End also hosted a community dinner for residents of the village with Aina leading the night sky viewing through telescopes.

The partial solar eclipse in late April presented an opportunity that ICRAR-Curtin researchers Dr Cathryn Trott and Dr Randall Wayth used for outdoor astronomy outreach at Bannister Creek Primary School in Perth where visibility proved much more favorable than in the Australian Eastern states.

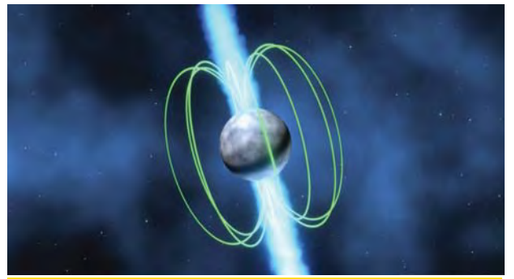
Providing a lasting "Astrophysicist's Guide to Exploring the Universe", CAASTRO former PhD student and now research staff member Dr Vanessa Moss featured in a video by the Government program "Bridges to Higher Education" that is available on YouTube. In addition to her virtual presence, she also visited Greystanes Public School and Catherine McAuley Catholic School in mid 2014.

CAASTRO researchers Associate Professor Chris Power, Dr Rick Newton, and Mr Paul Scott-Taylor from ICRAR-UWA had the opportunity to show off their exciting galaxy simulations to students as part of an episode of Channel Ten's children's science show "Scope". They explained what we can learn from these simulations and why we need supercomputers to run them.

CAASTRO Social Media

We continued communicating our science through the CAASTRO Twitter, Facebook and YouTube accounts, as well through news stories on our website. This communication strategy has proven a massive success with over 900 followers on Twitter, over 20,000 Facebook users who 'like' our page, and almost 100,000 video views of our YouTube channel. The latter was fed with the special "Pint in the Sky" recording from National Science Week 2013, starring Henry Reich ("Minute Physics") and "Bad Astronomer" Phil Plait, generating over 10,000 views by themselves.

A new Video Press Release (ViPR) was produced in April 2014, in conjunction with the publication of our ex-PhD student Kitty Lo's paper, illustrating how "Computers beat brainpower when it comes to counting stars".



The rapidly spinning pulsar emits radio waves.
Credit: Swinburne Astronomy Productions

Another CAASTRO press release, Dr Jean-Pierre Macquart's and Professor Ue-Li Pen's "Galactic lens yields precision pulsar measurement" was accompanied by a short animation of a spinning pulsar that attracted over 27,000 views. This overwhelming response highlighted the value of high-quality visualisations of CAASTRO research, to which end we are continuing to work with the talented team at Swinburne Astronomy Productions to add more such animations to our library. The CAASTRO website received over 66,000 views throughout the year, with just under a quarter coming from Australia and the rest internationally. The 'News' section, in particular, with its frequent influx of short research stories (on average, every fortnight) and press releases provides an attractive port of call for CAASTRO staff and students, collaborators, members of the astronomy community, industry and Government, as well as the general public.

Professional Development

The annual training workshop for our students and staff ahead of the 2014 CAASTRO Annual Retreat was presented by Dr Phil Crosby from CSIRO in Perth on the topic "Leading big projects in astronomy". Taking place at the University of Queensland in Brisbane on Tuesday 18 November, 30 Postdoctoral researchers and students learned about the challenges, risks, and rewards in project management. Having previously worked as Business Strategist for CSIRO, Dr Crosby was selected to join the SKA Program Development Office in Manchester, UK, as Manager for Industry Participation Strategy. His expertise in seeing an astronomy project through from conception via construction to completion made him a very engaging trainer to our members, who enjoyed the day. The participants self-assembled into workgroups to tackle questions and tasks and even came up with a project to create a 'death star'.

Networking and career advice by CAASTRO Mentors

CAASTRO continues to ensure our students and early-career researchers receive valuable training, gain transferable skills, and advance their careers. To this end, in 2014 we continued our mentoring program designed to provide support and guidance for our younger members by experienced mentors. The nature, frequency, and intensity of the mentoring sessions and activities are up to each mentor-mentee pairing, with the high resolution video conferencing equipment installed at all CAASTRO nodes assisting the program through virtual meetings. At every CAASTRO Annual Retreat, we schedule formal and informal time for our mentors and mentees to have face-to-face discussions. In 2014 we re-introduced speed mentoring at the Annual Retreat to increase the mentoring opportunities for those who chose to participate.

CAASTRO also continues to have a good relationship with the ARC Centre of Excellence for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), centred on monthly meetings between our respective Centre Directors and COOs and a corresponding continuous exchange of ideas and practices. In October 2014, CUDOS and CAASTRO held a joint careers workshop for researchers and students at the University of Sydney. This program was considered highly valuable by participants who heard presentations from industry partners as well as other scientists.

CAASTRO LOCATIONS

EoR Busy Week in Berkeley
Credit: Emil Lenc

International Centre for
Radio Astronomy Research

CAASTRO AT THE INTERNATIONAL CENTRE FOR RADIO ASTRONOMY RESEARCH (ICRAR)

Astronomy and astrophysics research in Western Australia is largely conducted at ICRAR, which is an equal joint venture between Curtin University and the University of Western Australia (UWA). ICRAR is a single organisation with two physical nodes, located near the main campus of each university. ICRAR has a unified business plan and conducts joint research programs, seminars and senior undergraduate astronomy programs. CAASTRO's engagement with ICRAR is through the CAASTRO Chief Investigators at the individual universities, Steven Tingay and Lister Staveley-Smith, who are Curtin and UWA node leaders respectively, and who are both Directors at ICRAR.

CAASTRO postdocs and students are mixed in with other ICRAR research groups, as encouraged by the ARC. Perth-area meetings are organised on a frequent basis by Se-Heon Oh and Cathyrn Trott and alternate between Curtin and UWA. ICRAR's significant pre-existing involvement with radio astronomy projects has allowed CAASTRO to leverage greater science return from its investment and benefit from considerable in-kind support from ICRAR's engineering, ICT and science staff.

ICRAR members
Credit: ICRAR

Curtin University

CAASTRO AT CURTIN UNIVERSITY

The Curtin Institute of Radio Astronomy was home to fourteen CAASTRO members in 2014 who contributed to the Dynamic and Evolving Universe research themes, the CAASTRO Education and Outreach program, and to the administration of the Curtin node.

In the Dynamic Universe, the Curtin team continued the hunt for, and analysis of, 'fast radio bursts' (FRBs), using the Murchison Widefield Array (MWA). With their pooled expertise in pulsars, high-time-resolution, voltage capture and statistics, CAASTRO is well positioned to be a major player in this exciting research field. Dr Steven Tremblay implemented an end-to-end pipeline to take raw voltage data from the MWA on-site and process incoherent fast transient event detection. In 2014, tens of hours of data were processed and used to provide a quality check on the pipeline and to refine methods for event detection. The CAASTRO Annual Retreat in November 2014 marked the start of coordinated follow-up observations that now see the MWA in Western Australia, along with the Giant Metrewave Radio Telescope (GMRT) in India, the Very Large Array (VLA) in the United States, and the Molonglo Observatory Synthesis Telescope (MOST) on the east coast of Australia, shadow CSIRO's Parkes radio telescope in the search for FRBs. Also in high-time-resolution science, CAASTRO PhD student Samuel Oronsaye, under the supervision of Dr Ramesh Bhat, Dr Stephen Ord, Dr Steven Tremblay and Professor Steven Tingay, cross-matched data from the MWA and from Parkes to identify giant pulses from the Crab pulsar.

In the Evolving Universe, the BIGHORNS Epoch of Reionisation (EoR) Global Signal project, led by Dr Randall Wayth and driven by Dr Marcin Sokolowski, gathered momentum in 2014. The week long deployment of the mobile set-up at a remote inland location in Western Australia in April allowed for the collection of good-quality data that fuelled the system-description paper, now published in the Publications of the Astronomical Society of Australia (PASA). Since October 2014, the full BIGHORNS set-up, featuring the final conical log-spiral antenna, has been deployed at the Murchison Radio-astronomy Observatory (MRO) in Western Australia. With over 3 TB of valuable data at 50 millisecond resolution collected since, data-analysis and improvements to the data analysis pipeline are in full swing.

CAASTRO Curtin MSc student Mehran Mossammaparast graduated in 2014, having developed an alternative radiometric receiver for the BIGHORNS set-up. Two summer students were further involved in the BIGHORNS project in 2014, and characterised a new front-end receiver for the set-up to improve the accuracy of the signal calibration process. This new system will soon be deployed at the MRO and will bring the BIGHORNS team closer to having a chance of discovering the EoR.

Data collected as part of the MWA EoR project (led by Dr Cathryn Trott) were successfully run through the pipeline for estimating the EoR power spectrum CHIPS (Cosmological HI Power Spectrum). The outputs were consistent given the amount of data and instrumental effects. The team continued to develop a better understanding of the impact of foregrounds on EoR detection, developed techniques to treat foreground contaminants in the data, and compared different observational techniques for performing the EoR experiment. This research has resulted in several papers that contribute to the literature in this field.

The Curtin node is the headquarters of the CAASTRO Education and Outreach team: the program leader is Professor Steven Tingay and the program coordinator, Dr Wiebke Ebeling. Activities include news stories, press releases, social media, school engagement, public-outreach activities and professional training opportunities for CAASTRO junior members. Having established Science Outreach as a novel research field at Curtin, Dr Ebeling and Professor Tingay also co-supervised a third-year project student who looked at different presentation formats of all-sky data sets in research and outreach. The previously developed MWA demonstrator tool was a well-received addition to the CAASTRO stand at Perth Astrofest in March 2014, and at the inaugural astronomy weekend at Uluru for National Science Week in August 2014. A successful press release originating from Curtin was the CAASTRO collaboration between Partner Investigator Professor Ue-Li Pen at the University of Toronto and Dr Jean-Pierre Macquart at Curtin in May 2014. Other Education and Outreach activities were conceived at and coordinated from the Curtin node and delivered nationally.

CAASTRO Curtin University team members

Prof Steven Tingay

CAASTRO Chief Investigator, Node Leader, Leader Education and Outreach

Themes: Dynamic, Evolving

Tingay's CAASTRO involvement continues to span the administrative, as member of the CAASTRO Executive, and the scientific. Tingay's interests in time-domain astronomy and instrumentation are reflected in his involvement with other CAASTRO staff in work to detect pulsars and fast radio bursts with the Murchison Widefield Array (MWA). Tingay's involvement in Epoch of Reionisation research, both via global signal and power spectrum techniques, continues strongly within CAASTRO. As Director of the MWA, Tingay has played a high level role in delivering one of the key elements of Australia's next-generation astronomy infrastructure, an element that forms a significant pillar of CAASTRO's scientific success.

Dr Ramesh Bhat

CAASTRO Associate Investigator

Theme: Dynamic

Bhat's research continues to focus on observational pulsar astronomy and the transient radio Universe. Highlights from 2014 include him pioneering the first pulsar-science publication with the newly-developed high-time-resolution capability for the MWA, and his involvement in the discovery of a fast radio burst in real-time, which enabled multi-wavelength followups for the first time. In the year ahead, Bhat plans to focus on further advancing the scientific capabilities for the MWA, while actively pursuing science with multiple instruments including the MWA, GMRT and the Parkes telescope.

Dr Jean-Pierre Macquart

CAASTRO Associate Investigator

Theme: Dynamic

In 2014 Macquart continued work on the properties of fast radio bursts as a means of probing the baryonic content of the Inter-Galactic Medium, and the use of FRBs as cosmological tools in their own right. Closer to home, he worked on the exceptionally unusual properties of the local interstellar medium as revealed by the scintillations of an intra-hour variable quasar. This work, performed in collaboration with Professor Ger de Bruyn at ASTRON in the Netherlands, revealed the presence of an exceptionally turbulent and dense patch of plasma only 1pc from Earth. Macquart also investigated optimal strategies for surveying the radio sky for transients whose bursts occur on relatively slow (>10 s) timescales.

Dr Stephen Ord

CAASTRO Associate Investigator

Theme: Dynamic

During 2014, Ord was heavily involved in the preliminary design of the SKA correlator. This project involves industrial partnerships with NVIDIA, IBM and CISCO Systems. Ord continues to work with Tremblay, Oronsaye, Bhat, and Tingay on the high-time-resolution pipeline for the MWA.

Dr Randall Wayth

CAASTRO Associate Investigator

Theme: Evolving

Wayth is a Senior Research Fellow, MWA staff scientist, project manager for the CAASTRO-supported BIGHORNS EoR Global Signal project, and team leader for the MWA GLEAM sky survey. Wayth co-supervises two CAASTRO PhD students working in the evolving theme. In addition to the GLEAM survey, Wayth works with several CAASTRO members on the MWA Epoch of Reionisation key science program.

Dr Wiebke Ebeling

CAASTRO Education & Outreach Coordinator

Theme: Education & Outreach

Ebeling project-manages all activities in the CAASTRO Education and Outreach program and liaises with program collaborators throughout Australia. In 2014, Ebeling continued to support Astrofest, "CAASTRO in the Classroom", National Science Week, "Telescopes in Schools" and Mount Burnett Observatory and was responsible for the CAASTRO website, social media channels, press releases and "CAASTRO Reader's Digest" booklets. New additions to Ebeling's portfolio were the partnership with Voyages Indigenous Tourism Australia, the CAASTRO planetarium show by Museum Victoria, and the production of a research specific media library by Swinburne Astronomy Productions. Ebeling published in her previous research field (neuroscience) in early 2014 and supervised a Curtin University third year project student in the newly established research field Education and Outreach in the first half of 2014. Ebeling also represented CAASTRO in the "Education, Outreach and Careers" Working Group to advise the National Committee for Astronomy for the Decadal Plan for Australian Astronomy 2016–2025.

Dr Paul Hancock

CAASTRO Affiliate

Theme: Dynamic

Hancock has taken the idea of image stacking and applied it to transient radio phenomena to provide insights into the nature of type Ia supernovae and long gamma-ray bursts. Hancock is one of the main contributors to the VAST pipeline, an analysis and visualisation tool designed to detect and classify variable and transient radio sources from the latest generation of radio surveys. Hancock is currently using the VAST pipeline to process data from the MWA in order to detect various signatures of variability. One such signature is the scintillation of distant galaxies that occurs as their light passes through the interstellar medium of the Milky Way.

Mr Mehran Mossammaparast

CAASTRO Masters Student

Theme: Evolving

Mossammaparast carried out extensive receiver characterisation including RF characteristics and temperature variations in a controlled laboratory environment. The receiver that he built is now ready to be integrated and tested in the BIGHORNS system. Mossammaparast completed his thesis for his M.Phil. in 2014.

Mr Samuel Oronsaye

CAASTRO PhD Student

Theme: Dynamic

In 2014, Oronsaye focused on the analysis of the Crab giant pulses observed simultaneously with the MWA and the Parkes radio telescope. The result of the analysis has been finalised and written into a paper currently undergoing collaboration review, and to be published in 2015.

Dr Marcin Sokolowski

CAASTRO Postdoctoral Researcher

Theme: Evolving

In early 2014 Sokolowski worked on improvements in the BIGHORNS system stability and calibration. In April 2014, Sokolowski and Wayth deployed the mobile system at the Wondinong Station in Western Australia.The inland location was chosen in order to avoid radio-frequency interference (RFI) identified in the data previously collected at the coastline location. The collection of several days worth of good-quality (low-RFI) data enabled him to finalise and submit a BIGHORNS system description paper to PASA. In the second half of the year he was preparing deployment of the conical log-spiral antenna at the Murchison Radio-astronomy Observatory (MRO). It was deployed at the MRO in October 2014 and has been collecting data since then. Thus, in the last part of the year Sokolowski was analysing the new data. Finally, in December he was also working together with his summer student Daniel Ung on characterisation and testing of the new front-end receiver which is planned to be deployed at the MRO in early 2015 in order to improve accuracy of the signal calibration.

Ms Kim Steele

CAASTRO Honours Student

Theme: Evolving

Steele was part of the 'Student Army' who helped constructing the 128-tile Murchison Widefield Array (MWA) in Western Australia. Her Honours thesis "Measuring HI absorption in distant quasars with the Murchison Widefield Array" used MWA commissioning data to look for absorption in the radio spectrum of TN0924-2201. The work confirmed previous results on this source and continued into 2014 with new data from the full MWA.

Dr Steven Tremblay

CAASTRO Postdoctoral Researcher

Theme: Dynamic

In 2014, Tremblay led the commissioning of the Voltage Capture System (VCS) on the MWA. This commissioning was completed and the system is now in general use by MWA observers. During this process, a number of pulsars, with varied dispersion measures and periods were observed with the MWA. The VCS system is also being utilised by Tremblay to search for fast radio bursts, using directors time in 2014 and now has an approved MWA project to continue this work. Tremblay is a co-supervisor of CAASTRO PhD student Samuel Oronsaye whose thesis involves searching for RRATs and bursty pulsars with the MWA and uses the VCS to do so. Additionally, Tremblay worked on the BIGHORNS EOR Global Signal Experiment. This system was deployed this year at the Murchison Radio-astronomy Observatory and is now taking continuous sky data. Further work on calibration of the system is underway at Curtin University.

Dr Cathryn Trott

CAASTRO Affiliate

Theme: Dynamic, Evolving

Trott's work in the Evolving Universe theme has focused on designing and implementing an Epoch of Reionisation (EoR) estimation algorithm, for application to data from the MWA. Trott is also leading efforts to understand the impact of foreground contamination on EoR estimation. Trott has derived a framework for understanding the noise properties of EoR datasets with low-frequency radio interferometers, contributing to the optimal design of EoR experiments. Trott continued her collaborative projects in 2014, working with medical physicists from Harvard to evaluate the utility of new medical imaging techniques for estimating the size and location of tumours. Trott also has an active collaboration with the Radiation Physics group at the University of Sydney. As part of the Dynamic Theme, Trott contributes across a range of projects predicting the rate of Fast Radio Bursts detections with the MWA and SKA-Low, developing a framework for accurately interpreting the results of current surveys, and understanding the statistical properties of high time resolution data in order to detect signals more efficiently. Trott is also performing cross-theme work, exploring the impact of ionospheric and interplanetary-induced intensity variations on the detectability of the EoR.

Mrs Angela Dunleavy

Administrative Coordinator

Dunleavy is responsible for collating non-financial data for CAASTRO reports and provides administrative support to the CAASTRO team at Curtin and at CAASTRO Annual Retreats.

Ms Tina Sallis

Finance Manager

Sallis is responsible for financial support to the CAASTRO team members and Curtin and for reconciliation of financial data against the CAASTRO budget.

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

CAASTRO AT THE UNIVERSITY OF WESTERN AUSTRALIA (UWA)

The UWA node of CAASTRO is situated at the International Centre for Radio Astronomy Research (ICRAR), a joint venture of Curtin and UWA. ICRAR has a vigorous research program involving continuum and HI surveys, optical surveys and cosmological and galaxy-formation simulations, which perfectly complements the research focus of CAASTRO researchers at UWA and other nodes.

Activities this year

CAASTRO research at UWA has ramped up this year with the appointment of two new CAASTRO researchers, Popping and Rhee. This now brings the number of CAASTRO postdoctoral research appointments at UWA to five. There was considerable research activity in 2014 in studying the kinematics of galaxies, both on a cosmological scale and a local scale through surveys such as 2MTF and SAMI, and through simulation and other observations.

CAASTRO researchers at UWA have contributed to CAASTRO's Dynamic science theme as follows:

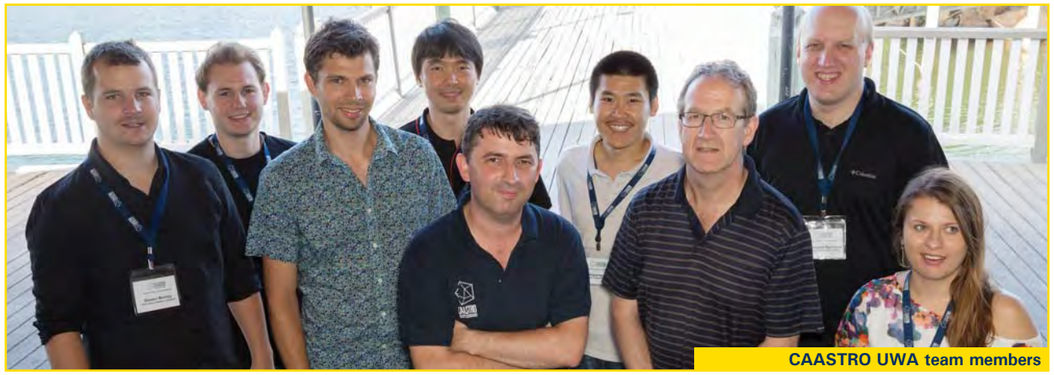
- Staveley-Smith, with Gaensler and PhD student Zanardo, led a paper with exciting new data from the Atacama Large Millimeter/sub-millimeter Array (ALMA) and the Australia Telescope Compact Array (ATCA), which detailed the relative contributions of dust and synchrotron emission in the remnant of the famous Supernova 1987, and examined a possible new contribution from a pulsar wind nebula.

Major contributions to the Evolving science theme have been:

- Cui is currently finalising his research on the cosmic web.
- As part of a joint program between the SAMI/GAMA/DINGO teams, Meyer, Obreschkow, Popping, Staveley-Smith and other CAASTRO members commenced a JVLA survey to carry out widefield HI observations in the G09 field. In January, they obtained ~60 pointings in this region, initially selecting fields to maximise the direct detection of SAMI sources. These observations will be used to carry out studies of angular momentum in galaxies, the impact of group environment on galaxy evolution, and HI stacking experiments at intermediate redshifts.
- Meyer, Popping, and other members of the DINGO and WALLABY survey teams obtained three ASKAP-BETA observations of the southern GAMA G23 region, which will ultimately also be the target for the DINGO ultradeep project. This data will be used for HI stacking experiments in the nearby Universe, with a comparison of results to existing Parkes data.
- Popping and Meyer started reducing new VLA data targeted at the GAMA fields to perform a stacking experiment and measure the cosmic gas evolution back to almost half the age of the Universe. The upgraded VLA allows measuring neutral hydrogen at redshifts that are currently unexplored.
- Popping contributed to the development of a new software package to perform automated source finding called SoFiA (Source Finding Application). This package is now publicly available and resulted in an accepted paper. The principle use of this software will be to perform source finding and parameterisation for the DINGO and WALLABY surveys.
- Popping and Meyer have successfully tested and implemented CASA scripts to combine data and generate image cubes for the CHILES (Cosmos HI Large Extragalactic) survey. CHILES is a large project on the VLA where a single pointing will be observed for 1000 hours. This ongoing project is the ultimate precursor for future HI surveys on ASKAP.
- Further development of the WALLABY 2D kinematics pipeline for resolved galaxies has occurred. Tests are being conducted on data from existing HI surveys in preparation for ASKAP.
- Investigation of central dark-matter distribution in nearby (< 11 Mpc) dwarf galaxies from high-resolution HI galaxy survey has concluded and a paper has been accepted for publication.
- Cosmological galaxy formation zoom simulations have been used to study Milky Way-mass galaxies in different environments.
- Important limits have been placed on the temperature of dark matter using galaxy-clustering measurements.

Major contributions to the Dark science theme have been:

- In a major milestone, Springob has led the publication of a cosmographic analysis using data from the 6dF Galaxy Survey. The paper was



CAASTRO UWA team members

accompanied by the public release of the peculiar-velocity data.

- Additional papers co-authored with the 6dF Galaxy Survey team at other nodes include the Fundamental Plane data release paper (Campbell *et al*. 2014) and the first cosmology results paper (Johnson *et al*. 2014).
- Peculiar velocities have also been derived for the 2MASS Tully-Fisher Survey (2MTF). The first measurement of the bulk flow of the local Universe using 2MTF has been published by PhD student Hong. This is the most accurate current measurement and was the basis for his PhD thesis, which was successfully defended this year.
- A cosmographic of the 2MTF peculiar-velocity field is under way.
- Planning for the TAIPAN survey has commenced.

Future goals

Over the next year, researchers at CAASTRO's UWA node aim to:

- complete the first analysis of Parkes HI intensity mapping experiment
- conclude analysis of HI spectral stacking studies in the COSMOS and VVDS fields
- lead an alternative cosmology simulation comparison project, collaborating with other groups, including the WiggleZ, TAO, SAMI and GAMA teams
- development of a physically-based model of the emission of radio continuum emission from AGN and star-forming galaxies
- contribute to ASKAP early science with stacking experiments
- analyse HI data from the JVLA in the GAMA regions to measure the cosmic gas density by using stacking techniques
- reduce and analyse HI data from the widefield JVLA program to study the angular momentum properties of SAMI galaxies, the impact of group environment on galaxy evolution, and to carry out further HI stacking experiments at intermediate redshifts
- complete the WALLABY 2D kinematics pipeline and publish a series of pipeline papers including the WALLABY velocity field extraction algorithm
- derive a (improved) rotation curve of the Large Magellanic Cloud (LMC) and mass model using the newly developed pipeline
- apply the pipeline to SAMI velocity fields and HI data from early ASKAP observations
- establish how satellite galaxy properties depend on the underlying dark-matter model and galaxy formation physics
- produce synthetic galaxy surveys in non-standard cosmological models of dark matter and dark energy
- complete the cosmographic analysis of 2MTF, and submit for publication
- continue analysis of 6dF Galaxy Survey peculiar velocities and bulk flow
- assist the TAIPAN collaboration to complete a survey strategy that accounts for the various scientific objectives
- contribute to the first data release of the Galactic and Extragalactic All-sky MWA survey (GLEAM)
- assemble the first samples of radio galaxies based on GLEAM.

Professor Lister Staveley-Smith

CAASTRO Deputy Director

Themes: Dark and Evolving

Staveley-Smith is Node Director and CAASTRO Deputy Director. He leads the 2MTF project under the Dark Theme and the Intensity Mapping and Wallaby/Dingo projects under the Evolving Theme. His main research contributions have been in the 2MTF project with the successful graduation of PhD student Tao Hong and the publication of the first tranche of papers, and the commencement of the Intensity Mapping project, jointly led with Stuart Wyithe at Melbourne. He has also contributed to the Radio Galaxy Environments project, by ensuring the continued success of the MWA GLEAM survey.

Dr Jonghwan Rhee

CAASTRO Postdoctoral Researcher

Themes: Evolving

Rhee joined CAASTRO at ICRAR/UWA in June 2014. He has worked on HI gas evolution out to $z \sim 0.4$ using 21-cm HI emission stacking technique. Now he is working on an HI intensity mapping experiment using the Parkes radio telescope to extend the research to higher redshift ($z \sim 0.9$). A large amount of data has been secured and more observations will be carried out in 2015 for WiggleZ fields. Using the data, Rhee will work on a data-analysis pipeline including removal of radio-frequency interference and foreground contamination from the observed data.

Dr Weiguang Cui

CAASTRO Affiliate

Theme: Evolving and Dark

Cui works on the cosmic web, using the cosmic web identification codes DISPERSE and Vweb, focusing on predictions of cosmic-web properties from simulations and comparisons with observation results. Cui also works on modified gravity/dark-energy simulations. He has a modified Gadget code to undertake cosmological simulations, and is applying a new minimalist modified gravity (gamma) model to the new updated Gadget-3 code. In collaboration, he runs cosmological simulations under modified gravity and alternative dark-energy models, and documents the changes in halo properties and merger histories. Cui also investigates the cosmic web in those models to examine any major differences with the standard ΛCDM model.

Mr Steven Murray

CAASTRO PhD Student

Theme: Evolving and Dark

Murray has continued his doctoral research developing statistical tests and innovative software frameworks for fundamental calculations with dark-matter halos, under the supervision of Chris Power at ICRAR UWA. These calculations make semi-empirical predictions for the spatial clustering of galaxies, and are able to connect this to the properties of dark matter. Using this framework, he is exploring means of testing the nature of the dark-matter particles using current and next-generation massive galaxy surveys, and his software has also been implemented as a web application, attracting the attention of researchers across the globe.

Associate Professor Danail Obreschkow

CAASTRO Affiliate

Theme: Evolving and Dark

Within the Evolving theme, Danail Obreschkow is leading theoretical and observational studies of angular momentum in galaxies. As part of these studies, he is leading the analysis of angular momentum in the spiral galaxies of SAMI. Within the Dark theme, Obreschkow is developing and applying statistical estimators for observational cosmology, e.g. the velocity function and the line-correlation function to distinguish between different dark-matter models. He also collaborates with Meyer in the WALLABY and DINGO projects and studies of the Tully-Fisher relation.

Mr Scott Meyer

CAASTRO PhD Student

Theme: Evolving and Dark

Meyer is investigating the Tully-Fisher relation using stacked HI profiles with his supervisors (Martin) Meyer, Obreschkow and Staveley-Smith. His research uses the S-cubed simulations and HIPASS data.

Ms Clare Peter

CAASTRO Administrator

Peter provides administrative support at the UWA node. She looks after the UWA node financials and reports back to the CAASTRO Chief Operating Officer. She works alongside the ICRAR UWA administration team.

Dr Paul Scott-Taylor

CAASTRO PhD Student

Theme: Evolving and Dark

Scott-Taylor has been investigating the formation and evolution of galaxies using simulation models with supervisors Power and Obreschow, and co-supervisors Staveley-Smith and Andrew Benson (Carnegie Observatories, Pasadena). This investigation has focused on the development of new semi-analytic models that will enhance Benson's Galacticus software and other codes, including METAXES, used to create the TIAMAT database (University of Melbourne). Scott-Taylor is also developing new software to model the distribution of HI gas in galaxies. Scott-Taylor intends to use the simulation data produced by the software to create mock galaxy catalogs and simulated skies. These products will be delivered using the latest 3D visualisation techniques.

Dr Attila Popping

CAASTRO Postdoctoral Researcher

Themes: Evolving

Popping joined CAASTRO at UWA in March 2014. He was already an active member of the DINGO and WALLABY surveys on ASKAP and will continue to contribute to these surveys. He is also a core member of CHILES (the Cosmos HI Large Extragalactic Survey), which is a very large project on the VLA. Popping is working on several experiments to do HI stacking and one of the goals is to use stacking techniques to do early science with ASKAP. Popping is member of the ACES team (ASKAP Commissioning and Early Science).

Dr Se-Heon Oh

CAASTRO Postdoctoral Researcher

Theme: Evolving

Oh has continued his work on the development of the WALLABY kinematics pipeline, particularly the tilted-ring analysis of 2D velocity fields based on Bayesian MCMC. A standalone C program has been developed and intensively tested using both simulated synthetic HI data cubes and those of the observed galaxies from ATCA LVHIS and VLA THINGS nearby

HI galaxy surveys. Oh has been working on a series of paper drafts that describe the pipeline algorithm and discuss its performance, and he aims to publish them early this year. Recently (Jan 2015), a paper ("High-resolution mass models of dwarf galaxies from LITTLE THINGS", Oh *et al*. 2015) which addresses the 'cusp/core' problem in ΛCDM simulations, was accepted for publication in the Astronomical Journal.

Professor Chris Power

CAASTRO Associate Investigator

Themes: Evolving

Power's CAASTRO-related work focuses on providing theory and simulations support for the SAMI galaxy survey, in collaboration with CAASTRO investigators Obreschkow and Croom, and on galaxy-formation modelling for future cold-gas surveys, in collaboration with CAASTRO investigators at the University of Melbourne (Kim, Wyithe) and at overseas nodes Durham University. He continues to supervise CAASTRO PhD students Murray (on the nature of dark matter and limits from future galaxy surveys), Scott-Taylor (on synthetic surveys for ASKAP and the SKA), and CAASTRO affiliate Cui (on modelling structure formation in non-standard cosmologies).

Dr Chris Springob

CAASTRO Postdoctoral Researcher

Theme: Dark

Springob has derived the Malmquist bias corrections for the 2MASS Tully-Fisher Survey (2MTF) peculiar velocities, and collaborated with Tao Hong on the analysis of these peculiar velocities. He has also examined the cosmography of the 6dF Galaxy Survey peculiar velocity field, working on comparisons with predicted velocity field models, which will also be applied to 2MTF.

Dr Anna Kapinska

CAASTRO Postdoctoral Researcher

Theme: Evolving

Kapinska joined CAASTRO at UWA in August 2013. She joined the Galactic and Extragalactic (GEG) Surveys MWA team to execute and complete the continuum MWA All-Sky Survey (GLEAM). The first data release is planned for late 2015. Kapinska is also part of the Radio Galaxies, Clusters & Cosmic Web GEG Science Team, focusing predominantly on radio galaxies and large scale AGN feedback; she investigates these subjects with the use of radio data and semi-analytical models. Kapinska also continues work on the LOFAR Deep Sky Surveys, which she joined in 2012. In addition, Kapinska is a science-team member of a citizen-science project Radio Galaxy Zoo, devised as a pilot study for classifying complex radio sources from the upcoming EMU (Evolutionary Map of the Universe) survey that will provide us with enormous amount of data. In 2014 Kapinska become Project Manager for the EMU survey, which is to be conducted with ASKAP.

Associate Professor Martin Meyer

CAASTRO Associate Investigator

Themes: Evolving

Martin Meyer's leadership role in the DINGO survey has seen him contribute to projects to stack HI data at moderate redshifts with telescopes such as Parkes, the VLA, and ASKAP-BETA. Studies of the cosmic HI density and the global Tully-Fisher relation are underway with PhD students. Through CAASTRO, he is also leading VLA survey program to obtain HI data of SAMI galaxies for a detailed study of angular momentum and galaxy evolution.

Dr Richard Newton

CAASTRO Affiliate

Theme: Evolving and Dark

Newton spent one year at ICRAR and CAASTRO at UWA from the Jodrell Bank Centre for Astrophysics as a Jim Buckee Fellow between November 2013 and November 2014. He worked on developing software for generating the inputs to simulations of galaxies and for creating rendered images and movies. He was a core member of the ICRAR/UWA simulations team who created and presented the "Spinning the Cosmic Web in a Supercomputer" planetarium show at Scitech in October 2014.

Mr Tao Hong

CAASTRO PhD Student

Theme: Dark

Hong is enrolled at the National Astronomical Observatories, Chinese Academy of Sciences and spent 50% of his time in Australia working on the 2MASS Tully-Fisher project (2MTF) as a CAASTRO student. He works with Springob and Staveley-Smith and has recently led a paper describing the first bulk flow measurements from 2MTF. Hong successfully defended his PhD thesis in 2014 and now holds a staff position at NAOC.

Dr Dan Taranu

CAASTRO Postdoctoral Researcher

Theme: Evolving

Taranu joined CAASTRO in late 2014 and his research areas are simulations of galaxy formation and evolution; synthetic observations of simulated galaxies; and modelling of spiral galaxies for the SAMI survey.

THE UNIVERSITY OF SYDNEY

CAASTRO AT THE UNIVERSITY OF SYDNEY

The CAASTRO Sydney node is located within the Sydney Institute for Astronomy (SIfA), which is part of the School of Physics within The University of Sydney. SIfA is one of Australia's largest research groups in astronomy and astrophysics, and carries out observational and theoretical research as well as developing novel astronomical techniques and instrumentation. SIfA's long-standing involvement in instrumentation and large-area astronomical surveys underpins many of the research activities at CAASTRO's Sydney node.

With the change in CAASTRO Directorship in September 2014, Elaine Sadler also took over from Bryan Gaensler as the Sydney node leader. In 2014 there were 31 CAASTRO team members at the Sydney node, including 10 students. The main research activities at the Sydney node fall within the Evolving and Dynamic themes.

In the Evolving Universe theme, our major activities for 2014 (and the researchers involved in them) included:

- The SAMI Galaxy survey, an ambitious new study of the internal structure and kinematics of stars and gas within galaxies that uses a novel 'hexabundle' multi-object integral-field spectrograph jointly developed by Sydney and AAO (Allen, Bland-Hawthorn, Bloom, Bryant, Croom, Fogarty, McElroy, Richards, Sadler, Schaefer, Scott),
- Studies of the redshifted 21-cm absorption line of neutral hydrogen as a probe of the cold gas content of galaxies in the distant Universe, as part of the ASKAP FLASH survey (Allison, Curran, Glowacki, Moss, Reeves, Sadler),
- Calibration and analysis of low-frequency radio data from the Murchison Widefield Array (MWA), with a particular focus on polarisation measurements and characterisation of the foreground source populations relevant to studies of the Epoch of Reionisation (Callingham, Gaensler, Lenc).

In the Dynamic Universe theme, our main activities were:

- Continuing development of the data pipeline and analysis tools for two ambitious new radio transient surveys, MWA transients and ASKAP VAST, including a particular focus on (i) understanding and calibrating ionospheric effects in MWA data and (ii) analysing large archival radio, optical and X-ray data sets to identify new and rare classes of transient sources (Burlon, Gaensler, Loi, Musaeva, Murphy),
- Upgrading the Molonglo radio telescope to a system with increased bandwidth and a new digital correlator, in collaboration with CAASTRO CI Matthew Bailes and colleagues at Swinburne. The huge collecting area and wide field of view of the Molonglo telescope will make this a powerful new facility for pulsar timing and identifying 'fast radio bursts' (Campbell-Wilson, Green).

Our visitors this year included Prof Roger Davies (Oxford), Dr Stephen Fine (University of Western Cape), Prof Martha Haynes (Cornell University), Prof Garth Illingworth (UC Santa Cruz), Prof Tom Landecker (University of Calgary), Dr Tom Mauch (SKA Africa) and Dr Kevin Schawinski (ETH Zurich), as well as the many researchers from other CAASTRO nodes who visited us for 'busy weeks' and workshops over the course of the year. In October 2014, we hosted a well-attended workshop on 'Extended Capabilities for the Murchison Widefield Array (MWA)'.

Our research highlights for 2014 are wide-ranging, and reflect the fact that two major new facilities with which we have been closely involved, MWA and SAMI, moved into full operational mode this year, while early results are also emerging from the commissioning phase of ASKAP. As a result, we are now starting to see exciting scientific returns from the effort put into survey design, data pipeline work and analysis tools over the past three years.

2014 saw the first public release of data from the SAMI galaxy survey, with a paper presenting fully-calibrated data cubes for a representative selection of 107 galaxies drawn from the GAMA regions, along with information about these galaxies from the GAMA catalogues. CAASTRO students Sam Richards and Adam Schaefer discovered a luminous star-forming complex in the outskirts of a dwarf galaxy observed by SAMI. This unresolved region contributes over 70% of the total star formation rate in its parent galaxy, and could easily have been missed in a conventional (single-fibre) spectroscopic survey.

This year also saw the first detection of neutral hydrogen in a distant galaxy with ASKAP. CAASTRO Affiliate James Allison and colleagues used commissioning data from the six-antenna test array to observe a set of bright, compact radio sources, and discovered a previously unknown HI absorption line at $z = 0.44$ towards a radio galaxy of unknown redshift. Optical spectroscopic observations (using Gemini South)

CAASTRO University of Sydney team members

confirmed that the absorbing gas is located within the host galaxy of the radio source, and this represents an important milestone for HI studies with ASKAP.

CAASTRO Honours student Cleo Loi discovered a series of spectacular wave-like structures in the ionosphere by analysing time-series data from the Murchison Widefield Array. Cleo's work was initially motivated by a desire to understand the effect of variations in the electron density of the ionosphere on the measured positions and flux densities of distant radio sources, but she discovered that the wide-field nature and excellent snapshot capabilities of the MWA also make it a powerful instrument for ionospheric science which can probe the ionosphere on regional (1–100 km) scales. Cleo's work represents the first time a radio telescope has been used to probe the ionosphere with such high spatio-temporal resolution over such a wide field of view.

One of our main education and outreach activities continues to be the "CAASTRO in the Classroom" (CitC) program, which uses our video-conferencing system to stream talks and discussion sessions with CAASTRO astronomers to high schools across New South Wales. Several Sydney node researchers and students also travelled to Uluru to take part in CAASTRO's new 'Astronomer in Residence' program at the Voyages resort.

The University of Sydney hosts CAASTRO's main administrative office, which in 2014 consisted of Kate Gunn (Chief Operating Officer), Debra Gooley (finance), Michelle Sullivan (executive support), Kylie Williams (events and communications) and Helen Sim (media and Annual Report). This team oversees a transparent reporting system across the Centre, handles all our financial obligations and transactions, organises our scientific workshops, manages the CAASTRO Mentoring Program and prepares the regular CAASTRO newsletter. A notable extra activity this year was the organisation and administrative support of the ARC Mid-Term Review of CAASTRO in November. A great deal of work went into making sure we were as well-prepared as possible, and it was gratifying to see things run so smoothly on the review day.

Professor Elaine Sadler

CAASTRO Director (from 15 Sep 2014)

Theme: Evolving

In 2014 Sadler has been working with Allison, Moss, Curran, Reeves and Glowacki on the identification and study of redshifted 21-cm HI absorption in galaxies out to redshift $z = 1$, using new tools and techniques developed for the forthcoming ASKAP FLASH survey. A particular highlight was the detection of HI absorption lines in early commissioning data from ASKAP, including the discovery of associated HI absorption in the radio galaxy PKS 1740-517. In 2015 they will continue a program of spectral-line observations as ASKAP moves into its Early Science phase.

Professor Bryan Gaensler

CAASTRO Chief Investigator
(Director until 15 September 2014)

Themes: Evolving and Dynamic

Gaensler leads the radio-galaxy environments project within CAASTRO's Evolving Theme. In 2014, he worked on catalogues of broadband polarisation of active galaxies, which probe the ionised material in which these sources are embedded. He also began a new joint Evolving/Dynamic project on hydrodynamic cosmological simulations of fast radio bursts, which he used to constrain the spatial distribution and energetics of these events. In 2015, he plans to investigate in detail the polarised emission from individual galaxies within the broadband catalogues his team has derived, and to obtain early-science polarisation data on radio galaxies from ASKAP and the MWA.

Associate Professor Scott Croom

CAASTRO Chief Investigator

Theme: Evolving

Croom is leading the SAMI Galaxy Survey within the CAASTRO Evolving theme. This is a project to observe thousands of galaxies using spatially resolved spectroscopy with the Sydney-AAO Multi-object Integral Field Spectrograph (SAMI) on the Anglo-Australian Telescope. In 2014 the SAMI Galaxy Survey was in full swing, with over 1000 galaxies observed to date. Exciting new results published included the discovery of dwarf galaxies with extreme star-forming regions, the characterisation of gas outflows in galaxies and the demonstration of a new universal dynamical scaling relationship between galaxy mass and the internal motions of gas and stars. In mid 2014 the team also produced the SAMI Early Data Release of over 100 galaxies for astronomers around the world to use. In 2015 there is much science to look forward to, including investigations into the role of environment in determining star formation and dynamics in galaxies, tests of the role of super-massive black holes in preventing star formation, examining the distribution of young and old stars in galaxies, and much more.

Dr Tara Murphy

CAASTRO Chief Investigator

Theme: Dynamic

Murphy's focus is on radio observations of transient and variable sources such as supernovae and gamma-ray bursts. In addition, she works on developing intelligent algorithms for detecting transient events in the large volumes of data that will be produced by next-generation radio telescopes. In 2014, Murphy used new low-frequency data from the MWA to investigate ultra-cool dwarf stars and exoplanets, as well as conducting a blind survey for radio transients.

Dr James Allen

CAASTRO Affiliate

Theme: Evolving

Allen has led development of the data-reduction pipeline for the SAMI Galaxy Survey, culminating in the Early Data Release of a subset of the survey galaxies. This data is now public, allowing researchers across the world to make use of the SAMI Galaxy Survey data. Allen has also been investigating the relationship between active galactic nuclei and their host galaxies, focusing on a small number of galaxies with unusual kinematic properties.

Dr James Allison

CAASTRO Affiliate

Theme: Evolving

Allison is a member of the ASKAP FLASH survey, which will probe the distribution and evolution of atomic hydrogen (HI) to high redshifts. His current research focuses on using HI absorption lines to study the role of neutral gas in fuelling active galactic nuclei and the subsequent feedback on the host galaxy. In 2014 he found a new HI absorption system in the young radio galaxy PKS 1740-517; the first discovery using the ASKAP six-antenna BETA prototype. In 2015 Allison will continue to make new discoveries with BETA and towards the end of the year he will help the FLASH team carry out an early science survey with ASKAP-12.

Dr Martin Bell

CAASTRO Postdoctoral Researcher

Theme: Dynamic

Bell is principle investigator of the Murchison Widefield Array Transients Survey (MWATS), which aims to survey almost the entire southern hemisphere multiple times at low frequencies, on timescales of one month. The aim of the project is to search for dynamic and explosive objects in the Universe. Bell is also a member of the Australian Square Kilometre Array Pathfinder (ASKAP) commissioning team. In the 2015 the team will prepare the instrument for early science later in the year.

Professor Joss Bland-Hawthorn

CAASTRO Associate Investigator

Theme: Evolving

Bland-Hawthorn leads the development of new survey instruments for the Anglo-Australian Telescope. These include (a) the SAMI 13-bundle spectrograph (in collaboration with Scott Croom); (b) the Hector 100-bundle spectrograph (in collaboration with Julia Bryant); and (c) the PRAXIS OH suppression spectrograph. His particular interest is understanding the evolution of galaxies in the context of their environment. As part of this effort, he is a member of the SSimPL consortium carrying out massive CDM + hydro simulations of how galaxies get their gas over a cosmological volume. He is a member of the GASKAP survey team that targets gas on the Galactic halo, and a member of the GAMA and CALIFA galaxy survey teams.

Dr Julia Bryant

CAASTRO Postdoctoral Researcher

Theme: Evolving

Bryant is deeply involved in the SAMI instrument and the SAMI Galaxy Survey. In 2014 she chaired the SAMI Target Selection Working Group, and selects the galaxies to be observed in the SAMI Galaxy Survey,

as well as developing and maintaining the SAMI instrument.

She continues to use the SAMI data to investigate whether gas gets into galaxies from internal or external processes, by looking at the resolved dynamics of both the gas and the stars in galaxies and the impact of the environments surrounding the galaxies. Working with Leslie and Sadler, she has on-going research into the radio properties of the SAMI galaxies, and she supervises PhD student Richards, who is researching aperture effects within the SAMI data.

In 2015 Bryant will not only continue her SAMI science but will also be Project Scientist for a future large integral-field instrument called HECTOR.

Dr Davide Burlon

CAASTRO Affiliate

Theme: Dynamic

Burlon is an expert on high-energy emission from black holes. His main focus in the past year has been to pave the way to the SKA in the theme of stellar explosions known as gamma-ray bursts. He is advising the Transients working group of the SKA.

Mr Duncan Campbell-Wilson

CAASTRO Affiliate

Theme: Dynamic

In the past year Campbell-Wilson's work has consisted of successfully developing a new radio receiver based on integrated radio receivers, field-programmable gate arrays and fibre optics. A number of subtle difficulties in operating digital technologies adjacent to very sensitive astronomical receiving equipment were identified. Solutions have been identified and tested. Implementing the engineering solutions is in progress. A highlight this year was the successful return of the telescope imaging capabilities using the new receivers. Since this success, system development and receiver fine-tuning has taken most of Campbell-Wilson's time. A number of critical systems within the telescope infrastructure are being redeveloped with newer technology. Testing of RF losses in materials and the testing of a well matched wideband antenna was successfully conducted at DRAO in Canada. The CHIME team have further developed the antenna for radio-astronomical applications.

Dr Steve Curran

CAASTRO Postdoctoral Researcher

Theme: Evolving

Curran is preparing for the First Large Absorption Survey in HI, to be undertaken with the Australian SKA Pathfinder, in the search for the cool, star-forming material in the early Universe. In 2012, in conjunction with Matt Whiting at CASS, he found that placing a powerful quasar in a galaxy of gas will ionise all of the neutral hydrogen (HI). Now, with James Allison and their CAASTRO student, Marcin Glowacki, they have expanded this to state-of-the-art optical data, with preliminary results indicating that singly ionised magnesium (MgII, which has a similar ionisation potential to HI) is also absent in the host galaxies of powerful quasars. The previous HI 21-cm observations, which first alerted us to this effect, cannot rule out that the gas is simply heated to beyond the detection threshold of current radio telescopes. The fact that HI and MgII exhibit a similar UV luminosity above which neither is detected, supports the theoretical model that ALL of the gas is indeed ionised. This has profound implications for quasar-mode feedback in these galaxies, through the suppression of star formation by the active nucleus, and means that there may exist a population of very distant gas-rich galaxies hidden from optical surveys.

Dr Jamie Farnes

CAASTRO Affiliate

Theme: Evolving

Since joining CAASTRO in 2012, Farnes has been organising the 'CAASTRO in the Classroom' programme together with Shane O'Sullivan, and has very recently handed over to new organisers. He's very excited to see how CAASTRO in the Classroom develops in the future, and is looking forward to now focusing on CAASTRO science in 2015.

Dr Sean Farrell

CAASTRO Affiliate

Theme: Dynamic

Farrell's specialisation is X-ray astronomy, focusing on the study of accreting compact objects (i.e. black holes, neutron stars and white dwarfs). His research in particular has targeted intermediate-mass black holes and the role they played in the formation and evolution of galaxies. As a CAASTRO Affiliate, in 2014 he applied machine-learning techniques to automatic classify X-ray sources in the Third XMM-Newton Serendipitous Source Catalogue (3XMM). He also provided support through his expertise in X-ray astronomy to various CAASTRO activities. In October 2014 Farrell left astronomy.

Dr Ilana Feain

CAASTRO Affiliate

Feain leads the development of a novel and cost-effective radiotherapy machine designed to level the playing field in global accessibility to equitable cancer treatment. Feain obtained her PhD in Astrophysics from the University of Sydney in 2006, and became a research astronomer and project scientist on the Australian Square Kilometre Array Pathfinder (ASKAP) at CSIRO Astronomy and Space Science. This led to Feain developing a cross-disciplinary research program to enable ASKAP's novel receiver technology to be used beyond astronomy, including in health and defence. She then made a major career change in 2014, when she moved into medical physics, working in the Radiation Physics Laboratory at the School of Medicine of the University of Sydney.

Dr Lisa Fogarty

CAASTRO Postdoctoral Researcher

Theme: Evolving

Fogarty works on the SAMI Galaxy Survey – a project to observe 3000 galaxies with integral field spectroscopy (IFS). In 2014 Fogarty published the first paper on the SAMI Pilot Survey, an investigation of the angular momentum of early-type galaxies in clusters. In 2015 Fogarty will extend this work, using the main SAMI Galaxy Survey observations to investigate the properties of galaxies in groups, to infer their evolutionary history.

Professor Anne Green

CAASTRO Affiliate

Themes: Dynamic, Evolving

Green leads the upgrade to the capabilities of the Molonglo telescope in collaboration with the Swinburne Node. In 2014 the new system achieved 'first light' imaging and detected several pulsars. In 2015, Green plans to focus on searches for transient sources at cosmological distances and deep imaging of radio relics and halos around massive galaxy clusters.

Dr Emil Lenc

CAASTRO Postdoctoral Researcher

Theme: Evolving

In 2014 Lenc primarily continued work to survey polarised point-sources and diffuse polarisation as part of the GLEAM/EoR projects within the MWA collaboration and investigated the effect of the ionosphere on polarisation at MWA wavelengths. He also commenced work half-time as a commissioning scientist for the Boolardy Engineering Test Array (BETA) as part of a secondment to CSIRO. In 2015 he plans to continue work on polarisation within the GLEAM and EoR projects and to search for evidence of the synchrotron cosmic web in diffuse emission mapped with the MWA.

Dr Vanessa Moss

CAASTRO Postdoctoral Researcher

Theme: Evolving

Moss joined the First Large Absorption Survey in HI (FLASH) team in mid-2014 and is working on science preparations for this survey, which will be made using the Australian SKA Pathfinder, as well as studies carried out with its precursor, the Boolardy Engineering Test Array. Her focus is on the galactic ecosystems of both intervening and associated absorbing systems, with an emphasis on their multi-wavelength footprints determined from large-scale datasets.

Dr Shane O'Sullivan

CAASTRO Affiliate

Theme: Evolving, Dynamic

In 2014 O'Sullivan worked on creating a new all-sky catalog of polarised radio sources, characterising their polarisation morphologies and optical host-galaxy properties. Initial results from this work will be published in ApJ in early 2015. The catalog has also been disseminated amongst the collaboration, generating several new exciting projects. O'Sullivan continued coordinating the CAASTRO in the Classroom outreach program in 2014, with a transition to new coordinators occurring towards the end of the year. In 2015, he will continue his research on radio-galaxy environments under the CAASTRO Evolving Universe theme, in his new position at the National Autonomous University of Mexico (UNAM) in Mexico City.

Dr Nicholas Scott

CAASTRO Postdoctoral Researcher

Theme: Evolving

In 2014 Scott worked on the SAMI Galaxy Survey, a ground-breaking new project to obtain spatially resolved spectroscopy of more than 3000 galaxies. Scott is currently leading the work on stellar populations and galactic dynamics within the survey. Scott also worked on a number of related smaller projects, publishing a study of slow and fast rotators in the Fornax cluster early in the year. Towards the end of 2014 Scott took over as co-coordinator of the CAASTRO in the Classroom program, which brings astronomy education to schools throughout New South Wales via video-conferencing.

Ms Jessica Bloom

PhD Student

Themes: Evolving, Dark

Bloom's focus is understanding the role of events such as mergers in galaxy evolution. In 2014, she used tools she had developed to identify perturbed galaxies. Early science results from this work include investigations into the colour, stellar mass and star-formation rates of these galaxies.

Mr Joseph Callingham

CAASTRO PhD Student

Theme: Evolving

Callingham has been working on spectral modelling of young radio galaxies using data from the MWA and ATCA. He has also been empirically modelling the primary beam of the MWA and constraining the low-radio-frequency flux scale for the southern hemisphere.

Mr Marcin Glowacki

CAASTRO PhD Student

Theme: Evolving

Glowacki has joined the FLASH (First Large Absorption Survey in HI) team working with ASKAP in its BETA commissioning stage. The aim of FLASH is to search for cool, star-forming material in the early Universe through HI 21-cm absorption, and through this learn more about galaxy evolution across epochs. In 2014 Glowacki created a publicly accessible website to aid in target selection, and used this to compile a target list of bright, red quasars that was searched against for HI 21-cm absorption with ASKAP. Glowacki also assisted in observing nearby compact sources with the Australia Telescope Compact Array (ATCA), and subsequent data reduction and analysis.

Ms Cleo Loi

CAASTRO Honours Student

Theme: Dynamic

Loi has been working with MWA data, looking for radio emission from low-mass stars and also characterising the ionosphere over the MWA. She completed an Honours project in 2014 supervised by Tara Murphy, focused on exploring the MWA's capabilities as an ionospheric probe. In 2015, she will begin a PhD project supervised by Tara Murphy, with the aim of performing a climatological study of the ionosphere using existing data from MWA transient surveys. Loi is working to establish the MWA as a quantitative tool for geospace physics, its high sensitivity and widefield nature allowing it to image the ionosphere in a novel and detailed way.

Ms Rebecca McElroy

CAASTRO PhD student

Theme: Evolving

McElroy works on integral-field spectroscopy of active galaxies and is also a member of the SAMI Galaxy Survey. In 2014 she presented her first talk at an international conference and published her first paper on AGN feedback. In 2015 McElroy will be helping with SAMI observations, and working to combine her AGN dataset and the SAMI sample in a new comparison paper.

Ms Aina Musaeva

CAASTRO PhD student

Theme: Evolving

In 2014 Musaeva submitted several X-ray and radio proposals for the (previously identified) most promising intermediate-mass black hole (IMBH) candidates, with some of them granted observing time in 2015. She presented the results of her research at an international workshop in Leiden, Netherlands, with her poster awarded the best poster of the workshop. At the end of 2014 Musaeva had a paper accepted (by Monthly Notices of the Royal Astronomical Society) on testing the hypothesis that the strongest candidate IMBH (HLX-1 in ESO 243-49) is the nucleus of a stripped dwarf galaxy.

Ms Sarah Reeves

CAASTRO PhD Student

Theme: Evolving

Reeves is working on HI emission- and absorption-line studies of galaxies, as part of preparation for the ASKAP-FLASH survey. In 2014 she completed a study of HI emission and absorption in a sample of nearby galaxies with the ATCA, as well as working on a new HI absorption stacking project. Reeves' focus in 2015 will be on finishing her PhD thesis, which she plans to submit in early 2015.

Mr Samuel Richards

CAASTRO PhD Student

Theme: Evolving

In 2014, Richards presented the result of an isolated dwarf galaxy with an intense HII region on its outskirts (the "LMC's lonely twin"), identified from the data of the SAMI Galaxy Survey. This dwarf galaxy, and ones similar to it, help in the evolutionary understanding of 'clump-cluster' systems at higher redshift ($z \sim 1$). Richards also used the resulting data from SAMI to test single-fibre aperture corrections that are used routinely in large surveys such as GAMA and SDSS. Identifying any systematic errors in these corrections is of great importance to studies of galaxy evolution in the local Universe.

Mr Adam Schaefer

CAASTRO PhD Student

Theme: Evolving

Schaefer is a postgraduate student working on the theme of the Evolving Universe who joined CAASTRO in mid 2013. Using data from the SAMI Galaxy Survey Schaefer used spatially resolved spectroscopy to study the environmental dependencies of the star formation profiles within galaxies.

Ms Kate Gunn

Chief Operating Officer

A start-up specialist with a wealth of business and University experience, Gunn has been well placed to establish the necessary foundations for CAASTRO to grow and achieve its goals. She has 25 years of management experience, and has a background in the commercialisation of University intellectual property.

Ms Debra Gooley

CAASTRO Finance Officer

Gooley is responsible for the co-ordination and management of ARC Centre of Excellence KPI and financial reporting and other associated reports for CAASTRO, to support the achievement of the Centre's goals and objectives.

Ms Michelle Sullivan

CAASTRO Executive Assistant

Sullivan provides executive assistance to the CAASTRO Director and other CAASTRO staff, including assisting the COO and Events and Communications Officer with their duties.

Ms Kylie Williams

CAASTRO Events and Communications Officer

Williams coordinates the regular CAASTRO newsletter and organises various events hosted by CAASTRO around Australia.

Ms Helen Sim

Public Relations Officer

Sim has extensive experience in writing and performing public relations for scientists, and is skilled in translating complex information into language for non-technical audiences.

THE UNIVERSITY OF MELBOURNE

CAASTRO AT THE UNIVERSITY OF MELBOURNE

CAASTRO University of Melbourne team members

The University of Melbourne node of CAASTRO is housed within the School of Physics. The Astrophysics group at Melbourne was founded less than 20 years ago, but has a track-record of excellence in observational and theoretical cosmology, areas which provide the basis for our contributions to CAASTRO.

University of Melbourne researchers are primarily engaged within the Evolving Universe theme of which Professor Stuart Wyithe is lead, with an emphasis on Epoch of Reionisation (EoR) science, including:

- A wide-field survey of neutral hydrogen in the high-redshift Universe with the Murchison Widefield Array (MWA) of which the University of Melbourne was a founding partner (Webster, McKinley, Mitchell, Pindor, Procopio, Riding, Line)
- Numerical simulation of the evolution of early galaxies and their interaction with the high redshift intergalactic gas (Wyithe, Tescari, Jeeson-Daniel, Bolton, Kim, Katsianis).

The University of Melbourne is also making contributions to the Dark Universe theme:

- The use of Ly-alpha in absorption and emission to study Baryonic acoustic oscillations at high redshift using the next generation of widefield spectroscopic surveys (Wyithe, Bolton, Greig, Jeeson-Daniel).

2014 saw activity at Melbourne in all of these areas. At its peak the CAASTRO team numbered 20 people this year, including four CAASTRO-funded postdocs, five PhD candidates, and a further five affiliated postdocs.

Summary of 2014 Research Highlights

We developed a semi-analytic method for assessing the impact of the large-scale IGM temperature fluctuations expected following He II reionisation on three-dimensional clustering measurements of the Ly-alpha forest. Our methodology builds upon the existing large volume, mock Ly-alpha forest survey simulations presented by Greig *et al*. by including a prescription for a spatially inhomogeneous ionising background, temperature fluctuations induced by patchy He II photoheating and the clustering of quasars. This approach enabled us to achieve a dynamic range within our semi-analytic model substantially larger than currently feasible with computationally expensive, fully numerical simulations. We use these simulations to show that large-scale temperature fluctuations introduce a scale-dependent increase in the spherically averaged 3D Ly-alpha forest power spectrum of up to 20–30 per cent at wavenumbers $k \sim 0.02$ Mpc^{-1}. We show that although these large-scale thermal fluctuations will not substantially impact upon the recovery of the baryon acoustic oscillation scale from existing and forthcoming dark-energy spectroscopic surveys, any complete forward modelling of the broad-band term in the Ly-alpha correlation function will nonetheless require their inclusion. (Greig, Bolton, Wyithe)

In 2014 we used high-resolution simulations of cosmological volumes to model galaxy formation at high redshift, with the goal of studying the photon budget for reionisation. We demonstrated that galaxy formation models that include a strong, thermally coupled supernovae scheme reproduce current observations of star-formation rates and specific star-formation rates, both during and after the reionisation era. These models produce enough UV photons to sustain reionisation at $z \leq 8$ ($z \leq 6$) through a significant population of faint, unobserved, galaxies for an assumed escape fraction of 20 per cent (5 per cent). This predicted population is consistent with extrapolation of the faint end of observed UV luminosity functions. We find that heating from a global UV/X-ray background after reionisation causes a dip in the total global star-formation rate density in galaxies below the current observational threshold. (Duffy, Wyithe)

Estimating the intergalactic medium ionisation level of a region needs proper treatment of the reionisation process for a large representative volume of the Universe. The clumping factor, a parameter which accounts for the effect of recombinations in unresolved, small-scale structures, aids in achieving the required accuracy for the reionisation history even in simulations with low spatial resolution. In 2014, we made the first study of the redshift evolution of clumping factors of different ionised species of H and He. We investigated the dependence of the value and redshift evolution of clumping factors on their definition, the ionisation level of the gas, the grid resolution, box size and mean dimensionless density of the simulations. (Jeeson-Daniel)

The rapid decline in the number of strong Ly-alpha emitting galaxies observed at $z > 6$ provides evidence for neutral hydrogen in the intergalactic medium, but is difficult to explain with plausible models for reionisation. In 2014 we demonstrated that the observed reduction in Ly-alpha flux from galaxies at $z > 6$ can be explained by evolution in the escape fraction of ionising photons. Specifically we found that the median observed drop in the fraction of galaxies showing strong Ly-alpha emission, as well as the observed evolution of the Ly-alpha luminosity function, both follow from a small increase. More generally, our analysis also showed that the drop in the Ly-alpha fraction is quantitatively consistent with the observed evolution in the Ly-alpha luminosity functions of Ly-alpha emitters. (Wyithe)

Dark matter self-annihilation holds promise as one of the most robust mechanisms for the identification of the particle responsible for the Universe's missing mass. In 2014 we examined the evolution of the dark-matter annihilation power produced by smooth and collapsed structures over cosmic time, taking into account uncertainties in the structure of dark-matter haloes. As astronomers search for observational signatures of annihilation, an understanding of this time evolution will help to best direct observational efforts, either with local measurements or investigation of the effects of annihilation on the intergalactic medium at high redshift. We find that there are several key sources of uncertainty in our ability to estimate the dark-matter annihilation from collapsed structures, including: the density profile of dark matter haloes; the small-scale cut-off in the dark matter halo mass function; the redshift-dependent mass-concentration relation for small haloes; and the particle-velocity dependence of the dark matter annihilation process. Varying assumptions about these quantities can result in annihilation power predictions that differ by several orders of magnitude. Our work demonstrates that these uncertainties must be resolved, through a combination of observation and modelling, before robust estimations of the cosmological annihilation signal can be made. (Mack)

During 2014 we used a new set of cosmological hydrodynamic simulations, ANGUS (AustraliaN GADGET-3 early Universe Simulations), run with a modified and improved version of the parallel TreePM-smoothed particle hydrodynamics code GADGET-3 called P-GADGET3(XXL), to study the role of feedback from supernovae (SN) and black holes in the evolution of the star formation rate function (SFRF) of $z \sim 4$–7 galaxies. We find that the SFRF is insensitive to feedback prescription at $z > 5$, meaning that it cannot be used to discriminate between feedback models during reionisation. However, the SFRF is sensitive to the details of feedback prescription at lower redshift. By exploring different SN-driven wind velocities and regimes for the AGN feedback, we found that the key factor for reproducing the observed SFRFs is a combination of 'strong' SN winds and early AGN feedback in low-mass galaxies. We then went on to investigate the evolution of the star formation rate–stellar mass relation (SFR-M*) and galaxy stellar mass function (GSMF) of $z \sim 4$–7 galaxies, using these simulations. We showed that our fiducial model, with strong energy-driven winds and early AGN feedback, is able to reproduce the observed stellar mass function obtained from Lyman-break selected samples of star-forming galaxies at redshift $6 < z < 7$. At $z \sim 4$, observed estimates of the GSMF vary according to how the sample was selected. We find that our simulations are more consistent with recent results from K-selected samples, which provide a better proxy of stellar masses and are more complete at the high-mass end of the distribution. Our simulations predict a population of faint galaxies not seen by current observations. (Katsianis, Tescari, Wyithe)

The correlation between 21-cm fluctuations and galaxies is sensitive to the astrophysical properties of the galaxies that drove reionisation. Thus, detailed measurements of the cross-power spectrum and its evolution could provide a powerful measurement of both the properties of early galaxies and the process of reionisation. In 2014 we studied the evolution of the cross-power spectrum between 21-cm emission and galaxies using a model which combines the hierarchical galaxy formation model GALFORM implemented within the Millennium-II dark-matter simulation, with a semi-numerical scheme to describe the resulting ionisation structure. We found that inclusion of different feedback processes changes the cross-power spectrum shape and amplitude. In particular,

the feature in the cross-power spectrum corresponding to the size of ionised regions is significantly affected by supernovae feedback. We predicted observational uncertainties of the cross-correlation coefficient based on specifications of the Murchison Widefield Array (MWA) combined with galaxy surveys of varying area and depth. We found that the cross-power spectrum could be detected over several square degrees of galaxy survey with galaxy redshift errors $\sigma_z \leq 0.1$.(Kim, Wyithe)

During 2014 we have used the MWA to undertake over 1000 of hours of observations targeted at the key Epoch of Reionization (EoR) fields. Working with the EoR collaboration, we have developed systems to ensure that this data is archived at the Pawsey Centre in WA with appropriate quality-control flags. We estimate that by the end of 2015 we will have obtained a sufficiently sensitive dataset to enable foreground removal and cosmic bias in each of our chosen fields. This experiment is designed to allow detection of the theoretically predicted HI signal of the EoR. (Webster, and the EoR collaboration: this includes Pindor, Procopio, McKinley, Line, Riding at Melbourne; Trott, Wayth, Tingay at Curtin; Offringa and Briggs at ANU; Lenc and Gaensler at Sydney; and Mitchell at CSIRO)

The first analysis of the MWA data uses a novel approach to compare the output of four different and independent pipelines developed by the Australian and US EoR collaboration. The same three-hour dataset is analysed by each pipeline, allowing a direct comparison of the outputs. The final output of each of these pipelines is compared using the two-dimensional power spectrum. This has allowed the EoR collaboration to understand different features in the power spectrum, and to perform an extensive set of experiments to understand the efficiency of the calibration and foreground removal algorithms. The key contribution to this program from the Melbourne node is the development of the Real Time System (RTS), an extensive data-reduction pipeline for the MWA. The RTS is being used to routinely analyse MWA data for other projects as well. (Pindor, Procopio, Webster, Line, Riding, McKinley)

The algorithm to detect weak three-dimensional gravitational lensing in relatively nearby spiral galaxies was fully developed and tested, showing that it was possible to detect shears of $\sim$0.02 for individual galaxies. This technique has been called Direct Shear Mapping (DSM) and will allow the measurement of the mass of dark-matter haloes around individual galaxies and potentially the shape of the dark-matter profile as well. Null tests of the algorithm on nearby high resolution three-dimensional radio datasets have confirmed the viability of the algorithm. In addition, several hundred potential pairs of galaxies have been identified in the GAMA catalogue, with estimated shears in the observable range. Observing time has been obtained on several telescopes to test for weak lensing. (de Burgh-Day, Taylor, Webster)

Outreach and Professional Development Activities

The Melbourne node continued to make strong contributions in outreach, public, and professional education activities throughout 2014. Activities ranged from public lectures, to school visits, to our terrific Year Ten work-experience program; contributing stories and comments to the popular science media and general press; continuing to host international visitors to engage and collaborate with local staff and students; and providing a range of conference, seminar and training workshop opportunities to our students and early-career researchers.

In June, for example, local members of the MWA EoR team (Webster, Pindor, Riding, Line) travelled to the US for the annual MWA Busy Week collaboration, held at UC Berkeley in California but organised by CAASTRO Executive Officer, Kim Dorrell, from Melbourne. Here researchers from around the world were able to compare notes from the past year's work in an intense but informal setting and map goals and tasks to be completed in the next year of the project.

Throughout 2014 CAASTRO affiliate Katie Mack continued her formidable outreach schedule. Her diverse engagements included guest speaking and panel participation at the World Science Fiction Convention followed by presenting a public lecture at Imperial College London in the UK; providing mentoring advice to young women at the "Girls on Film" festival "Girls Germs" event in Melbourne; performing in the National Science Week "Space Oddity" stage show in Sydney and Canberra; and participating in numerous national and international radio interviews, podcasts and chats with the public via Google 'hangouts'.

As in previous years, CAASTRO continued its sponsorship of the week-long work-experience program offered by the Astrophysics group which was held this year in concert with the inaugural CoEPP program. 2014 also saw the expansion and consolidation of the Telescopes in Schools Program developed by members of the Melbourne node. In all, eleven telescopes have been installed in underprivileged schools across Melbourne and regional Victoria. CAASTRO PhD students and postdocs regularly attend schools to give talks and to help out on observing nights for the program. Coordinating both of the aforementioned activities, Jacinta den Besten successfully generated involvement in the work experience programme across the wider School of Physics, enabling more outstanding students to get a taste of a future career involving science.

Professor Stuart Wyithe

CAASTRO Node leader

Theme: Evolving (Theme Leader)

In 2014 Wyithe worked on simulations of the star-formation rate functions and stellar-mass functions of high-redshift galaxies, and on modelling the effects of environment on Ly-alpha transmission studies using numerical simulations. In 2014 Wyithe also initiated new programs to model the cross-correlation between HI and galaxies with application to the CAASTRO intensity-mapping experiment, and to perform hydro-dynamic simulations of SAMI galaxies. In 2015 Wyithe will work on these new CAASTRO programs.

Professor Rachel Webster

CAASTRO Chief Investigator

Theme: Evolving

During 2014 Webster continued to manage the wider international Epoch of Reionisation (EoR) collaboration within the Murchison Widefield Array (MWA). This team is making good progress in the development of pipelines to analyse the massive EoR dataset that has been observed to date by the MWA. Webster continued her collaboration with Catherine de Burgh-Day and Edward Taylor on the Direct Shear Mapping technique, establishing that the technique is not only viable but has a high probability of being measured in local galaxies.

Ms Catherine de Burgh-Day

CAASTRO PhD student

Theme: Dark

De Burgh-Day is working on Direct Shear Mapping (DSM), a new method to measure 3D weak lensing using the velocity maps of rotating galaxies. She has fully tested the DSM fitting algorithm and is currently investigating promising targets for measuring galaxy-galaxy lensing with DSM, by searching for good lens-source pairs in the Galaxy and Mass Assembly (GAMA) public data release. She plans to directly target the best of the pairs she discovers in GAMA, measure their shear, and use this to measure properties of the lens galaxies dark matter halo. She also intends to develop a non-analytic formalism for flexion of a generalised lens, which unlike previous analytic derivations does not require circular symmetry in the lens. She is hoping to use this to extend DSM to include flexion fitting, which will allow her to probe the profile of dark-matter haloes as well as their shape.

Ms Jacinta den Besten

CAASTRO Affiliate

Theme: Education and Outreach

Midway through 2014 den Besten joined the CAASTRO administration team part-time to take on the social media and outreach activities while Ebeling was on parental leave. She provided support for the Mount Burnett Observatory Astronomy Festival during National Science Week and assisted with CAASTRO's Mid-Term Review by the ARC and the fourth Annual Retreat. In her affiliate role, den Besten continued implementing the Telescopes in Schools program, supported by CAASTRO for many years, and provided administration support for the expanded Year 10 work-experience program.

Ms Kim Dorrell

CAASTRO Executive Officer

In 2014 Dorrell continued her role as node administrator, liaising with the School of Physics, Faculty of Science and central University groups to ensure the appropriate integration of Centre activities into the University's overarching administrative structures. She also liaised with CAASTRO HQ in Sydney to ensure all reporting requirements for the node were met in an effective and timely manner. Dorrell also contributed to the burgeoning relationship between CAASTRO and the ARC Centre of

Excellence for Particle Physics at the Terascale (CoEPP) by helping to organise a second joint workshop on the theme of the direct detection of dark matter, held in regional Victoria. Other event management included assisting at the fourth CAASTRO Annual Retreat in Queensland and organising the MWA EoR Busy Week held at UC Berkeley in the USA.

Mr Antonios Katsianis

CAASTRO PhD student

Theme: Evolving

Katsianis began his PhD during 2012 studying the properties of high-redshift galaxies via numerical simulation, focusing on calculating the stellar mass function and star-formation rate function from the CAASTRO suite of simulations. In 2013 he worked on interpreting what these simulations imply for the feedback mechanisms important in high-redshift galaxies. He also tested the consistency of observations from different surveys and provided evidence of tension between different groups. In 2014 he expanded this work for lower redshifts and investigated the evolution of the star formation rate–stellar mass relation. In 2015 he is focusing on submitting his thesis.

Dr Han-Seek Kim

CAASTRO Affiliate

Theme: Evolving

In 2014 Kim worked on studies to predict the 21-cm power spectrum during the epoch of reionisation using large volume dark-matter simulations such as the GiggleZ and Millennium-XXL combined with a new method of making 21-cm mock observations. Additionally, he worked on the importance of the effect of reionisation on the HI mass-function of the local Universe.

Mr Jack Line

CAASTRO PhD student

Theme: Evolving

Line began working on his PhD in 2013, looking at the effects of time-averaging on interferometric data. It soon became clear that to properly probe these effects on a detection of the EoR using the RTS, a good knowledge of the radio foreground sources is necessary. In 2014, Line developed PUMA, software that uses positional and spectral information to cross-match existing catalogue data and flag extended sources. In 2015 he will enhance this software and apply it in various projects, including the effects of time- averaging.

Dr Katherine Mack

CAASTRO Affiliate

Themes: Evolving, Dark

Since December 2012, Mack has been working to improve models of the evolution of the reionisation-era universe and to explore new observational avenues by investigating the effects of dark-matter particle physics. Using her theoretical expertise, Mack has formed new collaborations within CAASTRO and with members of CoEPP, aiming to connect observational and numerical projects to new theoretical developments.

Dr Ben McKinley

CAASTRO Postdoctoral Researcher

Theme: Evolving

This year McKinley completed his PhD thesis “From the Moon to the nearest radio galaxies: early science with the Murchison Widefield Array”. The thesis consisted of three refereed journal articles related to the field of low-frequency radio astronomy, the most recent of which was a multi-wavelength study of the nearby radio galaxy Fornax A. McKinley is now employed at the University of Melbourne as CAASTRO postdoctoral Researcher in EoR science. Here, he continues to be part of the MWA team and in particular contributes to the project aiming to detect the signal emitted by neutral hydrogen in the early Universe. He still maintains an interest in studying radio galaxies as well as objects in earth orbit, such as space junk and the Moon!

Ms Sinem Ozbilgen

CAASTRO PhD student

Theme: Dark

Completing her CAASTRO-sponsored MSc studies in late 2013, Ozbilgen commenced her PhD candidature at Melbourne in March 2014. She has continued her earlier work to obtain WiFeS IFU cubes of spiral galaxies from the HICat to determine whether the velocity dispersion/circular velocity is a good indicator for galaxy type and whether it helps to reduce the scatter in the Tully-Fisher relation (TFR) as a third parameter. As this ratio does not depend on the distance of the galaxy this study could enable future inclusion of galaxies at higher redshifts in the analysis of the TFR.

Dr Bart Pindor

CAASTRO Affiliate

Theme: Evolving

Pindor is continuing his research as a core member of the MWA EoR team. In 2014, CAASTRO researchers at Melbourne, Curtin, ANU, and Sydney collaborated to create an integrated Australian-based end-to-end pipeline for processing MWA data from raw visibilities through to two-dimensional power spectra. In 2015 Pindor will use the Pawsey Centre’s Galaxy supercomputer to lead the production of power spectra from the first year of MWA EOR observations.

Dr Pietro Procopio

CAASTRO Postdoctoral Researcher

Theme: Evolving

During 2014 Procopio focused on new calibration techniques to be used in the pipeline for MWA EoR data reduction. These improvements resulted in a better handling of the noise levels in the final product, allowing a cleaner power-spectrum estimation. Procopio is also writing a pipeline for the processing of MWA GLEAM data, using the Real Time System (for calibration and peeling) and Miriad (for cleaning). This pipeline should lead to the realisation of the final phase of processing of the data, leading to what should be the definitive MWA source catalogue.

Ms Nastaran Rezaee

CAASTRO MPhil student

Theme: Evolving

In 2014, Rezaee submitted her Masters project, “Noise Characterization of Murchison Widefield Array Simulation”, and will re-submit her work in March of 2015.

Mr Tristan Reynolds

CAASTRO Masters student

Theme: Evolving

Commencing with CAASTRO in July 2013, Reynold’s thesis is investigating using the Five-hundred-metre Aperture Spherical Telescope (FAST), currently under construction in China, to detect quasar-generated HII regions during the EoR. He has modified the semi-numerical code for simulating the 21-cm signal from the EoR, 21cmFAST, to include quasar HII regions and added telescope and foreground noise to the simulated quasar line-of-sight 21-cm spectra. He next plans on determining what properties (HII region radius, temperature step across HII region boundary) of the HII region can be recovered from these spectra with FAST, following Geil and Wyithe (2008).

Mrs Jennifer Riding

CAASTRO PhD student

Theme: Evolving

During 2014 Riding worked on the newly commissioned MWA. ‘Shapelets’, a modelling method, was optimised for the most compact representation of a resolved source, reducing the computational requirements and keeping the RTS real time. This method is in the process of being evaluated in the RTS and early results suggest successful source subtraction allowing deeper foreground removal in our EoR fields. In 2015 Riding plans to spend time observing complex sources and then modelling them with shapelets.

Dr Edward (Ned) Taylor

CAASTRO Affiliate

Theme: Dark

Since June 2013 Taylor has been exploring a new approach to measuring the dark matter surrounding galaxies, exploiting the physical phenomenon of weak gravitational lensing. Connected to this work, he has been an active member of the SAMI Galaxy Survey team. The SAMI survey, already the largest in its class, will map the distribution and dynamics of stars and star formation within thousands of galaxies, and shed new light on the processes that drive and regulate star- and galaxy-formation.

Year Ten work-experience group presentations
Credit: Jacinta den Besten

Year Ten students and parents at the Observing Night at the University of Melbourne waiting while PhD student Craig Burnett sets up the instrument
Credit: Jacinta den Besten

2014 Year Ten work-experience group photo
Credit: Jacinta den Besten

Dr Edoardo Tescari

CAASTRO Postdoctoral Researcher

Theme: Evolving

In 2014 Tescari concluded the simulation project, "The interplay between galaxies and intergalactic gas", which was assigned a total of 5.5 Million CPU hours in three years through the CAASTRO CPU time-allocation scheme. Two papers on properties of galaxies at redshift $z \sim 4-7$ have been published in MNRAS. Two more papers are currently submitted to MNRAS. The first one is a follow up at lower redshift ($z \sim 1-4$) of the previous two papers on galaxy properties and the first author is CAASTRO PhD student Antonios Katsianis. The second is a study of both the metal and molecular content of simulated galaxy populations made in collaboration with Umberto Maio (University of Trieste) and Ryan Cooke (University of California, Santa Cruz). Since February 2014 Tescari has been co-supervising (with principal supervisor Emma Ryan-Weber) Swinburne CAASTRO PhD student Angela Garcìa on a project called "Diagnosing hydrogen reionisation with metal absorption line ratios".

Dr Laura Wolz

CAASTRO Postdoctoral Researcher

Theme: Evolving

In October 2014 Wolz joined CAASTRO to work on the theoretical modelling of HI intensity mapping surveys. She is realistically simulating the cross-correlation of optical data such as the WiggleZ galaxy survey with intensity-mapping observations. She is investigating how the joined analysis of optical and radio measurements gives insight into galaxy-evolution processes and might allow to distinguish between different star-formation scenarios. Furthermore, she will be involved into the processing and analysis of the intensity maps taken by the Parkes telescope.

CAASTRO AT SWINBURNE UNIVERSITY OF TECHNOLOGY

In 2014 Swinburne partnered with the University of Sydney and ANU to work on making the giant Molonglo Observatory Synthesis Telescope into an extremely flexible software instrument. The first maps were made in late 2014 and allowed us to measure the flux of SN1987A again for the first time in many years and complete a map of the lobes of Fornax A.

A glitch in the Vela pulsar was detected using timing data and 20 pulsars are being regularly timed using the new facility. New surveys for fast radio bursts and pulsars started at the Parkes telescope and CAASTRO PhD student Emily Petroff detected the first real-time fast radio burst using Parkes and achieved a great deal of media attention when the result was published. Dr Evan Keane was given an ongoing position with the SKA office.

In 2014 the CAASTRO cosmology group at Swinburne published new results using galaxy and velocity surveys to test the prevailing cosmological model. PhD student Andrew Johnson used the 6-degree Field Galaxy Survey peculiar-velocity dataset to test the laws of gravity on the largest scales achievable from a galaxy survey to date, measuring a scale-dependence consistent with the predictions of General Relativity.

Research associate Jun Koda finalised forecasts for how these results can be extended by future velocity surveys such as Taipan and WALLABY, and was awarded a prestigious Darklight postdoctoral fellowship in Italy. Research associate Eyal Kazin published an analysis doubling the accuracy of the measurements of the distance–redshift relation from the WiggleZ Dark Energy Survey; Eyal has since started a job in industry.

Research associate Felipe Marin has undertaken a careful comparison of large-scale structure in the overlap regions of WiggleZ and the Baryon Oscillation Spectroscopic Survey. The group has also used an allocation of CAASTRO supercomputing time to produce a large new suite of cosmological simulations. At the end of the year, the group was boosted by the arrival of new postdoc Ixandra Achitouv.

Chief Investigator Jeremy Mould is joint leader of a dark-matter direct-detection experiment in the Stawell gold mine. This arose from the second CAASTRO CoEPP workshop in September.

Mould commenced work with postdoctoral research fellow Elisabetta DaCunha on target selection for the Taipan Galaxy survey with the UK Schmidt Telescope at Siding Spring Observatory. This will result in the best map of local dark matter yet. Mould was successful in obtaining ARC LIEF funding for the KISS transient object survey at Dome A in Antarctica. An infrared camera will be built for a Chinese 0.85-metre telescope.

Jeremy Mould and Research associate David Lagattuta obtained high-resolution infrared spectra of galactic nuclei with the Magellan FIRE instrument.

Professor Matthew Bailes

CAASTRO Node Leader

Theme: Dynamic (Theme Leader)

Bailes is overseeing a project to refurbish the Molonglo Observatory Synthesis Telescope with new digital instrumentation to monitor pulsars and search for dispersed radio pulses from fast radio bursts, pulsars and rotating radio transients.

Associate Professor Chris Blake

CAASTRO Chief Investigator

Theme: Dark

Blake is co-ordinating the CAASTRO Dark Theme activities at Swinburne. His CAASTRO research involves cosmological analyses and simulations of galaxy surveys to extract information from large-scale structure, gravitational lensing and galaxy velocities. He is leading a new 50-night galaxy survey at the Anglo-Australian Telescope, the 2-degree Field Lensing Survey (2dFLenS), which began in 2014. The aim of the project is to test gravitational physics through the manner in which the distribution of matter imparts both velocities to galaxies, and deflections to passing light rays. Blake and his group work on the interface of observations and theory, testing the properties of the dark energy that fills the Universe using a variety of tools such as baryon acoustic oscillations, redshift-space distortions, peculiar velocity surveys, and galaxy voids.

Professor Jeremy Mould

Chief Investigator

Theme: Dark

During 2014 Mould and two CAASTRO students worked on improvements to two extragalactic distance indicators. The celebrated supernova 'standard candle' (Nobel Prize for Physics 2011) may be improved by measuring supernova brightness after separation into host-galaxy star-formation rate classes. The

CAASTRO Swinburne University of Technology team members

Tully-Fisher relation for SAMI galaxies may be improved by measuring the velocity dispersion of the galaxy's bulge as well as its rotation velocity. Luca Cortese (Swinburne) wrote an ApJ Letter on this. Mould also organised the second joint CAASTRO/CoEPP workshop on direct detection of dark matter. CoEPP is interested in hosting an INFN dark-matter detection experiment looking for annual modulation from a southern hemisphere site. If an underground physics lab can be developed in the Stawell gold mine, participants in the meeting have a strong interest in organising a collaboration between CoEPP and INFN for this purpose. A working group will refine the parameters of this collaboration.

Professor Karl Glazebrook

CAASTRO Affiliate

Theme: Dark

Glazebrook's main activity in CAASTRO has been the initiation and early development of the OzDES project, a collaboration between Australian researchers and the large international Dark Energy Survey (DES), which is carrying out a very deep large-area imaging survey of the southern sky. OzDES involves numerous CAASTRO senior investigators and PDRAs. Professor Glazebrook is also engaged in the SAMI survey for quantifying the role of angular momentum in galaxy formation.

Dr Willem van Straten

CAASTRO Affiliate

Theme: Dynamic

van Straten is an expert in high-precision pulsar timing and radio polarimetry. He has developed state-of-the-art instrumentation and high-performance data analysis software for the world's premier radio observatories and is currently leading the design of the pulsar-timing instrumentation for the Square Kilometre Array. van Straten is actively involved in the Survey for Pulsars and Extragalactic Radio Bursts (SUPERB) based at the Parkes Observatory in New South Wales. For this project, he supervises PhD student Emily Petroff's search for fast radio bursts and rotating radio transients and Masters student Vincent Morello's development of machine-learning techniques that differentiate between promising pulsar candidates and radio-frequency interference.

Dr Vikram Ravi

CAASTRO Postdoctoral Researcher

Theme: Evolving

Ravi joined CAASTRO in late 2014 to work on the UTMOST project with Professor Matthew Bailes. Ravi has been assisting with the development and commissioning of the various observing modes of this system, from making wide-angle images of the radio sky to searching for the mystifying fast radio bursts. Ravi has recently completed a PhD in Physics at the University of Melbourne, and will be taking up a Fellowship at the California Institute of Technology in September 2015.

Dr Chris Flynn

CAASTRO Postdoctoral Researcher

Theme: Dynamic

Flynn has been closely involved with the management of the Molonglo telescope project upgrade, including the GPU-based correlator and pulsar-folding systems, hardware upgrades to the receivers and digitisation systems, observing scheduler and automation of observing. Significant milestones during the year include operating the telescope as an array on 25% of the antennae, producing our first maps of radio sources, the first pulsar observation using the telescope as a coherent array, detection of individual pulses from the bright pulsar Vela, full remote operations of the telescope, resuming flux monitoring of the supernova 1987A, timing of about a dozen pulsars weekly, significant progress ameliorating the effects of mobile-telephone calls, shadowing of the Parkes radio telescope when it is conducting pulsar and radio-burst surveying, and development of our pipeline system to search for individual bursts (also known as fast radio bursts, one of our primary science drivers for the upgraded instrument).

Dr Alan Duffy

CAASTRO Affiliate

Themes: Evolving, Dark

Duffy has created a new simulation series tracking the formation of the first galaxies, properties of which will be crucial for determining the visibility of the Epoch of Reionisation by radio telescopes such as the Murchison Widefield Array. As well as working on the distant Universe, he has also created a bespoke online pipeline to image the local Universe from simulations in a similar fashion to ASKAP and to probe the nature of the IGM.

Mr Andrew Jameson

CAASTRO Affiliate

Theme: Dynamic

Jameson is highly experienced in software development, systems administration, high-performance computing and scientific visualisation. He has implemented several generations of pulsar instrumentation at the Parkes Radio Telescope. His work continues in the areas of data acquisition, high-speed networking, real-time systems, interference excision, GPU software development and 'big data' management.

Dr Ewan Barr

CAASTRO Postdoctoral Researcher

Theme: Dynamic

Barr has been at Swinburne since April 2013. His research expertise lies in the fields of digital signal processing, data-mining and high-performance computing, particularly in the field of pulsar astronomy. Since arriving at Swinburne, Barr has led a project to develop state-of-the-art high-performance software that uses graphics processing units to enable real-time searches for binary pulsars. This work has now facilitated the first real-time accelerated pulsar and transient survey, the Survey for Pulsars and Extragalactic Radio Bursts (SUPERB), which is currently making new discoveries. The main focus of Barr's current work is the the design and development of the required instrumentation for pulsar science with the Square Kilometre Array (SKA). This includes design and development of an SKA (and also MeerKAT) pulsar timing backend at Swinburne, but also development of a real-time pulsar search backend (the first dedicated instrument of its kind) with partners in Europe. Barr's work has also seen him involved in the re-commissioning of the Molonglo Observatory Synthesis Telescope (MOST). Here, we are working to vastly increase the scientific capabilities of the telescope, providing a world-class instrument for the discovery of fast radio bursts.

Dr Evan Keane

CAASTRO Postdoctoral Researcher

Theme: Dynamic

In 2014, Keane began the SUPERB survey at the Parkes telescope: this has the goal of discovering new pulsars and fast radio bursts. The project has has already made some discoveries. As part of the project, Keane identified ways to improve search techniques for fast radio bursts and to more accurately determine their characteristic parameters. He was also part of teams that performed the first low-frequency high time resolution transient searches with LOFAR, made focused studies of individual pulsars including PSRJ1227-4853, an X-ray binary that recently transitioned to a millisecond pulsar, and worked on a neural network for identifying new pulsar discoveries in radio-telescope data.

Ms Emily Petroff

CAASTRO PhD Student

Theme: Dynamic

Petroff started her PhD in 2012 with CAASTRO scientists Dr Willem van Straten, Dr Matthew Bailes, and Dr Simon Johnston. Her work focuses on searching large radio surveys from telescopes like Parkes for new pulsars and exotic radio transients through single-pulse emission. Her main work this year has centered around finding fast radio bursts, which are bright, millisecond pulses believed to come from other galaxies. She found one such event in 'real time' and coordinated the largest international follow-up ever attempted. She will be building on this work to develop triggering and shadowing programs with international collaborators to understand more about this mysterious class of objects.

Mr Rahul Sai Poruri

CAASTRO PhD Student

Theme: Evolving

Poruri is a final year student pursuing a BS & MS in Physics degree at the Indian Institute of Technology, Madras. At the Swinburne University of Technology, Poruri worked with Professor Jeremy Mould to construct a Tully-Fisher (TF) relationship from the SAMI survey data. Over the span of two months, Poruri worked to reduce IFS data cubes to extract the H alpha emission lines and built a data set to construct the TF relationship. Poruri discovered interesting double lobed H alpha emission line profiles, a characteristic of galactic HI observations. His work was presented as a poster at the conference on 'The Role of Hydrogen in the Evolution of Galaxies

Mr Fabian Jankowski

CAASTRO PhD Student

Theme: Dynamic

Jankowski commenced his PhD at Swinburne in September 2013 under the supervision of Professor Matthew Bailes, Dr Willem van Straten and Dr Evan Keane. He leads the pulsar-timing science programme at the Molonglo radio telescope and helps re-commission, debug and verify the instrument. More than a year's worth of high-cadence data has now been taken, mainly using an automatic observing mode designed by him, with the current timing program consisting of about 16 pulsars.

Ms Shivani Bhandari

CAASTRO PhD Student

Theme: Dynamic

Bhandari is involved with transforming Australia's largest radio telescope, the Molonglo Observatory Synthesis Telescope, into a wide-field camera capable of performing precision timing of multiple pulsars, radio-sky mapping, and searching the radio sky for fast radio bursts. The main challenges involve detection and excision of radio-frequency interference, and phasing the array to ultimately create tied-array beams and radio maps using the output of the supercomputer. Bhandari's science goals are related to

synthesis imaging using Molonglo, and also include the localisation of new pulsars that are being discovered at Parkes, and large-scale structure in red-shifted HI. Bhandari is also part of the High Time Resolution Universe surveys (HITRUN) and Surveys for Pulsars and Extragalactic Radio Burst (SUPERB) teams.

Mr Venkatraman Krishnan

CAASTRO PhD Student

Theme: Dynamic

Krishnan is a first year PhD student working with Professor Matthew Bailes, Dr Willem van Straten and Dr Evan Keane at Swinburne University of Technology. His thesis mainly focuses on developing new instrumentation techniques for time domain astronomy. He will specifically focus on new 'telescope generic' ways to detect and excise radio-frequency interference which is crucial at the dawn of the SKA era. He will also develop efficient algorithms for the detection, analysis and timing of pulsars and other fast radio transients in 'real time', harnessing the advancements in computer science such as massively parallel computing architectures and 'big data' management. Krishnan will primarily use the Molonglo Observatory Synthesis Telescope (UTMOST) for his thesis, and he will help with several aspects of the refurbishment of this telescope during the initial part of his PhD. Apart from UTMOST, he will also use the MEERKAT radio telescope and the CSIRO Parkes radio telescope for developing and testing his techniques. Once the techniques are developed, he will use them to do high-precision pulsar timing and transient searching with the telescopes mentioned above.

Dr David Lagattuta

CAASTRO Postdoctoral Researcher

Theme: Dark

In 2014 Lagattuta published a study of the gravitational lens 3C220.3. He obtained high-resolution infrared spectra of galactic nuclei with the Magellan FIRE instrument. Stellar population models will be compared with these data to see if the initial mass function is bottom heavy (an excess of low-mass stars) in massive ellipticals, possibly explaining their high mass-to-light ratios.

In addition, Lagattuta was also actively involved with the OzDES survey and the Uluru Astronomer in Residence scheme. In OzDES he is interested in the Strong Lensing Working Group: a team identifying and studying strong gravitational lenses in DES. With these newly discovered systems, he intends to expand upon the efforts of SHARP, a Keck project using gravitational lenses to find dwarf satellite galaxies. He has moved to Lyon to pursue this lensing work. It promises to confirm or deny one of cold dark matter's most controversial predictions: the prevalence of substructure.

Dr Eyal Kazin

CAASTRO Postdoctoral Researcher

Theme: Dark

Eyal Kazin's paper performing improved cosmological distance measurements to redshift $z = 1$, by applying reconstruction of the baryon acoustic feature to the WiggleZ Dark Energy Survey, was accepted for publication in MNRAS. In July 2014, Eyal left academia to take up a position in industry after three years as a CAASTRO Research Associate.

Syed A Uddin

CAASTRO PhD Student

Theme: Dark

Uddin's PhD thesis falls within the framework of CAASTRO's Dark theme. He is investigating the effect of host-galaxy environments on the light-curve parameters of Type Ia supernovae. Large datasets are being built from SNLS, SDSS, and CSP supernova surveys for this work. Additional datasets may come from the DES and SkyMapper surveys. With a large dataset and controlled analysis methods for photometry and SED fittings, this work has potential to improve systematic uncertainties originating from different host-galaxy properties (e.g. dust extinction) in supernovae light-curves. Understanding the force responsible for cosmic acceleration is an important implication of this work. Uddin has been involved in the OzDES collaboration where the AAOmega spectrograph on AAT is used to follow up supernovae candidates discovered by DES. First year OzDES observations are finished and an article has appeared in AAObserver. Several supernova discovery-confirmation telegrams have also been published by the IAU. Uddin plans to submit his PhD thesis by the middle of 2015.

Associate Professor Emma Ryan-Weber

CAASTRO Associate Investigator

Theme: Evolving

Ryan-Weber's research in 2014 continues to focus on metal absorption-line systems in the high redshift Universe. Two new PhD students have commenced at Swinburne on this project under her supervision. Luz Angela Garcia is collaborating with Edoardo Tescari and Stuart Wyithe on simulating metal absorption-line systems. Alex Codoreanu is working on high signal-to-noise ratio spectra of redshift 6 quasars to search for metal lines in the intergalactic medium at the conclusion of reionisation.

Alex Codoreanu

CAASTRO PhD Student

Theme: Evolving

Codoreanu commenced his PhD at Swinburne in May 2014 under the supervision of Associate Professor Emma Ryan-Weber, Professor Michael Murphy and Dr Neil Crighton. His work focuses on absorption systems in high-redshift quasar spectra as a way to understand the end of the Epoch of Reionisation and the stellar populations responsible for it. Studying the relative strengths of different ionisation states of carbon, oxygen, silicon and other metals will constrain the stellar-population models and their number density in order to better understand the process of reionisation of cosmic hydrogen.

Dr Ixandra Achitouv

CAASTRO Postdoctoral Researcher

Theme: Dark

Achitouv joined CAASTRO in 2014 as a postdoctoral fellow. Her research focuses on developing analytical models to describe large-scale structure. In particular, she has worked on predicting the abundance of voids and clusters in the case of non-standard cosmologies such as primordial non-Gaussianity or the quintessence model of dark energy. Achitouv's work also focuses on analysing N-body simulations in order to understand non-linear gravitational processes leading to cosmological observables.

Ms Luz Angela Garcia

CAASTRO PhD Student

Theme: Evolving

Garcia started her PhD in Febraury 2014 at Swinburne under the supervision of Associate Professor Emma Ryan-Weber, Dr Edoardo Tescari and Professor Stuart Wyithe. Garcia is studying the Epoch of Reionisation using hydrodynamical simulations to derive theoretical constraints on the end of this era and investigate different scenarios. She is focused on the existence of correlations among metal absorption-line ratios, which can give a quantitative measure of the neutral-to-ionised hydrogen at high redshift ($z \sim 6$).

Dr Jun Koda

CAASTRO Postdoctoral Researcher

Theme: Dark

Koda worked on forecasting the accuracy with which future peculiar-velocity surveys may be used to test the cosmological model. In July 2014, Koda moved to accept the Darklight post-doctoral fellowship at the Osservatorio Astronomico di Brera after three years as a CAASTRO Research Associate.

Mr Andrew Johnson

CAASTRO PhD Student

Theme: Dark

Johnson is involved in using a number of recent cosmological measurements with a focus on the velocities of galaxies, to try to understand the origin of the current accelerated expansion of the Universe. The many different theories attempting to explain the accelerated expansion predict different structure-formation histories and consequently change the velocities of galaxies, among other things. As a result these measurements will allow the researchers to narrow down the plethora of current theories, and perhaps identify a single physical cause for this cosmic mystery.

Dr Felipe Marin

CAASTRO Postdoctoral Researcher

Theme: Dark

Marin worked in finding the dependence of the measured growth-rate of structures on the galaxy tracer used via redshift-space distortions (RSD) of the clustering pattern. Using data from the Sloan Digital Sky Survey and from the WiggleZ Dark Energy Survey, he tested systematics of current RSD models using Koda's COLA mock galaxy catalogs, and then applied his findings to the real data catalogs, finding concordance in the measured growth rate for both tracers and with the standard cosmological model. The results of this investigation will be sent to MNRAS in early 2015. Blake and Koda have collaborated in this research. In addition, Marin worked on measuring and analysing the bispectrum of WiggleZ galaxies (higher-order clustering in Fourier space), which is a complementary measure of clustering that allows us to measure the growth of the Universe as a function of time. Also, using Koda's method for generating fast N-body simulations, Marin is working on generating mock catalogs for the 6dFGS and for the future TAIPAN survey. These will allow us to estimate uncertainties and forecast the performance of future surveys.

Vincent Morello

CAASTRO Masters Student

Theme: Dark

Morello mainly focuses on pulsar searching and the application of machine learning to radio-astronomy data, under the supervision of van Straten and Barr. In 2014 he developed an automated machine-learning based system to analyse pulsar-search survey outputs. It can differentiate rare pulsar signals from millions of radio-frequency interference signals with high accuracy, a task previously requiring a very large amount of human intervention and time. His work contributed to the discovery of 10 new pulsars to date, including some left behind in previously searched data.

Ms Sue Lester

Node Administrator

Lester continues to support the activities of CAASTRO personnel at Swinburne and was involved with the LSST Town Hall event as well as the annual retreat. 2014 saw a year of structural and personnel changes within the University with CAASTRO now sitting within a new Faculty of Science, Engineering and Technology.

Australian National University

CAASTRO AT THE AUSTRALIAN NATIONAL UNIVERSITY (ANU)

CAASTRO ANU team members

Research at the ANU node of CAASTRO spans the breadth of the Centre's activities, with extensive links into all of the other nodes through CAASTRO's major initiatives of Skymapper survey science, SAMI, fast radio bursts, the OZDES project, MWA science, and transient science.

Within the Evolving Universe, we welcomed PhD student Mayuri Sathyanarayana Rao to the team. She, along with Professor Frank Briggs and Professor Ravi Subrahmanyan (Raman Research Institute), is investigating the feasibility of detecting additive spectral distortions in the cosmic microwave background arising from the epochs of cosmological hydrogen and helium recombination.

ANU also welcomed Honours student Sarah Leslie, who successfully completed her degree working with the SAMI team at the University of Sydney, looking at optical and radio measures of star formation. Matthew Colless used the SAMI survey data to undertake analysis of the Fundamental Plane and other kinematic scaling relations: that work continues.

Jonghwan Rhee, Frank Briggs, and Matthew Colless used deep observations from the Giant Metrewave Radio Telescope (India) and Westerbork Synthesis Radio Telescope (Netherlands) to measure the neutral hydrogen content of normal field galaxies in the redshift range $0.1 < z < 0.4$, a period spanning roughly 30% of the age of the Universe. Despite looking back in time nearly four billion years in order to probe galaxies when they were forming stars nearly four times faster than they do at present, these observations show that the gas content of the galaxies has remained nearly constant over this time, implying that they are being replenished by accretion of fresh material from the intergalactic medium. Rhee completed his PhD thesis based on this work and took a postdoctoral research position at University of Western Australia.

Ben McKinley, André Offringa and Frank Briggs participated in commissioning and calibrating the Murchison Widefield Array (MWA), to develop software to characterise and mitigate radio-frequency interference (RFI), to help design and implement software that enables calibration and imaging. McKinley completed his PhD at the ANU using MWA observations to study the extended radio lobes of the nearby radio galaxies Centaurus A and Fornax A. He also explored the possibilities for using the Moon as a calibrating screen for use in Epoch of Reionisation studies of neutral gas at redshift 7 to 12, when the first stars are lighting up. Offringa built novel software for RFI characterisation and excision, as well as a novel implementation of the image deconvolution algorithm (CLEAN) that is especially efficient for the widefield imaging applications with the MWA.

Within the Dynamic Universe theme, student Manish Caleb, working with the team at Swinburne, has investigated the rates of fast radio bursts (FRBs). She is part of the team that is refurbishing the Molongo Radio Telescope (MOST) to substantially increase its sensitivity and bandwidth. This should enable large numbers of FRBs to be discovered in 2015 and beyond. Caleb has also been investigating the measurement of the polarisation of single pulses from rotating radio transients which could then be applied to the single pulses from FRBs. This method has proven successful and was used by Petroff *et al*. (2014) to measure for the very first time the polarisation of a real-time FRB detection.

Our Dynamic Universe work has also cut through the optical domains, with the team including Dr Fang Yuan, Dr Michael Childress, Dr Richard Scalzo, Dr Chris Wolf, and Professor Brian Schmidt overseeing activity. Scalzo has continued to refine his light-curve modeling technique for measuring masses of SNe Ia progenitors, applying it to other candidates for explosions of super-Chandrasekhar-mass white dwarfs, and for deriving the intrinsic distribution of masses for a large sample of Type Ia supernovae. Using SkyMapper, Wolf, Yuan, and Scalzo coordinated multi-wavelength monitoring campaigns with the MWA and Kepler Extragalactic teams, searching for young supernovae and fast radio bursts and for QSO micro-variability.

Dr Michael Childress led a sustained effort to spectroscopically observe a large number of supernovae throughout their evolution with the ANU-2.3m telescope, work that was combined with the optical group's continuing participation in the Public ESO Spectroscopic Survey of Transient Objects (PESSTO) project. Childress used this work to gain insights into the explosion dynamics of Type Ia Supernoae (SN Ia) from the evolution of their spectra.

Finally, within the Dynamic Universe, we have bolstered the theoretical capability of CAASTRO by welcoming Dr Ivo Seitenzahl and Dr Ashley Ruiter. Seitenzahl showed that the 5.9 keV X-ray line emission from the decay of iron-55 is a promising diagnostic to distinguish between Type Ia supernova explosion models, and build hydrodynamic explosion models for optical transients, including thermonuclear explosion models for the faint SNe Iax. Ruiter worked on the theoretical formation channels of interacting binary stars that lead to transient phenomena, in particular Type Ia supernova progenitors. Her models have given further credence to the notion that many Type Ia supernovae arise from exploding white dwarfs that are less massive than previously speculated, and provided new theoretical birthrates for Type Ia supernova progenitors that arise from exploding sub-Chandrasekhar mass white dwarfs.

Within the Dark Universe, we welcomed PhD student Bonnie Zhang. Zhang is working to undertake a joint cosmological analysis between SkyMapper SN Ia and those in the existing SNLS survey (with LPNHE CAASTRO affiliates), and the new objects discovered as part of the OZDES survey. Yuan has set up and maintained the OzDES database hosted at ANU, participated in observing and data analysis and is leading the first-year survey paper. The OZDES survey, in addition to Zhang and Yuan, includes efforts by Schmidt , Childress, Scalzo, and Wolf. Also within the Dark Universe, Colless helped complete the analysis of the WiggleZ survey, with two WiggleZ papers published in 2014.

Professor Brian Schmidt

CAASTRO Node Leader; Gender and Diversity Committee Chair

Theme: Dark

Schmidt continued to lead work on SkyMapper, which spent 2014 undertaking the Southern Sky Survey.

More than 80% through its short survey of the Southern Sky, in 2015 the telescope's attention will be turned to extending the survey to fainter limits. In 2014 Schmidt continued to oversee the software pipelines, with these expected to produce data for the wider CAASTRO community in 2015. A decision was made to postpone a major supernova survey with the telescope until 2015, but many reference frames (required for supernova detection) were taken.

Schmidt continues to make many public appearances both in Australia and internationally, including being a keynote speaker at the World Economic Forum in Davos, the Euroscience Open Forum (ESOF) in Copenhagen, The European Space Agency's 50th Anniversary Celebration, as well giving major lectures in New York City USA, Tokyo Japan, Groningen Netherlands, and Mainz Germany. In November, along with his High-Z Supernova Search Team Supernova Cosmology Project colleagues, he received the 2015 Breakthrough Prize in Physics in a ceremony held in Silicon Valley.

Professor Frank Briggs

CAASTRO Chief Investigator

Themes: Evolving, Dynamic

Briggs' research interests have focused on the use of the radio 21-cm line of neutral hydrogen to follow the history of galaxy formation and evolution. Atomic hydrogen is the most primitive and most common of the elements, and primordial clouds of hydrogen gas are the substance from which the visible components of the structure of the Universe (the stars and galaxies) form. Briggs has been a member of the MWA Consortium to design, build and operation the Murchison Widefield Array in Western Australia since the project's conception. He has also been engaged in an ongoing collaboration with Indian astronomers at the National Centre for Radio Astrophysics in Pune and with astronomers within Australian institutes to use the Giant Metrewave Radio Telescope (GMRT) to measure the evolution of the gas content of galaxies over the last seven billion years, and the relation of the gas to star-forming properties of galaxy populations.

Professor Matthew Colless

CAASTRO Chief Investigator

Themes: Evolving, Dark

Colless led the 6dF Galaxy Survey that used the UKST to map the density and velocity fields in the local Universe by measuring Fundamental Plane distances and peculiar velocities for 10,000 nearby galaxies. He brings this expertise to the WALLABY survey team, which will test the current cosmological paradigm that the distributions of dark and luminous matter are the same on the largest scales by combining the WALLABY all-sky neutral hydrogen survey using ASKAP with an all-sky optical survey using SkyMapper. Colless is engaged in the comparison of the radio and optical surveys and the analysis of the velocity field and its implications for cosmological models. The CAASTRO research program brings together the WALLABY and FLASH ASKAP surveys with the 6dF and the proposed TAIPAN UKST surveys. As a member of all four survey teams, Colless plans to study the co-evolution of gas and stars out to a redshift $z \sim 0.25$ using the

ASKAP radio surveys to measure the neutral hydrogen gas component of galaxies and the UKST optical spectroscopy to measure the stellar component.

Dr Fang Yuan

CAASTRO Postdoctoral Researcher

Theme: Dynamic

Yuan is a member of the SkyMapper transient team. The SkyMapper transient search found its first supernova in late 2013 and is expected to have a steadily increasing discovery rate as the survey area expands and the pipeline continues to be improved. Her main science interest involves understanding of a diverse range of stellar explosions. She studies core-collapse supernovae and is responsible for coordinating SkyMapper and the ANU 2.3-m to follow up gamma-ray bursts, fast radio bursts and gravitational-wave candidate events. Yuan is also a member of the OzDES team. In addition, she is running the "CAASTRO in the Chinese Classroom" outreach program.

Dr Michael Childress

CAASTRO Postdoctoral Researcher

Theme: Dark

Childress' research focuses on observations of nearby supernovae, particularly through optical spectroscopy. In 2014 Childress had three papers published: one on high-velocity features in spectra of Type Ia supernovae (accepted in 2013), one describing the data-reduction pipeline for the WiFeS instrument (accepted in 2013), and one on ages of Type Ia supernovae as a function of galaxy environment and cosmic time. Childress is the Theme Scientist for the Dark theme, and is a member of the SkyMapper, OzDES, and 2dFLenS surveys.

Dr Andre Offringa

CAASTRO Postdoctoral Researcher

Themes: Dynamic, Evolving

Offringa joined CAASTRO in 2012 as postdoctoral fellow at ANU. He is part of the Epoch of Reionisation team that uses the Murchison Widefield Array (MWA) to detect faint redshifted HI signals from a yet unseen era of our Universe. The MWA radio telescope will generate huge data volumes, and processing these efficiently is an exciting challenge. Offringa works on efficient algorithms that are required for processing these data. He is also involved in the analysis of observations for the Epoch of Reionisation to investigate the properties of foreground sources, and works on the mitigation of radio-frequency interference (RFI).

Dr Richard Scalzo

CAASTRO Associate Investigator

Themes: Dark, Dynamic

Scalzo's research focuses on observational studies of supernovae at optical wavelengths, with emphasis on Type Ia supernova progenitors and explosion physics. Scalzo published three papers in 2014 on the diversity of ejected masses in Type Ia supernovae, including (with CAASTRO Associate Investigators Stuart Sim and Ashley Ruiter) the first detailed distribution of ejected masses for a large sample of Type Ia supernovae used in dark-energy experiments. These results suggest that progenitor-mass variation plays an important role in explaining the empirical relations used to standardise supernova distances for cosmology, and have been featured in science media, talks at two international conferences, and invited seminars in Australia and the United States. Scalzo continues to build new collaborations with theorists and observers to work on supernova progenitors, with the goal in 2015 of creating a robust Bayesian inference framework for progenitor properties of massive star explosions.

Together with colleague Dr Fang Yuan, Scalzo has also continued development and operation of SkyMapper's Supernova Search, including coordinated observations with the Kepler Extra-Galactic Survey (KEGS) and the Murchison Wide-Field Array to search for supernovae and fast radio bursts. The Supernova Search also discovered and confirmed SN 2013hx, a rare, superluminous Type Ic supernova. The Supernova Search will begin taking data at full scale for its Type Ia supernova cosmology project in early 2015.

Dr Christian Wolf

CAASTRO Associate Investigator

Theme: Evolving, Dark

Wolf started work as SkyMapper Survey Scientist in April 2013 and currently works on optimising operations, preparing survey data releases, and helping third-party users to make best use of the telescope. He previously led the COMBO-17 optical multi-band survey, which explored the evolution of galaxies and quasars over most of cosmic time. He is an expert in photometric redshift and statistical classification techniques and pioneered high-precision photometric redshifts and their application to quasars. His research interests include galaxy evolution and the decline of star formation in spiral galaxies as well as supernovae, GRBs and their host galaxies. His most recent work focused on the transformation of spiral galaxies in clusters and the effects of ram-pressure stripping.

Dr Robert Sharp

CAASTRO Associate Investigator

Theme: Evolving, Dark

Sharp is instrument scientist for the Giant Magellan Telescope Integral Field Spectrograph, a new instrument under design at the Australian National University and destined for the Giant Magellan Telescope in Chile in 2021. Within CAASTRO Sharp is a leader of the SAMI Galaxy Survey data analysis group, for which the SAMI survey team delivered the first public data release in July 2014. For the OzDES supernova survey project (which completes the second full year of its five year campaign in early 2015), Sharp is the local coordinator for the 'reverberation mapping' component that will measure the masses of giant black holes in distant quasars. Additionally, Sharp has teamed up with radio astronomers interested in faint radio galaxies and is using the repeated visits to the OzDES supernova survey fields to record sensitive observations of these enigmatic galaxies to identify the underlying source types and their distances from Earth.

Dr Ashley Ruiter

CAASTRO Associate Investigator

Theme: Dynamic

Ruiter works in binary star evolution modelling to understand the formation of interacting stars that give rise to explosive phenomena. She is interested in transient sources involving white dwarfs (e.g., Type Ia supernovae), and uses theoretical methods to uncover the evolutionary channels that lead to their formation, predict their birth rates, and constrain their birth sites (ages). Ruiter has been a member of CAASTRO since 2013 and joined the ANU in April 2014.

Dr Ivo Seitenzahl

CAASTRO Associate Investigator

Theme: Dynamic

Seitenzahl became a CAASTRO Associate Investigator in October 2013 and joined ANU as a SkyMapper Fellow in April 2014. He is a theoretical nuclear astrophysicist and his research focuses on explosive nucleosynthesis and three-dimensional simulations of Type Ia supernova explosions. Seitenzahl's research also includes work on the formation and propagation of detonations powered by nuclear fusion, the Galactic chemical evolution of manganese, the atomic and nuclear physics of late-time supernova light-curves, and the detectability of the 5.9 keV X-ray line emission from the decay of 55Fe in thermonuclear supernovae.

Ms Sharon Rapoport

CAASTRO PhD Student

Theme: Dynamic

Rapoport joined CAASTRO's ANU team as a PhD student in 2011. She worked on studying the expected angle-dependent synthetic spectra from jet-driven models (using Stuart Sim's 3D radiative transfer code) to better understand the observational expectations from gamma-ray bursts associated with supernovae, and constrain physical phenomena of the explosions properties by studying their observational consequences. She submitted her thesis in August 2014.

Ms Manisha Caleb

CAASTRO PhD Student

Theme: Dynamic

Caleb began her PhD in July 2013 under the supervision of Frank Briggs at ANU and Matthew Bailes and Chris Flynn at Swinburne. 'Fast radio bursts' (FRBs) are bright, coherent, millisecond-duration radio emission of unknown origin thought to occur at cosmological distances. Only a handful of these sources have been discovered to date. When more sources are discovered they could potentially help unveil some of the mysteries of the cosmos. Caleb is part of the team at Swinburne that is taking part in the worldwide race to discover more of these exciting sources.

Caleb is also performing Monte Carlo simulations to determine the discovery rates of these FRBs at the Parkes and Molonglo radio telescopes. The Molonglo radio telescope, a interferometer near Canberra, is currently being collaboratively refurbished with state-of-the-art backend technology to transform it into a burst-detection machine. When fully recommissioned, the telescope will be able to detect events four times better than Parkes.

Ms Bonnie Zhang

CAASTRO PhD Student

Theme: Dark, Dynamic

Zhang began her PhD in February 2014 under the supervision of Brian Schmidt. Her research is in observational cosmology with Type Ia supernovae, with the goal of constraining dark energy. As part of both the SkyMapper team and the OzDES collaboration, she will analyse light-curves of supernovae discovered in the SkyMapper Supernova Survey, at low redshift, and the Dark Energy Survey, at high redshift. She will also compare the photometric calibrations of both surveys to quantify and minimise the systematic uncertainty associated with the calibration.

Ms Mayuri Sathyanarayana Rao

CAASTRO PhD Student

Theme: Evolving

Sathyanarayana Rao began her PhD in March 2014 under the supervision of Frank Briggs at ANU and Ravi Subrahmanyan at the Raman Research Institute. Theory predicts additive spectral distortions in the cosmic microwave background (CMB) radiation arising from photons emitted during the epochs of hydrogen and helium recombination. These distortions are expected to be buried in a sky spectrum that is eight orders of magnitude brighter. Although an experimental detection of these distortions of the CMB is extremely challenging, the benefits of such a detection are immense: it would provide a wealth of information about the early history of the Universe, a measure of pre-stellar helium abundance, and more.

For her PhD, she is developing a prototype element for an array of radio telescopes, custom-designed to detect the spectral signatures of the epochs of hydrogen and helium recombination. She is also working on developing efficient algorithms for foreground subtraction, with a potential application to other cosmological problems including the detection of the redshifted 21-cm signal from the Epoch of Reionisation.

Ms Sarah Leslie

CAASTRO Pre-PhD Student:

Theme: Evolving

In 2014 Leslie completed her Honours in Astronomy and Astrophysics at ANU under the supervision of Professor Lisa Kewley, and of the University of Sydney CAASTRO members Professor Elaine Sadler and Dr Julia Bryant. Leslie works with the SAMI galaxy survey, and her thesis involved combining the optical data from SAMI with radio-continuum data from the VLA FIRST survey. Aiming to better understand radio emission in star-forming galaxies, Leslie found that shocks could play an important role in enhancing radio emission in galaxies with large-scale winds. Leslie will expand on this work next year as a Masters student.

Ms Denise Sturgess

CAASTRO Administrator

Sturgess has worked as CAASTRO Node Administrator at the Australian National University, Mt Stromlo Observatory, since CAASTRO's inception.

She provides ongoing, broad administrative support to the team and works alongside Chief Investigator Professor Brian Schmidt as his assistant.

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CAASTRO AT THE UNIVERSITY OF QUEENSLAND

It has been an exciting year for UQ astrophysics, as 2014 saw us becoming a new node of CAASTRO. Being part of the CAASTRO community has has had a tangible impact on our group, particularly our students, and helped us build on our existing collaborations and establish new ones.

Research at the Queensland node focuses on the Dark and Evolving themes. In September we welcomed our new CAASTRO postdoctoral fellow, Edward Macaulay, who is working on measuring the lensing magnification of supernovae in the OzDES survey. This should improve the precision with which the supernovae can be used as standard candles, and also allow for the amplitude of density fluctuations to be measured from signals in the data that would previously be considered as noise. Macaulay has a background in peculiar velocities, and so will be working also with students for our peculiar-velocity projects.

David Parkinson has been drilling into non-standard cosmologies: in particular, he has made the first predictions for what large-scale structure should look like in Galileon cosmologies. These models have an extra degree of freedom, which may have stochastically independent initial conditions that can break complete correlation between density and velocity power spectra, and thus make interesting testable predictions. Meanwhile his Honours student Caitlin Adams has investigated the effect neutrinos would have on power spectra, using a combination of COLA simulations made by our CAASTRO colleagues in Swinburne and emulator techniques to fill in the gaps between models that were able to be simulated. Adams has now moved on to a PhD at Swinburne.

Despite the fact that Signe Riemer-Søresnsen has moved to the University of Oslo, we continue our active collaboration and co-supervision of students with her. In 2014 we published the strongest neutrino mass constraint to date from cosmology based on Planck observations of the cosmic microwave background combined with the galaxy power spectra from WiggleZ. The analysis also provided interesting information on the neutrino hierarchy. In related work Signe performed a case study for improving measurements of the primordial deuterium abundance in order to constrain the presence of beyond-standard-model physics around the time of Big Bang nucleosynthesis; and following the detection of a 3.5-keV emission line in stacked galaxy-cluster spectra by Bulbul *et al*. (2014), she performed a search for line emission from the Milky Way, which disproved the speculated dark-matter origin of the galaxy-cluster line.

Michael Drinkwater continues to work on SAMI science, and student Adam Thomas completed his Honours thesis on searching for ram-pressure stripping in galaxy clusters with SAMI. While no definite cases of ram-pressure stripping were present in his sample, he did find strong evidence for a trend of increasing gas ionisation with distance from the nucleus in several galaxies. Continuing our close CAASTRO ties, Adam has moved on to a PhD at ANU. Michael was also awarded a prestigious teaching fellowship at UQ to develop his innovative teaching methods.

The Type Ia supernova rate has been looked at in an unusual way by Holger Baumgardt who quantified the role that direct collisions between white dwarfs may play. He and his student Lara Cullinane simulated collision rates between single white dwarfs in various globular clusters, and also investigated the role of stellar binaries for these collisions.

Tamara Davis' work has focused on OzDES this year, with our second year of observations now complete. She worked with software engineering Honours student Samuel Hinton, who rewrote the 2dF redshifting software, making it much easier to use and more powerful, while being accessible from a web browser without needing any complex installation. Sam won several awards for his thesis including the Institute of Electrical and Electronics Engineers student thesis award and the GroundProbe Prize Award for best thesis in photonics, microwave and communications. Meanwhile Honours student Conor O'Neill completed a simulation of the efficiency of our OzDES strategy of re-observing supernova host galaxies until we obtain a successful redshift. He is currently in Chile on a Gemini studentship. Davis also wrote a non-technical review of Cosmological Dark Energy constraints for General Relativity and Gravitation.

It was our great pleasure to be the host node for the annual CAASTRO retreat at the Sunshine Coast in November and, earlier in the year, the OzDES busy week. We spoke about our CAASTRO research at numerous conferences worldwide, including the Aspen workshop on cosmology, the CoEPP-CAASTRO workshop on direct dark matter detection, the Dark Energy Survey collaboration meetings in Chicago and University of Illinois, and the Academy of Science Frontiers of Astronomy conference in Canberra.

CAASTRO University of Queensland team members

Outreach and other activities were also high on our agenda. Group members gave talks everywhere from the Australian Museum to TEDx, including a Cosmology Winter School in Taiwan and even the Woodford Folk Festival. Tamara presented New Zealand's Beatrice Hill Tinsley Lecture Tour, which consisted of a week travelling around New Zealand talking about astrophysics to schools and the public. Edward attended a Maths in Industry conference, and applied techniques from cosmology to solve commercial challenges for industry. UQ was awarded a Bronze in the inaugural Pleiades Awards for supporting Women in Physics, and is next year's host for the ASA's Women in Astronomy conference, which is being supported by CAASTRO.

Professor Tamara Davis

CAASTRO Node Leader

Theme: Dark (Theme Leader)

Davis specialises in interpreting cosmological observations in terms of their implications for fundamental physics. In particular she focuses on determining the nature of dark energy and dark matter, using supernovae, large-scale structure, and galaxy velocities. She is a leader of the OzDES project, which began in 2013 being awarded 100 nights over five years on the AAT to take spectra of sources discovered by the Dark Energy Survey (DES). This year the Australian Academy of Science announced that she will be the recipient of the 2015 Nancy Millis Medal for Women in Science.

Professor Michael Drinkwater

CAASTRO Associate Investigator

Theme: Evolving

Drinkwater's research focus is on the origin and evolution of dwarf galaxies. He is using high-resolution observations and simulations to test models of the formation of the smallest galaxies, ultra-compact dwarf galaxies, which he discovered. He is also using the new Sydney-AAO Multi-object Integral Field Spectrograph (SAMI) to determine the importance of hydrodynamic processes in the evolution of galaxies in rich cluster environments.

Dr Holger Baumgardt

CAASTRO Affiliate

Theme: Dynamic

Baumgardt's focus is on the role that direct collisions between white dwarfs play in determining the overall Supernova Type Ia rate in galaxies. In 2014, he and a student worked on calculating collision rates between single white dwarfs in various globular clusters. He also did simulations to investigate the role of stellar binaries for these collisions.

Dr David Parkinson

CAASTRO Affiliate

Theme: Dark

Parkinson has been leading research into testing theories of modified gravity, as an alternative explanation for the accelerated expansion of the universe. His work has focused on using measurements of the large-scale structure of the universe to test these models. He has developed theoretical predictions and numerical simulations for the formation of structure under alternative theories of gravity. He is part of the OzDES project, and an executive member of the 2dfLens survey, which will follow up large-area lensing surveys with spectroscopic observations.

Dr Edward Macauley

CAASTRO Postdoctoral Researcher

Theme: Dark

Macaulay's main research interest is testing fundamental physics with cosmological surveys, with a particular focus on understanding dark matter and dark energy with galaxy surveys. He is currently working on measuring the lensing magnification of supernovae in the OzDES survey. This should improve the precision with which the supernovae can be used as standard candles, and also allow for the amplitude of density fluctuations to be measured from signals in the data that would previously have been considered as noise.

Dr Signe Riemer-Sørensen

CAASTRO Affiliate

Theme: Dark

In 2014 Riemer-Sørensen published the strongest neutrino mass constraint to date from cosmology based on Planck observations of the cosmic microwave background combined with the galaxy power spectrum from WiggleZ. The analysis also provided interesting information on the neutrino hierarchy. She also did a case study for improving measurements of the primordial deuterium abundance in order to constrain the presence of beyond-standard-model physics around the time of Big Bang nucleosynthesis. Furthermore, following the detection of a 3.5-keV emission line in stacked galaxy cluster spectra by Bulbul *et al*. 2014, she performed a search for line emission from the Milky Way, which disproved the speculated dark-matter origin of the galaxy-cluster line.

Ms Caitlin Adams

CAASTRO Honours Student

Theme: Dark

Adams completed her Honours research in 2014, and was jointly supervised by Dr David Parkinson and Associate Professor Chris Blake. The project covered the construction of an emulation pipeline that could be used to estimate a galaxy power spectrum from a limited set of N-body simulation power spectra. This extended on previous emulation work by including a neutrino mass parameter. As a part of the project, the pipeline was incorporated into CosmoMC, and the WiggleZ power-spectrum data was used within this framework to constrain the neutrino mass. Her results indicated that the emulation approach could be used to produce strong constraints on cosmological parameters while reducing the computational cost by using fewer N-body simulations.

Mr Sam Hinton

CAASTRO Honours Student

Theme: Dark

Hinton completed his software engineering thesis under supervision of Professor Tamara Davis in 2014, where his project, *Marz*, was to provide the OzDES team a more efficient and advanced redshifting tool. Hinton has explored the limits of current standards and technology by implementing the program entirely as a client based web application, allowing complete platform independence. The web application is currently in 'open-beta', and Hinton intends to continue development whilst undertaking science honours as a CAASTRO student in 2015.

Ms Anthea King

CAASTRO PhD Student

Theme: Dark

King is investigating whether active galactic nuclei (AGN) are useful and viable standard-candle candidates using a technique called reverberation mapping (RM). It is her hope that we can use them to help constrain the properties of dark energy, as well as giving insight into galaxy–blackhole coevolution. King is involved in OzDES, which will regularly monitor 500 AGN over its five year duration, allowing a RM investigation. Her current work concentrates on predicting the expected performance and scientific output of the OzDES RM project as well as testing the most efficient survey extensions and optimal target selection.

Mr Conor O'Neill

CAASTRO Honours Student

Theme: Dark

O'Neill is a member of OzDES and has been working to optimise the observation strategy of the survey in order to maximise the number of redshift measurements, and therefore science results, that OzDES obtains. As part of his thesis he also investigated the effectiveness of SNe and BAO as measurement probes in the constraints they place on cosmological parameters. O'Neill's supervisors are Tamara Davis and Chris Lidman.

Mr Adam Thomas

CAASTRO Honours Student

Theme: Evolving

Thomas completed an honours project in 2014 under the supervision of Michael Drinkwater. His research made use of 2D spectral data from the SAMI Galaxy Survey to try to identify signs of ongoing ram-pressure stripping in cluster galaxies. He will continue to study galaxy evolution in a PhD in 2015.

Ms Sarah Thomson

CAASTRO Honours Student

Theme: Dark

Thomson has undertaken a project to determine whether it is possible to detect a suppression at large scales in the primordial power spectrum with galaxy surveys. Her project supervisors are Dr David Parkinson and Professor Ray Norris.

Ms Candy Wu

CAASTRO Administrator

Wu joined the CAASTRO UQ node in March 2014, having worked for School of Maths and Physics and School of Business at UQ in finance and HR for five years. Wu provides financial and administrative support to the CAASTRO members at UQ, and is responsible for reconciliation of financial data against the CAASTRO budget.

CAASTRO LINKAGES

CAASTRO has very strong national and international linkages through a substantial network of high-performing Australian and overseas researchers who participate in one or more of CAASTRO's three research themes. These carefully selected Partner Investigators offer some of the strongest scientific track records in international astronomy, with proven performance in the successful execution of large survey projects, and are from world-class institutions including the Australian Astronomical Observatory, CSIRO, Oxford, Caltech and the Max Planck Institutes. Our international Partner Investigators are not only active participants in research studies with Australian telescopes but also enhance these efforts by contributing results and techniques from major international projects. We also have Associate Investigators and Affiliates from our Partner Organisations.

The Australian Square Kilometre Array Pathfinder telescope combined with the Murchison Widefield Array, SkyMapper, the Square Kilometre Array Molonglo Prototype and the Pawsey High Performance Computing Centre for SKA Science, Australia's large investments in wide-field technologies and in high-performance computing will enable CAASTRO to create a world-leading research programme.

Along with the world-class team of CAASTRO researchers across our nodes based at Australia's highest-ranked universities and fastest growing centres of Australian astronomy, bringing together this expertise in radio astronomy, optical astronomy, theoretical astrophysics and computation will enable CAASTRO to reach its vision of being an international leader in wide-field astronomy.

Partner Organisations

Australian Astronomical Observatory

Professor Warrick Couch
CAASTRO Partner Investigator

As Director of the Australian Astronomical Observatory, Professor Couch has a significant role in supporting the operations and management of CAASTRO as the AAO is providing some of the Centre's key facilities, through the wide-field optical spectroscopic capabilities of the Anglo-Australian Telescope (AAT) and of the UK Schmidt Telescope (UKST). Of particular importance are the SAMI multi-integral field unit and AAOmega multi-fibre spectrograph facilities on the AAT and the new TAIPAN positioner and spectrograph on the UKST, each of which are or will play a key role in CAASTRO's three Evolving Universe, Dark Universe and Dynamic Universe theme areas. Furthermore, Couch has a major leadership role in the SAMI Galaxy Survey, being a member of its Executive, and directing and resourcing research being undertaken in the 'galaxy morphological transformation' area. In his position as AAO Director, he is also able to facilitate new scientific opportunities for CAASTRO through the AAO's involvement in projects such as the Dark Energy Spectroscopic Instrument (DESI) and 4MOST on the European Southern Observatory's 4-metre VISTA telescope.

Associate Professor Andrew Hopkins
CAASTRO Partner Investigator

Associate Professor Hopkins is coordinating the contributions of the Australian Astronomical Observatory to CAASTRO, together with AAO Director Professor Warrick Couch.

Hopkins manages and coordinates CAASTRO-supported student and postdoctoral researchers who observe with and utilise data from the Anglo-Australian Telescope and the UK Schmidt Telescope. He facilitates AAO support astronomer interactions with CAASTRO personnel, coordinating pipeline data processing for observations with AAO facilities, and managing access to computing resources. Hopkins is responsible for identifying programmes using AAO facilities that complement and add value to CAASTRO projects. By leveraging the existing effort on such projects, new scientific goals from CAASTRO projects will be enabled, increasing the return from the existing investment. Hopkins' primary research activities within CAASTRO fall under the Evolving Universe theme, although there are several overlapping aspects of his work with activities that CAASTRO will pursue under the Dark Universe theme. Within CAASTRO, Hopkins is primarily pursuing research on the EMU and the proposed TAIPAN projects.

Dr Chris Lidman
CAASTRO Associate Investigator

Dr Lidman is an Associate Investigator in CAASTRO, and his role is in the Dark Universe theme, where he is contributing to the follow-up of Type Ia supernovae discovered by SkyMapper and the Dark Energy Survey. His expertise is in observational cosmology, Type Ia supernova, galaxy clusters, primordial galaxies, and exotic transient phenomena. Lidman is an expert in adaptive optics, near-IR imaging and optical spectroscopy.

Dr Iraklis Konstantopoulos
CAASTRO Affiliate

Dr Iraklis Konstantopoulos is a CAASTRO Affiliate working in the Evolving Universe theme. Through his involvement in the SAMI Galaxy Survey he is revising the technological methodology of astronomical data archiving, and through his work on galaxy groups he aims to identify the 'glue' that keeps galaxies together, and which accelerates their evolution when they are at close quarters. Iraklis is an expert on two- and three-dimensional spectroscopy and an exponent of the astroinformatics movement.

Commonwealth Scientific and Industrial Research Organisation

Dr Brian Boyle
CAASTRO Partner Investigator

Dr Brian Boyle is the Acting SKA Director for the Department of Industry, following his role as CSIRO SKA Director. Previously, he was the Director of the CSIRO Australia Telescope National Facility (2003–2009) where he initiated the construction of ASKAP, and Director of the Anglo-Australian Observatory (1996–2003). His main research interests are cosmology, active galactic nuclei and quasars. During his career he has overseen the successful commissioning of world-class instruments and has led many international scientific collaborations. He has been a Fellow of the Australian Institute of Company Directors since 2005. As Chairman of the National Committee for Astronomy, he led the development of the Decadal Plan for Australian Astronomy 2006–15. He was also the facilitator for the NCRIS investment plan for optical and radio astronomy.

Dr Simon Johnston
CAASTRO Partner Investigator

Dr Johnston is Head of Astrophysics for CSIRO Astronomy and Space Science. His interests include pulsars, radio transients and Extreme Scattering Events and are thus closely aligned with the Dynamic theme. He is a key member of the VAST survey project and is a member of the Pulsar Science Working Group for the SKA.

Professor Ray Norris
CAASTRO Partner Investigator

Professor Norris has recently retired as the Chief Research Scientist within CSIRO Astronomy and Space Science, and Project Leader for EMU (Evolutionary Map of the Universe), one of the two key projects (the other being WALLABY) that were selected to drive the design and construction of ASKAP. EMU is an all-sky continuum survey that lies within CAASTRO's Evolving Universe theme, with its primary goal being to trace the origin and evolution of galaxies over cosmic time. EMU will also have a major impact on characterising Dark Energy and Modified Gravity, aligning it with the Dark Universe theme.

Dr Keith Bannister
CAASTRO Affiliate

Dr Bannister is an Affiliate in CAASTRO. His role in the Dynamic theme is in modelling fast radio bursts, following-up astronomical transients at radio wavelengths and radio transients surveys. His expertise is in radio data processing, radio transients and archival searches.

Dr Antonia Rowlinson
CAASTRO Affiliate

Dr Antonia Rowlinson is an Affiliate in CAASTRO and her role is in the Dynamic Universe theme contributing to the search for slow transients and fast radio bursts, typically using low-frequency radio images from the Murchison Widefield Array. Her expertise is in the analysis of radio-transient and variability surveys using automated imaging and analysis pipelines, using multi-wavelength data to constrain the progenitors of short gamma-ray bursts and the magnetar central-engine model for short gamma-ray bursts.

California Institute of Technology, USA

Professor Shri Kulkarni
CAASTRO Partner Investigator

Professor Kulkarni's focus within CAASTRO is in the Dynamic Universe theme. He has long-standing collaborative links with Professors Matthew Bailes and Brian Schmidt, as exemplified by a history of ARC Discovery and (formerly Large) grants in the areas of software correlation and instrumentation development applicable to the Square Kilometre Array, and gamma-ray bursts. Kulkarni is one of the originators of the Palomar Transient Factory (PTF), a northern-hemisphere complement to the Skymapper project. Using these facilities in concert, the CAASTRO team can monitor the entire sky for optical transients, and can share algorithmic and software development. Swinburne and Caltech have already signed a Memorandum of Understanding of scientific collaboration that spans the early years of CAASTRO and provides access to the Keck telescopes for Swinburne astronomers. This MoU has triggered a number of new collaborative projects involving scientists from these two institutions. Professor Kulkarni has taken an interest in the origin of the Fast Radio Bursts, ruling out some scenarios for their origin and trying to ascertain whether they can be at cosmological distances.

University of Arizona, USA

Professor Xiaohui Fan
CAASTRO Partner Investigator

Professor Fan's primary involvement in CAASTRO science is within the Evolving Universe theme. He is renowned for his expertise in the discovery of high-redshift quasars, and more generally in the use of all-sky surveys to discover rare objects, especially valuable for the Skymapper survey's search for high-redshift quasars.

University of Durham, USA

Professor Carlos Frenk
CAASTRO Partner Investigator

Professor Frenk's contributions to CAASTRO are under the themes of the Evolving and Dark Universes. Over the coming decade, CAASTRO will observe the moderate redshift neutral hydrogen Universe for the first time via the ASKAP FLASH, WALLABY and DINGO surveys. For this reason it is important to take stock of what theoretical galaxy formation models tell us about the abundance and distribution of HI in the Universe. Frenk, as the head of the Institute for Computational Cosmology and joint lead investigator on the Millennium simulation (the largest simulation of the Universe ever undertaken), is in a unique position to contribute the theoretical galaxy formation models that will be needed to exploit CAASTRO's scientific observations.

Max Planck Institute for Radio Astronomy, Germany

Professor Michael Kramer
CAASTRO Partner Investigator

Professor Kramer's research activities are under the Dynamic Universe theme of CAASTRO. His focus is on the exploration and exploitation of the dynamic radio sky, both in the study of pulsars as well as new types of transients, allowing CAASTRO to address a wide range of astrophysical questions, ranging from the state of matter at extreme densities, to cosmology and tests of theories of gravity. The enabling process of this exciting science starts with the search for fast transients. Kramer is contributing his expertise to this area by developing hardware and software solutions in collaboration with the CAASTRO partners.

Max Planck Institute for Extraterrestrial Physics, Germany

Dr Mara Salvato
CAASTRO Partner Investigator

Dr Salvato works in the High Energy Group and is a member of the eROSITA team. eROSITA is an X-ray satellite which is soon to be launched and will map the entire sky. As a Partner Investigator Salvato promotes collaboration between CAASTRO and eROSITA and leads project groups enhancing the synergy between X-ray, Radio and Optical surveys of AGN.

Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE), France

Dr Reynald Pain
CAASTRO Partner Investigator

Dr Pain is contributing to CAASTRO's Dark Universe theme within CAASTRO. Pain is the Director of LPNHE, a large physics research grouping that works in a broad range of high-energy and particle physics experiments. As French lead investigator of the Supernova Legacy Survey (SNLS) project, Pain is one of the leaders of using type Ia supernovae to measure the acceleration of the universe. As part of CAASTRO, Pain and his team at LPNHE actively participate in the SkyMapper supernova survey, taking leading roles in the calibration and precision photometric analysis of the supernova data.

University of Toronto, Canada

Professor Ue-Li Pen
CAASTRO Partner Investigator

Professor Pen brings to CAASTRO a wealth of experience in tackling fundamental problems in cosmology associated with many of the Centre's science themes. He has considerable experience in studies of the Epoch of Reionisation and of extragalactic hydrogen, and has worked in this area with fellow CAASTRO investigators. Within CAASTRO, Pen's research activities are primarily under the theme of the Evolving Universe. His specific focus is to quantify the errors in the power spectra of neutral hydrogen in galaxies, as measured by ASKAP surveys such as WALLABY and DINGO.

Raman Research Institute, India

Professor Ravi Subrahmanyan
CAASTRO Partner Investigator

Professor Subrahmanyan's focus within CAASTRO is the Evolving Universe theme. His background is in developing methods and instrumentation for all-sky measurements of the radio background, in particular detecting reionisation signatures in the cosmic radio background. Subrahmanyan and his colleagues at the Raman Research Institute are contributing primarily to the Murchison Widefield Array's efforts to detect the Epoch of Reionisation.

University of Oxford

Professor Roger Davies

Professor Roger Davies was until recently Head of Astrophysics at Oxford University. Within CAASTRO, Davies's contribution will be primarily in the Evolving Universe theme and the SAMI project. His research interests include cosmology: the distance scale, large scale motions of galaxies and galaxies at high redshift; galaxy evolution: dynamics, stellar populations and galaxy clusters; and telescopes, instruments and techniques.

National Computational Infrastructure

Professor Lindsay Botten
CAASTRO Partner Investigator

As Director of National Computational Infrastructure, Professor Lindsay Botten is supporting CAASTRO's access and usage of NCI's high-end computing services across all of CAASTRO's three themes and from all nodes. In 2014, some 8 million CPU hours were utilised.

Associated Organisations

University of Nottingham

Dr Jamie Bolton
CAASTRO Associate Investigator

Dr Bolton is an Associate Investigator in CAASTRO and he is currently a Royal Society University Research Fellow and lecturer at the University of Nottingham, a position he has held since October 2012. In 2014 he completed work with former CAASTRO PhD student Brad Greig on developing simulations to calculate the effect of temperature fluctuations on Lyman-alpha absorption statistics towards quasars. He also examined the impact of high mass X-ray binaries on the ionisation state of the intergalactic medium, in collaboration with CAASTRO Associate Investigator Professor Chris Power (UWA) and researchers at the University of Leicester.

University of Belfast

Dr Stuart Sim
CAASTRO Associate Investigator

Dr Sim's research focuses on the theory of supernova explosions. In particular, he works on developing models for Type Ia supernovae, the events that are used as 'standard candles' to map out the expansion history of the Universe. He is also working with CAASTRO student alumna Sharon Rapoport on new studies of bipolar supernovae, the class of explosion associated with gamma-ray bursts. Such theoretical modelling is an important part of understanding and interpreting observations taken as part of the next generation of astrophysical transient surveys, such as will be carried out with the SkyMapper telescope.

University of Cambridge

Dr Greg Madsen
CAASTRO Affiliate

Dr Greg Madsen is an Affiliate in CAASTRO within the Dynamic Universe theme. He is contributing to the interpretation of Fast Radio Bursts and is using historical plate archives to discover new populations of long term variable stars and quasars. His expertise is in the interstellar medium, planetary nebulae, and variable stars. He is an expert in Fabry-Perot spectroscopy and optical/near-IR imaging.

CAASTRO COLLABORATIONS

CAASTRO team members have been involved in a number of collaborations with institutions both in Australia and internationally during the course of 2014, including the following:

eROSITA

Institutions: Max-Planck-Institut für Extraterrestrische Physik, CAASTRO

The extended ROentgen Survey with an Imaging Telescope Array (eROSITA) is an instrument on the Russian Spektrum-Rötgen-Gamma (SRG) satellite, to be launched in 2015. eROSITA will perform an X-ray survey of the entire sky with unprecedented angular resolution and sensitivity. The German eROSITA consortium (eROSITA_DE) and CAASTRO have signed a memorandum of understanding that enables collaboration on projects requiring combined data from eROSITA and from Australian wide-field facilities such as ASKAP, MWA, SKAMP, Parkes, ATCA, SkyMapper, AAT and TAIPAN. The agreement is overseeing science projects that require the use of both eROSITA_DE and CAASTRO data, involve at least one member from each of eROSITA_DE and CAASTRO, do not conflict with existing eROSITA_DE or CAASTRO projects, allow participation by undergraduate and postgraduate students, and adhere to the existing policies for the individual facilities involved (e.g. proprietary periods, data access, survey teams, observing time, publications). This arrangement will provide exciting new opportunities for multi-wavelength astronomy projects across the southern sky.

SkyMapper

Institutions: Australian National University, CAASTRO, Monash University, AAO

SkyMapper is a 1.35-metre telescope with a 5.7 deg^2 imager, located near Coonabarabran NSW, which is owned and operated by the Research School of Astronomy and Astrophysics at ANU. CAASTRO has received $1.16m in ARC LIEF funding to secure membership of the SkyMapper consortium for all Australian astronomers from 2014–2019. This contributes to the operations costs needed for SkyMapper to undertake a 5-year survey of the entire southern sky, provides Australian astronomers with 20% of non-survey observing time on SkyMapper, and allows the development of robust and efficient software pipelines, analysis tools and data access facilities. This collaboration is providing CAASTRO researchers and the wider Australian astronomy community not only with science-quality SkyMapper data but also with a consistent photometric system over the whole sky by combining SkyMapper data with that from PanSTARRS-1.

SkyMapper Supernova Search

Institutions: HEP-Paris VI, Australian National University, OZ-DES Collaboration, PESSTO Collaboration

Among the core goals of SkyMapper is a large nearby supernovae survey. Working with the European PESSTO collaboration, the SkyMapper Supernova Search is obtaining spectra of all of the survey's discoveries to a limiting magnitude of g = 19. A principal survey aim is to produce a nearby SN Ia sample comparable in quality to those gathered by the Supernova Legacy Survey and the Sloan Digital Sky Survey. As part of the collaboration, The SkyDice (SkyMapper Direct Illumination Calibration Experiment) system – a dedicated photometric calibration device was installed in the SkyMapper enclosure. The ANU-HEP collaboration aims to provide the photometric datasets that minimise the systematic error components on SN Ia distances, and thereby provide a substantial improvement on the measurements of the Dark Energy equation of state parameter. The SkyMapper Supernova Search is also working as part of the OZ-DES Collaboration to combine the nearby SN dataset with the High-Z SN Dataset from the DES Survey. The Search made its first discoveries in 2013, and should continue to discover more than 50 objects per year.

ASKAP Early Science

Institutions: CSIRO, The University of Sydney, University of Western Australia, Curtin University, University of Minnesota, Monash University and others

The Australian Square Kilometre Array Pathfinder (ASKAP) currently has six operating antennas, all equipped with prototype phased-array feeds (the so-called Boolardy Engineering Test Array, BETA). It is currently being upgraded to an early science array, ASKAP-12, which consists of 12 antennas with the production phase-array feeds, and which is itself a stepping-stone toward the final 36-antenna system. ASKAP-12 is a powerful survey instrument in its own right, with survey speed comparable to that of the VLA. CSIRO has accordingly announced an ASKAP Early Science program using ASKAP-12. The focus for early science is continuum, HI and polarisation studies, and there is substantial CAASTRO involvement in all these programs. CAASTRO has made new postdoctoral appointments to enable ASKAP Early Science, and funded three CAASTRO secondments in 2014 to participate in the commissioning of the Early Science program.

S-PASS

Institutions: CSIRO, Max-Planck-Institut für Kernphysik, Australian National University, The University of Sydney, ICRAR / University of Western Australia, Radboud University Nijmegen, Leiden University, Harvard-Smithsonian Center for Astrophysics, INAF Osservatorio Astronomico di Cagliari

The S-band Polarisation All Sky Survey (S-PASS) has used the Parkes radio telescope to map the polarised emission from the entire southern sky at a frequency of 2.3 GHz and a resolution of nine arcminutes. The goal of S-PASS is to understand the foreground polarised emission from the Milky Way, and to then model and remove it for studies of the polarisation from the cosmic microwave background. The S-PASS team has reported the discovery of polarised emission from the 'Fermi bubbles' emanating from the centre of the Milky Way, and the detection of a synchrotron radio bridge in the galaxy cluster Abell 3667.

TAIPAN

Institutions: AAO, Australian National University, CSIRO CASS, Macquarie University, Monash University, Swinburne University of Technology, University of Melbourne, University of New South Wales, University of Queensland, The University of Sydney, University of Western Australia, University of Western Sydney

TAIPAN is a new facility for the UK Schmidt Telescope at Siding Spring observatory. It encompasses a novel optical fibre positioner using the new 'starbugs' technology, a purpose-built spectrograph, and refurbishment of the UKST itself. Funding for the facility is now secure, and construction of the positioner and spectrograph has begun, together with the telescope refurbishment. The TAIPAN facility will support two major new surveys. (1) The TAIPAN survey of half a million galaxies aims to make a 1% precision measurement of the Hubble constant, H_o, and measure the bulk motion of galaxies to better understand large-scale structure, Dark Matter and gravitation. Together with the WALLABY survey using ASKAP, it will link the star-formation and gas-fuelling properties of galaxies to better understand galaxy formation and evolution. (2) The Funnelweb survey plans to measure two million stars within our Milky Way Galaxy, uniquely characterising them and complementing the fainter GALAH Galactic Archaeology survey, as well as providing a robust input sample for the next-generation planet-finding satellite observatory, TESS. The TAIPAN surveys will begin in early 2016, with preliminary observations during commissioning activities in late 2015. While the scientific plans for the TAIPAN facility and surveys are closely aligned with CAASTRO goals, they are not presently receiving any funding from CAASTRO

OzDES

Institutions: AAO, Australian National University, University of Queensland, The University of Sydney, University of Melbourne, Swinburne University of Technology, Monash University, Macquarie University, CSIRO, The Dark Energy Survey (members from over 30 institutions worldwide)

OzDES is a collaboration of over 20 Australian scientists, the vast majority of whom are CAASTRO members, using the AAT to gather thousands of spectroscopic redshifts to complement the photometric Dark Energy Survey. Host-galaxy redshifts for Type Ia supernovae will facilitate construction of the largest SN Ia Hubble Diagram to date, while repeat spectroscopy of high-redshift active galactic nuclei will attempt to use AGN reverberation mapping for standard candle cosmology beyond redshift 2.

Cosmic neutral hydrogen absorption-line signals

Institutions: The University of Sydney, European Southern Observatory (ESO)

CAASTRO members are carrying out a project to search for a statistical HI absorption-line signals in the reprocessed HIPASS data. HIPASS is a blind HI survey of the whole southern sky, carried out with the Parkes radio telescope from 1997–2002. Recent reprocessing of the data with modern algorithms has resulted in improved noise properties and bandpass calibration, making it possible to search for weaker absorption-lines than was previously possible. By stacking spectra towards bright radio continuum sources, where the sight-lines pass near to known optical galaxies in the HIPASS volume, we hope to be able to detect faint intervening absorption-line signals in the local universe ($z < 0.04$). The results of this project provide important information in the preparation for ASKAP-FLASH (the 'First Large Absorption Survey in HI'), which will conduct a blind survey for HI absorption at redshifts $0.5 < z < 1.0$ in order to study the evolution of neutral hydrogen with cosmic time.

GaLactic and Extragalactic All-sky MWA (GLEAM) survey

Institutions: Arizona State University, Australian National University, Australia Telescope National Facility (CSIRO), ICRAR/Curtin University, Harvard University, ICRAR/University of Western Australia, Massachusetts Institute of Technology, National Radio Astronomy Observatory, Raman Research Institute, Swinburne University, University of Melbourne, The University of Sydney, University of Tasmania, Victoria University of Wellington, University of Washington, University of Wisconsin.

The GaLactic and Extragalactic All-sky MWA (GLEAM) survey aims to image the entire sky south of declination +30 degrees at frequencies from 80 to 230 MHz. This survey will deliver the deepest-ever low-frequency view of the southern radio sky. Its aims include: the detection of giant radio galaxies and colliding clusters; the birth of radio galaxies; the structure of the Galactic magnetic field; the discovery of Galactic supernova remnants; and the measurement of cosmic-ray energy density. MWA observations over two years (starting in August 2013) have been allocated, with first results now starting to be published.

WiggleZ

Institutions: Swinburne University of Technology, University of Toronto (Canada), AAO, The University of Sydney, University of Copenhagen (Denmark), University of Queensland, California Institute of Technology (United States), University of Waterloo (Canada), University of Chicago (United States), Institute of Astronomy and Astrophysics (Taiwan), CSIRO Astronomy and Space Science, Observatories of the Carnegie Institute of Washington (United States), Monash University, Swinburne University of Technology, University of British Columbia (Canada)

The collaboration has used the WiggleZ survey data taken with the Anglo-Australian Telescope to make new measurements of how the clumpy Universe on small scales transitions to a homogeneous Universe on large scales, which is a test of the cosmological model. It has also used the detection of the baryon acoustic peak in the WiggleZ survey data as a standard cosmological ruler to make new measurements of the distance-redshift relation in the distant Universe and produce new evidence in favour of cosmological-constant dark energy.

Large Synoptic Survey Telescope

Institutions: The Large Synoptic Survey Telescope (comprising more than 30 member organisations) and CAASTRO

CAASTRO and The Large Synoptic Survey Telescope (LSST) have entered into a Memorandum of Agreement on how CAASTRO can contribute to the operational support of LSST, which is planned to begin full scientific operations in the 2020 timeframe. In 2014 an LSST road show was conducted around Australia involving collaboration between CAASTRO, AAO, ANU, Swinburne and ICRAR.

DECam Deep Field

Institutions: Swinburne University of Technology, AAO, University of Melbourne, Space Telescope Science Institute, NOAO, CTIO

The DECam Epoch of Reionisation Project looks at the large-scale structure in the epoch of reionisation. It capitalises on the red sensitivity and large field of view of CTIO's DECam to detect the brightest and rarest galaxies at $z \sim 6–7$. Our results hint at the signature of large-scale structure. Data will also constrain the galaxy contribution to reionisation from the full galaxy luminosity function. The observations will be executed with a cadence and depth to detect 'super-luminous' supernovae at $z > \sim 6–7$. This is a recently observed class 10–100× more luminous than typical. This class includes pair-instability supernovae, a rare, third type of supernova explosion for which only three events are known. The observations will greatly extend the current reach of supernova research, examining rates and properties in the Epoch of Reionisation.

The 6dFGS Peculiar Velocity Field

Institutions: AAO, University of Melbourne, Swinburne University of Technology, University of Western Australia, University College London (United Kingdom), Monash University, University of Durham (United Kingdom), University of Western Kentucky (United States), Spitzer Science Center (California Institute of Technology, United States)

This collaboration has measured the distances to 10,000 galaxies belonging to the 6dF Galaxy Survey in order to measure the bulk flow of the local Universe and investigate the effect of gravity on the motions of galaxies. It has derived an accurate value for the density of ordinary matter in the local Universe.

The 2MASS Tully-Fisher (2MTF) collaboration

Institutions: Australia Telescope National Facility (CSIRO), ICRAR/University of Western Australia, Monash University, National Astronomical Observatories (Chinese Academy of Sciences), Swinburne University, Texas A&M University, University of Cape Town, University of Portsmouth

This collaboration is working on measuring accurate distances to 3,000 spiral galaxies to investigate the effect of dark matter on the dynamics of the local Universe, and the validity of cold dark matter theory on large scales. New 21-cm observations have been made with the GBT and Parkes radio telescopes, and are being combined with photometry from the 2MASS infrared survey and data from other telescopes.

Epoch of Reionisation with the MWA

Institutions: University of Melbourne, Australian National University, University of Sydney, Curtin University, MIT, Harvard-Smithsonian Center for Astrophysics, University of Washington, Arizona State University, Raman Research Institute

CAASTRO staff are key members of the EoR collaboration within the MWA Project. This team is producing a data-reduction pipeline and a power-spectrum pipeline. Techniques are being tested with small datasets from the Murchison Widefield Array. These will ultimately be tested on the complete data set of more than 1000 hrs. It is expected that the MWA will either detect or set limits on the detection of the HI signals from the Epoch of Reionisation.

The High Time Resolution Universe Survey for Pulsars and Fast Transients

Institutions: Osservatorio Astronomico di Cagliari, CSIRO Astronomy and Space Science, University of Manchester, West Virginia University, Max Planck Institute for Radioastronomy, NASA Jet Propulsion Laboratory, Curtin University, Swinburne University of Technology

CAASTRO staff were involved in the High Time Resolution Universe survey collaboration in 2014. This survey searches the sky using the Parkes Multibeam Receiver and looks for phenomena with a time resolution of just 64 microseconds. 2014 has been a very successful year with the announcement of the discovery of fast radio bursts from what appear to be cosmological distances.

Collaborations – Outreach

MWA game design with Quantum Victoria

The CAASTRO Education and Outreach team has partnered with the software developers at Melbourne's science learning centre 'Quantum Victoria', led by CAASTRO Advisory Board member Soula Bennett, to create a game based on the Murchison Widefield Array (MWA). CAASTRO provides scientific input into the game design and will be responsible for educational resources that enable science teachers to prepare their students, predominantly Year 9 and above, for their visit to Quantum Victoria and assess their experience afterwards.

Astronomy Weekend and 'Astronomer in Residence' at Uluru

In collaboration with Voyages Indigenous Tourism Australia, CAASTRO has 'Astronomers in Residence' at Uluru for most of the year and in 2014 we held the inaugural Uluru Astronomy Weekend as part of National Science week. CAASTRO team members gave presentations about the Universe and offered insights into current avenues of astrophysical research.

Animation library from Swinburne Astronomy Productions

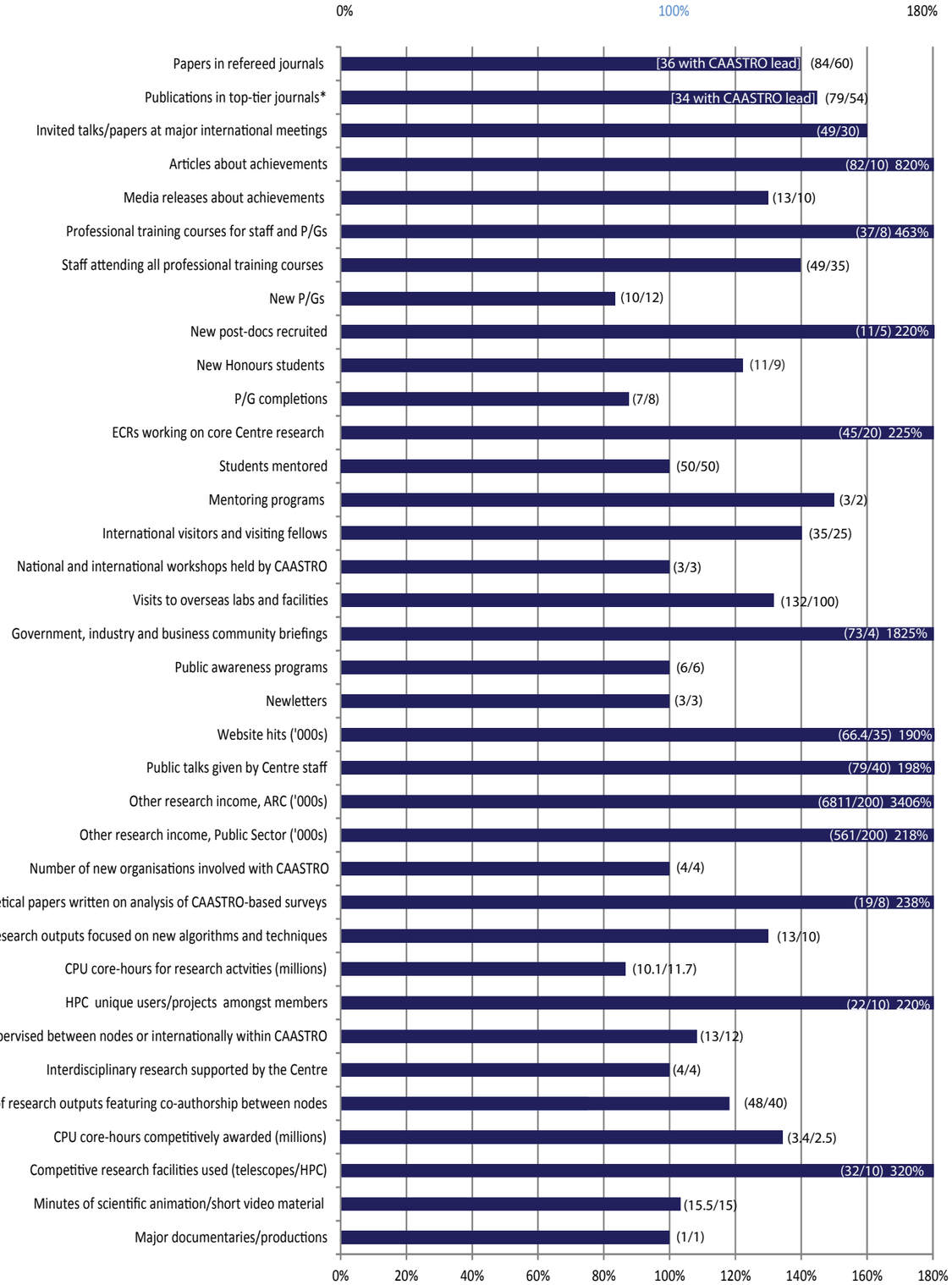
In 2014, CAASTRO continued its relationship with Swinburne Astronomy Productions to develop a large media library of high quality 2D and 3D animation material for use in CAASTRO presentations and outreach activities. All three CAASTRO themes will be well represented and able to draw on this valuable resource for explaining fundamental physical concepts and specific topics of CAASTRO research.

Production of a planetarium show

With the view that CAASTRO all-sky data is most naturally presented on a domed screen, CAASTRO has entered into a longer-term collaboration with Museum Victoria for the production of a planetarium show. Aiming at a premiere in 2016, CAASTRO and the team at Melbourne Planetarium are working towards showcasing CAASTRO research results and real datasets for shows in several Australian and overseas locations.

KPI DASHBOARD

January – December 2014



* Nature; Science; Annual Review of Astronomy & Astrophysics; The Astronomy & Astrophysics Review; Physical Review (including Letters) The Astrophysical Journal (including Supplemental Series and Letters); The Astronomical Journal; Monthly Notices of the Royal Astronomical Society (including Letters); Astronomy & Astrophysics (including Letters and Short Communications etc.); Journal of Cosmology and Astroparticle Physics

FINANCIAL STATEMENTS

CAASTRO FINANCIAL REPORT 2014

	2011 INCOME	2012 INCOME	2013 INCOME	2014 INCOME	ACTUAL	2015 INCOME	ESTIMATED
ARC Income	$3,000,000	$2,800,000	$3,100,000	ARC Income	$3,100,000	ARC Income	$3,100,000
ARC Indexation	$47,431	$153,527	$295,786	ARC Indexation	$398,406	ARC Indexation	$447,487
Node Contributions	$912,272	$1,039,569	$842,002	Node Contributions	$1,206,663	Node Contributions	$1,074,317
2013 Grants			$750,000	ARC LIEF Grant	$417,000		
				SIEF John Stocker Postdoctoral Fellowship	$457,437		
				Australian Maths & Science Partnerships Program Grant (DoE)	$195,000		
Other	$747,294	$13,685	$28,206	Other*	$296,930	Other	$7,500
Grants won[y] (and correction to 2011)	$400,000		-$400,000				
Total Income	**$5,106,997**	**$4,006,781**	**$4,615,994**	**Total Income**	**$6,071,436**	**Total Estimated Income**	**$4,629,304**
Carry Forward	$-	$2,930,552	$2,967,985	Carry Forward	$3,037,571	Carry Forward	$3,651,823
Total Funds Available	**$5,106,997**	**$6,937,333**	**$7,583,979**	**Total Funds Available**	**$9,109,007**	**Total Estimated Funds Available**	**$8,281,127**

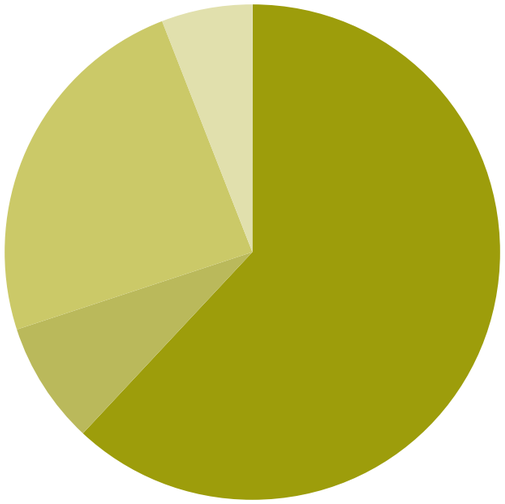
*Other income includes Dept of Industry grant, CAASTRO workshop income and Secondments (CSIRO, AAO)

[y] Includes NSW SLF Grant Part II, DIISR Travel Grants and LIEF Grant won by UWA

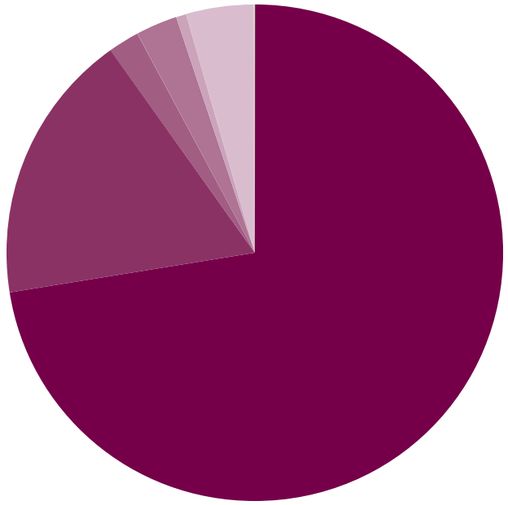
	2011 EXPENDITURE	2012 EXPENDITURE	2013 EXPENDITURE	2014 EXPENDITURE	ACTUAL	2015 EXPENDITURE	ESTIMATED
Salaries	$1,467,096	$2,807,859	$2,875,061	Salaries	$3,320,256	Salaries	$3,926,234
Travel, Accommodation and Conference	$363,516	$503,587	$778,788	Travel, Accommodation and Conference	$810,779	Travel, Accommodation and Conference	$644,000
Marketing & Outreach	$124,914	$139,732	$20,336	Marketing & Outreach	$92,675	Marketing & Outreach	$175,000
Operations & Maintenance	$103,342	$81,706	$56,535	Operations & Maintenance	$124,237	Operations & Maintenance	$99,706
Equipment	$102,993	$145,790	-$59,721	Equipment	$29,891	Equipment	$35,000
PhD Support	$5,709	$101,763	$126,522	PhD Suppport	$201,402	PhD Suppport	$126,000
Research materials/ Experiments	$8,874	$188,911	$5,766	Research materials/ Experiments	$3,507	Research materials/ Experiments	$-
Corrections			-$6,879				
2013 Grants			$750,000	ARC LIEF Grant **	$417,000		
				SIEF John Stocker Postdoctoral Fellowship **	$457,437		
				Australian Maths & Science Partnerships Program Grant (DoE) **	$195,000		
Total Expenditure	**$2,176,445**	**$3,969,348**	**$4,546,408**	**Total Expenditure**	**$5,457,184**	**Total Estimated Expenditure**	**$5,005,940**
Balance	**$2,930,552**	**$2,967,985**	**$3,037,571**	**Balance**	**$3,651,823**	**Estimated balance**	**$3,275,187**

** LIEF, SIEF & AMSPP Grants have been reported as fully expensed in 2014, although LIEF Grant to be spent over 5 years, SIEF Grant to be spent over 36 months and AMSPP Grant to be spent over 2 years.

2014 Income



2014 Expenditure



In-Kind	
University of Sydney	$1,043,578
University of Western Australia	$169,865
University of Melbourne	$304,602
Swinburne University of Technology	$524,226
Australian National University	$755,215
Curtin University of Technology	$271,474
CSIRO	$3,370,146
Anglo-Australian Observatory	$1,014,604
Max Planck Institute for Radio Astronomy	$146,695
California Institute of Technology	$134,673
The University of Oxford	$51,170
Durham University	$202,108
Max Planck Institute for Astrophysics	$76,137
The University of Arizona	$160,000
The University of Toronto	$41,300
Laboratoire de Physique Nucléaire et de Hautes Energies	$160,088
National Computational Infrastructure	$1,000,000
Raman Research Institute	$200,000
University of Queensland	$92,413
Voyages Indigenous Tourism	$45,000
Total In-Kind Contributions	**$9,763,294**

GRANTS WON BY CAASTRO MEMBERS IN 2014

ARC Discovery Project
Project Title: Mapping quasars: micro-imaging experiments
DP150101727
$357,000 over 3 years (2015, 2016, 2017)
Chief Investigator: Rachel Webster

ARC Discovery Project
Project Title: Galactic archaeology — fossil evidence of how our Galaxy's disk formed
DP150104667
$443,900 over 3 years (2015, 2016, 2017)
Chief Investigator: Jonathan Bland-Hawthorn

ARC Discovery Project
Project Title: Ultra-wide band receiver and back-end for Parkes
DP150102988
$384,700
Chief Investigator: Linqing Wen
CAASTRO investigator: Michael Kramer

ARC Discovery Project
Project Title: Reionisation and Diffuse Cosmic Gas
DP150102987
$350,000 over 3 years (2015, 2016, 2017)
Chief Investigator: Darren Croton
CAASTRO investigator: Emma Ryan-Weber

ARC Discovery Project
Project Title: Exploiting SkyMapper for Galactic Astrophysics
DP150103294
$384,700 over 3 years (2015, 2016, 2017)
Chief Investigator: Gary Da Costa
CAASTRO investigator: Brian Schmidt

ARC LIEF
Project Title: An Ultra-wideband Radio Receiver for the Parkes 64-metre Radio Telescope
LE150100155
$370,000
Chief Investigator: Matthew Bailes
Other CAASTRO Investigators: Bryan Gaensler, Stuart Wyithe, Ramesh Bhat, Willem van Straten, and Michael Kramer

ARC LIEF
Project Title: Mapping the Universe with the Panoramic Survey Telescope and Rapid Response System
LE150100024
$760,000
Chief Investigator: Jeremy Mould
Other CAASTRO investigator: Karl Glazebrook

ARC LIEF
Project Title: The Cherenkov Telescope Array
LE150100070
$270,000
Chief Investigator: Gavin Rowell
CAASTRO Investigator: Anne Green

ARC LIEF
Project Title: Hector – a revolutionary spectrograph for understanding how galaxies evolve
LE150100144
$430,000
Chief Investigator: Jonathan Bland-Hawthorn
Other CAASTRO investigators: Scott Croom, Matthew Colless, Julia Bryant, and Warrick Couch

ARC LIEF
Project Title: The Australian European Southern Observatory Positioner (AESOP)
LE150100055
$560,000
Chief Investigator: Simon Driver
CAASTRO investigators: Chris Power, Martin Meyer, and Warrick Couch

ARC Laureate Fellowship
FL140100278
$2,500,000 over 5 years (2014 to 2018)
Jonathan Bland-Hawthorn

The Department of Primary Industry – Conference Sponsorship Program
Project: ADASS 2015
$4,000 sponsorship of ADASS 2015

Australian Maths and Science Partnership Program (AMSPP), Department of Education
Project: CAASTRO in the Classroom
$195,000

The University of Sydney Post-doctoral Fellowship
Project Title: The origin of dwarf elliptical galaxies: little giants or regular irregulars?
$363,092 over 3 years
Investigator: Nicholas Scott

CAASTRO PEOPLE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CAASTRO Executive

1. Elaine Sadler (Director)
2. Lister Staveley-Smith (Deputy Director)
3. Kate Gunn (Chief Operating Officer)
4. Matthew Bailes (Dynamic theme leader)
5. Stuart Wyithe (Evolving theme leader)
6. Steven Tingay (Education and Outreach leader)
7. Tamara Davis (Dark theme leader)

Chief Investigators

8. Chris Blake
9. Frank Briggs
10. Matthew Colless
11. Scott Croom
12. Bryan Gaensler
13. Jeremy Mould
14. Tara Murphy
15. Brian Schmidt


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16. Rachel Webster

Partner Investigators

17. Lindsay Botten
18. Brian Boyle
19. Warrick Couch
20. Roger Davies
21. Xiaohui Fan
22. Carlos Frenk
23. Andrew Hopkins
24. Simon Johnston
25. Michael Kramer
26. Shri Kulkarni
27. Ray Norris
28. Reynald Pain
29. Ue-Li Pen
30. Mara Salvato
31. Ravi Subrahmanyan

Associate Investigators

32. Ramesh Bhat
33. Joss Bland-Hawthorn


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34. Jamie Bolton
35. Chris Lidman
36. Jean-Pierre Macquart
37. Martin Meyer
38. Stephen Ord
39. David Parkinson
40. Chris Power
41. Ashley Ruiter
42. Emma Ryan-Weber
43. Richard Scalzo
44. Ivo Seitenzahl
45. Robert Sharp
46. Stuart Sim
47. Randall Wayth
48. Christian Wolf

CAASTRO Research Staff

49. Ixandra Achitouv
50. Julia Bryant
51. Michael Childress


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52. Chris Flynn
53. Lisa Fogarty
54. Anna Kapinska
55. Eyal Kazin
56. Evan Keane
57. Jun Koda
58. David Lagattuta
59. Emil Lenc
60. Edward Macauley
61. Felipe Marin
62. Ben McKinley
63. Vanessa Moss
64. André Offringa
65. Se-Heon Oh
66. Attila Popping
67. Pietro Procopio
68. Vikram Ravi
69. Jongwah Rhee


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70. Nicholas Scott
71. Marcin Sokolowski
72. Christopher Springbob
73. Dan Taranu
74. Edoardo Tescari
75. Steven Tremblay
76. Laura Wolz
77. Fang Yuan

CAASTRO Professional Staff


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78. Kim Dorrell (Executive Officer, U. Melbourne)
79. Angela Dunleavy (Administrative Coordinator, Curtin U)
80. Wiebke Ebeling (Education & Outreach Coordinator)
81. Debra Gooley (Finance Officer)
82. Sue Lester (Administration Officer, Swinburne)
83. Clare Peter (Administrative Officer, UWA)
84. Helen Sim (Public Relations Officer)
85. Denise Sturgess (Administration Officer, ANU)
86. Michelle Sullivan (Executive Assistant to Director)
87. Kylie Williams (Events & Communications)


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88. Candy Wu (Administration Officer, ANU)

CAASTRO Affiliates


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89. James Allen
90. James Allison
91. Keith Bannister
92. Ewan Barr
93. Holger Baumgardt
94. Martin Bell
95. Davide Burlon
96. Mike Dalley
97. Jacinta den Besten
98. Duncan Campbell-Wilson
99. Weiguang Cui
100. Stephen Curran
101. Jason Dossett
102. Michael Drinkwater
103. Alan Duffy
104. Jamie Farnes
105. Sean Farrell


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106. Ilana Feain
107. Karl Glazebrook
108. Anne Green
109. Paul Hancock
110. Tao Hong
111. Andrew Jameson
112. Hansik Kim
113. Iraklis Konstantopoulos
114. Katherine Mack
115. Greg Madsen
116. Daniel Mitchell
117. Richard Newton
118. Shane O'Sullivan
119. Danail Obreschkow
120. Bart Pindor
121. Signe Riemer-Sørensen
122. Antonia Rowlinson
123. Edward Taylor


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CAASTRO Students

126. Caitlin Adams
127. Eromanga Adermann
128. Shivani Bhandari
129. Jessica Bloom
130. Loren Bruns Jr.
131. Manisha Pranati Caleb
132. Joe Callingham
133. Alexandru Codoreanu
134. Catherine De Burgh-Day
135. Angela Garcia
136. Marcin Glowacki
137. Samuel Hinton
138. Fabian Jankowski
139. Andrew Johnson
140. Antonios Katsianis
141. Anthea King


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142. Sarah Leslie
143. Jack Line
144. Cleo Loi
145. Rebecca McElroy
146. Scott Meyer
147. Vincent Morello
148. Mehran Mossammaparast
149. Steven Murray
150. Aina Musaeva
151. Conor O'Neill
152. Samuel Oronsaye
153. Sinem Ozbilgen
154. Emily Petroff
155. Rahul Sai Poruri
156. Mayuri Sathyanarayana Rao
157. Sharon Rapoport
158. Sarah Reeves
159. Tristan Reynolds


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160. Nastaran Rezaee
161. Samuel Richards
162. Jennifer Riding
163. Seonaid Rodgers
164. Adam Schaefer
165. Paul Scott-Taylor
166. Dana Tabbara
167. Adam Thomas
168. Sarah Thomson
169. Syed Ashraf Uddin
170. Vivek Venkatraman Krishnan
171. Bonnie Zhang

Not pictured

172. David Valcin
173. Tina Sallis (Finance Manager, Curtin U.)


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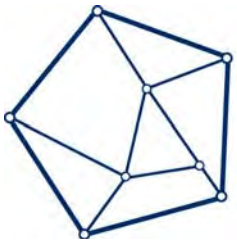
ACRONYM	DESCRIPTION	DEFINITION
2MTF	Project	2MASS Tully-Fisher
6dFGS	Project	6-degree Field Galaxy Survey
AAL	Organisation	Astronomy Australia Ltd
AAT	Facility	Australian Astronomical Telescope
ATCA	Facility	Australia Telescope Compact Array
ADASS	Conference	Astronomical Data Analysis Software and Systems
AGN	Object	Active Galactic Nuclei
ALMA	Facility	Atacama Large Millimeter Array
ANGUS	Project	AustraliaN GADGET-3 early Universe Simulations
ASKAP	Facility	Australian Square Kilometre Array Pathfinder
ASVO	Facility	All Sky Virtual Observatory
ASTRON	Organisation	Netherlands Institute for Radio Astronomy
ATLAS	Project	Australia Telescope Large Area Survey
ATNF	Facility	Australia Telescope National Facility
BAO	Term	Baryonic Acoustic Oscillation
BIGHORNS	Project	Broadband Instrument for the Global HydrOgen Reionisation Signal
CAASTRO	Research Centre	ARC Centre of Excellence for All-sky Astrophysics
CANDELS	Project	Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey
CASS	Research Centre	CSIRO Astronomy and Space Science
CitC	Outreach	CAASTRO in the Classroom
CTIO	Facility	Cerro Tololo Inter-American Observatory, Chile
DINGO	Project	Deep Investigation of Neural Gas Origins
DRAGONS	Project	Distant Radio Galaxies Optically Non-detected in the SDSS
EMU	Project	Evolutionary Map of the Universe
EoR	Object	Epoch of Reionisation
eROSITA	Project	extended ROentgen Survey with an Imaging Telescope Array
ESO	Facility	European Southern Observatory
FLASH	Project	First Large Absorption Survey in HI
FRB	Object	Fast Radio Bursts
GAMA	Project	Galaxy and Mass Assembly survey
GEG	Project	GaLactic and ExtraGalactic MWA group
GLEAM	Project	Galactic and Extragalactic MWA survey
GMRT	Facility	Giant Metrewave Radio Telescope, India
GMT	Facility	Giant Magellan Telescope
GRB	Object	Gamma-Ray Burst
HECTOR	Project	Follow-on IFU after SAMI
HETDEX	Project	Hobby-Eberly Telescope Dark Energy Experiment
HIPASS	Project	HI Parkes All-Sky Survey
HTRU	Project	High Time Resolution Universe
ICRAR	Research Centre	International Centre for Radio Astronomy Research
IFU	Instrument	Integral Field Unit (spectrograph)
LOFAR	Facility	Low Frequency Array telescope
LSST	Facility	Large Synoptic Survey Telescope
LWA	Facility	Long Wavelength Array, USA

ACRONYM	DESCRIPTION	DEFINITION
MOSFIRE	Project	Multi-Object Spectrometer for Infra-Red Exploration
MOST	Facility	Molonglo Observatory Synthesis Telescope
MWA	Facility	Murchison Widefield Array
NCI	Facility	National Computational Infrastructure
NRAO	Facility	National Radio Astronomy Observatory, USA
OzDES	Project	Australian Dark Energy Survey
PESSTO	Project	Public ESO Spectroscopic Survey of Transient Objects
PHISCC	Conference Committee	SKA Pathfinders HI Survey Coordination Committee
RFI	Term	Radio Frequency Interference
SAMI	Project	Sydney–AAO Multi-object Integral-field spectrograph
SKA	Facility	Square Kilometre Array
SKAMP	Facility	Square Kilometre Array Molonglo Prototype
SNe Ia	Object	Supernovae Ia
S-PASS	Project	S-band Polarisation All Sky Survey
SRG	Facility	Spektrum-Rötgen-Gamma, Russian satellite
SSA	Term	Space Situational Awareness
SSimPL	Project	Survey Simulations PipeLine
TAIPAN	Project	Transforming Astronomical Imaging surveys through Polychromatic Analysis of Nebulae
TESS	Facility	Transiting Exoplanet Survey Satellite
UKST	Facility	UK Schmidt Telescope
ULX	Object	Ultra Luminous X-ray sources
VAST	Project	Variable and Slow Transients
VLA	Facility	Very Large Array
VLA LITTLE THINGS	Project	Local Irregulars That Trace Luminosity Extremes; The HI Nearby Galaxy Survey
VLA THINGS	Project	The HI Nearby Galaxy Survey
WALLABY	Project	Widefield ASKAP L-Band Legacy All-sky Blind SurveY
WiFeS	Facility	Wide-Field Spectrograph, ANU
WiggleZ	Project	A large-scale galaxy redshift survey
WISE	Facility	Widefield Infrared Survey Explorer
WNSHS	Project	Westerbork Northern Sky HI Survey
WSRT	Facility	Westerbork Synthesis Radio Telescope
XMM-Newton	Facility	X-ray Multi Mirror Mission – Newton



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