CAASTRO

ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

SEVEN

ANNUAL REPORT 2017

CAASTRO acknowledges the support of the Australian Research Council and of NSW Trade and Investment. We also acknowledge the financial and in-kind support provided by our participating organisations: The University of Sydney, The University of Western Australia, The University of Melbourne, Swinburne University of Technology, The Australian National University, Curtin University and The University of Queensland.

www.caastro.org

Design by Go Media Design

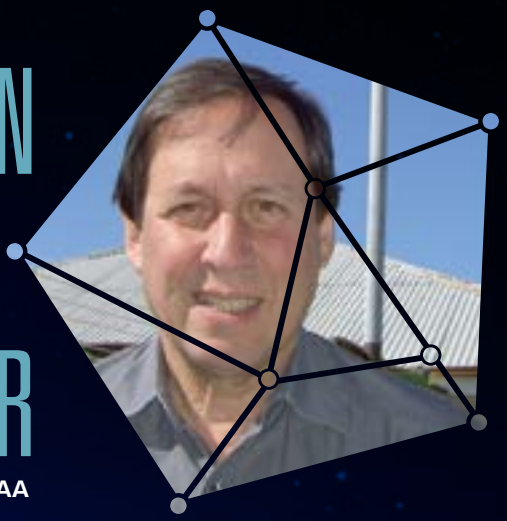
Australian Government
Australian Research Council

NSW GOVERNMENT Trade & Investment

CONTENTS

Introduction from the Chair	2
Vision & Mission Statement	4
Director's Report	6
Research Programs	8
Case Studies	26
CAASTRO Celebrates at Parliament House Canberra	40
Life Beyond CAASTRO	42
2017 Publications	44
Student Life	54
CAASTRO Students	56
CAASTRO Governance	60
CAASTRO Membership	62
Awards & Honours	64
Gender Action Committee	66
Presentations	68
Workshops	82
CAASTRO Annual Retreat	86
Education & Outreach	88
Industry and Innovation	94
The CAASTRO Legacy	96
CAASTRO Locations	98
CAASTRO Linkages	130
CAASTRO Collaborations	135
Key Performance Indicators	138
Financial Statements	141
Grants won by CAASTRO Members in 2017	143
CAASTRO People	144
Glossary	156

INTRODUCTION FROM THE CHAIR



PROFESSOR ROBERT WILLIAMSON AO FRS FAA
CHAIR, CAASTRO ADVISORY BOARD

Legacy, *noun*

/ˈlɛgəsi/ (*say* 'leguhsee)

1. a gift of property, especially personal property, as money, by will; a bequest.

2. anything handed down by an ancestor or predecessor.

3. a consequence …

– Macquarie Dictionary

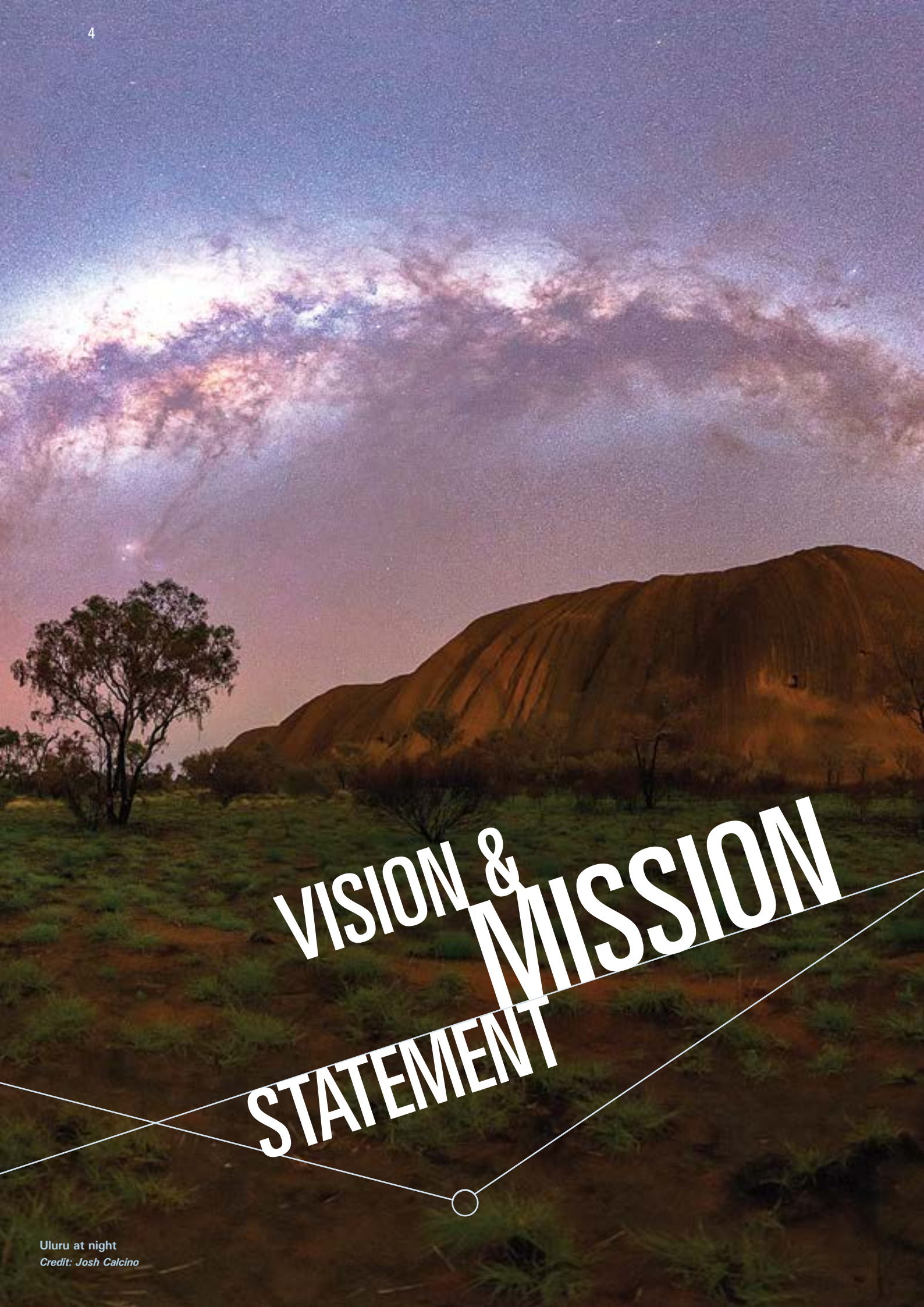
When we talk of a legacy, it is often to refer to the end of one phase of existence and the moving of people and things to another. This is a good way to think of CAASTRO.

CAASTRO is ending, but its legacy is important in at least three ways. First, it has produced a great deal of science its seven years, with a total of some 680 refereed publications. Second, CAASTRO's way of operating has influenced the people – students, postdocs, senior scientists – who have been its members. They, in turn, have contributed to the organisation's great programs. CAASTRO's gender-equity program is one of the best, perhaps the best, in Australia; the links between CAASTRO and Aboriginal initiatives at Uluru are a model for other academic centres; and international links always figured high on the list of achievements. At CAASTRO's final Annual Retreat in November, person after person talked about how the Centre had changed the culture of astronomy in Australia. Finally, CAASTRO's success helped give birth to two further ARC Centres of Excellence, those for All Sky Astrophysics in 3 Dimensions (ASTRO 3D) and for Gravitational Wave Discovery (OzGrav).

When CAASTRO was put together by Bryan Gaensler, Elaine Sadler and their colleagues in 2011, it was the first such centre to be proposed for the field of astronomy. There was no model to follow, so its policies and procedures had to be created from scratch. The start-up process was challenging; however, an excellent administrative team set CAASTRO up with very good foundations. During its seven years of life, CAASTRO has participated in some very exciting science, such as this year's detection of light and radio waves from a gravitational-wave event – the merger of two neutron stars. The two standout instruments CAASTRO has been associated with have been the Murchison Widefield Array – which had not yet been completed at the time CAASTRO was formed – and the SAMI (Sydney University–AAO Multi-object Integral-field spectrograph) instrument, which was also at a very early stage at the time. Both instruments have proved to be world-class and very productive.

A highlight this year was an Advisory Board-sponsored celebration of CAASTRO in Parliament House, Canberra, in August. Hosted by the Hon Craig Laundy MP, Assistant Minister for Industry, Innovation and Science, it allowed us to bring together CAASTRO researchers and students with parliamentarians and their advisers. Many who came for the formalities stayed on to chat about CAASTRO and astronomy in general. The event also gave every researcher a chance to thank Chief Operating Officer Kate Gunn and her colleagues, the fine team who oiled the wheels and kept CAASTRO moving forward.

As an 'outsider' (a geneticist, not an astrophysicist), I have been impressed not only by CAASTRO's science and its community initiatives, but also by the extent to which astronomers and astrophysicists collaborate across Australia (and, indeed, the world). Perhaps it is because their equipment is so expensive! However, it is a good example to other scientists: because we are funded by the community through government, we should work together to achieve results that will benefit the community, and as effectively as possible. CAASTRO has met this obligation in every way, and it has been a pleasure to help achieve this worthy outcome.



VISION & MISSION STATEMENT

Uluru at night
Credit: Josh Calcino

The CAASTRO Vision

CAASTRO aims to be an international leader in widefield 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 goals are:

DISCOVER To make groundbreaking 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, processing enormous volumes of astronomical measurements, and visualising complex datasets, so as to build unique expertise in widefield 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 has entered 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 $420 million both in innovative widefield telescopes and in the powerful computers needed to process the resulting torrents of data. Using these new tools, Australia now has established 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 widefield facilities. CAASTRO has delivered 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 has pursued three interlinked scientific programs, each of which can be addressed only with the all-sky perspective provided by widefield 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 widefield 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 of our discoveries and the strong public interest they generate to highlight Australian innovation to the general public, and to inspire students to consider careers in science and engineering.

CAASTRO has received 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

PROFESSOR ELAINE SADLER FAA
CAASTRO DIRECTOR

In our final year, it feels as though CAASTRO has been busier and more active than ever. Many of the projects started in previous years have now come to a successful conclusion, and in this report we look at CAASTRO's broad impact and legacy as well as the scientific highlights from this year.

2017 saw some changes in the membership of the CAASTRO Executive team. Early in the year, we said goodbye to CAASTRO Executive members Matthew Bailes (now Director of the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav)), Carole Jackson (now Director-General of the Netherlands Institute for Radio Astronomy (ASTRON)) and Stuart Wyithe (now deputy Director of the ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D)). In their place, we welcomed new Executive members Ramesh Bhat (Curtin University node leader), Jeremy Mould (Swinburne University node leader), Tara Murphy (Dynamic Universe theme leader) and Rachel Webster (University of Melbourne node leader). Deputy Director Lister Staveley-Smith has led the Evolving Universe theme since the start of 2017 and Tamara Davis continues to lead the Dark Universe theme.

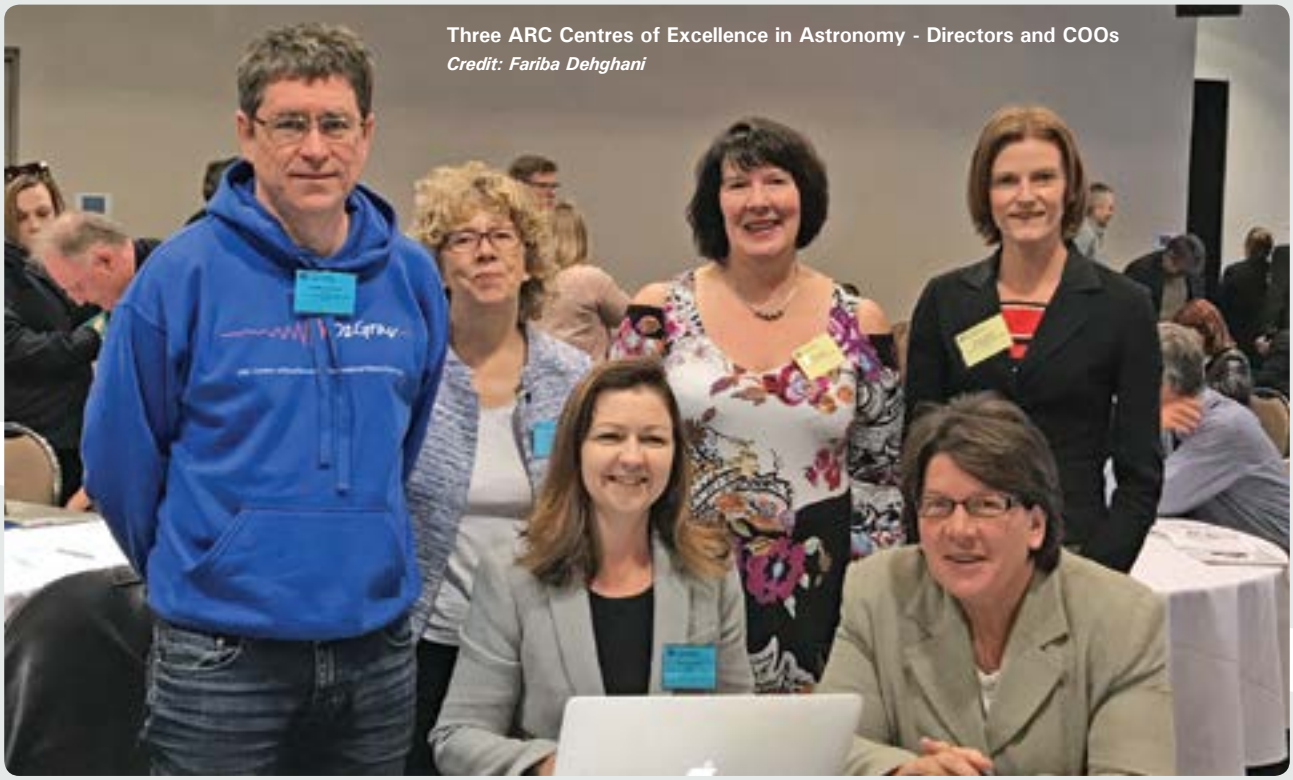
The CAASTRO Advisory Board held its last face-to-face meeting in Canberra in August, the day before a CAASTRO Celebration Breakfast at Parliament House hosted by the Hon Craig Laundy MP, Assistant Minister for Industry, Innovation and Science. Many CAASTRO members joined the Board and other guests at this event. Assistant Minister Laundy, Australia's Chief Scientist (and former CAASTRO Board Chair) Dr Alan Finkel, CAASTRO Chief Investigator Professor Brian Schmidt (Australian National University) and current Board Chair Professor Bob Williamson (University of Melbourne) spoke about CAASTRO and its achievements. Many of the parliamentarians and their advisors who attended the breakfast stayed on to look at our research displays and talk to CAASTRO's postdoctoral researchers and students about their work. Warmest thanks go to the members of the CAASTRO Advisory Board, who have consistently provided us with wise and useful advice on all aspects of CAASTRO's operations over the past seven years.

2017 saw the launch of our Gender Action toolkit, and CAASTRO was proud to receive the first Gold Pleiades Award from the Astronomical Society of Australia. These awards are given to organisations in astronomy that demonstrate a strong commitment to advancing the careers of women, and the Gold award recognises 'a truly outstanding sustained commitment' to best practice in this area.

Worldwide, the astronomy highlight of 2017 was undoubtedly the detection of gravitational waves from the merger of a pair of neutron stars, and the associated detection of an electromagnetic signal at many wavelengths. The Laser Interferometer Gravitational-Wave Observatory (LIGO) in the USA and the Virgo detector in Italy made the initial detection, and the alert they issued triggered astronomers around the globe into action. The CAASTRO team led by Tara Murphy (University of Sydney) was the first to confirm a radio detection of the event, and their work featured in several publications (including two in Science and one in Nature). The Australian results were announced to the media and streamed online from a press conference in Canberra arranged by OzGrav, and attracted considerable attention.

Our schedule of meetings and workshops was as busy as ever this year. We organized the third OzSKA meeting (in Sydney), the third Australia–China ACAMAR workshop (in Hobart) and the galaxy-evolution workshop 'From Black Hole to Environment' (in Canberra). We hosted two major international meetings: the Dark Energy Collaboration meeting in Brisbane in November, and 'Science at Low Frequencies IV' in Sydney in December. Our first Galaxy Convention in December, ably organised by Janette Ellis and her team, brought high school students from all over Australia, together with teachers, PhD students and Post Docs to Sydney for two days of meetings and workshops on female entrepreneurship in STEM (science, technology, engineering and mathematics), with an excellent program of inspiring speakers.

Our final Annual Retreat was held in South Australia's Barossa Valley in November. We enjoyed a wonderful program of science talks and meetings, as well as a chance to celebrate the full breadth of CAASTRO's achievements over the past seven years. It has been particularly rewarding to see a new generation of researchers move into leadership positions as CAASTRO has evolved. Only two members of the original 2011 CAASTRO Executive remain in place in 2017 – Deputy Director Lister Staveley-Smith and Chief Operating Officer Kate Gunn. Lister and Kate have been the custodians of CAASTRO's



Three ARC Centres of Excellence in Astronomy - Directors and COOs
Credit: Fariba Dehghani

corporate knowledge, and have ensured that the Centre continued to flourish in times of change. I am enormously grateful to them. Warmest thanks go also to Kylie Williams, Kate Gunn and the CAASTRO A-team for organising this seventh and last retreat, and for making it such a memorable occasion.

As CAASTRO moves towards its official end date of 31 March 2018, we are starting to say goodbye to some familiar faces. In November, our Events and Communications manager, Kylie Williams, moved to a new position as Senior Officer, Programs and Events, at the Sydney Dental Hospital. Kylie has done an outstanding job of running CAASTRO's events program for the past four and a half years, and we are grateful for all she has done for CAASTRO. CAASTRO's Education and Outreach manager Wiebke Ebeling begins a new position in February 2018 as Centre Manager of the Wave Energy Research Centre at UWA's Albany Campus. Kate Gunn will become the new Chief Operating Officer at the Garvan Institute of Medical Research on 1 March 2018. Kate's contributions to CAASTRO over the past seven years have been immense, and I wish her well in this exciting new role. Several of our CAASTRO professional staff are moving on to roles with the new ARC Centres ASTRO 3D and OzGrav, and our researchers are starting to take up new positions around Australia or overseas. To all those who have been part of CAASTRO over the past seven years, thank you once again for all you have contributed. I wish you every success in your future endeavours.

After seven years, CAASTRO leaves a tremendous legacy. I am proud of what we have achieved, and I hope you are too.

RESEARCH PROGRAMS

Professor Tamara Davis,
The Dark Universe
Theme Leader
Credit: Cristy Roberts

THE EVOLVING UNIVERSE

Theme Leader: Professor Lister Staveley-Smith | University of Western Australia

Theme Scientist: Dan Taranu | University of Western Australia

The Evolving Universe theme is concerned with the lives of galaxies: how they form, grow and die; the forces that shape them; and how they interact with their environment. This theme encompasses the whole history of galaxies, from the time of the first stars until today, and its researchers have undertaken a wide range of work during CAASTRO's lifetime. Particularly of note are the large projects carried out with the Murchison Widefield Array, SAMI (the Sydney University–AAO Multi-object Integral field spectrograph) and, more recently, the Australian SKA Pathfinder.

Observations with the Murchison Widefield Array

Epoch of Reionisation

The first stars formed during the Epoch of Reionisation (EoR), a time of transition between the 'dark ages', when no galaxies existed, and the modern era of abundant galaxies. The EoR is one of the last unexplored periods of cosmic history.

The best way we have to investigate the EoR is to measure the emission of un-ionised (neutral) hydrogen (HI), which was abundant in the early Universe. HI gas produces a unique spectral line that is detectable at radio wavelengths. As early galaxies formed and heated this gas, it became ionised (the atoms lost their sole electron) and no longer produced the HI spectral line. When all of the neutral hydrogen was ionised, the signal vanished, marking the end of the EoR.

The EoR HI signal is extremely weak, and heavily obscured by signals 100,000 times stronger from our own Galaxy and other galaxies. To detect the signal we need guidance from simulations that tell us at what frequency the radio signal is likely to be found and what it should look like; carefully calibrated telescopes; and sophisticated techniques for 'peeling' away the obscuring foregrounds.

Work along these lines for CAASTRO's EoR project started as soon as the Centre itself did. The first two years saw new supercomputing simulations of reionisation and the development of algorithms for subtracting foregrounds. These activities have continued throughout CAASTRO's life. This year a new analysis of foregrounds took into account for the first time the effects of galaxy clustering (page 29). Factoring this in will be important for future observations of the EoR, such as those to be done with the Square Kilometre Array. The analysis also showed that ignoring clustering could lead to a false detection of the EoR signal – that is, a foreground signal mimicking the real thing. Again, this is important for the analysis of any EoR detection.

The first 128 tiles of the Murchison Widefield Array (MWA) began operating in 2012 and observations for the MWA EoR experiment began in 2013. By the end of 2017, the MWA EoR team had collected four and half years of data, over three observing fields. Over those years, great effort has gone into developing pipelines for processing EoR data, characterising foregrounds and studying the effects of the ionosphere. More details of this work, particularly that of the last two years, are given on page 29. Much of it has implications for the low-frequency telescope of the Square Kilometre Array, SKA-low, which will be co-located with the MWA at the Murchison Radio-astronomy Observatory.

The EoR data has also been used as a space science tool to explore the ionosphere above the MWA, with results that are encouraging for SKA-low (page 11). It has been used to put limits on the synchrotron emission from the 'cosmic web' of intergalactic matter. In 2015 it was used for a 'blind' search for slow radio transients that put the most stringent limit to date on these sources. And in 2013, a CAASTRO Honours student, Cleo Loi (University of Sydney) discovered the formation of large, tubular ducts of plasma in the ionosphere, aligned with the Earth's magnetic field. Using the MWA, Loi made the first detailed images of these ducts, deduced their heights and sizes, and imaged their motion in real time. Her work gained worldwide attention. It also showed the MWA to be a superb instrument for studying the ionosphere.

Observing foregrounds with GLEAM

For researchers attempting to detect the Epoch of Reionisation signal, the foreground signals from our Galaxy and others are a nuisance, something that must be characterised in order to be excised from their data. For other researchers these sources are interesting in their own right. For both these reasons, the MWA was used to carry out the Galactic and Extragalactic MWA (GLEAM) survey, alongside the EoR observations. GLEAM was the first survey of the southern sky in its frequency range, 73–230 MHz. It complements southern-sky surveys made at higher frequencies and other low-frequency surveys of the northern sky, and its output will underpin the 'sky model' for the low-frequency component of the Square Kilometre Array, SKA-low, which will be co-located with the MWA.

Observations for GLEAM were carried out during 2013–2015. GLEAM's first-year data was published in 2017 as a catalogue of more than 300,000 sources. Low-frequency imaging surveys are challenging, and the experience gained from GLEAM will be directly useful for SKA-low.

Low-frequency polarimetry

Polarimetry, the measurement of polarised emission, is considered challenging at low frequencies. But the MWA has proved to have great potential for this kind of observation. It can detect both pulsars and flare stars through their circularly polarised emission, as shown in CAASTRO papers published this year (page 16) and in 2016. Other work in 2016 demonstrated that the MWA can also image the diffuse interstellar medium in linear polarisation: doing so over large areas may reveal structures, such as those associated with turbulence, that could not be detected any other way. This year Emil Lenc (University of Sydney) and collaborators published a paper addressing the technical challenges of polarimetry with the MWA and their solutions. Again, the lessons learned with the MWA will be valuable for SKA-low.

Detecting sources through scintillation

The MWA has also shown itself to be excellent for finding extragalactic radio sources that twinkle – change rapidly in brightness – as a result of charged particles flowing from the Sun. Only highly compact sources do this and so the technique can be used as a quick way to find them (page 35). The commonest type among the highly compact, strongly scintillating sources was the peaked-spectrum source – young, compact radio galaxies. These galaxies were also the subject of another ground-breaking CAASTRO study, one that used data from the GLEAM catalogue to identify them (page 12).

Understanding the history of neutral hydrogen

Neutral hydrogen (HI) filled the Universe before the Epoch of Reionisation and is still ubiquitous today. It is the material that ultimately becomes stars (after condensing into molecular hydrogen). But how it enters galaxies, and the paths it takes within them, are not wholly understood.

We want to understand the history of the gas the Universe: its abundance and distribution, and how these factors relate to the drastic drop-off in star formation over the last 10 billion years. CAASTRO researchers have contributed to this. In 2013 and 2016 they applied to radio observations a technique first used in optical astronomy, *stacking*, to measure the cosmic density of neutral hydrogen, showing that it appears to have changed little over the last four billion years. But the details of HI's life during that time – the ratio of warm to cool gas, and the gas's distribution – are still unknown. So too is the history of neutral hydrogen in individual galaxies beyond the local Universe.

HI studies with ASKAP

Neutral hydrogen's tell-tale radio emission, its 21-cm spectral line, is a workhorse of radio astronomy: it can help us learn how galaxies build up both gas and stars, and about their dynamics, structure and interactions with other galaxies.

Many of the questions we have about HI will be tackled by projects on the Australian SKA Pathfinder (ASKAP). This new radio telescope, a set of 36 dishes, is located at the same site as the MWA, CSIRO's Murchison Radio-astronomy Observatory in Western Australia. ASKAP has been under construction throughout the life of CAASTRO; 2017 saw the outfitting of the final dish. Commissioning observations have been made since 2013 with varying subsets of the 36 antennas. CAASTRO researcher Attila Popping (ICRAR–UWA) has been a member of the commissioning team and many CAASTRO researchers are part of the science teams planning big ASKAP projects.

One of these projects, WALLABY (the Widefield ASKAP L-Band Legacy All-Sky Blind Survey), will detect neutral hydrogen in about 600,000 galaxies out to a redshift of 0.26. These detections will be used to determine the distance, gas mass and total mass of every galaxy in the survey and used to investigate questions such as how galaxies form, evolve and interact, and how HI is distributed local Universe. ASKAP 'early science' observations for WALLABY began in October 2016 and were almost complete by the end of 2017: they amounted to 700 hours of observations – 220 TB of raw data – collected over four fields. The WALLABY team, which includes CAASTRO members, will now verify and analyse its data products.

WALLABY is complemented by DINGO (Deep Investigation of Neutral Gas Origins), a neutral-hydrogen survey covering a smaller area but with greater depth. DINGO will look for evolution in the density of neutral hydrogen and investigate – among other things – how galaxies acquire gas and angular momentum, and how the *cosmic web* of matter in the Universe grows over time. DINGO and WALLABY will together explore the process of galaxy formation over the last four billion years. DINGO is led by CAASTRO Associate Investigator Martin Meyer (ICRAR–UWA). ASKAP 'early science' observations for DINGO began in September 2017 and six nights of data have been collected to date. The DINGO team, including Attila Popping, is investigating ways to combine individual observations: given the very long exposure times needed for individual DINGO fields, this is vital for the survey's success.

Although neutral hydrogen is plentiful in the Universe, its 21-cm emission line is weak. To detect HI in distant galaxies, astronomers can look for absorption, the imprint that HI leaves on the spectrum of radio emission from a strong background source such as a quasar. One of ASKAP's major survey projects is FLASH (the First Large Absorption Survey in HI), which is aimed at finding several hundred new HI absorbing-line systems. This project, led by CAASTRO Director Elaine Sadler (University of Sydney) will be the first major study of the relationship between HI and the rate of star formation in galaxies at redshifts between 0.5 and 1.0 – that is, galaxies four to eight billion years back in the history of the Universe. Thanks to ASKAP's wide field of view, FLASH will cover a much larger volume of space than previous absorption surveys.

ASKAP's site, the Murchison Radio-astronomy Observatory, is well protected against radio interference, meaning that faint signals that might be missed elsewhere will stand out clearly in the data. This has been demonstrated by CAASTRO Affiliate James Allison (CSIRO), a member of the FLASH team, who in 2014 used ASKAP to make the first 'blind' search of HI in absorption (that is, a search that didn't target objects at known redshifts). Allison's search turned up a previously

undetected signal from the galaxy PKS B1740–517 at a redshift of 0.44, a promising result for FLASH.

Intensity mapping

Another way we can detect HI at great distances is with the new technique of intensity mapping. This involves capturing the aggregate HI emission over large patches of sky, not from individual galaxies. Evolving Theme leader Lister Staveley-Smith (ICRAR–UWA) and CAASTRO postdocs Jonghwan Rhee (ICRAR–UWA) and Laura Wolz (University of Melbourne) have extended our understanding of this. Rhee has an ongoing project on the Parkes telescope to measure the density of neutral hydrogen out to a redshift of 0.9. In 2016, Staveley-Smith, Rhee and CAASTRO student Tristan Reynolds (ICRAR-UWA) showed that using a phased-array feed receiver on the same telescope speeded up the intensity mapping fourfold and, by going to lower frequencies, was able to access HI at greater distances. This year Wolz, together with CAASTRO Chief Investigators Chris Blake (Swinburne) and Stuart Wyithe (Melbourne), showed that the average per-galaxy mass of HI can be derived by cross-correlating an HI intensity map with an optical galaxy survey (page 13). This promises to be an important analytical technique.

Looking inside galaxies with SAMI

To understand how galaxies evolve, and how their different properties are related, we need to look inside them in detail. At the same time, to draw sound conclusions that apply across populations, we need to examine large numbers of galaxies. SAMI, the Sydney University–AAO Multi-object Integral field spectrograph instrument, is a CAASTRO-funded instrument that achieves both these aims. SAMI samples the light from up to 61 points in a galaxy, for 12 galaxies (and one reference star) at a time. The spectrum of each sample shows how the stars and gas at that location are moving. SAMI is based on new technology developed at the University of Sydney: the 'hexabundle', a bundle of 61 optical fibres close-packed and fused together.

SAMI's life has coincided with CAASTRO's. It was commissioned on the Anglo-Australian Telescope in 2011; after an upgrade, it began work in 2013 on the SAMI Galaxy Survey, the largest survey of its kind at the time. Science results began to appear in 2014 and have included studies of kinematic morphology (classifying galaxies as fast or slow rotators), galactic winds, the effects of environment on star formation, the relation between angular momentum and optical morphology, and the relation between galaxy kinematics and stellar mass. Several SAMI papers were published this year, including the first accurate determination of the intrinsic shapes of galaxies (page 14). Other SAMI investigations are outlined on page 33, along with details of the project's first data release, issued this year. Plans are now under way for an Australian successor to SAMI, the Hector instrument. This will build on the experience gained with SAMI and make it possible to observe up to 100 galaxies at a time.

The SAMI project will transition to the new ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D), as will a number of other projects in the Evolving Universe theme.

Investigating the ionosphere at the Murchison Radio-astronomy Observatory

Ground-based optical telescopes must contend with 'seeing', the stability of the Earth's atmosphere, which can be variable. In the same way, radio astronomers working at low frequencies have to deal with variations in the behaviour of the ionosphere, a layer of the atmosphere in which a high fraction of gas molecules has been ionised, creating a soup of charged particles. When 'active', this layer can distort low-frequency cosmic radio signals in many ways.

Low-frequency astronomy has enjoyed a renaissance in the last few years. The Murchison Widefield Array (MWA) is one of the new generation of low-frequency radio telescopes. In the next few years it will be joined on the same site, the Murchison Radio-astronomy Observatory (MRO), by the low-frequency telescope of the Square Kilometre Array, SKA-low. To get the best out of these instruments we need to learn more about how the ionosphere above the MRO varies with time.

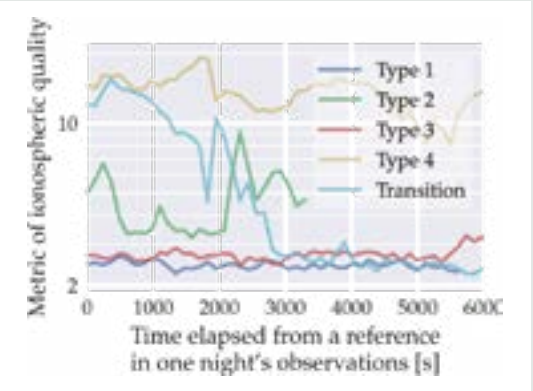
This year Chris Jordan (ICRAR–Curtin) led work to do just that. Jordan's team used 32 hours of observations already taken for the MWA Epoch of Reionisation project. They processed the data with the MWA real-time data pipeline, then examined and classified them for ionospheric activity. The real-time system gave information on the ionosphere with high spatial and temporal resolution.

The team found that only a small number of sampling points (100–200) is needed to show the intensity of ionospheric activity. It was able to categorise the activity into four types, and developed a simple metric, using only two statistics, to provide an 'at a glance' value for data quality under various ionospheric conditions. This technique is 'instrument agnostic' and could be used by LOFAR (Europe's Low Frequency Array) and SKA-low as well as by the MWA.

Jordan's team found that the severity and type of ionospheric activity tends to remain constant across an entire evening of observations. This is good news for low-frequency observatories, which could adapt their observing schedules to ionospheric conditions early in an evening. Most encouraging of all, the ionosphere was inactive three quarters of the time. This investigation suggests that the core of SKA-low, which will have about the same extent as the MWA, will be highly calibratable.

Publication

Jordan, C. H., Murray, S., Trott, C. M., Wayth, R. B., Mitchell, D. A., Rahimi, M., Pindor, B., Procopio, P., Morgan, J., "Characterization of the ionosphere above the Murchison Radio Observatory using the Murchison Widefield Array", Monthly Notices of the Royal Astronomical Society, 471, 3974 (2017)



Line plots of the ionospheric quality metric for each of the four ionospheric types identified in this work, as well as another night showing a transition from one type to another. Types 1, 3 and 4 vary little in their metric while Type 2 is less stable. The 'transitional' activity drops after about an hour: this indicates that ionospheric activity should be monitored at least hourly during observations. (From Jordan et al. 2017)

Young or frustrated? Data trove may help decide

The Murchison Widefield Array has revealed an abundance of unusual galaxies that may help to settle a decades-old question.

A radio source's spectrum (the energy it emits at different radio frequencies) is the chief clue to the processes producing its radio emission. Most sources can be readily classified this way. But some have a peak in their spectrum that has been argued about since the 1960s.

These sources differ in physical size and peak in different frequency ranges: this divides them into three groups (gigahertz-peaked spectrum, compact steep spectrum, and high-frequency peaked). Some are large enough to image, and doing so shows that they have a radio-emitting core flanked by two radio emitting lobes. They are compact but powerful versions of the much larger galaxies that harbour active black holes – *active galactic nuclei* or AGN.

Are the peaked-spectrum sources just young AGN in the making? Perhaps. But they might instead be 'frustrated', small only because their AGN activity is confined by a dense medium at the galaxy's core.

The sources' spectra should settle the question. Examined carefully, they should favour one radio-producing process (synchrotron self-absorption, SSA) or another (free-free absorption, FFA). That would point to the sources being either young (SSA) or frustrated (FFA).

To distinguish between the models like this, we need spectra that are well sampled (have lots of data points). Low-frequency data has been sparse until now. But the Murchison Widefield Array (MWA) has changed that.

The MWA survey GLEAM (Galactic Extragalactic All-sky MWA survey) recorded 300,000 sources, taking data simultaneously in 20 frequency bands between 72 and 231 MHz. PhD student Joseph Callingham (University of Sydney) has led an investigation looking for sources that peak in this data-rich region.

To select their sources, Callingham's team cross-matched the GLEAM catalogue with those of two other surveys, NVSS (NRAO VLA Sky Survey) and SUMSS (Sydney University Molonglo Sky Survey). This identified 1,483 sources that peak between 72 MHz and 1.4 GHz. Seventy-three of these sources were known and had had their spectral peaks determined but 1,410 were completely new.

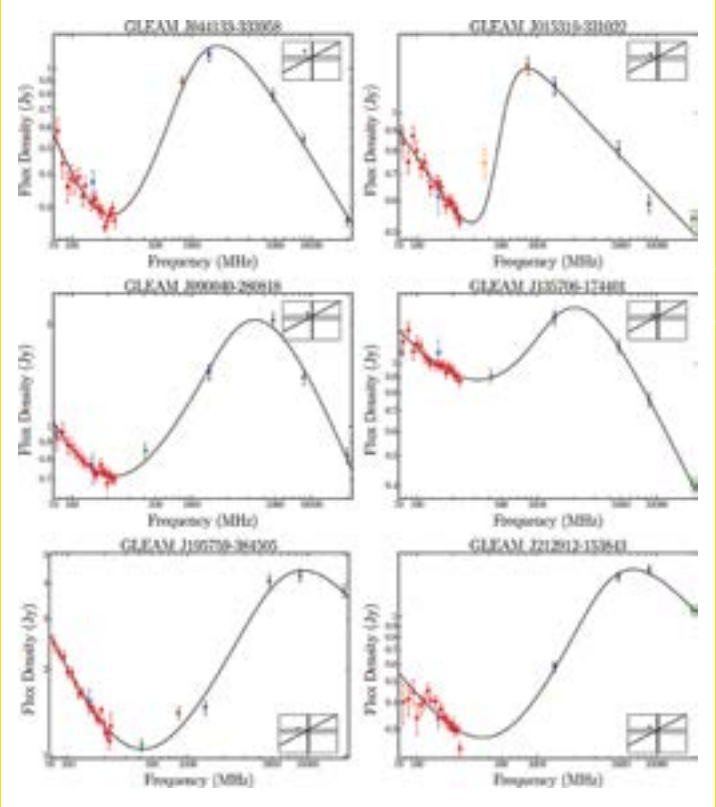
Callingham's team drew several conclusions from their rich haul.

- Some objects might have been active more than once. Six sources had spectra that peaked above 5 GHz, dipped then rose again at GLEAM frequencies.
- Steep-spectrum sources with a low-frequency peak may be likely to lie at high redshift (large distance). Previous studies had identified sources with a steeply falling spectrum and no peak. Callingham's team found that a number of these sources peaked in GLEAM frequencies. Where the redshift of these sources was known, it was high ($z > 2$).
- Each source's peak may be determined by an inhomogenous medium that differs from source to source. That's implied by the sources' diverse spectral characteristics.
- The frequency at which the spectrum peaks isn't related to the object's redshift. That suggests the sources are a mix of nearby ones that intrinsically peak at low frequencies, and distant (high-redshift) ones whose intrinsic high-frequency peaks have been redshifted to a lower frequency.
- Six sources may have spectra inconsistent with synchrotron self-absorption (SSA). If confirmed, this would indicate that they are 'frustrated' rather than young, perhaps settling 50 years of debate.

This investigation has uncovered a wealth of sources to be followed up, and highlights the value of low-frequency observations.

Publication

Callingham, J. R., Ekers, R. D., Gaensler, B. M. and 21 co-authors, "Extragalactic Peaked-spectrum Radio Sources at Low Frequencies", The Astrophysical Journal, 836, 174 (2017)



Spectra of six sources in this study that have a convex pattern between 72 MHz and 1.4 GHz. Dark green diamonds and yellow hexagons depict data from the AT20G and TXS surveys, respectively. The blue circle in the inset plot highlights the position of each source in colour–colour diagram. (From Callingham et al. 2017)

Wringing more from intensity mapping

CAASTRO researchers have developed another way to gain more information about neutral hydrogen in distant galaxies.

Searching individual galaxies for neutral hydrogen (HI) can be slow. And HI emission is weak: it can't be detected at great distances (high redshifts). This makes it difficult to test models of how HI has evolved in the Universe over time. We can overcome this through intensity mapping. Like spectral stacking, it is a way to aggregate information about HI in an ensemble of galaxies. But whereas in spectral stacking the aggregation takes place at the level of individual spectra, in intensity mapping we are effectively recording the HI signal within large, 3D pixels – large areas of sky (tens of megaparsecs across) within a narrow range of redshifts. Intensity mapping can tell us how HI distribution and abundance have changed over time. But CAASTRO postdoc Laura Wolz (Melbourne) and her collaborators Chris Blake (Swinburne) and Stuart Wyithe (Melbourne) have now shown that the technique offers more.

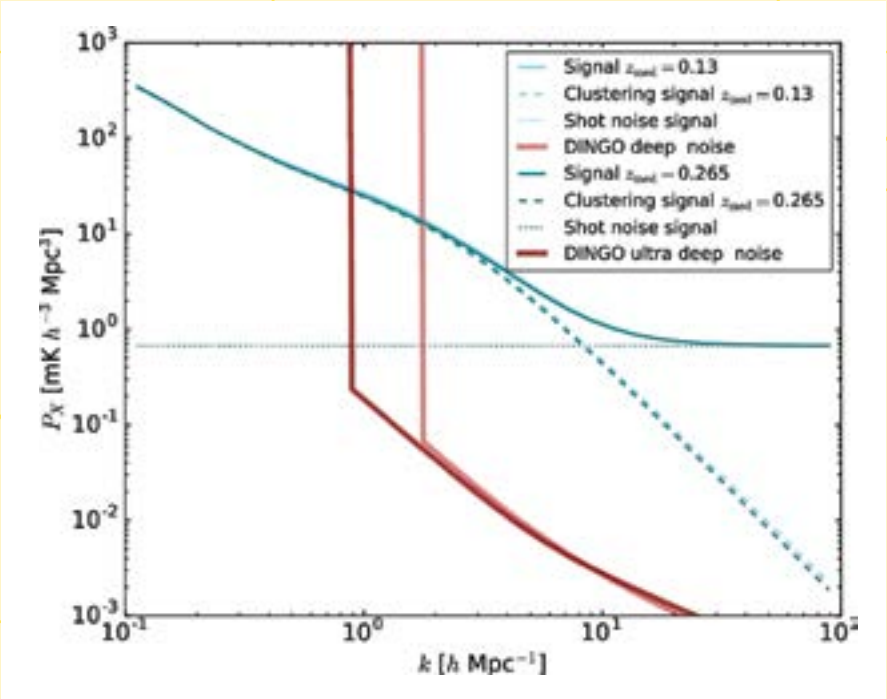
Like all techniques, intensity mapping has its problems. These include instability in telescope systems, radio interference from human activities, and foreground radio sources in our Galaxy. But it's been known for some years that these problems can be reduced by cross-correlating the HI intensity map with an optical survey of galaxies (a map of galaxies detected by visible light rather than radio waves).

In their new work, Wolz and her collaborators show that such cross-correlation can be used to measure the average HI content of the optically selected galaxies. Correlating the two maps produces a cross-power spectrum: this, they show, can be decomposed into a term that represents the galaxy clustering, and another – the *shot noise* term – that represents the average intensity of the HI emission from the optically selected galaxies. This technique can estimate the HI content of galaxy populations (e.g. distant ones) whose HI emission is too faint to observe. Furthermore, if the optically selected galaxies are chosen on the basis of particular attributes, such as luminosity or colour, it will be possible to determine any relationship between those properties and their HI content. Wolz and her co-authors demonstrate that HI masses could be recovered in this way from observations with the DINGO survey to be carried out with ASKAP (page 10).

Publication

Wolz, L., Blake, C., Wyithe, J. S. B., "Determining the HI content of galaxies via intensity mapping cross-correlations", Monthly Notices of the Royal Astronomical Society, 470, 3220 (2017)

The forecast for an intensity-mapping cross-power spectrum measurement between the ASKAP–DINGO survey and an overlapping optical survey, for the 'deep' and 'ultra-deep' DINGO configurations. The HI cross-shot noise contribution is marked as the dotted line assuming an average HI mass $10^9 h^{-2}\,\mathrm{M}_\odot$ per optical galaxy. The noise in the cross-power spectrum is marked as the red solid lines, which are up to three orders of magnitudes smaller than the expected shot noise signal for both DINGO surveys. (From Wolz et al. 2017)



Determining galaxies' true shapes with SAMI

A galaxy's shape reflects its history. The shape can indicate properties of the dark matter halo in which the galaxy formed. It will also be influence by mergers with other galaxies, and particular histories of star formation. Measuring the true shapes of galaxies will give us insight into these processes.

But it's not an easy problem: indeed, it's one astronomers have been trying to solve since the 1920s. The difficulty is that galaxies are scattered through space at random angles. We don't see them all face on, for instance. So we don't directly see their true, intrinsic shapes. Determining the shapes of elliptical galaxies is particularly hard. These are galaxies with significant thickness in three dimensions (they are more like footballs or squashed spheres than pancakes) and their shape is defined by three axes at right angles to each other.

A team led by Caroline Foster (University of Sydney) has now successfully tackled the problem of determining galaxy shapes, using a sample of 845 galaxies observed with SAMI (the Sydney–AAO Multi-object Integral-field instrument) – in fact, drawn from the SAMI Galaxy Survey (page 33). SAMI maps the interior motions of galaxies (their kinematics). For elliptical galaxies in particular, we need this kinematic information to reliably determine their intrinsic shapes.

Foster's team took the galaxies' observed properties – how elliptical they appeared, and their kinematic information – and calculated what underlying distribution of intrinsic properties would give rise to those observations, assuming that we see galaxies from random angles. In the last few years, other groups have followed the same path to try to determine galaxy shapes. But what sets this new work apart is the large sample from SAMI, more than three times bigger than that of any previous study. This larger sample makes it possible to look for how a galaxy's shape is related to other fundamental properties.

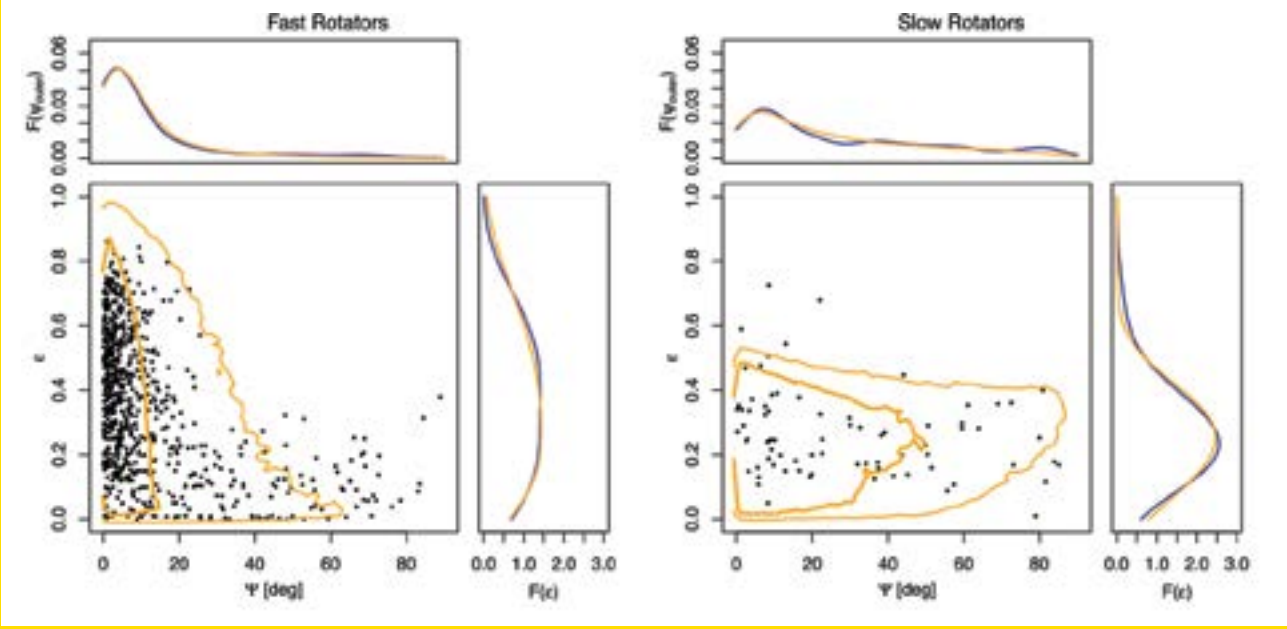
Foster and her team found that most galaxies in the SAMI Galaxy Survey resemble squashed spheres (they are oblate axisymmetric). Faster-spinning galaxies are flatter than their slower-spinning siblings. Among the spiral galaxies, which have disks of stars, the faster-spinning ones have more circular disks. All this is in line with theoretical predictions, but Foster's work is the first to demonstrate it from observations.

When the SAMI Galaxy Survey is complete it will be able to provide a sample twice as large as the one used for this work, allowing an even more detailed investigation of the relationship between a galaxy's shape and its other properties.

Publication

Foster, C., van de Sande, J., D'Eugenio, F., and 17 co-authors, "The SAMI Galaxy Survey: the intrinsic shape of kinematically selected galaxies", Monthly Notices of the Royal Astronomical Society, 472, 966 (2017)

The intrinsic shape of fast (left) and slow (right) rotators. The observed distribution of kinematic misalignments ψ and global apparent ellipticity ε is shown in the top panels with the observed (blue) and fitted (orange) smoothed and normalized distributions $F(\psi)$ and $F(\varepsilon)$. In the lower panels, distributions shown in orange with thick and thin lines represent the 68 and 95 per cent probability intervals, respectively. (From Foster et al. 2017)



THE DYNAMIC UNIVERSE

Theme Leader: Associate Professor Tara Murphy | The University of Sydney

Theme Scientist: Dr Christene Lynch | University of Sydney

Flares and flashes, pulses and bursts: the Dynamic Universe theme deals with rapid, dramatic events in the Universe. These events take place on human timescales, from milliseconds to years, and so can be studied as they happen. During the seven years of CAASTRO's existence the researchers in this theme have created new software and hardware tools, new collaborations and new surveys, for studying these fast-changing phenomena.

The Murchison Widefield Array (MWA) was completed in its initial form in 2013 and expanded in 2016. CAASTRO researchers have used it to put stringent low-frequency limits on slow transients and make exploratory low-frequency observations of other phenomena, such as stellar flares (page 16). They have also made pioneering observations of radio pulsars at low frequencies: for instance, in previous years they have shown that pulsars can be found not only by classical timing searches but also through their circular polarisation and even more complex effects. MWA pulsar observations published this year are described on page 17.

Classical, high-frequency observations of pulsars have not been ignored. Many of our researchers have taken part in the long-running High Time Resolution Survey, conducted with CSIRO's Parkes telescope. This survey recently found one of the most extreme binary pulsars known (page 37). A CAASTRO researcher initiated another major Parkes survey, SUPERB (Survey for Pulsars and Extragalactic Radio Bursts).

The still-mysterious fast radio bursts (FRBs) were discovered in 2007 with the Parkes telescope. The rate of discovery was initially slow but has picked up considerably during CAASTRO's lifetime: at the end of 2014 just nine FRBs had been published, but three years later the number has risen to around 30. In 2015 a CAASTRO PhD student using Parkes made the first detection of an FRB in 'real time' (that is, as it happened, rather than by searching recorded data).

Keen to make a mark in this new area of science, CAASTRO researchers upgraded the University of Sydney's Molonglo radio telescope, relaunching it in 2015 as UTMOST, a telescope dedicated to observing FRBs and pulsars. They continue to work to improve its abilities to localise FRBs on the sky. Using UTMOST, a CAASTRO PhD student showed in 2016 that FRBs are definitely cosmic, not terrestrial, signals.

Now another Australian telescope has entered the fray. CSIRO's Australian SKA Pathfinder, which has taken shape during CAASTRO's lifetime, has begun to find FRBs (page 32). Meanwhile, CAASTRO researchers have re-analysed the best existing FRB dataset and made it clear why more, and more uniform, observations are needed (page 18).

In just a few years' time, telescopes such as LSST (the Large Synoptic Survey Telescope) and the SKA (Square Kilometre Array) will be generating terabytes of data from sky surveys, every day. Picking out the best candidates for follow-up will have to be done by automated systems. In 2014 two CAASTRO PhD students worked on projects that bring such systems closer. One assessed how well an existing classifier, *Random Forest*, performed on variable and transient X-ray sources, and pointed to directions for future development. The second created a new classifier, based on *neural networks*, for picking the best pulsar candidates from a set – potentially of millions. This classifier, SPINN (Straightforward Pulsar Identification using Neutral Networks), was significantly better than previous ones for this task.

Worldwide, the landmark astronomical event of 2017 was the merger of two neutron stars, GW170817. This was the first event to be initially detected through the gravitational waves it created, and then through electromagnetic radiation – light, radio waves and other wavelengths. It marks the start of *multi-messenger* astronomy, in which gravitational waves will augment the information we get from the electromagnetic spectrum. The LIGO–Virgo team announced the gravitational-wave detection on 17 August 2017, triggering telescopes around the world into action. The contributions of many CAASTRO members are described on page 19 and a CAASTRO-led team's success in detecting and monitoring radio waves from the event is outlined more fully on page 39. Follow-up observations of gravitational-wave events will be major strand of work for one of CAASTRO's successor institutions, OzGrav (the ARC Centre of Excellence for Gravitational-wave Discovery). With the end of CAASTRO, the Dynamic Universe theme comes to a close, but the work it has pioneered continues.

UTMOST team | ***Credit: UTMOST***

Stellar flares found through polarised emission

M dwarfs are unassuming stars: small, dim and red. They are also plentiful. And, it's now thought, they might be good places to look for habitable planets. The dimming caused by a transiting planet would be relatively easy to spot. Planets crowded close enough to the star could fall into its habitable zone, where water is liquid and life is possible.

But there's another factor to consider. Some, perhaps all, M dwarfs are prone to sudden, unpredictable changes in brightness called *stellar flares*. Like flares on the Sun, they happen when magnetic field lines reconnect, releasing stored energy. And, like solar flares, stellar flares carry energy at all wavelengths, from radio to X-rays. But a crucial difference is that M-dwarf flares can unleash 1,000 times as much energy as solar ones. And that's not going to be good for life, particularly on planets without a protective magnetic field. With NASA's TESS (Transiting Exoplanet Survey Satellite) launching in 2018, it's timely to learn more about M-dwarf flares.

These flares have been well studied at radio frequencies of 1–4 GHz, but not much investigated below that. Plus, most observations have been made with single dishes, not with interferometers, which can more easily sort true signals from radio-frequency interference. Dynamic Theme Scientist Christene Lynch (University of Sydney) and collaborators explored this relatively uncharted territory by observing the 'classic' flare star, UV Ceti, with the Murchison Widefield Array at 154 MHz.

In four sets of observations, totalling about nine hours, Lynch's team detected four circularly polarised, low-level flares from UV Ceti – but not in total intensity images, only in the polarised (Stokes V) images, which are ten times more sensitive. This is the first detection of metre-wave flare-star emission using a modern low-frequency interferometer. It is also the first instance of stellar flares being seen in polarised emission but not in total intensity.

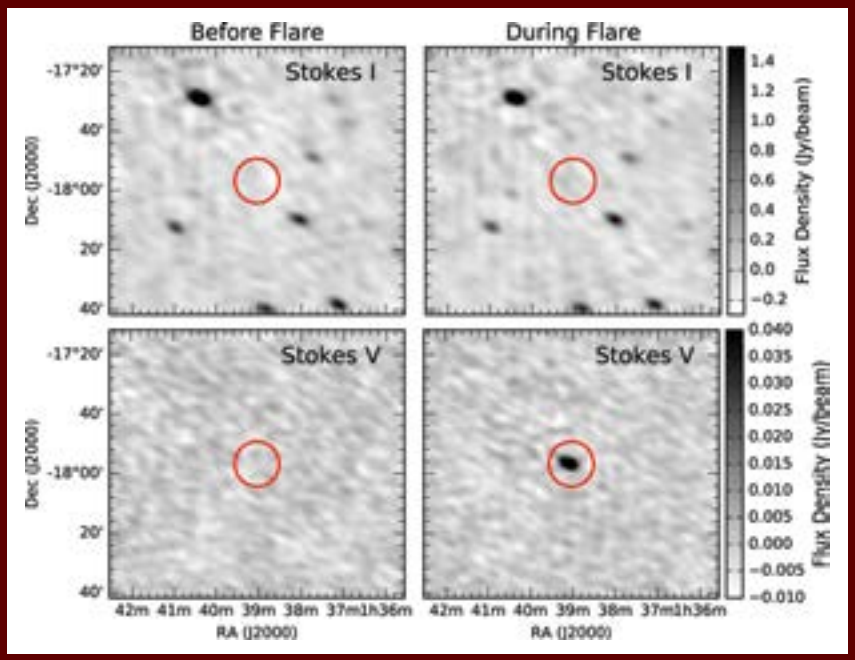
Lynch's team searched for, and found, linearly polarised emission during the brightest of the observed flares, indicating that this flare was *elliptically* polarised. The linear polarisation puts a limit on the Faraday rotation occurring in the atmosphere of UV Ceti: the measured rotation measure of 3.0 rad m^{-2} implies a total Faraday rotation (at 154 MHz) of 12 radians. That the flares are elliptically polarised suggests that electron cyclotron maser (ECM) emission is the mechanism at work. On this basis Lynch's team calculated a local magnetic field strength of 28 Gauss and a local electron density of $n_e \leq 7 \times 10^7$ cm^{-3}, values that accord well with previous estimates.

The rotational period of UV Ceti is unknown, but the projected rotational velocity, ~ 30 km s^{-1}, limits it to less than 6.5 hr. The observations fit several periods consistent with the limit, suggesting that the star's variability may be linked with its rotation. Follow-up observations will better constrain the flare period.

Publication

Lynch, C. R., Lenc, E., Kaplan, D. L., Murphy, T., Anderson, G. E., "154 MHz Detection of Faint, Polarized Flares from UV Ceti", The Astrophysical Journal, 836, L30 (2017)

Benz, A. O., Conway, J., & Gudel, M., "First VLBI images of a main-sequence star", Astronomy & Astrophysics, 331, 596 (1998)



MWA Stokes I (top) and Stokes V (bottom) images of the UV Ceti field, averaged over the 30 minutes before (left) and during (right) the strongest flare. The 1σ rms in the Stokes I image is 85 mJy and in the Stokes V image is 2 mJy. (From Lynch et al. 2017)

Ramping up low-frequency pulsar observations

Three CAASTRO PhD students have led projects pioneering low-frequency pulsar observations with the Murchison Widefield Array (MWA) this year. All three projects used the MWA's Voltage Capture System, which allows raw voltages to be recorded directly from each of the telescope's 128 tiles, with high resolution in both time and frequency (100 μs and 10 kHz respectively). The data can then be reduced in whatever way best suits the project in hand.

A 'drifting carousel' of pulsar subpulses

Radio pulsars were discovered 50 years ago, and yet the mechanism that produces their pulses is still not completely understood. Sam McSweeney (Curtin University) has investigated the phenomenon of *sub-pulse drifting*, which may hold clues. Sub-pulse drifting refers to substructures within individual pulses systematically changing their position in the pulse phase over time (for instance, gradually moving from the start of the pulse phase to the end). For this work McSweeney made new observations at 185 MHz of a bright single pulsar, PSR J0034−0721. Subpulses are thought to represent *sub-beams* caused by discrete emission regions that are stable over many pulsar rotations. In some cases they may be arranged in a 'carousel' pattern centered on the pulsar's magnetic axis and rotating around it.

An existing model explains the carousel's circular motion but doesn't predict the drift rates seen in some pulsars. PSR J0034−0721, for instance, has a drift rate that varies over time; abrupt changes result in different *drift modes*. In his project, McSweeney characterised the drifting behavior of PSR J0034−0721 with a small number of parameters. He showed that the drift rate in this pulsar varies gradually within individual drift modes, as well as sharply between them, and that the separation in time between two sub-pulses appears to be correlated with the pulsar's rotation phase. Overall, he found that the drifting behavior of PSR J0034−0721 is even more complex than previously thought! However, his observations also demonstrate for the first time that the MWA can produce high-quality single-pulse data.

Spectral flattening of Crab Giant Pulses

A second Curtin PhD student, Bradley Meyers, also studied pulses from a single object: the well-known Crab pulsar (PSR J0534+2200). This pulsar was discovered through its 'giant' pulses, short bursts of emission that last less than 10 μs but which can be thousands of times brighter than the 'regular' pulses. Just six pulsars are known to exhibit 'true' giant pulses, ones whose pulse energies follow a power-law distribution with frequency ($S_\nu \propto \nu^\alpha$). The physics behind giant pulses is unknown.

Meyers' team made simultaneous wideband observations of the Crab giant pulses with the Parkes radio telescope and the MWA. They showed, for the first time over a wide frequency range, that the average spectrum of Crab giant pulses flattens significantly at low frequencies. The spectral index, α, for giant pulses evolves from a steep, narrow distribution at high frequencies to (with a mean $\alpha = -2.6$ and width $\sigma_\alpha = 0.5$) to a wide, flat one at low frequencies (with a mean $\alpha = -0.7$ and width $\sigma_\alpha = 1.4$). No current model predicts this flattening.

One explanation put forward for fast radio bursts (page 15) is that at least some of them are super-giant pulses from extragalactic pulsars. Using their low-frequency value of α for the Crab giant pulses, Meyer's team suggests FRBs will be hard to detect at low frequencies, if a giant-pulse origin is relevant. This is bad news for the 'giant pulse' model.

A low-frequency census of southern pulsars

Pulsars were first discovered at a low frequency (81.5 MHz), yet of the ones we know now were found at much higher frequencies. This is the result of a trade-off: while pulsar signals are stronger at low frequencies, the signals are also broader, making them harder to detect, and telescope system temperature is also higher, due to diffuse Galactic emission. But with the more-sensitive low-frequency telescopes now operating, low-frequency pulsar observations are more feasible. Low-frequency emission is thought to arise from higher altitudes in the pulsar's magnetosphere, so multi-frequency observations allow us to model the magnetosphere and inform us about beam geometry. Finding and studying pulsars is an important goal of the Square Kilometre Array, and the MWA is a precursor for SKA-low, the low-frequency SKA. CAASTRO PhD student Mengyao Xue (Curtin University) has used archival MWA data (at 185 MHz) to make a first census of southern pulsars already known from high-frequency observations.

Xue's team processed about 2.6 PB of data from multiple projects, covering 17,000 deg^2, which is more than half the southern sky. The data were incoherently summed, to preserve the MWA's large field of view, but at the cost of reduced sensitivity. The processing made use of the *widefield pulsar pipeline* (WIPP) that Xue and her collaborators developed especially for this project: it automatically identifies and folds all known (catalogued) pulsars in the field.

Even with just ~1–10% of the full array sensitivity, more than 50 pulsars were detected. The team is now reprocessing the data to realise a ten-fold boost in sensitivity, by forming a coherent beam on every single pulsar within the sky visible to the MWA. This should lead to hundreds of pulsars being detected. Based on their MWA study, Xue's team and her collaborators estimate that Phase 1 of SKA-low will find ~9,400 pulsars, more than three times the number known to date.

Publications

McSweeney, S. J., Bhat, N. D. R., Tremblay, S. E., Deshpande, A. A., Ord, S. M., "Low-frequency Observations of the Subpulse Drifter PSR J0034−0721 with the Murchison Widefield Array", The Astrophysical Journal, 836:224 (2017)

Meyers, B. W., Tremblay, S. E., Bhat, N. D. R., Shannon, R. M., Kirsten, F., Sokolowski, M., Tingay, S. J., Oronsaye, S. I., Ord, S. M., "Spectral Flattening at Low Frequencies in Crab Giant Pulses", The Astrophysical Journal, 851, 20 (2017)

Xue, M., Bhat, N. D. R., Tremblay, S. E., Ord, S. M., Sobey, C., Swainston, N. A., Kaplan, D. L., Johnston, S., Meyers, B. W., McSweeney, S. J., "A Census of Southern Pulsars at 185 MHz", Publications of the Astronomical Society of Australia, 34, e070 (2017)

Conquering the *winner's curse* for fast radio bursts

CAASTRO astronomers have done the sums again on mysterious cosmic radio bursts, finding that they may have been more common earlier in the Universe's history than in recent times.

Fast radio bursts – millisecond blips of radio waves – were discovered in 2007. We still don't know what they are. Suggestions have ranged from neutron stars imploding to a propulsion system for alien spacecraft! Fortunately, we can examine the origins of FRBs just by measuring how the number of bursts (N) varies with their apparent brightness (S).

If the bursts come from relatively nearby galaxies, N will have a specific relationship to S: it will follow a power law with an index of −3/2 (because the volume of space increases as distance to the power 3 and the brightness decreases to the power 2). An index of −3/2 suggests that the bursts are distributed in a manner that's called 'Euclidean'. However, the power-law index could be much larger than −3/2. If so, that would imply that the bursts probably originated further away, and that the rate at which they occur has changed markedly over the lifetime of the Universe. Such a distribution would be 'non-Euclidean'.

The relationship between N and S has been a hot topic among astronomers studying FRBs, and so CAASTRO Advisory Board member Ron Ekers (CSIRO) and CAASTRO Associate Investigator Jean-Pierre Macquart (ICRAR–Curtin University) decided to take a fresh look at it.

They found that existing estimates of the relationship have been strongly influenced by the extreme brightness of the very first FRB discovered, the so-called Lorimer Burst. The Lorimer Burst is an example of discovery bias, also known as the *winner's curse*, in which the first detected instance of a new phenomenon is often highly unrepresentative of its underlying population. Removing the Lorimer Burst from the population statistics makes a big difference to estimates of the N–S relationship.

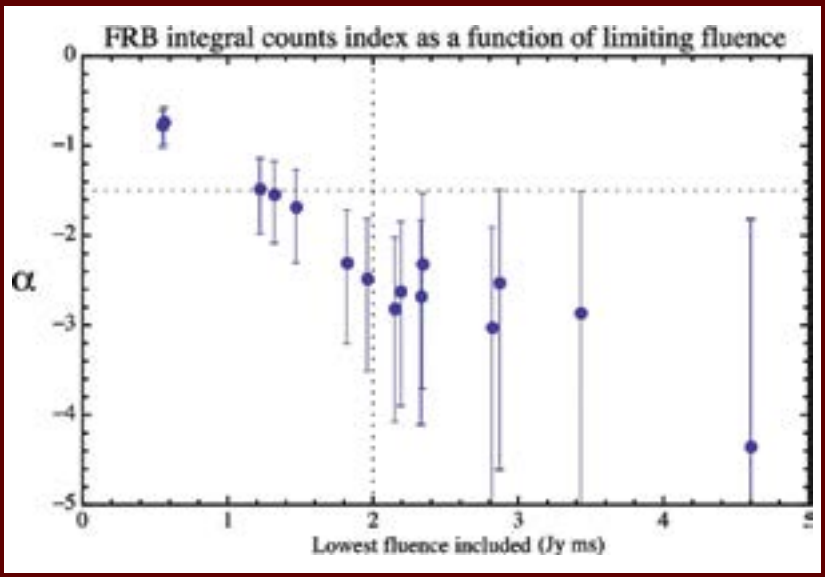
Macquart and Ekers re-analysed the FRB population using data from CSIRO's Parkes telescope, which has found more than half the known FRBs. All these detections were made using the telescope's 13-beam receiver, which looks in 13 different directions simultaneously. The brighter an FRB is, the more likely it is to show up in more than one of the telescope's 'beams', and so the fraction of multiple-beam detections to single-beam detections directly measures the ratio of extremely bright bursts to fainter ones. A previous analysis based on this ratio had suggested that the distribution is much shallower than the Euclidean value. However, Macquart and Ekers found that it is much easier to detect fainter FRBs in multiple beams than had been supposed.

To make a new estimate, Macquart and Ekers applied a maximum-likelihood technique developed in the 1970s to measure the distribution of quasars in space. They found that the most likely N–S relationship for FRBs was steeper than the Euclidean value. This suggests that the FRBs come from far off in the Universe and that, like quasars, they were more common earlier in the life of the Universe.

The Parkes FRB dataset has been the best available to date but this work has highlighted some of the difficulties of interpreting it. The more uniform observations now being made by telescopes such as the Australian SKA Pathfinder (page 32) will be free of such problems. With their large fields of view, these telescopes will also detect more of the very bright FRBs, which will better define the distribution.

Publication

Macquart, J.-P. & Ekers, R. D., "Fast radio burst event rate counts – I. Interpreting the observations", Monthly Notices of the Royal Astronomical Society, 474, 1900 (2018)



Maximum-likelihood source count slope. The vertical dotted line denotes the Parkes completeness limit, and the horizontal line indicates the Euclidean source count index. The error bars denote the 68 per cent confidence interval of each point, and are derived using the probability distribution of Crawford et al. (1970). (From Macquart & Ekers 2018)

CAASTRO helps detect landmark merger aftermath

Twenty-five CAASTRO astronomers from eight institutions contributed to landmark observations this year that brought gravitational-wave astronomy and conventional astronomy together for the first time.

On 17 August the Laser Interferometer Gravitational-wave Observatory (LIGO) in the USA and the Virgo detector in Italy picked up a gravitational-wave signal from an event dubbed GW170817. The signals' characteristics left little doubt that it had been produced by the merger of two neutron stars – exactly the kind of event LIGO and Virgo were expected to find. This was the fourth gravitational-wave detection to follow the historic first one announced in 2016, and the first one from a merging neutron-star binary.

The LIGO–Virgo collaboration sent out an alert, triggering astronomers worldwide to train their telescopes on the sky. The leader of CAASTRO's Dynamic Universe theme, Associate Professor Murphy (University of Sydney), roused her Australian team and asked for time on CSIRO's Compact Array telescope, getting it almost immediately. The team began observing as soon as the target area of sky rose over Australia.

Chile was the first country with the right kinds of telescopes to see the target area in darkness after the event. Images taken 11 hours after the neutron-star merger showed a new optical source in the galaxy NGC 4993, prompting other telescopes to zero in on this region. Professor Murphy's team worked in collaboration with observers using the Jansky Very Large Array (JVLA) radio telescope in the USA. Both teams detected a radio source in NGC 4993. The detection came some days after the neutron-star merger, as had been predicted.

While the radio observations were under way, other CAASTRO astronomers had swung into action with optical telescopes at Siding Spring Observatory. Researchers from the Australian National University (ANU) node used the SkyMapper telescope to carry out imaging and photometry (brightness measurements at specific wavelengths). The source was clearly seen through all six of SkyMapper's colour filters. The ANU result, sent out to the astronomical community in the middle of the night, was the first reported multi-band photometry of the source. This team also carried out spectrometry with the ANU's 2.3-m telescope at Siding Spring.

At the same time, CAASTRO Associate Investigator Chris Lidman (AAO) was busy obtaining spectra with the robotic optical-fibre system, 2dF, on the 3.9-m Anglo-Australian Telescope. Lidman was able to start observations just five minutes after the triggering alert came in, thanks to a new *target of opportunity* system that works out the minimum number of optical fibres that need to be moved.

Observations were made with other Australian facilities but, for a variety of reasons, they did not detect the source. On the theoretical side, CAASTRO Research Staff member Ashley Ruiter (UNSW) and Associate Investigator Ivo Seitenzahl (UNSW) contributed to modelling of the electromagnetic transient. This confirmed that, as predicted, the merger had created a *kilonova*, a transient event with specific spectral characteristics. The work also pointed to neutron-star mergers being the source of certain heavy elements, including gold.

GW170817 was detected during the second LIGO–Virgo observing run. LIGO is now being made even more sensitive. LIGO and Virgo will start their third observing run in the second half of 2018. When they do, Australian telescopes will be ready and waiting.

Publications

Andreoni, I., Ackley, K., Cooke, J., and 122 co-authors, "Follow Up of GW170817 and Its Electromagnetic Counterpart by Australian-Led Observing Programmes", Publications of the Astronomical Society of Australia, 34, e069 (2017)

Smartt, S. J., Chen, T.-W., Jerkstrand, A., and 119 co-authors, "A kilonova as the electromagnetic counterpart to a gravitational-wave source", Nature, 551, 75 (2017)

THE DARK UNIVERSE

Theme Leader: Professor Tamara Davis | University of Queensland

Theme Scientist: Dr Cullan Howlett | University of Western Australia

The Dark Theme tackles the forces that underpin our very existence: the parameters of spacetime and gravity that make the Universe the way it is, and indeed make it possible at all.

What are dark energy and dark matter? What is the correct description of gravity? These are simple questions to ask, but we don't yet have the answers. Over the course of CAASTRO, Dark Theme researchers have been working to understand them, by generating simulations and predictions, testing these against groundbreaking datasets, and planning future projects.

Measuring the expansion of the Universe

In 1929, Edwin Hubble showed that the Universe is expanding; in the 1990s, two teams showed that this expansion is speeding up. *Dark energy* is the name we give to whatever is causing the acceleration. In 2011 CAASTRO CI Brian Schmidt shared the Nobel Prize for that discovery. The two teams in the '90s got their evidence by using a special class of exploding star, Type Ia supernovae. They worked with just 52 supernovae; since then astronomers have searched for more, to better measure the acceleration. Two CAASTRO projects, the SkyMapper Transient Survey and OzDES, are part of that effort. SkyMapper has found over 60 nearby supernovae while OzDES + DES have spectroscopically confirmed over 300 distant supernovae. Most excitingly, OzDES + DES have obtained the redshifts of over 5,000 galaxies that hosted supernovae or other transients, which will soon enable an entirely new level of detail in the measurement of dark energy (page 21).

Type Ia supernovae (SNe Ia) are used for such work because they all have essentially the same brightness. But how uniform are they really? In 2012 CAASTRO researchers confirmed that SNe Ia allow distances to be measured with an accuracy of 4 per cent, and are still the best 'standard candles'. However, in 2014 other CAASTRO researchers found that SNe Ia progenitors vary significantly in mass, suggesting there may be more than one path leading to these explosions.

Baryon acoustic oscillations

Our astronomers have also addressed dark energy through by studying the large-scale distribution of galaxies. Sound waves travelling through the early Universe were 'frozen' into the distribution of galaxies as the young Universe expanded and cooled, leaving a pattern (*baryon acoustic oscillations* or BAO) that can still be detected today. The WiggleZ Dark Energy Survey, carried out with the Anglo-Australian Telescope, was designed to detect the BAO pattern. CAASTRO researchers have made many analyses of the WiggleZ dataset, alone and in combination with other datasets, using it to test both the 'standard model' of cosmology and extensions of general relativity. This year saw the publication of one of the last of CAASTRO's WiggleZ papers, which detected the BAO separately along the line of sight and perpendicular to it. In future, BAO surveys may also be done at radio wavelengths instead of with visible light. CAASTRO researchers have been exploring the new technique that would underpin this, *intensity mapping*.

Peculiar velocity surveys

The expanding and accelerating Universe drives galaxies apart. At the same time matter, both 'regular' (baryonic) and dark, generates gravity that draws neighbouring galaxies together. Galaxy movements reflect both these effects. If we measure galaxies' velocities as well as their positions in space, we can test cosmological models, including theories of gravity, by examining how fast the structure in the Universe is growing.

This is the role of *peculiar-velocity* surveys, which tease apart the galaxy motions due to the expanding Universe and those caused by local gravity. In 2014 a CAASTRO-led team released the largest sample of peculiar velocities to date, a subset of almost 9,000 objects from the 6-degree-Field Galaxy Survey (6dFGS). The size of this survey 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 correctly predicts galaxy movements. CAASTRO researchers have carried out several analyses of this dataset; two published in 2017 are described on page 23.

In 2013 a large CAASTRO team ran comprehensive simulations to demonstrate how well two planned Australian peculiar-velocity surveys, Taipan and WALLABY, would be able to test gravity and dark energy. That work is now reaching fulfillment, with WALLABY observations beginning in 2017 and Taipan due to start in 2018.

Gravitational lensing

Less than a fifth of all the matter in the Universe is the familiar (baryonic) kind; the rest is invisible dark matter. To map the mass in the Universe we need a technique that doesn't rely on seeing it. *Weak gravitational lensing* fits the bill. Foreground galaxies, those nearer to us, bend light coming from more distant ones, distorting their images. This distortion is usually slight but can be detected statistically. Different cosmological models predict different distributions of mass, and so weak gravitational lensing can distinguish between them. CAASTRO researchers have helped develop weak

lensing as a tool. In 2015 a PhD student devised *direct shear mapping*, which makes weak lensing possible with just one background galaxy. In 2016 another student found a promising way to get the redshifts of the background galaxies, by cross-correlating lensing observations with a spectroscopic survey.

A number of Dark Theme researchers are members of the international Dark Energy Survey (DES). In 2017, DES completed several analyses of its first-year results, one of which used weak lensing to construct the largest dark-matter map to date (page 24).

Testing tensions between datasets

Much work by CAASTRO researchers has been aimed at reducing systematic (measurement) uncertainties of various kinds, often by combining datasets: two examples appear on page 23. But as measurements become more precise, discrepancies between results from different datasets become more stark. A CAASTRO-led team has investigated in detail one of the most striking cases, making the first 'blind' analysis of the Hubble constant (page 27). Two other CAASTRO papers this year examine tensions between different types of data, and whether those tensions can be resolved by more complicated cosmological models (page 25).

Other developments

Astroparticles have also been in the Dark Theme's remit. Our researchers have constrained neutrino masses and modelled the self-annihilation of dark matter. The joint workshops we have held with CoEpp (the ARC Centre of Excellence for Particle Physics at the Terascale) have helped foster an astroparticle physics community in Australia. CAASTRO researchers are helping prepare for the southern hemisphere's first experiment to directly detect dark matter. Called SABRE (Sodium Iodide with Active Background Rejection), this will be run at an underground laboratory in Victoria.

Dark Theme researchers, like those in CAASTRO's other themes, have been developing the *machine-learning* systems now essential for large surveys, both photometric and spectroscopic. This year CAASTRO contributed to multidisciplinary work on how to make machine learning more efficient (page 31).

CAASTRO is coming to a close, but work begun in the Dark Theme will go on. Our researchers will continue to participate in the Dark Energy Survey and OzDES looks set to conclude successfully. Exciting new Australian surveys, Taipan and WALLABY, are just beginning, and will build on work carried out in the Dark Theme. What are dark energy and dark matter? What is the correct description of gravity? We have not yet arrived at the answers, but we are further along the road.

OzDES publishes three-year results

CAASTRO's OzDES project reached a milestone this year, publishing the results of its first three years of observations and making its first public release of data.

OzDES is the Australian arm of the international Dark Energy Survey (DES), which aims to elucidate the nature of dark energy. DES is imaging 5,000 square degrees of sky with its Dark Energy Camera (DECAM) on a 4-m telescope in Chile, and using these images to investigate dark energy by measuring supernova distances, weak gravitational lensing (page 24), and the distribution of galaxies. The supernova measurements show how the expansion of the Universe changes over time: *dark energy* is the name given to the cause of the acceleration. OzDES uses the AAT to measure the redshifts of the host galaxies of SNe Ia candidates that DES identifies with the Dark Energy Camera (DECam) in Chile. Where possible they also confirm the candidates as supernovae, by obtaining spectra of the supernova while it is live.

Observations are made with the 2dF (2-degree Field) system, a robotic fibre positioner on the 4-m Anglo-Australian Telescope (AAT), and its counterpart spectrograph, AAOmega. 2dF accesses an area of sky that matches DECam's field of view. OzDES was allocated 100 nights of observing time on the AAT over six years; observations began in 2013 and will finish in 2018. The project's key innovation is to measure the redshift of the host galaxy, rather than that of the (quickly fading) supernova itself. Since the redshift of the hosts can be obtained at any time after the SNe are discovered, one can use the 400 fibres of 2dF to obtain the redshifts of hundreds of host galaxies simultaneously rather than one at a time. They have pioneered a technique of efficiently targeting very faint objects by repeatedly visiting the same fields, and moving fibres to new objects as soon as enough signal to noise has been gathered.

Such advantages are reflected in OzDES's performance figures. By the end of 2017 OzDES had measured 26,000 redshifts by stacking over 100,000 spectra. By revisiting the ten DES fields at monthly intervals, OzDES has been able to measure redshifts for objects usually considered too faint for a 4-m telescope (down to r-band magnitude of 25): it exceeds the performance of some projects on 8-m class telescopes (for example VIPERS, the VIMOS Public Extragalactic Redshift Survey). In total, the OzDES team has redshifts for over 5,000 galaxies that hosted supernovae or other transients, and has spectroscopically confirmed over 300 supernovae.

OzDES has also broken new ground by monitoring a sample of 771 AGN (active galactic nuclei), galaxies with active black holes at their centres. The most distant of these has a redshift of 4.5. The monitoring is aimed at measuring the masses of the black holes through *reverberation mapping*, which depends on a time lag in the signal received from

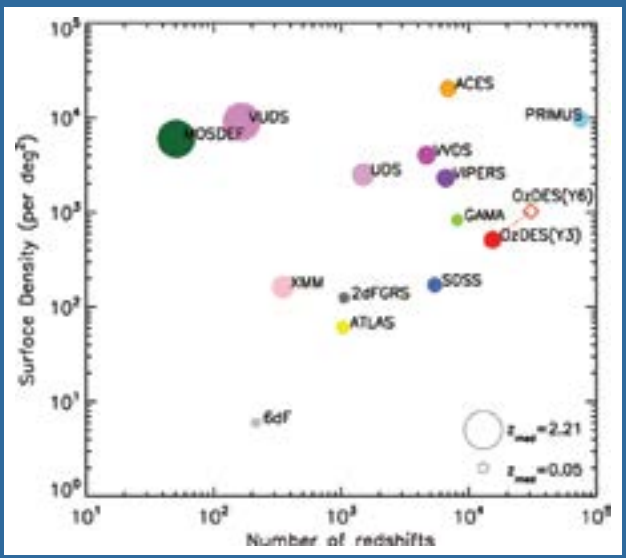
different parts of the AGN. When OzDES began, only about 60 black holes had had their masses measured this way. Excitingly, it may prove to be possible to use reverberation mapping to estimate an AGN's true luminosity. This would open the way to using AGN as 'standard candles' (sources of a known brightness), giving us another way to measure the expansion of the Universe at high redshifts. OzDES is also spectroscopically monitoring other transients, obtaining redshifts that can be used to train a machine-learning system for photometric classification, and using galaxies' redshifts to determine their membership of clusters.

By its second year of operations OzDES had began accumulating redshifts at a steady rate of 0.1 redshifts per fibre hour. In their three-year results paper, Childress et al. predict that OzDES will net a total of 5,700 supernova-host redshifts (barring bad weather). They also forecast the numbers that can be expected from future multi-object spectrographic surveys.

OzDES's first data release (DR1), issued along with the three-year results paper, consists of 14,693 redshifts of many types of galaxies; however, it excludes those of supernova host galaxies, which will be released with future DES analyses. A final redshift catalogue will be released soon after the survey finishes and a final data release, including OzDES spectra, will be made some time after that.

Publication

Childress, M. J., Lidman, C., Davis, T. M. and 98 co-authors, "OzDES multifibre spectroscopy for the Dark Energy Survey: 3-yr results and first data release", Monthly Notices of the Royal Astronomical Society, 472, 273 (2017)



Comparison of OzDES–DR1 against outcomes for other major redshift surveys. The average redshift surface density of the survey is plotted against total number of redshifts in the OzDES fields, with the size of each point corresponding to the median redshift of the survey in our fields. OzDES-DR1 represents the second highest number of redshifts produced in these fields, with a surface density approaching that of surveys on larger (8-m class) telescopes. As time progresses, this point will move further up and to the right, as shown by the dotted line. (From Childress et al. 2017)

Peculiar-velocity surveys

Measuring bulk flows

Space is expanding. Galaxies, carried along with it, move further apart. This *Hubble flow* accounts for most of their motion. But it's not the whole story. Galaxies are also pulled together by gravity, and this gives them another component of motion, their *peculiar velocities*. On small scales, galaxies feel the tug of their near neighbours. On larger scales, cluster of galaxies are reeled in by the gravity of superclusters – large concentrations of matter, both visible 'ordinary' matter and the unseen dark matter. The wholesale motion of galaxies towards superclusters is called *bulk flow*.

Bulk flows provide a way to measure the total mass of superclusters, and so tell us how mass is distributed on large scales. Different cosmological models predict different distributions; measuring bulk flows can distinguish between them.

To measure bulk flows, we have to compare two kinds of distance measurement, for many thousands of galaxies. One measurement comes from redshift (the stretching of wavelengths of light as space expands) while the other is derived from a galaxy's internal properties. Comparing the two for a galaxy indicates any deviation from the Hubble flow and hence the galaxy's peculiar velocity. Combining such measurements for thousands of galaxies measures bulk flows. However, both kinds of distance measurement can be subject to systematic errors. This year Fei Qin and Cullan Howlett (both ICRAR–UWA) and their collaborators looked at how to reduce such errors. The work is timely because Australia is now embarking on two of the new 'next generation' peculiar-velocity surveys, the optical survey Taipan (which will measure velocities for ~50,000 galaxies) and the radio survey WALLABY (which, with its northern-hemisphere counterpart, will measure velocities for ~30,000 galaxies).

For their study, Qin et al. drew on the 6dFGSv and 2MTF surveys (the 6-degree-Field Galaxy Survey and the 2MASS Tully-Fisher survey respectively). 6DFGSv goes deep and is also the largest of the current-generation peculiar-velocity surveys, with ~9,000 galaxies; however, it covers only the southern sky. The 2MTF survey is shallower and covers fewer galaxies, but has wider coverage. The researchers combined the two, creating a sample of ~11,000 galaxies. This increased the effective depth over 2MTF alone, and decreased the bias that 6dFGSv creates by covering only one hemisphere. (In their paper, Qin et al. show how this bias has affected previous peculiar-velocity measurements.) Combining the datasets improves the estimate of bulk flow and cosmological parameters. To analyse this data, Qin et al. developed a new maximum-likelihood method for estimating peculiar velocities. Given a cosmological model, the estimator calculates the peculiar velocity (or rather, a proxy for it) for each galaxy; these values are then compared with the measured values.

Qin et al. tested their new technique on mock catalogues and then applied it to the two datasets, both individually and combined. All their bulk flow measurements were consistent with the predictions

from the standard cosmological model. The error of the bulk flow determined from the combined dataset is about 30 per cent less than that of the 6dFGSv dataset alone, making this bulk-flow measurement the most accurate to date. This work also highlights how a survey's degree of sky coverage can introduce bias and systematic errors – valuable information for the forthcoming Taipan survey.

Publication

Qin, F., Howlett, C., Staveley-Smith, L., Hong, T., "Bulk flow in the combined 2MTF and 6dFGSv surveys," Monthly Notices of the Royal Astronomical Society.

Constraining the growth rate of structure

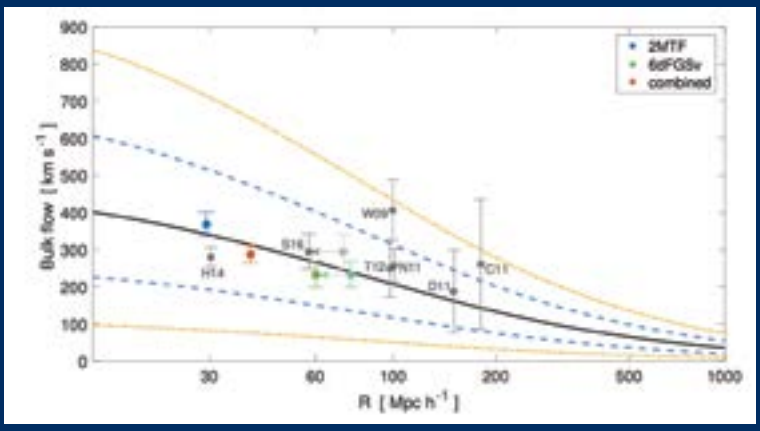
In related work, Cullan Howlett (ICRAR–UWA) used the peculiar velocities from the 2MTF survey to constrain the growth rate of structure, $f\sigma_8$, in the local Universe. $f\sigma_8$ quantifies how fast the web of matter in the Universe is growing. Gravity dictates this rate of growth and different theories of gravity predict different rates. To measure $f\sigma_8$, Howlett and his collaborators used the peculiar velocities from 2MTF to construct a *velocity power spectrum*, a more complex way to capture velocity information than the bulk flow, and one that incorporates information about smaller spatial scales.

Howlett's team's values for $f\sigma_8$ (calculated for different scales) were consistent with general relativity. The tight constraints they were able to obtain on their results highlight the strength of peculiar-velocity surveys. A future survey such as Australia's WALLABY, which will obtain large numbers of both galaxy redshifts and peculiar velocities, will be able to measure $f\sigma_8$ more precisely than traditional surveys of large-scale structure.

Publication

Howlett, C., Staveley-Smith, L., Elahi, P. J., Hong, T., Jarrett, T. H., Jones, D. H., Koribalski, B. S., Macri, L. M., Masters, K. L., Springob, C. M., "2MTF – VI. Measuring the velocity power spectrum", Monthly Notices of the Royal Astronomical Society, 471, 3135 (2017)

Measured bulk flow amplitudes and the prediction of ΛCDM (the standard cosmological model). The solid line indicates the most probable bulk flow and the blue (yellow) dashed lines the 1σ (2σ) values. Filled circles are from the new work by Qin et al.; other values are: H14 – Hong et al. (2014); W09 – Watkins et al. (2009); S16 – Scrimgeour et al. (2016); C11 – Colin et al. (2011); T12 – Turnbull et al. (2012); N11 – Nusser & Davis (2011); D11 – Dai et al. (2011). (From Qin et al.)



Reducing uncertainties through cross-correlation

Caitlin Adams and Chris Blake (both of Swinburne University) have also measured $f\sigma_8$, but with a different approach. Peculiar velocities are particularly suited for determining structures on large scales. However, their uncertainties grow with distance, so their usefulness is limited to low redshift. Calculating $f\sigma_8$ from just peculiar velocities over a small volume of space gives the measurement a minimum uncertainty, one intrinsic to the size of the survey. But uncertainty can be reduced (that is, the measurement made more precise) by using information about how peculiar velocities are correlated with another observable.

Adams and Blake have done this, establishing how peculiar velocities are correlated with the galaxy clustering. Previous work with these two kinds of data had involved determining peculiar velocities from galaxy clustering or vice versa, and comparing these 'reconstructed' fields with the observed ones. However, this 'reconstruction' technique doesn't allow you to test if the growth rate of structure is independent of scale, which is what general relativity predicts.

Adams and Blake have introduced a new approach. Rather than reconstructing one field from another, they have modelled how the two fields are correlated (their covariance). This correlation is then used in a maximum likelihood method to constrain the growth rate of structure. The mathematical expression for the covariance was published many years ago (Fisher 1995) but had not previously been applied to data. Adams and Blake used the method on data from the 6-degree-Field Galaxy Survey (6dFGS), obtaining an uncertainty on $f\sigma_8$ of 15 per cent. The value of $f\sigma_8$ itself they found to be consistent with general relativity. While the uncertainty only slightly bettered that of previous work, Adams and Blake's method can easily be expanded and improved. Like the other peculiar-velocity work discussed above, it will be valuable for new, large surveys such as Taipan and WALLABY.

Publications

Adams, C. & Blake, C., "Improving constraints on the growth rate of structure by modelling the density-velocity cross-correlation in the 6dF Galaxy Survey", Monthly Notices of the Royal Astronomical Society, 471, 839 (2017)

Fisher K. B., 1995, The Astrophysical Journal, 448, 494

The biggest dark-matter map to date

An international team with CAASTRO members has made the largest and most accurate map to date of the distribution of mass in the Universe, and used it to test the standard model of cosmology. This model, just two decades old, has the Universe dominated by dark energy and cold dark matter. 'Ordinary' (baryonic) matter runs a poor third, accounting for less than five per cent of the Universe's matter-energy content.

We can test this model by predicting how the Universe changes over time. Courtesy of the Planck satellite, we have a detailed 'baby photo' of the Universe, an image of the cosmic microwave background (CMB) taken just 380,000 years after the Big Bang. The CMB is slightly irregular, and its irregularities are the seeds that grew into galaxies. We can apply the 'standard model', including general relativity, to this picture and predict how the grown-up Universe should look now; then we can test the prediction against how it actually *does* look now. This sounds simple. But the trick is that because most of the matter in the Universe is dark, an accurate map of the Universe has to show where that dark matter is. The international Dark Energy Survey team has made such a map, using a phenomenon called *gravitational lensing*.

The gravitational pull of matter bends the path of any light passing by. As a result, foreground galaxies (which contain both normal and baryonic matter) bend the light from galaxies further away, distorting their images. The distortion can be used to map the distribution of foreground masses. Using its 570-million-pixel Dark Energy Camera (DECAM), the Dark Energy Survey (DES) team has precisely measured the shapes of the images of 26 million galaxies, over a thirtieth of the whole sky, and used these measurements to map the distribution of dark matter. This map is as detailed as the CMB image from Planck, allowing the two images to be directly compared. The researchers supplemented the map with information about galaxy clustering, then cranked the handle. It turns out that the Universe's adult likeness is what the standard model predicts the Planck image should evolve into.

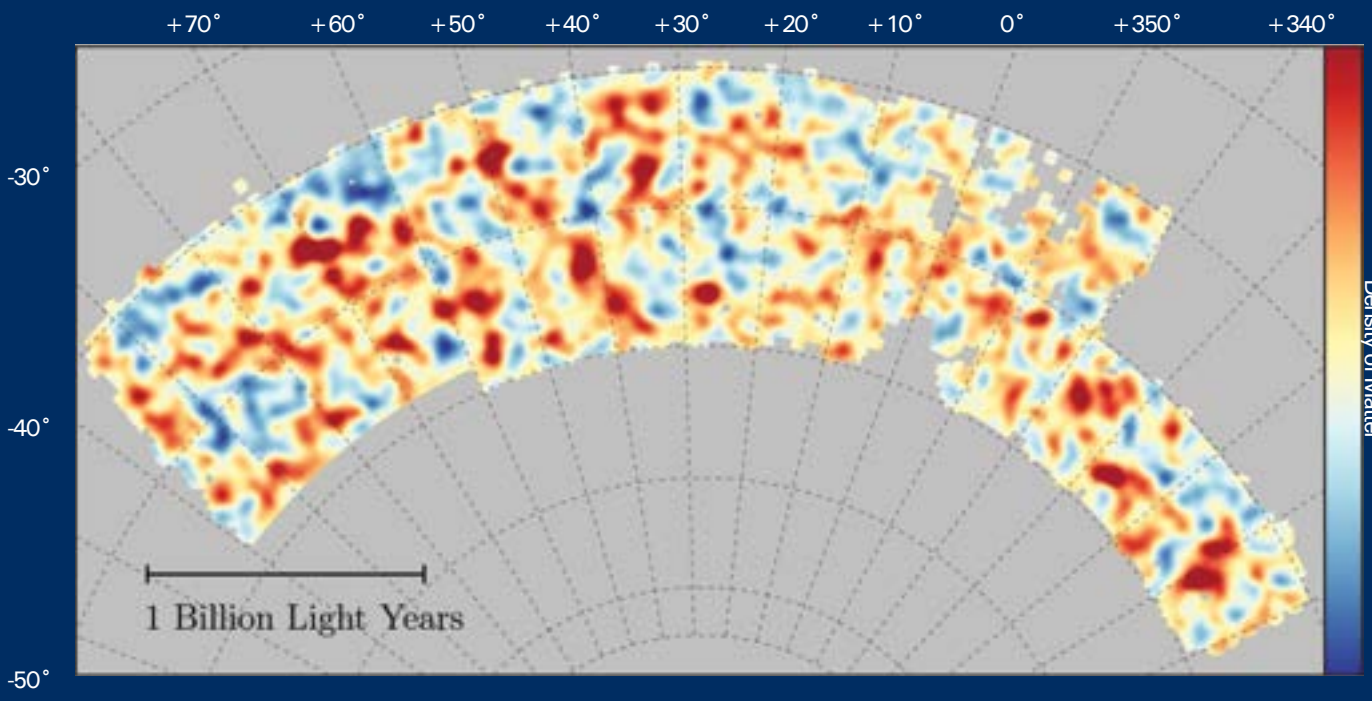
The nature of dark energy is still being explored. A strong contender is a *cosmological constant* – that is, an entity with a value that does not change over time. The DES team tested both the standard cosmological model (which has a dark-energy term equal to –1) and a variant of this. The standard model had the edge.

Two points about the analysis are worth noting. First, to prevent confirmation bias – the tendency to choose free parameters to achieve the 'right' result – most of the analysis was carried out 'blind', with the actual numerical values obscured by offsets. Second, combining galaxy clustering with weak lensing significantly reduces the effect of systematic errors (in redshifts, for instance), and gives more precise cosmological information than can be obtained with either method alone.

Remarkably, the dark-matter map was constructed from just the first year of data from DES, which is now in its fifth year of observations. DES's final map will cover three times as much area and encompass 300 million galaxies.

Publication

DES collaboration, "Dark Energy Survey Year 1 Results: Cosmological Constraints from Galaxy Clustering and Weak Lensing", arXiv e-print 1708.01530



The dark-matter map constructed by the Dark Energy Survey. The dark-matter density is high in red regions, low in blue ones. Image credit: Chihway Chang of the Kavli Institute for Cosmological Physics at the University of Chicago and the DES collaboration.

DISCOVER

Testing tensions between datasets

Different datasets give different results for certain cosmological parameters. Where measurement uncertainties are large, those discrepancies can be waved away. But as measurements have become more precise, we have started looking for ways to explain the differences. Are they the result of systematic (measurement) errors? Or do they point to new physics beyond cosmology's standard model? Two papers led by Shahab Joudaki (Swinburne) this year have examined the tensions between different datasets.

In the first work, Joudaki and his collaborators looked at the different distributions of matter implied by a weak gravitational lensing survey, KiDS (Kilo Degree Survey), and measurements of the cosmic microwave background made with the Planck satellite. They tried to resolve the discrepancy by extending the standard cosmological model with factors such as massive neutrinos, a non-zero curvature of space, evolving dark energy, and modified gravity, both separately and in combination. They also modelled systematic effects in weak lensing itself.

Changes to the lensing systematics didn't affect the discrepancy between KiDS and Planck, and neither did most of the extensions to cosmology. One that did was a time-dependent equation of state for dark energy. This both reconciled the KiDS and Planck measurements and was moderately favoured (over the standard model) by the combined dataset. It also aligned measurements of the Hubble constant made in the local Universe with those derived from Planck data (page 27). But it's too early to celebrate: this time-varying dark energy was at odds with results from at least three galaxy surveys.

In a second investigation, Joudaki worked with a different set of co-authors to infer how the Universe had expanded over time, and how structure had grown within it, without drawing on any specific cosmological model. To do this, the researchers applied a procedure called Gaussian process regression to several types of data (galaxy and quasar distances, local measurements of the Hubble constant, observations of Type Ia supernovae and measurements of the cosmic microwave background), in various combinations. This gave a number of different expansion histories. For each history, the researchers then calculated the rate of growth of structure and compared that with data from the Dark Energy Survey, the South Pole Telescope and Planck.

The inferred expansion histories showed that most of the datasets used are consistent with one another and with standard cosmological model; however, tension remains for measurements of the Hubble constant. Together, the datasets tightly constrain the expansion history, restricting the range of viable alternatives to the standard model. The derived growth rate of structure was also consistent with the standard model. In addition, the researchers constrained the density of dark energy with a precision of two per cent at $z = 0$ and roughly ten per cent by $z = 1$, and found it to be constant across redshift (that is, consistent with a cosmological constant). When data are available from the Dark Energy Spectroscopic Instrument (DESI), a US project starting in 2018, they will tighten these results by up to a factor of four.

Publications

Joudaki, S., Mead, A., Blake, C., and 16 co-authors, "KiDS-450: testing extensions to the standard cosmological model", Monthly Notices of the Royal Astronomical Society, 471, 1259 (2017)

Joudaki, S., Kaplinghat, M., Keeley, R., Kirkby, D., "Model independent inference of the expansion history and implications for the growth of structure", arXiv e-print 1710.04236

Galaxy Convention, December 2017
Credit: Nick Smith

CASE STUDIES

National Innovation Priority – Research

FIRST 'BLINDED' ANALYSIS OF THE HUBBLE CONSTANT

A new analysis has removed confirmation bias from the determination of the Hubble Constant, H_0.

The Hubble constant, H_0, measures the expansion rate of the local Universe; it therefore determines the cosmic distance scale. It relates the expansion velocity of a galaxy, v, to its distance, D:

$v = H_0D$.

This simple equation hides a world of complexity, mainly because cosmic distances are hard to measure accurately.

Two reliable methods for measuring H_0 are using Type Ia supernovae (SNe Ia) together with Cepheid variables (pulsating stars whose periods are related to their luminosities), and using the cosmic microwave background (CMB), assuming a cosmological model. Reiss et al. have published analyses of the first type, in 2011 ($H_0 = 73.8 \pm 2.4$ km s^{-1} Mpc^{-1}) and in 2016 ($H_0 = 73.0 \pm 1.8$ km s^{-1} Mpc^{-1}). These are based on hundreds of SNe Ia, calibrated by observations of dozens of Cepheid variables in each of their host galaxies. The Planck Collaboration has published much lower values of H_0 based on the CMB, most recently in 2016 ($H_0 = 67.8 \pm 0.9$ km s^{-1} Mpc^{-1}). Does this difference in H_0 arise from a systematic error in one or both of the measurements, or does it signal that we are assuming the wrong cosmology in the CMB value? As a step towards answering this question, Bonnie Zhang (ANU) and her collaborators have re-analysed the dataset used by Riess et al. (2011) (R11 for short). This dataset is well understood, having been also been re-analysed by Efstathiou et al. (2014) (E14), and was ideal for testing the validity of a new approach.

The local values of H_0 derived from SNe Ia do not depend on a cosmological model, but they *may* depend on certain choices made in the analysis (for example, any cuts to remove Cepheid outliers). Zhang and her collaborators wanted to carefully explore the analysis procedure itself, particularly the fitting procedures and the handling of uncertainties. They specifically wanted to eliminate *confirmation bias* – the tendency to shape the analysis to produce the 'right' result – so they chose to the do the first 'blinded' determination of H_0 based on SNe Ia observations. This involved injecting offsets (unknown to the researchers, but retrievable) into two degenerate variables in the analysis, including H_0. When the analysis was completed but the value of H_0 still obscured, Zhang's team submitted their paper for review. Once the paper was accepted for publication, they retrieved the offsets, determining a value for H_0.

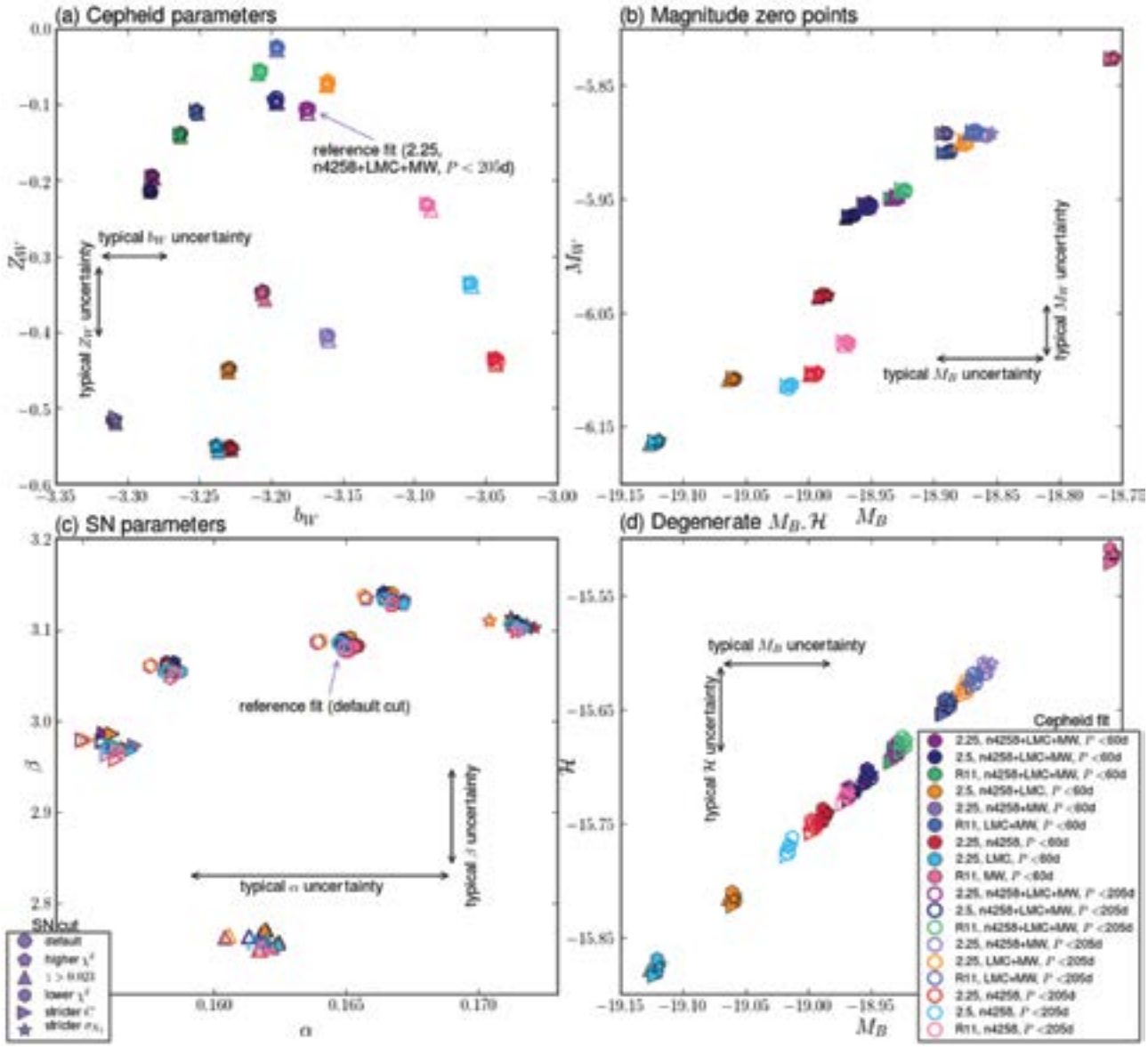
The analysis incorporated two other procedures not used in any previous determination of H_0 from SNe Ia. One was to fit for all 16 of the necessary parameters simultaneously. The other was to handle the systematic uncertainties in the SNe Ia data using a covariance matrix method, as has been done in recent supernova cosmology analyses. Systematic uncertainties, including those arising from calibration uncertainties, can be correlated between supernovae; covariance matrices track how observables vary together with each systematic.

The value of H_0 revealed by this analysis was 72.5 ± 3.1(statistical uncertainty) $\pm$ 0.77(systematic uncertainty) km s^{-1} Mpc^{-1}, which is in excellent agreement with that of both R11 (after adjusting for a new distance to NGC 4258) and E14. The total uncertainty, however, was larger: 4.4% in total, as compared to 3.3% in R11 and 3.4% in E14. This larger uncertainty lessens the difference with the value of H_0 derived from the CMB, but does not erase it. There is still a question to be answered here.

Having tested the validity of their analytical approach, Zhang's team will now apply it to the larger dataset from Riess et al. 2016.

Publication

Zhang, B. R., Childress, M. J., Davis, T. M., Karpenka, N. V., Lidman, C., Schmidt, B. P., Smith, M., "A blinded determination of H_0 from low-redshift Type Ia supernovae, calibrated by Cepheid variables", Monthly Notices of the Royal Astronomical Society, 471, 2254 (2017)



Global simultaneous fits to all SNe Ia and Cepheid data.
(From Zhang et al. 2017

National Innovation Priority – Research

CONFRONTING THE EPOCH OF REIONISATION

A team using the Murchison Widefield Array (MWA) is one of several around the world striving to explore the last big gap in the Universe's timeline.

The Universe's 'unknown years' stretch from the era of the cosmic microwave background (~300,000 years after the Big Bang) to about a billion years after the Big Bang. During this time, space was filled with a light-absorbing fog of hydrogen atoms, a barrier to conventional observations. But we can simulate what must have happened. Within the fog, matter collapsed, forming the first stars (or perhaps black holes). High-energy radiation emitted by these stars gnawed away the fog, turning it from the light-absorbing hydrogen atoms to ionised hydrogen, unbound electrons and ions, through which light passes freely. This transformation gives the period its name: the Epoch of Reionisation (EoR).

Observing the EoR was previously impossible. It is only now coming into the realm of the possible, as technology advances.

A key tool we have for observing the hydrogen fog is the radio waves emitted and absorbed by the hydrogen atoms themselves. This radiation, 21 cm long, is stretched by the expanding Universe, and has a much longer wavelength (hence a lower frequency) by the time it reaches Earth. Studying it will give us a detailed view of the density, temperature and velocity variations in the neutral hydrogen. This in turn will tell us how and when the first galaxies formed.

To image the EoR – to actually *see* the hydrogen fog being eroded – we'll need the sensitivity of the world's largest-ever radio telescope, the Square Kilometre Array (SKA). The design of the SKA is well under way. Meanwhile, low-frequency radio telescopes such as the MWA and the northern-hemisphere Low-Frequency Array (LOFAR) are pioneering technologies and observing procedures for the SKA. The MWA was the first completed 'SKA precursor': an SKA technology demonstrator on one of the sites intended for the SKA.

Current telescopes are not sensitive enough to image the EoR. But the MWA EoR team is striving to detect the EoR statistically, or at least put limits on its characteristics. By measuring the intensity of the 21-cm radio signal at many locations over the sky (and at different distances along the line of sight) we can obtain a statistical measure of the structure of the hydrogen gas: a 'power spectrum' that relates the intensity of the emission to the scale of features in the gas.

The first 128 tiles of the MWA began operating in 2012 and observations for the MWA EoR experiment began in 2013. By the end of 2017, the MWA EoR team had collected four and half years of data, over three observing fields.

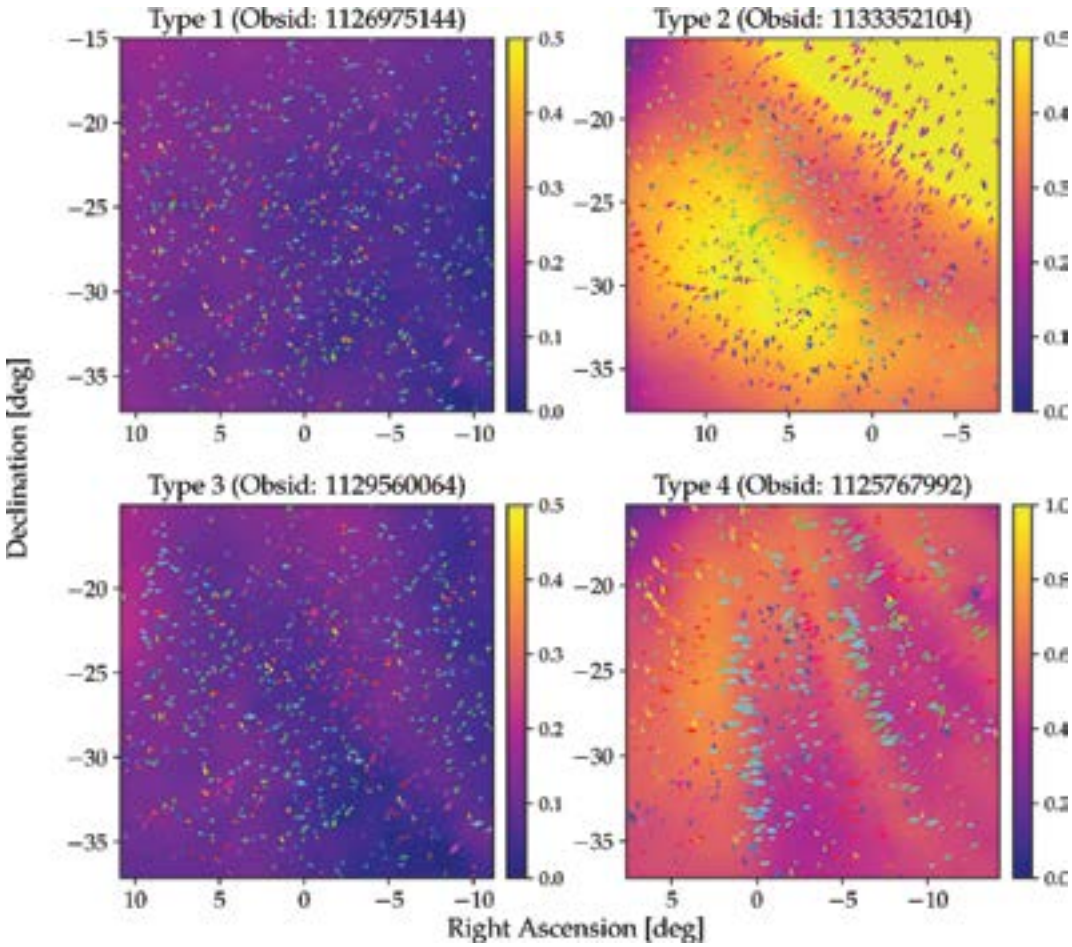
During this time the team has had to address many challenges. The main one is the presence of Galactic and extragalactic radio sources in the foreground (that is, between us and the EoR). These sources are $\sim 10^5$ stronger than the EoR signal itself. The MWA EoR team has put a large part of its effort into characterising and modelling foregrounds, and determining how they can be best removed from the data. The team has also studied other 'external' phenomena that impinge on the data, such as the behaviour of the ionosphere, 'interplanetary scintillation' (the 'twinkling' of radio sources caused by the solar wind, p. 35) and radio-frequency interference; and it has addressed a variety of processes that affect data quality: calibration processes, observing modes, antenna performance, and the development of robust pipelines. Throughout, team members have been passing on their experience and results to the SKA project.

During 2016–2017 the MWA EoR team has been focused on data quality, instrument models and sky models. CAASTRO members have made major contributions:

- Chris Jordan (Curtin University) led a detailed study of ionospheric conditions at the MWA site (the Murchison Radio-astronomy Observatory). Jordan's team identified a number of classes of ionospheric activity, measured how often those conditions apply, and determined how they affect EoR data
- Jack Line (University of Melbourne) and collaborators published the Positional Update and Matching Algorithm (PUMA), the primary software developed by the MWA EoR team to cross-match information from different catalogues to form the best EoR foreground and calibration sky model
- Steven Murray (Curtin University) and collaborators examined how the clustering of foreground sources affected the EoR power spectrum. They found that, under some circumstances, a failure to account for spatial clustering could lead to a false detection (that is, misinterpreting a foreground signal as the EoR signal)
- Bart Pindor (University of Melbourne) studied the MWA instrument bandpass (how the telescope's response varies with frequency) and explored ways to correct for it
- Pietro Procopio (University of Melbourne) led work exploring how closely-spaced double radio sources in the foreground affected EoR data calibration and analysis, and how to counter their effects
- Cathryn Trott (Curtin University) showed that wavelets, a technique commonly used in image processing, could be applied to EoR data to both make it easier to disentangle the EoR signal from the foreground and localise the signal in space.

Both the consortium that operates the MWA and the EoR team specifically are multinational collaborations involving many institutions. The connections and resources provided by CAASTRO have helped researchers learn quickly about how the MWA responds as instrument, and have facilitated the national and international collaborations.

Four observations with the Murchison Widefield Array, showing ionospheric offsets overlaid on the reconstructed scalar fields of total electron count. The colour scale for each plot is in units of 10^{16} m^{-2}. The ionospheric offsets are colour-coded according to their directions and scaled by a factor of 60. (From Jordan et al. 2017)



Publications

Jordan, C. H., Murray, S., Trott, C. M., Wayth, R. B., Mitchell, D. A., Rahimi, M., Pindor, B., Procopio, P., Morgan, J., "Characterization of the ionosphere above the Murchison Radio Observatory using the Murchison Widefield Array", Monthly Notices of the Royal Astronomical Society, 471, 3974 (2017)

Line, J. L. B., Webster, R. L., Pindor, B., Mitchell, D. A., Trott, C. M., "PUMA: The Positional Update and Matching Algorithm", Publications of the Astronomical Society of Australia, 34, e003 (2017)

Murray, S. G., Trott, C. M., Jordan, C. H., "An Improved Statistical Point-source Foreground Model for the Epoch of Reionization", The Astrophysical Journal, 845, 7 (2017)

Procopio, P., Wayth, R. B., Line, J., Trott, C. M., Intema, H. T., Mitchell, D. A., Pindor, B., Riding, J., Tingay, S. J., Bell, M. E., Callingham, J. R., Dwarakanath, K. S., For, B.-Q., Gaensler, B. M., Hancock, P. J., Hindson, L., Hurley-Walker, N., Johnston-Hollitt, M., Kapińska, A. D., Lenc, E., McKinley, B., Morgan, J., Offringa, A., Staveley-Smith, L., Wu, C., Zheng, Q., "A High-Resolution Foreground Model for the MWA EoR1 Field: Model and Implications for EoR Power Spectrum Analysis", Publications of the Astronomical Society of Australia, 34, e033 (2017)

Trott, C. M., "Exploring the evolution of reionization using a wavelet transform and the light cone effect". Monthly Notices of the Royal Astronomical Society, 461, 126 (2016)

National Innovation Priority – Interdisciplinary research

CUTTING THE COST OF MACHINE LEARNING

A cross-disciplinary team has evaluated ways to reduce the size of training sets for machine learning, which is an essential technique for large astronomical surveys.

The first data release from the SkyMapper Main Survey, issued in June this year, encompassed ~300 million unique astrophysical objects. This is typical of the numbers of objects astronomical surveys are now detecting – numbers that are far beyond what even the most dedicated postdocs can eyeball and interpret. These large surveys instead rely on *machine learning*: algorithms for classifying sources that learn from a carefully assembled *training set* of objects.

Creating a training set usually requires significant human effort. The CAASTRO-led Radio Galaxy Zoo project, for instance, has created a training set for the EMU (Evolutionary Map of the Universe) survey, using the voluntary labour of more than 10,000 citizen scientists. Not all astronomy projects will be able to draw on such a workforce, so it is vital to find ways to cut down the size of an effective training set and the cost and effort of compiling it.

The traditional way to construct a training set – *passive learning* – is to select at random instances from a large pool of data, classify them, and continue doing this until the set reaches a certain size, or the classifying algorithm reaches a certain level of performance. But even classifications by experts vary in the amount of information they carry: some choices are more valuable for training than others. Cases that are hard to classify could be more valuable than those that are easy, for example. Picking valuable cases for a training set is called *active learning*. Several active-learning heuristics (picking procedures) have been developed, and they can be used individually or combined in various ways. *Bandit algorithms* (a term derived from poker machines) combine heuristics sequentially, while *rank aggregators* combine them in parallel.

Machine learning can be applied to many fields, but data from one field (such as biology) may differ greatly from that in another (such as astronomy). In a cross-disciplinary exploration, CAASTRO's Christian Wolf (ANU) has worked with machine-learning experts from ANU (The Australian National University) and CSIRO Data61 to evaluate the performance of active-learning techniques on 12 diverse datasets. Eleven of these were drawn from the UCI Machine Learning Repository while the twelfth was astronomical, 2.8 million spectra from the Sloan Digital Sky Survey (SDSS). The researchers ran repeated trials to assess the performance of eight individual active-learning heuristics and compare them to passive learning.

The trials showed that active learning can perform much better than passive learning when the dataset is large. For the SDSS dataset, for example, one of the new tools was able to classify with 87 per cent accuracy when its training set reached a size of 200, while passive learning reached this mark only after the set reached 1000. A five-fold reduction in training effort is spectacular; however, a three-fold benefit from active learning is more typical.

Most of the heuristics performed similarly: the researchers therefore suggested that the simplest to compute, CONFIDENCE, is a good default choice. The combining algorithms also had little to separate them. Bandit algorithms are more difficult to work with, as they require a dataset to be hived off for computing the effectiveness of each heuristic the algorithm deploys. The team therefore favours using a simple rank aggregator.

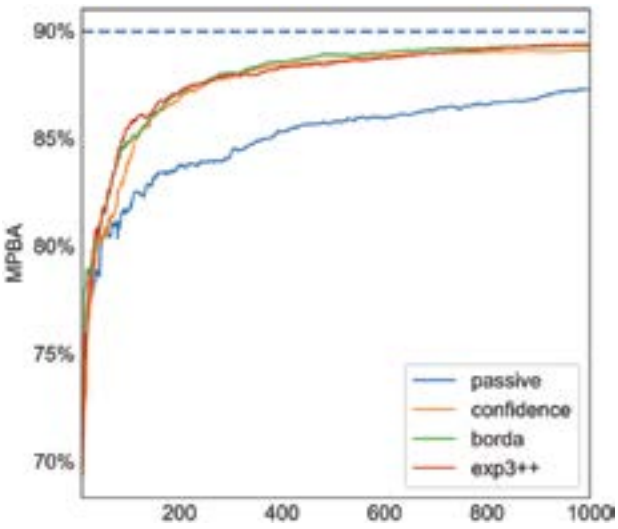
Following this comparison of methods, Wolf and colleagues will explore the benefits of active learning for astronomy in particular.

In astronomy, data for developing training sets is most likely to be obtained as a component of surveys that have other primary scientific goals. An example is the recent 2dFLenS survey carried out on the Anglo-Australian Telescope, using the 2dF optical-fibre positioner. A third of the fibres were not being used for the primary science objective and so, in a sub-project led by Wolf, they were used to obtain a good random sample for training sets. These training sets will be used for the SkyMapper Southern Survey to identify quasars and distinguish between stars and galaxies.

The Large Synoptic Survey Telescope in Chile, with its huge light-collecting capacity, will start operations in the early 2020s. In this era, training sets will need to include fainter objects. That would usually make them costlier, but the cost could be contained by using active learning.

Publication

Tran, A., Ong, C. S., Wolf, C., "Combining active learning suggestions", PeerJ Computer Science (submitted)



The performance of learning systems (accuracy achieved, Y-axis) plotted against the size of the training set (X-axis), for the astronomical (SDSS) dataset used in the study. Passive learning is in blue; the other curves show three active learning procedures. The top dotted line indicates the maximum performance achieved by using the entire pool of data for training. (From Tran et al. (submitted))

National Innovation Priority – Frontier technologies

A FASTER WAY TO FIND FAST RADIO BURSTS

ASKAP antennas were used in a non-standard way to cover 240 square degrees of sky, increasing the chance of detecting an FRB.
Credit: Kim Steele

Using new technology in an innovative way is making Australia a world leader in finding fast radio bursts and understanding their origins.

Fast radio bursts (FRBs) – millisecond blips of cosmic radio waves – were discovered in 2007. Exactly what they are is still unknown, which makes them one of the hottest topics in astronomy today.

To learn *what* the FRBs are, it will help to know *where* they are: how the population of the bursts is distributed in space. We can learn about the distribution of FRBs by measuring how the number of bursts (N) varies with their apparent brightness (flux density, S). If N and S follow a specific relationship ($dN \propto S^{-(\alpha+1)}dS$, with $\alpha = 3/2$), that implies that the bursts come from relatively nearby galaxies. If the relationship between N and S is significantly different, the bursts probably originate further away, and the rate at which they occur has changed over time.

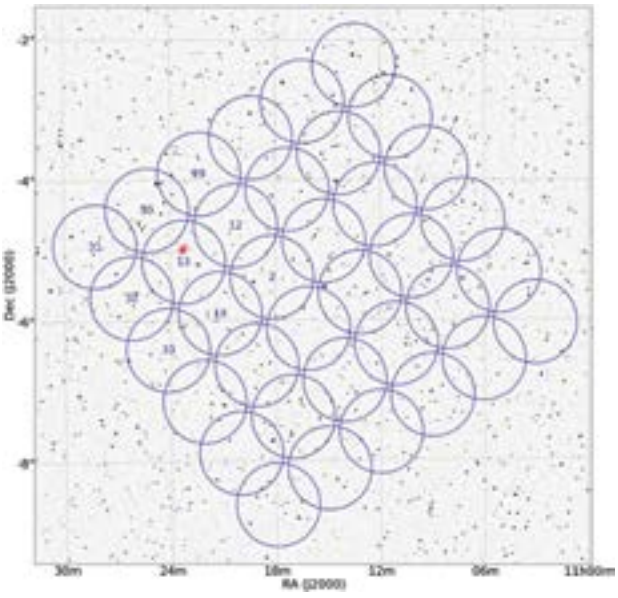
But even just measuring the number and brightness of the bursts can be difficult. Finding FRBs has been a fairly slow process – about 30 have been published to date – and instrumental effects have made it difficult to accurately determine the bursts' brightness. What we need is plenty of bursts, measured consistently with one instrument, and with accurately determined brightnesses.

We are now on the way to having that, thanks to the clever use of new technology. A team jointly led by CAASTRO Affiliate Keith Bannister (CSIRO) and CAASTRO Associate Investigator Jean-Pierre Macquart (Curtin–ICRAR) has used CSIRO's Australian SKA Pathfinder (ASKAP) in Western Australia to search huge amounts of sky for FRBs. The search is part of the more general CRAFT (Commensal Real-time ASKAP Fast Transients) project to find 'fast transient' radio sources of all kinds.

ASKAP is equipped with new phased-array feed receivers (PAFs), which can be thought of as 'radio cameras'. They give the telescope a large field of view, 30 square degrees, and produce a uniform response to an FRB appearing in any part of that field of view.

Bannister and his team used eight antennas in a non-standard mode, so that instead of all pointing at the same patch of sky, they pointed at different patches, thus covering a total of 240 square degrees. The larger area increased the chance of a detection. The researchers found their first FRB within four days of beginning the search. By the end of 2017, they had found 11.

This number suggests that the bursts originate in distant rather than nearby galaxies: if they came from nearby, the search process should have turned up many more. Bannister's team will continue to hunt for more FRBs, to determine the characteristics of the population more precisely.



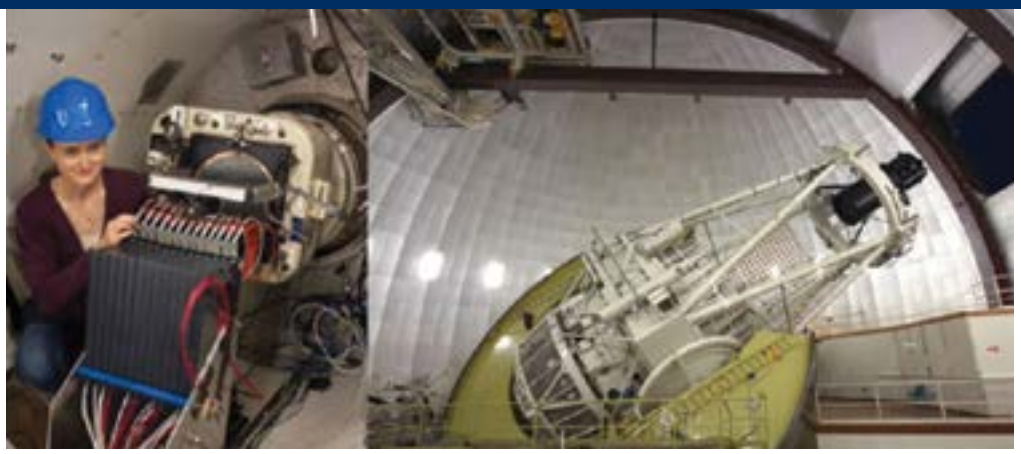
The location of the first fast radio burst found with ASKAP, FRB 170107 (in red). The blue circles are the half-power beam contours (1.2° at 1.3 GHz); the background greyscale image is from the NRAO–VLA Sky Survey. (From Bannister et al. 2017)

Publication

Bannister, K. W., Shannon, R. M., Macquart, J.-P. and 53 co-authors, "The Detection of an Extremely Bright Fast Radio Burst in a Phased Array Feed Survey", The Astrophysical Journal, 841, L12 (2017)

National Innovation Priority – Frontier technologies

SAMI GALAXY SURVEY FIRST DATA RELEASE



SAMI
Credit: Australian Astronomical Observatory

The SAMI Galaxy Survey has made public a wealth of data on almost 800 galaxies.

Dissecting human bodies has given us our understanding of anatomy, and so furthered our knowledge of how they function. So too, 'dissecting' galaxies – finely resolving their internal details – is helping us answer questions about a galaxy's physics and evolution, questions such as:

- How does a galaxy's environment affect how it evolves?
- How does gas get in and out of a galaxy, and how do these flows affect the galaxy's evolution?
- How do a galaxy's mass and angular momentum grow over time?

Using *integral-field spectroscopy (IFS),* astronomers can sample light from many well-defined points in a galaxy and analyse it, creating a spectrum for each point. The spectra give information on the galaxy's internal kinematics (the movement of gas and stars). In turn, the kinematics reveal gas flows, mass and angular momentum. By studying the kinematics of galaxies with a range of masses, and in a variety of environments (that is, ones more or less crowded with other galaxies), we can get a better understanding of how galaxies evolve.

The first generation of IFS surveys, targeting tens to hundreds of galaxies, were made up to about 2010. These surveys were carried out with instruments that targeted individual galaxies one at a time. Although they showed that IFS was a useful technique, they did not generate robustly large samples. Surveying thousands of galaxies requires a different approach. There are competing technologies, but for widefield, multi-object optical surveys, systems using optical fibres are the method of choice. This was the approach for the Sydney-AAO Multi-object Integral-field spectrograph (SAMI), which is deployed on the 3.9-m Anglo-Australian Telescope (AAT) at Siding Spring Observatory. The SAMI instrument has 13 integral-field units (IFUs), allowing it to observe 12 galaxies (and a calibration star) simultaneously.

SAMI was built at the University of Sydney and the Australian Astronomical Obsevatory and commissioned on the AAT in July 2011. Following an upgrade to the instrument, the SAMI Galaxy Survey began in February 2013. This survey, which will run until mid 2018, is targeting 3,600 galaxies, making it the first integral-field spectroscopic survey with enough galaxies to characterise the internal variation in galaxy properties as a function of both mass and environment.

In the spectral region around the Hα emission line (which is a measure of star formation), the SAMI Galaxy Survey has higher spectral resolution than most other first- and second-generation IFS surveys: as a result, analyses based on SAMI data can better separate distinct kinematic components (e.g. in outflows); can more accurately measure gas-velocity dispersion in galaxy disks; and can investigate the kinematics of dwarf galaxies. The survey covers a broad range of galaxy masses, sampling more low-mass galaxies than previous surveys do, for instance. The SAMI Galaxy Survey also has more complete and accurate measurements of environmental density than other IFS surveys, thanks to the depth and spectroscopic completeness of GAMA, the Galaxy and Mass Assembly Survey, which provides the main sample for SAMI.

The first major dataset from the SAMI Galaxy Survey, Data Release One (DR1) was released publicly in July 2017 (Green et al. 2018). It covers 772 galaxies, about a fifth of the whole survey. For each one, the release includes two spectral cubes (datasets with two spatial dimensions and a third, spectral, dimension) and value-added products: data for eight major emission lines, presented as a set of spatially-resolved 2D maps, and maps of dust extinction and star-formation rate. DR1 is available online from the Australian Astronomical Observatory's Data Central.

These data will enable a wide range of science. Thirty-six papers have been published to date on the survey and science derived from it. SAMI publications this year have covered topics as varied as the intrinsic shape of kinematically selected galaxies (Foster et al. 2017), a new model for disk galaxies (Taranu et al. 2017), the dependence of stellar populations on a galaxy's size, mass and environment (Scott et al. 2017), a new estimate of

the fraction of 'slow rotators' (van de Sande et al. 2017) and the Tully-Fisher relation (Bloom et al. 2017).

In an interdisciplinary collaboration, the SAMI team has been working with researchers at the University of Sydney's Centre for Translational Data Science to improve the modelling of how SAMI sampling interacts with atmospheric refraction. This has greatly improved the quality of SAMI data cubes.

In future, all data products from the SAMI Galaxy Survey will be added to the GAMA Survey within Data Central, allowing users to query SAMI and GAMA as a single dataset. The survey's next public data release is planned for mid 2018, and will include further value-added products.

Publications

Green, A.W., Croom, S.M., Scott, N. and 48 co-authors, "The SAMI Galaxy Survey: Data Release One with emission-line physics value-added products", Monthly Notices of the Royal Astronomical Society, 475, 716 (2018). ArXiv e-print: arxiv.org/abs/1707.08402

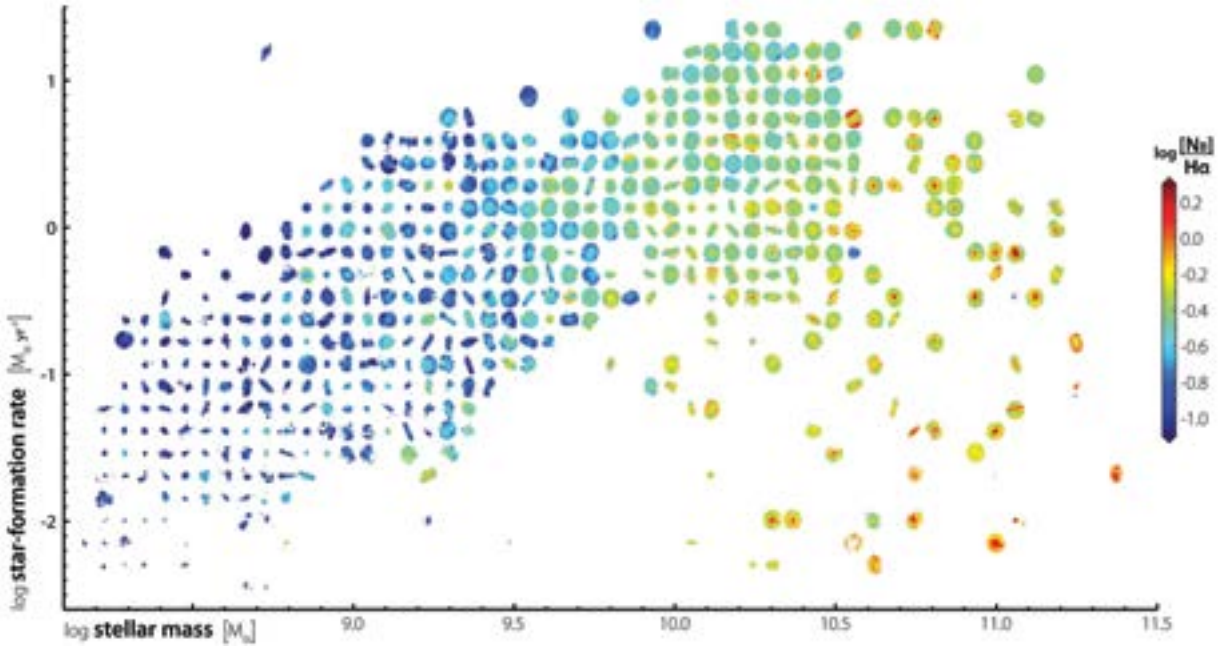
Foster, C., van de Sande, J., D'Eugenio, F. and 17 co-authors, "The SAMI Galaxy Survey: the intrinsic shape of kinematically selected galaxies", Monthly Notices of the Royal Astronomical Society, 472, 966 (2017)

Taranu, D. S., Obreschkow, D., Dubinski, J. J. and 26 co-authors, "Self-consistent Bulge/Disk/Halo Galaxy Dynamical Modeling Using Integral Field Kinematics", The Astrophysical Journal, 850, 70 (2017)

Scott, N., Brough, S., Croom, S. M., Davies, R. L., van de Sande, J., Allen, J. T., Bland-Hawthorn, J., Bryant, J. J., Cortese, L., D'Eugenio, F., Federrath, C., Ferreras, I., Goodwin, M., Groves, B., Konstantopoulos, I., Lawrence, J. S., Medling, A. M., Moffett, A. J., Owers, M. S., Richards, S., Robotham, A. S. G., Tonini, C., Yi, S. K., "The SAMI Galaxy Survey: global stellar populations on the size–mass plane", Monthly Notices of the Royal Astronomical Society, 472, 2833 (2017)

van de Sande, J., Bland-Hawthorn, J., Brough, S. and 15 co-authors, "The SAMI Galaxy Survey: revising the fraction of slow rotators in IFS galaxy surveys", Monthly Notices of the Royal Astronomical Society, 472, 1272 (2017)

Bloom, J. V., Croom, S. M., Bryant, J. J. and 22 co-authors, "The SAMI Galaxy Survey: the low-redshift stellar mass Tully-Fisher relation", Monthly Notices of the Royal Astronomical Society, 472, 1809 (2017)



The spatially-resolved maps of [NII]/ Hα within a 15-arcsec diameter in DR1 galaxies, arranged by stellar mass and star-formation rate. Some maps have been shifted slightly to avoid overlap. (From Green et al. 2018)

National Innovation Priority – Research

OLD TECHNIQUE COULD SIMPLIFY NEW TELESCOPE

Engineering Development Array
Credit: MWA

CAASTRO researchers have updated an old technique that could simplify the operation of the world's next large low-frequency radio telescope, SKA-low.

Astronomers look at the size and structure of a radio source to help determine the nature of the source and the physics at work in it. They usually measure source size with *very long baseline interferometry* (VLBI), a technique that requires radio telescopes with large distances (baselines) between them. But VLBI is slow: at present it can detect no more than 100 sources an hour. And while low-frequency measurements usefully complement those made at high frequencies, VLBI is technically challenging at low frequencies, where the ionosphere introduces phase errors.

A team led by CAASTRO Affiliate John Morgan (ICRAR–Curtin) and CAASTRO Researcher Rajan Chhetri (ICRAR –Curtin) has now used the Murchison Widefield Array (MWA) to demonstrate a technique that both works at low frequencies and is significantly faster than VLBI. This technique makes use of the solar wind, a plasma of charged particles streaming from the Sun. The plasma scatters radio signals that pass through it. As a result, compact radio cosmic sources (those less than half an arcsecond in angular size) appear to 'twinkle'. The phenomenon is called *interplanetary scintillation* (IPS). It was discovered in 1964 and quickly used for determining which radio sources have sub-arcsecond components. At the time, radio astronomers were desperate to measure the angular sizes of quasars, the nature of which was still unknown, and interferometers were not yet up to the task.

The technique fell out of favour with astronomers as interferometers moved to higher frequencies and gained resolving power. However, radio telescopes are now dramatically increasing their fields of view, becoming able to detect large numbers of sources in each observation, and astronomers want to marry this advantage with another: high resolution. In two papers, Morgan, Chhetri and their collaborators have shown that the MWA can swiftly measure IPS for many hundreds of sources over the whole of its large field of view ($\sim$900 deg^2 at $\sim$150 MHz), and have characterised the sources they detected.

For the paper led by Chhetri, the researchers made a single five-minute observation at 162 MHz, recording images of the full field every 0.5 seconds. They detected 2,550 continuum sources, of which 302 had an unambiguous sub-arcsecond component. When viewed at high frequencies, compact radio sources mainly have flat radio spectra, but the bright MWA IPS sources show a mixture of steep, flat and peaked spectra.

Surprisingly, the commonest type among the highly compact, strongly scintillating sources was the peaked-spectrum source: *all* the peaked-spectrum sources in the subsample were highly scintillating. Peaked-spectrum sources are young, compact radio galaxies. Using IPS on the MWA we can readily find examples with which to study the interplay of these young galaxies with their environment.

IPS has other exciting possibilities. It could be used, in combination with measurements of spectral indices, to efficiently search for extremely rare high-redshift ($z \sim 5$) radio galaxies: these were once seen as possible tools for exploring the early Universe, but have proved hard to find. IPS could also enhance the search for pulsars. All pulsars in the Galaxy will exhibit strong IPS, and looking for sources that show both strong IPS and a steep spectral index will reduce the number of contaminating extragalactic sources by a factor of about 45, very efficiently finding pulsar candidates for conventional follow-up. Morgan and Chhetri's team detected a known pulsar, PSR J0034–0721, showing that the MWA is on the threshold of the sensitivity needed to make new pulsar detections. That sensitivity will come with SKA-low, the low-

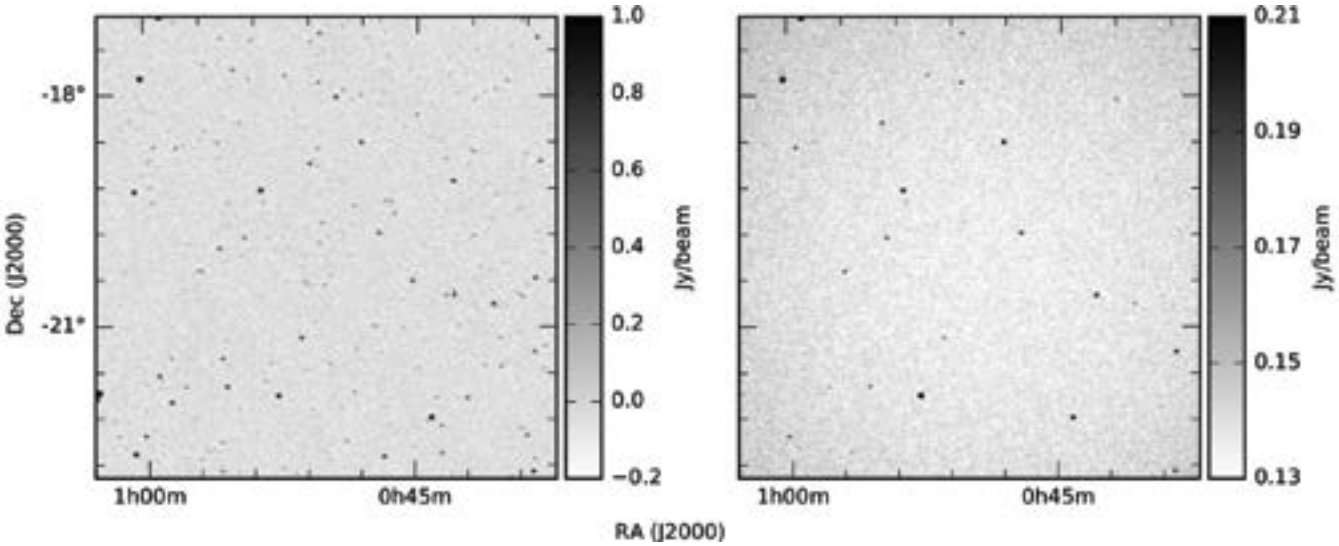
frequency component of the international Square Kilometre Array telescope, which will be co-located with the MWA at CSIRO's Murchison Radio-astronomy Observatory.

In addition, IPS observations could influence the operation and even design of SKA-low. MWA IPS observations could provide candidates for the compact sources SKA-low will need for calibrators. Furthermore, source fluctuations created by the ionosphere would normally complicate sub-arcsecond imaging at low frequencies, but IPS observations can be made on baselines so short that ionospheric effects will almost never be a problem. Information about sub-arcsecond structure is encoded in the IPS scintillations and cannot be removed by the ionosphere. Exploring the IPS technique further may show that SKA-low could study sub-arcsecond sources without the need for long baselines, side-stepping the effects of the ionosphere.

Publications

Morgan, J.S., Macquart, J-P., Ekers, R. and six co-authors, "Interplanetary Scintillation with the Murchison Widefield Array I: A sub-arcsecond survey over 900 degrees^2 at 79 and 158 MHz", Monthly Notices of the Royal Astronomical Society, 473, 2965 (2018)

Chhetri, R., Morgan, J., Ekers, R.D., Macquart, J-P., Sadler, E.M., Giroletti, M., Callingham, J.R., "Interplanetary Scintillation studies with the Murchison Wide-field Array – II: Properties of sub-arcsecond compact sources at low radio frequencies", Monthly Notices of the Royal Astronomical Society, 474, 4937 (2018)



At left, a standard image of part of the field observed with the MWA and, at right, only the scintillating sources in that area of sky, as revealed by the IPS observations. Each dot is a radio–emitting galaxy. The X and Y axes are right ascension (hh:mm:ss) and declination (dd:mm:ss) respectively. (From Chhetri et al. 2018)

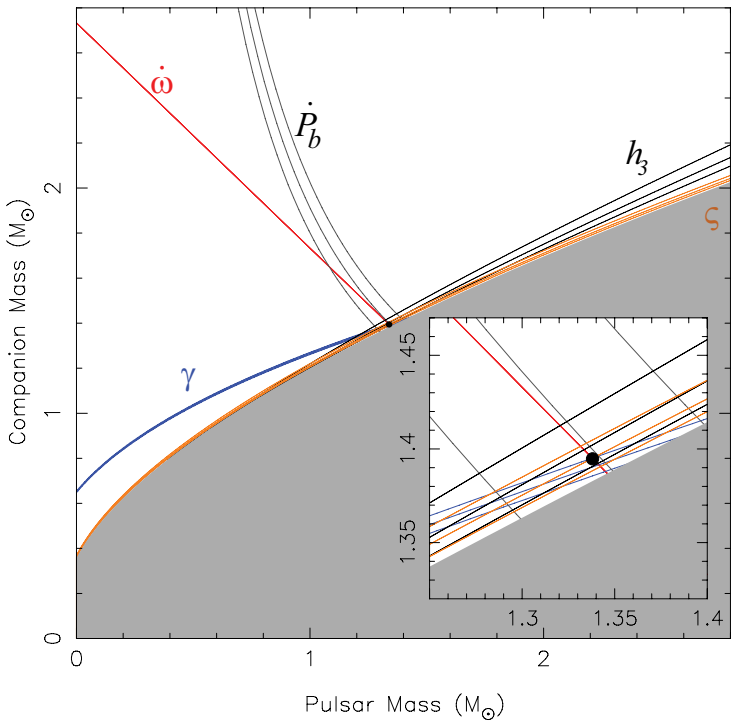
National Innovation Priority – International collaboration

CAASTRO COMPUTING HELPS FIND RECORD-SETTING PULSAR

Supercomputing time awarded through Australia's National Computational Infrastructure (NCI) has led to the discovery of one of the most relativistic binary pulsars yet known.

Einstein's general theory of relativity (GR) has been around for a century. It has resisted all attempts to disprove it; it is one of our most successful physical theories. But it doesn't work well with our other most successful physical theory, quantum mechanics, and so astronomers are continuing to test the limits of GR and those of alternative theories of gravity.

Gravitational waves, first directly detected in 2016, offer opportunities for testing GR, but the tests we can currently make using ground-based detectors such as LIGO (the Laser Interferometer Gravitational-Wave Observatory) aren't as challenging as those natural systems provide. For instance, the first known *double pulsar* system, PSR J0737–3039 – two pulsars orbiting each other – offers a test of GR that is around 1000 times better than that which LIGO can achieve. This double pulsar has passed five independent tests of GR, the most stringent of them (a limit on the quadrupolar gravitational-wave radiation) with a measurement uncertainty of only 0.05 per cent (Kramer et al. 2006; Breton et al. 2008): this is currently the best limit for this parameter. Pulsar tests will continue to be competitive with, and provide confirmation of, tests made with ground-based gravitational-wave detectors, as long as we can find more of the extremely relativistic pulsar systems. For example, a system like the double pulsar but with a shorter, tighter orbit would provide an even tougher test of the quadrupolar gravitational-wave radiation, while some alternative theories of gravity (scalar-tensor theories) would be best tested by binary pulsar systems in which the two members have very different masses.



Mass–mass diagram for PSR J1757–1854. Shown are the mass constraints imposed under general relativity by each post-Keplerian parameter, along with their 1-σ error bars. The inset shows a zoomed view of the region of intersection; the black dot marks the masses of the pulsar and its companion derived with the DDGR (Damour–Deruelle General Relativity) model. The grey region is excluded by orbital geometry. (From Cameron et al. 2018)

Finding such extreme systems was a key goal of a search for pulsars called the High Time Resolution Universe (HTRU) South Low Latitude pulsar survey. Led by Germany's Max Planck Institute for Radioastronomy (MPIfR) and involving several CAASTRO members, this survey was part of the overall HTRU project, a collaboration between institutions in Australia, the UK, Italy and Germany. Observing for the South Low Latitude survey was done with CSIRO's 64-m Parkes telescope and covered the inner Galactic plane ($-80° < l < 30°$ and $|b| < 3.5°$), the region predicted to have the greatest number of extremely relativistic binaries.

The survey used a novel search method: each observation was divided into smaller and smaller time segments and each segment searched for evidence of an accelerating object (which would reveal a pulsar in a binary orbit). To fully explore the parameter space for binary pulsars targeted by this new technique, at least 1.46 million Fourier transform operations must be computed for each telescope 'beam' (on-sky pixel): the complete survey consists of more than 16,000 'beams', representing more than 260 TB of data. Part of the processing of this formidable dataset has been carried out with supercomputing time allocated to CAASTRO through the Flagship Allocation Scheme of the National Computational Infrastructure (NCI).

Among the hundreds of thousands of pulsar candidates examined so far, one stood out because of its extreme acceleration. This object was studied further with Parkes and other telescopes – the University of Manchester's 76-m Lovell telescope in the UK, the 100-m Robert C. Byrd Green Bank Telescope in the USA, and MPIfR's 100-m Effelsberg telescope in Germany. These follow-up observations confirmed that the HTRU survey had found a pulsar, PSR J1757–1854, that is locked in a highly eccentric orbit ($\varepsilon = 0.61$) with another neutron star. The two bodies rocket around each other in just 4.4 hours; at their point of closest approach, the distance between them is less than the radius of the Sun. The pulsar experiences a maximum acceleration of ~ 684 m s^{-2}, almost 70 times that due to the Earth's gravity, and the most extreme known for a pulsar.

The compactness, high eccentricity and short orbital period of this binary make it one of the most relativistic systems known, one that therefore allows powerful tests of GR and other theories of gravity. For example, the pulsar's orbit is shrinking as gravitational waves carry away orbital energy: the HTRU team measured the rate of this shrinkage, and found it to agree with the value predicted by GR to within five per cent. The team was also able to measure the Shapiro delay, a time delay each radio pulse experiences when it travels through spacetime curved by the neutron-star companion. The two parameters that characterise the delay agreed with the GR predictions to within an uncertainty of only 1σ. By observing the binary system over a number of years, the astronomers will be able to test at least two more effects predicted by GR: the Lense–Thirring effect (which causes the pulsar's orbit to precess) and deformation of the elliptical orbit.

The HTRU-S LowLat survey has so far found another 104 pulsars (but none as dramatic as PSR J1757–1854). The chances are good that, with further surveys and more advanced computational methods, we will continue to find extreme binary pulsars and 'push the envelope' of general relativity.

Publications

Cameron, A. D., Champion, D. J., Kramer, M. and 27 co-authors, "The High Time Resolution Universe Pulsar Survey – XIII. PSR J1757–1854, the most accelerated binary pulsar", Monthly Notices of the Royal Astronomical Society: Letters, 475, L57 (2018)

Kramer, M., Stairs, I. H., Manchester, R. N. and 12 co-authors, "Tests of General Relativity from Timing the Double Pulsar", Science, 314, 97 (2006)

Breton, R. P., Kaspi, V. M., Kramer, M. and seven co-authors, "Relativistic Spin Precession in the Double Pulsar", Science, 321, 104 (2008)

National Innovation Priority – International collaboration

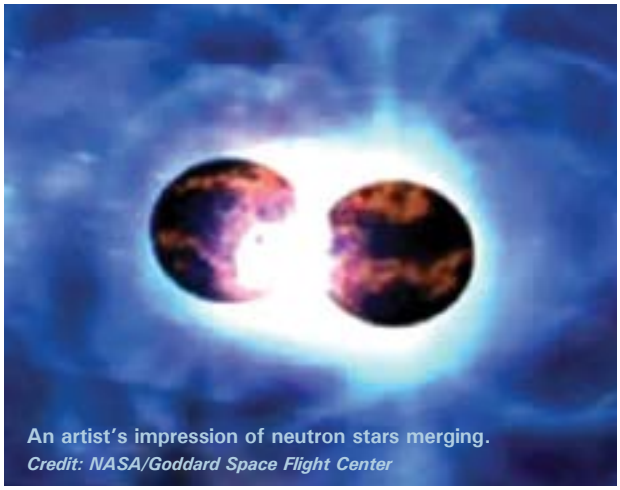
A RADIO DETECTION FROM THE FIRST BINARY NEUTRON-STAR MERGER

Australian observers have taken part in a worldwide effort to study the first confirmed merger of two neutron stars.

Short gamma-ray bursts – cosmic bursts of gamma rays lasting less than two seconds – have been a mystery for decades. The most likely cause seemed to be the merger of two neutron stars, but such an event had never been unambiguously detected. So when one finally was, by the LIGO and Virgo gravitational-wave detectors on 17 August 2017, astronomers worldwide scrambled for their telescopes. This was only the fifth detection of gravitational waves. The previous four events had been mergers of black holes, which held little promise of generating electromagnetic radiation. But a neutron-star merger was expected to be a different story.

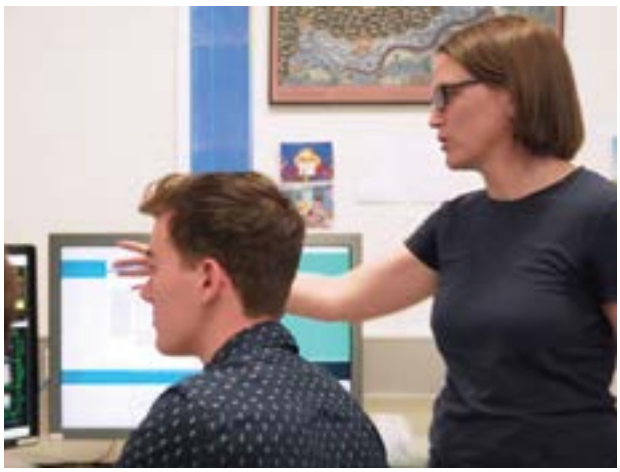
Models predict that the ejecta from such an event ploughs out through material in the interstellar medium (ISM) surrounding the doomed stars, generating radio synchrotron radiation. The mass and speed of the ejecta, and the density of the ISM, determine how bright the radio source becomes and when its brightness peaks.

Within a few hours of the gravitational-wave detection being announced, CAASTRO's Dynamic Theme leader, Tara Murphy (University of Sydney) and her colleagues applied for *target of opportunity* observing time on CSIRO's Australia Telescope Compact Array. They worked in collaboration with observers using the Jansky Very Large Array (JVLA) radio telescope in the USA. Both telescopes detected a radio source in the galaxy that had been identified as the source of the blast. The source was weak, but detecting it with the two telescopes gave the observers confidence that it was real. (The Australian observers also used the Australian SKA Pathfinder and the Murchison Widefield Array, but these telescopes did not detect the source.)



An artist's impression of neutron stars merging.
Credit: NASA/Goddard Space Flight Center

PhD student Dougal Dobie and Associate Professor Tara Murphy.
Credit: Helen Sim



The ATCA, JVLA and the Giant Meter-wave Radio Telescope (GMRT) in India continued to monitor the source. Models of short gamma-ray bursts require that the merging neutron stars create an extremely fast, 'ultrarelativistic' jet of material. But the ongoing radio observations didn't show any evidence for one. Instead, they strongly suggest that the radio emission is instead arising from a slower, broader outflow of radio-emitting material – a 'cocoon'. This is probably matter thrown out by the explosion that's been powered up by a jet hidden inside it. The jet may later break free of the cocoon and create the classic signature of a short gamma-ray burst.

The aftermath of the merger will be studied for years to come, and the radio observations will remain key evidence for understanding its physics. They will also help us understand all neutron-star mergers – events that could account for many kinds of transients.

Publications

Hallinan, G. and 31 co-authors, "A radio counterpart to a neutron star merger", Science, 358, 1579 (2017)

Mooley, K. P. and 24 co-authors, "A mildly relativistic wide-angle outflow in the neutron-star merger event GW170817", Nature 554, 207 (2017)

All photos – credit: CAASTRO

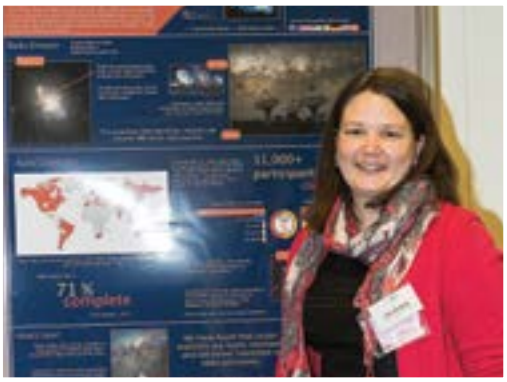
CAASTRO CELEBRATES

The CAASTRO Advisory Board held its last face-to-face meeting in Canberra on Tuesday 8 August. The next morning CAASTRO hosted a Celebration Breakfast at Parliament House, hosted by the Hon Craig Laundy MP, Assistant Minister for Industry, Innovation and Science. Eighty people attended the event, including Members of Parliament, Advisors, CAASTRO members, the Board and other guests at this event. Assistant Minister Laundy, Australia's Chief Scientist (and former CAASTRO Board Chair) Dr Alan Finkel, CAASTRO Chief Investigator Professor Brian Schmidt (Australian National University) and current Board Chair Professor Bob Williamson (University of Melbourne) spoke about CAASTRO and its achievements.

Many of the parliamentarians and their advisors who attended the breakfast stayed on to look at our research displays and talk to CAASTRO's postdoctoral researchers and students about their work. Along with our scientific work, CAASTRO's gender action activities were clearly of great interest to many, and we were commended once again for our activities in this area and our online Gender Action Toolkit.

CAASTRO also presented a short video of its lifetime highlights, which was very well received. This and other videos are available for viewing on our CAASTRO Legacy website at www.caastro.org.

Many thanks go to Kate Gunn, Kylie Williams and the CAASTRO administration team for their hard work in organising this very successful event.



AT PARLIAMENT HOUSE CANBERRA

LIFE BEYOND CAASTRO

Many past members of CAASTRO are now part of our alumni network, *CAASTRO Connections*. While many are still working in astronomy, others have moved into different fields. Below are descriptions of some of the diverse paths our alumni have taken.

Jessica Bloom (right) was part of the "Shirtloads of Science" team with Dr Karl and Dr Alice Williamson
Credit: Isabelle Benton

Jessica Bloom

CAASTRO PhD student
University of Sydney

Bloom is excited to be starting work in 2018 at McKinsey & Company, a global consulting firm that serves a huge range of industries and governments at the highest levels. She will be using the analytical skills she learnt during her PhD to tackle problems in an applied industry setting. Bloom will also continue her work in science communication; she is exploring opportunities with several podcasts and TV shows.

Mike Dalley

CAASTRO Affiliate
Voyages Indigenous Tourism

Dalley recently started a business, *Inspiring Skies*, that helps tourism businesses develop and operate astronomy outreach. Some of his services include organising VIP/celebrity astronomy experiences, servicing and/or installing new astronomy equipment, reviewing and developing current astronomy experiences, creating exciting new astronomy tours and events, and training in-house astronomy team members. Dalley recently installed a 3D unit with a brand new telescope at a resort in the Maldives, making it the world's first resort to offer 3D astronomy.

Mike Dalley, Inspiring Skies sets up a telescope in the Maldives
Credit: Mike Dalley

Catherine de Burgh-Day

CAASTRO PhD student
University of Melbourne

After completing her PhD in early 2016, de Burgh-Day moved to the Bureau of Meteorology, taking up the role of Software Testing Lead for Numerical Modelling in the group responsible for the development and maintenance of the Bureau's operational models. Her first responsibility was to help transfer the Bureau's suite of models to its new supercomputer, *Australis*. She then moved back into research, and now works on developing applications for the Bureau's new global seasonal forecasting model. She is currently assessing the model's utility for making forecasts of the ocean around New Zealand for fisheries and aquaculture industries.

Jacinta den Besten

CAASTRO Outreach and Telescopes in Schools
University of Melbourne

Den Besten has a background in education. After working on astronomy outreach with CAASTRO, at the end of 2016 she became the coordinator for first-year physics at the University of Melbourne. In this role she has been teaching labs, lecturing, and helping to manage casual teaching staff and senior teaching fellows, while ensuring that 1,500 first-year physics students are happy and working hard! In addition, den Besten leads the department's Equity and Diversity Committee and is involved in a similar committee at the faculty level: in both, she is continuing her commitment to inclusion and diversity that she developed while in CAASTRO. Den Besten is also continuing with her love of science outreach, and in 2017 contributed to the annual *AstroLight* festival at Scienceworks (supported by CAASTRO). Recently, thanks to the Laby Foundation, den Besten flew over Antarctica to measure the radiation and magnetic field on the approach to the south magnetic pole.

Jacinta Den Besten flew over Antarctica (thanks to the Laby Foundation) to measure the radiation and magnetic field on the approach to the South Magnetic Pole.
Credit: Jacinta Den Besten

Eyal Kazin

CAASTRO Postdoctoral Researcher
Swinburne University of Technology

After finishing his postdoc at Swinburne University, Kazin moved to London to start a new career in data science. For the past three years he has both worked in applied (client-facing) roles and developed tools for more efficiently analysing data. For clients he has modelled topics as varied as the propensity of customers to choose particular restaurants, how people are likely to vote in an upcoming election, and where a bus company should expand its operations. Kazin's academic research provided him with transferable skills required for the profession (scientific research, statistics and inference, computer programming and communications); he has supplemented these by acquiring proficiency with machine learning, database techniques and artificial intelligence.

Jenny Lynch

CAASTRO School Education Officer
University of Sydney

Since leaving CAASTRO in 2017, Lynch has focused on her Sydney-based science communication business, *Creative Science*. She runs hands-on science workshops in preschools and childcare centres and presents professional development workshops for early childhood teachers and educators. During National Science Week in 2017, she performed science shows at the Australian Museum and the Australian Botanic Garden, Mount Annan; year round, she offers live science shows to primary schools. Jenny is a product designer for the *WILD! Science* brand of science kits and works as a science consultant, researcher and scriptwriter for children's television programs.

Emily Petroff

CAASTRO PhD student
Swinburne University of Technology

After completing her PhD at Swinburne University in 2015, Petroff took a position at ASTRON, the Netherlands Institute for Radio Astronomy. She has continued her research into fast radio bursts (FRBs), powerful extragalactic radio pulses of unknown origin, and is building on her pioneering thesis work in this field to try to determine that origin. Petroff has recently developed tools for the FRB community: real-time triggering templates for communicating new events and a publicly available catalogue of all published bursts, *www.frbcat.org*. She is also contributing to an upgrade of ASTRON's 50-year-old Westerbork telescope that will increase the instrument's sensitivity and field of view, making it an ideal tool for finding and studying fast radio bursts.

Sarah Reeves

CAASTRO PhD student
University of Sydney

For her PhD Reeves studied intervening neutral hydrogen (HI) absorption in nearby, gas-rich galaxies, as part of preparation for the FLASH (First Large Absorption Survey in HI) project. She submitted her thesis in 2016 and graduated in 2017. In mid 2016 Reeves became a science curator at the Museum of Applied Arts and Sciences (Powerhouse Museum). Her role involves designing science exhibitions for visitors of all ages, writing about the Museum's science collection for the online collection database and blog, and acquiring objects that capture both historic and cutting-edge scientific advances into the collection. She has a particular interest in documenting astronomical advances and discoveries, and the telescopes and technology that make these possible. In the last 18 months Reeves has worked on the exhibition *Experimentations*, which introduces primary school aged students to concepts of physics and chemistry and the process of scientific investigation; and has also managed the Museum's acquisition of a perfect silicon sphere made by CSIRO, and of Australia's first ever payload to the International Space Station, which was launched by Sydney start-up *Cuberider*. Reeves also works occasionally as an astronomy guide at Sydney Observatory, a historic site managed by the Powerhouse.

Richard Scalzo

CAASTRO Postdoctoral Researcher
Australian National University

Scalzo is currently a Senior Research Fellow at the University of Sydney's Centre for Translational Data Science, which leads interdisciplinary research into new data science and machine-learning techniques that can be applied to grand-challenge science problems with high social impact. He has continued his astrophysics research on Type Ia supernovae (and, more recently, the SAMI Galaxy Survey – page 33) with CAASTRO collaborators; at the same time, he has been leading engineering teams working on problems in new areas such as molecular biology, geology and geophysics, political science and environmental science. Scalzo's prior experience in software development, parallel computing and hierarchical Bayesian inference, honed in the SkyMapper project, has proven useful in his new role.

Syed Uddin

CAASTRO PhD student
Swinburne University of Technology

Uddin is now a postdoctoral fellow working on supernova cosmology at the Purple Mountain Observatory, Chinese Academy of Sciences. He works closely with the Chinese Centre for Antarctic Astronomy to discover supernovae from the Antarctic Transient Survey, and is building a large sample of Type Ia supernovae to improve distance measurements and improve cosmological constraints.

Fang Yuan

CAASTRO Postdoctoral Researcher
Australian National University

Yuan now works as an Earth-observation data scientist at Geoscience Australia. She is a member of the Digital Earth Australia team, using satellite imagery to support decision-making by the Australian Government. Yuan develops information products that will help the agency's clients understand changes in land cover and respond to natural disasters such as floods and bushfires.

2017 PUBLICATIONS

Abbott, T., Cooke, J., Curtin, C., Joudaki, S., Katsianis, A., Koekemoer, A., Mould, J., Tescari, E., Uddin, S., Wang, L., "Superluminous Supernovae at High Redshift", Publications of the Astronomical Society of Australia, 34, e012 (2017)

Abellán, F. J., Indebetouw, R., Marcaide, J. M., Gabler, M., Fransson, C., Spyromilio, J., Burrows, D. N., Chevalier, R., Cigan, P., Gaensler, B. M., Gomez, H. L., Janka, H.-T., Kirshner, R., Larsson, J., Lundqvist, P., Matsuura, M., McCray, R., Ng, C.-Y., Park, S., Roche, P., Staveley-Smith, L., van Loon, J. T., Wheeler, J. C., Woosley, S. E., "Very Deep inside the SN 1987A Core Ejecta: Molecular Structures Seen in 3D", The Astrophysical Journal, 842, L24 (2017)

Achitouv, I., Blake, C., Carter, P., Koda, J., Beutler, F., "Consistency of the growth rate in different environments with the 6-degree Field Galaxy Survey: Measurement of the void-galaxy and galaxy-galaxy correlation functions", Physical Review D, 95, 083502 (2017)

Achitouv, I., "Improved model of redshift-space distortions around voids: Application to quintessence dark energy", Physical Review D, 96, 083506 (2017)

Adams, C., Blake, C., "Improving constraints on the growth rate of structure by modelling the density-velocity cross-correlation in the 6dF Galaxy Survey", Monthly Notices of the Royal Astronomical Society, 471, 839 (2017)

Allison, J. R., Moss, V. A., Macquart, J.-P., Curran, S. J., Duchesne, S. W., Mahony, E. K., Sadler, E. M., Whiting, M. T., Bannister, K. W., Chippendale, A. P., Edwards, P. G., Harvey-Smith, L., Heywood, I., Indermuehle, B. T., Lenc, E., Marvil, J., McConnell, D., Sault, R. J., "Illuminating the past 8 billion years of cold gas towards two gravitationally lensed quasars", Monthly Notices of the Royal Astronomical Society, 465, 4450 (2017)

Anderson, G. E., Horesh, A., Mooley, K. P., Rushton, A. P., Fender, R. P., Staley, T. D., Argo, M. K., Beswick, R. J., Hancock, P. J., Pérez-Torres, M. A., Perrott, Y. C., Plotkin, R. M., Pretorius, M. L., Rumsey, C., Titterington, D. J., "The peculiar mass-loss history of SN 2014C as revealed through AMI radio observations", Monthly Notices of the Royal Astronomical Society, 466, 3648 (2017)

Andreoni, I., Ackley, K., Cooke, J., Acharyya, A., Allison, J. R., Anderson, G. E., Ashley, M. C. B., Baade, D., Bailes, M., Bannister, K., Beardsley, A., Bessell, M. S., Bian, F., Bland, P. A., Boer, M., Booler, T., Brandeker, A., Brown, I. S., Buckley, D. A. H., Chang, S.-W., Coward, D. M., Crawford, S., Crisp, H., Crosse, B., Cucchiara, A., Cupák, M., de Gois, J. S., Deller, A., Devillepoix, H. A. R., Dobie, D., Elmer, E., Emrich, D., Farah, W., Farrell, T. J., Franzen, T., Gaensler, B. M., Galloway, D. K., Gendre, B., Giblin, T., Goobar, A., Green, J., Hancock, P. J., Hartig, B. A. D., Howell, E. J., Horsley, L., Hotan, A., Howie, R. M., Hu, L., Hu, Y., James, C. W., and 75 colleagues, "Follow Up of GW170817 and Its Electromagnetic Counterpart by Australian-Led Observing Programmes", Publications of the Astronomical Society of Australia, 34, e069 (2017)

Andreoni, I., Jacobs, C., Hegarty, S., Pritchard, T., Cooke, J., Ryder, S., "Mary, a Pipeline to Aid Discovery of Optical Transients", Publications of the Astronomical Society of Australia, 34, e037 (2017)

Arcavi, I., Howell, D. A., Kasen, D., Bildsten, L., Hosseinzadeh, G., McCully, C., Wong, Z. C., Katz, S. R., Gal-Yam, A., Sollerman, J., Taddia, F., Leloudas, G., Fremling, C., Nugent, P. E., Horesh, A., Mooley, K., Rumsey, C., Cenko, S. B., Graham, M. L., Perley, D. A., Nakar, E., Shaviv, N. J., Bromberg, O., Shen, K. J., Ofek, E. O., Cao, Y., Wang, X., Huang, F., Rui, L., Zhang, T., Li, W., Li, Z., Zhang, J., Valenti, S., Guevel, D., Shappee, B., Kochanek, C. S., Holoien, T. W.-S., Filippenko, A. V., Fender, R., Nyholm, A., Yaron, O., Kasliwal, M. M., Sullivan, M., Blagorodnova, N., Walters, R. S., Lunnan, R., Khazov, D., Andreoni, I., Laher, R. R., and 3 colleagues, "Energetic eruptions leading to a peculiar hydrogen-rich explosion of a massive star", Nature, 551, 210 (2017)

Arthur, J., Pearce, F. R., Gray, M. E., Elahi, P. J., Knebe, A., Beck, A. M., Cui, W., Cunnama, D., Davé, R., February, S., Huang, S., Katz, N., Kay, S. T., McCarthy, I. G., Murante, G., Perret, V., Power, C., Puchwein, E., Saro, A., Sembolini, F., Teyssier, R., Yepes, G., "nIFTy galaxy cluster simulations - V. Investigation of the cluster infall region", Monthly Notices of the Royal Astronomical Society, 464, 2027 (2017)

Bailes, M., Jameson, A., Flynn, C., Bateman, T., Barr, E. D., Bhandari, S., Bunton, J. D., Caleb, M., Campbell-Wilson, D., Farah, W., Gaensler, B., Green, A. J., Hunstead, R. W., Jankowski, F., Keane, E. F., Krishnan, V. V., Murphy, T., O'Neill, M., Osłowski, S., Parthasarathy, A., Ravi, V., Rosado, P., Temby, D., "The UTMOST: A Hybrid Digital Signal Processor Transforms the Molonglo Observatory Synthesis Telescope", Publications of the Astronomical Society of Australia, 34, e045 (2017)

Bannister, K. W., Shannon, R. M., Macquart, J.-P., Flynn, C., Edwards, P. G., O'Neill, M., Osłowski, S., Bailes, M., Zackay, B., Clarke, N., D'Addario, L. R., Dodson, R., Hall, P. J., Jameson, A., Jones, D., Navarro, R., Trinh, J. T., Allison, J., Anderson, C. S., Bell, M., Chippendale, A. P., Collier, J. D., Heald, G., Heywood, I., Hotan, A. W., Lee-Waddell, K., Madrid, J. P., Marvil, J., McConnell, D., Popping, A., Voronkov, M. A., Whiting, M. T., Allen, G. R., Bock, D. C.-J., Brodrick, D. P., Cooray, F., DeBoer, D. R., Diamond, P. J., Ekers, R., Gough, R. G., Hampson, G. A., Harvey-Smith, L., Hay, S. G., Hayman, D. B., Jackson, C. A., Johnston, S., Koribalski, B. S., McClure-Griffiths, N. M., Mirtschin, P., Ng, A., and 6 colleagues, "The Detection of an Extremely Bright Fast Radio Burst in a Phased Array Feed Survey", The Astrophysical Journal, 841, L12 (2017)

Bassett, R., Bekki, K., Cortese, L., Couch, W. J., Sansom, A. E., van de Sande, J., Bryant, J. J., Foster, C., Croom, S. M., Brough, S., Sweet, S. M., Medling, A. M., Owers, M. S., Driver, S. P., Davies, L. J. M., Wong, O. I., Groves, B. A., Bland-Hawthorn, J., Richards, S. N., Goodwin, M., Konstantopoulos, I. S., Lawrence, J. S., "The SAMI Galaxy Survey: kinematics of dusty early-type galaxies", Monthly Notices of the Royal Astronomical Society, 470, 1991 (2017)

Bhattacharyya, S., Bera, A., Bharadwaj, S., Ramesh Bhat, N. D., Chengalur, J. N., "FRB Event Rate Predictions for the Ooty Wide Field Array", Journal of Astrophysics and Astronomy, 38, 17 (2017)

Bloom, J. V., Croom, S. M., Bryant, J. J., Callingham, J. R., Schaefer, A. L., Cortese, L., Hopkins, A. M., D'Eugenio, F., Scott, N., Glazebrook, K., Tonini, C., McElroy, R. E., Clark, H. A., Catinella, B., Allen, J. T., Bland-Hawthorn, J., Goodwin, M., Green, A. W., Konstantopoulos, I. S., Lawrence, J., Lorente, N., Medling, A. M., Owers, M. S., Richards, S. N., Sharp, R., "The SAMI Galaxy Survey: the low-redshift stellar mass Tully-Fisher relation", Monthly Notices of the Royal Astronomical Society, 472, 1809 (2017)

Bloom, J. V., Fogarty, L. M. R., Croom, S. M., Schaefer, A., Bryant, J. J., Cortese, L., Richards, S., Bland-Hawthorn, J., Ho, I.-T., Scott, N., Goldstein, G., Medling, A., Brough, S., Sweet, S. M., Cecil, G., López-Sánchez, A., Glazebrook, K., Parker, Q., Allen, J. T., Goodwin, M., Green, A. W., Konstantopoulos, I. S., Lawrence, J. S., Lorente, N., Owers, M. S., Sharp, R., "The SAMI Galaxy Survey: asymmetry in gas kinematics and its links to stellar mass and star formation", Monthly Notices of the Royal Astronomical Society, 465, 123 (2017)

Brienza, M., Godfrey, L., Morganti, R., Prandoni, I., Harwood, J., Mahony, E. K., Hardcastle, M. J., Murgia, M., Röttgering, H. J. A., Shimwell, T. W., Shulevski, A., "Search and modelling of remnant radio galaxies in the LOFAR Lockman Hole field", Astronomy and Astrophysics, 606, A98 (2017)

Brough, S., van de Sande, J., Owers, M. S., d'Eugenio, F., Sharp, R., Cortese, L., Scott, N., Croom, S. M., Bassett, R., Bekki, K., Bland-Hawthorn, J., Bryant, J. J., Davies, R., Drinkwater, M. J., Driver, S. P., Foster, C., Goldstein, G., López-Sánchez, Á. R., Medling, A. M., Sweet, S. M., Taranu, D. S., Tonini, C., Yi, S. K., Goodwin, M., Lawrence, J. S., Richards, S. N., "The SAMI Galaxy Survey: Mass as the Driver of the Kinematic Morphology-Density Relation in Clusters", The Astrophysical Journal, 844, 59 (2017)

Brown, S., Vernstrom, T., Carretti, E., Dolag, K., Gaensler, B. M., Staveley-Smith, L., Bernardi, G., Haverkorn, M., Kesteven, M., Poppi, S., "Limiting magnetic fields in the cosmic web with diffuse radio emission", Monthly Notices of the Royal Astronomical Society, 468, 4246 (2017)

Brown, T., Catinella, B., Cortese, L., Lagos, C. d. P., Davé, R., Kilborn, V., Haynes, M. P., Giovanelli, R., Rafieferantsoa, M., "Cold gas stripping in satellite galaxies: from pairs to clusters", Monthly Notices of the Royal Astronomical Society, 466, 1275 (2017)

Bryant, J. J., Bland-Hawthorn, J., Lawrence, J., Croom, S., Brown, D., Venkatesan, S., Gillingham, P. R., Zhelem, R., Content, R., Saunders, W., Staszak, N. F., van de Sande, J., Couch, W., Leon-Saval, S., Tims, J., McDermid, R., Schaefer, A., "Hector: a new massively multiplexed IFU instrument for the Anglo-Australian Telescope", Ground-based and Airborne Instrumentation for Astronomy VI, 9908, 99081F (2016)

Calcino, J., Davis, T., "The need for accurate redshifts in supernova cosmology", Journal of Cosmology and Astro-Particle Physics, 1, 038 (2017)

Caleb, M., Flynn, C., Bailes, M., Barr, E. D., Bateman, T., Bhandari, S., Campbell-Wilson, D., Farah, W., Green, A. J., Hunstead, R. W., Jameson, A., Jankowski, F., Keane, E. F., Parthasarathy, A., Ravi, V., Rosado, P. A., van Straten, W., Venkatraman Krishnan, V., "The first interferometric detections of fast radio bursts", Monthly Notices of the Royal Astronomical Society, 468, 3746 (2017)

Calistro Rivera, G., Williams, W. L., Hardcastle, M. J., Duncan, K., Röttgering, H. J. A., Best, P. N., Brüggen, M., Chyży, K. T., Conselice, C. J., de Gasperin, F., Engels, D., Gürkan, G., Intema, H. T., Jarvis, M. J., Mahony, E. K., Miley, G. K., Morabito, L. K., Prandoni, I., Sabater, J., Smith, D. J. B., Tasse, C., van der Werf, P. P., White, G. J., "The LOFAR window on star-forming galaxies and AGNs - curved radio SEDs and IR-radio correlation at $0<z<2.5$", Monthly Notices of the Royal Astronomical Society, 469, 3468 (2017)

Callingham, J. R., Ekers, R. D., Gaensler, B. M., Line, J. L. B., Hurley-Walker, N., Sadler, E. M., Tingay, S. J., Hancock, P. J., Bell, M. E., Dwarakanath, K. S., For, B.-Q., Franzen, T. M. O., Hindson, L., Johnston-Hollitt, M., Kapińska, A. D., Lenc, E., McKinley, B., Morgan, J., Offringa, A. R., Procopio, P., Staveley-Smith, L., Wayth, R. B., Wu, C., Zheng, Q., "Extragalactic Peaked-spectrum Radio Sources at Low Frequencies", The Astrophysical Journal, 836, 174 (2017)

Childress, M. J., Lidman, C., Davis, T. M., Tucker, B. E., Asorey, J., Yuan, F., Abbott, T. M. C., Abdalla, F. B., Allam, S., Annis, J., Banerji, M., Benoit-Lévy, A., Bernard, S. R., Bertin, E., Brooks, D., Buckley-Geer, E., Burke, D. L., Carnero Rosell, A., Carollo, D., Carrasco Kind, M., Carretero, J., Castander, F. J., Cunha, C. E., da Costa, L. N., D'Andrea, C. B., Doel, P., Eifler, T. F., Evrard, A. E., Flaugher, B., Foley, R. J., Fosalba, P., Frieman, J., García-Bellido, J., Glazebrook, K., Goldstein, D. A., Gruen, D., Gruendl, R. A., Gschwend, J., Gupta, R. R., Gutierrez, G., Hinton, S. R., Hoormann, J. K., James, D. J., Kessler, R., Kim, A. G., King, A. L., Kovacs, E., Kuehn, K., Kuhlmann, S., Kuropatkin, N., and 51 colleagues, "OzDES multifibre spectroscopy for the Dark Energy Survey: 3-yr results and first data release", Monthly Notices of the Royal Astronomical Society, 472, 273 (2017)

Codoreanu, A., Ryan-Weber, E. V., Crighton, N. H. M., Becker, G., Pettini, M., Madau, P., Venemans, B., "The comoving mass density of Mg II from $z \sim 2$ to 5.5", Monthly Notices of the Royal Astronomical Society, 472, 1023 (2017)

Contigiani, O., de Gasperin, F., Miley, G. K., Rudnick, L., Andernach, H., Banfield, J. K., Kapińska, A. D., Shabala, S. S., Wong, O. I., "Radio Galaxy Zoo: cosmological alignment of radio sources", Monthly Notices of the Royal Astronomical Society, 472, 636 (2017)

Contreras, S., Padilla, N., Lagos, C. D. P., "Angular momentum evolution in dark matter haloes: a study of the Bolshoi and Millennium simulations", Monthly Notices of the Royal Astronomical Society, 472, 4992 (2017)

Coughlan, C. P., Ainsworth, R. E., Eislöffel, J., Hoeft, M., Drabent, A., Scaife, A. M. M., Ray, T. P., Bell, M. E., Broderick, J. W., Corbel, S., Grießmeier, J.-M., van der Horst, A. J., van Leeuwen, J., Markoff, S., Pietka, M., Stewart, A. J., Wijers, R. A. M. J., Zarka, P., "A LOFAR Detection of the Low-mass Young Star T Tau at 149 MHz", The Astrophysical Journal, 834, 206 (2017)

Cowley, W. I., Béthermin, M., Lagos, C. d. P., Lacey, C. G., Baugh, C. M., Cole, S., "The far infra-red SEDs of main sequence and starburst galaxies", Monthly Notices of the Royal Astronomical Society, 467, 1231 (2017)

Crain, R. A., Bahé, Y. M., Lagos, C. d. P., Rahmati, A., Schaye, J., McCarthy, I. G., Marasco, A., Bower, R. G., Schaller, M., Theuns, T., van der Hulst, T., "The EAGLE simulations: atomic hydrogen associated with galaxies", Monthly Notices of the Royal Astronomical Society, 464, 4204 (2017)

Crocker, R. M., Ruiter, A. J., Seitenzahl, I. R., Panther, F. H., Sim, S., Baumgardt, H., Möller, A., Nataf, D. M., Ferrario, L., Eldridge, J. J., White, M., Tucker, B. E., Aharonian, F., "Diffuse Galactic antimatter from faint thermonuclear supernovae in old stellar populations", Nature Astronomy, 1, 0135 (2017)

Cui, W., Power, C., Borgani, S., Knebe, A., Lewis, G. F., Murante, G., Poole, G. B., "On the dynamical state of galaxy clusters: insights from cosmological simulations - II.", Monthly Notices of the Royal Astronomical Society, 464, 2502 (2017)

da Cunha, E., Hopkins, A. M., Colless, M., Taylor, E. N., Blake, C., Howlett, C., Magoulas, C., Lucey, J. R., Lagos, C., Kuehn, K., Gordon, Y., Barat, D., Bian, F., Wolf, C., Cowley, M. J., White, M., Achitouv, I., Bilicki, M., Bland-Hawthorn, J., Bolejko, K., Brown, M. J. I., Brown, R., Bryant, J., Croom, S., Davis, T. M., Driver, S. P., Filipovic, M. D., Hinton, S. R., Johnston-Hollitt, M., Jones, D. H., Koribalski, B., Kleiner, D., Lawrence, J., Lorente, N., Mould, J., Owers, M. S., Pimbblet, K., Tinney, C. G., Tothill, N. F. H., Watson, F., "The Taipan Galaxy Survey: Scientific Goals and Observing Strategy", Publications of the Astronomical Society of Australia, 34, e047 (2017)

Dabbech, A., Wolz, L., Pratley, L., McEwen, J. D., Wiaux, Y., "The w-effect in interferometric imaging: from a fast sparse measurement operator to superresolution", Monthly Notices of the Royal Astronomical Society, 471, 4300 (2017)

Davies, R. L., Groves, B., Kewley, L. J., Medling, A. M., Shastri, P., Maithil, J., Kharb, P., Banfield, J., Longbottom, F., Dopita, M. A., Hampton, E. J., Scharwächter, J., Sutherland, R., Jin, C., Zaw, I., James, B., Juneau, S., "Dissecting galaxies: separating star formation, shock excitation and AGN activity in the central region of NGC 613", Monthly Notices of the Royal Astronomical Society, 470, 4974 (2017)

de Lera Acedo, E., Trott, C. M., Wayth, R. B., Fagnoni, N., Bernardi, G., Wakley, B., Koopmans, L. V. E., Faulkner, A. J., bij de Vaate, J. G., "Spectral performance of SKA Log-periodic Antennas I: mitigating spectral artefacts in SKA1-LOW 21 cm cosmology experiments", Monthly Notices of the Royal Astronomical Society, 469, 2662 (2017)

Deeley, S., Drinkwater, M. J., Cunnama, D., Bland-Hawthorn, J., Brough, S., Cluver, M., Colless, M., Davies, L. J. M., Driver, S. P., Foster, C., Grootes, M. W., Hopkins, A. M., Kafle, P. R., Lara-Lopez, M. A., Liske, J., Mahajan, S., Phillipps, S., Power, C., Robotham, A., "Galaxy and Mass Assembly (GAMA): formation and growth of elliptical galaxies in the group environment", Monthly Notices of the Royal Astronomical Society, 467, 3934 (2017)

Delvecchio, I., Smolčić, V., Zamorani, G., Lagos, C. D. P., Berta, S., Delhaize, J., Baran, N., Alexander, D. M., Rosario, D. J., Gonzalez-Perez, V., Ilbert, O., Lacey, C. G., Le Fèvre, O., Miettinen, O., Aravena, M., Bondi, M., Carilli, C., Ciliegi, P., Mooley, K., Novak, M., Schinnerer, E., Capak, P., Civano, F., Fanidakis, N., Herrera Ruiz, N., Karim, A., Laigle, C., Marchesi, S., McCracken, H. J., Middleberg, E., Salvato, M., Tasca, L., "The VLA–COSMOS 3 GHz Large Project: AGN and host-galaxy properties out to $z \leq 6$", Astronomy and Astrophysics, 602, A3 (2017)

Dimitriadis, G., Sullivan, M., Kerzendorf, W., Ruiter, A. J., Seitenzahl, I. R., Taubenberger, S., Doran, G. B., Gal-Yam, A., Laher, R. R., Maguire, K., Nugent, P., Ofek, E. O., Surace, J., "The late-time light curve of the Type Ia supernova SN 2011fe", Monthly Notices of the Royal Astronomical Society, 468, 3798 (2017)

Farnes, J. S., Gaensler, B. M., Purcell, C., Sun, X. H., Haverkorn, M., Lenc, E., O'Sullivan, S. P., Akahori, T., "Interacting large-scale magnetic fields and ionized gas in the W50/SS433 system", Monthly Notices of the Royal Astronomical Society, 467, 4777 (2017)

Federrath, C., Salim, D. M., Medling, A. M., Davies, R. L., Yuan, T., Bian, F., Groves, B. A., Ho, I.-T., Sharp, R., Kewley, L. J., Sweet, S. M., Richards, S. N., Bryant, J. J., Brough, S., Croom, S., Scott, N., Lawrence, J., Konstantopoulos, I., Goodwin, M., "The SAMI Galaxy Survey: a new method to estimate molecular gas surface densities from star formation rates", Monthly Notices of the Royal Astronomical Society, 468, 3965 (2017)

Feng, L., Vaulin, R., Hewitt, J. N., Remillard, R., Kaplan, D. L., Murphy, T., Kudryavtseva, N., Hancock, P., Bernardi, G., Bowman, J. D., Briggs, F., Cappallo, R. J., Deshpande, A. A., Gaensler, B. M., Greenhill, L. J., Hazelton, B. J., Johnston-Hollitt, M., Lonsdale, C. J., McWhirter, S. R., Mitchell, D. A., Morales, M. F., Morgan, E., Oberoi, D., Ord, S. M., Prabu, T., Udaya Shankar, N., Srivani, K. S., Subrahmanyan, R., Tingay, S. J., Wayth, R. B., Webster, R. L., Williams, A., Williams, C. L., "A Matched Filter Technique for Slow Radio Transient Detection and First Demonstration with the Murchison Widefield Array", The Astronomical Journal, 153, 98 (2017)

Ferreras, I., Hopkins, A. M., Gunawardhana, M. L. P., Sansom, A. E., Owers, M. S., Driver, S., Davies, L., Robotham, A., Taylor, E. N., Konstantopoulos, I., Brough, S., Norberg, P., Croom, S., Loveday, J., Wang,

L., Bremer, M., "Galaxy and Mass Assembly (GAMA): probing the merger histories of massive galaxies via stellar populations", Monthly Notices of the Royal Astronomical Society, 468, 607 (2017)

Fisher, D. B., Glazebrook, K., Abraham, R. G., Damjanov, I., White, H. A., Obreschkow, D., Basset, R., Bekiaris, G., Wisnioski, E., Green, A., Bolatto, A. D., "Connecting Clump Sizes in Turbulent Disk Galaxies to Instability Theory", The Astrophysical Journal, 839, L5 (2017)

Fisher, D. B., Glazebrook, K., Damjanov, I., Abraham, R. G., Obreschkow, D., Wisnioski, E., Bassett, R., Green, A., McGregor, P., "DYNAMO-HST survey: clumps in nearby massive turbulent discs and the effects of clump clustering on kiloparsec scale measurements of clumps", Monthly Notices of the Royal Astronomical Society, 464, 491 (2017)

Fogasy, J., Knudsen, K. K., Lagos, C. D. P., Drouart, G., Gonzalez-Perez, V., "On the frequency of star-forming galaxies in the vicinity of powerful AGNs: The case of SMM J04135+10277", Astronomy and Astrophysics, 597, A123 (2017)

Foster, C., van de Sande, J., D'Eugenio, F., Cortese, L., McDermid, R. M., Bland-Hawthorn, J., Brough, S., Bryant, J., Croom, S. M., Goodwin, M., Konstantopoulos, I. S., Lawrence, J., López-Sánchez, Á. R., Medling, A. M., Owers, M. S., Richards, S. N., Scott, N., Taranu, D. S., Tonini, C., Zafar, T., "The SAMI Galaxy Survey: the intrinsic shape of kinematically selected galaxies", Monthly Notices of the Royal Astronomical Society, 472, 966 (2017)

Galluzzi, V., Massardi, M., Bonaldi, A., Casasola, V., Gregorini, L., Trombetti, T., Burigana, C., De Zotti, G., Ricci, R., Stevens, J., Ekers, R. D., Bonavera, L., di Serego Alighieri, S., Liuzzo, E., López-Caniego, M., Mignano, A., Paladino, R., Toffolatti, L., Tucci, M., "Multifrequency polarimetry of a complete sample of PACO radio sources", Monthly Notices of the Royal Astronomical Society, 465, 4085 (2017)

García, L. A., Tescari, E., Ryan-Weber, E. V., Wyithe, J. S. B., "Simulated metal and H I absorption lines at the conclusion of reionization", Monthly Notices of the Royal Astronomical Society, 470, 2494 (2017)

García, L. A., Tescari, E., Ryan-Weber, E. V., Wyithe, J. S. B., "Theoretical study of an LAE-C IV absorption pair at $z = 5.7$", Monthly Notices of the Royal Astronomical Society, 469, L53 (2017)

Geil, P. M., Mutch, S. J., Poole, G. B., Duffy, A. R., Mesinger, A., Wyithe, J. S. B., "Dark-ages reionization and galaxy formation simulation - XII. Bubbles at dawn", Monthly Notices of the Royal Astronomical Society, 472, 1324 (2017)

George, L. T., Dwarakanath, K. S., Johnston-Hollitt, M., Intema, H. T., Hurley-Walker, N., Bell, M. E., Callingham, J. R., For, B.-Q., Gaensler, B., Hancock, P. J., Hindson, L., Kapińska, A. D., Lenc, E., McKinley, B., Morgan, J., Offringa, A., Procopio, P., Staveley-Smith, L., Wayth, R. B., Wu, C., Zheng, Q., "A study of halo and relic radio emission in merging clusters using the Murchison Widefield Array", Monthly Notices of the Royal Astronomical Society, 467, 936 (2017)

Ghavamian, P., Seitenzahl, I. R., Vogt, F. P. A., Dopita, M. A., Terry, J. P., Williams, B. J., Winkler, P. F., "Integral Field Spectroscopy of Balmer-dominated Shocks in the Magellanic Cloud Supernova Remnant N103B", The Astrophysical Journal, 847, 122 (2017)

Gieseke, F., Bloemen, S., van den Bogaard, C., Heskes, T., Kindler, J., Scalzo, R. A., Ribeiro, V. A. R. M., van Roestel, J., Groot, P. J., Yuan, F., Möller, A., Tucker, B. E., "Convolutional neural networks for transient candidate vetting in large-scale surveys", Monthly Notices of the Royal Astronomical Society, 472, 3101 (2017)

Glowacki, M., Allison, J. R., Sadler, E. M., Moss, V. A., Curran, S. J., Musaeva, A., Deng, C., Parry, R., Sligo, M. C., "H I absorption in nearby compact radio galaxies", Monthly Notices of the Royal Astronomical Society, 467, 2766 (2017)

Goz, D., Monaco, P., Granato, G. L., Murante, G., Domínguez-Tenreiro, R., Obreja, A., Annunziatella, M., Tescari, E., "Panchromatic spectral energy distributions of simulated galaxies: results at redshift $z = 0$", Monthly Notices of the Royal Astronomical Society, 469, 3775 (2017)

Graikou, E., Verbiest, J. P. W., Osłowski, S., Champion, D. J., Tauris, T. M., Jankowski, F., Kramer, M., "Limits on the mass, velocity and orbit of PSR J1933-6211", Monthly Notices of the Royal Astronomical Society, 471, 4579 (2017)

H.E.S.S. Collaboration, Abdalla, H., Abramowski, A., Aharonian, F., Ait Benkhali, F., Akhperjanian, A. G., Andersson, T., Angüner, E. O., Arakawa, M., Arrieta, M., Aubert, P., Backes, M., Balzer, A., Barnard, M., Becherini, Y., Becker Tjus, J., Berge, D., Bernhard, S., Bernlöhr, K., Blackwell, R., Böttcher, M., Boisson, C., Bolmont, J., Bordas, P., Bregeon, J., Brun, F., Brun, P., Bryan, M., Büchele, M., Bulik, T., Capasso, M., Carr, J., Casanova, S., Cerruti, M., Chakraborty, N., Chalme-Calvet, R., Chaves, R. C. G., Chen, A., Chevalier, J., Chrétien, M., Coffaro, M., Colafrancesco, S., Cologna, G., Condon, B., Conrad, J., Cui, Y., Davids, I. D., Decock, J., Degrange, B., Deil, C., and 216 colleagues, "First limits on the very-high energy gamma-ray afterglow emission of a fast radio burst. H.E.S.S. observations of FRB 150418", Astronomy and Astrophysics, 597, A115 (2017)

Hampton, E. J., Medling, A. M., Groves, B., Kewley, L., Dopita, M., Davies, R., Ho, I.-T., Kaasinen, M., Leslie, S., Sharp, R., Sweet, S. M., Thomas, A. D., Allen, J., Bland-Hawthorn, J., Brough, S., Bryant, J. J., Croom, S., Goodwin, M., Green, A., Konstantantopoulos, I. S., Lawrence, J., López-Sánchez, Á. R., Lorente, N. P. F., McElroy, R., Owers, M. S., Richards, S. N., Shastri, P., "Using an artificial neural network to classify multicomponent emission lines with integral field spectroscopy from SAMI and S7", Monthly Notices of the Royal Astronomical Society, 470, 3395 (2017)

Hansen, T. T., Simon, J. D., Marshall, J. L., Li, T. S., Carollo, D., DePoy, D. L., Nagasawa, D. Q., Bernstein, R. A., Drlica-Wagner, A., Abdalla, F. B., Allam, S., Annis, J., Bechtol, K., Benoit-Lévy, A., Brooks, D., Buckley-Geer, E., Carnero Rosell, A., Carrasco Kind, M., Carretero, J., Cunha, C. E., da Costa, L. N., Desai, S., Eifler, T. F., Fausti Neto, A., Flaugher, B., Frieman, J., García-Bellido, J., Gaztanaga, E., Gerdes, D. W., Gruen,

D., Gruendl, R. A., Gschwend, J., Gutierrez, G., James, D. J., Krause, E., Kuehn, K., Kuropatkin, N., Lahav, O., Miquel, R., Plazas, A. A., Romer, A. K., Sanchez, E., Santiago, B., Scarpine, V., Smith, R. C., Soares-Santos, M., Sobreira, F., Suchyta, E., Swanson, M. E. C., Tarle, G., and 2 colleagues, "An r-process Enhanced Star in the Dwarf Galaxy Tucana III", The Astrophysical Journal, 838, 44 (2017)

Harnois-Déraps, J., Tröster, T., Chisari, N. E., Heymans, C., van Waerbeke, L., Asgari, M., Bilicki, M., Choi, A., Erben, T., Hildebrandt, H., Hoekstra, H., Joudaki, S., Kuijken, K., Merten, J., Miller, L., Robertson, N., Schneider, P., Viola, M., "KiDS-450: tomographic cross-correlation of galaxy shear with Planck lensing", Monthly Notices of the Royal Astronomical Society, 471, 1619 (2017)

Hinton, S. R., Kazin, E., Davis, T. M., Blake, C., Brough, S., Colless, M., Couch, W. J., Drinkwater, M. J., Glazebrook, K., Jurek, R. J., Parkinson, D., Pimbblet, K. A., Poole, G. B., Pracy, M., Woods, D., "Measuring the 2D baryon acoustic oscillation signal of galaxies in WiggleZ: cosmological constraints", Monthly Notices of the Royal Astronomical Society, 464, 4807 (2017)

Howlett, C., Percival, W. J., "Galaxy two-point covariance matrix estimation for next generation surveys", Monthly Notices of the Royal Astronomical Society, 472, 4935 (2017)

Howlett, C., Robotham, A. S. G., Lagos, C. D. P., Kim, A. G., "Measuring the Growth Rate of Structure with Type IA Supernovae from LSST", The Astrophysical Journal, 847, 128 (2017)

Howlett, C., Staveley-Smith, L., Blake, C., "Cosmological forecasts for combined and next-generation peculiar velocity surveys", Monthly Notices of the Royal Astronomical Society, 464, 2517 (2017)

Howlett, C., Staveley-Smith, L., Elahi, P. J., Hong, T., Jarrett, T. H., Jones, D. H., Koribalski, B. S., Macri, L. M., Masters, K. L., Springob, C. M., "2MTF - VI. Measuring the velocity power spectrum", Monthly Notices of the Royal Astronomical Society, 471, 3135 (2017)

Hurley-Walker, N., Callingham, J. R., Hancock, P. J., Franzen, T. M. O., Hindson, L., Kapińska, A. D., Morgan, J., Offringa, A. R., Wayth, R. B., Wu, C., Zheng, Q., Murphy, T., Bell, M. E., Dwarakanath, K. S., For, B., Gaensler, B. M., Johnston-Hollitt, M., Lenc, E., Procopio, P., Staveley-Smith, L., Ekers, R., Bowman, J. D., Briggs, F., Cappallo, R. J., Deshpande, A. A., Greenhill, L., Hazelton, B. J., Kaplan, D. L., Lonsdale, C. J., McWhirter, S. R., Mitchell, D. A., Morales, M. F., Morgan, E., Oberoi, D., Ord, S. M., Prabu, T., Shankar, N. U., Srivani, K. S., Subrahmanyan, R., Tingay, S. J., Webster, R. L., Williams, A., Williams, C. L., "GaLactic and Extragalactic All-sky Murchison Widefield Array (GLEAM) survey - I. A low-frequency extragalactic catalogue", Monthly Notices of the Royal Astronomical Society, 464, 1146 (2017)

Hutter, A., Dayal, P., Müller, V., Trott, C. M., "Exploring 21cm-Lyman Alpha Emitter Synergies for SKA", The Astrophysical Journal, 836, 176 (2017)

Ikarashi, S., Ivison, R. J., Caputi, K. I., Nakanishi, K., Lagos, C. D. P., Ashby, M. L. N., Aretxaga, I., Dunlop, J. S., Hatsukade, B., Hughes, D. H., Iono, D., Izumi, T., Kawabe, R., Kohno, K., Motohara, K., Ohta, K., Tamura, Y., Umehata, H., Wilson, G. W., Yabe, K., Yun, M. S., "Extremely Red Submillimeter Galaxies: New $z \geq 4$-6 Candidates Discovered using ALMA and Jansky VLA", The Astrophysical Journal, 835, 286 (2017)

Johnson, A., Blake, C., Amon, A., Erben, T., Glazebrook, K., Harnois-Deraps, J., Heymans, C., Hildebrandt, H., Joudaki, S., Klaes, D., Kuijken, K., Lidman, C., Marin, F. A., McFarland, J., Morrison, C. B., Parkinson, D., Poole, G. B., Radovich, M., Wolf, C., "2dFLenS and KiDS: determining source redshift distributions with cross-correlations", Monthly Notices of the Royal Astronomical Society, 465, 4118 (2017)

Johnston, S., Keane, E. F., Bhandari, S., Macquart, J.-P., Tingay, S. J., Barr, E., Bassa, C. G., Beswick, R., Burgay, M., Chandra, P., Honma, M., Kramer, M., Petroff, E., Possenti, A., Stappers, B. W., Sugai, H., "Radio light curve of the galaxy possibly associated with FRB 150418", Monthly Notices of the Royal Astronomical Society, 465, 2143 (2017)

Jordan, C. H., Murray, S., Trott, C. M., Wayth, R. B., Mitchell, D. A., Rahimi, M., Pindor, B., Procopio, P., Morgan, J., "Characterization of the ionosphere above the Murchison Radio Observatory using the Murchison Widefield Array", Monthly Notices of the Royal Astronomical Society, 471, 3974 (2017)

Jordan, C. H., Walsh, A. J., Breen, S. L., Ellingsen, S. P., Voronkov, M. A., Hyland, L. J., "MALT-45: A 7 mm survey of the southern Galaxy - II. ATCA follow-up observations of 44 GHz class I methanol masers", Monthly Notices of the Royal Astronomical Society, 471, 3915 (2017)

Joudaki, S., Mead, A., Blake, C., Choi, A., de Jong, J., Erben, T., Fenech Conti, I., Herbonnet, R., Heymans, C., Hildebrandt, H., Hoekstra, H., Joachimi, B., Klaes, D., Köhlinger, F., Kuijken, K., McFarland, J., Miller, L., Schneider, P., Viola, M., "KiDS-450: testing extensions to the standard cosmological model", Monthly Notices of the Royal Astronomical Society, 471, 1259 (2017)

Köhlinger, F., Viola, M., Joachimi, B., Hoekstra, H., van Uitert, E., Hildebrandt, H., Choi, A., Erben, T., Heymans, C., Joudaki, S., Klaes, D., Kuijken, K., Merten, J., Miller, L., Schneider, P., Valentijn, E. A., "KiDS-450: the tomographic weak lensing power spectrum and constraints on cosmological parameters", Monthly Notices of the Royal Astronomical Society, 471, 4412 (2017)

Kapińska, A. D., Staveley-Smith, L., Crocker, R., Meurer, G. R., Bhandari, S., Hurley-Walker, N., Offringa, A. R., Hanish, D. J., Seymour, N., Ekers, R. D., Bell, M. E., Callingham, J. R., Dwarakanath, K. S., For, B.-Q., Gaensler, B. M., Hancock, P. J., Hindson, L., Johnston-Hollitt, M., Lenc, E., McKinley, B., Morgan, J., Procopio, P., Wayth, R. B., Wu, C., Zheng, Q., Barry, N., Beardsley, A. P., Bowman, J. D., Briggs, F., Carroll, P., Dillon, J. S., Ewall-Wice, A., Feng, L., Greenhill, L. J., Hazelton, B. J., Hewitt, J. N., Jacobs, D. J., Kim, H.-S., Kittiwisit, P., Line, J., Loeb, A., Mitchell, D. A., Morales, M. F., Neben, A. R., Paul, S., Pindor, B., Pober, J. C., Riding, J., Sethi, S. K., Udaya Shankar, N., and 20 colleagues, "Spectral Energy Distribution and Radio Halo of NGC 253 at Low Radio Frequencies", The Astrophysical Journal, 838, 68 (2017)

Kapińska, A. D., Terentev, I., Wong, O. I., Shabala, S. S., Andernach, H., Rudnick, L., Storer, L., Banfield, J. K., Willett, K. W., de Gasperin, F., Lintott, C. J., López-Sánchez, Á. R., Middelberg, E., Norris, R. P., Schawinski, K., Seymour, N., Simmons, B., "Radio Galaxy Zoo: A Search for Hybrid Morphology Radio Galaxies", The Astronomical Journal, 154, 253 (2017)

Katsianis, A., Tescari, E., Blanc, G., Sargent, M., "The evolution of the star formation rate function and cosmic star formation rate density of galaxies at z ˜ 1-4", Monthly Notices of the Royal Astronomical Society, 464, 4977 (2017)

Kerzendorf, W. E., McCully, C., Taubenberger, S., Jerkstrand, A., Seitenzahl, I., Ruiter, A. J., Spyromilio, J., Long, K. S., Fransson, C., "Extremely late photometry of the nearby SN 2011fe", Monthly Notices of the Royal Astronomical Society, 472, 2534 (2017)

Kilbinger, M., Heymans, C., Asgari, M., Joudaki, S., Schneider, P., Simon, P., Van Waerbeke, L., Harnois-Déraps, J., Hildebrandt, H., Köhlinger, F., Kuijken, K., Viola, M., "Precision calculations of the cosmic shear power spectrum projection", Monthly Notices of the Royal Astronomical Society, 472, 2126 (2017)

Kim, H.-S., Wyithe, J. S. B., Baugh, C. M., Lagos, C. d. P., Power, C., Park, J., "The spatial distribution of neutral hydrogen as traced by low H I mass galaxies", Monthly Notices of the Royal Astronomical Society, 465, 111 (2017)

Kim, J., Chung, A., Wong, O. I., Lee, B., Sung, E.-C., Staveley-Smith, L., "HI properties and star formation history of a fly-by pair of blue compact dwarf galaxies", Astronomy and Astrophysics, 605, A54 (2017)

Krumpe, M., Husemann, B., Tremblay, G. R., Urrutia, T., Powell, M., Davis, T. A., Scharwächter, J., Dexter, J., Busch, G., Combes, F., Croom, S. M., Eckart, A., McElroy, R. E., Perez-Torres, M., Leung, G., "The Close AGN Reference Survey (CARS). Mrk 1018 halts dimming and experiences strong short-term variability", Astronomy and Astrophysics, 607, L9 (2017)

Lagattuta, D. J., Mould, J. R., Forbes, D. A., Monson, A. J., Pastorello, N., Persson, S. E., "Evidence of a Bottom-heavy Initial Mass Function in Massive Early-type Galaxies from Near-infrared Metal Lines", The Astrophysical Journal, 846, 166 (2017)

Lagos, C. d. P., Theuns, T., Stevens, A. R. H., Cortese, L., Padilla, N. D., Davis, T. A., Contreras, S., Croton, D., "Angular momentum evolution of galaxies in EAGLE", Monthly Notices of the Royal Astronomical Society, 464, 3850 (2017)

Lenc, E., Anderson, C. S., Barry, N., Bowman, J. D., Cairns, I. H., Farnes, J. S., Gaensler, B. M., Heald, G., Johnston-Hollitt, M., Kaplan, D. L., Lynch, C. R., McCauley, P. I., Mitchell, D. A., Morgan, J., Morales, M. F., Murphy, T., Offringa, A. R., Ord, S. M., Pindor, B., Riseley, C., Sadler, E. M., Sobey, C., Sokolowski, M., Sullivan, I. S., O'Sullivan, S. P., Sun, X. H., Tremblay, S. E., Trott, C. M., Wayth, R. B., "The Challenges of Low-Frequency Radio Polarimetry: Lessons from the Murchison Widefield Array", Publications of the Astronomical Society of Australia, 34, e040 (2017)

Leslie, S. K., Bryant, J. J., Ho, I.-T., Sadler, E. M., Medling, A. M., Groves, B., Kewley, L. J., Bland-Hawthorn, J., Croom, S. M., Wong, O. I., Brough, S., Tescari, E., Sweet, S. M., Sharp, R., Green, A. W., López-Sánchez, Á. R., Allen, J. T., Fogarty, L. M. R., Goodwin, M., Lawrence, J. S., Konstantopoulos, I. S., Owers, M. S., Richards, S. N., "The SAMI Galaxy Survey: disc-halo interactions in radio-selected star-forming galaxies", Monthly Notices of the Royal Astronomical Society, 471, 2438 (2017)

Line, J. L. B., Webster, R. L., Pindor, B., Mitchell, D. A., Trott, C. M., "PUMA: The Positional Update and Matching Algorithm", Publications of the Astronomical Society of Australia, 34, e003 (2017)

Lutz, K. A., Kilborn, V. A., Catinella, B., Koribalski, B. S., Brown, T. H., Cortese, L., Dénes, H., Józsa, G. I. G., Wong, O. I., "The HIX galaxy survey I: Study of the most gas rich galaxies from HIPASS", Monthly Notices of the Royal Astronomical Society, 467, 1083 (2017)

Lynch, C. R., Lenc, E., Kaplan, D. L., Murphy, T., Anderson, G. E., "154 MHz Detection of Faint, Polarized Flares from UV Ceti", The Astrophysical Journal, 836, L30 (2017)

Lynch, C. R., Murphy, T., Kaplan, D. L., Ireland, M., Bell, M. E., "A search for circularly polarized emission from young exoplanets", Monthly Notices of the Royal Astronomical Society, 467, 3447 (2017)

Macaulay, E., Davis, T. M., Scovacricchi, D., Bacon, D., Collett, T., Nichol, R. C., "The effects of velocities and lensing on moments of the Hubble diagram", Monthly Notices of the Royal Astronomical Society, 467, 259 (2017)

Matsuura, M., Indebetouw, R., Woosley, S., Bujarrabal, V., Abellán, F. J., McCray, R., Kamenetzky, J., Fransson, C., Barlow, M. J., Gomez, H. L., Cigan, P., De Looze, I., Spyromilio, J., Staveley-Smith, L., Zanardo, G., Roche, P., Larsson, J., Viti, S., van Loon, J. T., Wheeler, J. C., Baes, M., Chevalier, R., Lundqvist, P., Marcaide, J. M., Dwek, E., Meixner, M., Ng, C.-Y., Sonneborn, G., Yates, J., "ALMA spectral survey of Supernova 1987A – molecular inventory, chemistry, dynamics and explosive nucleosynthesis", Monthly Notices of the Royal Astronomical Society, 469, 3347 (2017)

McCully, C., Hiramatsu, D., Howell, D. A., Hosseinzadeh, G., Arcavi, I., Kasen, D., Barnes, J., Shara, M. M., Williams, T. B., Väisänen, P., Potter, S. B., Romero-Colmenero, E., Crawford, S. M., Buckley, D. A. H., Cooke, J., Andreoni, I., Pritchard, T. A., Mao, J., Gromadzki, M., Burke, J., "The Rapid Reddening and Featureless Optical Spectra of the Optical Counterpart of GW170817, AT 2017gfo, during the First Four Days", The Astrophysical Journal, 848, L32 (2017)

McSweeney, S. J., Bhat, N. D. R., Tremblay, S. E., Deshpande, A. A., Ord, S. M., "Low-frequency Observations of the Subpulse Drifter PSR J0034-0721 with the Murchison Widefield Array", 2017, The Astrophysical Journal, 836

Meyers, B. W., Hurley-Walker, N., Hancock, P. J., Franzen, T. M. O., Carretti, E., Staveley-Smith, L., Gaensler, B. M., Haverkorn, M., Poppi, S., "A

Southern-Sky Total Intensity Source Catalogue at 2.3 GHz from S-Band Polarisation All-Sky Survey Data", Publications of the Astronomical Society of Australia, 34, e013 (2017)

Meyers, B. W., Tremblay, S. E., Bhat, N. D. R., Shannon, R. M., Kirsten, F., Sokolowski, M., Tingay, S. J., Oronsaye, S. I., Ord, S. M., "Spectral Flattening at Low Frequencies in Crab Giant Pulses", The Astrophysical Journal, 851, 20 (2017)

Morabito, L. K., Williams, W. L., Duncan, K. J., Röttgering, H. J. A., Miley, G., Saxena, A., Barthel, P., Best, P. N., Bruggen, M., Brunetti, G., Chyży, K. T., Engels, D., Hardcastle, M. J., Harwood, J. J., Jarvis, M. J., Mahony, E. K., Prandoni, I., Shimwell, T. W., Shulevski, A., Tasse, C., "Investigating the unification of LOFAR-detected powerful AGN in the Boötes field", Monthly Notices of the Royal Astronomical Society, 469, 1883 (2017)

Moss, V. A., Allison, J. R., Sadler, E. M., Urquhart, R., Soria, R., Callingham, J. R., Curran, S. J., Musaeva, A., Mahony, E. K., Glowacki, M., Farrell, S. A., Bannister, K. W., Chippendale, A. P., Edwards, P. G., Harvey-Smith, L., Heywood, I., Hotan, A. W., Indermuehle, B. T., Lenc, E., Marvil, J., McConnell, D., Reynolds, J. E., Voronkov, M. A., Wark, R. M., Whiting, M. T., "Connecting X-ray absorption and 21 cm neutral hydrogen absorption in obscured radio AGN", Monthly Notices of the Royal Astronomical Society, 471, 2952 (2017)

Moss, V. A., Lockman, F. J., McClure-Griffiths, N. M., "Tracing Dense and Diffuse Neutral Hydrogen in the Halo of the Milky Way", The Astrophysical Journal, 834, 155 (2017)

Mould, J., "Modified gravity and large scale flows, a review", Astrophysics and Space Science, 362, 25 (2017)

Mudd, D., Martini, P., Tie, S. S., Lidman, C., McMahon, R., Banerji, M., Davis, T., Peterson, B., Sharp, R., Seymour, N., Childress, M., Lewis, G., Tucker, B., Yuan, F., Abbot, T., Abdalla, F., Allam, S., Benoit-Lévy, A., Bertin, E., Brooks, D., Camero Rosell, A., Carrasco Kind, M., Carretero, J., da Costa, L. N., Desai, S., Diehl, T., Eifler, T., Finley, D., Flaugher, B., Glazebrook, K., Gruen, D., Gruendl, R., Gutierrez, G., Hinton, S., Honscheid, K., James, D., Kuehn, K., Kuropatkin, N., Macaulay, E., Maia, M. A. G., Miquel, R., Ogando, R., Plazas, A., Riel, K., Sanchez, E., Santiago, B., Schubnell, M., Sevilla-Noarbe, I., Smith, R. C., Soares-Santos, M., and 8 colleagues, "Discovery of a z = 0.65 post-starburst BAL quasar in the DES supernova fields", Monthly Notices of the Royal Astronomical Society, 468, 3682 (2017)

Murphy, T., Kaplan, D. L., Bell, M. E., Callingham, J. R., Croft, S., Johnston, S., Dobie, D., Zic, A., Hughes, J., Lynch, C., Hancock, P., Hurley-Walker, N., Lenc, E., Dwarakanath, K. S., For, B.-Q., Gaensler, B. M., Hindson, L., Johnston-Hollitt, M., Kapińska, A. D., McKinley, B., Morgan, J., Offringa, A. R., Procopio, P., Staveley-Smith, L., Wayth, R., Wu, C., Zheng, Q., "Low-Frequency Spectral Energy Distributions of Radio Pulsars Detected with the Murchison Widefield Array", Publications of the Astronomical Society of Australia, 34, e020 (2017)

Murphy, T., Kaplan, D. L., Croft, S., Lynch, C., Callingham, J. R., Bannister, K., Bell, M. E., Hurley-Walker, N., Hancock, P., Line, J., Rowlinson, A., Lenc, E., Intema, H. T., Jagannathan, P., Ekers, R. D., Tingay, S., Yuan, F., Wolf, C., Onken, C. A., Dwarakanath, K. S., For, B.-Q., Gaensler, B. M., Hindson, L., Johnston-Hollitt, M., Kapińska, A. D., McKinley, B., Morgan, J., Offringa, A. R., Procopio, P., Staveley-Smith, L., Wayth, R., Wu, C., Zheng, Q., "A search for long-time-scale, low-frequency radio transients", Monthly Notices of the Royal Astronomical Society, 466, 1944 (2017)

Murray, S. G., Trott, C. M., Jordan, C. H., "An Improved Statistical Point-source Foreground Model for the Epoch of Reionization", The Astrophysical Journal, 845, 7 (2017)

Neveu, J., Ruhlmann-Kleider, V., Astier, P., Besançon, M., Guy, J., Möller, A., Babichev, E., "Constraining the ΛCDM and Galileon models with recent cosmological data", Astronomy and Astrophysics, 600, A40 (2017)

O'Sullivan, S. P., Purcell, C. R., Anderson, C. S., Farnes, J. S., Sun, X. H., Gaensler, B. M., "Broad-band, radio spectro-polarimetric study of 100 radiative-mode and jet-mode AGN", Monthly Notices of the Royal Astronomical Society, 469, 4034 (2017)

Owers, M. S., Allen, J. T., Baldry, I., Bryant, J. J., Cecil, G. N., Cortese, L., Croom, S. M., Driver, S. P., Fogarty, L. M. R., Green, A. W., Helmich, E., de Jong, J. T. A., Kuijken, K., Mahajan, S., McFarland, J., Pracy, M. B., Robotham, A. G. S., Sikkema, G., Sweet, S., Taylor, E. N., Verdoes Kleijn, G., Bauer, A. E., Bland-Hawthorn, J., Brough, S., Colless, M., Couch, W. J., Davies, R. L., Drinkwater, M. J., Goodwin, M., Hopkins, A. M., Konstantopoulos, I. S., Foster, C., Lawrence, J. S., Lorente, N. P. F., Medling, A. M., Metcalfe, N., Richards, S. N., van de Sande, J., Scott, N., Shanks, T., Sharp, R., Thomas, A. D., Tonini, C., "The SAMI Galaxy Survey: the cluster redshift survey, target selection and cluster properties", Monthly Notices of the Royal Astronomical Society, 468, 1824 (2017)

Paillas, E., Lagos, C. D. P., Padilla, N., Tissera, P., Helly, J., Schaller, M., "Baryon effects on void statistics in the EAGLE simulation", Monthly Notices of the Royal Astronomical Society, 470, 4434 (2017)

Palmese, A., Hartley, W., Tarsitano, F., Conselice, C., Lahav, O., Allam, S., Annis, J., Lin, H., Soares-Santos, M., Tucker, D., Brout, D., Banerji, M., Bechtol, K., Diehl, H. T., Fruchter, A., García-Bellido, J., Herner, K., Levan, A. J., Li, T. S., Lidman, C., Misra, K., Sako, M., Scolnic, D., Smith, M., Abbott, T. M. C., Abdalla, F. B., Benoit-Lévy, A., Bertin, E., Brooks, D., Buckley-Geer, E., Carnero Rosell, A., Carrasco Kind, M., Carretero, J., Castander, F. J., Cunha, C. E., D'Andrea, C. B., da Costa, L. N., Davis, C., DePoy, D. L., Desai, S., Dietrich, J. P., Doel, P., Drlica-Wagner, A., Eifler, T. F., Evrard, A. E., Flaugher, B., Fosalba, P., Frieman, J., Gaztanaga, E., Gerdes, D. W., and 42 colleagues, "Evidence for Dynamically Driven Formation of the GW170817 Neutron Star Binary in NGC 4993", The Astrophysical Journal, 849, L34 (2017)

Petroff, E., Burke-Spolaor, S., Keane, E. F., McLaughlin, M. A., Miller, R., Andreoni, I., Bailes, M., Barr, E. D., Bernard, S. R., Bhandari, S., Bhat, N. D. R., Burgay, M., Caleb, M., Champion, D., Chandra, P., Cooke, J., Dhillon, V. S., Farnes, J. S., Hardy,

L. K., Jaroenjittichai, P., Johnston, S., Kasliwal, M., Kramer, M., Littlefair, S. P., Macquart, J. P., Mickaliger, M., Possenti, A., Pritchard, T., Ravi, V., Rest, A., Rowlinson, A., Sawangwit, U., Stappers, B., Sullivan, M., Tiburzi, C., van Straten, W., ANTARES Collaboration, Albert, A., André, M., Anghinolfi, M., Anton, G., Ardid, M., Aubert, J.-J., Avgitas, T., Baret, B., Barrios-Martí, J., Basa, S., Bertin, V., Biagi, S., Bormuth, R., and 367 colleagues, "A polarized fast radio burst at low Galactic latitude", Monthly Notices of the Royal Astronomical Society, 469, 4465 (2017)

Procopio, P., Wayth, R. B., Line, J., Trott, C. M., Intema, H. T., Mitchell, D. A., Pindor, B., Riding, J., Tingay, S. J., Bell, M. E., Callingham, J. R., Dwarakanath, K. S., For, B.-Q., Gaensler, B. M., Hancock, P. J., Hindson, L., Hurley-Walker, N., Johnston-Hollitt, M., Kapińska, A. D., Lenc, E., McKinley, B., Morgan, J., Offringa, A., Staveley-Smith, L., Wu, C., Zheng, Q., "A High-Resolution Foreground Model for the MWA EoR1 Field: Model and Implications for EoR Power Spectrum Analysis", Publications of the Astronomical Society of Australia, 34, e033 (2017)

Reynolds, T. N., Staveley-Smith, L., Rhee, J., Westmeier, T., Chippendale, A. P., Deng, X., Ekers, R. D., Kramer, M., "Spectral-Line Observations Using a Phased Array Feed on the Parkes Telescope", Publications of the Astronomical Society of Australia, 34, e051 (2017)

Richards, S. N., Leon-Saval, S., Goodwin, M., Zheng, J., Lawrence, J. S., Bryant, J. J., Bland-Hawthorn, J., Norris, B., Cvetojevic, N., Argyros, A., "Performance of a Novel PMMA Polymer Imaging Bundle for Field Acquisition and Wavefront Sensing", Publications of the Astronomical Society of Australia, 34, e008 (2017)

Ridden-Harper, R., Tucker, B. E., Sharp, R., Gilbert, J., Petkovic, M., "Capability of detecting ultraviolet counterparts of gravitational waves with GLUV", Monthly Notices of the Royal Astronomical Society, 472, 4521 (2017)

Riemer-Sørensen, S., Kotuš, S., Webb, J. K., Ali, K., Dumont, V., Murphy, M. T., Carswell, R. F., "A precise deuterium abundance: remeasurement of the z = 3.572 absorption system towards the quasar PKS1937-101", Monthly Notices of the Royal Astronomical Society, 468, 3239 (2017)

Robitaille, J.-F., Scaife, A. M. M., Carretti, E., Gaensler, B. M., McEwen, J. D., Leistedt, B., Haverkorn, M., Bernardi, G., Kesteven, M. J., Poppi, S., Staveley-Smith, L., "A new perspective on turbulent Galactic magnetic fields through comparison of linear polarization decomposition techniques", Monthly Notices of the Royal Astronomical Society, 468, 2957 (2017)

Robotham, A. S. G., Taranu, D. S., Tobar, R., Moffett, A., Driver, S. P., "PROFIT: Bayesian profile fitting of galaxy images", Monthly Notices of the Royal Astronomical Society, 466, 1513 (2017)

Rorai, A., Becker, G. D., Haehnelt, M. G., Carswell, R. F., Bolton, J. S., Cristiani, S., D'Odorico, V., Cupani, G., Barai, P., Calura, F., Kim, T.-S., Pomante, E., Tescari, E., Viel, M., "Exploring the thermal state of the low-density intergalactic medium at z = 3 with an ultrahigh signal-to-noise QSO spectrum", Monthly Notices of the Royal Astronomical Society, 466, 2690 (2017)

Sánchez-Ramírez, R., Hancock, P. J., Jóhannesson, G., Murphy, T., de Ugarte Postigo, A., Gorosabel, J., Kann, D. A., Krühler, T., Oates, S. R., Japelj, J., Thöne, C. C., Lundgren, A., Perley, D. A., Malesani, D., de Gregorio Monsalvo, I., Castro-Tirado, A. J., D'Elia, V., Fynbo, J. P. U., Garcia-Appadoo, D., Goldoni, P., Greiner, J., Hu, Y.-D., Jelínek, M., Jeong, S., Kamble, A., Klose, S., Kuin, N. P. M., Llorente, A., Martín, S., Nicuesa Guelbenzu, A., Rossi, A., Schady, P., Sparre, M., Sudilovsky, V., Tello, J. C., Updike, A., Wiersema, K., Zhang, B.-B., "GRB 110715A: the peculiar multiwavelength evolution of the first afterglow detected by ALMA", Monthly Notices of the Royal Astronomical Society, 464, 4624 (2017)

Sasdelli, M., Hillebrandt, W., Kromer, M., Ishida, E. E. O., Röpke, F. K., Sim, S. A., Pakmor, R., Seitenzahl, I. R., Fink, M., "A metric space for Type Ia supernova spectra: a new method to assess explosion scenarios", Monthly Notices of the Royal Astronomical Society, 466, 3784 (2017)

Scalzo, R. A., Yuan, F., Childress, M. J., Möller, A., Schmidt, B. P., Tucker, B. E., Zhang, B. R., Onken, C. A., Wolf, C., Astier, P., Betoule, M., Regnault, N., "The SkyMapper Transient Survey", Publications of the Astronomical Society of Australia, 34, e030 (2017)

Schaefer, A. L., Croom, S. M., Allen, J. T., Brough, S., Medling, A. M., Ho, I.-T., Scott, N., Richards, S. N., Pracy, M. B., Gunawardhana, M. L. P., Norberg, P., Alpaslan, M., Bauer, A. E., Bekki, K., Bland-Hawthorn, J., Bloom, J. V., Bryant, J. J., Couch, W. J., Driver, S. P., Fogarty, L. M. R., Foster, C., Goldstein, G., Green, A. W., Hopkins, A. M., Konstantopoulos, I. S., Lawrence, J. S., López-Sánchez, A. R., Lorente, N. P. F., Owers, M. S., Sharp, R., Sweet, S. M., Taylor, E. N., van de Sande, J., Walcher, C. J., Wong, O. I., "The SAMI Galaxy Survey: spatially resolving the environmental quenching of star formation in GAMA galaxies", Monthly Notices of the Royal Astronomical Society, 464, 121 (2017)

Scholz, P., Camilo, F., Sarkissian, J., Reynolds, J. E., Levin, L., Bailes, M., Burgay, M., Johnston, S., Kramer, M., Possenti, A., "Spin-down Evolution and Radio Disappearance of the Magnetar PSR J1622-4950", The Astrophysical Journal, 841, 126 (2017)

Scott, N., Brough, S., Croom, S. M., Davies, R. L., van de Sande, J., Allen, J. T., Bland-Hawthorn, J., Bryant, J. J., Cortese, L., D'Eugenio, F., Federrath, C., Ferreras, I., Goodwin, M., Groves, B., Konstantopoulos, I., Lawrence, J. S., Medling, A. M., Moffett, A. J., Owers, M. S., Richards, S., Robotham, A. S. G., Tonini, C., Yi, S. K., "The SAMI Galaxy Survey: global stellar populations on the size-mass plane", Monthly Notices of the Royal Astronomical Society, 472, 2833 (2017)

Scovacricchi, D., Nichol, R. C., Macaulay, E., Bacon, D., "Measuring weak lensing correlations of Type Ia supernovae", Monthly Notices of the Royal Astronomical Society, 465, 2862 (2017)

Shimwell, T. W., Röttgering, H. J. A., Best, P. N., Williams, W. L., Dijkema, T. J., de Gasperin, F., Hardcastle, M. J., Heald, G. H., Hoang, D. N., Horneffer, A., Intema, H., Mahony, E. K., Mandal, S., Mechev, A. P., Morabito, L., Oonk, J. B. R., Rafferty, D., Retana-Montenegro, E., Sabater, J., Tasse, C., van Weeren, R. J., Brüggen, M., Brunetti, G., Chyży, K. T.,

Conway, J. E., Haverkorn, M., Jackson, N., Jarvis, M. J., McKean, J. P., Miley, G. K., Morganti, R., White, G. J., Wise, M. W., van Bemmel, I. M., Beck, R., Brienza, M., Bonafede, A., Calistro Rivera, G., Cassano, R., Clarke, A. O., Cseh, D., Deller, A., Drabent, A., van Driel, W., Engels, D., Falcke, H., Ferrari, C., Fröhlich, S., Garrett, M. A., Harwood, J. J., and 22 colleagues, "The LOFAR Two-metre Sky Survey. I. Survey description and preliminary data release", Astronomy and Astrophysics, 598, A104 (2017)

Smartt, S. J., Chen, T.-W., Jerkstrand, A., Coughlin, M., Kankare, E., Sim, S. A., Fraser, M., Inserra, C., Maguire, K., Chambers, K. C., Huber, M. E., Krühler, T., Leloudas, G., Magee, M., Shingles, L. J., Smith, K. W., Young, D. R., Tonry, J., Kotak, R., Gal-Yam, A., Lyman, J. D., Homan, D. S., Agliozzo, C., Anderson, J. P., Angus, C. R., Ashall, C., Barbarino, C., Bauer, F. E., Berton, M., Botticella, M. T., Bulla, M., Bulger, J., Cannizzaro, G., Cano, Z., Cartier, R., Cikota, A., Clark, P., De Cia, A., Della Valle, M., Denneau, L., Dennefeld, M., Dessart, L., Dimitriadis, G., Elias-Rosa, N., Firth, R. E., Flewelling, H., Flörs, A., Franckowiak, A., Frohmaier, C., Galbany, L., and 72 colleagues, "A kilonova as the electromagnetic counterpart to a gravitational-wave source", Nature, 551, 75 (2017)

Smolčić, V., Novak, M., Bondi, M., Ciliegi, P., Mooley, K. P., Schinnerer, E., Zamorani, G., Navarrete, F., Bourke, S., Karim, A., Vardoulaki, E., Leslie, S., Delhaize, J., Carilli, C. L., Myers, S. T., Baran, N., Delvecchio, I., Miettinen, O., Banfield, J., Baloković, M., Bertoldi, F., Capak, P., Frail, D. A., Hallinan, G., Hao, H., Herrera Ruiz, N., Horesh, A., Ilbert, O., Intema, H., Jelić, V., Klöckner, H.-R., Krpan, J., Kulkarni, S. R., McCracken, H., Laigle, C., Middleberg, E., Murphy, E. J., Sargent, M., Scoville, N. Z., Sheth, K., "The VLA-COSMOS 3 GHz Large Project: Continuum data and source catalog release", Astronomy and Astrophysics, 602, A1 (2017)

Sokolowski, M., Colegate, T., Sutinjo, A. T., Ung, D., Wayth, R., Hurley-Walker, N., Lenc, E., Pindor, B., Morgan, J., Kaplan, D. L., Bell, M. E., Callingham, J. R., Dwarakanath, K. S., For, B.-Q., Gaensler, B. M., Hancock, P. J., Hindson, L., Johnston-Hollitt, M., Kapińska, A. D., McKinley, B., Offringa, A. R., Procopio, P., Staveley-Smith, L., Wu, C., Zheng, Q., "Calibration and Stokes Imaging with Full Embedded Element Primary Beam Model for the Murchison Widefield Array", Publications of the Astronomical Society of Australia, 34, e062 (2017)

Stevens, A. R. H., Lagos, C. d. P., Contreras, S., Croton, D. J., Padilla, N. D., Schaller, M., Schaye, J., Theuns, T., "How to get cool in the heat: comparing analytic models of hot, cold, and cooling gas in haloes and galaxies with EAGLE", Monthly Notices of the Royal Astronomical Society, 467, 2066 (2017)

Su, H., Hurley-Walker, N., Jackson, C. A., McClure-Griffiths, N. M., Tingay, S. J., Hindson, L., Hancock, P., Wayth, R. B., Gaensler, B. M., Staveley-Smith, L., Morgan, J., Johnston-Hollitt, M., Lenc, E., Bell, M. E., Callingham, J. R., Dwarkanath, K. S., For, B.-Q., Kapińska, A. D., McKinley, B., Offringa, A. R., Procopio, P., Wu, C., Zheng, Q., "Galactic synchrotron emissivity measurements between 250° < l < 355° from the GLEAM survey with the MWA", Monthly Notices of the Royal Astronomical Society, 465, 3163 (2017)

Suresh, A., Sharma, R., Oberoi, D., Das, S. B., Pankratius, V., Timar, B., Lonsdale, C. J., Bowman, J. D., Briggs, F., Cappallo, R. J., Corey, B. E., Deshpande, A. A., Emrich, D., Goeke, R., Greenhill, L. J., Hazelton, B. J., Johnston-Hollitt, M., Kaplan, D. L., Kasper, J. C., Kratzenberg, E., Lynch, M. J., McWhirter, S. R., Mitchell, D. A., Morales, M. F., Morgan, E., Ord, S. M., Prabu, T., Rogers, A. E. E., Roshi, A., Udaya Shankar, N., Srivani, K. S., Subrahmanyan, R., Tingay, S. J., Waterson, M., Wayth, R. B., Webster, R. L., Whitney, A. R., Williams, A., Williams, C. L., "Wavelet-based Characterization of Small-scale Solar Emission Features at Low Radio Frequencies", The Astrophysical Journal, 843, 19 (2017)

Swinbank, A. M., Harrison, C. M., Trayford, J., Schaller, M., Smail, I., Schaye, J., Theuns, T., Smit, R., Alexander, D. M., Bacon, R., Bower, R. G., Contini, T., Crain, R. A., de Breuck, C., Decarli, R., Epinat, B., Fumagalli, M., Furlong, M., Galametz, A., Johnson, H. L., Lagos, C., Richard, J., Vernet, J., Sharples, R. M., Sobral, D., Stott, J. P., "Angular momentum evolution of galaxies over the past 10 Gyr: a MUSE and KMOS dynamical survey of 400 star-forming galaxies from z = 0.3 to 1.7", Monthly Notices of the Royal Astronomical Society, 467, 3140 (2017)

Taranu, D. S., Obreschkow, D., Dubinski, J. J., Fogarty, L. M. R., van de Sande, J., Catinella, B., Cortese, L., Moffett, A., Robotham, A. S. G., Allen, J. T., Bland-Hawthorn, J., Bryant, J. J., Colless, M., Croom, S. M., D'Eugenio, F., Davies, R. L., Drinkwater, M. J., Driver, S. P., Goodwin, M., Konstantopoulos, I. S., Lawrence, J. S., López-Sánchez, Á. R., Lorente, N. P. F., Medling, A. M., Mould, J. R., Owers, M. S., Power, C., Richards, S. N., Tonini, C., "Self-consistent Bulge/Disk/Halo Galaxy Dynamical Modeling Using Integral Field Kinematics", The Astrophysical Journal, 850, 70 (2017)

Thomas, A. D., Dopita, M. A., Shastri, P., Davies, R., Hampton, E., Kewley, L., Banfield, J., Groves, B., James, B. L., Jin, C., Juneau, S., Kharb, P., Sairam, L., Scharwächter, J., Shalima, P., Sundar, M. N., Sutherland, R., Zaw, I., "Probing the Physics of Narrow-line Regions in Active Galaxies. IV. Full Data Release of the Siding Spring Southern Seyfert Spectroscopic Snapshot Survey (S7)", The Astrophysical Journal Supplement Series, 232, 11 (2017)

Tremblay, C. D., Hurley-Walker, N., Cunningham, M., Jones, P. A., Hancock, P. J., Wayth, R., Jordan, C. H., "A first look for molecules between 103 and 133 MHz using the Murchison Widefield Array", Monthly Notices of the Royal Astronomical Society, 471, 4144 (2017)

Trott, C. M., de Lera Acedo, E., Wayth, R. B., Fagnoni, N., Sutinjo, A. T., Wakley, B., Punzalan, C. I. B., "Spectral performance of Square Kilometre Array Antennas - II. Calibration performance", Monthly Notices of the Royal Astronomical Society, 470, 455 (2017)

Uddin, S. A., Mould, J., Lidman, C., Ruhlmann-Kleider, V., Hardin, D., "Cosmological Inference from Host-Selected Type Ia Supernova Samples", Publications of the Astronomical Society of Australia, 34, e009 (2017)

Uddin, S. A., Mould, J., Lidman, C., Ruhlmann-Kleider, V., Zhang, B. R., "The Influence of Host Galaxies in Type Ia Supernova Cosmology", The Astrophysical Journal, 848, 56 (2017)

Uddin, S. A., Mould, J., Wang, L., "Average Spectral Properties of Type Ia Supernova Host Galaxies", The Astrophysical Journal, 850, 135 (2017)

van de Sande, J., Bland-Hawthorn, J., Brough, S., Croom, S. M., Cortese, L., Foster, C., Scott, N., Bryant, J. J., d'Eugenio, F., Tonini, C., Goodwin, M., Konstantopoulos, I. S., Lawrence, J. S., Medling, A. M., Owers, M. S., Richards, S. N., Schaefer, A. L., Yi, S. K., "The SAMI Galaxy Survey: revising the fraction of slow rotators in IFS galaxy surveys", Monthly Notices of the Royal Astronomical Society, 472, 1272 (2017)

van de Sande, J., Bland-Hawthorn, J., Fogarty, L. M. R., Cortese, L., d'Eugenio, F., Croom, S. M., Scott, N., Allen, J. T., Brough, S., Bryant, J. J., Cecil, G., Colless, M., Couch, W. J., Davies, R., Elahi, P. J., Foster, C., Goldstein, G., Goodwin, M., Groves, B., Ho, I.-T., Jeong, H., Jones, D. H., Konstantopoulos, I. S., Lawrence, J. S., Leslie, S. K., López-Sánchez, Á. R., McDermid, R. M., McElroy, R., Medling, A. M., Oh, S., Owers, M. S., Richards, S. N., Schaefer, A. L., Sharp, R., Sweet, S. M., Taranu, D., Tonini, C., Walcher, C. J., Yi, S. K., "The SAMI Galaxy Survey: Revisiting Galaxy Classification through High-order Stellar Kinematics", The Astrophysical Journal, 835, 104 (2017)

van Straten, W., Tiburzi, C., "The Statistics of Radio Astronomical Polarimetry: Disjoint, Superposed, and Composite Samples", The Astrophysical Journal, 835, 293 (2017)

Vernstrom, T., Gaensler, B. M., Brown, S., Lenc, E., Norris, R. P., "Low-frequency radio constraints on the synchrotron cosmic web", Monthly Notices of the Royal Astronomical Society, 467, 4914 (2017)

Vogt, F. P. A., Seitenzahl, I. R., Dopita, M. A., Ghavamian, P., "[Fe XIV] and [Fe XI] reveal the forward shock in SNR 1E 0102.2-7219", Astronomy and Astrophysics, 602, L4 (2017)

Vogt, F. P. A., Seitenzahl, I. R., Dopita, M. A., Ruiter, A. J., "Linking the X3D Pathway to Integral Field Spectrographs: YSNR 1E 0102.2-7219 in the SMC as a Case Study", Publications of the Astronomical Society of the Pacific, 129, 058012 (2017)

Vohl, D., Pritchard, T., Andreoni, I., Cooke, J., Meade, B., "Enabling Near Real-Time Remote Search for Fast Transient Events with Lossy Data Compression", Publications of the Astronomical Society of Australia, 34, e038 (2017)

Wang, J., Koribalski, B. S., Jarrett, T. H., Kamphuis, P., Li, Z.-Y., Ho, L. C., Westmeier, T., Shao, L., Lagos, C. d. P., Wong, O. I., Serra, P., Staveley-Smith, L., Józsa, G., van der Hulst, T., López-Sánchez, Á. R., "The Local Volume H I Survey: star formation properties", Monthly Notices of the Royal Astronomical Society, 472, 3029 (2017)

Weigel, A. K., Schawinski, K., Caplar, N., Wong, O. I., Treister, E., Trakhtenbrot, B., "AGNs and Their Host Galaxies in the Local Universe: Two Mass-independent Eddington Ratio Distribution Functions Characterize Black Hole Growth", The Astrophysical Journal, 845, 134 (2017)

Westmeier, T., Obreschkow, D., Calabretta, M., Jurek, R., Koribalski, B. S., Meyer, M., Musaeva, A., Popping, A., Staveley-Smith, L., Wong, O. I., Wright, A., "A deep Parkes H I survey of the Sculptor group and filament: H I mass function and environment", Monthly Notices of the Royal Astronomical Society, 472, 4832 (2017)

Wolf, C., Johnson, A. S., Bilicki, M., Blake, C., Amon, A., Erben, T., Glazebrook, K., Heymans, C., Hildebrandt, H., Joudaki, S., Klaes, D., Kuijken, K., Lidman, C., Marin, F., Parkinson, D., Poole, G., "The 2-degree Field Lensing Survey: photometric redshifts from a large new training sample to r < 19.5", Monthly Notices of the Royal Astronomical Society, 466, 1582 (2017)

Wolz, L., Blake, C., Abdalla, F. B., Anderson, C. J., Chang, T.-C., Li, Y.-C., Masui, K. W., Switzer, E., Pen, U.-L., Voytek, T. C., Yadav, J., "Erasing the Milky Way: new cleaning technique applied to GBT intensity mapping data", Monthly Notices of the Royal Astronomical Society, 464, 4938 (2017)

Wolz, L., Blake, C., Wyithe, J. S. B., "Determining the H I content of galaxies via intensity mapping cross-correlations", Monthly Notices of the Royal Astronomical Society, 470, 3220 (2017)

Wong, O. I., Vega, O., Sánchez-Argüelles, D., Narayanan, G., Wall, W. F., Zwaan, M. A., Rosa González, D., Zeballos, M., Bekki, K., Mayya, Y. D., Montaña, A., Chung, A., "Early Science with the Large Millimeter Telescope: discovery of the ^{12}CO(1–0) emission line in the ring galaxy VIIZw466", Monthly Notices of the Royal Astronomical Society, 466, 574 (2017)

Wright, W. P., Kneller, J. P., Ohlmann, S. T., Röpke, F. K., Scholberg, K., Seitenzahl, I. R., "Neutrinos from type Ia supernovae: The gravitationally confined detonation scenario", Physical Review D, 95, 043006 (2017)

Xue, M., Bhat, N. D. R., Tremblay, S. E., Ord, S. M., Sobey, C., Swainston, N. A., Kaplan, D. L., Johnston, S., Meyers, B. W., McSweeney, S. J., "A Census of Southern Pulsars at 185 MHz", Publications of the Astronomical Society of Australia, 34, e070 (2017)

Zhang, B. R., Childress, M. J., Davis, T. M., Karpenka, N. V., Lidman, C., Schmidt, B. P., Smith, M., "A blinded determination of H_0 from low-redshift Type Ia supernovae, calibrated by Cepheid variables", Monthly Notices of the Royal Astronomical Society, 471, 2254 (2017)

Zhou, L., Federrath, C., Yuan, T., Bian, F., Medling, A. M., Shi, Y., Bland-Hawthorn, J., Bryant, J. J., Brough, S., Catinella, B., Croom, S. M., Goodwin, M., Goldstein, G., Green, A. W., Konstantopoulos, I. S., Lawrence, J. S., Owers, M. S., Richards, S. N., Sanchez, S. F., "The SAMI Galaxy Survey: energy sources of the turbulent velocity dispersion in spatially resolved local star-forming galaxies", Monthly Notices of the Royal Astronomical Society, 470, 4573 (2017)

STUDENT LIFE

Andrew Zic
University of Sydney

I am a first-year PhD student supervised by Tara Murphy and Christene Lynch at The University of Sydney, and work within CAASTRO's Dynamic Theme.

I've always been interested in astronomy. One of my earliest memories is of a trip to Siding Spring Observatory in NSW, where my sister and I became terrified of the sheer number of stars above us. My interest grew stronger as I undertook several undergraduate research projects in astronomy, as well as summer scholarships at The University of Sydney, Nanjing University and the Australian Astronomical Observatory. For my Honours degree, I worked on devising and testing methods to detect pulsars in Murchison Widefield Array (MWA) images by exploiting their interstellar scintillation.

My current research is focused on low-frequency radio emission from low-mass stars, such as M dwarfs and ultra-cool dwarfs. We don't fully understand the processes that lead these stars to emit strong radio bursts. By studying the bursts with low-frequency telescopes, such as the MWA and the Giant Metre-wave Radio Telescope in India, we aim to determine the physical conditions within the stars' magnetospheres and coronae.

Being a student member of CAASTRO has been a wonderful experience. CAASTRO has supported my travel within Australia and overseas for conferences, meetings, and observing runs. This exposure to the Australian and international astronomical communities in the first year of my PhD has been invaluable. It has enabled me to get to know the people and ideas directly in my research field, and helped me connect with fellow Australian astronomers across a broad range of research areas. I was also fortunate to be the CAASTRO Uluru *Astronomer in Residence* in September, and it was a fantastic experience to undertake outreach in such an amazing setting. I feel very privileged to have been a member of CAASTRO, and am sad to see it end.

Ronniy Joseph
Curtin University, ICRAR

I am doing my PhD with Cathryn Trott and Randall Wayth at CAASTRO's Curtin University node within the International Centre for Radio Astronomy Research (ICRAR). My research involves developing a generalised calibration framework for fine-tuning radio antennas in the Murchison Widefield Array (MWA) and the future Square Kilometre Array (SKA); my goal is to find the best way to combine models of the known radio sky with information from the measurements of the many antennas in these radio telescopes. This project has been inspired by the stringent fine-tuning requirements of the MWA Epoch of Reionisation (EoR) project within the CAASTRO Evolving theme.

I was born and raised in the Netherlands, completing an Astronomy Bachelor's degree at the University of Groningen. There I worked with the EoR group using LOFAR (the Low Frequency Array), on design requirements for the SKA and its EoR science goal. I finished my time in the Netherlands with a Master's degree at Leiden University, doing one project on exoplanet instrumentation and another on the hunt for protoclusters, the progenitors of galaxy clusters. For this last project I returned to radio telescopes, using radio data from LOFAR and infrared data from the Herschel space telescope. Having worked on both sides of a radio telescope, as a designer and an observer, I wanted to understand how radio astronomy really worked.

This ambition led me to my current PhD project, which has already proven to be a great opportunity to get to understand the fundamentals of this form of astronomical observation. And CAASTRO has been a great help in this endeavour. Thanks to CAASTRO I've been able to visit many conferences in my first year, which has allowed me to meet collaborators from the United States, Europe and of course across Australia. Those people have been great sources of knowledge and have helped me in making advances in my project. On top of that, CAASTRO has organised some great workshops on skills essential for a modern researcher: coding, writing papers, and staying resilient in the face of stress. Without these opportunities I wouldn't be where I am today.

Katherine Harborne
University of Western Australia, ICRAR

I am a PhD Student at the International Centre for Radio Astronomy and Research (ICRAR) at the University of Western Australia, supervised by Chris Power and Aaron Robotham. I work in the Evolving theme, building galaxy simulations and creating mock IFU (integral field unit) kinematic data cubes, in close collaboration with the team using SAMI (the Sydney–AAO Multi-object Integral field spectrograph).

I completed my integrated Master's degree in physics and astronomy at the University of Nottingham in the UK. During this time I worked on both computational and observational research projects, most notably studying the dynamics of a high-speed galaxy collision in the NGC 6338 galaxy group. I did this work at the Observatório Nacional in Rio de Janeiro, using the Chandra X-ray Telescope.

I began my PhD at ICRAR in October 2016, switching from being an observer to being a theorist, and jumping into building stable, isolated galaxy models. Having worked only with simulation data generated for me in the past, this was a big leap; in the last year I have learned a huge amount with the help of my supervisors and CAASTRO. I now produce models and study how observational effects such as projection, seeing conditions and instrumentation limitations affect our ability to accurately measure galaxy kinematics.

As a member of CAASTRO, I have had the opportunity to meet and work with astronomers Australia-wide and beyond. In particular, the chance to travel to Uluru as the CAASTRO *Astronomer in Residence* was a wonderful break from my work as a theorist, as I got to revisit that excitement of looking at the sky through telescopes and passing on stories of the stars to the general public.

CAASTRO funding has allowed me to travel and attend conferences across the country. Through meetings and workshops, such as *Mock Perth* and SAMI meetings, I have been able to collaborate and expand my work to provide useful tools to a greater number of people. I hope this work will contribute to the lasting and incredible legacy of CAASTRO, and continue on within ASTRO 3D.

Fiona Panther
Australian National University

I am a PhD student at the Australian National University's Research School of Astronomy and Astrophysics. My supervisors are Roland Crocker and Anais Möller at the ANU, Ashley Ruiter and Ivo Seitenzahl at UNSW in Canberra, and Chris Lidman at the Australian Astronomical Observatory. I've been working to understand the origin of most of the antimatter in the Milky Way, which we theorise comes from a type of exploding star, a supernova. Within CAASTRO's Dynamic theme, I've done the first IFU (integral field unit) survey of some of the host galaxies of these peculiar, 'SN1991bg-like' supernovae, and am working with data from the Dark Energy Survey to try to understand how the rate of these supernovae varies across cosmic time.

Through CAASTRO, I've been able to travel to scientific institutions in Australia and beyond. I've taken part programs such as *CAASTRO in the Classroom* and Uluru *Astronomer in Residence*, which have been great opportunities to learn how to communicate science more effectively. And I've also been able to develop my teaching and project management skills through CAASTRO, by delivering the student writing workshop (page 95) at the ANU.

CAASTRO has enabled me to attend three annual retreats, where I've had the opportunity to meet a diverse range of individuals and develop rich, ongoing collaborations that I hope will continue long after CAASTRO is gone. And thanks to CAASTRO I was also able to attend the 2017 ISAPP international astroparticle physics conference in the Netherlands. This conference opened up new career avenues for me to pursue, and a chance to share with others what CAASTRO has shared with me: a spirit of collaboration and excellence in multidisciplinary astronomy research.

CAASTRO STUDENTS

2017 CAASTRO New students

Australian National University

Zefeng Li, *Dark, Pre PhD*
SUPERVISOR Christian Wolf (ANU)
THESIS TITLE A Survey of Luminous Quasars at z ~ 5 in the Southern Hemisphere in SkyMapper, PanStarrs and WISE

ICRAR/Curtin

Dilpreet Kaur, *Dynamic, PhD*
SUPERVISORSS Ramesh Bhat (CUR) and Steven Tremblay (CUR)
THESIS TITLE Tracing interstellar space weather towards timing array millisecond pulsars

Nicholas Swainston, *Dynamic, Honours*
SUPERVISORS Steven Tremblay (CUR), Ramesh Bhat (CUR)
THESIS TITLE A blind search for pulsars using the Murchisong Widefield Array Phase 2 compact array

ICRAR/UWA

Qingxiang Chen, *Evolving, PhD*
SUPERVISORS Martin Meyer (UWA), Atilla Popping (UWA), Lister Staveley-Smith (UWA), and Jie Wang (NAOC, China)
THESIS TITLE Neutral hydrogen study using stacking technique

Lincheng Li, *Evolving, PhD NAOC, China*
SUPERVISORS Lister Staveley-Smith (UWA), Jonghwan Rhee (UWA), and Bo Qin (NAOC, China)
THESIS TITLE HI intensity mapping with the Parkes Telescope

Rhys Poulton, *Evolving/Dark, PhD*
SUPERVISORS Aaron Robotham (UWA) and Chris Power (UWA)
THESIS TITLE Studying the orbits and interactions of satellite galaxies in the next generation of surveys and simulations

Tristan Reynolds, *Evolving, PhD*
SUPERVISORS Lister Staveley-Smith (UWA), Tobias Westmeier (UWA), Jonghwan Rhee (UWA), Martin Meyer (UWA), and Baerbel Koribalski (CSIRO)
THESIS TITLE Observing neutral hydrogen in the local universe

Swinburne University of Technology

Elise Beaufils, *Dark, Pre PhD*
SUPERVISOR Chris Blake (SWIN)
THESIS TITLE Searching for fifth forces: cosmic growth versus environment

Ellert van der Velden, *Evolving/Dark, PhD*
SUPERVISORS Alan Duffy (SWIN), Jeremy Mould (SWIN), Chris Power (UWA) and Darren Croton (SWIN)
THESIS TITLE Utilizing cosmological simulations to model the growth of galaxies and their role in ionizing the universe

University of Melbourne

Mohit Bhardwaj, *Evolving, Masters*
SUPERVISORS Rachel Webster (UMELB) and Ben McKinley (UMELB)
THESIS TITLE Epoch of Reionisation Studies: understanding artefacts in the data due to shape of the telescope beam

University of Queensland

Lucas Grimes, *Evolving, Honours*
SUPERVISORS Michael Drinkwater (UQ) and Tamara Davis (UQ)
THESIS TITLE High velocity outflows from the centre of active galaxies

University of Sydney

Dougal Dobie, *Dynamic, PhD*
SUPERVISORS Tara Murphy (USYD) and Richard Hunstead (USYD)
THESIS TITLE Radio Transients with the Australian Square Kilometre Array Pathfinder

Hao Qiu, *Dynamic, PhD*
SUPERVISORS Tara Murphy (USYD) and Keith Bannister (CSIRO)
THESIS TITLE Exploring the dynamic radio sky with ASKAP

Matthew Varidel, *Evolving, PhD*
SUPERVISORS Scott Croom (USYD) and Geraint Lewis (USYD)
THESIS TITLE Disk Rotation and Turbulence in SAMI Galaxies

Andrew Zic, *Dynamic, PhD*
SUPERVISORS Tara Murphy (USYD) and Christene Lynch (USYD)
THESIS TITLE Low Frequency Radio Emission from Flare Stars

2017 Continuing Students

Australian National University

Matthew Alger, *Evolving/Dark/Dynamic, Pre PhD*
SUPERVISORS Chris Wolf (ANU) and Chengsoon Ong (ANU/Data61)
THESIS TITLE A public Python module for active learning

Dilyar Barat, *Evolving, PhD*
SUPERVISORS Matthew Colless (ANU), Franscesco D'Eugenio (ANU), Elisabete Lima da'Cunha (ANU), and Andrew Hopkins (AAO)
THESIS TITLE Measuring cosmological parameters in the local universe through galaxy scaling relations

Manisha Caleb, *Dynamic, PhD*
SUPERVISORS Frank Briggs (ANU), Matthew Bailes (SWIN), Brian Schmidt (ANU), and Chris Flynn (ANU)
THESIS TITLE A pursuit of fast radio transients with the UTMOST and Parkes radio telescopes

Jacob Golding, *Evolving, Pre PhD*
SUPERVISOR Christian Wolf (ANU)
THESIS TITLE What can SkyMapper do to map recent star formation changes in nearby galaxies?

Daniel Muthukrishna, *Dark, PhD*
SUPERVISORS Brad Tucker (ANU) and Matthew Colless (ANU)
THESIS TITLE Analysing tensions in local H_0 using TAIPAN galaxies and SN1a from SkyMapper and OzDES

2017 CAASTRO Students

Fiona Panther, *Dynamic, PhD*
SUPERVISORS Roland Crocker (ANU) and Brian Schmidt (ANU)
THESIS TITLE Stellar origins of galactic bulge positrons

Mayuri Sathyanarayana Rao, *Evolving, PhD*
SUPERVISORS Frank Briggs (ANU), Ravi Subrahmayan (RRI), Charley Lineweaver (ANU), and Brian Schmidt (ANU)
THESIS TITLE On the detection of Spectral Distortions in the CMB: Recombination to Reionization

Natalia Eire Sommer, *Dark, PhD*
SUPERVISORS Brad Tucker (ANU) and Rob Sharp (ANU)
THESIS TITLE Probing the Transition From Cosmic Deceleration to Acceleration With Reverberation Mapping

Bonnie Zhang, *Dark/Dynamic, PhD*
SUPERVISORS Brian Schmidt (ANU), Chris Lidman (AAO), Tamara Davis (UQ), Anais Moller (ANU) and Michael Childress (Southampton)
THESIS TITLE Precise cosmological analysis of Type Ia supernovae: the Hubble constant and dark energy

ICRAR/Curtin

Ronniy Joseph, *Evolving, PhD*
SUPERVISORS Cath Trott (CUR), Randall Wayth (CUR), and Carole Jackson (ASTRON)
THESIS TITLE Probing the Epoch of Reionisation with non-traditional hybrid radio interferometers

Samuel McSweeney, *Dynamic, PhD*
SUPERVISORS Ramesh Bhat (CUR), Steven Tremblay (CUR)
THESIS TITLE 3D tomography of pulsar magnetospheres

Bradley Meyers, *Dynamic, PhD*
SUPERVISORS Steven Tremblay (CUR), Ramesh Bhat (CUR)
THESIS TITLE A high time, low frequency study of intermittent emission phenomena in radio bursts

Mengyao Xue, *Dynamic, PhD*
SUPERVISORS Ramesh Bhat (CUR), Steven Tremblay (CUR), Stephen Ord (CSIRO)
THESIS TITLE New Polarimetric Pulsar Observations with the Murchison Widefield Array

Xiang Zhang, *Dynamic, PhD*
SUPERVISORS Randall Wayth (CUR), Paul Hancock (CUR), Steven Tingay (INAF), Carole Jackson (ASTRON)
THESIS TITLE Detection of radio emission from fireballs with the MWA

ICRAR/UWA

Kamran Ali, *Dark, PhD*
SUPERVISORS Danail Obreschkow UWA) and Chris Power (UWA)
THESIS TITLE Information on the cosmic large scale structure

Rodrigo Cañas Vazquez, *Evolving, PhD*
SUPERVISORS Claudia Lagos (UWA) and Chris Power (UWA)
THESIS TITLE Diffuse stellar halos in state-of-the-art cosmological simulations of galaxy formation

Garima Chauhan, *Evolving, Pre PhD*
SUPERVISORS Chris Power (UWA) and Martin Meyer (UWA)
THESIS TITLE HI in galaxies

Katherine Harborne, *Evolving, PhD*
SUPERVISORS Chris Power (UWA) and Aaron Robotham (UWA)
THESIS TITLE Feedback processes in dwarf galaxies

Katharine Kelley, *Dark, PhD*
SUPERVISORS Lister Staveley-Smith (UWA), Peter Quinn (UWA) and Ian MacArthur (UWA)
THESIS TITLE A radio astronomy search for axion dark matter

Fei Qin, *Dark, PhD*
SUPERVISORS Lister (UWA), Cullan Howlett (UWA), and Tao Hong (NAOC)
THESIS TITLE Bulk flow and the peculiar velocity field of galaxies

Khaled Said, *Dark, PhD University of Cape Town*
SUPERVISORS Renee C Kraan-Korleweg (UCT), Thomas Jarrett (UCT), and Lister Staveley-Smith (UWA)
THESIS TITLE Peculiar flow fields in the ZoA from the NIR Tully-Fisher relation

Swinburne University of Technology

Caitlin Adams, *Dark, PhD*
SUPERVISORS Chris Blake (Swin), David Parkinson (Korea), and Ixandra Achitouv (Swin)
THESIS TITLE Testing the cosmological model in the low-redshift universe

Igor Andreoni, *Dynamic, PhD*
SUPERVISORS Jeff Cooke (SWIN) and Matthew Bailes (SWIN)
THESIS TITLE Deep multi-wavelength exploration of the fast transient Universe

Shivani Bhandari, *Dynamic, PhD*
SUPERVISORS Matthew Bailes (SWIN), Willim van Straten (Auck Univ Technology, NZ) and Evan Keane (SKA Organisation)
THESIS TITLE Searching and localisation of sources of dispersed radio emission

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

Christopher Curtin, *Dynamic/Evolving, PhD*
SUPERVISORS Jeff Cooke (SWIN) and Jeremy Mould (SWIN)
THESIS TITLE High red-shift superluminous supernovae: theory, observatories and implications

Angela Garcia, *Evolving, PhD*
SUPERVISORS Emma Ryan-Webber, (SWIN) Edoardo Tescari (UMELB), and Stuart Wyithe (UMELB)
THESIS TITLE Diagnosing hydrogen reionisation with metal absorption line ratios

Fabian Jankowski, *Dynamic, PhD*
SUPERVISORS Matthew Bailes (SWIN), Willim van Straten (Auck Univ Technology, NZ) and Evan Keane (SKA Organisation)
THESIS TITLE Spectral and rotational properties of radio pulsars

Aditya Parthasarathy Madapusi, *Dynamic, PhD*
SUPERVISORS Matthew Bailes (SWIN) and Willem van Straten (SWIN)
THESIS TITLE High precision pulsar timing in the SKA era

Vivek Venkatraman Krishnan, *Dynamic, PhD*
SUPERVISORS Matthew Bailes (SWIN), Willim van Straten (Auck Univ Technology, NZ) and Evan Keane (SKA Organisation)
THESIS TITLE Next generation instrumentation for pulsar and fast transient studies with the SKA

University of Melbourne

Stephanie Bernard, *Dynamic/Evolving, PhD*
SUPERVISORS Rachel Webster (UMELB) and Jeff Cooke (SWIN)
THESIS TITLE Galaxies and supernovae at cosmic dawn

Sinem Ozbilgen, *Dark, PhD*
SUPERVISORS Rachel Webster (UMELB) and Jeremy Mould (SWIN)
THESIS TITLE Calibrating the Tully-Fisher relationship

Mahsa Rahimi, *Evolving, PhD*
SUPERVISORS Rachel Webster (UMELB) and Bart Pindor (UMELB)
THESIS TITLE Measuring EoR Signal with MWA

Jarryd Rasti, *Evolving, Honours*
SUPERVISORS Rachel Webster (UMELB) and Ben McKinley (UMELB)
THESIS TITLE Measuring the beam pattern of the MWA tiles

Jennifer Riding, *Evolving, PhD*
SUPERVISORS Rachel Webster (UMELB) and Daniel Mitchell (CSIRO)
THESIS TITLE Extremely low frequency radio astronomy techniques to confirm Epoch of Reionisation theories

University of Queensland

Per Andersen, *Dark, PhD*
SUPERVISORS University of Copenhagen Jens Hjorth (Univ. Copenhagen) and Tamara Davis (UQ)
THESIS TITLE Peculiar velocities

Joshua Calcino, *Dark, PhD*
SUPERVISOR Tamara Davis (UQ)
THESIS TITLE Microlensing with the Dark Energy Survey

Simon Deeley, *Evolving, Honours*
SUPERVISORS Michael Drinkwater (UQ) and Tamara Davis (UQ)
THESIS TITLE Galaxy types and galaxy growth in the group environment

Samuel Hinton, *Dark, PhD*
SUPERVISORS Tamara Davis (UQ) and Alex Kim (LBNL)
THESIS TITLE Hierarchical Bayesian methods for supernova cosmology

Harry Hobson, *Dark, Honours*
SUPERVISOR Tamara Davis (UQ)
THESIS TITLE Preliminary reverberation mapping measurement of an AGN using DES/OzDES data

Henning Schmitz, *Dark, Masters*
SUPERVISOR Tamara Davis (UQ)
THESIS TITLE Gravitational lensing to search for MACHOS in the range of stellar black holes

Merryn Taylor, *Dark, Honours*
SUPERVISOR Tamara Davis (UQ)
THESIS TITLE Signal in the Noise - using scatter In Supernova magnitudes to test cosmology

University of Sydney

Jessica Bloom, *Evolving, PhD*
SUPERVISORS Joss Bland-Hawthorn (USYD) and Scott Croom (USYD)
THESIS TITLE Dynamical interactions in nearby galaxies

Marcin Glowacki, *Evolving, PhD*
SUPERVISORS Elaine Sadler (USYD) and James Allison (USYD)
THESIS TITLE Studies of HI absorption against distant radio sources with ASKAP

Jing Li, *Evolving, Honours*
SUPERVISOR Julia Bryant (USYD)
THESIS TITLE Investigating SFRs and the impact of AGN on galaxies within clusters using SAMI

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

Aina Musaeva, *Evolving, PhD*
SUPERVISORS Elaine Sadler (USYD) and Bärbel Koribalski (CSIRO)
THESIS TITLE Intermediate mass black holes in dwarf galaxies

Adam Schaefer, Evolving, PhD
SUPERVISOR Scott Croom (USYD)
THESIS TITLE The modulation of star formation by galaxy environment using the Sydney-AAO Multi-object Integral field spectrograph (SAMI)

Charlotte Ward, Dynamic, Honours
SUPERVISORS Tara Murphy (USYD) and Matthew Kerr (CSIRO)
THESIS TITLE Exploring machine learning techniques for classification of signals in pulsar search data

ANNUAL REPORT OF THE CAASTRO STUDENT COMMITTEE

This year the CAASTRO Student Committee concentrated on delivering workshops that would give PhD students skills they need to succeed in their careers.

We ran a trial paper-writing workshop at CAASTRO's 2016 Annual Retreat. After receiving useful feedback on that, we worked closely with Christian Wolf (Australian National University) to expand the materials and make them suitable for a comprehensive, day-long workshop on scientific writing in 2017. The content covered how to structure and plan a manuscript, how to refine first drafts, and what to expect from the peer-review process. We ran the workshop in Melbourne, Brisbane, Sydney, Canberra and Perth, and had over 100 attendees. We intend to release the workshop materials as a CAASTRO legacy item so that the event can be run again in future.

Programming is a major part of PhD projects. We supported Samuel Hinton (University of Queensland) and Fiona Panther (Australian National University) throughout the year as they developed a day-long workshop on good practices for programming, particularly when you want to make your code publicly available. This workshop ran in December and covered how to write clear documentation and how to test your code, share it and make it citable.

The Student Committee teamed up with the CAASTRO Postdoc Committee to run a workshop for early-career researchers just before CAASTRO's 2017 Annual Retreat. This event featured sessions on building resilience and developing 'the perfect pitch'.

We hope that students will both apply the skills they've learned and share them with others, so that the benefits of CAASTRO will continue even as the organisation itself wraps up. Students have been a key part of CAASTRO and the Student Committee is proud to have represented them. We look forward to seeing CAASTRO students spread around the world, working in academia, industry or areas we can't even imagine!

Caitlin Adams
Chair 2017

ANNUAL REPORT OF THE CAASTRO POSTDOCTORAL COMMITTEE

The CAASTRO Postdoc Committee had a very productive first year in 2016: it started a database for jobs and grant proposals for early-career researchers, composed fact sheets to guide people applying for Australian Research Council Fellowships, and organised sessions on career advice for the 2016 CAASTRO Annual Retreat.

This year started with the election of a new committee Chair to take over from Dr Wiebke Ebeling (Curtin University). The Committee would like to thank Wiebke for her hard work in establishing the committee.

For its major project of 2017, the committee decided to record on video the experiences of CAASTRO's early-career researchers and students. The committee composed the interview questions and the committee representatives of each CAASTRO node organised the filming and directed the interviews at their respective nodes. Fifteen people were interviewed.

For most of us it was a new and very exciting experience to be behind the camera for the first time – and sometimes also in front of it – and we learned valuable lessons about filming and interviewing practices. We reviewed and sorted the five hours of collected footage with the help of professional editors.

The results were three insightful and entertaining videos, *Being part of CAASTRO*, *Work Life Balance* and *Career Path,* which premiered at the CAASTRO Annual Retreat in November 2017. The videos are a great reflection on the insights of students and postdocs and will be part of CAASTRO's legacy material. For its final event, the Postdoc Committee organised a professional development day for early-career researchers at the CAASTRO retreat with sessions on dealing with stress and pitching ideas. We closed the day with a game of Trivial Pursuit, inviting all CAASTRO members to join in.

Laura Wolz
Chair 2017

2017 CAASTRO Postdoctoral Researchers

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 teleconference 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

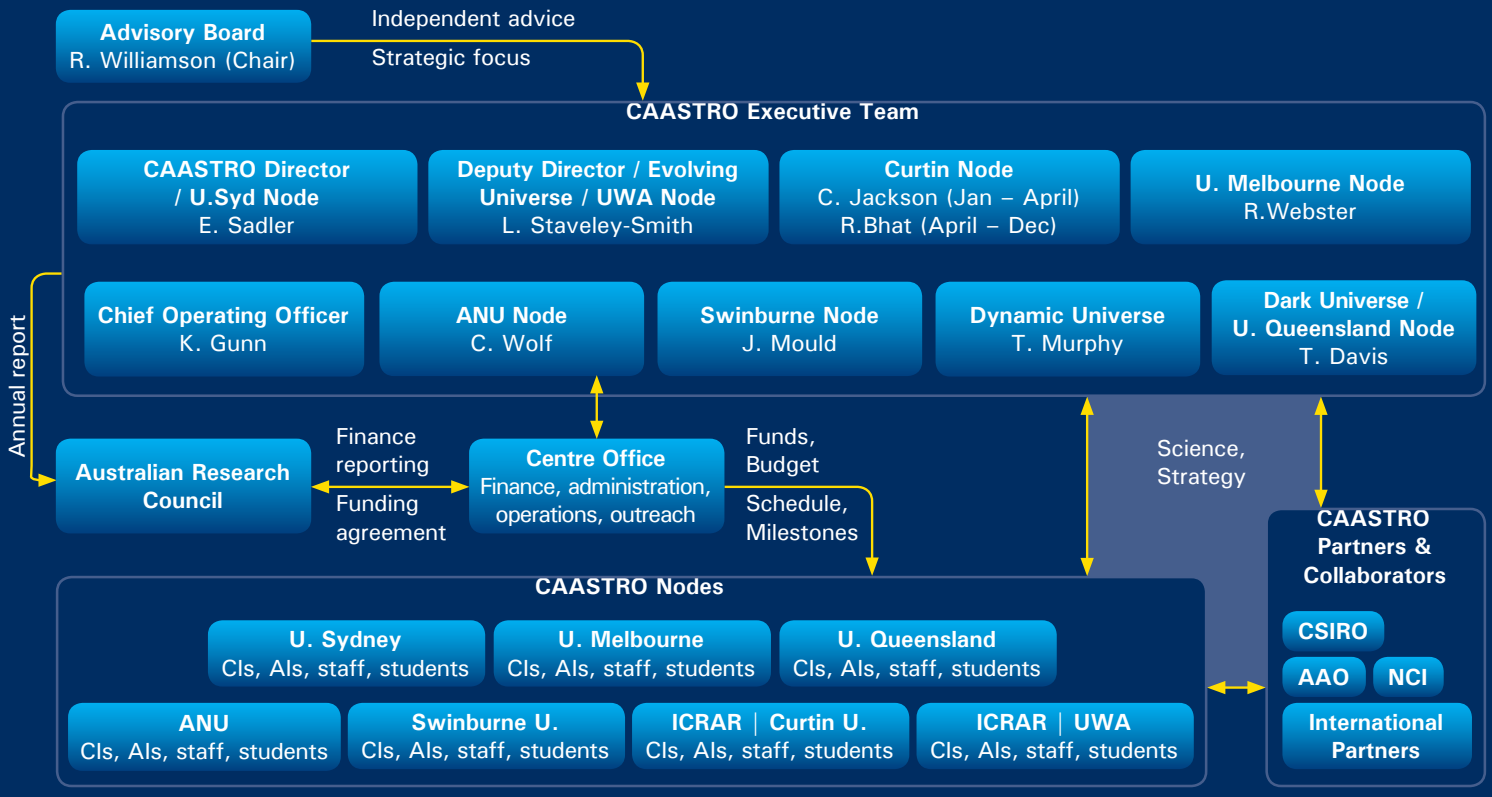
Professor Lister Staveley-Smith
Deputy Director

Ms Kate Gunn
Chief Operating Officer

In 2017, the CAASTRO Executive met 8 times, including face-to-face meetings at Swinburne, the University of Melbourne, ICRAR University of Western Australia and ICRAR Curtin University. During 2017 area meetings were held in Sydney, Canberra, Brisbane, Melbourne and Perth.

In 2017 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 Dan Taranu (Evolving), Dr Christene Lynch (Dynamic) and Dr Cullan Howlett (Dark) for their hard work as CAASTRO Theme Scientists in 2017. 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 twice in 2017, including a half-day strategic meeting held in Canberra in August 2017. At this meeting the Board assisted the CAASTRO Executive with transition planning and legacy item discussions. The Board 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 in order to understand CAASTRO activities.

CHAIR

Professor Robert Williamson AO FRS FAA

Medical researcher and geneticist

MEMBER

Ms Soula Bennett

Director
Quantum Victoria

MEMBER

Professor Peter Davies

Pro Vice-Chancellor Research
University of Western Australia

MEMBER

Professor Hugh Durrant-Whyte

The School of Information Technologies
University of Sydney

MEMBER

Professor Ron Ekers

CSIRO Fellow

MEMBER

Dr Bronwyn Evans

Chief Executive Officer
Standards Australia

MEMBER

Professor Kenneth Freeman

Duffield Professor of Astronomy, Australian National University

MEMBER

Professor Martha Haynes

Goldwin Smith Professor of Astronomy
Cornell University

MEMBER

Professor Garth Illingworth

Professor of Astronomy & Astrophysics
University of California Santa Cruz

MEMBER

Dr Rachel Nowak

Director The Brain Dialogue
Monash University

MEMBER

Professor Elaine Sadler

CAASTRO Director

CAASTRO Executive

(L–R) Jeremy Mould, Tamara Davis, Ramesh Bhat, Lister Staveley-Smith, Christian Wolf, Elaine Sadler, Tara Murphy, Kate Gunn. Missing: Rachel Webster.

Credit: CAASTRO

The CAASTRO Advisory Board

Credit Kylie Williams

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 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

The CAASTRO team gained further external recognition in 2017, with a number of members receiving awards and honours for their achievements.

ACT Young Tall Poppy Awards

Julie Banfield is the ACT Young Tall Poppy of the year
Credit: Australian Institute of Policy and Science

The Young Tall Poppy Science Awards given by the Australian Institute of Policy and Science recognise up-and-coming scientists who combine world-class research with a passionate commitment to communicating science. In October CAASTRO's Dr Julie Banfield (Australian National University) was named the ACT Young Tall Poppy of the Year at a ceremony in Canberra.

Gruber Foundation Fellowship

Mr Khaled Said, a CAASTRO PhD student studying at the University of Western Australia node of ICRAR and at the University of Cape Town, South Africa, received the 2017 International Astronomical Union Fellowship of The Gruber Foundation. This annual award, worth US$50 000, is given to a promising young astronomer working in any field of astrophysics.

Khaled studies the distribution and dynamics of galaxies in the local Universe, by looking at galaxies in the region of the sky obscured by the Milky Way. During his Fellowship, which he will take up at the Australian National University, he will continue this work, extending it to cover the whole southern sky.

Order of Australia

A CAASTRO Advisory Board member, Professor Ken Freeman of the Australian National University, was made a Companion of the Order of Australia in the mid-year Queen's Birthday Honours List. The citation reads:

> *For eminent service to astronomy through pioneering contributions in the field of galactic archaeology, as a leading astrophysicist and researcher, to tertiary science education, to professional academies, and as a mentor of young scientists.*

Ken was a founding member of the Astronomical Society of Australia (ASA) and has served on the ASA Council several times. He is a Fellow of both the Australian Academy of Science and the Royal Society, and has received the Prime Minister's Science Prize and The Gruber Foundation's Cosmology Prize. Along with his outstanding scientific achievements, Ken has supervised more than 50 PhD students. He remains an active collaborator and a mentor to the Australian astronomical community.

CAASTRO Flashback to 2011

NOBEL PRIZE CEREMONY | ***The Nobel Foundation 2011*** | ***Photos: Frida Westholm***

ASTRONOMICAL SOCIETY OF AUSTRALIA

This year CAASTRO received a Gold Pleiades Award from the Astronomical Society of Australia's Inclusion, Diversity and Equity in Astronomy (IDEA) Chapter – the first organisation to do so. The Pleiades Awards are given to astronomical organisations that demonstrate a strong commitment to advancing the careers of women, and the Gold award recognizes 'a truly outstanding sustained commitment' to best practice in this area.

Applications for Pleiades Awards are assessed against the selection criteria by an independent panel of astronomers, in a process endorsed by the ASA's executive committee. CAASTRO was awarded with a certificate at the ASA Annual Science Meeting's IDEA Lunch in July 2017.

The result is an accolade for CAASTRO's hard-working Gender Action Committee, and for all members of CAASTRO who have striven to promote equity and diversity in the workplace.

CAASTRO wins the ASA Gold Pleiades Award
Credit: Helen Sim

In addition to this award, several CAASTRO members received individual ASA awards this year.

Louise Webster Prize for outstanding research by a scientist early in their post-doctoral career

Awarded to Dr Keith Bannister (CSIRO) for the paper, 'Real-time detection of an extreme scattering event: Constraints on Galactic plasma lenses', Bannister, et al. (2016) Science, Vol. 351, Issue 6271, pp. 354–356.

Bok Prize for outstanding research in astronomy by an Honours or eligible Masters student

A Highly Commended award was presented to Daniel Muthukrishna for his Honours thesis 'Deep Learning for the Spectral Classification of Transient Astronomical Objects' completed at the University of Queensland and supervised by David Parkinson (University of Queensland) and Brad Tucker (Australian National University).

Charlene Heisler Prize for the most outstanding PhD thesis in astronomy

A Highly Commended award was presented to Emily Petroff for her thesis, 'The transient radio sky observed with the Parkes radio telescope', completed at Swinburne University of Technology and supervised by Willem van Straten (Swinburne University), Matthew Bailes (Swinburne University) and Simon Johnston (CSIRO).

GENDER ACTION COMMITTEE

Professor Brian Schmidt AC, FRS, FAA,
CAASTRO Gender Action Committee Chair

CAASTRO Gender Action Committee. Credit: Sue Lester

The CAASTRO Gender Action Committee completed its fourth year of operation this year. The Committee draws broadly from across the Centre: its members are from different institutions, at different career stages, and of different genders and nationalities. Its role has been to contribute to the development of strategies to meet gender-action challenges, to best achieve CAASTRO's goals and objectives. It recommends ways in which CAASTRO can balance its gender representation and boost opportunities for our female staff and students; it also monitors progress in these areas. The creation of the Committee fast-tracked many of our gender initiatives.

Activities in 2017

The Committee met three times this year, twice by videoconference and once face-to-face (at Swinburne University in November). It worked on three major projects.

The first was our most ambitious initiative yet: *Professors for Change,* an independent spinout company. Based on *Male Champions of Change*, this new endeavour will encourage senior science academics and professional staff to promote gender balance. The organisation will be launched in mid 2018 and will be chaired by Professor Matthew Colless, CAASTRO Chief Investigator at the Australian National University. *Professors for Change* has become a reality largely thanks to the hard work of two members of the Gender Action Committee, Jessica Bloom and James Allison.

The Committee also worked with the Australian Tertiary Education Managers (ATEM) on providing a leadership program for women, and men, in CAASTRO. This program involved four online learning modules and a face-to-face training session held in Adelaide in November, just before CAASTRO's annual retreat.

The Committee's last official action was to survey CAASTRO members about sexual harassment. The survey's responses will be collated and analysed by an independent academic at the University of Melbourne, and the results made available in early 2018. The Committee considered at length the best way to report incidents of sexual harassment so as to limit repeat offences.

Impact and legacy

The Australian Research Council (ARC) carried out its mid-term review of CAASTRO in 2014. The reviewing panel noted that:

> *The gender-equity program is a highly noteworthy development within the Centre, fostering a high degree of awareness of gender-equity issues throughout the Centre staff. The Centre has a range of implementation arrangements in place. It promotes a culture of increased staff awareness by hosting workshops and encouraging staff to attend women in leadership conferences, targeted appointments and mentoring, and a strong focus on family-friendly employment arrangements (such as offering part-time appointments and child-care arrangements at major conferences).*

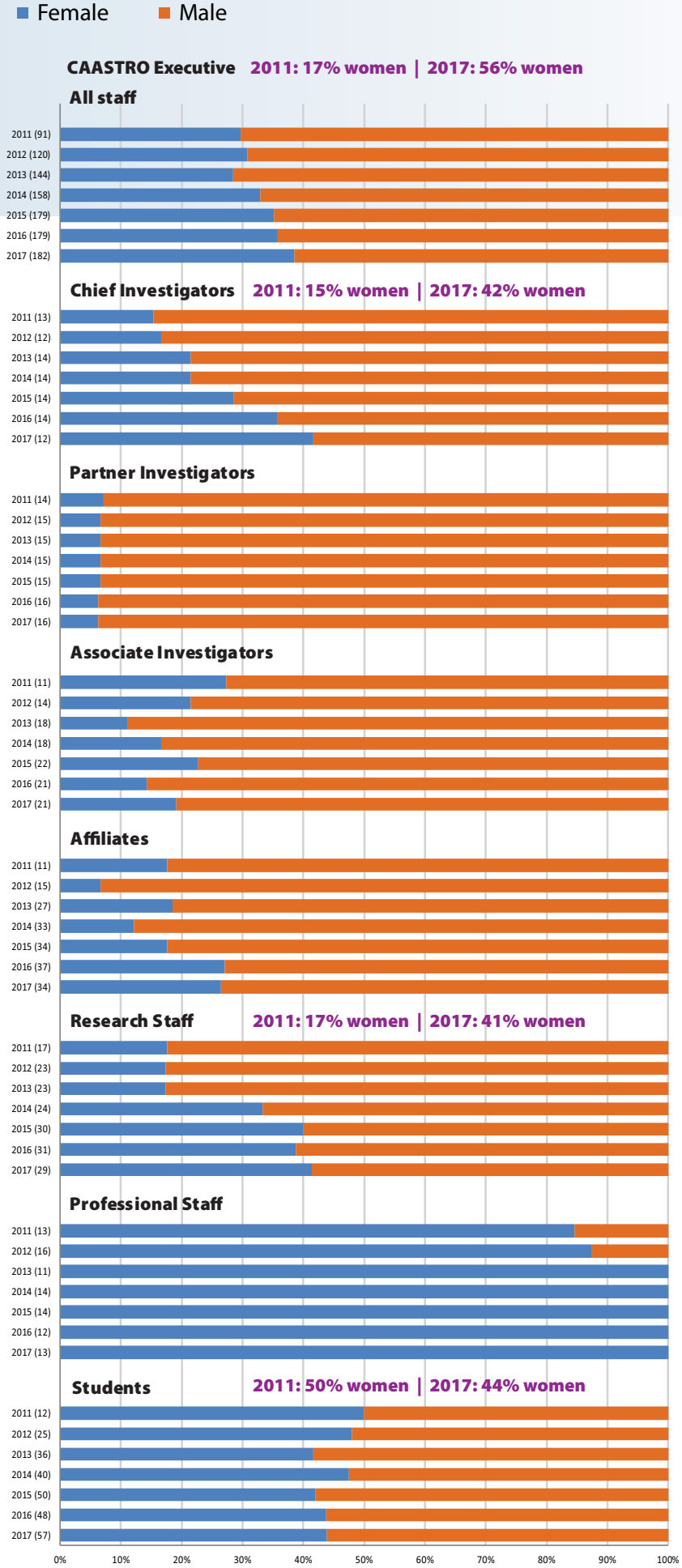
The reviewing panel commended the percentage of women in the Centre, from students to employees, and the gender balance on committees and among conference speakers. And even just halfway through CAASTRO's life, the panel saw that CAASTRO's gender initiatives were changing the culture not only of CAASTRO but also of our member organisations.

The Gender Action Committee has always been committed to creating a legacy that will last beyond CAASTRO's lifetime and reach into other organisations. In 2017 we finished work on two major legacy items: our case study, *CAASTRO's Path to Gender Equality*, and the *CAASTRO Gender Toolkit*, a set of tools other organisations can use to help them build more gender-inclusive workplaces. This toolkit is available for download on the current CAASTRO website; more importantly it will available on our legacy website, which will be at *www.caastro.org* when the Centre ends on 31 March 2018.

The greatest impact we may have had is the national SAGE (Science in Australia Gender Equity) initiative, which is directly linked to CAASTRO's gender-action program. The Chair of the Gender Action Committee, Professor Brian Schmidt (ANU), has acknowledged that CAASTRO's activities were

> *what motivated and empowered me to co-start that initiative [SAGE] in the Academy of Science, and this has now blossomed into a federally-funded initiative that 40 institutions are participating in, representing hundreds of thousands of students and employees.*

Gender Profile



Membership

Professor Brian Schmidt, CAATRO Chief Investigator and Australian National University Vice-Chancellor, chairs the Committee. In the past year the other committee members were:

- Dr David Parkinson (Affiliate, University of Queensland)
- Dr James Allison (Affiliate, CSIRO)
- Dr Anais Möller (Researcher, Australian National University)
- Professor Rachel Webster (Chief Investigator, University of Melbourne)
- Professor Elaine Sadler (Centre Director/Chief Investigator, University of Sydney)
- Ms Jessica Bloom (PhD Student, University of Sydney)
- Ms Bonnie Zhang (PhD student, Australian National University)
- Dr Steven Tremblay (Researcher, Curtin University)
- Dr Danail Obreschkow (Affiliate, University of Western Australia)
- Ms Kate Gunn (CAASTRO Chief Operating Officer, University of Sydney).

PRESENTATIONS

Kate Gunn presents at the final CAASTRO Annual Retreat
Credit: Cristy Roberts

INVITED TALKS 2017

Major Conferences

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

The spectra of early type galaxies
Jeremy Mould, Galactic Renaissance, Caltech, CA, USA, February 2017

Illuminating the dark ages of the Universe
Rachel Webster, Global Conference on Cosmology and Frontiers in Applied Astro Science (CFAAS 2017), Chennai, India, February 2017

Integral field spectroscopy - science with SAMI, Hector and ULTIMATE-IFU
Julia Bryant, Subaru International Partnership and Instrumentation Workshop, National Astronomical Observatory Japan, Tokyo, Japan, March 2017

Fast transient science
Jeff Cooke, Subaru International Partnership and Instrumentation Workshop, National Astronomical Observatory Japan, Tokyo, Japan, March 2017

Aspects of the Dark Energy survey
Tamara Davis, Aspects of Gravity and Cosmology, Inter-University Centre for Astronomy and Astrophysics, Pune, India, March 2017

Near field cosmology
Joss Bland-Hawthorn, Subaru International Partnership and Instrumentation Workshop, National Astronomical Observatory Japan, Tokyo, Japan, March 2017

MWA polarisation studies
Emil Lenc, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, March 2017

LWA: lessons learned
Steven Tremblay, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, March 2017

MWA lessons
Randall Wayth, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, March 2017

Blinding the Hubble Constant
Bonnie Zhang, Blind Analysis in High-Stakes Survey Science: When, Why, and How?, SLAC National Accelerator Laboratory, CA, USA, March 2017

Uncovering galaxy individuality with multiplexed integral field spectroscopy
Scott Croom, Integral field spectroscopy workshop, Korean Astronomy and Space Science Institute, Daejeon, Republic of Korea, April 2017

Uncovering galaxy individuality with multiplexed integral field spectroscopy
Scott Croom, Korean Astronomical Society Meeting, Changwon, Republic of Korea, April 2017

Dark matter in the cosmic context
Katie Mack, CosKASI Conference 2017, Korea Astronomy and Space Science Institute, Daejeon, Republic of Korea, April 2017

SkyMapper transient surveys: recent results and future
Anais Möller, Cook's Branch, Mitchell Institute Workshop, Texas A&M University, USA, April 2017

Words about Marc
Jeremy Mould, Aaronson Symposium 2017, Arizona, USA, April 2017

Testing for tensions between datasets
David Parkinson, CosKASI Conference 2017, Korea Astronomy and Space Science Institute, Daejeon, Republic of Korea, April 2017

The state of the Universe in 2017
Brian Schmidt, Aaronson Symposium 2017, Arizona, USA, April 2017

Deeper, wider, faster: chasing the fastest bursts in the Universe
Jeff Cooke, Diving into Gravitational Waves, US Virgin Islands, May 2017

Surveys for superluminous at $z > 2$
Jeff Cooke, MIAPP Superluminous supernovae in the next decade, Germany, May 2017

Are mergers factories for massive stars?
Jeff Cooke, MIAPP Superluminous supernovae in the next decade, Germany, May 2017

Cosmology in the era of the SKA
Tamara Davis, Fundamental Physics with the Square Kilometre Array, Mauritius, May 2017

Klaus Meisenheimer: dealing with galaxies from a distance and students close-up
Christian Wolf, Honorary Scientific Conference, Max Planck Institute for Astronomy, Heidelberg, Germany, May 2017

Hector - A massive new Integral field spectroscopic instrument for the AAT
Julia Bryant, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, June 2017

Surveying the cosmos with ELTs
Matthew Colless, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, June 2017

Uncovering galaxy individuality with SAMI
Scott Croom, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, June 2017

Radio surveys and their connection to other wavelengths
Elaine Sadler, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, June 2017

Searching for HI absorption in the brightest southern radio galaxies
Elizabeth Mahony, HI Absorption 2017 Workshop, Dwingeloo, The Netherlands, June 2017

A successful search for intervening 21cm HI absorption at $0.4 < z < 1$ with ASKAP
Elaine Sadler, HI Absorption 2017 Workshop, Dwingeloo, The Netherlands, June 2017

Galaxy and mass assembly: studies in galaxy demographics from the GAMA survey
Edward Taylor, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, June 2017

The K2 supernova cosmology experiment
Brad Tucker, Kepler and K2 SciConIV, NASA Ames Research Center, CA, USA, June 2017

Pulsar Science with the Murchison Widefield Array
Ramesh Bhat, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

Low-frequency observations of nearby galaxies
George Heald, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

Exploring the dynamic radio sky with SKA pathfinders
Tara Murphy, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

Radio AGN populations and their evolution
Elaine Sadler, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

Low frequency imaging
Andre Offringa, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

The EoR with LOFAR
Andre Offringa, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

Observing the EoR with the MWA
Cathryn Trott, The Broad Impact of Low Frequency Observing, Bologna, Italy, June 2017

A review on gas in galaxies and their evolution
Claudia Lagos, In & Out: What rules the galaxy baryon cycle? Munich Institute for Astro- and Particle Physics, Germany, July 2017

A review on gas in galaxies and their evolution
Claudia Lagos, The Galaxy Ecosystem - Flow of Baryons Through Galaxies, Germany, July 2017

Neutral hydrogen in the distant Universe
Elaine Sadler, New Heights in Astronomy, ESO, Garching, Germany, August 2017

Radio Galaxy Zoo and Citizen Science
Julie Banfield, ADACS Data Intensive Astronomy Workshop, Melbourne, Australia, August 2017

The SAMI galaxy survey: origins of gas in galaxies traced by kinematic misalignments
Julia Bryant, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, August 2017

Dark matter in the cosmic context
Katie Mack, Current Themes in High Energy Physics and Cosmology, Copenhagen, Denmark, August 2017

AGN feeding and feedback in central galaxies
Chris Power, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, August 2017

Radio Galaxy Zoo and Citizen Science
Julie Banfield, ACAMAR 3, Hobart, Australia, September 2017

Galaxy surveys and the distance scale
Matthew Colless, Stellar populations and the distance scale, Shanghai, China, September 2017

SkyMapper and the transient survey
Anais Möller, ACAMAR 3, Hobart, Australia, September 2017

A comparison of distance ladders
Jeremy Mould, Stellar populations and the distance scale, Shanghai, China, September 2017

Type 1a Supernova progenitors
Ashley Ruiter, Steller Evolution, SN & Nucleosynthesis across Cosmic Time, Japan, September 2017

MWA pulsar science and survey plans
Ramesh Bhat, Radio Astronomy Forum 2017 (RAF2017), Hanglong, China, September 2017

The 300: Cluster Comparison project
Pascal Elahi, Groups and Clusters II, La Serena, Chile, October 2017

The SKA EoR project
Cathryn Trott, IAUS 333: Peering towards Cosmic Dawn, Dubrovnik, Republic of Croatia, October 2017

Results from MWA-EOR
Rachel Webster, IAUS 333: Peering towards Cosmic Dawn, Dubrovnik, Republic of Croatia, October 2017

Cosmic clustering and homogeneity
Tamara Davis, A Fractured Universe? Fundamental Physics, Symmetry, and Life, Sydney, Australia, November 2017

Murchison Widefield Array
Randall Wayth, SKA Regional Pathfinders workshop, Sydney, Australia, November 2017

Radio AGN populations and their cosmic evolution
Elaine Sadler, Science at Low Frequencies IV, Sydney, Australia, December 2017

MWA status and plans
Randall Wayth, Science at Low Frequencies IV, Sydney, Australia, December 2017

An overview on HI intensity mapping
Laura Wolz, Science at Low Frequencies IV, Sydney, Australia, December 2017

Other Presentations 2017

(Conferences, workshops, colloquia, projects, collaborations)

Modelling dark matter
Pascal Elahi, CAASTRO-CoEPP Workshop, Melbourne, Australia, Jan 2017

Mrk 1018 returns to the shadows
Rebecca McElroy, 229th American Astronomical Society Meeting, Dallas, USA, Jan 2017

Astrophysics overview
Katie Mack, CAASTRO-CoEPP Workshop, Melbourne, Australia, Jan 2017

Radio Galaxy Zoo: citizen science and machine learning
Julie Banfield, Detecting the Unexpected: Discovery in Astronomically Big Data, Baltimore, USA, Feb 2017

Gravitational potential and surface density drive the stellar population of ETGs
Tania Barone, SAMI-GAMA Meeting, Perth, Australia, Feb 2017

Current follow-up efforts
Shivani Bhandari, Fast Radio Bursts, Aspen, USA, Feb 2017

The first interferometric detections of FRBs
Manisha Caleb, Fast Radio Bursts, Aspen, USA, Feb 2017

Deeper, wider, faster: a novel program to resolve the nature of fast radio bursts with a single detection
Jeff Cooke, Fast Radio Bursts, Aspen, USA, Feb 2017

Distinguishing FRB cosmological models
Bryan Gaensler, Fast Radio Bursts, Aspen, USA, Feb 2017

Extracting useful kinematics from simulations
Katherine Harborne, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

Extracting useful kinematics from simulations
Katherine Harborne, SAMI Kinematics Meeting, Perth, Australia, Feb 2017

FRBs as astrophysical tools
Jean-Pierre Macquart, Fast Radio Bursts, Aspen, USA, Feb 2017

Studying HI absorption in AGN with ASKAP
Elizabeth Mahony, PHISCC-2017, Pune, India, Feb 2017

SkyMapper transient survey and SN2016hhd
Anais Möller, K2 Supernova experiment & workshop, USA, Feb 2017

FLASH – the first large absorption survey in HI: commissioning and early results
Vanessa Moss, PHISCC-2017, Pune, India, Feb 2017

An improved statistical foreground model for the EoR
Steven Murray, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

WTF: discovering the unexpected in next-generation radio surveys
Ray Norris, Detecting the Unexpected: Discovery in Astronomically Big Data, Baltimore, USA, Feb 2017

Positron annihilation in a dynamic ISM
Fiona Panther, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

Testing for tensions between datasets
David Parkinson, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

Learning from FRB scattering/scintillation/RM
Ue-Li Pen, Fast Radio Bursts, Aspen, USA, Feb 2017

ASKAP update
Attila Popping, PHISCC2017, Pune, India, Feb 2017

Imaging galaxies intergalactic and nearby environment
Attila Popping, PHISCC2017, Pune, India, Feb 2017

Be nice to satellites, they're going through a tough phase
Rhys Poulton, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

The gaseous outskirts of galaxy clusters
Chris Power, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

Parkes 21-cm intensity mapping
Jonghwan Rhee, PHISCC2017, Pune, India, Feb 2017

Quenching star formations in galaxy groups
Adam Schaefer, SAMI Kinematics Meeting, Perth, Australia, Feb 2017

MUSE observations of 1E 0102.2-7219
Ivo Seitenzahl, 331 IAU Symposium: SN 1987A, 30 years later – Cosmic Rays and Nuclei from Supernovae and their aftermaths, Saint-Gilles-Les-Bains, France, Feb 2017

The WALLABY survey with ASKAP
Lister Staveley-Smith, PHISCC2017, Pune, India, Feb 2017

Using wavelets to explore the Epoch of Reionisation
Cathryn Trott, ANITA 2017 (Australian National Institute for Theoretical Astrophysics), Hobart, Australia, Feb 2017

AAOmega
Brad Tucker, K2 Supernova experiment & workshop, USA, Feb 2017

C16 & C17 overview
Brad Tucker, K2 Supernova experiment & workshop, USA, Feb 2017

The importance of the identification of simulated galaxies
Rodrigo Cañas, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Synthetic universes for surveys
Pascal Elahi, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Extracting useful kinematics from simulations
Katherine Harborne, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Ionospheric conditions above the MRO with MWA EoR
Christopher Jordan, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, Mar 2017

Physical processes that govern the formation of galaxies with low HI mass (using GALFORM)
Hansik Kim, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

A hybrid multiresolution scheme to efficiently model the structure of reionisation on the largest scales
Hansik Kim, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

HI in galaxies: a simulation perspective
Claudia Lagos, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

MWA polarisation studies
Emil Lenc, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, Mar 2017

MWA primary beam determination
Ben McKinley, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, Mar 2017

Dependence on HI mass on halo mass in ALFALFA-GAMA survey overlap
Martin Meyer, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

What ASKAP will tell us about galaxy evolution: early science results and prospects for the future
Martin Meyer, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Overview of ionospheric analyses and calibration
Daniel Mitchell, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, Mar 2017

Observational status of angular momentum in galaxies
Danail Obreschkow, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Pulsar observations and processing with MWA
Steve Ord, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, Mar 2017

The extended HI properties of galaxies with IMAGINE
Attila Popping, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Tracing the low column density HI with IMAGINE
Attilla Popping, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

Outskirts of galaxy clusters – view from cosmological simulations
Chris Power, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

HI gas evolution over the cosmic time
Jonghwan Rhee, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

#nofilter: SAGE and the Epoch of Reionization, how relevant is the filtering mass?
Jacob Seiler, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Future prospects for detecting the 21cm signal from the EoR
Cathryn Trott, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Overview of focus groups
Cathryn Trott, SKA EoR/CD Science Working Group Meeting, Pisa, Italy, Mar 2017

Connecting galaxy dynamics to cosmic flows
Charlotte Welker, Mock Perth: challenges for simulations in the era of SKA and large IFU surveys, Australia, Mar 2017

Transforming galaxies: star formation and morphology
Christian Wolf, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

Purify: imaging using compressive sensing techniques
Laura Wolz, Realising SKA-Low: new technologies & techniques for imaging and calibration of low frequency arrays, Perth, Australia, Mar 2017

Fast-evolving galaxies
Ivy Wong, From Field to Clusters: HI as a tracer of galaxy evolution, Melbourne, Australia, Mar 2017

GLUV
Brad Tucker, CubeSat, Sydney, Australia, Apr 2017

ASKAP and ITSO: Understanding feedback and fuelling radio galaxies
James Allison, 2017 International Telescopes Support Office Science Symposium, Canberra, Australia, May 2017

HI galaxy science SWG
James Allison, OzSKA 3, Sydney, Australia, May 2017

The present and the future of the DWF program
Igor Andreoni, 2017 International Telescopes Support Office Science Symposium, Canberra, Australia, May 2017

Optical constraints on extreme scattering events
Keith Bannister, 2017 International Telescopes Support Office Science Symposium, Canberra, Australia, May 2017

Searching for FRBs with ASKAP
Keith Bannister, OzSKA 3, Sydney, Australia, May 2017

Keck spectroscopy of $z \sim 7$ galaxies: probing the physics of reionisation
Stephanie Bernard, 2017 International Telescopes Support Office Science Symposium, Canberra, Australia, May 2017

Fast radio bursts
Shivani Bhandari, OzSKA 3, Sydney, Australia, May 2017

Pulsars with the Murchison Widefield Array
Ramesh Bhat, OzSKA, Sydney, Australia, May 2017

Hector
Julia Bryant, OzSKA 3, Sydney, Australia, May 2017

MANIFEST destiny – why MOS and IFS instruments are needed on ELTs
Matthew Colless, 2017 International Telescopes Support Office Science Symposium, Canberra, Australia, May 2017

High redshift superluminous supernovae surveys
Jeff Cooke, Superluminous supernovae in the next decade, MIAPP, Germany, May 2017

DLAs in galaxy spectra
Jeff Cooke, 2017 International Telescopes Support Office Science Symposium, Canberra, Australia, May 2017

DECam detection and Keck spectroscopy on ongoing high redshift superluminous supernovae
Chris Curtin, Munich Institute for Astro- and Particle Physics (MIAPP) Seminar, Germany, May 2017

Cosmology in the era of the SKA
Tamara Davis, Fundamental Physics with the SKA, Flic-en-Flac, Mauritius, May 2017

Tracing HI in obscured AGN
Marcin Glowacki, OzSKA 3, Sydney, Australia, May 2017

Extragalactic continuum SWG
Minh Huynn, OzSKA 3, Sydney, Australia, May 2017

Searching for axion dark matter with the SKA
Katharine Kelley, Fundamental Physics with the SKA, Flic-en-Flac, Mauritius, May 2017

Joint microlensing and reverberation mapping analysis of HE0435-1223
Anthea King, Manhattan Microlensing, New York, USA, May 2017

HI and soft X-ray absorption
Vanessa Moss, OzSKA 3, Sydney, Australia, May 2017

The DECamERON project
Jeremy Mould, Superluminous supernovae in the next decade, MIAPP, Germany, May 2017

Radio transients SWG
Tara Murphy, OzSKA 3, Sydney, Australia, May 2017

Between wedge and window: an improved statistical point-source foreground model for the EoR
Steven Murray, Fundamental Physics with the SKA, Flic-en-Flac, Mauritius, May 2017

Cold gas models
Danail Obreschkow, OzSKA 3, Sydney, Australia, May 2017

Testing dark energy and modified gravity with the evolutionary map of the Universe survey
David Parkinson, Fundamental Physics with the SKA, Flic-en-Flac, Mauritius, May 2017

Cosmic HI density evolution
Jonghwan Rhee, OzSKA 3, Sydney, Australia, May 2017

The potential of the SKA from a particle physicist's perspective
Signe Reimer-Sorenson, Fundamental Physics with the SKA, Flic-en-Flac, Mauritius, May 2017

The EoR/CD science working group
Cathryn Trott, OzSKA, Sydney, Australia, May 2017

Murchison Widefield Array update
Randall Wayth, OzSKA, Sydney, Australia, May 2017

Investigating the HI distributions after reionisation with SKA-Low
Laura Wolz, Fundamental Physics with the SKA, Flic-en-Flac, Mauritius, May 2017

Precision cosmology with Type Ia supernovae: the Hubble constant and dark energy
Bonnie Zhang, Centre for Astrophysics & Supercomputing Colloquium, Swinburne University, Melbourne, Australia, May 2017

The history of cold gas in the Universe using the SKA
James Allison, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, Jun 2017

MWA high time resolution science update
Ramesh Bhat, MWA Project Meeting, Padova, Italy, Jun 2017

GLEAM: calibration, images, and catalogues
Paul Hancock, The Broad Impact of Low Frequency Observing, Bologna, Italy, Jun 2017

The Taipan Galaxy Survey
Andrew Hopkins, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, Jun 2017

Update on the 4MOST system for the Vista Telescope
Andrew Hopkins, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, Jun 2017

Ionospheric characterisation above the Murchison Radio Observatory with EoR datasets
Christopher Jordan, The Broad Impact of Low Frequency Observing, Bologna, Italy, Jun 2017

OzDES multi-object spectroscopy for the Dark Energy Survey
Chris Lidman, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, Jun 2017

Simulations beyond the point source; more realistic simulations to better understand foreground removal
Jack Line, MWA Project Meeting, Padova, Italy, Jun 2017

Status of SKA for HI absorption
Martin Meyer, HI absorption 2017, ASTRON, The Netherlands, Jun 2017

Spectral classification update. DASH: deep learning for supernova classification
Daniel Muthukrishna, Dark Energy Survey meeting, Chicago, USA, Jun 2017

EoR science update
Bart Pindor, MWA Project Meeting, Padova, Italy, Jun 2017

Linking absorption and emission of the CGM with IMAGINE
Attila Popping, HI absorption 2017, ASTRON, The Netherlands, Jun 2017

Imagine galaxies intergalactic and nearby environment
Attila Popping, What Matters around Galaxies, Durham, UK, Jun 2017

Evolution of cosmic gas density
Lister Staveley-Smith, HI absorption 2017, ASTRON, The Netherlands, Jun 2017

Dissecting galaxies with 6D physical models using SAMI/GAMA data
Dan Taranu, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, Jun 2017

Director's report
Randall Wayth, MWA Project Meeting, Padova, Italy, Jun 2017

Studying black holes at high redshift with SkyMapper and Taipan
Christian Wolf, Southern Cross 2017: Surveying the Cosmos, The Science from Massively Multiplexed Surveys, Sydney, Australia, Jun 2017

A low frequency census of southern pulsars
Mengyao Xue, The Broad Impact of Low Frequency Observing, Bologna, Italy, Jun 2017

The drivers of stellar population in early-type galaxies
Tania Barone, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

Chasing the bright end of the z > 8 galaxy luminosity function: follow-up imaging of galaxies during reionisation with Spitzer IRAC
Stephanie Bernard, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

Pulsar science with the Murchison Widefield Array
Ramesh Bhat, 13th Asian-Pacific Regional IAU Meeting (APRIM 2017), Taipei, Taiwan, Jul 2017

Sub-arcsec compact source properties using wide field interplanetary scintillation with the Murchison Widefield Array
Rajan Chhetri, The Broad Impact of Low Frequency Observing, Bologna, Italy, Jul 2017

SURFS: Synthetic UniveRses For Surveys
Pascal Elahi, Canadian Astronomical Society, Edmonton, Canada, Jul 2017

Fireballs and space debris with the MWA
Paul Hancock, Astronomical Society of Australia Annual Scientific meeting, Canberra, Canberra (Australia), Jul 2017

ASKAP pre-early science: GAMA23 field
Andrew Hopkins, SPARCS SPARCS VII The Precursors Awaken, Perth, Australia, Jul 2017

CASDA
Minh Huynn, SPARCS SPARCS VII The Precursors Awaken, Perth, Australia, Jul 2017

Challenging EoR Challenges with Array Redundancy
Ronniy Joseph, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

MWA polarisation studies
Emil Lenc, SPARCS SPARCS VII The Precursors Awaken, Perth, Australia, Jul 2017

The Epoch of Reionisation
Jack Line, Harley Wood Winter School, Sydney, Australia, Jul 2017

An update on the MWA EoR experiment
Jack Line, Astronomical Society of Australia Annual Meeting 2017, Sydney, Australia, Jul 2017

SkyMapper transient survey
Anais Möller, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

Profile variability studies with PPTA pulsars
Aditya Parthasarathy, International Pulsar Timing Array, Sevres, France, Jul 2017

Explaining Galactic antimatter with faint thermonuclear supernovae
Ashley Ruiter, The Impact of Binaries on Stellar Evolution, Garching, Germany, Jul 2017

Neutral hydrogen in the distant Universe: new results from the Australian SKA Pathfinder (ASKAP) telescope
Elaine Sadler, 13th Asian-Pacific Regional IAU Meeting (APRIM 2017), Taipei, Taiwan, Jul 2017

Reverberation mapping in bulk with DES/OzDES
Natalia Eiré Sommer, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

Murchison Widefield Array
Randall Wayth, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

Radio Galaxy Zoo DR1
Ivy Wong, SPARCS SPARCS VII:The Precursors Awaken, Perth, Australia, Jul 2017

A blinded determination of H_0 from low-redshift type Ia supernovae, calibrated by Cepheid variables
Bonnie Zhang, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Jul 2017

Shaping the circumgalactic medium through radio-loud AGN interactions on kpc scales
Julie Banfield, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Properties of subarcsecond compact source population identified using widefield interplanetary scintillation with the MWA
Rajan Chhetri, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Resolving the 40-year-old mystery of the size of high redshift DLAs
Jeff Cooke, The Circle of Life: Connecting the Intergalactic, Circumgalactic, and Interstellar Media, Kruger Park, South Africa, Aug 2017

Resolving environmental quenching of star formation with SAMI
Scott Croom, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Black holes in both normal and disrupted dwarf galaxies
Michael Drinkwater, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

The Milky Way: evidence for the Seyfert activity in the recent past
Joss Bland-Hawthorn, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Jet-driven outflows of cold gas: the case of 3C293
Elizabeth Mahony, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Reverberation in mapping with DES/OzDES
Natalia Eiré Sommer, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Feedback and the structure of local galaxies: insight from simulations and integral field kinematics
Dan Taranu, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Galactic winds and metallicities: EAGLE vs SAMI
Edoardo Tescari, The Circle of Life: Connecting the Intergalactic, Circumgalactic, and Interstellar Media, Kruger Park, South Africa, Aug 2017

Signal processing with heterogeneous digital filterbanks: lessons from the MWA and EDA
Randall Wayth, CASPER Workshop 2017, Pasadena, USA, Aug 2017

Conference summary
Rachel Webster, Shedding Light on Dark Matter with Extremely Large Telescopes, Lanzhou, China, Aug 2017

The growth of supermassive black holes
Christian Wolf, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

The SkyMapper southern survey
Christian Wolf, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Radio Galaxy Zoo DR1
Ivy Wong, From Black Hole to Environment: galaxy evolution over multiple wavelengths, Canberra, Australia, Aug 2017

Detection of radio emission from fireballs with the MWA
Xiang Zhang, International Union of Radio Science (URSI) GASS 2017, Montreal, Canada, Aug 2017

Millisecond pulsars across the MWA band
Ramesh Bhat, ACAMAR 3, Hobart, Australia, Sep 2017

A first SkyMapper variability census and the search for counterparts to high-energy events
Seo-Won Chang, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Sep 2017

HI cosmic density via stacking
Qingxiang Chen, ACAMAR 3, Hobart, Australia, Sep 2017

Stellar populations and dynamics from resolved spectroscopy of galaxies
Matthew Colless, Chemical Evolution of the Universe, Tarrytown, USA, Sep 2017

Testing gravity with 4MOST-based peculiar velocity surveys
Cullan Howlett, 4MOST All Hands Meeting, Lyon, France, Sep 2017

Calibration in the era of large N-arrays
Ronniy Joseph, ICRAR con, Mandurah, Australia, Sep 2017

Epoch of Reioniation update
Ronniy Joseph, ICRAR con, Mandurah, Australia, Sep 2017

The SKA
Evan Keane, IAUS 337: Pulsar Astrophysics – The Next 50 Years, Jodrell Bank Observatory, UK, Sep 2017

The wedge and the window
Steven Murray, ICRAR con, Mandurah, Australia, Sep 2017

Where is the gas? detecting neutral hydrogen in the IGM
Attila Popping, ACAMAR 3, Hobart, Australia, Sep 2017

Lessons from Parkes, ATCA and ASKAP
Lister Staveley-Smith, RAF 2017, Guizhou, China, Sep 2017

GLUV – a high-altitude UV survey
Brad Tucker, 68th International Astronautical Congress, Adelaide, Australia, Sep 2017

Strong field tests of gravity with PSR J1141–6545
Vivek Venkatraman, IAUS 337: Pulsar Astrophysics – The Next 50 Years, Jodrell Bank Observatory, UK, Sep 2017

MWA phase II status and plans
Randall Wayth, ACAMAR 3, Hobart, Australia, Sep 2017

Radio Galaxy Zoo DR1
Ivy Wong, ICRAR con, Mandurah, Australia, Sep 2017

Pulsar and transients group
Mengyao Xue, ICRAR con, Mandurah, Australia, Sep 2017

Detection of meteors and space debris with the MWA
Xiang Zhang, ACAMAR 3, Hobart, Australia, Sep 2017

Toward measuring the global EoR signal with the moon and the MWA
Benjamin McKinley, IAUS 333: Peering towards Cosmic Dawn, Dubrovnik, Croatia, Oct 2017

Between wedge and window: an improved statistical point-source foreground model for the EoR
Steven Murray, IAUS 333: Peering towards Cosmic Dawn, Dubrovnik, Croatia, Oct 2017

MWA observations of EOR1 field
Bart Pindor, IAUS 333: Peering towards Cosmic Dawn, Dubrovnik, Croatia, Oct 2017

Faint thermonuclear supernovae and Ti-44
Ashley Ruiter, With one hand waving free – John Lattanzio's 60th birthday, Port Douglas, Aus, Oct 2017

The Kepler extra-galactic survey
Brad Tucker, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Oct 2017

Mapping the Sky — from ancient times to the modern Australian SkyMapper Telescope
Christian Wolf, Annual Seminar of Mapping Sciences Institute of Australia, Australia, Oct 2017

An atlas of SFR changes in nearby galaxies from SkyMapper
Christian Wolf, Astronomical Society of Australia Annual Scientific meeting, Canberra, Australia, Oct 2017

Improved constraints on the growth rate of structure from modelling the density-velocity cross-correlation in the 6dF Galaxy Survey
Caitlin Adams, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Cosmology with Type Ia Supernova gravitational lensing
Jacobo Asorey, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

A unified galaxy scaling relations with SAMI
Dilyar Barat, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Seven Years of low frequency time-domain surveys: achievements and future prospects
Martin Bell, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Chasing the bright end of the z > 8 galaxy luminosity function with the BoRG
Stephanie Bernard, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Supernova cosmology
Bonnie Zhang, Sam Hinton and Dillon Brout, The Dark Energy Collaboration Meeting, Brisbane, Australia, Nov 2017

A first SkyMapper variability census and the search for counterparts to high-energy events
Seo-Won Chang, CAASTRO 2017 Annual Retreat, Barossa Valley, AUS, Nov 2017

HI cosmic density via stacking
Qingxiang Chen, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Stellar populations and dynamics from resolved spectroscopy of galaxies
Matthew Colless, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

The SAMI galaxy survey
Scott Croom, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Three of the highest redshift supernova spectra ever collected from the first HSC-SSP supernova survey Keck follow-up campaign
Chris Curtin, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Radio follow-up of GW170817
Dougal Dobie, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Radio follow-up of gravitational wave events
Dougal Dobie, Stars in Sydney, Macquarie University, Australia, Nov 2017

WISE data as a photometric redshift indicator for radio AGN
Marcin Glowacki, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

A numerical investigation into the spin parameter
Katherine Harborne, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Preserving your project: software tooling and resources
Sam Hinton, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Evolutionary map of the Universe
Andrew Hopkins, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Taipan galaxy survey
Andrew Hopkins, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Cosmology with peculiar velocity surveys
Cullan Howlett, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

The GAMA legacy ATCA southern survey
Minh Huynn, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Pulse profile and scintillation studies of PSR J2241-5236
Dilpreet Kaur, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Investigating AGN structure using a joint reverberation mapping and microlensing analysis of lensed quasar HE0435–1223
Anthea King, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Investigating AGN structure using a joint reverberation mapping and microlensing analysis of lensed quasar HE0435-1223
Anthea King, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

The UTMOST SMIRF survey
Vivek Venkatraman Krishnan, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Angular momentum in galaxies: lesson from the EAGLE simulations
Claudia Lagos, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Current and future simulations for multi-wavelength galaxy surveys
Claudia Lagos, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

OzDES: current status and first cosmological constraints
Chris Lidman, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Chasing low frequency burst from magnetically active stars
Christene Lynch, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Fast radio burst source counts
Jean-Pierre Macquart, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Searching for HI absorption in the brightest southern radio galaxies
Elizabeth Mahony, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Mapping emission regions in magnetospheres: simultaneous observations of subpulse drifting with the MWA and the GMRT
Sam McSweeny, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Deep investigation of neutral gas origins
Martin Meyer, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Spectral flattening of Crab giants pulses at low frequencies
Bradley Meyers, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

SkyMapper transient survey towards the first data release
Anais Möller, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

First results of the SkyMapper transient survey
Anais Möller, IAUS 339: Southern Horizons in Time-Domain Astronomy, Cape Town, South Africa, Nov 2017

SkyMapper and the transient survey
Anais Möller, The Dark Energy Collaboration Meeting, Brisbane, Australia, Nov 2017

The SkyMapper transient survey
Anais Möller, Cherenkov Telescope Array Workshop, Canberra, Australia, Nov 2017

Between window and wedge: a new statistical point-source model of EoR
Steven Murray, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Revealing the local stellar populations of SN1991bg-like supernova host galaxies
Fiona Panther, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Conference summary
Attila Popping, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Does what we know of galaxy halos tell us anything about what dark matter is?
Chris Power, CAASTRO CoEPP Workshop, Barossa Valley, Australia, Nov 2017

Seeking the signatures of dark matter in future galaxy formation surveys
Chris Power, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

The magic of accretion: how to make a neutron star from a white dwarf
Ashley Ruiter, Stars in Sydney 2017, Sydney, Nov 2017

Datacube construction for SAMI via transformed Gaussian process priors
Richard Scalzo, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

A night in the deep beyond
Brian Schmidt, The Dark Energy Collaboration Meeting, Brisbane, Australia, Nov 2017

Extragalactic archaeology with SAM
Nic Scott, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Galactic centre annihilation
Lister Staveley-Smith, CAASTRO CoEPP Workshop, Barossa Valley, Australia, Nov 2017

WALLABY: an all-sky HI survey
Lister Staveley-Smith, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

From time-lags to dark energy: reverberation mapping with DES/OzDES
Natalia Eiré Sommer, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

I'm batman! (and here's why..)
Natalia Eiré Sommer, Mount Stromlo Christmas Student Seminars, Canberra, Australia, Nov 2017

Reverberation mapping in bulk
Natalia Eiré Sommer, The Dark Energy Collaboration Meeting, Brisbane, Australia, Nov 2017

Dissecting disk galaxies with multiwavelength data
Dan Taranu, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Dissecting disks – galaxy modelling synergies with deep imaging, SAMI and simulations
Dan Taranu, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

The scatter matters: measuring the dispersion in the stellar-to-halo mass relation
Ned Taylor, GAMA: Final data release, legacy, and future galaxy evolution surveys, Perth, Australia, Nov 2017

Investigating magnetospheres of pulsars with the MWA
Stephen Tremblay, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Seven years of CAASTRO EoR – where are we now?
Cathryn Trott, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

The SkyMapper search for Planet 9
Brad Tucker, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Deriving gas kinematics for irregular disk galaxies using trans-dimensional Bayesian Gaussian mixtures
Mathew Varidel, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Gender action committee report
Rachel Webster, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

From the ashes to…15 years of SkyMapper project
Christian Wolf, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Optical follow-up of GW events with ANU telescopes (past and future)
Christian Wolf, OzGrav Retreat 2017, Melbourne, Australia, Nov 2017

Testing galaxy evolution through HI intensity mapping cross-correlations
Laura Wolz, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Radio Galaxy Zoo
O. Ivy Wong, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Low-frequency pulsar polarimetry across the MWA Band
Mengyao Xue, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

Supernova cosmology with the Dark Energy Survey 3-year 'spectroscopic' sample
Bonnie Zhang, CAASTRO 2017 Annual Retreat, Barossa Valley, Barossa, Nov 2017

Studies of bursty and quiescent emission of two ultra-cool dwarfs with the GMMRT
Andrew Zic, CAASTRO 2017 Annual Retreat, Barossa Valley, Australia, Nov 2017

MWA high time resolution science update
Ramesh Bhat, MWA project meeting, Sydney, Australia, Dec 2017

MWA pulsar science and survey plans
Ramesh Bhat, Science at Low Frequencies IV, Sydney, Australia, Dec 2017

Radio follow-up of gravtitational wave events
Dougal Dobie, Bolton Symposium, Sydney, Australia, Dec 2017

New capabilities for the MWA: rapid response triggers
Paul Hancock, MWA project meeting, Sydney, Australia, Dec 2017

Near-field transients: detecting satellites and space debris with the MWA
Paul Hancock, Science at Low Frequencies IV, Sydney, Australia, Dec 2017

Unexpected, exciting developments in ionospheric imaging
Christopher Jordan, Science at Low Frequencies IV, Sydney, Australia, Dec 2017

Toward measuring the Global EoR signal with the Moon and the MWA
Benjamin McKinley, MWA project meeting, Sydney, Australia, Dec 2017

Neutral hydrogen in distant galaxies: the ASKAP FLASH survey
Elaine Sadler, Hunstead Workshop 2017, Sydney, Australia, Dec 2017

Engineering development array: a low frequency radio telescope utilising SKA precursor technology
Marcin Sokolowski, Science at Low Frequencies IV, Sydney, Australia, Dec 2017

Bayesian physical galaxy modelling using MagRite
Dan Taranu, Workshop on Statistical Challenges in Astronomy, Sydney, Australia, Dec 2017

Dissecting disks with SAMI
Dan Taranu, Hunstead Workshop 2017, Sydney, Australia, Dec 2017

Extended source models for EoR Science
Cathryn Trott, Science at Low Frequencies IV, Sydney, Australia, Dec 2017

MWA Director's report
Randall Wayth, MWA project meeting, Sydney, Australia, Dec 2017

Public Talks 2017

SN 1006
Brian Schmidt, St Gallen, Switzerland, January 2017

Exploding stars, dark energy, and the end of the Universe
Brad Tucker, Kioloa, January 2017

The past, present, and future of Mount Stromlo Observatory and space
Brad Tucker, Kioloa, January 2017

Our Universe
Brad Tucker, ANU, Canberra, six sessions in January 2017

Our Universe from Mount Stromlo
Brad Tucker, ANU, Canberra, January 2017

Speed date a scientist
Rachel Webster, ACT National Youth Science Forum (NYSF) Partners' Day, Canberra, January 2017

An intermediate-mass black hole in the globular cluster 47 Tuc
Holger Baumgardt, Brisbane Astronomical Society, Brisbane, February 2017

Dark energy and dark matter
Tamara Davis, Queensland Museum, Brisbane, February 2017

Around the Universe in 3 years with the Murchison Widefield Array (MWA)
Emil Lenc, Western Sydney University, Sydney, February 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Astronomical Society of Victoria, Melbourne, February 2017

Unravelling the dark side of the Universe
Katie Mack, Renaissance Weekend, Santa Fe, New Mexico, USA, February 2017

The dark side of the Universe
Katie Mack, North Carolina Museum of Natural Sciences, Raleigh, North Carolina, USA, February 2017

The life and times of stars
Brad Tucker, ANU, Canberra, February 2017

Using space telescopes to look for the first galaxies
Stephanie Bernard, Mt Burnett Observatory, Melbourne, March 2017

History of supernova cosmology
Tamara Davis, University of Queensland Physics Students Society, Brisbane, March 2017

Collision: A unique Insight into the world of hadron
Tamara Davis, World Science Festival, Brisbane, March 2017

EARTH 2.0: a future habitat for humanity
Brian Schmidt, Tamara Davis, Alan Duffy, World Science Festival, Brisbane, March 2017

Why do we think there was a Big Bang?
Bart Pindor, Mornington Peninsula Astronomical Society Winter Lecture, Melbourne, March 2017

Australian radio astronomy: past, present and future, Astronomer in Residence
Tristan Reynolds, Astronomer in Residence, Uluru, two sessions in March 2017

The future is in good hands: a next generation perspective
Brian Schmidt, World Science Festival, Brisbane, March 2017

Gravitational waves: a new era of astronomy begins
Brian Schmidt, World Science Festival, Brisbane, March 2017

Philosophy of the cosmos
Brad Tucker, ANU, Canberra, March 2017

The life and times of stars
Brad Tucker, ANU, Canberra, March 2017

The past, present, and future of Mount Stromlo Observatory and space
Brad Tucker, ANU, Canberra, March 2017

The future of space
Brad Tucker, Questacon, Canberra, March 2017

Mount Stromlo past, present, and future
Brad Tucker, Greenway Probus Club, Canberra, March 2017

Mount Stromlo Observatory
Brad Tucker, ANU Collections, Museums, and Heritage Studies, Canberra, March 2017

The dark side of the Universe
Tamara Davis, ANSTO, Sydney, April 2017

Cosmic shambles live, end of the Universe
Katie Mack, Melbourne, April 2017

How to Use Twitter for good (and science)
Katie Mack, Melbourne, April 2017

The dark and energetic Universe
Natalia Eiré Sommer, Mt Stromlo Public Astronomy night, Canberra, April 2017

Past, present, and future of Mt Stromlo
Brad Tucker, ANU, Canberra, April 2017

Explosions and collisions in space
Brad Tucker, ANU, Canberra, April 2017

Insomnia: stories to keep you up at night
Tamara Davis, Brisbane, May 2017

Legacy of Einstein
Michael Drinkwater, New Scientist Live Masterclass, Sydney, May 2017

Journey to the edge of the Universe – 3 years of research with the MWA
Emil Lenc, Western Sydney Amateur Astronomy Group, Sydney, May 2017

Evolution of the Universe
Claudia Lagos, Fremantle, WA, May 2017

Dispatches from a dark Universe
Katie Mack, Space Association of Australia, Melbourne, May 2017

The dark and energetic Universe
Natalia Eiré Sommer, Questacon, Canberra, May 2017

Black holes - what are they, really?
Natalia Eiré Sommer, ANU, Canberra, May 2017

Are we alone?
Brad Tucker, ANU, Canberra, May 2017

Past, present, and future of Mt Stromlo
Brad Tucker, ANU, Canberra, May 2017

From garbage truck driver to astrophysicist and science communicator
Brad Tucker, Australian Science Communicators, Canberra, May 2017

The future of space exploration
Brad Tucker, Questacon, Canberra, May 2017

The nature of things – do aliens exist?
Brad Tucker, Ursula Hall, Canberra, May 2017

Exoplanets and life in space
Katie Mack, Royal Society of Victoria, Melbourne, June 2017

The story of light: surveying the cosmos
Katie Mack and Tara Murphy (panel), Vivid Sydney, Sydney, June 2017

Dispatches from a dark Universe
Katie Mack, Staff Stuff Byron Bay, Byron Bay, June 2017

The future of space travel and exploration
Brad Tucker, ANU, Canberra, June 2017

Kepler's view of exploding stars
Brad Tucker, De Anza College, Cupertino, CA, USA, June 2017

The science behind alien: Covenant
Brad Tucker, ANU Film Group, Canberra, June 2017

The future of space travel and exploration
Brad Tucker, ANU, Canberra, June 2017

The Universe explained in 15 minutes or less
Jessica Bloom, Sydney Astrofest 2017, Sydney, July 2017

What can observations tell us about Fundamental Physics?
Tamara Davis, University of Copenhagen, Copenhagen, Denmark, July 2017

Building models of the Milky Way (and other galaxies), Astronomer in Residence
Katherine Harbourne, Astronomer in Residence, Uluru, two sessions in July 2017

The search for new worlds
Christene Lynch, Sydney Astrofest 2017, Sydney, July 2017

Humans in Space
Katie Mack, Melbourne, July 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Perth, July 2017

Dispatches from a dark Universe
Katie Mack, Women in Physics Lecture Tour, Brisbane, July 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Brisbane, July 2017

A tour of the Universe (and selected cosmic mysteries)
Katie Mack, Women in Physics Lecture Tour, Brisbane, July 2017

Dispatches from a dark Universe
Katie Mack, Women in Physics Lecture Tour, Canberra, July 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Canberra, July 2017

A tour of the Universe (and selected cosmic mysteries)
Katie Mack, Women in Physics Lecture Tour, Canberra, July 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Sydney, July 2017

The invisible universe
Tara Murphy, Sydney Astrofest 2017, Sydney, July 2017

The most distant galaxies
Michele Trenti, Astronomer in Residence, Uluru, two sessions in July 2017

Collisions and exploisions in space
Brad Tucker, Sydney Astrofest 2017, Sydney, July 2017

Exploding stars, dark energy, and the end of the Universe
Brad Tucker, CWAS Astrofest, Parkes, July 2017

Explosions and collisions in space
Brad Tucker, CWAS Astrofest, Parkes, July 2017

Astronomy for fun – historical astronomy
Brad Tucker, ANU, Canberra, July 2017

Astronomy for fun – The life of stars
Brad Tucker, ANU, Canberra, July 2017

Exploding stars and the expanding Universe
Brad Tucker, Mt Stromlo, Canberra, July 2017

Wake up astronomy
James Allison, Science Week, Sydney, August 2017

Radio galaxies
Julie Banfield, Astronomer in Residence, Uluru, August 2017

Women in astronomy
Tamara Davis, Macarthur Astronomy Society, Sydney, August 2014

What's next? To infinity and beyond
Tamara Davis, Women on Mars, Sydney Opera House, Sydney, August 2017

The dark side of the Universe
Tamara Davis, Capstone talk, University of Queensland, Brisbane, August 2017

The dynamic radio sky
Dougal Dobie, Astronomer in Residence, Uluru, two sessions in August 2017

Immersive science: The next frontier in Australian astronomy
Katie Mack & Alan Duffy, National Science Week VR Show, Melbourne, August 2017

Dispatches from a dark Universe
Katie Mack, Women in Physics Lecture Tour, Melbourne, August 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Melbourne, August 2017

A tour of the Universe (and selected cosmic mysteries)
Katie Mack, Women in Physics Lecture Tour, Melbourne, August 2017

Dispatches from a dark Universe
Katie Mack, Women in Physics Lecture Tour, Tasmania, August 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Tasmania, August 2017

A tour of the Universe (and selected cosmic mysteries)
Katie Mack, Women in Physics Lecture Tour, Tasmania, August 2017

A tour of the Universe (and selected cosmic mysteries)
Katie Mack, Women in Physics Lecture Tour, Adelaide, August 2017

Everything you wanted to know about dark matter but were afraid to ask
Katie Mack, Women in Physics Lecture Tour, Adelaide, August 2017

Finding planets around other stars
Ben Pope, Astronomer in Residence, Uluru, August 2017

Finding planets around other stars
Ben Pope, Astronomer in Residence, Uluru, August 2017

Falling into a black hole
Natalia Eiré Sommer, Physics in the Pub, Canberra, August 2017

Astronomy for fun – The solar system
Brad Tucker, ANU, Canberra, August 2017

Astronomy for fun – practical astronomy
Brad Tucker, ANU, Canberra, August 2017

The science of Interstellar
Brad Tucker, Science at the Cinema, Canberra, August 2017

Astronomy for fun – galaxies
Brad Tucker, ANU, Canberra, August 2017

Loving science, science loves you
Brad Tucker, The Wholesome Show, Canberra, August 2017

What's out there?
Brad Tucker, Strictly Science, Canberra, August 2017

Astronomy for fun – cosmology
Brad Tucker, ANU, Canberra, August 2017

Radio galaxies
Julie Banfield, Astronomer in Residence, Uluru, September 2017

Super-massive black holes: friend or foe
Julie Banfield, Starfest, Canberra, Canberra, September 2017

The size and age of the Universe
Julie Banfield, Starfest, Canberra, Canberra, September 2017

Dark matter
Tamara Davis, Queensland Skeptics, Brisbane, Brisbane, September 2025

Simulating the Universe (and other fun things to do on cloudy nights)
Paul Geil, Astronomer in Residence, Uluru, September 2017

Going walkabout with the Murchison Widefield Array (MWA)
Emil Lenc, Western Sydney University Public Astronomy Night, Sydney, September 2017

Future of space
Katie Mack, AstroLight, Melbourne, September 2017

The end of the Universe
Katie Mack, AstroLight, Melbourne, September 2017

How do we study the dark side of the Universe?
Anais Möller, Starfest, Canberra, September 2017

What can light from far, far away tell us?
Anais Möller, Starfest, Canberra, September 2017

CAASTRO and gender equity in astronomy
Elaine Sadler, Science in Australian Gender Equity, Sydney, September 2017

Explosions and collisions in space
Brad Tucker, Cassini Grand Final, Canberra, September 2017

Citizen science project & supernova sighting
Anais Möller and Brad Tucker, Universe Today Weekly Space Hangout, USA and Canada, September 2017

Citizen science in astronomy
Brad Tucker, GeoScience Australia, Canberra, September 2017

UN space 50
Brad Tucker, Questacon, Canberra, September 2017

Explosions and collisions in space
Brad Tucker, ANU, Canberra, September 2017

Looking for the first galaxies in the Universe
Stephanie Bernard, Katie Mack and Laura Wolz, AstroLight Festival, Melbourne, September 2017

How galaxies start and stop forming stars
Ivy Wong, Starfest, Canberra, September 2017

The hunt for new worlds
Andrew Zic, Astronomer in Residence, Uluru, two sessions in September 2017

The dark side of the Universe
Tamara Davis, University of Southern Queensland, Toowoomba, October 2017

Breakthrough! The detection of gravitational waves from a neutron star merger
Tara Murphy, Allison Levick Memorial Lecture, Sydney, October 2017

Exploring the invisible universe
Tara Murphy, Uluru Astronomy Weekend 2017, Uluru, October 2017

Black holes in the distant Universe
Elaine Sadler, Uluru Astronomy Weekend 2017, Uluru, October 2017

The future of Australian space
Brad Tucker, ACT YMCA Space Camp, Canberra, October 2017

Space's Influence on Policy
Brad Tucker, ANU, Canberra, October 2017

Space Mining
Brad Tucker, US Space Summit, Canberra, Canberra, October 2017

Planet 9 and our solar system
Brad Tucker, ANU, Canberra, October 2017

Beginning – and end – of the Universe
Rachel Webster, Uluru Astronomy Weekend 2017, Uluru, October 2017

Dark cosmos
Rachel Webster, Uluru Astronomy Weekend 2017, Uluru, October 2017

Exploring the hidden Universe
Dougal Dobie, Science in a Lunchtime, Sydney, November 2017

Xenoepidemiology – more reality than you think
Brad Tucker, Australian Medical Association, Canberra, November 2017

Citizen science
Julie Banfield, Peterborough, Canada, December 2017

Citizen science
Julie Banfield, Toronto, Canada, December 2017

INTERNATIONAL VISITORS TO CAASTRO IN 2017

Per Andersen
University of Copenhagen, Denmark

Nichole Barry
University of Washington, USA

Gianni Bernardi
Rhodes University, South Africa

Garima Chauhan
University of Glasgow, Scotland

Avinash Deshpande
Raman Research Institute, India

Bryan Gaensler
University of Toronto, Canada

Greg Hallinan
California Institute of Technology, USA

Kelley Hess
Kapteyn and ASTRON, The Netherlands

Nick Kaiser
Institute for Astronomy, University of Hawaii, USA

David Kaplan
University of Wisconsin-Madison, USA

Ben Keller
McMaster University, Canada

Joern Kuensmueller
Bielefeld University, Germany

Kathleen Labrie
Gemini Observatory North, USA

Xuecong Liu
Nankai University, China

James Mason
University of Colorado, USA

Javier Mejuto
Universidad Nacional Autónoma de Honduras, Honduras

Raffaella Morganti
ASTRON, The Netherlands

Colin Norman
Johns Hopkins University, USA

Andre Offringa
ASTRON, The Netherlands

Harvey Richer
University of British Columbia, Canada

Jayanta Roy
National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Pune, India

Matthieu Schaller
Durham University, UK

Stuart Sim
Queens University, Northern Ireland, UK

Evangelia Tremov
Michigan State University, USA

Tessa Vernstrom
University of Toronto, Canada

Mark Wilkinson
University of Leicester, UK

VISITS TO OVERSEAS LABORATORIES AND FACILITIES IN 2017

Jacobo Asorey
University of Chicago, USA

Julie Banfield
California Institute of Technology, USA

Julie Banfield
Carnegie Observatory, USA

Julie Banfield
Science Space Telescope Institute, USA

Julie Banfield
Dunlap Institute for Astronomy and Astrophysics, University of Toronto, Canada

Shivani Bhandari
West Virginia University, USA

Ramesh Bhat
The Five-hundred metre aperture spherical telescope (FAST), China

Ramesh Bhat
University of Bielefeld, Germany

Rajan Chhetri
INAF – Astronomical Observatory of Padova, Italy

Rajan Chhetri
Instituto di Radioastronomia, Italy

Alex Codoreanu
Durham University, UK

Jeff Cooke
Keck Observatory, USA

Jeff Cooke
National Astronomical Observatories of Japan, Japan

Scott Croom
Korea Astronomy and Space Science Institute, Republic of Korea

Scott Croom
Yonsei University, Republic of Korea

Chris Curtin
Max Planck Institute for Astro- and Particle Physics, Germany

Tamara Davis
Inter-University Centre for Astronomy and Astrophysics, Pune, India

Tamara Davis
University of Chicago, USA

Dougal Dobie
University of Wisconsin Milwaukee, USA

Dougal Dobie
University of the Virgin Islands, USA

Pascal Elahi
Hertzberg Institute of Astronomy, Canada

Pascal Elahi
University of Victoria, Canada

Pascal Elahi
University of Washington, USA

Kate Gunn
Cranfield University, UK

Kate Gunn
Imperial College London, UK

Kate Gunn
Institute of Physics, UK

Kate Gunn
Kings College London, UK

Kate Gunn
Loughborough University, UK

Kate Gunn
Swansea University, Wales, UK

Kate Gunn
University College London, UK

Kate Gunn
University of Cambridge, UK

Kate Gunn
University of Liverpool, UK

Kate Gunn
University of Nottingham, UK

Kate Gunn
University of Sheffield, UK

Cullan Howlett
Durham University, UK

Anthea King
American Museum of Natural History, New York, USA

Anthea King
Gemini North Telescope, Hawaii, USA

Claudia Lagos
ALMA Observatory, Belgium

Claudia Lagos
Cardiff University, UK

Jack Line
INAF – Astronomical Observatory of Padova, Italy

Jack Line
Kumamoto University, Japan

Katie Mack
California Institute of Technology, USA

Katie Mack
Haverford College, USA

Katie Mack
Imperial College London, United Kingdom

Katie Mack
Korea Astronomy and Space Science Institute, Republic of Korea

Katie Mack
Niels Bohr Institute, Denmark

Katie Mack
Swarthmore College, USA

Elizabeth Mahony
ASTRON, The Netherlands

Elizabeth Mahony
The National Centre for Radio Astrophysics (NCRA-TIFR), Pune, India

Rebecca McElroy
Leibniz Institute for Astrophysics, Potsdam, Germany

Rebecca McElroy
Max Planck Institute for Astronomy, Germany

Rebecca McElroy
Yale University, USA

Sam McSweeney
Raman Research Institute, India

Martin Meyer
Zagreb University, Croatia

Bradley Meyers
SKA Office, Jodrell Bank, UK

Vanessa Moss
The National Centre for Radio Astrophysics (NCRA-TIFR), Pune, India

Jeremy Mould
California Institute of Technology, USA

Jeremy Mould
Max Planck Institute for Astro- and Particle Physics, Germany

Jeremy Mould
University of the Virgin Islands, USA

Daniel Muthukrishna
Kavli Institute of Cosmological Physics, University of Chicago, USA

Fiona Panther
Heidelberg Institute for Theoretical Studies (HITS), Germany

Fiona Panther
Max Planck Institute for Astronomy, Germany

Fiona Panther
Max Planck Institute for Extraterrestrial Physics, Germany

Fiona Panther
Max Planck Institute for Kernphysik, Germany

Bart Pindor
INAF – Astronomical Observatory of Padova, Italy

Bart Pindor
Ruder Boskovic Institute, Republic of Croatia

Bart Pindor
University of Gronigen, Kapetyn Astronomical Institute, The Netherlands

Attila Popping
SKA Office, Jodrell Bank, UK

Attila Popping
The National Centre for Radio Astrophysics (NCRA-TIFR), Pune, India

Jongwhan Rhee
The National Centre for Radio Astrophysics (NCRA-TIFR), Pune, India

Ashley Ruiter
European Southern Observatory Garching, Germany

Ashley Ruiter
Heidelberg Institute for Theoretical Studies (HITS), Germany

Ashley Ruiter
St. Mary's University, Canada

Elaine Sadler
ASTRON, The Netherlands

Elaine Sadler
European Southern Observatory, Garching, Germany

Ivo Seitenzahl
European Southern Observatory, Santiago, Chile

Ivo Seitenzahl
Very Large Telescope, Chile

Lister Staveley-Smith
SKA Office, Jodrell Bank, UK

Lister Staveley-Smith
The National Centre for Radio Astrophysics (NCRA-TIFR), Pune, India

Natalia Eiré Sommer
Ohio State University, USA

Dan Taranu
McMaster University, Canada

Dan Taranu
University of Toronto, Canada

Dan Taranu
University of Washington, USA

Edoardo Tescari
South African Astronomical Observatory, South Africa

Steven Tremblay
Bielefeld University, Germany

Cathryn Trott
INAF – Astronomical Observatory of Padova, Italy

Cathryn Trott
Scuola Normale Superiore, Italy

Brad Tucker
Challenger Centre for Space Science Education, Washington, DC, USA

Brad Tucker
Google X, USA (four visits)

Brad Tucker
NASA Ames, USA (four visits)

Brad Tucker
NASA Goddard, USA

Brad Tucker
Smithsonian Institute, USA

Brad Tucker
Space Telescope Science Institute, USA

Brad Tucker
University of California Berkeley, USA (four visits)

Brad Tucker
University of Maryland, USA

Vivek Venkatraman
Auckland University of Technology, New Zealand

Randall Wayth
California Institute of Technology, USA

Randall Wayth
INAF – Astronomical Observatory of Padova, Italy

Rachel Webster
City University of New York, USA

Rachel Webster
Ethiraj College for Women, Chennai, India

Rachel Webster
Institute of Modern Physics, Chinese Academy of Sciences, China

Rachel Webster
Royal Society of New Zealand, New Zealand

Rachel Webster
Ruder Boskovic Institute, Republic of Croatia

Rachel Webster
University of Gronigen, Kapetyn Astronomical Institute, The Netherlands

Christian Wolf
Centre de Données astronomiques de Strasbourg, France

Christian Wolf
European Southern Observatory Garching, Germany

Christian Wolf
Max Planck Institute for Astronomy, Germany

Ivy Wong
ETH-Zurich, Switzerland

Mengyao Xue
INAF – Astronomical Observatory of Padova, Italy

Bonnie Zhang
SLAC National Accelerator Laboratory, Stanford University, CA, USA

WORKSHOPS

CAASTRO hosted a number of interesting, well-attended and stimulating workshops during 2017.

CAASTRO–CoEPP Joint Workshop: Connecting Astrophysical Dark Matter with Direct Detection

30 January–1 February 2017, The University of Melbourne, Victoria

The third CAASTRO–CoEPP Joint Workshop was a great success, bringing together about 60 astronomers and particle physicists from Australia and overseas.

The workshop was designed to promote interaction and collaboration between members of the astronomy and particle physics communities who are interested in the problem of dark matter and its role in cosmology. Like the previous CAASTRO–CoEPP Joint Workshop, this event was partly motivated by current and possible future Australian investment in dark-matter detection programs at the Stawell Underground Physics Laboratory in Victoria.

Researchers from several overseas institutions have recently put together an exciting new proposal for a directional dark matter detector – one that could distinguish the direction of the recoils of atomic nuclei, and so perhaps determine the direction in which dark-matter particles are travelling. The collaboration to build such a directional detector is called CYGNUS. This project has already attracted a great deal of interest within CoEPP. Part of the purpose of this CAASTRO–CoEPP workshop was to introduce the concept to CAASTRO astronomers, because directional detectors may be able to give us detailed information about properties of our Galaxy's dark-matter halo.

The workshop consisted of two days of talks followed by a CYGNUS collaboration meeting. The first day of the workshop focused on dark matter's role in astronomy and what we have learned from observations and experiments up to this point. The second day was a deeper dive into the future of dark-matter detection experiments, both directional and non-directional. We heard from a wide range of speakers, from graduate students to group leaders, who represented universities in Australia, Asia, the USA and Europe. Some of the participants, both speakers and others, attended the workshop remotely, from their home locations.

By the end of the meeting we had a document, signed by many of the meeting's participants, that expressed support for the ongoing use of the Stawell Underground Physics Laboratory (SUPL) for dark-matter studies. This was very well received by the Northern Grampians Shire Council, which administers SUPL's region.

Mock Perth: Challenges for Simulations in the Era of SKA and Large IFU Surveys

20–22 March 2017, Trinity College, Crawley, Western Australia

The galaxy surveys of the next decade will transform how we view galaxies of all sizes and all periods of the Universe's history – from the smallest dwarfs to the most massive galaxies in the centres of clusters, and from the Epoch of Reionisation to the present day. The Mock Perth meeting, hosted by ICRAR–UWA, was a look at how well prepared our galaxy-formation models are for making predictions for these surveys. Some 40 observational, theoretical, and computational astronomers from around the world came together to discuss what we can expect from future surveys, based on the current state-of-the-art observations; what current galaxy-formation models predict; and what future galaxy-formation models need to do if they are to be useful for interpreting the surveys' datasets. The meeting focused on star formation, feedback and environmental processes, such as ram-pressure stripping: there were special sessions on, for example, the Epoch of Reionisation and neutral hydrogen (HI) in galaxies, and more general ones on understanding what the major challenges are for simulations and how they can be overcome. Current simulations can successfully reproduce many statistical properties of observed galaxy population but struggle to capture their detailed internal properties. The meeting highlighted that, to make useful predictions, future models must be better at handling feedback processes, binary stellar evolution, and turbulence in the interstellar medium.

Mock Perth Workshop ***Credit: Chris Power***

David Luchetti speaking at OzSKA 3 Workshop
Credit: Phil Edwards

OzSKA 3 Workshop

8–9 May 2017, University of Sydney, New South Wales

This year's OzSKA workshop, like the previous ones, was held to inform participants about developments related to the Square Kilometre Array (SKA) project. Sixty-four people attended. There were updates from the SKA Board and Australian SKA Office, progress reports from the Australian and South African precursors and pathfinders, summaries of activities within most of the SKA Science Working Groups and Focus Groups, descriptions of the new ARC Centres of Excellence (OzGrav and ASTRO 3D), introductions to a number of multiwavelength projects, and a number of contributed talks from the astronomical community. In addition to these longer presentations, Warren Bax (CSIRO) and Natasha Hurley-Walker (ICRAR–Curtin) gave short reports on their SKA Fellowship visits to the SKA Organisation in the UK.

Five talks were presented remotely, including three by women who were, for family reasons, unable to attend in person (and who were grateful for the opportunity to present remotely). *Zoom* was used for these presentations and worked well.

CAASTRO, ICRAR and CSIRO sponsored the meeting and CAASTRO's event coordinator, Kylie Williams, gave support throughout.

Fundamental Physics with the Square Kilometre Array
Credit: Bryan Gaensler

Fundamental Physics with the Square Kilometre Array Conference

1–5 May 2017, Flic en Flac, Mauritius

This CAASTRO workshop, organised by Bryan Gaensler had a goal to engage the theoretical-physics community in the science case and design of the Square Kilometre Array (SKA), and to bring together radio astronomers and theorists to jointly consider how the SKA can test and explore fundamental physics.

Around 70 scientists attended, from 23 countries across all six inhabited continents. We particularly wanted to engage the African scientists who will be involved in constructing the SKA; astronomers from South Africa, Mauritius, Kenya and Ghana all attended and gave invited reviews of the radio-astronomy research being carried out in their countries.

The remaining science talks were divided into four topics: Cosmic Dawn and Reionisation, Cosmology and Dark Energy, Dark Matter and Astroparticle Physics, and Gravity and Gravitational Radiation. For each topic there were invited reviews from both observers and theorists, followed by several shorter contributed talks. (All talks are available at http://skatelescope.ca/fundamental-physics-ska/presentations/). We held breakout discussion sessions on specific questions within each topic then reconvened in a plenary session for more discussion.

The meeting generated such excitement and momentum that we are now writing a white paper summarising the prospects for fundamental physics with the SKA, addressing the same four topics as the meeting did. This paper will be submitted as a refereed manuscript to Publications of the Astronomical Society of Australia; the draft will be available to all meeting participants beforehand.

Participants found this meeting highly stimulating and enjoyable, with an excellent mix of theorists and observers, faculty and students. We hope that the ideas from this meeting will become part of the framework and discussion around the specifications for the full SKA, and that we can hold a follow-up meeting in a few years to develop them further.

ACAMAR 3 Workshop, Hobart *Credit: Andreas Wicenec*

From Black Hole to Environment

21–24 August 2017, Australian National University, Canberra

This meeting drew a mix of observational and theoretical astronomers, 85 in all. Its subject was how galaxies evolve through feeding and feedback processes, broken down into four themes:

- galaxy groups, clusters, large-scale structure: dynamics; mergers and interactions
- galaxies in the high-redshift Universe: AGN (active galactic nuclei) feedback and gaseous outflows
- galaxies in the low-redshift Universe: the refuelling and feeding black holes; star formation
- centres of galaxies: black-hole accretion; the launching jets of and galactic winds; starbursts and star formation.

The meeting focused on multiwavelength science that addressed these areas of science, and members of major galaxy surveys and simulation projects gave updates on their work. The conference organisers made every effort to create a balanced program into different career stages and between observations and theory.

Following on the success of the 2016 CAASTRO Annual Scientific Conference The Changing Faces of Galaxies, the Scientific Organising Committee (SOC) blind ranked the submitted abstracts. The SOC was given only the talk title, abstract, and a note if the submission was from a student. Ensuring an even split among the four themes along with observation and theory presentations, the end result was a balance program including 8 female and 8 male highlight talks from student to full professor. The invited speakers included Jorge Morano (Pomona College) who provided the overview for the meeting while survey specific talks were given by Christian Wolf (ANU) for SkyMapper, Natasha Hurley-Walker (Curtin) for GLEAM, and Elisabete Da Chuna (ANU) for TAIPAN.

The meeting strayed from the normal format of talks and question time to include 30 - 40 minute discussion periods. The discussion included a panel containing a selection of speakers from the previous talk sessions with the invited speakers leading the discussion. The discussions were lively with full participation from all attendees. Having observations and theory discussed in the same room contributed to the success of these discussions. The conference dinner was held at Old Parliament House.

ACAMAR 3, Australia–China Workshop on Astrophysics

18–20 September 2017, Wrest Point Conference Centre, Hobart, Tasmania

The third Australia–China Workshop on Astrophysics, organised by the Australia–China Consortium for Astrophysical Research (ACAMAR), was an exciting and well-attended event, drawing more than 70 participants. Sessions covered Antarctic astronomy, gravitational waves, radio astronomy, instrumentation and big-data challenges. The workshop was an excellent opportunity to strengthen existing research collaborations between Australia and China, and to plan new ones. A highlight was the workshop dinner at the Museum of Old and New Art (MONA), both the dinner itself and the ferry ride along the river that we took to get there. On the final day of the workshop we visited the Australian Antarctic Division of the Department of Environment and Energy. Here we explored the life of krill, the tiny crustaceans that underpin the ocean's food chain, and visited the Division's clothes store, to see how we'd dress if heading south on an icebreaker! It was a thoroughly enjoyable educational activity.

Dark Energy Survey Collaboration Meeting

6–10 November 2017, University of Queensland, Brisbane

The international Dark Energy Survey (DES) this year held one of its biannual collaboration meetings at the Department of Physics of the University of Queensland. A hundred and ten scientists from around the world spent a week discussing all aspects of the survey, which is now entering its fifth year.

The cosmological analysis of the first three years of DES data is now under way. At the meeting we made excellent progress towards getting all the tools in place for the analysis. We look forward to seeing the results of this work over the course of the next year.

In addition to the cosmology, there were talks on the stellar streams and satellite galaxies orbiting the Milky Way, and on the kilonovae that result from the merging of two neutron stars. (The first confirmed such merger was detected this year: see page 19.)

A highlight of the meeting was the public lecture given by three DES scientists. Hosted by Nobel Laureate Brian Schmidt (Australian National University), the event was attended by 450 people. Another 2,000 viewed the lecture online, while on Facebook it reached 34,000 people.

The meeting's success was thanks to the support of CAASTRO, and to the efficient and dedicated work of the staff, postdoctoral fellows and students at the University of Queensland.

DES Meeting, Brisbane *Credit: Josh Calcino*

Fourth CAASTRO-CoEPP Joint Workshop: Challenging Dark Matter

21 November 2017, Novotel Barossa Valley, South Australia

In this fourth and last of the joint CoEPP–CAASTRO workshops, we started by reminding ourselves that, while the organisational landscape is changing, the desire to collaborate continues. When putting this event together we had in mind a challenge thrown out by Anthony Williams (University of Adelaide): is there any way around dark matter? Is it the 20th century's equivalent of phlogiston? The workshop's program focused less on conventional cold dark matter models and more on the 'roads less well travelled'.

Elisabetta Barberio (University of Melbourne) opened the meeting by presenting the cross section–mass diagram for dark-matter particles (the probability of an interaction with 'normal' matter, as a function of the mass of the dark-matter particle). All dark-matter experiments cover some region of this parameter space. In nuclear-recoil experiments the sensitivity requirement is <1 event/10 kg/day, much less than the background. We expect annual modulation of a detected signal. The notable experiments of this nature are Xenon 1T and DAMA-LIBRA.

The talks that followed Elisabetta's were wide ranging. Gary Hill (University of Adelaide) described the operations of the world's largest neutrino detector, IceCube, which is built deep in the ice at the South Pole. Victor Flambaum (UNSW) considered electron relativistic effects that are important near the nucleus. Katie Mack (North Carolina State University), speaking by videolink, discussed how future gravitational-wave detections could inform our dark-matter models. Chris Power (ICRAR–UWA) talked about cold dark matter versus warm dark matter, and how we might separate the effects of dark-matter particle physics from those of galaxy assembly. Lister Staveley-Smith (ICRAR–UWA) spoke about Galactic Centre annihilation processes; Nick Iwanus (University of Sydney) described self-interacting dark matter; Christian Reichardt (University of Melbourne) spoke about the cosmic microwave background constraints on dark matter; and Ray Volkas (University of Melbourne) floated the idea that dark matter might be the stable component of the dark sector. There were also contributions from Nicole Bell (University of Melbourne), Martin White (University of Adelaide), Peter Quinn (ICRAR–UWA) and Michael Tobar (UWA).

In summing up, Jeremy Mould (Swinburne University) reminded everyone that dark matter is one of the top problems in astrophysics, ever. It's right up there with the Copernican system. Diverse experiments and observations are needed to explore the wide range of possible interactions of dark and non-dark matter. Whether you are a particle-physics experimenter, a particle-physics theorist, a high-energy astrophysicist, a simulator, an observational astronomer or a lab physicist, there is much work to be done.

Participants appreciated the efforts of Silvana Santucci (CoEpp), Kylie Williams (CAASTRO) and their colleagues in organising this well-run meeting.

Science at Low Frequencies IV

12–15 December 2017, University of Sydney, New South Wales

This meeting drew representatives from all the major low-frequency facilities, including the Murchison Widefield Array (MWA) in Australia, the Low Frequency Array (LOFAR) in Europe and the Giant Metre Wave Radio Telescope (GMRT) in India. We had 130 people attend, from institutions around the world.

The science topics ranged from space physics to galactic and extragalactic science and cosmology. A highlight was an invited talk by Dr Masafumi Imai (University of Iowa), who presented recent results from the Juno mission to study Jovian auroral emission. Dr Gregg Hallinan (California Institute of Technology) gave a special talk on the first radio detection of an afterglow to a gravitational-wave event, GW170817 – work that a number of CAASTRO researchers were involved in. Many students attended the meeting, presenting their work through science talks, sparkler talks, and poster presentations. Several research teams took the opportunity to hold breakout meetings, to advance their collaborations on topics such as the Epoch of Reionisation, low-frequency studies of pulsars and all-sky surveys.

Talks in the science program were chosen to reflect diversity in gender and seniority, and to represent a range of countries and facilities. We received excellent feedback from participants on the outstanding organisation by CAASTRO staff, and special praise for the catering. The local organising committee involved many CAASTRO students and postdocs, and did an excellent job of creating a smoothly-run event. The meeting was funded by CAASTRO, The University of Sydney (through the Hunstead Fund), The University of Melbourne, and the International Centre for Radio Astronomy Research (ICRAR).

CAASTRO ANNUAL RETREAT

CAASTRO's final annual retreat was held in South Australia's Barossa Valley over 22–24 November. Although this was a formal farewell to the organisation, it was also an occasion for CAASTRO members to do what they have always done: report on plans and achievements, and collaborate with each other.

CAASTRO Celebrates its last Annual Retreat and toasts founding Director Bryan Gaensler
Credit: Kate Gunn

CAASTRO Director Elaine Sadler opened the proceedings, reminding us how remarkably collaborative CAASTRO has always been. In 2014, *Nature* measured the degree of collaboration among multi-institution centres like CAASTRO, and found we were number one in Australia and among the top five in the world. This intense collaboration has continued, and was evident throughout the retreat. Elaine also highlighted how much the centre has achieved. To August 2017, we had published 583 papers, which have generated more than 11,000 citations. Three papers had been in *Nature* and five in *Science*, and more have appeared in those journals in the months since. CAASTRO finished the year with 189 members, 59 of them students.

Following Elaine's talk the three theme leaders expanded on each theme's achievements. Lister Staveley-Smith, who took up the role of Evolving Universe theme leader in early 2017, ran through the theme's eight major projects. Of these, four – the MWA Epoch of Reionisation observations (page 29), simulations of the Epoch of Reionisation, the SAMI Galaxy Survey (page 29) and the GLEAM (the GaLactic and Extragalactic MWA survey) survey – are well advanced, or mature: the SAMI team produced 14 papers in 2017, the GLEAM survey 5. The BIGHORNS (Broadband Instrument for the Global HydrOgen Reionisation Signal) experiment is ongoing. The WALLABY and FLASH surveys for neutral hydrogen (in emission and absorption respectively), both being carried out with the Australian SKA Pathfinder, are in their early stages; so too is the relatively new technique of neutral-hydrogen intensity mapping (page 13). We will see results from all of these over the next several years.

Tamara Davis, leader of the Dark Universe theme, also had much to report on. The OzDES survey, now in its fifth year, stood out as an example of consistent achievement: at the time of the meeting it had observed the 35,000 objects, taken 100,000 spectra, determined 26,000 redshifts and spectroscopically confirmed many supernovae – more that 50 in just one recent run (page 21). The related DES (Dark Energy Survey) cosmology project, in which several CAASTRO members take part, is now getting constraints on some cosmological parameters that are as good as Planck's (page 24). At the time of the meeting, the SkyMapper transient survey had also spectroscopically confirmed 41 Type Ia supernovae. Those low-redshift supernovae are going to be used, indirectly, in determining the Hubble constant, which measures the rate at which the Universe is expanding. Tamara spoke about the work of Bonnie Zhang (ANU), who this year made the first calculation of the Hubble constant in a way specifically designed to eliminate human bias (page 24). Tamara also mentioned other great projects in the Dark theme such as ongoing analyses of the rate of growth of structure in the Universe (page 22).

But 2017 really belonged to the Dynamic theme, and Theme Leader Tara Murphy (Sydney) positively glowed as she recounted her team's success in capturing radio waves from GW170817, the merger of two neutron stars. As its name shows, this event was first detected from the gravitational waves it had created. That detection, and the subsequent detection of light, radio waves and other electromagnetic radiation from the source, has opened the door on a new era of astronomy (page 19). Also exciting were the many detections of fast radio bursts – five from the UTMOST telescope and a number (still unpublished at year's end) from the Australian SKA Pathfinder (page 32) – and pioneering low-frequency studies of pulsars with the Murchison Widefield Array (page 17).

These projects were described in more detail in the sessions that followed, which (more or less) progressed from the 'smaller' objects of the Dynamic theme to the galaxy-scale physics of the Evolving theme, and then onto the big-picture topics in the Dark theme. Along the way there were 'sparkler' sessions – short descriptions of work presented in posters, lasting no more than 30 seconds – that covered interesting territory. "Are the laws of gravity uniform across the Universe?" cosmologist Chris Blake (Swinburne) asked.

"The Murchison Widefield Array will do a pulsar survey 1000 times faster than the Parkes telescope," Ramesh Bhat (Curtin) predicted. "We can use gravitational waves to measure the Hubble constant!" Dark theme leader Tamara Davis (Queensland) announced. The diversity of the talks showed how CAASTRO's research program has branched and expanded, as members have seized new opportunities as they have arisen.

SkyMapper is a nice example of this. Its planned 'short survey' of the southern sky is complete, and the first data release, DR1, was issued this year (page 33); the main survey will take another few years. Among the telescope's achievements has been the discovery of the oldest (most chemically pristine) star known, SMSS J0313–6708. SkyMapper has faced many travails – fire and smoke, an infestation of ladybirds, crucial equipment arriving from abroad in pizza boxes, excessive cold, and more – eloquently described by Christian Wolf (ANU) in his talk at the retreat. But now the telescope is carrying out its first variability survey, led by ANU postdoc Seo-Won Chang, and looks set to do something else not originally planned for: team up with the Australian SKA Pathfinder (ASKAP) to find and localise fast radio bursts as they happen. Brad Tucker (ANU) too talked about a search he has run that "it turned out SkyMapper would be well suited to" – one for 'Planet 9', a putative new planet in our Solar System. For this project, Tucker harnessed the power of citizen scientists: a joint *Stargazing Live* event with the BBC in March saw more than four million classifications done in under three days.

Such citizen-science projects have grown in size, number and sophistication during CAASTRO's lifetime and other CAASTRO researchers have also been using them to good effect, particularly as a foundation for future large surveys. *Radio Galaxy Zoo*, led by CAASTRO's Julie Banfield (ANU) and Ivy Wong (UWA) has about 12,000 registered citizen scientists. At the retreat, Wong described how these volunteers have cross-matched more than two million radio sources with optical host galaxies, doing work that would have taken more than 80 years, if done conventionally, in under four. Anais Möller (ANU) described a second project, started more recently, in which 1,800 volunteers are classifying transients found by the SkyMapper transient survey: they have made more than 36,000 classifications to date. These projects generate training sets for *machine learning*, another area that has burgeoned during CAASTRO's lifetime, and which is now used to handle the huge datasets appearing in every area of astronomy (page 28).

As always, instrumental developments have shaped discovery. Within CAASTRO, SAMI (the Sydney University–AAO Multi-object Integral-field spectrograph) has opened up great possibilities. Nicholas Scott (Sydney) spoke at the retreat about how SAMI is extending the concept of 'galactic archaeology' – unraveling a galaxy's formation history – from our own Galaxy to others: although we cannot observe individual stars in these galaxies, SAMI gives us enough detail from which to draw conclusions. Dan Taranu (UWA) talked about how he is extrapolating from SAMI data to work out the best ways to measure the fundamental properties of spiral galaxies. And Chief Investigator Matthew Colless (ANU) described a major SAMI study that has looked at what drives stellar age and metallicity in early-type galaxies. (Matthew did provide the answers, but those interested should read the paper (Barone et al. 2018).) SAMI data looks set to get even better: Richard Scalzo (University of Sydney) described new analysis techniques that are dramatically improving the quality of SAMI data cubes. Richard and his colleague Sebastian Hahn are doing this work within the University's Centre for Translational Data Science, which also works on projects in human metabolism, the environment and social studies: it is a true interdisciplinary environment.

CAASTRO has always been keen to connect astronomers with enterprises beyond astronomy. At the retreat, Chief Operating Officer Kate Gunn spoke about CAASTRO's extensive industry engagement program. There were several strands to this: workshops for students on career paths outside astronomy; internships with industry; participation in 'hackathons', where astronomers displayed their coding skills; the inaugural *Galaxy Convention* (page 93), which connected students, including university students, with entrepreneurs in STEM (science technology, engineering and mathematics); an e-book on intellectual property, which forms part of CAASTRO's legacy; seed funding for a coding project with applications in industry; and relationships with other sectors, such as defence. These were targeted initiatives, with results usually achieved by partnering with other institutions.

As always, the annual retreat was full of stimulating talks. But this year it was also laced through with a little sadness at CAASTRO's demise. The last session of the last day was naturally devoted to reflecting on CAASTRO's seven years. What were the problems and challenges? The group identified a few: the initial difficulty of getting the best out of our high-profile overseas members ("big names are busy people") and the lack of career progression for postdocs (something CAASTRO successor ASTRO 3D will tackle). But there were many more pluses. "Students felt taken seriously and appreciated the generosity of the organisation," said PhD student Chris Curtin (Swinburne). "We had the opportunity to meet the whole community and learn about projects," added CAASTRO Affiliate James Allison (CSIRO). "Changing the culture", "so many great science results", "creating an exceptional environment for students and postdocs", were other contributions. "CAASTRO has allowed big teams to function in a human way," said Matthew Colless (ANU), a veteran of many large projects. And, as Director Elaine Sadler said, "it has been particularly rewarding to see a new generation of researchers move into leadership positions as CAASTRO has evolved."

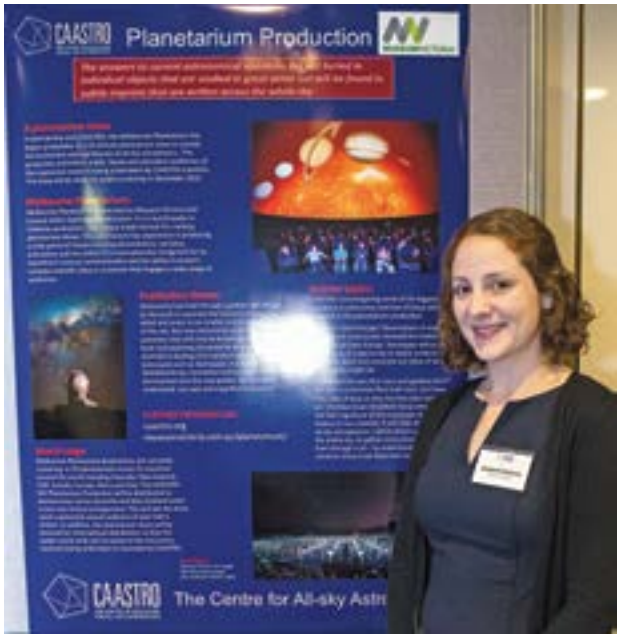
A few tears may have been shed at this final gathering (particularly in the bar late at night), but there were certainly no regrets. CAASTRO has fulfilled the Australian Research Council's vision for what a Centre of Excellence can be and can achieve. As Dynamic Theme leader Tara Murphy said at the summing-up, "CAASTRO has changed the culture of Australian astronomy".

Like all CAASTRO retreats, this final one was a successful and memorable event. And, as always, that was thanks to the organising skills and hard work of the CAASTRO A-team, particularly COO Kate Gunn and CAASTRO's inimitable Events Manager, Kylie Williams. They have set the bar high for CAASTRO's successors!

EDUCATION & OUTREACH

When CAASTRO began, we set out to do astronomy education and public outreach a bit differently to other organisations. A major consideration was how to make best use of our resources, as the Education and Outreach (E&O) program was well funded but minimally staffed. Almost seven years on, as CAASTRO draws to a close, we can be pleased with our success in E&O. We stuck to our vision and achieved our goals. Our legacy is a combination of examples of best practice and high-quality productions. The CAASTRO brand slotted seamlessly into a busy research and outreach landscape in Australian astronomy, without creating duplication or competition. No matter how far they were from the E&O headquarters at Curtin University, CAASTRO members at *all* locations played an integral role in the portfolio, writing news stories, interacting with our audiences, participating in working groups and receiving relevant training.

CAASTRO created the positive momentum that helped establish two successors: the ARC Centre of Excellence for All-sky Astrophysics in 3 Dimensions (ASTRO 3D) and the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav). We can be proud that these centres are adopting some of our E&O programs and extending our work.



Elizabeth Mahoney, University of Sydney
Credit: CAASTRO

Social media – an integrated approach

Today every research centre has a presence on social media: always a website, usually Facebook and Twitter accounts, and often other channels such as Instagram, Flickr, YouTube or Vimeo. But much social-media activity is poorly thought through, lacking relevance, consistency, timeliness and responsiveness. For CAASTRO, we decided that we did not want to maintain a social media presence just "because we had to" but because we were really dedicated to sharing our research and outreach news with a large community.

Sourcing content was therefore our top priority. We monitored CAASTRO's internal records of publications and wrote short, semi-technical research summaries for every CAASTRO first-author paper that had been accepted by a journal. These stories became the main source for the News section on the CAASTRO website, giving insight into the everyday research efforts of a large collaboration. To make best use of the time and effort we put into the stories, we also made them available in our CAASTRO Reader's Digest booklets. These could be downloaded from the website and were also printed and distributed to High School students, amateur astronomy societies, science discovery centres and audiences at public astronomy events. We published 127 research stories: 109 that appeared in 5,700 printed copies of the Digest, and 18 online-only.

To track our impact, we set up more than 200 alerts to pick up online mentions of our members, key research facilities and publications. This gave us a wealth of news items for Facebook (about two items per week, which went to more than 21,000 users) and Twitter (about two items per day, delivered to more than 2,000 followers). The contents were specific to CAASTRO, avoiding the unfortunate impression of "oh look, here's a random astronomy picture".

The CAASTRO YouTube channel, with more than 1,700 subscribers, has been home to 256 short video productions. Some covered our research projects; many of these re-used material from our internal media library of 90 animations (seven of which were new in 2017). Other YouTube videos were interviews and career advice from some of our most senior members and international partners; recordings of research seminars and outreach presentations; and our Video Press Releases (ViPRs). These last were produced in-house to accompany written CAASTRO press releases. ViPRs always featured the lead researcher of the work in question, who

explained the results and their significance. We produced 11 ViPRs over six years: they covered diverse areas and showed the impressive talent of many of CAASTRO's junior members. Our two ViPRs in 2017 netted 1,500 views for the CAASTRO YouTube channel. The overall champion, however, remains the 2015 ViPR *Cosmic cinema: astronomers make real-time, 3D movies of plasma tubes drifting overhead*, which featured the work of a University of Sydney Honours student, Cleo Loi. This video was viewed more than 1.3 million times.

School engagement on the national scale

Our first big school outreach program, *CAASTRO in the Classroom*, has gone from strength to strength since we started it six years ago. Enabled by a New South Wales Department of Education grant and inspired by the government's Connected Classrooms initiative, the program was initially coordinated by a single postdoc at the University of Sydney. Through videoconferencing we delivered astronomy and career presentations to more school groups, at more diverse locations, than even the most dedicated researcher could visit in person.

At first we reached 200 to 900 students every year. The program expanded when CAASTRO won an Australian Maths and Science Partnership Program (AMSPP) grant from the Commonwealth Government. This grant allowed us to appoint a School Education Officer, Jenny Lynch, who mapped sessions to the curriculum and began offering the program to all Australian States and Territories. Videoconferencing was not suitable for many schools outside New South Wales, so we had to explore other technologies such as Skype (with the researcher talking to a single school) and live-streaming via YouTube. In 2016 the program went national and student numbers skyrocketed to more than 3,500 students (3,000 of whom attended the very first live-streaming event). That year we also boosted the long-term value of the program by posting video recordings on the CAASTRO YouTube channel and producing teaching resources (available from the CAASTRO website). The latter were also used in teachers' professional development seminars that we offered at several national science teachers' conferences, in collaboration with the Advancing Science by Enhancing Learning in the Laboratory (ASELL) program, which had also received an AMSPP grant.

The CAASTRO in the Classroom sessions for 2017 are described in a separate report (page 91).

In 2017 we received a Women in STEM and Entrepreneurship grant from the Australian Government. This allowed us to offer sessions specifically on careers within *CAASTRO in the Classroom*, and to present *Galaxy Convention*, an event designed to inspire the next generation of female entrepreneurs in STEM fields (science, technology, engineering and mathematics). We held the first *Galaxy Convention* in December 2017: it is described in detail on page 93.

Resources for schools

Bright Stars calendar

CAASTRO Education and Outreach led the production of two major school resources and made them available to Australian schools free of charge. A joint effort with *Telescopes in Schools* at the University of Melbourne, our *Bright Stars* wall calendar for 2017 featured ten researcher profiles, significant dates in astronomy and space exploration, and stunning imagery. An intern supervised by CAASTRO's E&O team led the interviews, drafted the profiles and designed the calendar. The researchers profiled ranged from PhD students to professors: they shared their personal stories and experiences, and advice for the next generation of aspiring scientists. We sent a copy of the calendar to every one of the 1,500 high schools in Australia. A further 3,500 copies were made available at public outreach events such as Sydney Astrofest and the Melbourne AstroLight Festival, for gold-coin donations. The money raised has gone to science-outreach activities such as the building of a new telescope dome at Mount Burnett Observatory in Melbourne, a facility that will host citizen-science projects.

Rebecca McElroy and Tara Murphy present CAASTRO in the Classroom
Credit: CAASTRO

Capturing the Cosmos Planetarium Show
Credit: Museum Victoria and CAASTRO

COLLABORATIONS

The Cosmic Adventures of Alice and Bob

Our second major school resource was the CAASTRO children's comic, *The Cosmic Adventures of Alice and Bob*. This, our first product specifically for a pre-teen audience, has now found a home in 7,200 Australian primary schools. The comic was created by Perth-based artists and science communicators Cristy Burne (author) and Aśka (illustrator), in collaboration with the CAASTRO E&O team. Its quirky plot entertains young readers, at the same time showing how success can require creativity and resilience. The comic includes stories of real and sometimes serendipitous science discoveries, to encourage young people to persist; it also shows how space research has led to some of the most common everyday products, highlighting the value of 'blue sky' research. A double spread covers CAASTRO's involvement in next-generation telescope surveys and citizen-science projects. We boosted the comic's value as a teaching resource by producing notes that relate its content to the curricula for science, maths, visual arts, English, and design and technology, and suggesting classroom activities. These teaching notes have now been downloaded more than 400 times.

Each school received a free copy of the comic for its library, but was also invited to order class sets (30 copies) – an offer enthusiastically taken up by more than 60 schools, home schoolers and other science-education institutions. The comic book was officially launched at the 2017 Perth Astrofest, as the keynote event. We made available there, and at other public events, the copies from our 15,000 print-run that had not already been committed for distribution. As for the Bright Stars calendar, this generated donations that have been used to help science outreach projects: money raised in Perth, for example, went towards the indigenous sky-knowledge program of the Gravity Discovery Centre and Gingin Observatory.

Museum Victoria

Just as CAASTRO was born from the conviction that working together delivered better results than working in isolation, our Education and Outreach portfolio established powerful partnerships to maximise its impact. One of these partnerships was with the Melbourne Planetarium team at Museum Victoria, for the production of the 25-minute full-dome show, *Capturing the Cosmos*, which used CAASTRO research to explain all-sky astronomy to the public. We dedicated a substantial proportion of our outreach budget to this two-year project. The show's beautiful visualisations and immersive time-lapse photography were accompanied by narration from Academy Award-winning actor Geoffrey Rush. We launched the show in March 2016, synchronising the main event in Melbourne with launches in other States. This was the first-ever simultaneous launch of a planetarium show in Australia: licensing constraints usually make them impossible, but CAASTRO had secured early distribution and free licenses for all members of the Australasian Planetarium Society. In just the first 6 months after its release the show played in eight fixed planetaria and four portable venues around Australia, attracting more than 40,000 visitors (including 1,500 school students). *Capturing the Cosmos* was entered into eight national and six international film festivals and received much praise. The flat-screen version of the show, completed in mid 2016, was used at public events such as astronomy nights and in CAASTRO's Uluru outreach partnership (described below). Capturing the Cosmos is a major legacy of the CAASTRO Education and Outreach portfolio and our partnership with Museum Victoria benefited both institutions.

Voyages Indigenous Tourism Australia

Another example of an advantageous partnership is the one we have had with Voyages Indigenous Tourism Australia for the *Astronomer in Residence* and *Uluru Astronomy Weekend* programs. Each year since 2014 we have sent between 13 and 20 astronomers-in-residence to Ayers Rock Resort for fortnightly stays between March and November. The researchers interact with resort guests by providing information, activities and give-aways at the CAASTRO table in

Tara Murphy presents *Waves in the Sky*, March 2017. Filmed at NSW Department of Education studio, Strathfield.
Credit: CAASTRO

Students at St Joan of Arc School, Haberfield, enjoying Scott Croom's *Wake up to Astronomy* show during National Science Week.
Credit: St John of Arc School

the Market Place; giving presentations about research; offering question-and-answer sessions; and joining the resort's stargazing tours as the astronomy experts. Every astronomer-in-residence engages with 100 or so resort guests, making this a program that reaches beyond the self-selected audiences at most public astronomy events.

In addition, our researchers have taken part in an annual *Uluru Astronomy Weekend*, which has drawn about 100 participants every year. The event programs have been packed with free astronomy-themed activities: talks by senior members of CAASTRO, astrophotography sessions, movies and hands-on telescope demonstrations. Resort guests have also been able to attend the special 'dinner under the stars', at which CAASTRO researchers share their knowledge. The Uluru partnership has been a very rewarding one for Voyages Indigenous Tourism; for the resort guests who have met our researchers (and who frequently send us emails of thanks); and for CAASTRO members, who have always returned from their stay with positive reports.

Media releases

The Education and Outreach portfolio has collaborated not only big projects but also on the smaller, more frequent activities, notably media releases. We have always worked with the media office of the lead author's university to create and distribute releases. Over the course of CAASTRO's lifetime, we have issued 48 press releases about particularly newsworthy research, ten of them published in 2017. We drove the collaborative effort behind these press releases, getting all leading institutions on board – if they wished to join – and coordinating the locally adapted drafts, sharing our resources and scheduling the release. In most cases the university media office would not have been aware of an upcoming paper if it had not been for us starting the conversation. And more often than not, the conversation had to deal with differences in priorities and sensitivities: understandably, a university or research institute is mainly interested in promoting itself, while our goal was to have all CAASTRO nodes and members represented. Six years after the first CAASTRO press release, we acknowledge that we did not choose the easiest path, but we stand by our decision to work collaboratively. At least partly as a result of our actions, Australian astronomy institutions now collaborate more in promoting their research than they did six years ago. For example, 2017 saw many Australian institutions involved in the follow-up to a neutron-star merger detected through gravitational waves (page 19). Many of the institutions collaborated in promoting the research, achieving great media success.

CAASTRO IN THE CLASSROOM

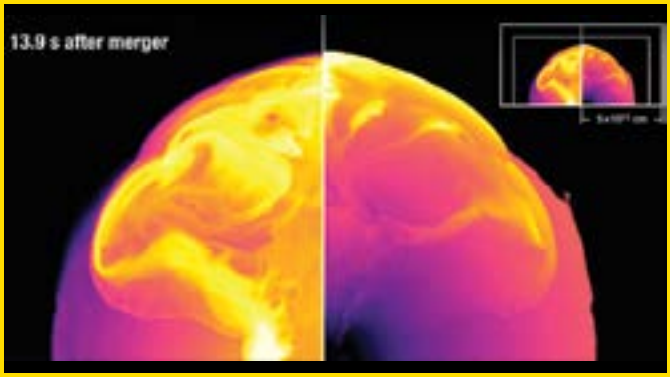
CAASTRO has run *CAASTRO in the Classroom* (CitC), an outreach program that connects astrophysicists to schools, since 2012. In 2016 it was expanded into a national program by our then School Education Officer, Jenny Lynch. Jenny left CAASTRO in May this year, and her successor, Janette Ellis (University of Sydney), guided the program from June onwards.

CitC originally used traditional video-conferencing, and one such session was held this year. However, teachers have indicated that they prefer live streaming, so we held 13 streaming sessions this year via CAASTRO's YouTube channel. Thousands of students across Australia tuned in. Streaming creates high-quality recordings that can be viewed at any time, and students can participate via Twitter or Live Chat. All the streaming videos from 2017 *CitC* sessions were viewed many times after the live event, and they are still available on YouTube. This year we also created new resources for students in Years 7, 10 and 11 that complement the live streams.

One of 2017's streaming sessions was *Waves in the Sky*, a collaboration with the NSW Department of Education's Distance and Rural Technology Unit (DEC DART). The presenter, Associate Professor Tara Murphy, described her current role and the course her career has taken, and explained how her CAASTRO Masters student Cleo Loi used the Murchison Widefield Array (MWA) to discover plasma tubes in the Earth's ionosphere (work described in CAASTRO's 2015 annual report).

We held ten streaming sessions during National Science Week in August. *Wake up to Astronomy* was a 15-minute question-and-answer (Q&A) show held each morning, with astrophysicists answering questions sent in by students in the preceding weeks. *Lunchtime Astronomy*, also held daily during Science Week, was a 30-minute show either linked to school syllabuses or featuring a CAASTRO PhD student talking about his or her favourite aspect of astrophysics.

Uluru Astronomer in Residence Program
Credit: Natalie Eiré Sommer



Binary star merger
Credit: University of Sydney

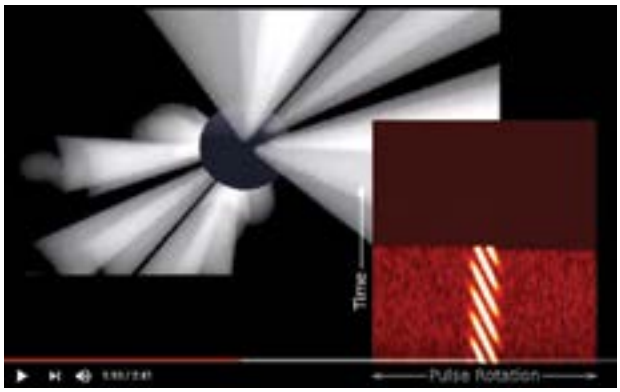
In November we collaborated with the Museum of Applied Arts and Sciences (MAAS) and DEC DART to run two streaming sessions at Sydney Observatory: *Days of Darkness* for Year-5 students and *Reasons for Seasons & Days in a Phase* for Year-7 students. These were presented by Sarah Reeves (a former CAASTRO student now at MAAS), Jason Drury and Kathryn Ross.

This year we also held 13 Q&A sessions, which give schools the chance to have a one-to-one conversation with an astrophysicist. We delivered most of these sessions via Skype, and some via Zoom and Google Hangouts. Everyone involved told us how much they enjoyed them.

CitC met face-to-face with teachers in Hobart in July, when we were one of the exhibitors at CONASTA66, the 66th annual science education conference of the Australian Science Teachers Association (ASTA). We also presented at TeachMeet at the Museum of Sydney during National Science Week. TeachMeets are informal events where anyone involved in education can share ideas and experiences. We have found that primary-school teachers are particularly eager for astronomy resources: Year-5 students are the most-represented school grade across all *CitC* activities.

CitC is presented with the support of the Australian Government through a *Women in STEM and Entrepreneurship* (WISE) grant. This grant has allowed us to expand the program to incorporate activities (such as *Galaxy Convention*, held in December) that encourage and educate young entrepreneurs.

CAASTRO Youtube Library
Credit: CAASTRO



SYD ASTROFEST16

Second Sydney Astrofest draws 3000 people
1 July 2017, University of Sydney

CAASTRO and the University of Sydney held the second Sydney Astrofest on Saturday 1 July 2017. This stargazing event came with a great line-up of speakers, activities for kids, a plethora of exhibitors and a travelling planetarium.

It took place in and around the Charles Perkins Centre, next to Oval no. 2, and at the Sydney Veterinary Science Centre. The astronomy-keen rolled in from 3:30pm, instantly forming a queue for planetarium tickets. They then stormed the lecture theatre for the official opening by Professor Elaine Sadler (CAASTRO Director). That was followed by the first talk, by CAASTRO PhD Student Jessica Bloom. Many people settled down in the theatre for a night of great talks, while others formed lines to look through the eight telescopes on site at Mars, Saturn, Jupiter and the odd nebula. Inside in the warmth kids were busy building space stations and aliens out of LEGO and concocting telescopes out of toilet rolls, while their elders checked out goodies on the stalls, from liquid-nitrogen demos to virtual-reality goggles. After all that activity had fed the mind, the Lions Club Sausage Sizzle was there to feed the body too – and raise funds for the Starlight Foundation charity in the process.

Sydney Astrofest was organised by CAASTRO and well supported by the School of Physics. The many exhibitors and sponsors also gave the event great support, with Sydney Observatory and Celestron, both of which donated prizes, deserving special mention.

Astrofest 2017, Sydney
Credit: Geoff Wyatt

Galaxy Convention **(GalCon) delegates.**
Credit: CAASTRO

Michelle Melbourne from Intelledox speaking at GalCon.
Credit: CAASTRO

Galaxy Convention

The inaugural *Galaxy Convention* was held 4–5 December 2017 at the University of Sydney's Nanoscience Hub. This unique event brought together nearly 150 high-school students, teachers, university students, academics and members of the business community. It was designed to inspire the next generation of female entrepreneurs in STEM fields (science, technology, engineering and mathematics), and was supported by the Australian Government through a *Women in STEM and Entrepreneurship* (WISE) grant. Galaxy Convention talks were live-streamed and have been made available on CAASTRO's YouTube channel.

Female students in years 10–12 from all over Australia applied to take part. Their keenness was clear from comments such as this one, from a Year 11 student: "I wish to participate in this convention because I'm really interested in the growing influence of women in STEM careers, and I wish to be one of these influential women in the future." Thirty-seven students, and a number of teachers, came from interstate, from as far away as the Northern Territory and Tasmania.

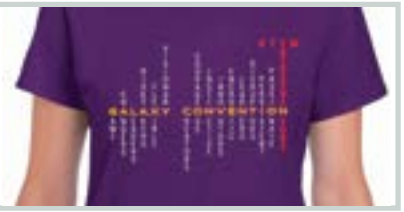
Attendees heard personal stories from entrepreneurs including Deb Noller (Switch Automation), Solange Cunin (Cuberider), Michelle Melbourne (Intelledox), Lynnette Terrett (Iconyx), Tara Murphy (Grok Learning), Dharmica Mistry (BCAL Diagnostics) and Daniel Shaddock (Liquid Instruments). The speakers' experience was diverse, from creating prosthetics with recycled waste to running student-built experiments on the International Space Station, showing how broad are the career possibilities for STEM graduates.

They also threw themselves into marketing and strategy workshops, which were the hands-on component of the event. One of these involved developing a marketing plan for an existing enterprise, Cuberider, whose founder, Solange Cunin, was on hand to provide a reality check. Another exercise required teams to develop a strategy for getting to Mars by 2032.

The combination of talks and practical activities helped delegates understand how entrepreneurs bring their ideas to the marketplace, the challenges they face, the strategies they employ and the lessons that have been learned in start-up journeys. They also learned that to be a successful entrepreneur takes resilience, humour, creativity and courage!

The workshop was well received, especially by the school students. One year-12 student from Western Australia said, "[i]t has opened my eyes to so many possibilities and has made me excited for the future." We hope these talented young women will stay excited about their futures and become the change-makers of tomorrow.

The T-shirt worn by Galaxy Convention volunteers.
Credit: CAASTRO



ANU academic Daniel Shaddock telling the story of his company, *Liquid Instruments*, **at GalCon.**
Credit: CAASTRO

The Leadership Kitchen's **Felicity Waterford coaching GalCon delegates in how to pitch an idea.**
Credit: CAASTRO

Solange Cunin of *Cuberider* **speaking at GalCon.**
Credit: CAASTRO

INDUSTRY AND INNOVATION

The CAASTRO "Intellectual property, Industry engagement and your career!" eBook was finally completed in 2017, and was revised later in the year after feedback from IP Australia regarding some productivity commission recommendations. It provides an invaluable resource for CAASTRO members who are interested in innovation, or wanting to find a job in industry.

In 2017 CAASTRO assisted two PhD students and one post doctoral researcher gain paid industry internships. These range in length from length from 4–12 weeks, and provide invaluable experience of work outside academia. All placements were with software development companies.

NASA International Space Apps Challenge

Over 29–30 April, a team of CAASTRO members from around the country gathered in Sydney to take part in NASA's International Space Apps Challenge. This annual event is held simultaneously around the world in selected cities. During an intense 48 hours, problem solvers work closely together, using real NASA data to solve one of many posed challenges. The challenges can be related to either Earth or space: this year, they were focused on Earth.

The CAASTRO team delivered a product titled Polar Explorer, designed to display polar-ice regions in 3D on a website, making them available to anyone in the world. Using the website, the viewer can see the changes in the ice profile with time, giving a sense of how the world's climate is changing. With more development time, the website could be extended into a virtual-reality app, which would give a full-scale view of the ice and how it is shrinking with time.

We did not place among the top three of the 28 participating teams, but we did give an excellent presentation on the motivation and execution of our product, and enjoyed the experience of working in a team with a tight schedule.

PROFESSIONAL DEVELOPMENT

Career Development

In November 2017, the CAASTRO Postdoc Committee and the CAASTRO Student Committee arranged a career development day for Early Career Researchers which took place a day prior to the CAASTRO retreat in the Barossa Valley. The event was specifically designed to provide training for students and post doctoral researchers embarking on their career as independent researchers, but it was open to all interested members within CAASTRO. The members of the Committees had some enlightening discussions on the challenges we each face in our daily work-life and we identified self-management and proposal writing as the most prominent training requirements.

We organised two professional facilitators from the University of Adelaide to give two half-day seminars, *Building your Personal Resilience* and *The Perfect Pitch*. During the Resilience program, the participants learnt about the physiological and psychological science of stress, and were invited to reflect on their own reactions to stressful events. During group discussions, we discovered that most of us responded very similarly to stressful situations and shared strategies to build up resilience.

The afternoon training was active, compared to the contemplative morning, and focused on how to convincingly present ideas. We studied structures for coherent proposals, as well as body language, and had to convince each other of our research ideas. The day concluded with pizza and a very lively group trivia where people could already be observed applying skills of both trainings of the day.

Professional Development has been a focus of CAASTRO activity
Credit: SIfA

Paper Writing

CAASTRO ran a trial paper-writing workshop at CAASTRO's 2016 Annual Retreat. After receiving useful feedback on this trial, the CAASTRO Student Committee worked closely with Christian Wolf (CAASTRO ANU Node Leader) to expand the materials and make them suitable for a comprehensive, day-long workshop on scientific writing. The content covered how to structure and plan a manuscript, how to refine first drafts, and what to expect from the peer-review process. The workshop was run in Melbourne, Brisbane, Sydney, Canberra and Perth, and had over 100 attendees. At each event, the touring presenters Caitlin Adams and Chris Wolf were supported by local presenters including: Michael Brown, Jack Line, Janie Hoormann, Jacobo Asorey, James Allison, Fiona Panther, Dougal Mackey, Sarah White and Paul Hancock. The workshops were organised by Caitlin Adams, Stephanie Bernard, Natalia Sommer, Marcin Glowacki, Rebecca McElroy, Josh Calcino, Tristan Reynolds, Bradley Meyers, Kylie Williams and Kate Gunn.

The feedback from attendees was incredibly positive: many students commented that there were useful tips on grammar and style for both native and non-native English speakers. Attendees were grateful for the hands-on approach, and their active participation made each event a great success. The workshop materials will be released as a CAASTRO legacy item so that these events can be run again.

Coding

In December 2017, CAASTRO ran a coding workshop in Sydney, Melbourne, Brisbane, Canberra and Perth. Facilitated by Samuel Hinton (UQ PhD student) and Fiona Panther (ANU PhD Student) the workshop was well received and considered a great success.

Coding makes up a significant part of astrophysics research, and yet the majority of astrophysics researchers are self-taught programmers. As such, there are often useful tools, tips and tricks when coding that are often unknown or under-used. This workshop aimed to change this, and sessions covered:

- coding practices
- coding tools
- code documentation
- code testing
- resources to help get software open source and online, build pipelines, archiving code, publishing and getting your code citable.

Mentoring

CAASTRO has continued its internal mentoring program in 2017, which matched up senior and junior members at different CAASTRO locations. It is designed to build and offer an initial professional network where questions around career progression can be discussed. Feedback on the program suggests that most participates have valued the career advice from their mentor the most.

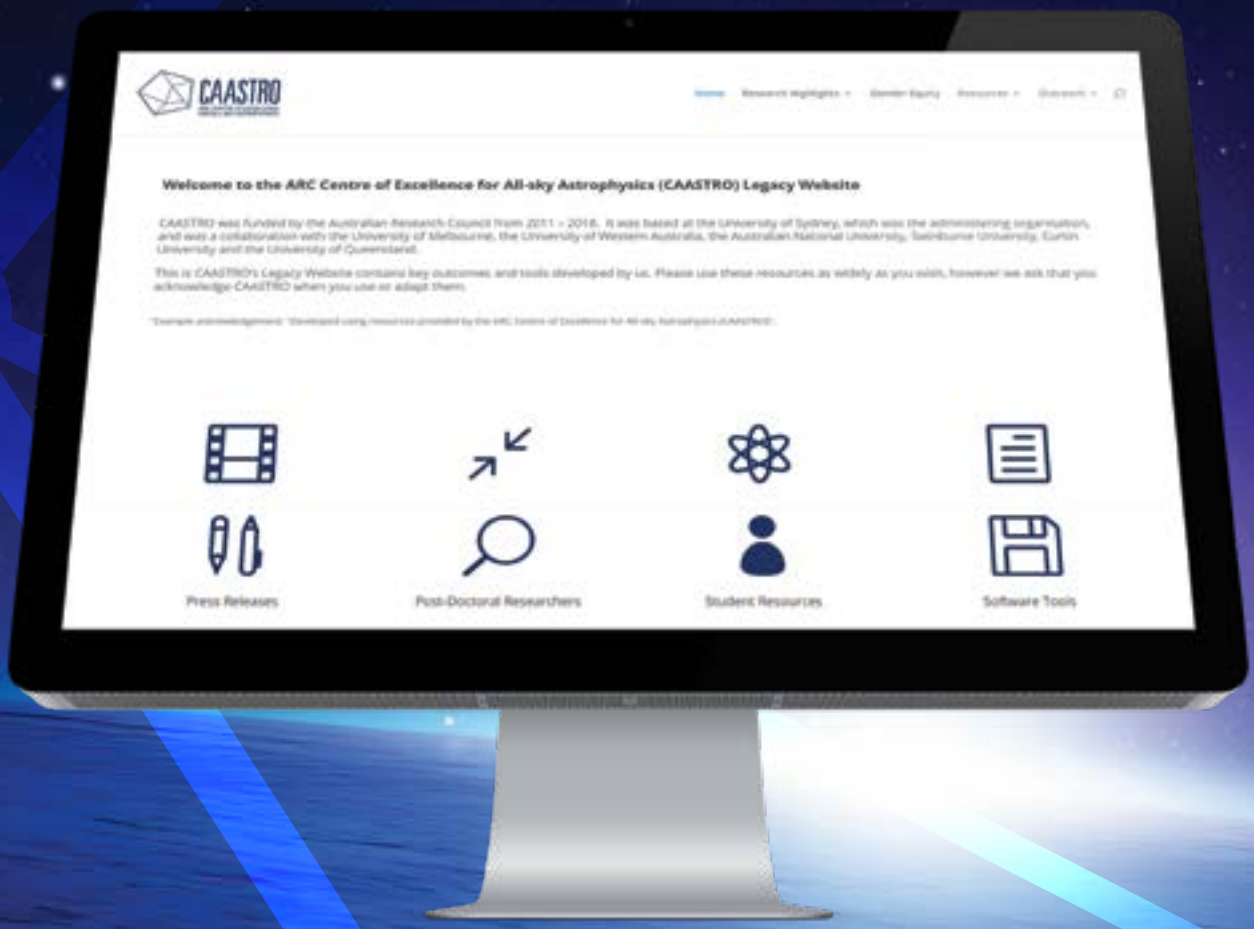
PERFORM

THE CAASTRO LEGACY

At the end of its funding period (2017–2018) CAASTRO is keen to leave behind a legacy of useful items for future researchers, outreach and professional staff members working within astrophysics, and other disciplines.

CAASTRO has created a Legacy website where the resources we have created over our funding period are available for download.

www.caastro.org



CAASTRO Research Highlights Video

CAASTRO 5 Minute Highlight Video

CAASTRO Animation Library

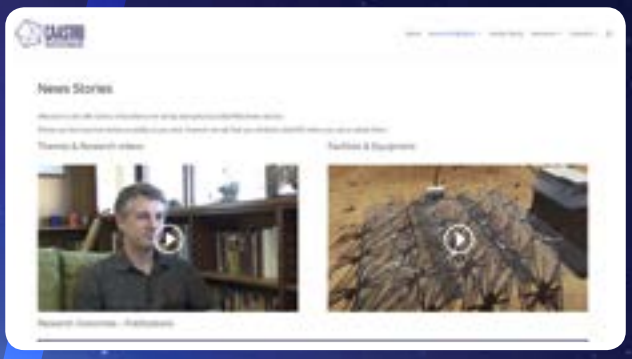
CAASTRO Postdoc and Student Resources

CAASTRO Software Tools

CAASTRO Gender Equity Toolkit

CAASTRO Teacher resources

CAASTRO News Stories



CAASTRO "Intellectual property, Industry engagement and your career!" eBook

CAASTRO Mentoring e-book

CAASTRO LOCATIONS

2017 ICRAR members *Credit: ICRAR*

International Centre for
Radio Astronomy Research

CAASTRO AT THE INTERNATIONAL CENTRE FOR RADIO ASTRONOMY RESEARCH (ICRAR)

ICRAR hosts astronomy and astrophysics research in CAASTRO's two WA member Universities and 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, Ramesh Bhat at Curtin, and Lister Staveley-Smith the node leader from UWA. CAASTRO postdocs and students are mixed in with other ICRAR research groups, as encouraged by the ARC. Perth-area meetings are organised on a regular basis 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.

EDUCATE

CAASTRO Curtin University team members

CAASTRO AT CURTIN UNIVERSITY

Curtin University

The Curtin Institute of Radio Astronomy (CIRA) at Curtin University is a partner in the International Centre for Radio Astronomy Research (ICRAR) and the managing organisation of the Murchison Widefield Array (MWA). Research at CAASTRO's Curtin node continues to focus on the Evolving and Dynamic themes; Curtin is also the headquarters for CAASTRO Education and Outreach. This year the node had 23 members, including two newly enrolled students; a new affiliate, Ben McKinley; and a new research staff member, Dr Clancy James, who has been recruited to work on the fast radio burst program under way at ASKAP. Dr Marcin Sokolowski continued to work on Curtin's SKA developments and to support MWA operations and scheduling. CAASTRO Associate Investigator Dr Randall Wayth continued in the role of MWA Director. Curtin engineering intern Ms Mia Walker contributed to CAASTRO-related activities as well as undertaking MWA technical duties, and Ms Kim Steele filled in the role of outreach coordinator (part-time) from April 2017 while Dr Wiebke Ebeling was on maternity leave. Dr Ramesh Bhat became CAASTRO's Curtin node leader in April after Professor Carole Jackson moved to ASTRON.

Evolving Universe Theme

In the Evolving Universe theme, CAASTRO members at Curtin contributed to advances in instrumentation, observations and theory, particularly ones relating to SKA development and the MWA's Epoch-of-Reionisation (EOR) experiment.

- The Engineering Development Array (EDA), a low-frequency radio telescope using SKA precursor technology, has been commissioned at the Murchison Radio-astronomy Observatory (MRO). The EDA is for prototyping and verifiying technology for the SKA, as detailed in Wayth et al. (2017). The array is sky-noise limited over the 60–240 MHz range; MWA infrastructure was used to measure its absolute sensitivity by obtaining calibrated visibilities. The EDA's unique ability to record Nyquist-sampled, full-band voltage data is being used to detect millisecond pulsars and improve the MWA's time resolution.
- Chris Jordan processed 972 EoR0 observations from 2015 (32 hours of data) with the MWA Real-Time Data Pipeline, and examined and classified them for ionospheric activity. This work is now published (Jordan et al. 2017). From these quality-assessed data, Cathryn Trott selected a subset showing low ionospheric activity and processed them with the EoR power-spectrum pipeline. Until this work, the best (systematic-limited) limit on the cosmological EoR power spectrum had been that of Beardsley et al. (2016). Now, thanks to the preliminary classifications, Trott and Jordan have been able to obtain a deeper limit from only half as much data.
- Cathryn Trott and Randall Wayth investigated the potential bias caused by extended radio sources in the EoR power spectrum, to arrive at useful insights pertaining to the design of SKA-low. Their work suggests that the telescope needs additional short baselines as well as long ones (up to 5 km) baselines, so that it can handle information on a wide range of scales, which will be needed for measuring the EoR power spectrum.
- Trott also led the work that looked at the spectral performance SKA antennas need to have for studying the EoR. In Trott et al. (2017), she and her collaborators investigated the performance of two SKA1 log-periodic dipole antennas, SKALA2 and SKALA3, and the MWA dipole antenna. The EoR detection experiment will be primarily limited by the sky-calibration accuracies and thermal-noise performance, and this work suggests that the designs of both SKALA3 and the MWA dipole will be able to meet this requirement. SKALA4 may resolve this.
- Steven Murray and collaborators extended the mathematical description of the foreground 'noise' in EoR observations to include the clustering of foreground galaxies, using the latest estimates of the broad differential source count from MWA and other deep observations. The formalism involves estimating a modified covariance. Murray and his collaborators show that failing to include this contribution may lead to an under-estimation of the uncertainty and potentially a false detection of the EoR signal. The work is reported in Murray et al. (2017).

- Ronniy Joseph, a CAASTRO PhD student supervised by Trott, continued his work on exploring calibration strategies using hybrid arrays for the detection of EoR signal.

Dynamic Universe Theme

The Curtin node's contribution to the Dynamic Universe theme comes largely from MWA pulsar data. We are beginning to see rewards from the years of effort put into developing the MWA's high-time-resolution capability: a wide range of science making use of the MWA's unique features is beginning to emerge. Other significant research includes the fast radio burst program taking off at the Australian SKA Pathfinder (page 32), studies of interplanetary scintillation with the MWA (page 35), and the hunt for radio emission from fireballs (very bright meteors).

- This year two new CAASTRO students joined the MWA pulsar team: PhD student Dilpreet Kaur started in June 2017 and Nicholas Swainston was with us through the year as an Honours student. Kaur is studying millisecond pulsars while Swainston worked on a pilot pulsar search with the Phase 2 MWA. Their research was supervised by CAASTRO Chief Investigator Ramesh Bhat and CAASTRO postdoc Steven Tremblay, who are also overseeing the work of three other PhD students, Mengyao Xue, Bradley Meyers and Samuel McSweeney.
- The work of McSweeney et al. (2017), MWA observations of 'drifting subpulses' with high sensitivity and time resolution (page 17), shows that the MWA is now mature. The analysis of the MWA data revealed previously unknown subtleties in the emission of PSR J0034–0721; the rate at which the emission structure moves in phase shows a more complex pattern than seen before. Understanding such puzzling results may be the key that unlocks the secrets of the pulsar emission mechanism.
- Bradley Meyers led a study of giant radio pulses from the Crab pulsar, using the complementary frequency ranges of the MWA and the Parkes telescope to study them at the widest range of frequencies (page 17). The work suggests that the giant-pulse spectrum flattens at low frequencies, which has implications for the detectability of fast radio bursts in that frequency range.
- Mengyao Xue and collaborators exploited the MWA's huge field of view by making the first pulsar census with the MWA, at a frequency of 185 MHz. From 40 hours of data they detected 50 pulsars, many of them for the first time at low frequencies. Xue's team extended their analysis to forecast the capability of SKA-low, predicting that it may find as many as 9,400 pulsars.
- Chhetri, Morgan, Ekers and Macquart worked on the phenomenon of interplanetary scintillation (IPS), the scattering of radio signals by charged particles flowing off the Sun (page 35). These particles cause compact cosmic radio sources to 'twinkle' (scintillate) at radio wavelengths. The MWA is well suited to making IPS observations and can survey for compact sources at low frequency with unprecedented depth and breadth. Along with CAASTRO Director Elaine Sadler, Chhetri, Morgan and Ekers investigated the nature of compact radio sources newly discovered this way. This work has now appeared in papers by Chhetri et al. (2018) and Morgan et al. (2018).
- Jean-Pierre Macquart continued his work on the detection and interpretation of fast radio bursts. Macquart is the co-Principal Investigator of the CRAFT (Commensal Real-time ASKAP Fast Transients) survey, which has already made several successful detections. The first fast radio burst from ASKAP was reported in Bannister et al. (2017) (page 32). The project is ramping up, and many papers now being prepared will report on new detections and their cosmological significance.
- Paul Hancock and his PhD student Xiang Zhang continued to hunt fireballs (very bright meteors) with the MWA, carrying out a 322-hour survey. They were able to constrain the limits on radio emission in the MWA's 72–103 MHz band. Their analysis reached a detection threshold of 3.5 Jy/beam, and the derived upper limit on the radio spectral index is –3.7 at the 95 per cent confidence level. Hancock and Zhang made convincing detections of reflected FM broadcast signals from small satellites, showing that the MWA can detect and track space debris as small as 10 cm across.

Dr Ramesh Bhat

CAASTRO Node Leader
Theme: Dynamic

Bhat's research continues to focus on pulsar astronomy and fast radio bursts (FRBs). A significant part of his research this year involved exploiting the newly developed capabilities of the Murchison Widefield Array (MWA) for pulsar science. He supervises four PhD students who are using the MWA to study pulsar emission physics, pulsars as probes of the interstellar medium, and millisecond pulsars as an aid to pulsar timing array experiments. He has also facilitated the MWA's participation in the ASKAP CRAFT (Commensal Real-time ASKAP Fast Transients) project, which is beginning to detect FRBs at an impressive rate, and is co-supervising a Curtin PhD candidate who is exploring the use of FRBs as cosmic probes. Bhat is the Science Lead of the MWA high-time-resolution science group and in April 2017 also became Curtin Node Leader.

Dr Rajan Chhetri

CAASTRO Research Staff
Theme: Evolving

Chhetri joined CAASTRO's Curtin node in 2016. As part of a small team, he has helped to develop the widefield *interplanetary scintillation* (IPS) technique with the MWA. This technique identifies sub-arcsecond compact structures in low-frequency radio sources: it improves the MWA's angular resolution by more than two orders of magnitude and can be implemented quickly to cover large parts of the sky. The IPS team's work, described in more detail on page 35, is providing unprecedented insights into the properties of low-frequency compact source populations. It also offers a new way to identify candidate high-redshift radio galaxies and high-quality calibrators for the future SKA.

Mrs Angela Dunleavy

CAASTRO Administrator

Dunleavy is responsible for collating non-financial data for CAASTRO reports and provides administrative support to the Curtin CAASTRO team and CAASTRO events held at Curtin. As part of the CAASTRO A-Team, Dunleavy also provided support for CAASTRO Annual Retreats during 2012–2017.

Dr Wiebke Ebeling

CAASTRO Education and Outreach Manager
Theme: Education and Outreach

Ebeling had oversight of the Education and Outreach portfolio as it made the transition from final major productions to legacy status in 2017. The highlight was the launch of the CAASTRO children's comic *The Cosmic Adventures of Alice and Bob* in a keynote stage show at Perth Astrofest. Over 7,200 free copies of the comic book were sent to the libraries of all Australian primary schools; similarly, more than 1,500 free copies of CAASTRO's other school resource, the *Bright Stars* wall calendar, were sent to all Australian high schools. Ebeling also coordinated the compilation of teaching notes accompanying the comic (which related the story to the science, maths, English, design and technology, and visual arts curricula), and fulfilled requests for additional class sets from more than 60 Australian schools, home schoolers and other educational institutions. In 2017, two short video productions supporting a CAASTRO press release made available via YouTube, as were recordings of presentation from the inaugural *CAASTRO Galaxy Convention* (page 93).

Dr Paul Hancock

CAASTRO Affiliate
Theme: Evolving, Dynamic

Hancock has a strong background in radio surveys, radio variability, and software to support astronomy. He is the main developer of the Aegean source-finding algorithm and the analysis pipeline for the Variable and Slow Transients (VAST) survey, which is to be carried out with the Australian SKA Pathfinder. Hancock is currently leading projects that use Murchison Widefield Array (MWA) data to detect radio emission from fireballs (bright meteors), characterise the scintillation seen from cosmic radio sources at low frequencies, and detect and monitor space debris with passive radar techniques. He is also collaborating on a project that aims to detect the prompt radio emission from short gamma-ray bursts with the MWA. In collaboration with the Desert Fireball Network, Hancock has led the installation of a commercial-grade camera to monitor the night sky above the MWA.

Dr Clancy James

CAASTRO Postdoctoral Researcher
Theme: Dynamic

James specialises in the detection of high-energy neutrinos and cosmic rays with radio telescopes. His PhD work was with the LUNASKA project to detect neutrinos hitting the Moon with CSIRO's Parkes telescope and the Australia Telescope Compact Array, for which he was awarded the 2010 Bragg Gold Medal. From 2009 to 2011 he worked on the LOFAR (Low-Frequency Array) cosmic-rays key science project to study extensive air showers in the Earth's atmosphere. He is a co-chair of the SKA's High Energy Cosmic Particles Focus Group, and co-author of the CoREAS code for calculating the radio emission from cosmic ray cascades. From 2011 to 2017, James worked in Erlangen, Germany, on the ANTARES and KM3NeT neutrino telescopes, in particular using multi-messenger observations with the TANAMI collaboration to study high-energy astrophysical processes. James is currently working on the CRAFT (Commensal Real-time ASKAP Fast Transients) project to detect fast radio bursts with ASKAP.

Dr Christopher Jordan

CAASTRO Affiliate
Theme: Evolving

Jordan works in the Epoch of Reionisation (EoR) group at Curtin University, using the Murchison Widefield Array (MWA) radio telescope. In 2017 he analysed MWA Epoch of Reionisation (EoR) data collected over four years, to observe trends in ionospheric activity. This research is vital to understanding one of the biggest impediments to detecting the EoR signature, and aids all other avenues of low-frequency radio astronomy. In the course of this work Jordan identified unusual, rapidly varying properties of the ionosphere, which may be caused by 'space weather' or terrestrial weather. In addition to aiding other EoR-related work, and taking part in discussions related to the SKA, Jordan contributes to the Australian star-formation community: in particular, he co-leads a legacy project on the Australia Telescope Compact Array that is searching for tracers of star formation across the Galactic plane.

Mr Ronniy Joseph

CAASTRO PhD Student
Theme: Evolving

In October 2016 Joseph commenced his PhD under supervision of Trott and Wayth, after which he joined CAASTRO as part of the Evolving Universe theme. His project focuses on the use of heterogeneous radio interferometers to probe the weak signals from the Epoch of Reionisation (EoR). He will study the use and benefits of combining antennas from different arrays. In particular, he will look at whether combining antennas in this way provides additional information not available from traditional arrays, and whether it makes array calibration easier.

Ms Dilpreet Kaur

CAASTRO PhD Student
Theme: Dynamic

Kaur started her PhD in mid 2017, and is supervised by Bhat and Tremblay. She is studying the interstellar medium (ISM) in the line of sight to millisecond pulsars, particularly those used in pulsar timing array experiments that aim to detect gravitational waves. ISM effects on propagation of pulsar signals are highly pronounced at low observing frequencies: the MWA is therefore an excellent instrument for studying these pulsars and characterising the ISM towards them. This work will help us to develop effective methods for correcting noise in timing measurements that arises from the ISM. It will also inform optimal strategies for doing PTA experiments with the Square Kilometre Array.

Dr Jean-Pierre Macquart

CAASTRO Associate Investigator
Theme: Dynamic

This year Macquart has worked primarily on fast radio bursts (FRBs); in particular, he worked with CAASTRO Advisory Board member Ron Ekers on the statistical properties (source counts) of the FRB population to understand how the prevalence of FRBs has evolved over the history of the Universe (page 18). Macquart is a co-Principal Investigator of the CRAFT (Commensal Real-time ASKAP Fast Transients) project survey, which is using the Australian SKA Pathfinder to characterise the rare but bright end of the FRB population. These bright FRBs the key to understanding the cosmological distribution of FRBs (page 32). With Ekers and fellow CAASTRO members Morgan and Chhetri, Macquart has also harnessed the resolving power of interplanetary scintillation to probe compact sources with the MWA (page 35).

Dr Benjamin McKinley

CAASTRO Affiliate
Theme: Evolving

In July 2017 McKinley moved from the University of Melbourne to Curtin University, where he has continued his work on the Epoch of Reionisation (EoR). McKinley is attempting to measure the global (all-sky averaged) signal from the EoR using a novel method that employs the Murchison Widefield Array (MWA) and observations of the Moon. In 2017 he published a paper on our nearest neighbouring radio galaxy, Centaurus A, which gained some media attention. In 2018 McKinley will transition to a new ARC Centre of Excellence, ASTRO 3D, to continue his work on detecting the EoR signal.

Mr Samuel McSweeney

CAASTRO PhD Student
Theme: Dynamic

Sam started his PhD at Curtin in 2016, under the supervision of Bhat and Tremblay (both at Curtin) and Avinash Deshpande (Raman Research Institute, India). He investigates the radio emission mechanism of pulsars by studying the sub-pulse drifting behaviour that some pulsars exhibit. His wider research interests include applying machine-learning techniques to science. He also helps maintain the software pipeline for processing pulsar data obtained with the Murchison Widefield Array.

Mr Bradley Meyers

CAASTRO PhD Student
Theme: Dynamic

Meyers' research interests are primarily in pulsar emission physics and interstellar propagation effects, especially at low frequencies. Meyers joined CAASTRO in early 2016 to work with Tremblay and Bhat at Curtin University on his PhD project, investigating sporadic emission phenomena from pulsars using the MWA Voltage Capture System. He has studied giant pulses from the Crab pulsar, using simultaneous observations with the MWA and Parkes to characterise the giant pulse spectral behaviour and energetics (page 17). Meyers is also searching for *rotating radio transients* with the MWA, and recently began an observing campaign using both the MWA and UTMOST to observe the 'intermittent' pulsar J1107–5907. In the final year of his PhD project Meyers will use low-frequency MWA observations to explore the links between pulsar populations. Meyers is the Curtin representative on the CAASTRO Student Committee.

Dr John Morgan

CAASTRO Affiliate
Theme: Evolving

Morgan works with data from the Murchison Widefield Array, investigating how the ionosphere affects radio waves and looking at how the solar wind makes radio sources 'twinkle' (scintillate): this work is described on page 35. Morgan is also helping to produce the MWA survey catalogue.

Dr Steven Murray

CAASTRO Research Staff
Theme: Evolving

Murray is a postdoc working with the MWA Epoch of Reionisation (EoR) team. He works on sophisticated statistical models of the radio sources that lie between us and the EoR, obscuring and distorting it: in particular, he has developed an analytic description of how the cosmological structure of the foreground sources affects the EoR signal. Other work he contributes to includes characterising the ionosphere and its effects on EoR observations and using halo-modelling techniques to understand the biasing of HI sources.

Ms Tina Salisbury

CAASTRO Administrator

Salisbury organises financial support for the CAASTRO team members at Curtin and reconciles financial data against the CAASTRO budget.

Dr Marcin Sokolowski

CAASTRO Associate Investigator
Theme: Evolving

In 2017 Sokolowski began a project to measure the absolute flux of calibrator sources, using the BIGHORNS total-power radiometer and the Engineering Development Array (EDA) at the Murchison Radio-astronomy Observatory. He also became responsible for scheduling Murchison Widefield Array (MWA) and EDA observations, and monitoring MWA data quality. In 2017 he finalised his testing of a new MWA beam model developed in 2016 and continued to work on extending the EDA's observing capabilities, mainly for pulsars and spectral lines, and calibrating EDA data.

Ms Kimberly Steele

CAASTRO Affiliate
Themes: Evolving, Dynamic, Education and Outreach

In early 2017 Steele acted in part of Ebeling's Education and Outreach role, updating CAASTRO's social media presence, collaborating with researchers to write news stories, distributing CAASTRO's comic book *The Cosmic Adventures of Alice and Bob*, and performing other tasks. In September she returned to her original full-time role as the CIRA (Curtin Institute of Radio Astronomy) Engineering Graduate Intern, documenting and participating in on-site activities at the Murchison Radio-astronomy Observatory, mainly maintenance of the Murchison Widefield Array and other projects.

Mr Nick Swainston

CAASTRO Honours Student
Themes: Dynamic

Swainston joined CAASTRO in 2017 as an Honours student. His project used the Murchison Widefield Array to perform a pulsar search, for which he developed a pipeline using PYTHON, BASH, and SQLITE. This pipeline used ~71,000 CPU hours and successfully detected three pulsars. Swainston has also worked with the CIRA (Curtin Institute of Radio Astronomy) Pulsar Team to produce a PYTHON script that processes pulsar detections and uploads them to a pulsar database using SQLITE, and contributed to an MWA pulsar census (page 17) by developing a PYTHON script to list known pulsars within an observation's field of view.

Professor Steven Tingay

CAASTRO Affiliate
Theme: Evolving, Dynamic

Tingay is the John Curtin Distinguished Professor, the Executive Director of the Curtin Institute of Radio Astronomy, and the Deputy Executive Director of the International Centre of Radio Astronomy Research. As a CAASTRO Affiliate, Tingay continues collaborations with CAASTRO Staff and students he started as a CAASTRO Chief Investigator, primarily on research projects being carried out with the Murchison Widefield Array (MWA).

Dr Steven Tremblay

CAASTRO Research Staff
Theme: Dynamic

Tremblay has continued to lead the Murchison Widefield Array's (MWA) Voltage Capture System (VCS) group. A significant portion of his effort in 2017 went into verifying the polarimetric pulsar profiles created with the MWA against those of other instruments operating at similar frequencies. He also continued to develop the VCS software, making it ever more approachable to new users. Tremblay co-supervised four CAASTRO PhD students in 2017 and also continued as a member of CAASTRO's Gender Action Committee.

Associate Professor Cathryn Trott

CAASTRO Associate Investigator
Theme: Dynamic, Evolving

Trott's work in the Evolving Universe theme has focused on processing Epoch of Reionisation (EoR) data from the MWA. She is also leading efforts to understand the impact of foreground contamination on EoR estimation. She has derived a framework for understanding the impact of ionospheric activity on EoR power spectra, and has published work exploring the benefits of wavelet analysis for studying signal evolution.

Trott played a large role in shaping the EoR experiment for the SKA this year, participating in the Science Working Group Board and contributing to the design and specifications of the telescope and the SKA-low antenna. She is also an active member of the SKA Science and Engineering Advisory Committee and several SKA Resolution Teams.

In addition, Trott works in the Dynamic Universe theme. Here she participates in a range of projects: for instance, understanding the statistical properties of high-time-resolution data in order to detect signals more efficiently.

Associate Professor Randall Wayth

CAASTRO Associate Investigator
Theme: Evolving

Wayth is a member of the Curtin University Department of Electrical and Computer Engineering and has both engineering and science interests in astrophysics. He took on the MWA Director role in 2016 and also manages the CAASTRO-supported BIGHORNS Epoch of Reionisation Global Signal project. Wayth co-supervises two CAASTRO PhD students working in the Evolving Universe theme and one in the Dynamic theme. He has continued as Project Scientist within the SKA-low Aperture Array Design and Construction (AADC) consortium, a role that he took up in 2015. Wayth works with several CAASTRO members on the MWA's GLEAM survey and Epoch of Reionisation key science program.

Ms Mia Walker

CAASTRO Affiliate
Themes: Evolving, Dynamic, Education and Outreach

Walker's main activity in 2017 was helping to deploy the Murchison Widefield Array (MWA)'s new long-baseline configuration. Her work in the Operations team at the Curtin Institute of Radio Astronomy also includes the ongoing development of receiver technology to be used in an even larger array in the future.

Ms Mengyao Xue

CAASTRO PhD Student
Theme: Dynamic

Xue started her PhD studies in Nov 2015 and joined CAASTRO in early 2016: she is supervised by Bhat, Tremblay, and Ord. She has carried out a low-frequency census of southern pulsars with the MWA (Xue et al. 2017). This work was based mainly on archival, high-time-resolution data generated by the MWA Voltage Capture System (VCS) since 2014. Xue is now working on testing the fidelity and stability of the polarimetric response of the MWA when observing pulsars at different zenith angles and different frequencies.

Ms Xiang Zhang

CAASTRO PhD Student
Theme: Dynamic

Zhang is a PhD student who joined CAASTRO in September 2016. She works with Wayth and Hancock on a project to detect radio emissions from fireballs (bright meteors). In this project she searches for intrinsic radio emission from fireballs with the Murchison Widefield Array radio telescope and compares the results with data from the Desert Fireball Network. To date she has processed 300 hours of radio observations and used these to put an upper limit on fireball emission. In the course of this work she has also detected several transient radio events caused by reflection from satellites.

CAASTRO UWA team members

CAASTRO AT THE UNIVERSITY OF WESTERN AUSTRALIA

THE UNIVERSITY OF WESTERN AUSTRALIA

The UWA node of CAASTRO is located alongside the International Centre for Radio Astronomy Research at the Ken and Julie Michael Building near the university's main campus. This node hosts four CAASTRO-funded research staff, 10 researchers (Chief Investigators, Associate Investigators and Affiliates), one administrator and nine PhD students. In 2017, our major CAASTRO research topics were cosmological and galaxy-evolution studies, neutral-hydrogen surveys, and optical surveys with imaging spectrometers, and our researchers contributed to 57 of CAASTRO's refereed publications. UWA researchers are engaged mainly in the Dark and Evolving Universe themes.

Dark Theme

In the Dark Universe theme, a highlight this year was Cullan Howlett's computation of the velocity power spectrum of galaxies in the CAASTRO-led 2MTF (2MASS Tully-Fisher) survey. This has allowed a new estimate of the growth rate of structure formation in the nearby Universe, independent of the effects of galaxy bias. The results imply that the growth rate does not depend on scale, and are completely consistent with the predictions of general relativity.

Evolving Theme

As part of the GLEAM (GaLactic and Extragalactic All-sky MWA) survey undertaken with the Murchison Widefield Array, Anna Kapínska made a new study of the nearby starburst galaxy NGC 253. She examined the energy spectrum of electrons generated by low-energy cosmic rays in several regions of the galaxy, revealing the influence of the dense nuclear plasma on the radio emission from the well-known central starburst region.

Dan Taranu developed a powerful method of simultaneously modelling the kinematics and morphology of galaxies in a fully self-consistent manner. His MagRite algorithm is suitable for estimating bulge, disk and dark-halo parameters, and has been developed especially for data from integral-field spectrographs such as SAMI (page 33) and future HI surveys.

Tristan Reynolds studied the spectral-line performance of a phased-array feed on the Parkes radio telescope to determine the usefulness of this technology for deep studies of neutral hydrogen in the distant Universe. In this study, Reynolds stacked neutral-hydrogen spectra of distant galaxies and made intensity maps for redshifts up to one. The results were encouraging: it was particularly pleasing that the phased-array feed greatly reduced the levels of standing-wave interference experienced on the telescope.

Jonghwan Rhee continued his work on intensity mapping and neutral-hydrogen stacking with interferometers and single dishes. He has developed techniques to combat foreground/background contamination and radio-frequency interference.

Other highlights

- Khaled Said, a co-supervised PhD student of the University of Cape Town, was awarded his PhD. Following this, he received The Gruber Foundation Annual Fellowship for 2017, for his work on the Zone of Avoidance. He will hold the Fellowship at the ANU.
- CAASTRO research scientist Kapínska accepted an ongoing staff scientist position at the National Radio Astronomy Observatory, Socorro, USA.
- Obreschkow was successful in his application to hold a Focus meeting, *Galactic Angular Momentum*, at the General Assembly of the International Astronomical Union in Vienna in 2018. The three-day meeting will highlight recent work in this field.
- A simulation meeting, *Mock Perth*, was held during 20–22 March 2017, and attracted 46 participants including Colin Norman (Johns Hopkins University) and CAASTRO visitor Matthieu Schaller (Durham University).

Professor Lister Staveley-Smith

CAASTRO Deputy Director, Evolving Theme Leader, Node Leader and Chief Investigator
Themes: Evolving and Dark

Staveley-Smith is UWA node leader, Evolving Theme leader and CAASTRO Deputy Director. He co-supervises five CAASTRO PhD students. His activities in 2017 included facilitating activities within the Australia–China ACAMAR collaboration (page 137) and co-organising the 2017 ACAMAR workshop in Tasmania. He has also assisted the executive of CAASTRO and ASTRO 3D (the ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions) in appointments and other transition arrangements, and assumed the role of Evolving Theme leader for the remainder of CAASTRO. His CAASTRO research this year included using a phased-array feed on the Parkes telescope for intensity mapping, starting early science for WALLABY (an all-sky HI survey), and continuing to exploit results from the 2MTF (2MASS Tully-Fisher) survey.

Mr Kamran Ali

CAASTRO PhD Student
Theme: Dark

Ali, supervised by Obreschkow, has dedicated most of his time to looking at the excess information in the line-correlation function for various cosmological models. Alternative (non-standard) cosmology models possess a rich phenomenology in the transition to a non-linear regime. Ali is interested in statistical measures that are highly sensitive to the underlying gravitational physics at these scales.

Mr Rodrigo Adolfo Cañas Vazquez

CAASTRO PhD Student
Theme: Evolving

Cañas Vazquez is a second-year PhD student at UWA. He uses numerical simulations to study the diffuse stellar component that surrounds galaxies, galaxy groups and clusters. In 2017 he contributed to improving the halo finder VELOCIraptor, which identifies galaxies in numerical simulations. Cañas Vazquez is the lead investigator of the Intra-Cluster Light project: this is part of a larger international collaboration, *The Three Hundred*, which compares different galaxy-formation simulation codes and semi-analytic models.

Mr Qingxiang Chen

CAASTRO PhD Student
Theme: Evolving

Chen began his PhD at UWA in November 2015. Supervised by Meyer, he uses the VLA–DINGO early-science data to investigate the properties of gas in galaxies through spectral stacking. Chen processes the data and then measures the average density of neutral hydrogen by stacking the 21-cm radio emission from thousands of galaxies. This work will help us understand the evolution of the gas content in galaxies, and help to constrain galaxy-evolution theory.

Dr Pascal Elahi

CAASTRO Affiliate
Themes: Evolving and Dark

Elahi is a computational astrophysicist studying cosmic structure in multiple cosmologies, dark-matter haloes, galaxy evolution and the physics of galaxy formation. He works in the Evolving and Dark Universe themes. Recently Elahi has focused on developing tools for N-body simulations, studying the evolution of dark-matter haloes across cosmic time and the lives of subhaloes/satellite galaxies, and identifying observational signatures of modified dark-matter models. He is involved in several major research projects: he leads the ICRAR-based project SURFS (Synthetic UniveRses For Surveys); is a key member of the international, multi-institutional nIFTy Cosmology collaboration; and has recently joined the new ARC Centre of Excellence ASTRO 3D as a key member of the GENESIS computational program.

Ms Katherine Harborne

CAASTRO PhD Student
Theme: Evolving

Harborne has been a member of CAASTRO since she began her PhD in 2016. Supervised by Chris Power, she uses hydrodynamic simulations to study dwarf galaxies. She recently worked on a pipeline to construct mock kinematic data cubes from simulated galaxy models. This work stems from the wish to better understand results from the SAMI survey (page 33) by exploring the effects that observational limitations have on our ability to recover galaxy kinematics.

Dr Cullan Howlett

CAASTRO Postdoctoral Researcher
Theme: Dark

Over the last year Howlett has focused on using peculiar-velocity surveys to constrain cosmology. He has measured the correlations between the velocities of galaxies in the 2MTF (2MASS Tully-Fisher) survey, and from these obtained constraints on the growth rate of structure in the Universe; he has also predicted how well this growth rate could be measured using Type IA supernovae detected with the future Large Synoptic Sky Telescope. Howlett is the Dark Theme Scientist and also a key member of the Taipan Galaxy Survey, which will start observations in 2018.

Dr Minh Huynh

CAASTRO Associate Investigator
Theme: Evolving

Huynh is a Senior Data Scientist and Research Astronomer, jointly employed by CSIRO and ICRAR–UWA. She is the project leader for the CSIRO ASKAP Science Data Archive, which will house data obtained with the Australian SKA Pathfinder (ASKAP). From 2010 to 2013 she was the Deputy International Project Scientist for the Square Kilometre Array. Huynh studies galaxy formation and evolution. She is working on the identification of radio sources detected by the GLEAM (GaLactic and Extragalactic All-sky MWA) survey, using existing data from the Australia Telescope Compact Array. This will pave the way for science that combines observations by the Murchison Widefield Array and ASKAP's EMU (Evolutionary Map of the Universe) survey.

Ms Katharine Kelley

CAASTRO PhD Student
Theme: Dark

Kelley joined CAASTRO in 2015 as part of the Dark theme. Her doctoral research relates mainly to understanding and modelling the interactions of quantum chromodynamic (QCD) axions, hypothetical subatomic particles. QCD axions have long been considered a strong candidate for cold dark matter. Kelley is modelling the all-sky signal resulting from the conversion of QCD axions in the Galactic magnetic field and investigating the potential axion signatures from interactions in the early Universe. This work could pave the way to using radio telescopes to detect dark matter.

Dr Claudia Lagos

CAASTRO Associate Investigator
Theme: Evolving

Lagos has been a DECRA fellow at the UWA node of ICRAR since May 2015; prior to that, she was a Fellow at the European Southern Observatory in Germany. She works on galaxy-formation simulations and semi-analytic models: she has explored relevant physical processes such as black-hole accretion and galaxy co-evolution, and has modelled the interstellar medium, star formation and supernovae dynamics and feedback. Recently Lagos has focused on theoretical studies of the kinematics of galaxies and their connection with galaxy assembly and growth. Lagos has been awarded several international prizes, including the Springer Theses 2014 and the MERAC prize 2014 for the best PhD in Europe in the area of theoretical astrophysics (awarded by the European Astronomical Society). At UWA she was the Institute for Advanced studies Distinguished Fellow in 2016.

Mr Lincheng Li

CAASTRO PhD Student
Theme: Evolving

Li is a joint PhD student from National Astronomical Observatories, Chinese Academy of Sciences. He carried out two years of research in China on a project to investigate the effect a galaxy's environment on its neutral hydrogen content. Since 2016 he has continued his studies at UWA, working on the intensity-mapping project led by Staveley-Smith.

Dr Martin Meyer

CAASTRO Associate Investigator
Theme: Evolving

Meyer's research focuses on neutral hydrogen (HI) surveys and the role played by hydrogen gas in the formation and evolution of galaxies. He leads DINGO (Deep Investigation of Neutral Gas Origins), a project that will take deep HI observations with the Australian SKA Pathfinder and use them to understand how the HI content of the Universe has evolved over the past four billion years. He also works on surveys with the Very Large Array in New Mexico, including a 1000-hour deep HI survey, CHILES (the COSMOS HI Large Extragalactic Survey), and a widefield HI-stacking experiment in the GAMA G09 field. In 2017 Meyer was awarded a fellowship to visit the Square Kilometre Array (SKA) Organisation's UK headquarters and also completed his term as co-chair of the SKA HI galaxy-science working group.

Dr Danail Obreschkow

CAASTRO Associate Investigator
Themes: Evolving and Dark

Obreschkow's key focus is galactic angular momentum, which he is now investigating with hydrodynamic simulations. In 2017 Obreschkow continued as the primary supervisor of CAASTRO postdoc Taranu, who is modelling galaxies observed in the SAMI Galaxy Survey and who this year published his first SAMI paper. Obreschkow also supervises two PhD students: Kamran Ali, who this year published his first paper on the two-point statistics of star-forming material in galaxies, and Scott Meyer, who works on HI line stacking.

Ms Clare Peter

CAASTRO Administrator

Peter joined CAASTRO in 2013. She coordinates reporting and financials for the UWA node and provides administrative support.

Dr Attila Popping

CAASTRO Postdoctoral Researcher
Theme: Evolving

Popping's research interests lie in galaxy evolution, particularly the neutral hydrogen content of galaxies. He leads IMAGINE (Imaging Galaxies' Intergalactic and Nearby Environment), a large 'legacy' project of the Australia Telescope Compact Array (ATCA): this is aimed at improving our understanding of how galaxies interact with the surrounding intergalactic medium. Popping is an active contributor to the DINGO and WALLABY neutral-hydrogen surveys being carried out with the Australian SKA Pathfinder (ASKAP) and is co-leading the ASKAP spectral-line processing working group. He is working on several experiments involving HI stacking and plans to use stacking techniques to do early science with ASKAP. Popping is also a core member of the CHILES survey, a large neutral-hydrogen survey being carried out with the VLA (Karl G. Jansky Very Large Array) in the USA, and co-supervises PhD student Qingxiang Chen, who is working on a widefield HI survey using the VLA.

Mr Rhys Poulton

CAASTRO PhD Student
Themes: Evolving and Dark

Poulton is a computational astrophysicist working with a leading suit of N-body simulations, SURFS (Synthetic UniveRses For Surveys). He will be using SURFS to study the orbital evolution of satellite dark-matter halos throughout cosmic history, to better understand properties such as mass-loss rate and the timescales of dynamical friction.

Professor Chris Power

CAASTRO Associate Investigator
Theme: Evolving

Power's CAASTRO work in 2017 focused on the use of simulated galaxies to better understand how well integral field unit (IFU) observations can recover intrinsic kinematic structure. He has worked with ICRAR–UWA PhD student Kate Harborne to construct a sample of galaxies of fixed mass and explore

how well the galaxy stellar spin parameter can be recovered. Power and Harborne have also started to examine how well the Toomre Q parameter, which measures the stability of discs, can be reconstructed from observations. This work is being written up by Harborne for publication, and feeds directly into the SAMI Galaxy Survey.

Mr Fei Qin

CAASTRO PhD Student
Theme: Dark

Qin is a second-year PhD student supervised by Staveley-Smith and Howlett. For his thesis he is working with measurements of the bulk-flow velocity, the weighted mean of the peculiar velocities of galaxies: he is using bulk-flow measurements to test the standard cosmological model and is also developing new algorithms for measuring the bulk flow. Qin is using a combined data set from the 2MTF (2MASS Tully-Fisher) survey and the peculiar-velocity component of the 6dF Galaxy Survey to measure the bulk-motion dipole term. He plans to develop new algorithms to measure higher-order moments, using Cosmicflows–3 data.

Mr Tristan Reynolds

CAASTRO PhD Student
Theme: Evolving

This year Reynolds published results from trial observations made with an ASKAP MkII phased-array feed mounted on the Parkes radio telescope in 2016, which demonstrated the capabilities of phased-array feed receivers on single-dish telescopes. He then joined the spectral-line working group for the WALLABY neutral-hydrogen survey, helping to process and image spectral-line observations and test the automated data-reduction pipeline for ASKAP (the Australian SKA Pathfinder).

Dr Jonghwan Rhee

CAASTRO Postdoctoral Researcher
Theme: Evolving

Rhee's research interests lie in galaxy evolution and cosmology using HI observations: in particular, he is working on the evolution of HI gas out to a redshift of one, using HI spectral stacking and an intensity-mapping technique. Rhee's main project at present is an HI intensity-mapping experiment with the Parkes radio telescope. In 2017 Rhee examined various foreground-removal techniques and their effects on power-spectrum results, knowledge needed for properly analysing HI intensity-mapping observations made with Parkes. Rhee also helped Reynolds reduce and analyse pilot intensity-mapping data taken with a phased-array feed on Parkes.

Dr Dan Taranu

CAASTRO Postdoctoral Researcher
Theme: Evolving

Taranu is a member of the SAMI Galaxy Survey. This year he published a paper (Taranu et al. 2017) directly applicable to the survey: it details a novel method and code for building realistic 3D models of spiral galaxies, with components that include a thin, rotating stellar disk; a compact, spherical stellar bulge; and a spherical halo of invisible dark matter. These 3D models fully reproduce the motions of stars in galaxies observed with SAMI, allowing for more precise measurements of the sizes and masses of each part of the galaxy. Taranu also completed dozens of sophisticated supercomputer simulations of collisions of spiral galaxies in groups. Such dramatic galaxy mergers are thought to have created the most massive elliptical galaxies in the nearby universe. The modelling suggests that massive ellipticals have several distinct components as a result of their complicated formation histories – signatures seen in high-resolution images of SAMI galaxies.

Dr Charlotte Welker

CAASTRO Affiliate
Theme: Evolving

Welker is a Research Associate and Jim Buckee Fellow at ICRAR–UWA. She works on hydrodynamic cosmological and zoom simulations. Welker's main research interest is the interplay between the cosmic web on large scales and galaxy evolution: in particular, she is examining how the filamentary pattern of the cosmic web funnels the gas inflows and infalling satellites down to the cores of haloes, affecting the advection of angular momentum, the ultimate shaper of galaxies. In 2017 and 2018 Welker was granted four million CPU hours on Australian supercomputers to produce highly resolved groups and clusters that she uses to investigate the fate of the gas in more detail. These studies will help us both understand the impact of cosmic flows on galaxies and design new methods to infer the properties of real cosmic flows from galaxy observations.

Dr O. Ivy Wong

CAASTRO Affiliate
Theme: Evolving

Wong works on multiwavelength observations of low-redshift galaxies. She aims to determine the physical processes that govern how galaxies start and stop forming stars, grow supermassive black holes and evolve. She plans to use the new radio telescopes located in Western Australia to help her answer some of these questions. Wong is a member of the ASKAP spectral-line processing team and examines early science data that has been taken for WALLABY, a survey for neutral hydrogen gas being carried out with ASKAP. Wong also belongs to teams carrying out other ASKAP surveys (DINGO, EMU and FLASH) and MeerKAT surveys (MALS and MHONGOOSE). With Dr Julie Banfield (ANU), Wong co-leads an online citizen-science project, Radio Galaxy Zoo (radio.galaxyzoo.org), in which participants cross-match radio jets to the host galaxies from which the jets emanate.

CAASTRO University of Sydney team members

CAASTRO AT THE UNIVERSITY OF SYDNEY

THE UNIVERSITY OF SYDNEY

The CAASTRO node is co-located with the Sydney Institute for Astronomy (SIfA) within the University of Sydney's School of Physics. 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. In 2017 there were 31 CAASTRO team members at the Sydney node, including 12 students. The research activities at this node mainly fall within the Evolving and Dynamic themes.

In the Dynamic Universe theme, our major activities for 2017 were:

- radio follow-up of gravitational-wave events detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO), in collaboration with an international network of colleagues at observatories around the world. Tara Murphy led the radio follow-up of these events using the Australia Telescope Compact Array (ATCA), Australian SKA Pathfinder (ASKAP) and Murchison Widefield Array (MWA), with Dobie, Lynch, Lenc and Sadler also involved
- the analysis of data from several radio-transient surveys, in preparation for the Variables and Slow Transients (VAST) survey to be carried out with ASKAP. The researchers involved were Dobie, Lenc, Lynch, Murphy, Qi and Zic
- searches for fast radio bursts with the upgraded Molonglo radio telescope (UTMOST), in collaboration with CAASTRO Chief Investigator Adam Deller and colleagues at the Swinburne node. Green and Murphy participated in this work.

In the Evolving Universe theme, our major activities were:

- continuation of the Sydney–AAO Multi-object Integral-field spectrograph (SAMI) Galaxy Survey, an ambitious integral-field spectroscopic survey of 3,400 low-redshift ($z < 0.12$) galaxies, covering both isolated galaxies and those in groups and clusters. The SAMI instrument uses a novel 'hexabundle' technology jointly developed by Sydney and the Australian Astronomical Observatory (AAO). The Sydney node researchers taking part were Bland-Hawthorn, Bloom, Bryant, Croom, McElroy, Sadler, Schaefer, Scott and Varidel
- analysis of low-frequency radio data from the MWA, with a focus on polarised and peaked-spectrum extragalactic radio sources. This work involved Callingham, Lenc, Murphy and Sadler. Sadler and Mahony also worked with CAASTRO Curtin researchers on the analysis of a pilot survey for compact low-frequency sources using the new widefield interplanetary scintillation (IPS) technique
- studies of the redshifted 21-cm absorption line of neutral hydrogen (HI) as a probe of the cold gas content of galaxies in the distant Universe, as part of an ASKAP survey, FLASH (the First Large Absorption Survey in HI)
- the analysis of spectral-line commissioning data from ASKAP. This was our largest undertaking this year. Glowacki, Mahony, Moss and Sadler were involved.

Our overseas visitors this year included Professor Raffaella Morganti (ASTRON, The Netherlands), Associate Professor David Kaplan (University of Wisconsin–Milwaukee, USA), Professor Colin Norman (Johns Hopkins University, USA) and Dr Evangelia Tremou (Michigan State University, USA). We also hosted many researchers from other CAASTRO nodes who visited us for Busy Weeks and workshops.

The highlight of 2017 for the Dynamic Universe theme was the first detection of light and radio waves associated with the merger of two neutron stars, initially detected by LIGO (the Laser Interferometer Gravitational-Wave Observatory) as a gravitational-wave event (GW170817) and by NASA's Fermi Gamma-ray Space Telescope as a short gamma-ray burst. Tara Murphy led the successful Australian search for a radio counterpart, and also represented CAASTRO at a joint press conference with OzGrav

held in Canberra in October. Other highlights included Christene Lynch's novel work on searching for young exoplanet systems through their circularly polarised radio emission and Tara Murphy's paper on the low-frequency radio properties of pulsars.

This year also saw a big step in the Evolving Universe theme, the first major release of data (DR1) from the SAMI Galaxy Survey. The release included spectral cubes and spatially resolved 2D maps for 772 galaxies (about 20 per cent of the full SAMI galaxy survey). Other science highlights from the SAMI team included Nic Scott's paper on the global stellar populations of SAMI galaxies and Jessica Bloom's work on the low-redshift Tully-Fisher relation (which showed how the 2D spatially resolved kinematics data from SAMI can increase the accuracy of this technique). On the radio-astronomy side of the Evolving theme, the highlights were Vanessa Moss's paper connecting neutral hydrogen (HI) and X-ray absorption in gas-rich radio AGN (active galactic nuclei) and Emil Lenc's paper on the challenges of making accurate polarisation measurements with the MWA.

One of the main education and outreach activities at the Sydney node continues to be the *CAASTRO in the Classroom program*, and in 2017 our School Education Officer Janette Ellis did an outstanding job of streaming talks and discussion sessions with CAASTRO astronomers to high schools across Australia. Janette also organised the first CAASTRO *Galaxy Convention* for high-school, undergraduate, PhD students and Post docs , held in Sydney in December 2017. Several Sydney node researchers and students again travelled to Uluru throughout the year to take part in CAASTRO's *Astronomer in Residence* program at the Voyages resort. The second Sydney Astrofest, held at the University of Sydney in July, was an extremely successful and well-attended event.

The University of Sydney hosts CAASTRO's main administrative office, which in 2017 consisted of Kate Gunn (Chief Operating Officer), Debra Gooley (Finance), Helen Keys (Executive Support), Janette Ellis (School Education Officer), Kylie Williams (Events and Communications) and Helen Sim (Media and Public Relations). This team oversees the reporting system across the Centre, handles all our financial obligations and transactions, organises our scientific workshops, manages the CAASTRO Mentoring Program and prepares the CAASTRO newsletters and Annual Report. The Admin team organised two major international conferences in 2017, along with our Annual Retreat and a range of smaller workshops.

Professor Elaine Sadler

CAASTRO Chief Investigator
CAASTRO Director and Sydney Node Leader
Theme: Evolving

Sadler works with Mahony, Moss, and Glowacki and other members of the FLASH (First Large Absorption Survey in HI) team to study HI absorption in galaxies out to redshift $z = 1$. In 2017 the team continued its analysis of the data obtained with the first 12 dishes of the Australian SKA Pathfinder (ASKAP) telescope, and was awarded time to carry out follow-up observations of ASKAP detections with the Atacama Large Millimetre Array (ALMA) and large optical telescopes in Chile. Results from this work were presented at international astronomy meetings in Germany, the Netherlands and Taiwan. Sadler also worked with Curtin CAASTRO researcher Rajan Chhetri on the analysis of MWA measurements of interplanetary scintillation (as a new way to identify compact low-frequency radio sources in the southern sky), and with Dynamic theme members on analysis of the host galaxy of the gravitational wave event GW 170817.

Professor Scott Croom

CAASTRO Chief Investigator
Theme: Evolving

Croom is leading the SAMI Galaxy Survey, a project to carry out spatially resolved spectroscopy on thousands of galaxies with the Sydney–AAO Multi-object Integral-field spectrograph (SAMI) on the Anglo-Australian Telescope. In 2017 the SAMI Galaxy Survey continued apace: it has now observed more than 2,400 galaxies. Fifteen SAMI papers were published this year, covering work that included a study of spatially resolved star-formation quenching, the connection between star formation and dynamical disturbance, new approaches to measuring angular momentum, and a new measurement of the intrinsic shape of galaxies. July 2017 saw the survey's first major data release, DR1 (page 33). The SAMI team will complete observations for the Galaxy Survey in May 2018 and then analyse the full dataset.

Associate Professor 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 (at gigahertz frequencies) and exoplanets and flare stars (at low frequencies). She also works to develop intelligent algorithms for detecting transient events in the large volumes of data that will be produced by next-generation radio telescopes. In 2017 Murphy led a team that detected radio emission from gravitational wave event GW170817 (page 39). In 2018 she will continue to monitor this source, prepare for the next observing run of LIGO (the Laser Interferometer Gravitational-Wave Observatory), and conduct surveys for radio transients with the Australian SKA Pathfinder (ASKAP) telescope.

Dr James Allison

CAASTRO Affiliate
Theme: Evolving

Allison is a principal investigator of the ASKAP FLASH (First Large Absorption Survey in HI) survey, which probes the distribution and evolution of atomic hydrogen (HI) to high redshifts. He is interested in using HI absorption lines to determine how the cold neutral gas in galaxies has changed over the past 10 billion years. He also studies the role of neutral gas in fuelling radio-loud active galactic nuclei and the mechanisms for feedback in their host galaxies. Allison served on the CAASTRO Gender Action Committee in 2017.

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 the SAMI 13-bundle spectrograph (in collaboration with Scott Croom), the Hector 100-bundle spectrograph (in collaboration with Julia Bryant), and the PRAXIS OH suppression spectrograph. Bland-Hawthorn's particular interest is to understand the evolution of galaxies in the context of their environment. He is a member of the teams carrying out the GAMA and CALIFA galaxy surveys, and of the team conducting GASKAP, which targets gas in the Galactic halo. Bland-Hawthorn is an ARC Australian Laureate Fellow.

Ms Jessica Bloom

CAASTRO PhD Student
Themes: Evolving, Dark

Bloom's research focus is the role of events such as mergers in galaxy evolution. She has identified perturbed galaxies and studied the relationships between kinematic asymmetry, stellar mass and star formation, showing that kinematic asymmetry is inversely proportional to stellar mass and is linked to an increased concentration of star formation. She has also studied the kinematics of low-mass galaxies and the influence of environment on kinematic perturbation. Bloom completed her PhD in 2017.

Dr Julia Bryant

CAASTRO Postdoctoral Researcher
Theme: Evolving

Bryant's key projects centre on using the dynamics of stars and gas, as measured by the SAMI Galaxy Survey, to identify how gas gets into galaxies to build up mass and make galaxies look the way they do in different formation environments. Bryant is on the SAMI Galaxy Survey Executive team, chairs the Target Selection workgroup, is SAMI Instrument Scientist and runs the observations with the SAMI instrument at the Anglo-Australian Telescope. Bryant is also the Project Scientist for the Hector instrument, SAMI's successor: Hector will be able to take spectra of more than ten times as many galaxies. As Project Scientist, Bryant links astronomers and instrument teams. She is also continuing to work on astronomical instrumentation, developing new astrophotonic optical-fibre imaging bundles for Hector.

Mr Dougal Dobie

CAASTRO PhD Student
Theme: Dynamic

Dobie started his PhD in 2017 and is working on electromagnetic follow-up of gravitational wave events with Australian radio telescopes. His main focus has been on developing an optimised observing strategy for the Australian Square Kilometre Array Pathfinder to detect long-term radio emission from poorly localised gravitational-wave events. This year Dobie was involved in the follow-up, with the Australia Telescope Compact Array, of the first detection of a neutron star merger, GW170817. These follow-up observations will continue, and will help to determine the energy of the merger, its orientation and the properties of its environment.

Ms Janette Ellis

CAASTRO School Education Officer

Ellis is an experienced high-school science teacher who has run the national outreach program *CAASTRO in the Classroom* since June 2017. With support from the Australian Government through a *Women in STEM and Entrepreneurship* (WISE) grant, *CAASTRO in the Classroom* has expanded to include entrepreneurship events such as *Galaxy Convention* (page 93), which was designed to inspire the next generation of female entrepreneurs in STEM (science, technology, engineering and mathematics). This year Ellis delivered several new web-based resources and facilitated numerous live-streaming events for schools, building on the excellent work of her predecessor, Ms Jenny Lynch.

Mr Marcin Glowacki

CAASTRO PhD Student
Theme: Evolving

Glowacki is part of the FLASH (First Large Absorption Survey in HI) team working with the Australian SKA Pathfinder. The aim of FLASH is to search for cool, star-forming material in the early Universe ($0.4 < z < 1.0$) by looking for the absorption of the 21-cm radio signal from neutral hydrogen gas (HI). This will tell us more about galaxy evolution across epochs. Glowacki has been working with a commissioning sample of radio-bright obscured quasars. He has also worked on HI 21-cm absorption with the Australia Telescope Compact Array (ATCA), using a sample of compact radio galaxies selected from the Australia Telescope 20-GHz survey. In addition, he has created a photometric method for obtaining redshifts for radio AGN. Glowacki submitted his PhD thesis in 2017.

Ms Debra Gooley

CAASTRO Finance Officer

Gooley has been the Finance Officer for CAASTRO for seven years. She helps CAASTRO to achieve its goals by coordinating and managing the KPI (key performance indicator) and financial reports required for its primary funding body, the Australian Research Council (ARC).

Emeritus Professor Anne Green

CAASTRO Affiliate
Theme: Dynamic

Green is a collaborator on a project with CAASTRO's Swinburne node to develop the capabilities of the Molonglo telescope as a multi-tasking detector of transient sources, a project called UTMOST. UTMOST was launched in December 2015 to coincide with the 50th anniversary of the telescope's opening. It has now detected five fast radio bursts, including the first to be found with an interferometer. Green continues to focus on searching for transient sources at cosmological distances and measuring the properties of pulsars.

Ms Kate Gunn

CAASTRO Chief Operating Officer

Gunn has been CAASTRO's Chief Operating Officer for seven years. A start-up specialist with a wealth of business and university experience, she has 25 years in management and a background in the commercialisation of university intellectual property.

Ms Helen Keys

CAASTRO Executive Assistant

Keys joined CAASTRO in 2015 to provide executive assistance to the Director and Chief Operating Officer. She has had extensive experience working at The University of Sydney in various roles associated with the Senior Executive Group.

Dr Emil Lenc

CAASTRO Postdoctoral Researcher
Theme: Dynamic

Lenc joined the Slow Transients group at the University of Sydney in 2016. His research focuses on developing new search techniques for transients and pulsar-like objects in Murchison Widefield Array (MWA) data. This work builds on earlier research he undertook in the Evolving theme, in which he developed tools for MWA polarimetry and difference imaging. Lenc plans to continue exploring these techniques and apply them to existing survey data to search for pulsars, exoplanets and flare stars.

Ms Jing Li

CAASTRO Honours Student
Theme: Evolving

Li worked with data from SAMI Galaxy Survey to measure the star-formation rates (SFRs) of galaxies in clusters. She compared these SFRs with those measured by radio and infrared surveys, to investigate how the radio-SFR correlation varies with environment. In 2017 Li completed her Honours project, which was supervised by Bryant. She will do further research on SFRs and AGN (active galactic nuclei) for her Master's degree, at the Australian National University.

Dr Christene Lynch

CAASTRO Postdoctoral Researcher
Theme: Dynamic

In 2017 Lynch continued her work with the Slow Transients group at The University of Sydney. Her research focused on using observations of Solar System planets to predict the brightness and frequency of radio emission from known extrasolar planets. She was also involved with follow-up observations, made with the Australia Telescope Compact Array, of a gravitational-wave event produced by the merger of two neutron stars, GW170817. These observations confirmed the first detection of radio emission associated with a gravitational-wave event.

Ms Jenny Lynch

CAASTRO School Education Officer

An experienced science communicator and project manager, Lynch was responsible until early 2017 for running the outreach program *CAASTRO in the Classroom.* With support from the Commonwealth Government through the Australian Maths and Science Partnerships Program (AMSPP), *CAASTRO in the Classroom* was expanded in 2016 to reach a national audience through videoconferencing and live streaming sessions for schools. In 2017 year Lynch worked with experienced science teachers to develop classroom resources and deliver professional-development workshops for teachers. She left CAASTRO in May and was succeeded by Janette Ellis.

Dr Elizabeth Mahony

CAASTRO Postdoctoral Researcher
Theme: Evolving

In 2017 Mahony continued working on the upcoming First Large Absorption Survey in HI (FLASH) survey, along with fellow CAASTRO members Sadler, Allison, Moss and Glowacki. Using commissioning data, Mahony has detected HI absorption in a number of bright radio galaxies, providing insight into the fuelling mechanisms at play in active galactic nuclei. She has also been testing data pipelines and compiling multiwavelength datasets, to prepare for a larger, blind survey for HI absorption that will be carried out with the Australian SKA Pathfinder during its Early Science phase.

Ms Rebecca McElroy

CAASTRO PhD student
Theme: Evolving

McElroy works on integral-field spectroscopy of active galaxies. She is a member of the SAMI Galaxy Survey, helped with SAMI observations, and has worked to combine her dataset of AGN (active galactic nuclei) with the SAMI sample in a new comparison paper. McElroy completed her PhD in 2017.

Dr Vanessa Moss

CAASTRO Postdoctoral Researcher and Affiliate
Theme: Evolving

Moss joined the First Large Absorption Survey in HI (FLASH) team in mid 2014. Her focus is on the galactic ecosystems of both intervening and associated absorbing systems, with an emphasis on their multiwavelength footprints. She was the primary observer for the FLASH team when it used the six-antenna BETA array of the Australian SKA Pathfinder during 2015–2106 to make observations towards more than 100 galaxies. This year Moss published an analysis of the connection between HI and X-ray absorption. She also represented CAASTRO in science communication and outreach activities, such as *CAASTRO in the Classroom*. In the middle of the year Moss moved to The Netherlands to take up a new research position at ASTRON.

Ms Aina Musaeva

CAASTRO PhD Student
Themes: Evolving

Musaeva's PhD project aimed to search for intermediate-mass black holes (IMBHs) in nearby dwarf galaxies using X-ray catalogues from the Chandra and XMM–Newton space observatories. This search revealed only one strong IMBH candidate in NGC 404, and so Musaeva plans to request X-ray observations of nearby dwarf galaxies similar to NGC 404 that have not been observed before. Musaeva submitted her PhD thesis in 2017.

Mr Hao Qiu

CAASTRO PhD Student
Theme: Dynamic

Qiu is a PhD student working on the detection of radio transients. He started his degree in mid 2017 and is supervised by Tara Murphy, Keith Bannister (CSIRO) and Ryan Shannon (Swinburne). Qiu is part of the Commensal Real-time ASKAP Fast Transients survey (CRAFT) group that is working on the detection of radio transients such as fast radio bursts (FRBs) with the Australian SKA Pathfinder (ASKAP). He has recently been simulating FRBs to help improve the accuracy of the software used to detect these sources. In 2018 Qiu will continue to work on FRB observation searches.

Dr Richard Scalzo

CAASTRO Affiliate
Theme: Dark, Dynamic

In late 2015 Scalzo moved to a research position at the University of Sydney's Centre for Translational Data Science, but he has remained involved with CAASTRO as an Affiliate. He is continuing his research on Type Ia supernovae, developing hierarchical Bayesian models to provide the largest and most accurate available suite of bolometric light curves to date.

Mr Adam Schaefer

CAASTRO Postgraduate Student
Theme: Evolving

Until 2017 Schaefer was a postgraduate student working in the Evolving Universe theme. He used spatially resolved spectroscopy from the SAMI Galaxy Survey to investigate the influence of galaxies' environments on their star formation. Schaefer completed his PhD in 2017 and has taken up a position at the University of Wisconsin, USA.

Dr Nicholas Scott

CAASTRO Affiliate
Theme: Evolving

Scott is a University of Sydney Postdoctoral Research Fellow. His research focuses on understanding the processes of galaxy assembly through the use of spatially resolved spectroscopy. In 2017 he published a study examining the stellar populations of galaxies in the SAMI Galaxy Survey as a function of galaxy mass, size, morphology and environment. Scott is currently leading the second major public release of SAMI Galaxy Survey data.

Ms Helen Sim

CAASTRO 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. She writes news stories and media releases, and items for CAASTRO's annual report, newsletters and the web.

Mr Mathew Varidel

CAASTRO PhD Student
Theme: Evolving

Varidel's focus is to understand the processes that drive and sustain gas turbulence within galaxies. He is developing a fully Bayesian method to model gas kinematics within galaxies, which he will apply to data taken with SAMI (the Sydney–AAO Multi-object Integral field spectrograph).

Ms Charlotte Ward

CAASTRO Honours Student
Theme: Dynamic

This year Ward's research focused on time-domain radio astronomy, particularly the automated detection of fast radio bursts and other transients from Parkes telescope survey data. Ward has been developing machine-learning techniques for detecting these events, to address the difficulties of identifying single pulses in large datasets and the need to identify bursts quickly for multiwavelength follow-up. Her past work includes using pulsars to study refractive scintillation in the interstellar medium and studying radio emission from ultra-cool dwarfs.

Ms Kylie Williams

CAASTRO Events and Communications Officer

Williams coordinates the regular CAASTRO newsletter and organises events hosted by CAASTRO around Australia. In 2017 she organised or assisted with 17 meetings, including the final CAASTRO Board meeting; the Australian Parliament House celebratory finale event; the CAASTRO annual retreat in the Barossa Valley, SA; and two international conferences, ACAMAR 3 in Hobart and *From Black Hole to Environment* in Canberra. In March 2017, Williams was funded by the School of Physics to attend a professional development course, the Executive Certificate in Event Management, at the University of Technology Sydney.

Mr Andrew Zic

CAASTRO PhD Student
Theme: Dynamic

Zic is interested in radio transients, particularly in techniques to detect them. His PhD research focuses on low-frequency radio emission from low-mass stars, such as M dwarfs and ultra-cool dwarfs. We understand little about what generates these stars' strong magnetic fields and the processes that lead them to emit strong radio bursts. Zic is studying these bursts with low-frequency telescopes, such as the Murchison Widefield Array and the Giant Metre-wave Radio Telescope in India, to investigate the physical conditions within the stars' magnetospheres and coronae.

CAASTRO University of Melbourne team members

CAASTRO AT THE UNIVERSITY OF MELBOURNE

THE UNIVERSITY OF MELBOURNE

The University of Melbourne node of CAASTRO is located within the School of Physics. Although the Astrophysics group at Melbourne is only 25 years old, it has a record of excellence in observational and theoretical cosmology, areas that provide the basis for our contributions to CAASTRO. Melbourne node researchers are primarily engaged within the Evolving Universe theme (formerly led by Melbourne's Professor Stuart Wyithe), with an emphasis on Epoch of Reionisation (EoR) science.

Evolving Theme

The Epoch of Reionisation (EoR) is the major project within the Melbourne node of CAASTRO. One of the challenges of modelling reionisation is to account both for the sub-halo-scale physics of galaxy formation and the regions of ionisation on scales that are many orders of magnitude larger. This year Research Fellow Hansik Kim, with Chief Investigator Stuart Wyithe and PhD student Jaehong Park, used the hierarchical galaxy-formation model GALFORM to predict the correlation function of HI-detected galaxies. These simulations showed that the detection limit of the observations affected the measurement of the clustering amplitude and slope, and thus the interpretation of halo occupancy. Kim also used the simulations to predict the contribution of galaxies with low HI mass to the 21-cm intensity-mapping signal.

The team carrying out the EoR project with the MWA continued to analyse its archived EoR dataset, paying particular attention to understanding the systematics that affect the removal of the foreground signals. PhD student Jack Line published the algorithm he developed to match MWA low-frequency radio sources to radio sources from higher-resolution surveys (Line et al. 2017). Matching sources allows source positions to be determined more accurately, which in turn allows sources to be subtracted more effectively. The first results of the studies with our Japanese collaborators of the cross-correlation between Lyman-alpha galaxies and the 21-cm signal showed that the chance of a detection was significantly improved if redshifts were obtained for the galaxies using the PFS (point spread function) on the Subaru telescope (Kubota et al. 2017).

With Wyithe and collaborators, Research Fellow Paul Geil explored the possibility of combining observations from the Square Kilometre Array (SKA) with near-infrared data from NASA's planned Wide Field Infrared Survey Telescope (WFIRST), to map reionisation by imaging the HI bubbles around massive galaxies. Individual bubbles will be too small to detect, but stacking the images would reveal the EoR signal. This method, while it could be difficult to implement, would show whether the HI radiation was in absorption or emission.

Intensity mapping of neutral hydrogen (HI) is a new observational tool to efficiently map large-scale structure over wide redshift ranges. Associate Investigator Laura Wolz continued her active involvement in a range of studies focussed on HI-intensity mapping. With Chief Investigators Chris Blake and Stuart Wyithe, Wolz developed a new method to estimate the HI brightness temperature of optically detected galaxies too faint to be directly detected. This technique will be a powerful tool for investigating galaxy evolution, extending available datasets from telescopes such as the Australian SKA Pathfinder. Wolz and Blake also led a study to demonstrate a new foreground-removal technique, which was applied to the HI-intensity dataset from the Green Bank Telescope. This independent component analysis technique, *FASTICA*, was shown to be effective in removing foreground sources and robust against the loss of 21-cm signal. FASTICA complements the standard Singular Value Decomposition (SVD) technique.

Dark Theme

This year CAASTRO Affiliate Katherine Mack continued her studies of potential candidates for dark matter. She completed a project with Jerry Ostriker (Columbia University) and Massimo Ricotti (University of Maryland)

to calculate how a population of non-evaporating, 30-solar-mass black holes would distort the cosmic microwave background. Mack also continued to work on the Stawell Underground Physics Laboratory experiment with members of the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP)

Other highlights

The Melbourne node was very active in public outreach and professional education activities throughout the year. Key events included hosting two CAASTRO–CoEPP joint workshops in January and November; a student writing workshop in August; public science presentations by research staff and PhD students to members of the Mount Burnett Observatory; participation in September's AstroLight Festival staged at Melbourne's Scienceworks Museum; and many media, panel and ad-hoc science outreach activities undertaken by Dr Katherine Mack throughout the year, in Australia and overseas.

CAASTRO Postdoctoral Research Fellow Dr Edoardo Tescari has formed a collaboration for exploring indigenous astronomical knowledge in Australia and Central America. Local researchers involved are Dr Paola Oliva-Altamirano from Swinburne University and Dr Duane Hamacher from the Monash Indigenous Studies Centre. This year Tescari initiated a visit by Professor Javier Mejuto from the Universidad Nacional Autónoma de Honduras, to take the work further.

In August, Professor Rachel Webster made her annual 'pilgrimage' to the Northern Territory as one of four guest astronomers at the annual Uluru Astronomy Weekend, further strengthening the ties between CAASTRO and the Northern Territory community. In late September, Paul Geil was the final Melbourne representative as CAASTRO Astronomer in Residence at the Ayers Rock Resort in the Northern Territory.

As in past years, many secondary school students engaged with CAASTRO as part of the Telescopes in Schools initiative, in which Melbourne researchers took part, and via Melbourne's Year-10 work-experience program, which now includes an observing night to which parents are invited.

Future goals

The University of Melbourne node will largely cease its participation in CAASTRO science projects at the end of 2017. Its major projects, theoretical and observational studies of the Epoch of Reionisation, will continue within one of CAASTRO's successor institutions, the new ARC Centre of Excellence for All-sky Astrophysics in 3 Dimensions (ASTRO 3D).

Professor Rachel Webster

CAASTRO Chief Investigator
Theme: Evolving

Webster's primary focus has been on the continuing development of the pipeline for analysing the substantial EoR dataset obtained with the Murchison Widefield Array (MWA); in particular, making a robust pipeline that is accessible to the wider MWA community. She has also continued her collaboration with Japanese colleagues on the cross-correlation of the EoR HI signal with the high-redshift population of Lyman-alpha galaxies. At the same time, she has begun a new program of simulating observational and systematic effects in the measurement of the EoR signal, using the OSKAR program on the gSTAR supercomputer.

Ms Stephanie Bernard

CAASTRO PhD Student
Theme: Dynamic, Evolving

Stephanie Bernard is a PhD student at the University of Melbourne who is studying bright galaxies during the Epoch of Reionisation. In 2017 she led the analysis of new data from the Brightest of Reionizing Galaxies (BoRG) survey (made with the Hubble Space Telescope, HST) and identified a large sample of new galaxy candidates from only 500 million years after the Big Bang. She also continued to lead a program using NASA's Spitzer Space Telescope to follow up these galaxies, and worked with ASTRO-3D researchers on new HST data of early galaxies. In another line of research, Barnard this year worked with CAASTRO researchers who are studying the most distant supernovae known, using the Subaru and Keck telescopes in Hawai'i.

Ms Kim Dorrell

CAASTRO Administrator

In 2017 Dorrell continued her role as node administrator, ensuring the integration of the Centre's procedures and activities within the University's overarching structures. She also continued her work as Secretary to the Project Steering Committee of the Stawell Underground Physics Laboratory (SUPL). The University of Melbourne hosts nodes of two new ARC Centres of Excellence that follow on from CAASTRO, OzGrav and ASTRO 3D, and Dorrell expects to be busy in 2018 as these nodes begin operating at full speed.

Dr Paul Geil

CAASTRO Postdoctoral Researcher
Theme: Evolving

Geil was originally a postdoctoral fellow working with Stuart Wyithe in Wyithe's ARC Laureate DRAGONS project. In this role he undertook research into the Epoch of Reionisation, particularly the formation and evolution of the first galaxies, their effects on the intergalactic medium, and the detectability of these effects. Geil is experienced in simulating observations from radio interferometers such as the MWA and SKA, and so can bridge the gap between the numerical simulation of the first galaxies and low-frequency observations. He has authored a number of peer-reviewed papers, especially in collaboration with Wyithe.

Ms Clare Kenyon

CAASTRO Affiliate
Theme: Education and Outreach

In 2017 Kenyon took on a new outreach role at the University of Melbourne, with an emphasis on the high-school observing program, *Telescopes in Schools* (TiS). TiS hosted a stall at a major event called *Stargazing Live*, hosted by the ABC and based on a BBC program of the same name. Over 5,000 people attended the four-hour event. Kenyon and her colleague Jacinta den Besten also hosted a professional development night for teachers and volunteers of the TiS program at Museum Victoria's *Scienceworks*, in collaboration with Scienceworks' volunteers, and participated in the *AstroLight Festival* held at Scienceworks in September. Kenyon redeveloped and managed the Year-10 work-experience program at the University of Melbourne, for which CAASTRO funded a student supervisor.

Dr Hansik Kim

CAASTRO Postdoctoral Researcher
Theme: Evolving

In 2017 Kim continued to investigate the importance of low-HI-mass galaxies for future HI studies. He showed that for redshifts higher than 0.5, a dark-matter halo mass resolution better than $\sim 10^{10} h^{-1}\ M_{\odot}$ is required to predict converged 21-cm brightness-temperature fluctuations. Kim also investigated the importance of modelling star-formation laws for understanding galaxy formation and evolution at high redshifts.

Dr Anthea King

CAASTRO Affiliate
Theme: Dark, Evolving

King is a postdoctoral researcher working with Rachel Webster at the University of Melbourne. She is a member of the OzDES team and helps the efforts to perform reverberation mapping with the AGN (active galactic nuclei) sample from that survey. She is also leading a pioneering project that combines reverberation mapping and gravitational microlensing in a single object to study the inner regions of AGN. King's expertise is predominantly in AGN science and her main research interests are in understanding AGN structure and how we can apply this information to obtain more accurate mass estimates of AGN and use AGN as 'standard candles'. She is especially excited about the information high-redshift AGN may be able to provide, for studies of both galaxy evolution and dark energy. Her project with CAASTRO straddles the Dark and Evolving themes and involves modelling the structure of AGN using photoionisation modelling and microlensing.

Mr Jack Line

CAASTRO Postdoctoral Researcher
Theme: Evolving

Line submitted his thesis in February 2017 and graduated in December. From February he worked in the Murchison Widefield Array (MWA) collaboration as a postdoctoral researcher at the University of Melbourne. Line continued to produce interferometric simulations, collaborating with colleagues from Kumamoto University. He also took up the lead role in a project to measure the MWA primary beam using ORBCOMM satellites.

Dr Katherine Mack

CAASTRO Affiliate, Postdoctoral Researcher
Theme: Evolving, Dark

In 2017 Mack continued her joint appointment as a CAASTRO–CoEPP Postdoctoral Research Fellow in Theoretical Cosmology while maintaining her prolific science-outreach activities. Mack's research has mainly been in particle physics, cosmology and theoretical astrophysics. Her current interests include the physics of the early Universe, dark matter, the Epoch of Reionisation, Big Bang relics, compact objects and supermassive black holes. The unifying goal of her work is to find ways to use observational cosmology to better understand the fundamental physical nature of the components and evolution of the Universe. In September Mack returned to the USA to take up a faculty position at the University of North Carolina (Raleigh).

Dr Ben McKinley

CAASTRO Affiliate
Theme: Evolving

This year McKinley's work focused on detecting the global, redshifted 21-cm signal from the Epoch of Reionisation, using the Murchison Widefield Array telescope and a novel technique involving lunar occultations of the sky. He also continued to co-supervise CAASTRO student Jarryd Rasti in a project to measure the beam patterns of individual MWA tiles by recording power measurements of ORBCOMM communications satellites. McKinley continued his role as an active researcher within the MWA EoR collaboration. In June McKinley left the Melbourne node to take up a research position at Curtin University.

Ms Sinem Ozbilgen

CAASTRO PhD student
Theme: Dark

Ozbilgen's project continued to focus on tightening the Tully-Fisher relation. She has compared data taken with the ANU 2.3-m telescope at Siding Spring Observatory with results from 100 galaxies in the EAGLE simulation. Ozbilgen argues that adding velocity dispersion as a third parameter to the Tully-Fisher relation reduces the relation's scatter considerably. She is preparing papers on her findings.

Dr Bart Pindor

CAASTRO Postdoctoral Researcher
Theme: Evolving

Pindor concentrates on the problem of processing and calibrating data from the Murchison Widefield Array (MWA) Epoch of Reionisation (EOR) experiment. In 2017, as a member of the Australian EOR team, Pindor continued to refine the EOR processing pipeline and characterise the systematic errors that limit our ability to detect the cosmological signal. Pindor has been involved in transferring knowledge gained from the MWA to the design of the Square Kilometre Array's low-frequency telescope, SKA-low.

Ms Mahsa Rahimi

CAASTRO PhD student
Theme: Evolving

Rahimi was on maternity leave for most of 2017. Returning to work late in the year, she continued to process data to place a new limit on cosmological HI power. In 2018 she will also work on improving calibration algorithms and studying the temperature of sky over the target fields of EoR experiments.

Mr Jarryd Rasti

CAASTRO Masters student
Theme: Evolving

Rasti's project is to measure the beam patterns of MWA tiles, using downlink transmissions from low-Earth-orbit satellites (particularly the ORBCOMM satellites): he will measure the power received by each tile, relative to a reference dipole antenna. In 2017 he made such measurements for eight MWA, analysed the data and wrote up the results from publication.

Mrs Jennifer Riding

CAASTRO PhD student
Theme: Evolving

Riding's PhD is focused on finding methods to remove bright, complex sources (such as radio galaxies and nebulae) from EoR data. This work was delayed when she started a job with Siding Spring Observatory in northwest NSW. In 2017 she quantified her work on source subtraction in the power spectrum and continued to write her up final thesis plans.

Dr Edoardo Tescari

CAASTRO Postdoctoral Researcher
Theme: Evolving

Throughout 2017, Tescari continued to work on the SAMI project to study galactic outflows at low redshift by means of hydrodynamic simulations such as EAGLE. He and his collaborators have found that the outflowing activity of unperturbed disc galaxies correlates with stellar mass and star-formation rate surface density. This year Tescari started a cross-cultural collaboration to explore indigenous astronomical knowledge in Australian and Central America: this involves colleagues from Swinburne and Monash Universities, and Dr Javier Mejuto (National Autonomous University of Honduras). Tescari also co-supervised to completion CAASTRO PhD student Angela Garcia (Swinburne) on a project to study the Epoch of Reionisation with metal absorption lines. In October Tescari took up a continuing position, focused on academic engagement, in the Faculty of Science at The University of Melbourne.

Dr Laura Wolz

CAASTRO Affiliate, Postdoctoral Researcher
Theme: Evolving

This year Wolz continued her work studying cosmology and galaxy evolution using HI intensity mapping. She published a study on how to measure the averaged HI mass of a sample of very distant galaxies by cross-correlating the galaxy positions with HI intensity mapping data. This new measurement technique could be feasible for future intensity-mapping observations with ASKAP (the Australian SKA Pathfinder). In collaboration with CAASTRO postdoc Steven Murray (Curtin), Wolz also worked on formulating a theoretical framework for the intensity-mapping cross-correlations. Wolz is a member of a team that published a detection of the intensity-mapping signal in the cross-correlation of radio data from the Parkes telescope with optical data from the 2dF survey, and which continues new projects on the interpretation of data from the Green Bank radio telescope. This year Wolz also increased her involvement with the Square Kilometre Array (SKA) and began co-chairing the SKA Cosmology Working Group in December 2017.

CAASTRO Swinburne University of Technology team members

CAASTRO AT SWINBURNE UNIVERSITY OF TECHNOLOGY

Research at the Swinburne node is predominantly in the Dark and Dynamic Universe themes but the Evolving theme is also represented. In 2016 the node had three Chief Investigators: node leader Professor Matthew Bailes, Professor Jeremy Mould and Associate Professor Chris Blake. In 2017 Bailes left CAASTRO to become director of one of CAASTRO's successor institutions, the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav), and Professor (now Emeritus) Mould stepped into the role of node leader.

Within the Dark theme, researchers led by Blake this year measured clustering, cosmic shear and matter density in the standard model of cosmology by combining data from the Kilo Degree Survey (KiDS), the 2-degree Field Lensing Survey (2dFLenS), and the Galaxy and Mass Assembly (GAMA) survey. Dark-theme researchers also made cosmological forecasts for combined and next-generation peculiar-velocity and supernova surveys. One of the important upcoming surveys is the Taipan Galaxy Survey, which will measure a million galaxy redshifts with the refurbished UK Schmidt Telescope at Siding Spring Observatory. Edward Taylor worked on Taipan, and also on the Anglo Australian Telescope's GAMA and Sydney-AAO Multi-Object Integral Field Spectrograph Galaxy Survey (SAMI) surveys.

In September, Mould was honoured by a special conference organised to mark a 'significant birthday'. Called *Stellar Populations and the Distance Scale*, this meeting was held at the Kavli Institute of Astronomy and Astrophysics at Peking University. The topic recognised Mould's important contributions to the field, such as his part in the HST Key Project to measure the local value of the Hubble constant. This project used Cepheid variables (pulsating stars) to make a ground-breaking value of this parameter, a result with almost 4,000 citations. The Hubble Constant, H, is the expansion rate of the Universe; it is crucial to determining distances in the Universe. As discussed elsewhere in this report (page 27), the value of H that we measure locally may be at odds with the value measured from the cosmic microwave background. If so, cosmology's 'standard model', the ΛCDM model, may be lacking something important. The jury is still out, and the race is on for better data. Australia's Taipan survey is one of the projects playing a part in this.

The highlight of the year at Swinburne was, as elsewhere, the first confirmed merger of two neutron stars. This event, GW170817, was detected by the gravitational waves it created and then followed up with conventional telescopes. Swinburne's Igor Andreoni headed a paper summarising the Australian-led follow-up (page 19). In recent years Andreoni has been active in a program led by Swinburne's Jeff Cooke that aims to capture as much information as possible about transients such as fast radio bursts (FRBs) and gravitational-wave events. This *Deeper, Wider, Faster* program (DWF) chases the fastest bursts in the sky with multi-facility, multiwavelength, simultaneous observations and rapid follow up, probing the milliseconds-to-hours time domain with deep observations, wide regions of the sky and fast cadence. DWF is proactive: target fields are observed simultaneously and continuously with multiple telescopes. If a transient such as an FRB is detected during DWF observations, not only are several telescopes ready to observe the region interest just seconds after the detection, but observations have also been made of the field during the transient's appearance and even before. DWF originated within CAASTRO and has now transferred to the new ARC Centre of Excellence for Gravitational Wave Discovery, OzGrav.

In the Evolving Universe theme, Alan Duffy and Greg Poole are members of a simulations team working on the Epoch of Reionisation. The team has published results on the ultraviolet luminosity function, the quenching of star formation by AGN (active galactic nuclei) and the sizes of high-redshift galaxies and ionised bubbles. CAASTRO PhD student Chris Curtin has been studying the rare superluminous supernovae. Now nearing the end of his thesis, he has led the announcement of the spectroscopic confirmation of the highest-redshift superluminous supernovae known ($z \sim 2$). These objects were discovered in the course of a collaborative project between Japan and Australia

that uses 'live' data from Japan's Subaru telescope and follows up candidate events with the Keck telescope. In another project, DECamERON (Dark Energy Camera Epoch of ReionizatiON), researchers including Cooke, Mould and other CAASTRO members found a candidate for the highest-redshift superluminous supernova (still awaiting confirmation). In May, Mould, Cooke and their collaborators ran a workshop on superluminous supernovae at the Munich Institute for Astro- and Particle Physics (MIAPP) in Germany, bringing together more than 40 experts in the field.

Professor Jeremy Mould

CAASTRO Node Leader
Theme: Dark

This year Mould published results from the DECamERON (Dark Energy Camera Epoch of ReionizatiON) survey, finding the highest-redshift candidate superluminous supernova. He plans to pursue this work with Professor Lifan Wang (Purple Mountain Observatory) through the ACAMAR collaboration (page 137), using the future James Webb Space Telescope. Mould worked with Chris Blake (Swinburne) and Matthew Colless (ANU) on the Taipan survey. Former CAASTRO PhD student Christina Magoulas rejoined CAASTRO, following a postdoctoral position in South Africa, to support this work. Mould is also part of the OzDES project, which in 2017 made its first data release and hosted the Dark Energy Survey collaboration meeting at the University of Queensland. Mould is involved in preparing a proposal for a new ARC Centre of Excellence on dark-matter research, which would see ongoing research conducted at the Stawell Underground Physics Lab in Victoria. Mould chairs the Advisory Board of the ARC Centre of Excellence for Particle Physics at the Terascale, CoEPP, making him a link between the two Centres. The joint CoEPP–CAASTRO workshops have fostered the growth of the astroparticle community in Australia: the fourth and final one was held in conjunction with CAASTRO's 2017 Annual Retreat in South Australia.

Professor Chris Blake

CAASTRO Chief Investigator
Theme: Dark

Blake and his research group use a variety of observations to search for evidence of new physics, beyond the standard cosmological model, that affects the gravity or matter-energy sectors. They published new results in 2017 in the areas of gravitational lensing, peculiar velocities and large-scale structure. One of these results was the first joint cosmological analysis of overlapping gravitational lensing and galaxy-redshift survey data, based on the Kilo-Degree Survey (KiDS) and 2-degree Field Lensing Survey (2dFLenS): it places new constraints on the cosmological model. The group also developed novel techniques for joint analysis of local direct peculiar-velocity and redshift surveys, including the cross-correlations induced by the force of gravity. Finally, the group studied the physics governing outflow from voids, under-dense regions of the Universe that may experience modified gravitational force fields in alternative models of gravity. While general relativity still provides a consistent description of most of the existing data, interesting anomalies remain, and these will be intensely scrutinised over the next few years.

Dr Adam Deller

CAASTRO Chief Investigator
Theme: Dynamic

Deller studies fast radio bursts (FRBs) using the Molonglo and Australian SKA Pathfinder (ASKAP) radio telescopes. Despite being just a few milliseconds in duration, FRBs are visible from cosmological distances, and their production mechanism (or mechanisms) remains an open question of great interest, because they may represent previously unknown physical processes. Localising FRBs to their host galaxies and hence obtaining a precise distance is a major step along the way to understanding the physics at work, and both Molonglo and ASKAP will be able to localise FRBs once upgrades, now under way, are completed. This year the first raw 'voltage' data were saved from an FRB detected in real time with Molonglo: this is a crucial prerequisite for localisation.

Dr Ixandra Achitouv

CAASTRO Postdoctoral Researcher
Theme: Dark

Achitouv continued her studies of how the gravitational field around voids, empty regions of the Universe, generate velocities in surrounding galaxies that may be used to test the cosmological model. She published analyses measuring these redshift-space distortions in N-body simulations corresponding to a standard cosmological constant model, and a quintessence model of dark energy, modelling the velocity profile in each case. These techniques may be applied to future observations by the Taipan Galaxy Survey.

Ms Caitlin Adams

CAASTRO PhD Student
Theme: Dark

Adams published the results of her joint cosmological analysis of the galaxy density and peculiar-velocity field in the 6-degree Field Galaxy Survey, detecting and modelling the cross-correlation driven by gravitational physics, and improving constraints on the growth rate of structure. This year Adams also played an active role in the CAASTRO Student Committee, developing and presenting a writing workshop attended by over 100 participants in several cities.

Mr Igor Andreoni

CAASTRO PhD Student
Theme: Dynamic

Andreoni is a third-year PhD candidate at Swinburne University, supervised by Jeff Cooke (Swinburne), Matthew Bailes (Swinburne) and Stuart Ryder (AAO). His research interests include the detection and science of transient events, and multi-messenger searches for counterparts to gravitational wave signals. Andreoni is the primary member of the *Deeper, Wider, Faster* observing program, which is exploring the fast (seconds to hours) transient Universe with simultaneous observations by radio, infrared, optical, UV, X-ray, and gamma ray telescopes, plus multi-messenger facilities. In early 2017 Andreoni moved from CAASTRO to the new ARC Centre of Excellence in Gravitational Wave Discovery, OzGrav.

Ms Elise Beaufils

CAASTRO Pre-PhD Student
Theme: Dark

Beaufils was a pre-PhD student working on a four-month project under the direction of Chris Blake. Her project focused on the large-scale structure of the Universe. Beaufils was interested in testing the peculiar-velocity and over-density equation in the frame of linear-perturbation theory. She used numerical simulations to test the first-order derivation by measuring the growth rate. As this work highlighted that a significant error in the growth rate can propagate, she derived this relationship to the second order and applied the same tests. She and Blake defined a precise frame of validity for these equations. Beaufils is now interested in how these errors in the growth rate propagate in other methods, such as redshift space distortion.

Ms Shivani Bhandari

CAASTRO PhD Student
Theme: Dynamic

Bhandari's work revolves around searching for and localising fast radio bursts (FRBs), a relatively new class of transient radio source. She is involved in two large collaborations: the High Time Resolution Universe (HTRU) survey, a legacy survey done with the Parkes telescope, and the Search for Pulsars and Extragalactic Bursts (SUPERB), an ongoing survey for pulsars and FRBs in real time, also being done with Parkes. Bhandari's work involves looking for bright single pulses in HTRU low-latitude data and leading the multiwavelength follow-up for bursts discovered by SUPERB. Bhandari is a part of the UTMOST commissioning team, which is making radio images with the Molonglo radio telescope. She is also involved with two surveys planned for the Australian SKA Pathfinder telescope: VAST, a survey for variable and slow transients, and CRAFT, which is looking for fast transients, including fast radio bursts.

Mr Alexandru Codoreanu

CAASTRO PhD Student
Theme: Evolving

Codoreanu is working on understanding the enrichment and ionisation of metals towards the end of the Epoch of Reionisation by identifying absorption features in the spectra of quasar. He has made the first measurement on the amount of SiIV present when the Universe was just one billion years old and has provided the first column-density functions for MgII and SiIV during the same time period. This year he participated in the *CAASTRO in the Classroom* program and in the *What Matter(s) Around Galaxies* conference in Durham, England.

Dr Jeff Cooke

CAASTRO Associate Investigator
Themes: Dynamic, Evolving

Cooke leads research on high-redshift ($z \sim 2–6$) supernovae, high-redshift galaxies, and the fastest bursts in the Universe. Cooke supervises CAASTRO PhD students Chris Curtin and Igor Andreoni, and co-supervises Stephanie Bernard. This year, analysis of deep images acquired over several years via Cooke's collaboration with the Hyper SuprimeCam Subaru Strategic Program and the Dark Energy Survey has revealed dozens of $z \sim 2–4$ supernovae, with three confirmed by Curtin and Cooke from Keck spectroscopy. Deep Keck spectroscopy has helped the team discover a population of high-redshift galaxies that may be largely responsible for cosmic reionisation, and Cooke has a Hubble Space Telescope program to image these galaxies. Finally, Andreoni and Cooke head up the *Deeper, Wider, Faster* (DWF) program, which coordinates more than 40 telescopes to detect and study transients with millisecond-to-hours durations. DWF performs simultaneous observations, Swinburne supercomputer real-time data processing and analysis, and follow-up observations via a network of telescopes worldwide and in space.

Mr Chris Curtin

CAASTRO PhD Student
Theme: Dynamic

Curtin has been searching for superluminous supernovae at high redshift ($z > 2$). In May he attended a workshop on the topic at the Munich Institute for Astro and Particle Physics (MIAPP); in December he attended the second Keck LRIS spectroscopic follow-up run, led by Swinburne, of targets from the *Survey Using DECam for Superluminous Supernovae* (SUDSS). Curtin also spent several months preparing a paper outlining Keck spectroscopic follow-up of targets from the *Subaru HI-Z sUpernova CAmpaign* (SHIZUCA).

Dr Alan Duffy

CAASTRO Affiliate
Themes: Evolving, Dark

Duffy created and published a new simulation series tracking the formation of the first galaxies, the properties of which will be crucial for determining the visibility of the Epoch of Reionisation. Duffy continues as a Chief Investigator of the first southern-hemisphere deployment of SABRE (Sodium-iodide with Active Background REjection), a dark-matter detection experiment that will be run at the Stawell Underground Physics Laboratory in Victoria.

Dr Chris Flynn

CAASTRO Associate Investigator
Theme: Dynamic

Flynn has co-led (with Matthew Bailes) the transformation of the Molonglo radio telescope into UTMOST, a machine for finding pulsars and fast radio bursts. In mid 2017 the UTMOST team completed the refitting of the telescope's 1.6-km-long east-west arm. Following this, pulsar timing and searches for fast radio bursts (FRBs) began with nearly round-the-clock operations. Late in the year the team discovered two FRBs, one of which is the narrowest found to date and shows remarkable time and frequency structure. The discovery was possible because the project team had implemented a deep learning system to recognise FRBs and save the native time- and frequency-resolution data around the event, a world-first for an initial FRB detection. In late 2017 the team put in place a program for timing pulsars and searching for pulsars and bursts, and this has proven remarkably stable and efficient.

New timing solutions for over 200 pulsars have been made during the upgrade and will be published in early 2018. Work on refitting the telescope's dormant north-south arm began mid-year, with receivers designed and installed by year's end. Initial results have been immensely encouraging and 2018 promises to be an exciting time as the refit is rolled out.

Ms Angela Garcia

CAASTRO PhD Student
Theme: Evolving

Garcia was awarded her PhD in November 2017. Her research involved running a set of high-redshift ($4 < z < 8$) cosmological hydrodynamical simulations. As the stars in these mock Universes evolve, they produce supernova winds that enriched the surrounding circumgalactic and intergalactic medium with metals such as carbon, silicon and oxygen. The medium is then 'viewed' along random lines of sight, mimicking observations for quasar absorption-line spectroscopy. Garcia's simulations successfully reproduce the evolution of the cosmological mass density (Ω) – the average density of a particular metal ion – of CII and CIV, with Ω(CII) exceeding Ω(CIV) at $z > 6$, consistent with the current picture of the tail of the Epoch of Reionisation.

Professor Karl Glazebrook

CAASTRO Affiliate
Theme: Dark

Glazebrook is Distinguished Professor and Director of Swinburne's Centre for Astrophysics and Supercomputing. His research interests include observational cosmology and the formation and evolutionary history of galaxies. In 2017 Glazebrook was elected to the Australian Academy of Science.

Mr Andrew Jameson

CAASTRO Affiliate
Theme: Dynamic

Jameson is experienced in software development, systems administration, high-performance computing and data management. He has substantial expertise in the design and implementation of radio-astronomy instrumentation for single-pixel feeds and interferometers, and has worked on systems deployed at the Parkes, Molonglo and MeerKAT telescopes and on pre-construction design for the Square Kilometre Array. He is continuing to work in the areas of data acquisition, high-speed networking, real-time systems, interference excision, GPU software development and the management of 'big data'.

Ms Susan Lester

CAASTRO Administrator

In 2017 Lester continued to assist Swinburne node members with their travel requirements and oversee KPI reporting, finance and budgeting.

Mr Aditya Parthasarathy

CAASTRO PhD Student
Theme: Dynamic

Parthasarathy is a PhD candidate at Swinburne, supervised by Bailes, van Straten and Osłowski. His interests lie in achieving the highest precision in pulsar timing through robust statistical techniques. Parthasarathy is involved in the Parkes Pulsar Timing Array (PPTA) collaboration and is interested in studying profile variability in radio pulsars. His work in the past year has been focused on developing a generalised template-matching algorithm that accounts for jitter/self-noise in observations of bright millisecond pulsars. He is also a part of the UTMOST commissioning team and has contributed towards developing the automatic scheduling and observing system at Molonglo.

Ms Kathryn Plant

CAASTRO Research Assistant
Theme: Dark

Plant was a pre-PhD student working on a one-year project in the pulsar/fast radio burst group at Swinburne, building firmware for a new digital receiver for the Molonglo telescope. She is interested in how new instrumentation can address the challenges of detecting and localising FRBs. Her Molonglo project focused on FPGA (field-programmable gate array) programming to acquire spectra at high frequency resolution and high time resolution.

Dr Danny Price

CASTRO Postdoctoral Research Fellow
Theme: Dynamic

Price is a postdoctoral fellow based at Swinburne University of Technology, studying instrumentation and data analysis for fast radio bursts (FRBs). He is helping to upgrade the Molonglo radio telescope (UTMOST) to localise bursts in real time, and is running an FRB detection program on the Parkes telescope.

Associate Professor Emma Ryan-Weber

CAASTRO Associate Investigator
Theme: Evolving

Ryan-Weber's research in 2017 continued to focus on metal absorption-line systems in the high-redshift Universe. She has been supervising two Swinburne PhD students in this area, Luz Ángela García and Alexandru Codoreanu. García collaborated with Edoardo Tescari and Stuart Wyithe on simulating metal absorption-line systems, and was officially award her PhD in November; Codoreanu is working on high signal-to-noise ratio spectra of redshift-6 quasars to search for intervening metal lines, in particular Mg II, at redshift 2–6.

Dr Edward (Ned) Taylor

CAASTRO Affiliate
Theme: Dark

Taylor has explored a new approach to measuring the dark matter surrounding galaxies through weak gravitational lensing. He has also 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.

Ellert van der Velden

CAASTRO PhD Student
Theme: Dynamic

Van der Velden's primary supervisor is Alan Duffy; he is also supervised by Jeremy Mould, Darren Croton, and Chris Power. His thesis is titled "Utilizing cosmological simulations to model the growth of galaxies and their role in ionizing the universe", and he is working on a method (called PRISM) for analysing complex galaxy formation models that is an alternative to Markov Chain Monte Carlo.

Dr Willem van Straten

CAASTRO Affiliate
Theme: Dynamic

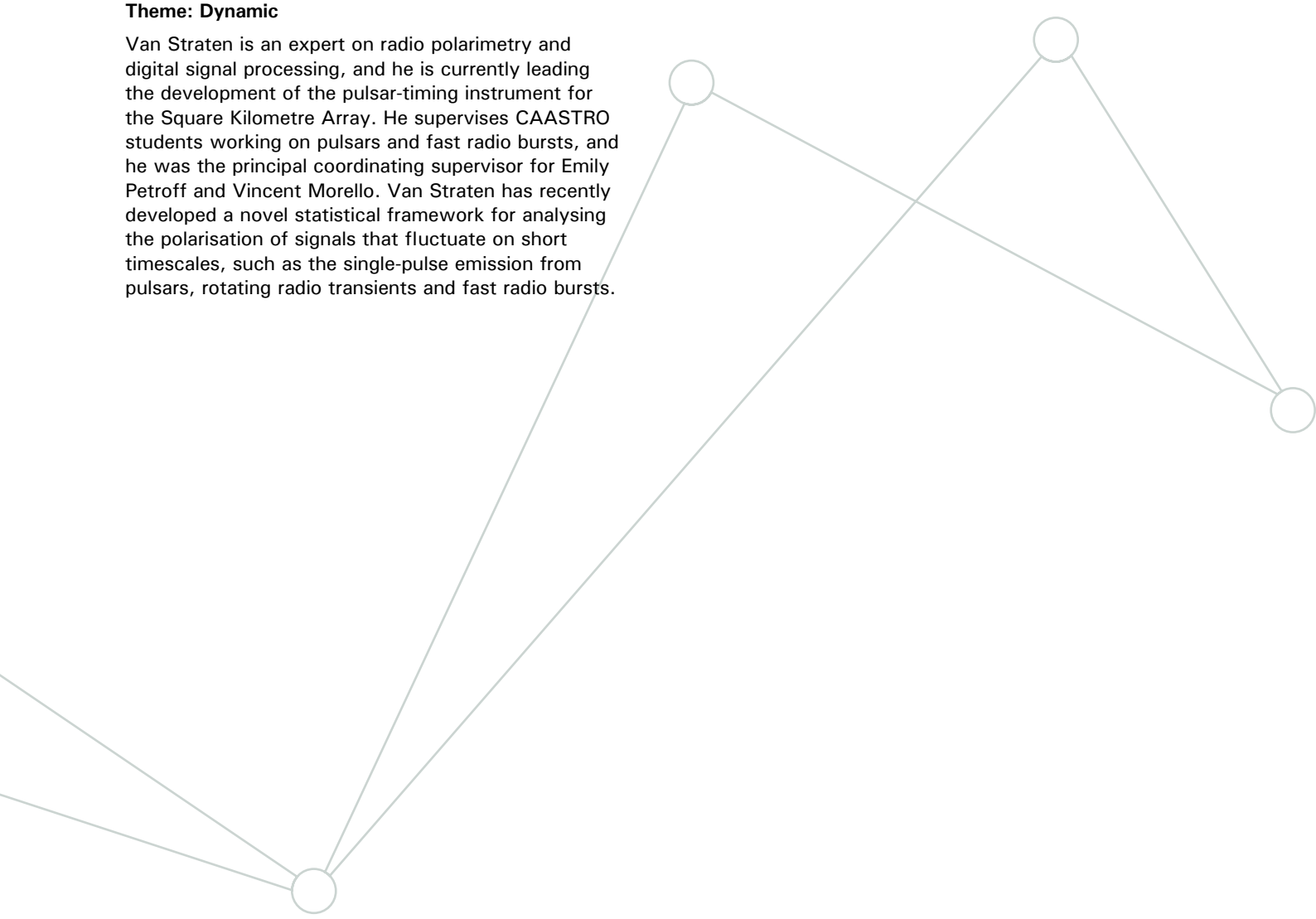
Van Straten is an expert on radio polarimetry and digital signal processing, and he is currently leading the development of the pulsar-timing instrument for the Square Kilometre Array. He supervises CAASTRO students working on pulsars and fast radio bursts, and he was the principal coordinating supervisor for Emily Petroff and Vincent Morello. Van Straten has recently developed a novel statistical framework for analysing the polarisation of signals that fluctuate on short timescales, such as the single-pulse emission from pulsars, rotating radio transients and fast radio bursts.

Mr Vivek Venkatraman Krishnan

CAASTRO PhD Student
Theme: Dynamic

Venkatraman Krishnan spent most of 2017 working on upgrading the UTMOST telescope into a completely robotic facility. The telescope now automatically times pulsars, follows up the fields of fast radio bursts and performs a survey of the Galactic plane for new intermittent pulsars, all without human intervention. This state-of-the-art instrumentation is the first of its kind for a radio telescope and could be used in telescopes such as the Canadian Hydrogen Intensity Mapping Experiment (CHIME), the Australian SKA Pathfinder (ASKAP), and the Square Kilometre Array (SKA). The candidates from the Galactic plane survey are automatically fed through a classifier that rejects radio-frequency interference and known pulsars and provides the shortlisted candidates to the user for further inspection and follow-up.

In 2017 Krishnan also led the first-ever detection of a frame-dragging effect (Lense–Thirring precession) predicted by general relativity. This was obtained from the long-term timing campaign of a relativistic binary pulsar system, PSR J1141–6545.



CAASTRO ANU team members

CAASTRO AT THE AUSTRALIAN NATIONAL UNIVERSITY

Australian National University

The Australian National University (ANU) node of CAASTRO has 21 researchers, ranging from undergraduates to professors. It does research across CAASTRO's three themes. Work at this node includes observations and theoretical modelling of optical and radio transients; characterisation of dark energy and dark matter through cosmological surveys; and efforts to understand the evolving Universe through optical and radio observations.

In the Dark Universe theme, PhD student Bonnie Zhang this year published a 'blinded' study that explored a significant discrepancy between measurements of the Hubble constant (page 27). Zhang and ANU colleagues Anais Möller, Natalia Sommer, Brad Tucker participated in the OzDES survey: the ANU team helps particularly with the observations and analysis of superluminous supernovae and AGN (active galactic nuclei) reverberation mapping. Möller also leads the SkyMapper telescope's supernova survey, which by the end of 2017 had identified nearly 50 Type Ia supernovae for cosmological analysis, as well as a number of unusual events. Former ANU CAASTRO member Richard Scalzo led the first publication presenting the survey; further papers are in preparation. Möller and Zhang are also working on the cosmology analysis of the international Dark Energy Survey (DES).

CAASTRO's Dynamic Universe theme is coming to an end with a 'bang' that was felt across several nodes. The merger of a binary neutron star was detected for the first time in August 2017 by the gravitational-wave detectors LIGO (the Laser Interferometer Gravitational-Wave Observatory) and Virgo. Triggered by LIGO, the SkyMapper team at ANU imaged an optical fireball resulting from the merger as soon as twilight fell over Siding Spring Observatory. The team followed it for four nights before it faded from view. The ANU 2.3-m telescope was on source at the same time. The story of GW170817, as the event was called, was reported in more than 800 news stories in Australia alone. CAASTRO researchers joined over 3,000 others around the world for the concerted worldwide detection and follow-up (page 19).

In the Evolving Universe theme, Matthew Colless, Francesco D'Eugenio and Tania Barone used the SAMI survey to explore the links between stellar populations and dynamical properties such as mass, gravitational potential and surface density. They found that the colour–potential diagram is a more precise tool for determining the developmental stage of the stellar population than the conventional colour–mass or colour–magnitude diagrams. Gravitational potential is also the primary regulator of global stellar metallicity, via its relation to the gas escape velocity. However, age and alpha-element over-abundance are most closely correlated with surface density, either as a result of compactness-driven quenching mechanisms or as a fossil record of the relation between the surface density of star-formation rate and gas in their disk-dominated progenitors.

Christian Wolf led the publication of Data Release 1 from the SkyMapper Southern Survey. This is the culmination of five years of work to which many CAASTRO members have contributed. Following the worldwide public release of the data in December 2017, the SkyMapper node of the All-Sky Virtual Observatory registered more than 23,000 unique users in just the first month.

Several undergraduate project students made important contributions in 2017. At the start of the year Matthew Alger developed the *active machine learning* module Acton (available on GitHub). And just before Christmas pre-PhD student Zefeng Li helped to discover the first two redshift-5 quasars from SkyMapper.

The ANU node gained new members this year, including astronomer Seo-Won Chang, who works on transients and variable phenomena with SkyMapper, and administrator Cristy Roberts. Zefeng Li joined us from Beijing in China, for a two-month project. We had to say goodbye to Administrator Susanne Meinen, who returned to Germany. Mayuri Sathyanarayana Rao and Manisha Caleb finished their PhDs while Ashley Ruiter and Ivo Seitenzahl took up Future Fellowships at UNSW Canberra: we congratulate all four, and wish them the best for the future.

CAASTRO at ANU led the *Stargazing Live* events held by the ABC and BBC in March and April. Over two million viewers tuned into the ABC, and the BBC saw a record 16.1 million. CAASTRO ANU also led the main citizen-science project, a search for Planet 9 with SkyMapper, which saw over 100,000 people participate in three days and provide four million classifications – a record. Over the year, Brad Tucker and his outreach team hosted more than 12,000 people for stargazing events and talks.

CAASTRO will close its doors In 2018, but work will continue on the analysis of data from OzDES, SAMI, SkyMapper and citizen-science projects in Galaxy Zoo. The intense collaboration across the country that CAASTRO initiated has spawned new ideas and triggered new lines of research. A new centre, OzGrav (the ARC Centre of Excellence for Gravitational Wave Discovery), will continue to follow up future neutron-star mergers identified with LIGO.

Dr Christian Wolf

CAASTRO Node Leader
Theme: Evolving, Dynamic, Dark

Wolf leads the SkyMapper Southern Survey and the SkyMapper node of the All-Sky Virtual Observatory (ASVO). His research interests include galaxy evolution and the decline of star formation in spiral galaxies. He works on improving measurements of star-formation rates in the infrared and radio domains. He is currently searching for quasars at high redshift and investigating the growth of super-massive black holes in the early Universe. Wolf also works on dust extinction in the Milky Way and external galaxies, and on AGN variability. He has worked for 20 years on photometric redshift and statistical classification techniques and pioneered high-precision photometric redshifts and their application to quasars; he led the COMBO-17 multiband survey, which explored the evolution of galaxies and quasars over most of cosmic time. Wolf recently began working on statistical and active machine-learning methods to design training sets of maximal value for minimal cost.

Professor Brian Schmidt

CAASTRO Chief Investigator
Theme: Dark

Professor Schmidt is the Australian National University's 12th Vice-Chancellor. He continues to be active in CAASTRO as a Chief Investigator; he also supervises a graduate student in the Dark Universe theme and chairs CAASTRO's Gender Action Committee.

Professor Schmidt makes many public appearances both in Australia and internationally. This year he spoke at the World Science Festival in Brisbane and the World Economic Forum in Davos, and delivered the Hintze Lecture at the University of Oxford.

Professor Matthew Colless

CAASTRO Chief Investigator
Theme: Evolving, Dark

Colless led the 6dF Galaxy Survey, which has provided the largest single contribution to the map of the density and velocity fields in the local Universe. This map will be combined with the WALLABY all-sky survey for neutral hydrogen and the SkyMapper all-sky optical survey to test whether the distributions of dark and luminous matter are the same on the largest scales. Colless is also using the SAMI survey to investigate dynamical scaling relations in galaxies and their relation to the stellar populations, both to understand galaxy evolution and to obtain more general and precise distance estimates. Colless will combine data from the SAMI survey with that from two radio surveys, WALLABY and FLASH, to study the co-evolution of gas and stars at low redshifts, using the radio surveys to measure the neutral hydrogen gas and the SkyMapper and SAMI optical spectroscopy to measure the stellar component.

Dr Julie Banfield

CAASTRO Postdoctoral Researcher
Theme: Evolving

Banfield's research is centred on radio-galaxy environments. She is a co-principal investigator of the citizen-science program Radio Galaxy Zoo, a project to cross-match radio sources with their host galaxies in preparation for the radio-continuum surveys that will be carried out with the Australian Square Kilometre Array Pathfinder (ASKAP) and South Africa's MeerKAT telescope. Banfield's most recent work has been to map the host galaxies of radio-loud active galactic nuclei with the Australian National University's 2.3-m telescope, to examine the interaction between the radio source and the host galaxy.

Mr Dilyar Barat

CAASTRO PhD student:
Theme: Dark, Evolving

In 2017 Barat continued his PhD in Astronomy at the ANU under the supervision of Professor Matthew Colless. Barat continues to work closely with the SAMI Galaxy Survey. His research focuses on the optimisation of galaxy scaling relations and using them as distance probe to measurement cosmological parameters. Barat is also a member of the Taipan survey, for which he will be mapping the matter distribution in the local Universe from the peculiar-velocity survey. This year Barat took part in a CAASTRO industry placement with Intelledox, where he worked for two months as a software developer.

Ms Tania Barone

CAASTRO PhD student:
Theme: Dark, Evolving

Barone's involvement with CAASTRO began in her Honours degree in 2016, when she researched the stellar populations of early-type galaxies from the SAMI Galaxy Survey under the supervision of Matthew Colless. Now in the first year of her PhD, Barone has continued working in this field. She is investigating the trends between a galaxy's stellar population, and its structural and dynamical properties, to try to understand the processes that govern galaxy evolution from its star-forming phase to quiescence.

Professor Frank Briggs

CAASTRO Affiliate
Theme: Evolving, Dynamic

Briggs' research interests have focused on the use of the 21-cm radio spectral line of neutral hydrogen to follow the history of galaxy formation and evolution. Briggs

has been a member since its inception of the MWA Collaboration that has designed, built and operated the Murchison Widefield Array in Western Australia. He has also been engaged in a long-term collaboration with astronomers in India and Australia to use India's Giant Metre-wave Radio Telescope (GMRT) to measure the evolution of the gas content of galaxies over the last seven billion years, with the aim of learning how the gas is related to galaxies' star-forming properties.

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 University. She studies fast radio bursts (FRBs): 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. Caleb is taking part in the worldwide race to discover more of these exciting sources, using the upgraded Molonglo Observatory Synthesis Telescope near Canberra. Caleb and her team made the first interferometric detections of FRBs in 2016, placing their origin at beyond the ~10,000 km Fresnel limit of the telescope, and so ruling out local sources of interference as a possible origin. Caleb finished her PhD in January 2017.

Dr Seo-Won Chang

CAASTRO Postdoctoral Fellow
Theme: Dynamic, Dark

Chang joined CAASTRO in January 2017 and has a research background in stellar magnetic activity and its related variability. He works with the SkyMapper Team, where he is in charge of studying optical counterparts to gravitational-wave events, fast radio bursts and other exotic transients. Chang also spearheads the development of a probabilistic classification of variable sources based on their multi-epoch, multi-band data. This will allow the SkyMapper Transient survey to better detect and characterise variability of several types, on a range timescales. Chang is passionate about preparing for future time-domain surveys such as those that will be carried out with the LSST (Large Synoptic Survey Telescope).

Dr Francesco D'Eugenio

CAASTRO Postdoctoral Fellow
Theme: Dark, Evolving

Using SAMI, D'Eugenio is working on scaling relations including the fundamental plane, dynamical modelling of early-type galaxies, and de-projected angular momentum. His other research projects include galaxy evolution at intermediate redshift and the slow/fast rotator kinematic-classification paradigm.

Mr Zefeng Li

CAASTRO pre-PhD student
Theme: Dark

Zefeng finished his undergraduate degree at Peking University in 2017. He joined CAASTRO at ANU in late 2017 for a project with Christian Wolf on finding high-redshift quasars with SkyMapper, successfully discovering two new bright quasars at z ~ 5. Li also works on quasar variability on long timescales.

Dr Anais Möller

CAASTRO Postdoctoral Fellow
Theme: Dark, Dynamic

Möller's research interests focus on Type Ia supernova (SNe Ia) cosmology and machine learning. She is working on both high-redshift SNe Ia surveys such as SNLS (the Supernova Legacy Survey) and DES (the Dark Energy Survey) and the low-redshift survey with SkyMapper Transient Survey. Möller has been leading the Transient Survey and is also involved in the search for optical counterparts of gravitational-wave events and fast radio bursts. She is currently working on a new deep-learning algorithm for photometric classification of supernovae; spectroscopy of supernovae and their host galaxies with the 2dF–AAOmega system on the Anglo-Australian Telescope; and, within OzDES, selection biases for the DES cosmology analysis.

Mr Daniel Muthukrishna

CAASTRO PhD student
Themes: Dark

Muthukrishna is a member of both the OzDES collaboration and the SkyMapper Transient Survey team. He is interested in supernovae and their use in cosmological surveys. His research involves the development of machine-learning software to automate the classification of supernovae. He also models interesting and unusual transient events, to understand the physics behind them. Muthukrishna is continuing his PhD at the University of Cambridge, where he moved in September.

Dr Christopher Onken

CAASTRO Associate Investigator
Themes: Dark, Dynamic, Evolving

Onken is the Operations Manager for the SkyMapper Telescope, a facility contributing to all three CAASTRO themes. He joined CAASTRO in April 2015. Onken's main research interests are active galactic nuclei and the measurement of black-hole masses.

Ms Fiona Panther

CAASTRO PhD student
Theme: Dynamic

Panther began her PhD in July 2015. Her CAASTRO research involves improving our understanding of peculiar sub-luminous thermonuclear supernovae: her project LEnsS (Local Environments of Sub-luminous Supernovae) aims to measure the ages of the stellar populations that give rise to SN1991bg-like supernovae, the largest subclass of SNe °Ia. This project will give insight into the possible progenitors of these cosmic explosions and help us to understand how the rate of these events evolves over cosmic time. These sub-luminous supernovae might also be the source of the Milky Way's mysterious positrons.

Ms Cristy Roberts

CAASTRO Administrator
Roberts joined the ANU node in 2017. She provides administrative support to the team.

Dr Ashley Ruiter

CAASTRO Postdoctoral Fellow
Theme: Dynamic

Ruiter models the evolution of binary star systems: her aim is to understand the formation of interacting stars that give rise to explosive phenomena and compact objects. She is interested in transient sources such as supernovae, RCrB stars, neutron stars formed by accretion-induced collapse, and binary stars that can be used as verification sources for gravitational-wave detectors. Ruiter uses theoretical methods to uncover the evolutionary channels that lead to these stars forming, predict their birth rates, and constrain their birth sites and ages. Ruiter joined the University of New South Wales Canberra in late 2017 as an ARC Future Fellow.

Ms Mayuri Sathyanarayana Rao

CAASTRO PhD student
Theme: Evolving

Rao completed her PhD under the guidance of Frank Briggs at the Australian National University and Ravi Subrahmanyan at the Raman Research Institute in India. The focus of her thesis was spectral distortions of the cosmic microwave background (CMB), particularly those arising from the epoch of recombination through reionisation. She has developed methods to model and subtract foregrounds for experiments seeking to detect these CMB spectral distortions. Rao is now developing a prototype element of an array to detect these and other cosmological distortions of the CMB. Her focus is on aspects of high-level system design and integration, calibration techniques and system analysis.

Dr Ivo Seitenzahl

CAASTRO Associate Investigator
Theme: Dynamic

Seitenzahl is a theoretical nuclear astrophysicist and his research focuses on explosive nucleosynthesis and three-dimensional simulations of Type Ia supernova explosions. His current research also includes work on the neutrino and gravitational-wave signals of thermonuclear supernovae, the Galactic chemical evolution of Fe-peak elements, the atomic and nuclear physics of late-time supernova light curves, and optical observations (made with integral field units) of oxygen-rich and Balmer-dominated supernova remnants in the Magellanic Clouds and the Milky Way. Seitenzahl joined the University of New South Wales in Canberra in May as an ARC Future Fellow.

Dr Robert Sharp

CAASTRO Associate Investigator
Theme: Evolving, Dark

Sharp is instrument scientist for the Giant Magellan Telescope Integral Field Spectrograph (GMTIFS), a new instrument being designed at the Australian National University and destined for the Giant Magellan Telescope in Chile in 2024. Within CAASTRO, Sharp is a leader of the SAMI Galaxy Survey data-analysis group. For the OzDES supernova survey project, Sharp is the local coordinator for the reverberation-mapping project that will measure the masses of giant black holes in distant quasars. In addition, 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.

Ms Natalia Eiré Sommer

CAASTRO PhD Student
Theme: Dark

Sommer investigates supermassive black holes at centres of active galaxies using the method of reverberation mapping. Reverberation mapping involves comparing two signals originating at different places outside the black holes, and looking for a time lag between them. From these time lags one can estimate black hole masses and study black hole evolution; the technique might even help us learn about the nature of dark energy. Sommer's work is particularly focused on the possibility of stacking data from a large number of supermassive black holes, to obtain results that individual objects cannot provide.

Dr Brad Tucker

CAASTRO Postdoctoral Fellow
Theme: Dark, Dynamic

Tucker is currently working on projects aimed at understanding dark energy through supernovae (SNe). He studies early and multiwavelength observations of SNe to learn about their physics and progenitors. Tucker is involved in many supernova surveys, including the SkyMapper Supernova Survey, OzDES, the Carnegie Supernova Project and ESSENCE (Equation of State: SupErNovae trace Cosmic Expansion) survey. He leads the Kepler Extra-Galactic Survey, a NASA Kepler K2 key project to search for supernovae, black holes and other extragalactic transient objects, and the SkyMapper search for Planet 9. Tucker frequently speaks to school groups and the general public about astronomy, and has regular TV and radio segments (*Sunrise* and the *Morning Show* on Channel 7, ABC 7:30 and ABC News 24) where he talks about astronomy news and events.

Ms Bonnie Zhang

CAASTRO PhD student
Themes: Dark, Dynamic

Zhang is a PhD student studying observational cosmology. Her research is on using Type Ia supernovae to measure the cosmic distance scale, including precise analysis of supernova systematics. Her work spans the nearby and high-redshift Universe, from measurements of the Hubble constant from low-redshift SNe to studies of cosmic acceleration and dark energy at higher redshifts. In particular, she is interested in improving estimates of errors in supernova-based Hubble constant measurements. She is part of both the SkyMapper team and the OzDES collaboration, and involved in cosmological analysis of supernova light curves in the Dark Energy Survey at high redshift.

CAASTRO University of Queensland team members

CAASTRO AT THE UNIVERSITY OF QUEENSLAND

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

The University of Queensland joined CAASTRO as a new node in 2014. Our research concentrates on the Dark and Evolving themes. In 2017, five staff and eight students were involved in CAASTRO projects including the Australian Dark Energy Survey (OzDES), the Evolutionary Map of the Universe (EMU) and the SAMI galaxy survey. Node leader Professor Tamara Davis also leads CAASTRO's Dark Universe Theme.

Dark Universe Theme

The most exciting highlights of 2017 for our CAASTRO science were the publication of the first cosmological results from the international Dark Energy Survey (DES) and the first data releases from both DES and OzDES. We participated in the DES release of the largest-ever map of the distribution of dark matter in the Universe (DES Collaboration 2017, including 12 OzDES and four UQ authors, "Dark Energy Survey Year 1 Results: Cosmological Constraints from Galaxy Clustering and Weak Lensing"). This dark-matter map was created by examining the shapes of 26 million distant galaxies over 1,300 deg^2 of sky. Travelling towards us, the light from these background galaxies is bent by the mass in foreground galaxies, a phenomenon called weak gravitational lensing. This slightly distorts our images of the background galaxies, and from the nature and degree of distortion we can determine the mass that caused it. The final DES sample will be completed by 2019 and will include 300 million galaxies over 5,000 deg^2.

Observing for DES and OzDES continues apace. We already have detections and redshifts for over 5,000 supernovae. Some 2,000 of these are Type Ia supernovae with data good enough to be used in cosmological analyses. With one year of observing still to go, we are well on our way to achieving our target of 2,500 cosmology-quality supernovae by the end of the survey. Next year will see the release of our first cosmological results from Type Ia supernova studies.

This year our researchers published several other exciting papers on supernova-related science, including those by Edward Macaulay ("The effects of velocities and lensing on moments of the Hubble diagram"), Joshua Calcino ("The need for accurate redshifts in supernova cosmology") and Per Andersen ("Cosmology with peculiar velocities: observational effects"). These papers look at the effects of inhomogeneities on our cosmological measurements.

In preparation for the beginning of the Taipan peculiar-velocity survey in 2018, we contributed to the survey paper, "Taipan Galaxy Survey: Scientific Goals and Observing Strategy". Meanwhile, observations have ramped up for the Evolutionary Map of the Universe (EMU) survey, which will be carried out with the Australian SKA Pathfinder (ASKAP). UQ CAASTRO Associate Investigator David Parkinson is leading the EMU cosmology working group. Finally, we were excited to be part of Bonnie Zhang's eagerly awaited re-analysis of the Type Ia supernova measurement of Hubble's constant (page 27). Her results brought the value of Hubble's constant measured using 'standard candles' such as supernovae slightly closer to the value seen by standard rulers such as baryon acoustic oscillations and the cosmic microwave background.

This year saw the publication of the final two WiggleZ Dark Energy papers, the culmination of work that started even before CAASTRO. WiggleZ was one of the major Dark Theme projects supported by CAASTRO. One paper, led by Samuel Hinton, completed our dark-energy measurements. This work involved measuring the baryon acoustic oscillation signal from galaxy separations in two dimensions: along the line of sight and, separately, perpendicular to the line of sight.

Evolving Universe Theme

Our main paper from the Evolving theme this year was the second of the final two from the WiggleZ survey (see above). Led by Michael Drinkwater, this paper covered the survey's final data release and measurements of the metallicity of UV-luminous galaxies.

Dynamic Universe Theme

For the UQ node, this year's Dynamic theme highlight was the very exciting discovery by Holger Baumgardt and his collaborators that faint thermonuclear supernovae could be responsible for most of the antimatter that is being generated in the centre of the Milky Way. In a study published in May 2017, the authors showed that the cause of this antimatter was a series of weak supernova explosions over millions of years, each created by the convergence of two white dwarfs.

Other highlights

The University of Queensland was delighted to host the Dark Energy Survey Collaboration Meeting in November 2017. This was the first time DES had held its collaboration meeting outside the USA or Europe. One hundred and ten astrophysicists from around the world descended on UQ for a week of discussions and workshops. In conjunction with the conference we held a public talk with four of the eminent astrophysicists from DES, and this attracted over 450 members of the public.

Professor Harvey Richer (University of British Columbia) visited the University of Queensland in September 2017 to work with us. CAASTRO PhD student Samuel Hinton ran a series of coding workshops around the CAASTRO nodes (page 57), and a second CAASTRO PhD student, Joshua Calcino, was a finalist in the University of Queensland's Faculty of Science *Future Superstars* award.

Tamara Davis

CAASTRO Node Leader
Theme: Dark

Davis studies dark energy and black holes using supernovae, the large-scale structure of the Universe, and active galactic nuclei. She helps manage the Dark Energy Survey, an international project that now has more than 450 members. Her 2017 outreach activities included over 40 public events, including TV appearances on *Ben's Food Lab*, prime-time news, two ABC *Catalyst* episodes, a BBC documentary, and talks at high-profile events such as the *World Science Festival* and a *Women in Physics* session at the Sydney Opera House.

Mr Per Andersen

CAASTRO PhD Student
Theme: Dark

Andersen is using observations of Type Ia supernovae to study the bulk cosmological flow of our local group of galaxies, and the bulk combined velocity of our own and nearby galaxies. The bulk cosmological flow is sensitive to large-scale structures, and our cosmological models put a constraint on the size of large-scale structure. By measuring the bulk flow of our local group we can test the current cosmological models and learn more about dark energy and dark matter.

Dr Jacobo Asorey

CAASTRO Postdoctoral Researcher
Theme: Dark

Asorey is a postdoctoral research fellow at Swinburne University and is based at the University of Queensland with Tamara Davis. His research interests lie in testing cosmological models by studying the expansion and growth histories of the Universe, using maps of its large-scale structure from surveys such as DES (the Dark Energy Survey) or OzDES.

Holger Baumgardt

CAASTRO Affiliate
Theme: Dynamic

Baumgardt studies the dynamical evolution of star clusters and galactic nuclei and the dynamics of the dense stellar systems surrounding massive black holes. In 2017 he published two *Nature* papers and gave media interviews about the possible existence of an intermediate-mass black hole in the globular cluster 47 Tucanae.

Mr Joshua Calcino

CAASTRO PhD Student
Theme: Dark

Calcino is a PhD student at the University of Queensland, supervised by Tamara Davis. His research focuses on cosmology but he has a strong interest in all areas of astronomy.

Mr Simon Deeley

CAASTRO Honours Student
Theme: Evolving

Deeley is an Honours student at the University of Queensland, supervised by Michael Drinkwater. During his undergraduate studies at UQ he completed two projects looking the structures and star formation rates of galaxies in the WiggleZ Dark Energy Survey, and began looking at galaxy morphology within galaxy groups. For his Honours project he looked at how the fraction of elliptical galaxies varies across groups of different masses, using data from the Galaxy and Mass Assembly (GAMA) survey. He has since compared these results with merger simulations, finding that galaxy mergers appear to be the dominant driver of galaxy evolution in these environments.

Professor Michael Drinkwater

CAASTRO Associate Investigator
Theme: Evolving

Drinkwater's research focus is on the origin and evolution of galaxies. He is using observations from the SAMI galaxy survey to determine the role of black holes in driving high-velocity outflows in galaxies. With Simon Deeley, he recently demonstrated a strong correlation between galaxy mergers and the formation of elliptical galaxies in galaxy groups.

Mr Lucas Grimes

CAASTRO Honours Student
Theme: Evolving

Grimes is a PhD student at the University of Queensland and the topic of his thesis is High-velocity outflows from the centre of active galaxies. His supervisors are Michael Drinkwater and Tamara Davis.

Mr Samuel Hinton

CAASTRO PhD Student
Theme: Dark

Hinton is a PhD student at the University of Queensland. In his undergraduate software and Physics theses, he developed the redshifting code MARZ and analysed the two-dimensional baryon acoustic oscillation signal in data from the WiggleZ survey. Hinton has worked with the OzDES team and is now looking into a fully Bayesian approach to supernova cosmology. In 2017 he delved further into Bayesian analysis.

Mr Harry Hobson

CAASTRO Honours Student
Theme: Dark

Hobson is studying at the University of Queensland under the supervision of Tamara Davis. Using the DES/OzDES reverberation-mapping dataset, he is investigating emission-line properties of active galactic nuclei and how these properties affect the mass estimates made with reverberation mapping.

Mr Henning Schmidt

CAASTRO Honours Student
Theme: Dark

In 2017 Schmidt completed an Honours thesis under Tamara Davis, using gravitational lensing to search for MACHOS (massive compact halo objects) that could be stellar-mass black holes.

Ms Merryn Taylor

CAASTRO Honours Student
Theme: Dark

Merryn is an undergraduate student at the University of Queensland. In 2017 she completed an Honours thesis, supervised by Professor Tamara Davis, in which she looked at the weak gravitational lensing of Type Ia supernovae.

Ms Candy Wu

CAASTRO Administrator
Wu joined the CAASTRO UQ node in March 2014, having worked in finance and HR for six years at UQ's School of Maths and Physics and School of Business. Wu provided financial and administrative support to the CAASTRO members at the node until she left in June 2017.

CAASTRO LINKAGES

CAASTRO has very strong national and international linkages through an extensive 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 have some of the strongest scientific records in international astronomy: they have proven success in executing large survey projects and are from world-class institutions, including the Australian Astronomical Observatory, CSIRO, Oxford University, Caltech (California Institute of Technology) 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 other major international projects. We also have Associate Investigators and Affiliates within our Partner Organisations.

Australia has made large investments in widefield technologies and high-performance computing, in the form of the Australian Square Kilometre Array Pathfinder telescope, the Murchison Widefield Array, SkyMapper, Molonglo, and the Pawsey Supercomputing Centre. CAASTRO has outstanding researchers at Australia's highest-ranked universities and fastest-growing astronomy centres, with expertise in radio astronomy, optical astronomy, theoretical astrophysics and computation. Combined, these facilities and researchers enable CAASTRO to do world-leading science in widefield astronomy.

PARTNER ORGANISATIONS

Australian Astronomical Observatory

Professor Warrick Couch
CAASTRO Partner Investigator

Professor Couch, Director of the Australian Astronomical Observatory (AAO) has a significant role in supporting the operations and management of CAASTRO because the AAO provides some of the key facilities CAASTRO uses. The AAO operates the 3.9 Anglo-Australian Telescope (AAT) and the 1.2m UK Schmidt Telescope (UKST), which both offer widefield optical spectroscopy. The AAT is equipped with the SAMI multi-object integral field unit and AAOmega multi-fibre spectrograph, and the UKST has recently been outfitted with its new TAIPAN positioner and spectrograph. All of these instruments play, or will soon play, a key role in research for CAASTRO's three theme areas. Furthermore, Couch has a major leadership role in the SAMI Galaxy Survey, being a member of its Executive, and directs and resources research on galaxy morphological transformation. 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 the 4MOST instrument on the European Southern Observatory's 4-m VISTA telescope.

Professor Andrew Hopkins
CAASTRO Partner Investigator

Together with AAO Director Professor Warrick Couch, Professor Hopkins coordinates the AAO's contributions to CAASTRO. Hopkins manages CAASTRO-supported student and postdoctoral researchers who observe with, and use 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 made with AAO telescopes and managing access to computing resources. Hopkins is responsible for identifying programs using AAO facilities that complement and add value to CAASTRO projects. Leveraging the existing effort on such projects allows more scientific goals to be achieved, increasing the return from existing investment. Hopkins's primary research activities within CAASTRO fall under the Evolving Universe theme, although some aspects of his work overlap with activities in the Dark Universe theme. Within CAASTRO, Hopkins is mainly pursuing research on EMU (the Evolutionary Map of the Universe, a survey of 70 million galaxies), and projects proposed for TAIPAN.

Dr Chris Lidman
CAASTRO Associate Investigator

Dr Lidman is an Associate Investigator in CAASTRO. 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 supernovae, galaxy clusters, primordial galaxies, and exotic transient phenomena. Lidman is an expert in adaptive optics, near-IR imaging and optical spectroscopy.

Commonwealth Scientific and Industrial Research Organisation

Dr Simon Johnston
CAASTRO Partner Investigator

Dr Johnston is based at CSIRO Astronomy and Space Science and his research interests are pulsars, radio transients and Extreme Scattering Events (of signals by the interstellar medium): they are thus

closely aligned with the Dynamic Universe theme. He is a key member of the VAST (Variables and Slow Transients) survey project proposed for the Australian SKA Pathfinder telescope, and is a member of the Pulsar Science Working Group for the Square Kilometre Array.

Dr George Heald
CAASTRO Partner Investigator

Dr Heald leads the CSIRO Astronomy and Space Science (CASS) Astrophysics team in Perth, which is based at the Australian Resources Research Centre next to the Pawsey Supercomputing Centre. His research interests include how galaxies' gas content and magnetic fields affect star formation. Dr Heald has extensive experience in designing and performing all-sky imaging surveys at low radio frequencies. He co-leads the ASKAP POSSUM survey, an investigation of cosmic magnetic fields; is a core member of the Cosmic Magnetism Science Working Group for the SKA; and serves on the Executive Board of the Murchison Widefield Array.

Dr Keith Bannister
CAASTRO Affiliate

Dr Bannister is an Affiliate in CAASTRO, with expertise in radio data processing, radio transients and archival searches. His role in the Dynamic Universe theme is in modelling fast radio bursts, following-up astronomical transients at radio wavelengths, and conducting surveys for radio transients; he has also developed a new technique for searching for Extreme Scattering Events. Bannister is currently helping to commission the Australian SKA Pathfinder, which he hopes to use to search for afterglows of gravitational-wave bursts.

Dr Daniel Mitchell
CAASTRO Affiliate

Dr Mitchell is a research scientist with the Software and Computing Group in CSIRO Astronomy and Space Science. He specialises in widefield interferometric imaging and calibration, and is a senior member of the Australian Square Kilometre Array Pathfinder calibration and imaging team; he is also a member of the Square Kilometre Array (SKA) Science Data Processor consortium and of the SKA's Cosmic Dawn / Epoch of Reionisation Working Group. Mitchell is a lead developer and maintainer of ASKAPsoft, the calibration and imaging package for ASKAP, and of the Real-Time System, a GPU-accelerated pipeline used to process Murchison Widefield Array data.

Professor Ray Norris
CAASTRO Affiliate

Professor Norris is an emeritus fellow at CSIRO and is the 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 the Australian SKA Pathfinder telescope. EMU is an all-sky continuum survey that lies within CAASTRO's Evolving Universe theme. Its primary goal is to trace the origin and evolution of galaxies over cosmic time. EMU will also have a major impact on characterising dark energy and constraining modified gravity, which aligns it with the Dark Universe theme. Professor Norris is also a Professor, undertaking research, at Western Sydney University.

California Institute of Technology, USA

Professor Shri Kulkarni
CAASTRO Partner Investigator

Professor Kulkarni's research interests fall within CAASTRO's Dynamic Universe theme. Kulkarni is one of the originators of the Palomar Transient Factory (PTF), a northern-hemisphere counterpart 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 between the two facilities. Professor Kulkarni also has an interest in the origin of fast radio bursts, ruling out some scenarios and trying to ascertain whether they can come from 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 for his use of all-sky surveys to discover rare objects; strengths that are especially valuable for the Skymapper survey's search for high-redshift quasars.

University of Durham, UK

Professor Carlos Frenk
CAASTRO Partner Investigator

Professor Frenk contributes to CAASTRO in the Evolving and Dark Universe themes. Theoretical galaxy-formation models predict the abundance and distribution of neutral hydrogen gas 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 falls under CAASTRO's Dynamic Universe theme. His focus is on the exploration and exploitation of the dynamic radio sky, in the study of both pulsars and new types of transients, phenomena that allow us to address astrophysical questions ranging from the state of matter at extreme densities to cosmology and tests of theories of gravity. Kramer is contributing his expertise to the search for fast transients by developing hardware and software solutions in collaboration with 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: soon to be launched, it 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 active galactic nuclei.

Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE), France

Dr Nicolas Regnault
CAASTRO Partner Investigator

Dr Regnault worked on the preparation and the design of the SkyMapper supernovae survey, and he has been involved in the spectroscopic follow-up of the first SNe discovered by SkyMapper, through CAASTRO's participation in the PESSTO program. He has worked on the recalibration and refurbishing of the SkyDICE light source, and has assisted the SkyMapper team with the photometry and photometric calibration of the SkyMapper SN Ia light curves.

University of Toronto, Canada

Professor Bryan Gaensler
CAASTRO Partner Investigator

Professor Gaensler is the Director of the Dunlap Institute at the University of Toronto. In 2017 he worked on wide-field survey data from the Murchison Widefield Array, which he used to search for the synchrotron cosmic web and to study a new sample of peaked-spectrum radio galaxies. In 2018 he will work on early-science observations made with the Australian SKA Pathfinder.

Professor Ue-Li Pen
CAASTRO Partner Investigator

Professor Pen brings to CAASTRO a wealth of experience in tackling the fundamental problems in cosmology that are 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 these areas 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 surveys on the Australian SKA Pathfinder such as WALLABY and DINGO.

Raman Research Institute, India

Professor Ravi Subrahmanyan
CAASTRO Partner Investigator

Professor Subrahmanyan is in the CAASTRO Evolving Universe theme, and his current research lies in using spectral distortions in the cosmic microwave background as a diagnostic of the cosmic baryon evolution in the Universe. The research develops methods and instrumentation for all-sky measurements of the radio background, at centimetre and longer wavelengths, for detecting global spectral-distortion signals from cosmological reionisation and recombination. The research work of Subrahmanyan and his colleagues at the Raman Research Institute with the Murchison Widefield Array is primarily in efforts to detect the Epoch of Reionisation.

University of Oxford, UK

Professor Roger Davies
CAASTRO Partner Investigator

Professor Roger Davies is Philip Wetton Professor of Astrophysics and Director of the Centre for Astrophysical Surveys at Oxford University. Within CAASTRO, Davies's contributions are 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.

Dr Jamie Farnes
CAASTRO Affiliate

Dr Farnes is a Research Associate at the University of Oxford and an affiliate of CAASTRO. His research interests fall under the Evolving Universe theme, focusing on radio galaxy environments and the evolution of galaxies over cosmic time.

National Computational Infrastructure, Australia

Professor Lindsay Botten
CAASTRO Partner Investigator

As Director of National Computational Infrastructure (NCI) until early 2017, Professor Lindsay Botten supported CAASTRO's access to, and usage of, NCI's high-end computing services, for all of its themes and for researchers from all CAASTRO nodes. In 2017 CAASTRO members used eight million CPU hours on NCI facilities.

ASSOCIATED ORGANISATIONS

Astron, Netherlands

Professor Carole Jackson
CAASTRO Affiliate

Professor Jackson is the General and Scientific Director of ASTRON, the Netherlands Institute for Radio Astronomy. She was previously the Western Australian Premier's Fellow at Curtin University, Director of the Curtin Institute of Radio Astronomy and a Science Director of the International Centre for Radio Astronomy Research (ICRAR) in Perth, as well as CAASTRO Node leader at Curtin.

Dr Antonia Rowlinson
CAASTRO Affiliate

Dr Rowlinson is an Assistant Professor in a joint position at the University of Amsterdam and ASTRON (The Netherlands Institute for Radio Astronomy). Her research interests fall under the Dynamic Universe theme, focusing on radio transient sources and compact binary mergers.

University of Belfast, UK

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.

Korea Astronomy and Space Science Institute (KASI)

Dr David Parkinson
CAASTRO Associate Investigator

Dr Parkinson is a Senior Researcher at the Korea Astronomy and Space Science Institute and an Associate Investigator in CAASTRO. His research interests fall under the Dark Universe theme, focusing on using the large-scale structure of the matter distribution in the universe to determine the physics of dark energy and test the theory of gravity.

University of New South Wales

Professor Brian Boyle
CAASTRO Affiliate

Professor Boyle is the Deputy Vice-Chancellor (Enterprise) at the University of New South Wales. Professor Boyle was previously the Acting SKA (Square Kilometre Array) Director for the Australian Department of Industry, following his role as CSIRO SKA Director. Prior to that, he was the Director of the CSIRO Australia Telescope National Facility (2003–2009), where he initiated the construction of the Australian SKA Pathfinder, and Director of the Anglo-Australian Observatory (1996–2003).

Associate Professor Sarah Brough
CAASTRO Affiliate

Dr Brough is a CAASTRO Affiliate. Her role is in the Evolving Universe theme, where she is working with CAASTRO to bring the Large Survey Synoptic Telescope (LSST) project to astronomers in Australia. Brough is also a member of the SAMI survey team and contributes environmental measurements and angular-momentum expertise to that survey. Her primary research interest is galaxy evolution, and the dependence of that evolution on environment, particularly for Brightest Cluster Galaxies.

University of Nottingham, UK

Dr Jamie Bolton
CAASTRO Associate Investigator

Dr Bolton is a Royal Society University Research Fellow at the University of Nottingham and an Associate Investigator in CAASTRO. His research interests fall under the Evolving Universe theme, focusing on numerical simulations of the intergalactic medium and the epoch of reionisation.

National Astronomical Observatories, Chinese Academy of Sciences

Dr Tao Hong
CAASTRO Affiliate

Dr Hong is an Assistant Investigator in the National Astronomical Observatories, Chinese Academy of Sciences (NAOC), and is a CAASTRO Affiliate. He works in the Dark Universe Theme, mainly studying the peculiar-velocity field of the local Universe with the data from the 2MASS Tully-Fisher Survey. His research interests are H I in galaxies, observational cosmology, large-scale structures and galaxy clusters.

University of Oslo, Norway

Dr Signe Riemer-Sørensen
CAASTRO Affiliate

Dr Riemer-Sørensen is a CAASTRO Affiliate working under the Dark Universe Theme. She investigates how non-standard particles such as dark matter and neutrinos affect the Universe, and how their properties can be derived from cosmological observations. These observations cover all scales and range from chemical abundances in quasar absorption systems to galaxy surveys (for example, WiggleZ) and X-ray emission from galaxy clusters. Riemer-Sørensen's work involves using advanced statistical methods for model selection and parameter determination, and comparing observations with simulations.

Purple Mountain Observatory, China

Dr Syed Ashraf Uddin
CAASTRO Affiliate

Dr Uddin is a President's International Fellow of the Chinese Academy of Sciences at the Purple Mountain Observatory. His research topic is supernova cosmology, which falls under the Dark Universe theme of CAASTRO. He is a core member of the OzDES collaboration and Australia China Consortium for Astrophysical Research (ACAMAR).

SKA Organisation

Dr Evan Keane
CAASTRO Affiliate

Dr Keane is a CAASTRO Affiliate. His role is in the Dynamic Universe Theme, where he works mainly in the areas of pulsars and fast radio bursts. Dr Keane is a Project Scientist with the SKA Organisation, based at Jodrell Bank in the UK. There he is contributing to the design of the telescope and its science programme. He is also Principal Investigator of the Survey for Pulsars and Extragalactic Radio Bursts (SUPERB) at Parkes. Through his visiting role at Swinburne he supervises three CAASTRO PhD students and is involved with the UTMOST project. He also leads a science working group on TRAPUM (Transients and Pulsars with MeerKAT) project.

University of Technology Sydney

Dr Martin Bell
CAASTRO Affiliate

Dr Bell is an Affiliate in CAASTRO. He is a principle investigator of the Murchison Widefield Array Transients Survey (MWATS), which will survey almost the entire southern sky 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.

Victoria University of Technology, New Zealand

Dr Stephen Curran
CAASTRO Affiliate

Dr Curran is a CAASTRO affiliate member based at the Victoria University of Wellington in New Zealand. His work is in the Evolving Universe theme. He maintains close collaborations with other CAASTRO members of the theme, particularly those involved with the survey team for FLASH (the First Large Absorption Survey in H I): this survey, to run on the Australian SKA Pathfinder, will research the reservoir of star-forming gas in the distant Universe.

Richard Scalzo (CAASTRO Alumni), Martin Bell (UTS) and Chris Lidman (AAO)
Credit: Cristy Roberts

CAASTRO COLLABORATIONS

This year CAASTRO team members have been involved in a number of Australian and international collaborations. The most significant are listed below.

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-Röntgen-Gamma (SRG) satellite, which will be launched in 2018. 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 Australian widefield facilities such as ASKAP, MWA, Molonglo, Parkes, ATCA, SkyMapper, AAT and TAIPAN. In 2017 the eROSITA telescope has been completed, assembled and shipped to Russia for final test and integration into the spacecraft. The first all-sky survey should be completed in early 2019, and it is anticipated that seven more passes of the whole sky will be completed by early 2022. In 2018 Astronomy Australia Limited (AAL) will take over the management of this agreement.

eROSITA commissioning
Credit: MPE eROSITA

ACAMAR: the Australia-ChinA Consortium for Astrophysical Research

Institutions: Purple Mountain Observatory of the Chinese Academy of Sciences (Nanjing, China), National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), CAASTRO

ACAMAR is an umbrella and coordination point for bilateral astronomical collaborations. The centre's stellar namesake, Acamar (θ Eridani), is a bright naked-eye star visible from both countries. ACAMAR maximises the scientific return on investments in astronomy infrastructure, particularly by helping the two countries to cooperate in running telescopes based in Australia, Antarctica and China, and to coordinate observations and share data. It will also help to develop skills and knowledge, by facilitating the exchange of students, researchers and technical staff between institutions. In 2018 Astronomy Australia Limited (AAL) will take over the management of this agreement.

SkyMapper

Institutions: Australian National University, CAASTRO, Monash University, Australian Astronomical Observatory

SkyMapper is a 1.35-metre telescope with a 5.7 deg^2 imager, located near Coonabarabran, New South Wales, and owned and operated by the Research School of Astronomy and Astrophysics at the Australian National University. CAASTRO secured a $1.16m ARC Linkage Infrastructure Equipment and Facilities (LIEF) grant to secure membership of the SkyMapper consortium for all Australian astronomers during 2014–2019. This funding contributes to the operating costs needed for SkyMapper to undertake a 5-year survey of the entire southern sky, provides Australian astronomers with 20 per cent of non-survey observing time on SkyMapper, and allows the development of robust and efficient software pipelines, analysis tools and data-access facilities. In 2017, SkyMapper published its Data Release 1 through its node in the All-Sky Virtual Observatory (ASVO). During the first month of world-wide access the database was hit by over 23,000 unique users. The release includes almost 300 million astrophysical objects and covers nearly the entire southern hemisphere.

TAIPAN

Institutions: Australian Astronomical Observatory, Australian National University, CSIRO Astronomy and Space Science, Macquarie University, Monash University, Swinburne University of Technology, University of Melbourne, University of New South Wales, University of Queensland, University of Sydney, University of Western Australia, Western Sydney University

TAIPAN is a new facility for the UK Schmidt Telescope (UKST) at Siding Spring Observatory. It encompasses a novel optical-fibre positioner using the new 'starbugs' technology and a purpose-built spectrograph; the project also involves refurbishment of the UKST itself. The TAIPAN facility will support two major new surveys, Taipan and Funnelweb. The Taipan survey of one and a half million galaxies began observations in 2017. It is aimed at:

- measuring the Hubble constant, H_0, with a precision of one per cent
- measuring the bulk motion of galaxies, to better understand dark matter
- linking the star-formation and gas-fuelling properties of galaxies, to understand galaxy evolution. (This will be done in conjunction with the WALLABY radio survey, made with the Australian SKA Pathfinder,)

The Funnelweb survey is designed to:

- measure two million stars within our Milky Way Galaxy, uniquely characterising them and complementing the fainter GALAH Galactic Archaeology survey
- provide a robust input sample for the next-generation planet-finding satellite observatory, TESS.

The first Taipan paper has been published in 2017, da Cunha et al., 2017, PASA, 34, 47, and while the scientific goals of the TAIPAN facility and surveys are closely aligned with CAASTRO goals, these projects are not currently receiving any CAASTRO funding.

OzDES

Institutions: Australian Astronomical Observatory, Australian National University, University of Queensland, University of Sydney, University of Melbourne, Swinburne University of Technology, Monash University, Macquarie University, CSIRO, The Dark Energy Survey (~480 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 Anglo-Australian Telescope to gather thousands of spectroscopic redshifts to complement the photometric Dark Energy Survey. Host-galaxy redshifts for Type Ia supernovae (SN Ia) will facilitate construction of the largest SN Ia Hubble diagram to date, while repeat spectroscopy of high-redshift active galactic nuclei (AGN) may make it possible to use AGN reverberation mapping for standard-candle cosmology beyond a redshift of two. In 2017 the DES Collaboration meeting was held in Brisbane.

Large Synoptic Survey Telescope

Institutions: the Large Synoptic Survey Telescope (comprising more than 30 member organisations), Australian Astronomical Observatory 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 slated to begin full scientific operations around 2020. In 2017 the Australian Astronomical Observatory and CAASTRO worked together to engage the whole Australian astronomy community in this project. In 2018 Astronomy Australia Limited (AAL) will take over the management of this agreement.

Murchison Widefield Array

Institutions: University of Melbourne, Australian National University, University of Sydney, Curtin University, Massachusetts Institute of Technology, Harvard-Smithsonian Center for Astrophysics, University of Washington, Arizona State University, Brown University, University of Toronto, University of Wisconsin–Milwaukee, Raman Research Institute

CAASTRO members make key contributions to the Epoch of Reionisation (EoR) project within the Murchison Widefield Array (MWA) collaboration. The EoR team will obtain a significant dataset with the MWA 128-tile array with the aim of either detecting or setting limits on the detection of the radio signals from neutral hydrogen at the Epoch of Reionisation. In 2016 the MWA was expanded, with 72 new antenna tiles installed in two sets of regular hexagons. These new antennas are specifically to improve the sensitivity of the MWA for the EoR power spectrum experiment. In 2017 CAASTRO members commenced an enhanced all-sky survey with the expanded MWA, using the newly commissioned long baselines. The new survey will build upon the successful GLEAM survey with improved sensitivity and resolution.

Stawell Underground Physics Lab

Institutions: University of Melbourne, Swinburne University of Technology, University of Adelaide, Australian National University, Australian Nuclear Science and Technology Organisation, Italian National Institute of Nuclear Physics (INFN), Princeton University

The design for the Stawell Underground Physics Lab (SUPL) began in 2015 and construction is expected to start in March 2018. Called SABRE (Sodium iodide with Active Background Rejection), the detection experiment – the first direct-detection experiment for dark matter in the Southern Hemisphere – is being developed by a consortium of institutions from Australia, the Italian National Institute of Nuclear Physics (INFN) and Princeton University. While this is primarily a physics experiment, CAASTRO astrophysicists joined the collaboration to model the expected kinetic-energy distribution of dark-matter particles and do related work. It is anticipated that an ARC Centre of Excellence, Particle Physics at the Cosmic Frontier will compete in the CE20 round, focusing on this dark matter research.

OUTREACH COLLABORATIONS

Astronomy Weekend and *Astronomer in Residence* at Uluru

In collaboration with Voyages Indigenous Tourism Australia, CAASTRO again had "Astronomers in Residence" at Uluru for the majority of the months in the year. We also held our fourth *Uluru Astronomy Weekend*, where CAASTRO team members gave presentations about the Universe and offered insights into current astrophysical research.

Planetarium show and educational resources

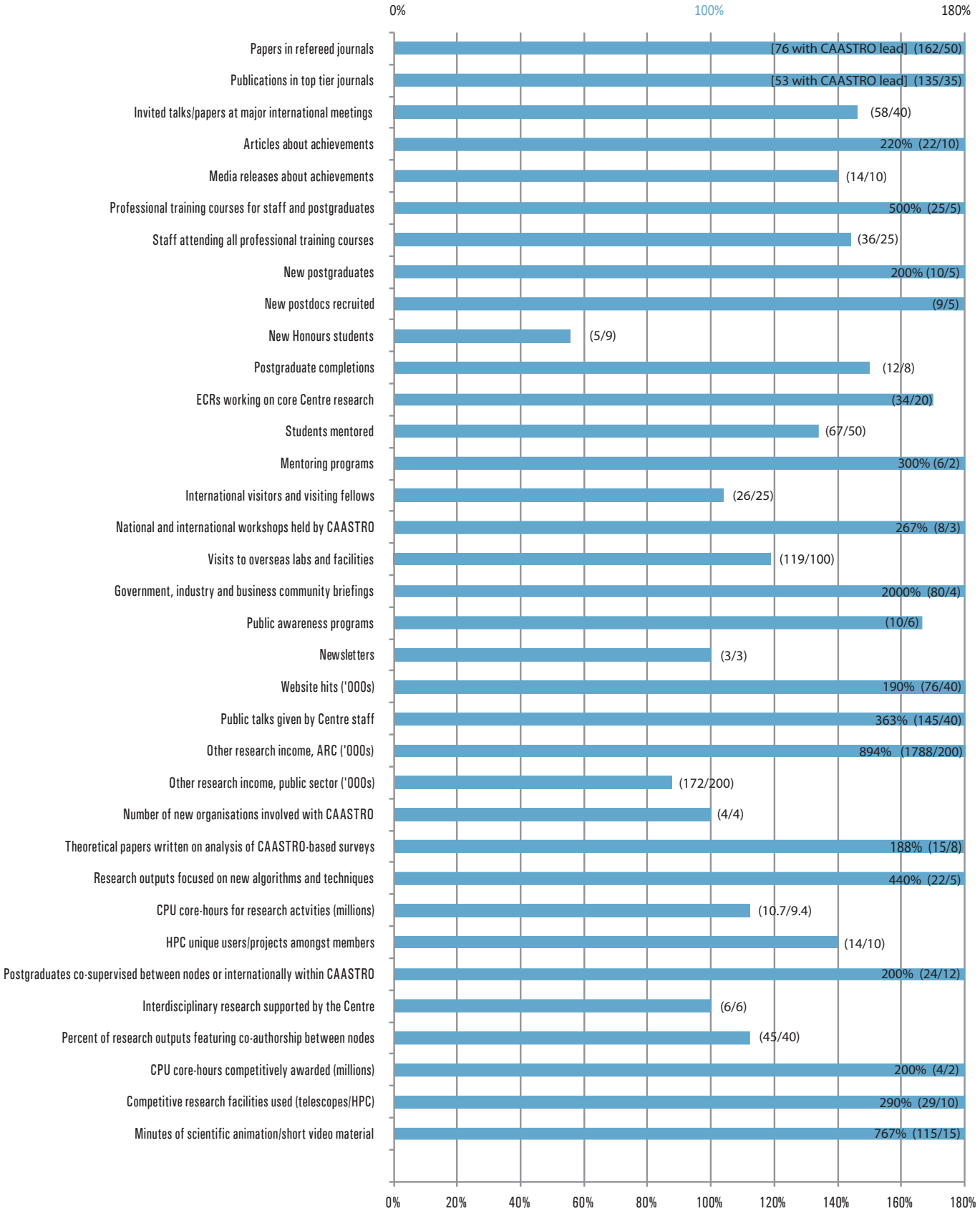
With the view that CAASTRO all-sky data is most naturally presented on a domed screen, CAASTRO entered into a collaboration with Museum Victoria (MV) for the production of a planetarium show. The show was launched in early 2016, and the show is still running regularly in many locations. CAASTRO Education and Outreach has worked closely with the MV Astronomy and Space Sciences team to create educational resources, both hands-on and digital, that tie in with both the show and the Australian curriculum.

Science writing for younger audiences

CAASTRO Education and Outreach has worked with freelance science-communication professionals in Perth to create the *Bright Stars* school calendar and a comic book, "The cosmic adventures of Alice and Bob". *Bright Stars* features the personal profiles of our researchers and their advice to high-school students, which we hope will spark their interest in astronomy. The calendar was produced in collaboration with CAASTRO's outreach partner *Telescopes in Schools* and is being distributed to Australian high schools as a free resource. The comic book was launched in March 2017: it too was distributed for free, to all Australian primary and many combined schools. Both resources will be major legacy products of the CAASTRO Education and Outreach portfolio.

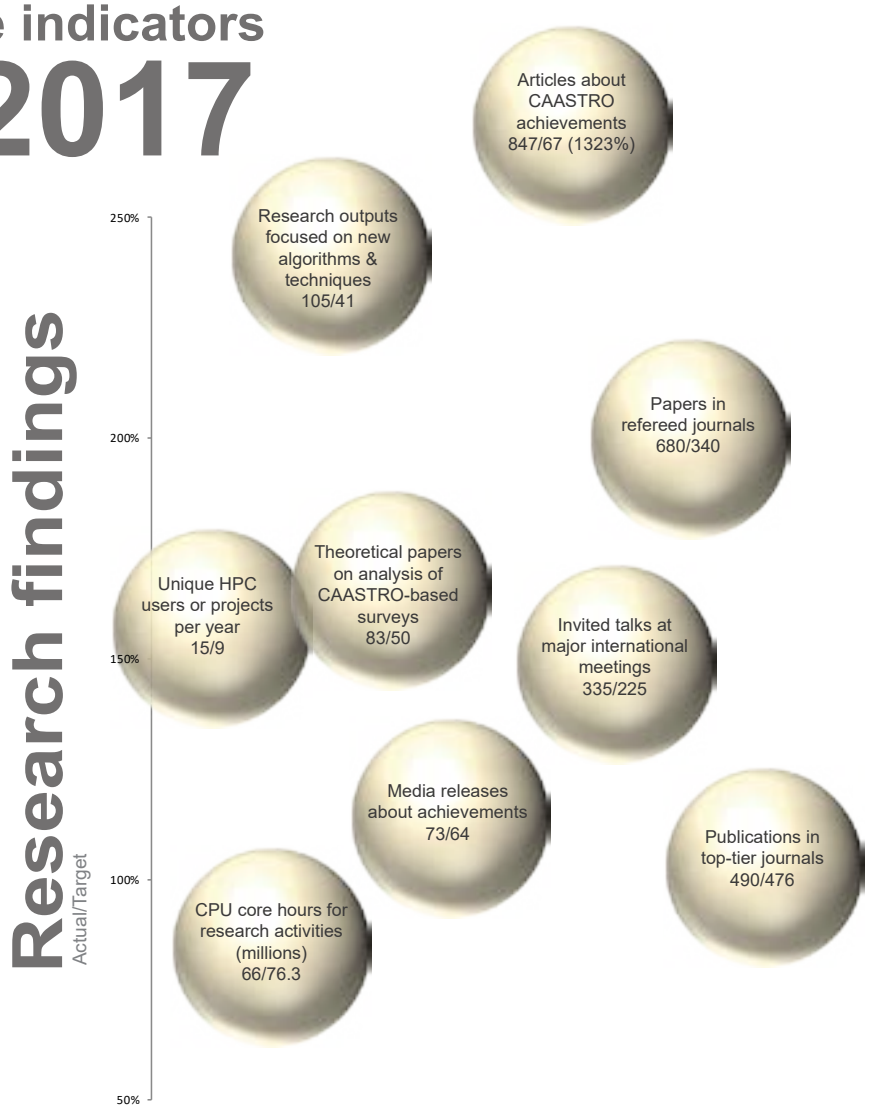
KPI DASHBOARD

January – December 2017

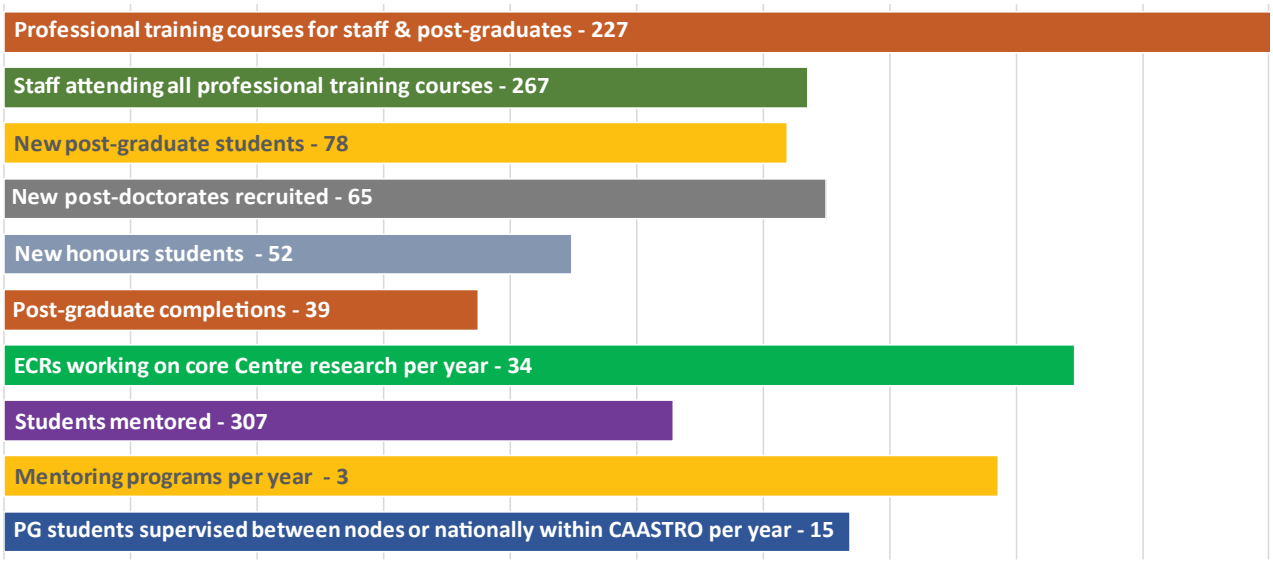


* Nature; Science; Annual Review of Astronomy & Astrophysics; The Astronomy & Astrophysics Review; Physical Review (including Letters) The Astrophysical Journal (including Supplemental Series and Letters); The Astronomical Journal; Monthly Notices of the Royal Astronomical Society (including Letters); Astronomy & Astrophysics (including Letters and Short Communications etc.); Journal of Cosmology and Astroparticle Physics

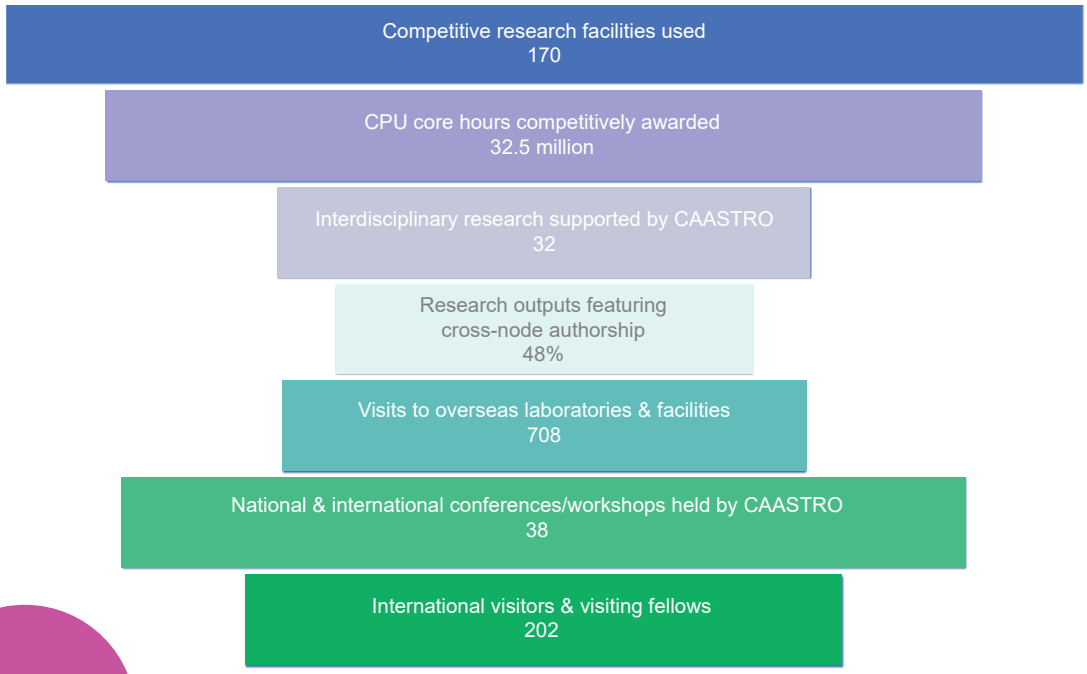
Key performance indicators 2011–2017



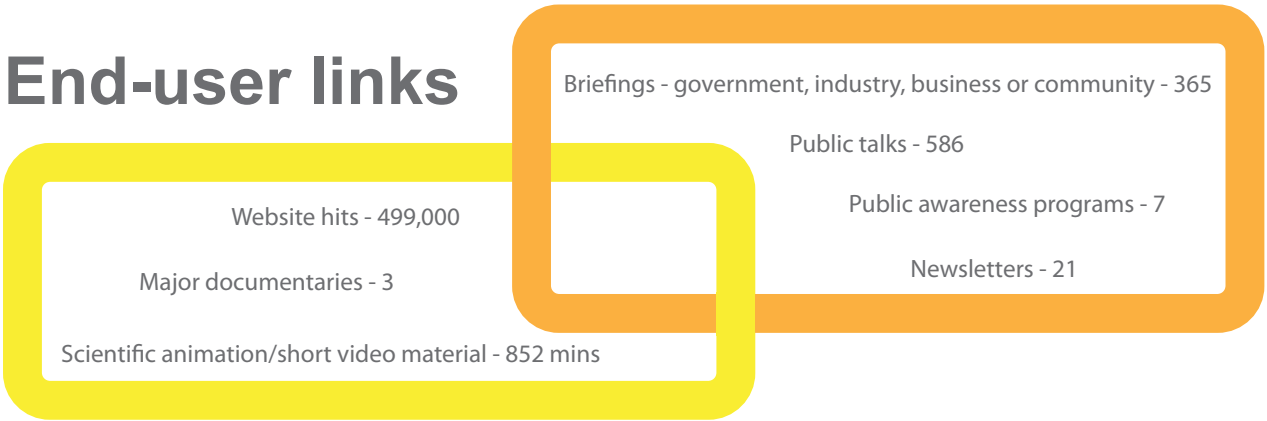
Research training & professional education



Links & networks



End-user links



FINANCIAL STATEMENTS

CAASTRO FINANCIAL REPORT 2017

INCOME

	2011	2012	2013	2014	2015	2016	2017 INCOME	ACTUALS	2018 INCOME	ESTIMATED
ARC Income	$3,000,000	$2,800,000	$3,100,000	$3,100,000	$3,100,000	$2,800,000	ARC Income	$2,700,000	ARC Income	$-
ARC Indexation	$47,431	$153,527	$295,786	$398,406	$461,065	$471,130	ARC Indexation	$501,614	ARC Indexation	$-
Node Contributions	$912,272	$1,039,569	$842,002	$1,206,663	$997,980	$1,059,247	Node Contributions	$980,191	Node Contributions	$-
Other Grants			$750,000	$1,264,437						
Other	$747,294	$13,685	$28,206	$296,930	$301,210	$152,457	Other	$260,455	Other	$84,534
Grants won[¥] (and correction to 2011)	$400,000		-$400,000							
Total Income	**$5,106,997**	**$4,006,781**	**$4,615,994**	**$6,266,436**	**$4,860,255**	**$4,482,834**	**Total Income**	**$4,442,260**	**Total Estimated Income**	**$84,534**
Carry Forward	$-	$2,930,552	$2,967,985	$3,037,571	$3,456,823	$3,184,858	Carry Forward	$2,736,186	Carry Forward	$1,734,744
Total Funds Available	**$5,106,997**	**$6,937,333**	**$7,583,979**	**$9,304,007**	**$8,317,078**	**$7,667,692**	**Total Funds Available**	**$7,178,446**	**Total Estimated Funds Available**	**$1,819,278**

*Other income includes CAASTRO workshop income/sponsorship, Secondments (CSIRO, AAO), reimbursement from TAIPAIN project

[¥] Includes NSW SLF Grant Part II, DIISR Travel Grants and LIEF Grant won by UWA

*** ANU contributed remaining 2015 funds of $84,215 in Jan 2016

EXPENDITURE

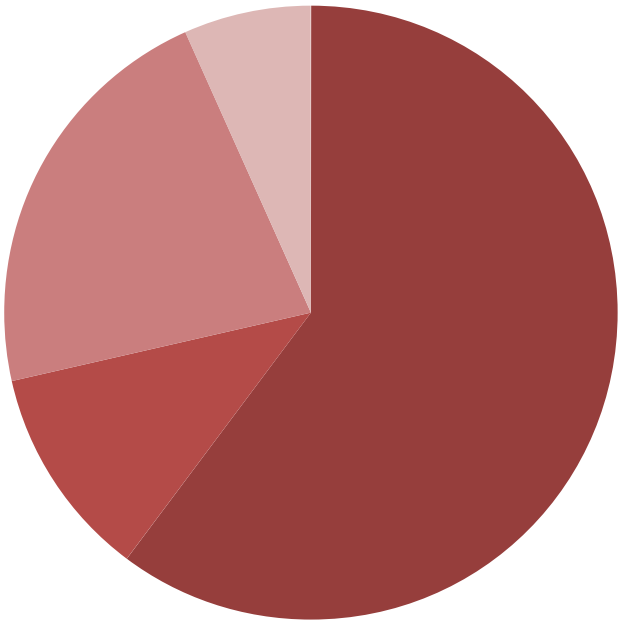
	2011	2012	2013	2014	2015	ACTUAL	2017 EXPENDITURE	ACTUALS	2018 EXPENDITURE	ESTIMATED
Salaries	$1,467,096	$2,807,859	$2,875,061	$3,320,256	$3,874,054	$3,708,004	Salaries	$4,034,098	Salaries	$1,477,028
Travel, Accommodation and Conference	$363,516	$503,587	$778,788	$810,779	$831,743	$1,018,045	Travel, Accommodation and Conference	$877,219	Travel, Accommodation and Conference	$188,000
Marketing & Outreach	$124,914	$139,732	$20,336	$92,675	$133,937	$165,440	Marketing & Outreach	$233,694	Marketing & Outreach	$20,000
Operations & Maintenance	$103,342	$81,706	$56,535	$124,237	$66,916	$108,392	Operations & Maintenance	$174,198	Operations & Maintenance	$46,000
Equipment	$102,993	$145,790	-$59,721	$29,891	$24,157	$32,674	Equipment	$9,316	Equipment	$30,000
PhD Support	$5,709	$101,763	$126,522	$201,402	$182,211	$111,613	PhD Suppport	$115,071	PhD Suppport	$58,250
Research materials/ Experiments	$8,874	$188,911	$5,766	$3,507	$19,202	$13,266	Research materials/ Experiments	$106	Research materials/ Experiments	$-
Corrections			-$6,879			-$225,928				
2013 Grants **			$750,000	$1,264,437						
Total Expenditure	**$2,176,445**	**$3,969,348**	**$4,546,408**	**$5,847,184**	**$5,132,220**	**$4,931,506**	**Total Expenditure**	**$5,443,702**	**Total Estimated Expenditure**	**$1,819,278**

Balance	**$2,930,552**	**$2,967,985**	**$3,037,571**	**$3,456,823**	**$3,184,858**	**$2,736,186**	**Balance**	**$1,734,744**	**Estimated balance**	**$0**

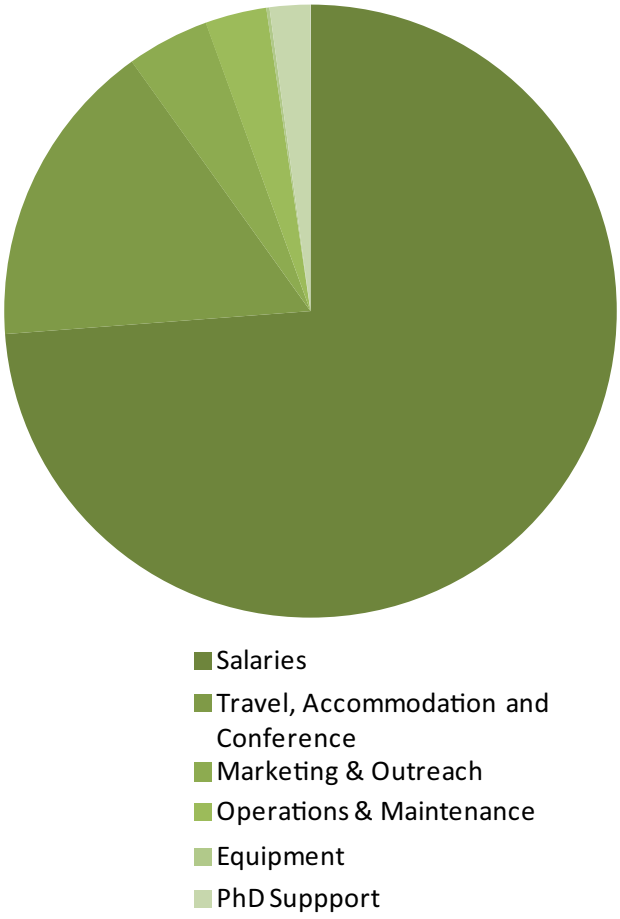
** LIEF, SIEF & AMSPP Grants have been reported as fully expensed in 2014, although LIEF Grant to be spent over 5 years, SIEF Grant to be spent over 36 months and AMSPP Grant to be spent over 2 years.

` Credit for non-ARC salary expenses - Collaborations

2017 INCOME



2017 EXPENDITURE



CAASTRO IN-KIND REPORT JANUARY - DECEMBER 2017	
University of Sydney	$570,305
University of Western Australia	$336,117
University of Melbourne	$167,423
Swinburne University of Technology	$553,809
Australian National University	$277,199
Curtin University of Technology	$317,131
CSIRO	$3,920,194
Australian Astronomical Observatory	$1,805,117
Max Planck Institute for Radio Astronomy	$146,696
California Institute of Technology	$134,673
The University of Oxford	$53,792
Durham University	$202,108
Max Planck Institute for Extraterrestrial Physics (MPIEP)	$8,500
The University of Arizona	$160,000
The University of Toronto	$86,300
Laboratoire de Physique Nucléaire et de Hautes Énergies	$160,088
National Computational Infrastructure	$270,000
Raman Research Institute	$1,000,000
University of Queensland	$123,977
Total In-Kind Contributions	**$10,293,428**

GRANTS WON BY CAASTRO MEMBERS IN 2017

ARC Future Fellowship
Explosive evidence: connecting stellar abundances to supernova progenitors.
This project aims to determine the evolutionary scenarios of thermonuclear supernovae through numerical simulations. Supernova explosions create heavy elements, such as iron, that enable life on Earth, and are instrumental in proving that the Universe is expanding at an accelerating rate. For all their importance, the nature of their progenitors is still a mystery, which has implications for many fields of astrophysics. Through building inter-institutional and international collaborations, the project is expected to determine where, when, and how often these explosions occur. Benefits will include development of new technological methods and exploitation of Australian-led survey data from national facilities.

FT170100243
$715,004
Chief Investigator: Ashley Ruiter

ARC LIEF
Doubling the power of a unique astronomical survey facility.
This project aims to double the number of fibres in the spectrograph on the UK Schmidt Telescope and so double the number of stars and galaxies that it can observe simultaneously. This would allow rapid and timely completion of two major projects: the Taipan galaxy survey would be first to test a potential discrepancy in the expansion rate of the universe that may signal new physics, while the FunnelWeb stellar survey would (in tandem with two space missions) identify potential nearby exoplanets and trace the history of the Milky Way. The benefits include high scientific impact for the two surveys, international showcasing of the Australian Starbug technology, and a national astronomical survey facility for the next decade.

LE180100009
$340,160
Chief Investigator: Matthew Colless
CAASTRO investigators: Scott Croom; Christopher Blake; Edward Taylor; Michael Drinkwater; Tamara Davis; Sarah Brough; Raymond Norris; and Andrew Hopkins

ARC Discovery Early Career Researcher Award
How galaxies lose their gas: jet-driven outflows in the distant Universe.
This project aims to make measurements of the impact that powerful radio jets, launched from supermassive black holes at the heart of galaxies, have on their host galaxy. Understanding how galaxies evolve remains a key unanswered question in astronomy. The project will map the interaction between radio jets and the cold gas in galaxies to further distances than ever before, shedding light on how jets impact their environment at a crucial point in the lifecycle of radio galaxies. These results will challenge our understanding of how galaxies have evolved over the past 8 billion years and provide a much-needed observational basis to inform future simulations of galaxy evolution.

DE180100448
$336,288
Chief Investigator: Elizabeth Mahony

ARC Discovery Project
Weighing the Universe using fast radio bursts.
Fast radio bursts are a newly-discovered astronomical phenomenon whose millisecond-timescale emission occurs at cosmological distances, rendering them exceptional probes of the matter that lies in intergalactic space. This project aims to measure the positions and obtain the distances to these bursts to make a direct measurement of the density of ordinary matter in the Universe, at least 50 per cent of which is believed to remain undetected in intergalactic space. This project will measure the distribution of this missing matter, and find how it has evolved throughout the history of the Universe. This will provide significant benefits, such as addressing two fundamental questions about our Universe: how much matter does it contain, and has a large fraction of it hitherto evaded detection in intergalactic space?

DP180100857
$367,072
Chief Investigator: Jean-Pierre Macquart
CAASTRO investigators: Keith Bannister

Other Public Sector Funding

The University of Sydney, Sydney Research Accelerator Fellowship
Tara Murphy
$50,000

Astronomy Australia Limited, eScience
Christian Wolf
$50,000

Astronomy Australia Limited, eScience, ADACS
Julie Banfield
$45,000

Ian Potter Foundation
Tamara Davis
$6,666

University of Queensland, Global Strategy and Partnerships Seed Funding Scheme
Tamara Davis
$20,000

CAASTRO PEOPLE


1


2


3


4


5


6


7


8


9


10


11


12


13


14


15

CAASTRO Executive

1. Elaine Sadler (Director)
2. Lister Staveley-Smith (Deputy Director)
3. Ramesh Bhat
4. Tamara Davis
5. Kate Gunn (Chief Operating Officer)
6. Jeremy Mould
7. Tara Murphy
8. Rachel Webster
9. Christian Wolf

Chief Investigators

10. Chris Blake
11. Matthew Colless
12. Scott Croom
13. Adam Deller
14. Brian Schmidt

Partner Investigators

15. Lindsay Botton


16


17


18


19


20


21


22


23


24


25


26


27


28


29


30

16. Warrick Couch
17. Roger Davies
18. Xiaohui Fan
19. Carlos Frenk
20. George Heald
21. Andrew Hopkins
22. Simon Johnston
23. Michael Kramer
24. Shri Kulkarni
25. Ue-Li Pen
26. Nicolas Regnault
27. Mara Salvato
28. Ravi Subrahmanyan
29. Bryan Gaensler

Associate Investigators

30. Joss Bland-Hawthorn


31


32


33


34


35


36


37


38


39


40


41


42


43


44


45


46


47

31. Jamie Bolton
32. Jeff Cooke
33. Michael Drinkwater
34. Minh Huynh
35. Claudia Lagos
36. Chris Lidman
37. Jean-Pierre Macquart
38. Martin Meyer
39. John Morgan
40. Danail Obreschkow
41. Chris Power
42. Ashley Ruiter
43. Emma Ryan-Weber
44. Ivo Seitenzahl
45. Robert Sharp
46. Stuart Sim
47. Cathryn Trott


48


49


50


51


52


53


54


55


56


57


58

48. Randall Wayth
49. Christopher Onken

CAASTRO Research Staff


59


60


61

50. Ixandra Achitouv
51. Jacobo Asorey
52. Julie Banfield
53. Julia Bryant
54. Seo-Won Chang
55. Rajan Chhetri
56. Clancy James
57. Francesco D'Eugenio
58. Paul Geil
59. Cullan Howlett
60. Shahab Joudaki
61. Hansik Kim
62. Emil Lenc
63. Jack Line
64. Christene Lynch


62


63


64


65


66


67


68


69


70


71


72


73


74


75


76


77


78


79


80


81

65. Katherine Mack
66. Elizabeth Mahoney
67. Anais Möller
68. Steven Murray
69. Bart Pindor
70. Kathryn Plant
71. Attila Popping
72. Daniel Price
73. Jonghwan Rhee
74. Marcin Sokolowski
75. Dan Taranu
76. Edoardo Tescari
77. Steven Tremblay
78. Brad Tucker
79. Laura Wolz
80. Ding Yan

CAASTRO Professional Staff

81. Kim Dorrell (Executive Officer, U. Melbourne)


82


83

82. Angela Dunleavy (Administrative Coordinator, Curtin U)
83. Wiebke Ebeling (Education & Outreach Manager, Curtin U)
84. Debra Gooley (Finance Officer, U. Sydney)
85. Helen Keys (Executive Assistant to Director U. Sydney)
86. Sue Lester (Administrator, Swinburne)
87. Jenny Lynch (School Education Officer, University of Sydney)
88. Janette Ellis (School Education Officer, University of Sydney)
89. Clare Peter (Administrative Officer, UWA)
90. Helen Sim (Public Relations Officer, U. Sydney)
91. Cristy Roberts (Administrator, ANU)
92. Kylie Williams (Events & Communications, U. Sydney)
93. Candy Wu (Administration Officer, U. QLD)


84


85


86


87


88


89


90


91


92


93

CAASTRO Affiliates

94. James Allison
95. Keith Bannister
96. Holger Baumgardt
97. Martin Bell
98. Brian Boyle


94


95


96


97


98

Not pictured

Tina Salisbury (Operations Coordinator, Curtin U)


99


100


101


102


103


104


105


106


107


108


109


110


111


112


113


114


115

99. Frank Briggs
100. Sarah Brough
101. Stephen Curran
102. Alan Duffy
103. Pascal Elahi
104. Jamie Farnes
105. Chris Flynn
106. Karl Glazebrook
107. Anne Green
108. Paul Hancock
109. Tao Hong
110. Carole Jackson
111. Andrew Jameson
112. Christopher Jordan
113. Anna Kapinska
114. Evan Keane
115. Clare Kenyon


116


117


118


119


120


121


122


123


124


125


126


127


128


129


130


131


132

116. Anthea King
117. Ben McKinley
118. Daniel Mitchell
119. Vanessa Moss
120. Ray Norris
121. David Parkinson
122. Signe Riemer-Sørensen
123. Antonia Rowlinson
124. Richard Scalzo
125. Nicholas Scott
126. Kimberly Steele
127. Edward Taylor
128. Steven Tingay
129. Syed Uddin
130. Willem van Straten
131. Mia Walker
132. Charlotte Welker


133


134


135


136


137


138


139


140


141


142


143


144


145


146


147


148


149

133. Ivy Wong

CAASTRO Students

134. Caitlin Adams
135. Matthew Alger
136. Kamran Ali
137. Per Andersen
138. Igor Andreoni
139. Dilyar Barat
140. Elise Beaufils
141. Stephanie Bernard
142. Shivani Bhandari
143. Mohit Bhardwaj
144. Jessica Bloom
145. Joshua Calcino
146. Manisha Caleb
147. Roderigo Canas Vazquez
148. Garima Chauhan
149. Qingxiang Chen


150


151


152


153


154


155


156


157


158


159


160


161


162


163


164


165


166

150. Alexandru Codoreanu
151. Christopher Curtin
152. Simon Deeley
153. Dougal Dobie
154. Luz Angela Garcia Penaloza
155. Marcin Glowacki
156. Jacob Golding
157. Guido Granda Munoz
158. Lucas Grimes
159. Katherine Harborne
160. Samuel Hinton
161. Harry Hobson
162. Fabian Jankowski
163. Ronniy Joseph
164. Dilpreet Kauer
165. Katharine Kelly
166. Jing Li


167


168


169


170


171


172


173


174


175


176


177


178


179


180


181


182


183

167. Lincheng Li
168. Rebecca McElroy
169. Samuel McSweeney
170. Bradley Meyers
171. Vincent Morello
172. Aina Musaeva
173. Daniel Muthukrishna
174. Sinem Ozbilgen
175. Fiona Panther
176. Aditya Parathasarathy Madapusi
177. Rhys Poulton
178. Fei Qin
179. Hao Qiu
180. Mahsa Rahimi
181. Mayuri Rao
182. Jarryd Rasti
183. Tristan Reynolds


184


185


186


187

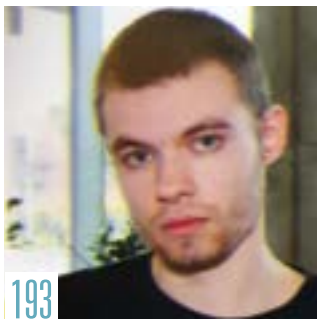

188


189


190


191


192


193


194


195


196


197


198


199


200

184. Jennifer Riding
185. Khaled Said
186. Diane Salim
187. Adam Schaefer
188. Henning Schmitz
189. Jacob Seiler
190. Natalia Eiré Sommer
191. Nicholas Swainston
192. Merryn Taylor
193. Ellert van der Velden
194. Matthew Varidel
195. Vivek Venkatraman
196. Charlotte Ward
197. Mengyao Xue
198. Bonnie Zhang
199. Xiang Zhang
200. Andrew Zic

GLOSSARY

ACRONYM	DESCRIPTION	DEFINITION
2MTF	Project	2MASS Tully-Fisher
6dFGS	Project	6-degree Field Galaxy Survey
AAL	Organisation	Astronomy Australia Ltd
AAT	Facility	Anglo-Australian Telescope
ACAMAR	Virtual Centre	Australia-ChinA ConsortiuM for Astrophysical Research
ASELL	Organisation	Advancing Science by Enhancing Learning in Laboratories
ASTRO 3D	Research Centre	ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions
ATCA	Facility	Australia Telescope Compact Array
AGN	Object	Active Galactic Nuclei
ASKAP	Facility	Australian Square Kilometre Array Pathfinder
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
DINGO	Project	Deep Investigation of Neutral 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 burst
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
GRB	Object	Gamma-Ray Burst

ACRONYM	DESCRIPTION	DEFINITION
HECTOR	Project	Follow-on IFU after SAMI
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)
LIGO	Facility	The Laser Interferometer Gravitational-Wave Observatory
LOFAR	Facility	Low Frequency Array telescope
LSST	Facility	Large Synoptic Survey Telescope
MOST	Facility	Molonglo Observatory Synthesis Telescope
MWA	Facility	Murchison Widefield Array
NCI	Facility	National Computational Infrastructure
NRAO	Facility	National Radio Astronomy Observatory, USA
NVSS	Project	NRAO VLA Sky Survey
OzDES	Project	Australian Dark Energy Survey
OzGrav	Research Centre	ARC Centre of Excellence for Gravitational Wave Discovery
PESSTO	Project	Public ESO Spectroscopic Survey of Transient Objects
PHISCC	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
SNe Ia	Object	Supernovae Ia
S-PASS	Project	S-band Polarisation All Sky Survey
SRG	Facility	Spektrum-Rötgen-Gamma, Russian satellite
TAIPAN	Facility	Transforming Astronomical Imaging surveys through Polychromatic Analysis of Nebulae
UKST	Facility	UK Schmidt Telescope
UTMOST	Facility	An upgrade of the Molonglo Observatory Synthesis Telescope
VAST	Project	Variable and Slow Transients
VLA	Facility	Very Large Array
WALLABY	Project	Widefield ASKAP L-Band Legacy All-sky Blind SurveY
WiggleZ	Project	A large-scale galaxy redshift survey
WSRT	Facility	Westerbork Synthesis Radio Telescope

CAASTRO
ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

School of Physics, Building A28
The University of Sydney
NSW 2006 Australia
PHONE +61 2 9351 2893
EMAIL info@caastro.org
WEB www.caastro.org

THE UNIVERSITY OF SYDNEY

THE UNIVERSITY OF MELBOURNE

THE UNIVERSITY OF WESTERN AUSTRALIA

Australian National University

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

International Centre for Radio Astronomy Research

Australian Government
Australian Research Council

NSW GOVERNMENT Trade & Investment