ASTRO 3D

ANNUAL REPORT 2017

ARC CENTRE OF EXCELLENCE
FOR ALL SKY ASTROPHYSICS IN 3D

Australian Government
Australian Research Council

ACKNOWLEDGEMENT

ASTRO 3D acknowledges the support of the Australian Research Council and all of the collaborating and partner institutions in the Centre.

OUR COLLABORATING UNIVERSITIES

Australian National University

Curtin University

The University of Western Australia

Swinburne University of Technology

The University of Melbourne

The University of Sydney

OUR PARTNER INSTITUTIONS

CSIRO

California Institute of Technology 1891

Chinese Academy of Sciences

University of Washington

University of Toronto

NCI National Computational Infrastructure

University of Oxford

AAO

ASTRON

Heidelberg Institute for Theoretical Studies HITS

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ACRONYMS AND ABBREVIATIONS

AAO	Australian Astronomical Observatory
AAT	Anglo Australian Telescope
AGN	Active Galactic Nuclei
ANU	The Australian National University
APOGEE	APO Galactic Evolution Experiment
ARC	Australian Research Council
ASKAP	Australian Square Kilometre Array Pathfinder
ASTRO 3D	Centre of Excellence for All Sky Astrophysics in 3 Dimensions
ASTRON	Netherlands Institute for Radio Astronomy
ASVO	All-Sky Virtual Observatory
CAASTRO	Centre of Excellence for All Sky Astrophysics
CitC	CAASTRO in the Classroom
CASDA	CSIRO ASKAP Data Science Archive
CEERS	Cosmic Evolution Early Release Science
CFHT	Canada France Hawaii Telescope
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DALiuGE	Data Activated Flow Graph Engine
DECRA	Discovery Early Career Researcher Award
DES	Dark Energy Survey
DIAP	Data Intensive Astronomy Program
DINGO	Deep Investigation of Neutral Gas Origins
EAGLE	Editor for the Astronomical Graph Language Environment
ECR	Early Career Researcher
EoR	Epoch of Reionisation
ESO	European Southern Observatory
FLASH	First Large Absorption Survey in HI
GALAH	GALactic Archeology with HERMES
GMT	Giant Magellan Telescope
GUI	Graphical User Interface
HERMES	High Efficiency and Resolution Multi-Element Spectrograph

HI	H one (neutral hydrogen)
HPC	High-Performance Computing
ICRAR	International Centre for Radio Astronomy Research
IGM	InterGalactic Medium
ISM	Inter-Stellar Medium
JWST	James Webb Space Telescope
LIEF	Linkage Infrastructure Equipment and Facilities grant
MOSFIRE	Multi-Object Spectrograph For Infra-Red Exploration
MPI	Message Passing Interface
MUSE	Multi-Unit Spectroscopic Explorer
MWA	Murchison Widefield Array
NCI	National Computational Infrastructure
NCSA	National Centre for Supercomputing Applications
NIR	Near Infra-Red
RSAA	Research School for Astronomy and Astrophysics
SAGE	Semi-Analytic Galaxy Evolution model
SAMI	Sydney-AAO Multi-object Integral field unit
SED	Spectral Energy Distribution
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared
SKA	Square Kilometre Array
STEM	Science Technology Engineering Mathematics
TAO	Theoretical Astrophysical Observatory
UCSD	University of California San Diego
UNSW	University of New South Wales
UV	UltraViolet
UWA	University of Western Australia
VLT	Very Large Telescope
VO	Virtual Observatory
WALLABY	Widefield ASKAP L-Band Legacy Allsky Blind Big Survey
WiFeS	WideField Spectrograph

DIRECTOR'S WELCOME AND REPORT

In the coming decade, astronomy will enter a new era of discovery, with the next generation of telescopes becoming operational. The Square Kilometre Array in Australia and South Africa, the Giant Magellan Telescope and the Extremely Large Telescope in Chile will come on-line in the early to mid-2020s.

Australia is at the forefront of technology for these telescopes, building the high-frequency array for the Square Kilometre Array and two of the first-light instruments for the Giant Magellan Telescope. These telescopes will be fundamentally 3D, creating not single images or single spectra, but data cubes which will yield vastly more information about the early universe than has ever been possible before.

The ASTRO 3D Research Centre of Excellence uses key 3D technology, Australia's prototypes for the Square Kilometre Array and the Giant Magellan Telescope, to train young astronomers for leading breakthrough programs on the next generation telescopes.

With this technology, we aim to understand the evolution of the matter, elements and light in the Universe from the Big Bang to the present day. To answer such enormous questions, we must combine Australian and International expertise in radio astronomy, optical astronomy and theory. This coming together of minds has already begun, at the Centre strategic planning retreat in November, through project busy weeks, cross-node meetings and visits and the strategic hires of young astronomers from overseas and within Australia. We have such a fantastic group of astronomers from diverse backgrounds and expertise that one can almost taste the excitement of discoveries to come through the Centre science.

LAUNCHING ASTRO 3D

The Centre launched in July, with an exciting opening event at Questacon. Highlights of the opening included a 3D movie of the highlights of ASTRO 3D science, created by Swinburne University, a hologram of the Giant Magellan Telescope to be built in Chile, and speeches by the ANU Vice-Chancellor Prof. Brian Schmidt, the ANU Deputy Vice Chancellor for Research, Prof. Margaret Harding, and Acting Director of the ARC, Ms Leanne Harvey. The evening closed with a talk by Prof Tim de Zeeuw, Chair of the ASTRO 3D International Advisory Board and then-Director General of the European Southern Observatory.

We aim to understand the evolution of the matter, elements and light in the Universe from the Big Bang to the present day.

BUILDING CRITICAL MASS

Between July 2017 and February 2018, ASTRO 3D recruited a critical mass of research and professional staff. In addition to our COO, Sheri Norton, we welcomed Denise Castle, Business Manager and Ingrid McCarthy, our Education, Outreach and Communications Manager. As at 28 February 2018 we have built a team of 165 highly talented people including 15 Chief Investigators, 16 Partner Investigators, 55 Associate Investigators, 5 Research Fellows, 13 staff researchers, 11 Affiliates, 38 PhD, Masters and Honours students, and 12 professional staff.

FOCUSING ON DIVERSITY

One of the goals of ASTRO 3D is to achieve 50% female representation at all levels of the Centre by 2021. New hires bring our female representation to 38% as at February 2018, ahead of the 30% KPI set for 2017. Our equity policies build on the Gender Action Toolkit created under CAASTRO and include family-friendly meeting times, all positions available as part-time, child care at all Centre-run and Centre-sponsored events, 50% female speakers at all Centre-sponsored meetings and conferences and 50% females nominated for awards/prizes.

Diversity in astrophysics has, to date, focused predominantly on achieving gender diversity to close the gap that has impacted the field. However, true diversity not only includes gender, but different ages, races, socio-economic backgrounds, physical ability, and sexual orientation. Our ASTRO 3D Equity and Diversity Committee, which is chaired by Prof. Rachel Webster from the University of Melbourne, aims to be ensure the Centre is fully inclusive through thoughtfully worded Centre policies, the Centre-wide mentoring program and Centre sponsored events, meetings and retreats. Prof. Webster gave a presentation at the Centre Retreat in November and the committee had its inaugural meeting in December. We look forward to the Equity and Diversity Committee's engagement as the Centre increases its activities and programs in 2018.

CONNECTING WITH OUR PARTNERS

Our Centre includes seven international partner institutions — University of Washington, Caltech, University of Toronto, the Heidelberg Institute of Advanced Studies, the ASTRON Institute in the Netherlands, Oxford University and the Chinese Academy of Sciences. In 2017, we connected with astronomers at the University of Washington, with Partner Investigator Julianne Dalcanton attending our Strategic Planning Retreat and the recent hire of University of Washington PhD Student Nell Byler into our Galaxy Evolution program at the ANU. Partner Investigator Rafaella Morganti (ASTRON) visited the University of Sydney, University of Western Australia and the ANU and continued her collaboration with Chief Investigator Elaine Sadler and her team. Partner Investigator Volker Springel from HITS was involved in a publication to be submitted shortly by ASTRO 3D PhD student Anshu Gupta, which utilizes Springel's Illustris Simulation to understand galaxy cluster formation and evolution observations using the Keck telescope.

NEW OPPORTUNITIES FOR AUSTRALIAN ASTRONOMY

2017 was a year of great opportunity for Australian astronomy with two Centres of Excellence in astrophysics launched — Ozgrav and ASTRO 3D. This is the first time that two Centres have operated in astronomy and we plan to hold joint seminars and workshops for PhD students as well as outreach activities. I will be meeting with Ozgrav Director Matthew Bailes regularly to discuss areas of potential collaboration and opportunities to help each Centre succeed.

Another landmark event in astronomy occurred in July 2017, when the federal government signed an agreement for the strategic partnership of Australia with the European Southern Observatory. This partnership provides Australian astronomers with access to the world's forefront telescopes, including the four 8m Very Large Telescopes (VLT) in Chile. The instrument suite on these telescopes is unparalleled and includes world-leading 3D instruments SINFONI and MUSE.

Several ASTRO 3D investigators and recently recruited postdoctoral researchers already have experience with the VLT and are poised to conduct their ASTRO 3D research programs on these cutting-edge telescopes.

The James Webb Space Telescope will be launching in 2019. In 2017, NASA announced the proposals which were awarded Early Release Science observations on the James Webb. Two ASTRO 3D researchers (myself and ASTRO 3D researcher and DECRA Rachel Livermore) are Co-Investigators in the Cosmic Evolution Early Release Science (CEERS) Survey, led by U.Texas Professor Steven Finkelstein. CEERS will study the youngest galaxies in the early universe to understand how fast stars formed in these early galaxies and how galaxies evolve over time. Congratulations to Steven, Rachel and the CEERS team for this fantastic achievement, and we look forward to seeing the first James Webb data for this program later in the Centre!

DEVELOPING OUR RESEARCH PROGRAMS

The ASTRO 3D research programs began in mid-2017 with the first meeting of the Science Management Committee, led by Deputy Director Stu Wyithe. The Science Management Committee oversees the science programs of the Centre, tracks progress against science goals, monitors new opportunities, and makes recommendations for funding to the executive. Each survey/project has developed a work plan for 2018, which has been reviewed by the Committee and then presented at the November Strategic Planning Retreat. These work plans include detailed descriptions of the goals to be reached in 2018, the research to be conducted by each investigator and research staff member, as well as the timing of workshops and busy weeks for the survey/projects in 2018. The Science Management Committee will meet again in May 2018 to review half-yearly progress.

Significant progress has been made in key research areas of the Centre, including the ASKAP Survey, the GALAH Survey, the Genesis Theory Program and the Galaxy Evolution Project. The ASKAP survey has begun taking data, with 3D images of nearby galaxies in neutral hydrogen for the WALLABY survey, led by Bärbel Koribalski. The WALLABY survey is already discovering new dwarf galaxies surrounding nearby larger galaxies.

The GALAH survey reached a major milestone, with half a million stars observed and analysed. The GALAH survey aims to observe a million stars in the Milky Way to track its formation using a technique called Galactic Archaeology. The half million stars have been released to the team to begin their detailed data analysis to chemically tag and match stars which may have formed together during the history of the Milky Way.

The Galaxy Evolution project has been observing distant galaxies using the Keck and VLT telescopes. ASTRO 3D Fellow Tiantian Yuan at Swinburne University has discovered the most distant spiral galaxy. This spiral galaxy is only 2 billion years old, and has primitive spiral arms, much earlier than expected by theoretical simulations.

The Genesis Theory Project has brought together a large group of theorists from around Australia to simulate galaxy formation and evolution and to produce 3D data cubes for direct comparison with the Centre's survey data. The team is using supercomputing time provided to the Centre by the National Computational Infrastructure in Canberra, and the project is well underway.

EDUCATION AND OUTREACH PROGRAMS

In 2017, ASTRO 3D began working with the Voyages Indigenous Tourism Group on the Uluru Astronomy programs, originally part of the CAASTRO Centre of Excellence. These programs support the Indigenous community in the Uluru region. ASTRO 3D will have an astronomer at Uluru full-time for 9 months of the year, on a fortnightly roster. The astronomers engage the public in astronomy through lectures, Q&A sessions, and public viewing nights. We will also coordinate the Uluru Astronomy Weekend where our leading astronomers engage in discussions about the structure and history of the Universe as well as participate in fun family activities. We are proud to be continuing these worthy and exciting programs.

ASTRO 3D will also be carrying on the work of CAASTRO with the ASTRO 3D in the Classroom program, which will include live streaming interactive videos where our astronomers discuss topics with school students, and STEM and entrepreneurship workshops.

BRING ON 2018!

I look forward with great anticipation to working with such a fantastic and engaged team in 2018. I can't wait to see the exciting scientific discoveries, to engage further with our international and national partner institutions, to drive diversity initiatives in astrophysics departments across Australia, and to develop innovative ways to inspire and train our young scientists.

Lisa Kewley
Centre Director

M51 spiral galaxy colliding with NGC 5195.
IMAGE CREDIT: vdHoeven NASA JPL Caltech R. Kennicutt (Univ. of Arizona)

ABOUT THE CENTRE

The ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D) commenced in July 2017 and is a Research Centre of Excellence led by the Australian National University (ANU) from its Mt Stromlo Observatory. The Centre is comprised of six collaborating universities — ANU, the University of Melbourne, the University of Sydney, Swinburne University of Technology, the University of Western Australia and Curtin University — and a number of world class Australian and international partners, including:

- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- The Australian Astronomical Observatory (AAO)
- National Computational Infrastructure (NCI)
- California Institute of Technology, USA (Caltech)
- University of Washington, USA (UW)
- University of Toronto, Canada
- Netherlands Institute for Radio Astronomy (ASTRON)
- Heidelberg Institute for Theoretical Studies (HITS)
- Chinese Academy of Sciences (CAS)
- University of Oxford, UK

The Centre has been funded over seven years with a $30.3m grant from the Australian Research Council (ARC), $8.4m in cash from the six Australian universities and $144m of in-kind resources from across the collaborating and partner institutions.

OUR VISION

To unlock the mysteries of the Universe using innovative 3D technology, while sharing the excitement and wonder of astronomy to inspire the broader community.

OUR MISSION

- To propel Australia to the forefront of astronomical research by combining Australia's radio, optical and theoretical expertise to understand the origins of our Universe and the galaxies within it.
- To train future Australian astronomers to lead breakthrough science on the next generation of telescopes.
- To share our discoveries and passion for research with the broadest possible audience and inspire the scientists of the future.

IMAGE CREDIT: ANU Research School of Astronomy and Astrophysics

"The ASTRO 3D Centre of Excellence is a magnificent achievement and underlines the strength of top-class research at ANU, particularly our Research School of Astronomy and Astrophysics. I look forward to the amazing new discoveries that will help the world better understand the Universe and our place in it."

Professor Brian Schmidt, ANU Vice-Chancellor, Astrophysicist. Awarded 2011 Nobel Prize in Physics

OUR STRATEGIC GOALS

1. TRANSFORM OUR UNDERSTANDING OF THE UNIVERSE AND HOW WE GOT HERE

- We will conduct ground breaking new 3 Dimensional surveys alongside an observationally-driven theory program with dedicated telescope and supercomputing facilities.
- We will develop new data intensive astronomy infrastructure to analyse the Petabytes of data that will ensue from the Square Kilometre Array.
- We will translate this research into high impact publications with broad and far-reaching international dissemination of our results, through our unified and cohesive scientific collaborations and our efficient administrative structure.

2. BUILD AND MAINTAIN THE INFRASTRUCTURE, SKILLS AND EXPERTISE REQUIRED TO MAXIMISE AUSTRALIA'S INVESTMENT IN THE NEW ERA OF MEGA-SCALE OPTICAL AND RADIO TELESCOPES

- Through our research programs, skills workshops, mentoring, leadership and succession planning, we will train young Australian scientists to drive the future world-leading programs on the next generation of telescopes.
- Through the long-term investment and continuity that ASTRO 3D provides, we will ensure that the Federal government's investment in the Square Kilometre Array and Giant Magellan telescopes is realised.

3. INSPIRE, TRAIN AND MENTOR THE NEXT GENERATION OF DIVERSE AUSTRALIAN SCIENTIFIC LEADERS

We will inspire students to study science, technology, engineering and mathematics (STEM) through new teacher education programs and our ambitious nation-wide public outreach campaigns.

4. PROVIDE YOUNG AUSTRALIAN SCIENTISTS WITH TRANSFERRABLE SKILLS FOR THE MODERN WORKFORCE

We will train the new generation of young Australian astrophysicists in transferrable skills including data intensive science, providing a broad range of career options outside astrophysics, including market analysis, population statistics, medical science, bioinformatics, genomics, and commercial sector data analytics.

5. CREATE AN INNOVATION CULTURE TO FACILITATE THE TRANSFER AND COMMERCIALISATION OF ASTRONOMICAL TECHNOLOGY TO OTHER DISCIPLINES

We will identify fresh ideas and aid the commercialisation of new astronomical technology through our Intellectual Property and Innovation Committee, comprised of experts in commercialisation.

WE HAVE LIFT OFF!

ASTRO 3D was officially launched on Wednesday 11 July 2017

Over 150 of our key stakeholders, including ANU Vice Chancellor, Professor Brian Schmidt, representatives from the Australian Research Council, the Department of Industry, Innovation and Science and partner universities, joined us at Questacon in Canberra to celebrate this important milestone. Also joining us was special guest, the then-Director General of the European Southern Observatory and Chair of our International Advisory Board, Professor Tim De Zeeuw.

PICTURED AT THE LAUNCH, FROM TOP TO BOTTOM ARE: Centre Director, Professor Lisa Kewley and Acting CEO of the ARC, Leanne Harvey. Professor Tim DeZueew. Professor Brian Schmidt

GOVERNANCE

We have established a collaborative and cohesive structure that will focus on the effective and efficient delivery of the Centre's Strategic Goals and meeting our Key Performance Indicators.

ADVISORY BOARDS

Two proactive and engaged external Advisory Boards will meet at least annually from early 2018 to provide support and advice to the Director and Executive Committee on the effectiveness of the Centre in reaching its scientific, technical, and education/outreach goals.

The ***INTERNATIONAL ADVISORY BOARD*** will focus on the effectiveness of the Centre in reaching its international goals and ensuring the Centre is known as a world-leading scientific research body. It will identify opportunities for international collaboration and innovation, provide feedback on the international competitiveness of the Centre, provide support in benchmarking against comparative centres around the world and contribute to the development of the Centre's strategic direction.

The Chair of the International Advisory Board is:

Professor Tim De Zeeuw, Professor of Theoretical Astronomy at Leiden University and former Director General of the European Southern Observatory

Board members include:

Professor Meg Urry, Israel Munson Professor of Physics and Astronomy; Director, Yale Center for Astronomy & Astrophysics; President, American Astronomical Society

Dr Linda Tacconi, Scientist, Max Planck Institute for Extraterrestrial Physics

Professor Lars Hernquist, Mallinckrodt Professor of Astrophysics, Harvard-Smithsonian Centre for Astrophysics

Professor Garth Illingworth, Professor, University of California Santa Cruz

The ***NATIONAL ADVISORY BOARD*** will focus on the effectiveness of the Centre in training the next generation of scientists, implementing public outreach programs and the strategic management of the Centre. Its role is to provide advice on the Centre's progress towards achievement of the Government's National Science and Innovation Agenda, advise on the development and delivery of education and outreach programs, and identify opportunities for further scientific collaboration and engagement with industry and government.

The Chair of the National Advisory Board is:

Dr Rob Vertessy, former Director of the Bureau of Meteorology

Board members include:

Dr Sue Barrell, Chief Scientist and Group Executive, Science and Innovation, Bureau of Meteorology

Sylvan Browne, Partner, FB Rice Law

Dr Bobby Cerini, Senior Manager Inspiring Australia and National Programmes, Questacon

Dr Tanya Hill, Senior Curator, Melbourne Planetarium

Professor Joan Leach, Director, Australian National Centre for the Public Awareness of Science

Sue Weston, Deputy Secretary, Department of Industry, Innovation and Science

EXECUTIVE MANAGEMENT COMMITTEE

The Executive Management Committee works collaboratively to oversee day to day operations, including financial and risk management, the development of the strategic plan and monitoring performance against agreed outcomes. All Collaborating Universities are represented on the Committee, which is comprised of:

- the Centre Director;
- the Centre Deputy Director;
- the Node Leaders at each collaborating university; and
- The Chief Operating Officer.

SCIENCE MANAGEMENT COMMITTEE

The Science Management Committee concentrates the Centre's extensive science survey management expertise and is tasked with:

- ensuring that ASTRO 3D meets its science goals;
- driving the translation of ASTRO 3D science into maximum measurable outcomes; and
- maintaining focus on training and supporting ECRs to lead Australia's future science programs on the next generation telescopes.

Membership of the Committee ensures that all scientific areas of the Centre are represented and includes:

- two Theme Leaders;
- two Thread Leaders;
- a collaboration leader; and
- two key Chief Investigators.

EQUITY AND DIVERSITY COMMITTEE

The Centre is committed, in the pursuit of its objectives, to equality of opportunity and to a pro-active and inclusive approach to equality, which supports and encourages all under-represented groups, promotes an inclusive culture and values diversity. The role of the Equity and Diversity Committee is to establish goals, provide advice and take action to ensure the Centre meets these objectives.

Membership of the Committee includes a broad cross-section of individuals from different levels, nodes, genders and nationalities within the Centre, a representative from CSIRO and the AAO and one independent member from within the astronomical community.

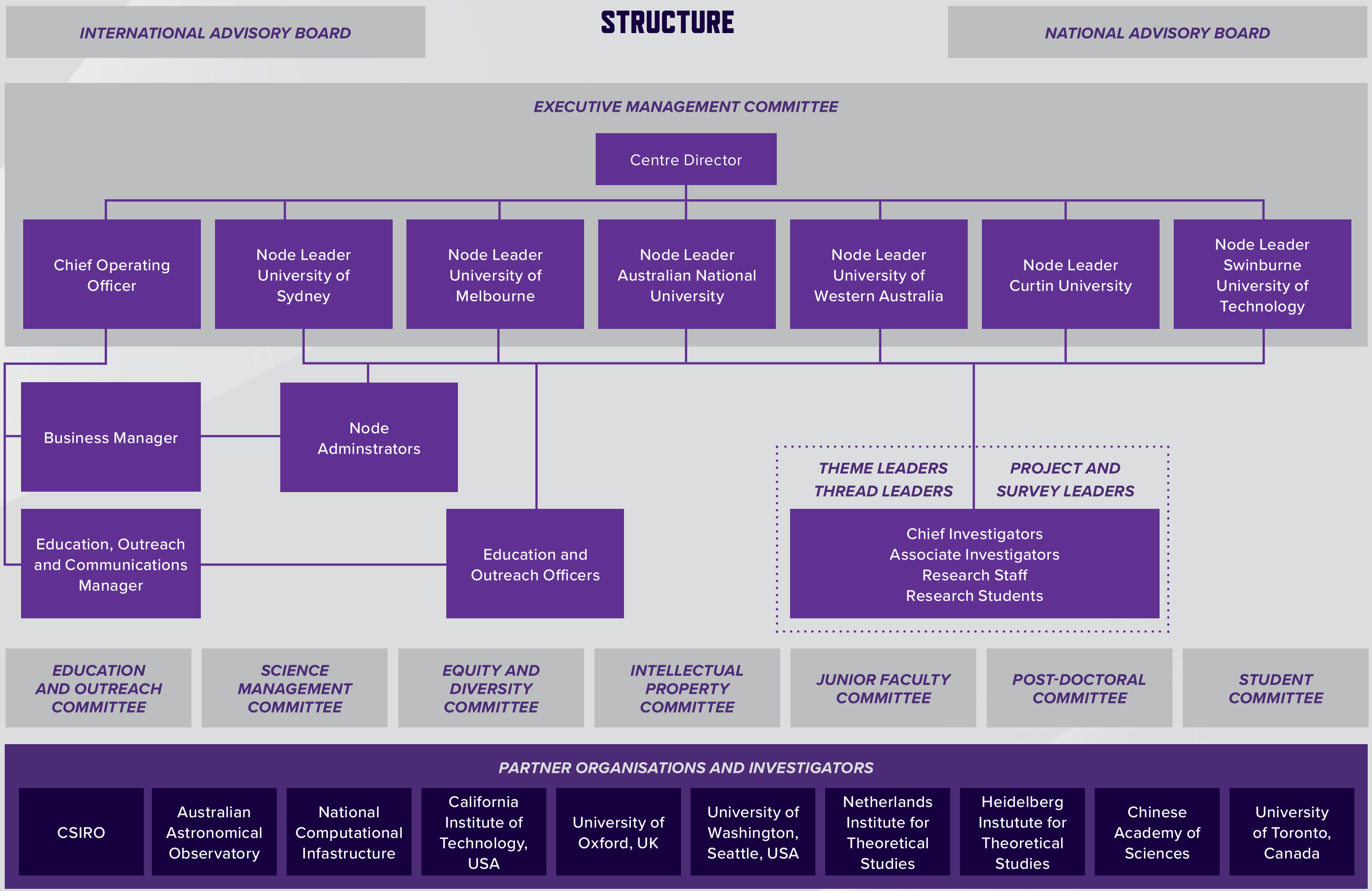
OTHER COMMITTEES

A number of other Committees will be formed in early 2018 to support the work of the Centre and its people. These include:

- Education and Outreach Committee
- Intellectual Property Committee
- Junior Faculty Committee
- Post-Doctoral Committee
- Student Committee

The Centre is committed, in the pursuit of its objectives, to equality of opportunity and to a pro-active and inclusive approach to equality.

STRUCTURE


INTERNATIONAL ADVISORY BOARD
NATIONAL ADVISORY BOARD
EXECUTIVE MANAGEMENT COMMITTEE
Centre Director
Chief Operating Officer
Node Leader University of Sydney
Node Leader University of Melbourne
Node Leader Australian National University
Node Leader University of Western Australia
Node Leader Curtin University
Node Leader Swinburne University of Technology
Business Manager
Node Adminstrators
Education, Outreach and Communications Manager
Education and Outreach Officers
THEME LEADERS THREAD LEADERS
PROJECT AND SURVEY LEADERS
Chief Investigators
Associate Investigators
Research Staff
Research Students
EDUCATION AND OUTREACH COMMITTEE
SCIENCE MANAGEMENT COMMITTEE
EQUITY AND DIVERSITY COMMITTEE
INTELLECTUAL PROPERTY COMMITTEE
JUNIOR FACULTY COMMITTEE
POST-DOCTORAL COMMITTEE
STUDENT COMMITTEE
PARTNER ORGANISATIONS AND INVESTIGATORS
CSIRO
Australian Astronomical Observatory
National Computational Infastructure
California Institute of Technology, USA
University of Oxford, UK
University of Washington, Seattle, USA
Netherlands Institute for Theoretical Studies
Heidelberg Instutute for Theoretical Studies
Chinese Academy of Sciences
University of Toronto, Canada

OUR PEOPLE

FROM LEFT: Sheri Norton, Lisa Kewley, Denise Castle and Ingrid McCarthy

MANAGEMENT

PROF LISA KEWLEY
CENTRE DIRECTOR

Lisa brings not only an exceptionally high international profile but also extensive strategic planning experience and broad research management expertise to ASTRO 3D.

Skilled at creating world-class and diverse teams across multiple countries and institutions, she spent more than a decade overseas, developing in excess of 200 international collaborators. While in the US, Lisa led a series of successful NASA and National Science Foundation programs, heading up a large team across six countries in an ambitious program to measure the chemical history of galaxies utilising the world's largest telescopes.

Lisa has been instrumental in building long-term research capacity for Australian astronomy and was one of five editors of the 2015-2026 Australian Astronomy Decadal Plan.

Prior to her role as ASTRO 3D Director, Lisa was Associate Director of the ANU Research School for Astronomy & Astrophysics and played an active role on the Advisory Committee for the Anglo Australian Observatory, the Science Steering Committee for the Keck Observatory in Hawaii, and the Optical Telescopes Advisory Committee. She was also a Board Director of Astronomy Australia Limited and currently chairs the Australian Academy of Science National Committee for Astronomy.

SHERI NORTON
CHIEF OPERATING OFFICER

Sheri joined ASTRO 3D in early 2017 and brings a wealth of senior management experience in both corporate and operational roles across a range of sectors including government, banking and property, not for profit and education.

Sheri's key strengths in governance, strategy and policy development, business planning, resource management, financial management, performance reporting and service delivery have been acquired working for such organisations as Macquarie Bank, Westfield, Red Nose, Yass Valley Council and the University of NSW.

She has a Bachelor of Economics Degree in Accounting and Financial Management and a Masters' Degree in Commercial Law.

INGRID MCCARTHY
EDUCATION, OUTREACH AND COMMUNICATIONS MANAGER

Ingrid came to ASTRO 3D in late 2017 after three years with the Inspiring Australia program in the ACT building connections to foster public participation in STEM and innovation through entrepreneurship.

Ingrid has formal qualifications in Science, Education and Gifted Education. She is skilled at developing STEM education programs, both in schools and through extracurricular programs such as STEM Sells, CSIRO's Discovery Centre and NSW National Parks and Wildlife Service. She also has significant experience in developing outreach and community programs such as National Science Week events and the NSW Rivercare program.

Her role focusses on driving connections between ASTRO 3D research and the broader community through education and outreach.

DENISE CASTLE
BUSINESS MANAGER

Denise joined ASTRO 3D in late 2017, after three years with the ANU's National Security College, Crawford School of Public Policy. The college is a joint venture between the ANU and Australian Government, and conducts programs relating to national security policy including postgraduate education, executive and professional development courses, research and outreach. Denise was responsible for the development of budgets, analysis of unit costs and financial reporting for each area of the college.

Her qualifications include a Masters in Professional Accounting and she has substantial experience in both financial and management accounting, gained across the education, health and finance sectors in Australia and the UK. This experience includes financial reporting and analysis, strategic planning, budget development, implementation and analysis and policy and process development.

CHIEF INVESTIGATORS

PROF MARTIN ASPLUND

Institution: ANU

Project Lead: The First Stars

Survey Lead: GALAH

Professor Martin Asplund is an international leading authority in stellar/solar astrophysics, Galactic astronomy and the origin of the elements.

Martin and his First Stars team are using the ANU SkyMapper telescope to identify stars from the very first stellar generations in the Universe which have survived to the present day and now inhabit our Milky Way Galaxy. In conjunction with the Genesis Simulations, his time is spent analysing how the First Stars produce the chemical elements and how they enrich and ionise their surrounding environment.

He is also brings mentoring abilities to train young researchers to lead programs on the next generation of telescopes.

PROF JOSS BLAND-HAWTHORN

Institution: University of Sydney

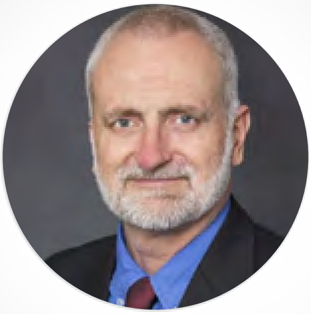
Collaboration Leader

Survey Lead: GALAH

Professor Joss Bland-Hawthorn is an ARC Laureate Fellow renowned for innovative and broad-reaching science of both theory and observational astronomy, covering optical, infrared and radio astronomy. Joss also develops astronomical instrumentation, having developed SAMI and HERMES instruments that will be used in the SAMI and GALAH surveys.

Joss is leading the GALAH survey to trace the chemical and mass assembly history of the Milky Way. In combination with the Genesis dynamical models, Joss is untangling the many complex processes involved in shaping a typical spiral galaxy like ours.

He is also driving the KPIs to identify the science areas that require more collaboration. He is prioritising visits for these areas, identifying, and directing key participants to facilitate and encourage collaboration.



PROF MATTHEW COLLESS

Institution: ANU

Survey Lead: SAMI/HECTOR

Professor Matthew Colless is Director of the Research School for Astronomy and Astrophysics (RSAA) at the ANU. He plays a significant role in supporting ASTRO 3D, as RSAA provides some of the Centre's key facilities, through the wide-field optical capabilities of the SkyMapper Telescope and through the ANU's collaboration with the Keck Observatory.

Matthew has made major contributions to astronomical research in the fields of galaxy evolution, clusters of galaxies, the large-scale structure and motions of galaxies, and observational cosmology. As part of ASTRO 3D, he is leading a research team to investigate how matter aggregated to form galaxies and the role of the environment in galaxy formation.

He is also using data from the SAMI and HECTOR instruments to explore the dynamical scaling relations of galaxies.

PROF SCOTT CROOM

Institution: University of Sydney

Survey Lead: SAMI/HECTOR

Professor Scott Croom brings over a decade of experience leading large spectroscopic surveys to ASTRO 3D.

Scott leads the SAMI and HECTOR surveys. SAMI results include new insights into galaxy scaling relations, the discovery of outflows in star-forming galaxies, and greater understanding of the formation mechanism behind dispersion dominated galaxies.

SAMI will be replaced by the HECTOR spectrograph in 2018. It will survey 100,000 galaxies within a five year period and be significantly faster than SAMI.

Scott is also facilitating collaborations with the Genesis team to compare the theoretical star formation history with observations.

PROF DARREN CROTON

Institution: Swinburne University of Technology

Project Lead: Genesis Simulations

Professor Darren Croton is an internationally known theoretical astrophysicist who works on the formation of galaxies in the nearby and distant Universe. He conducts massive cutting-edge supercomputer simulations and mines large observational data sets from some of the world's largest telescopes.

Darren is using his extensive experience working as a theorist within large survey teams to lead the development of new models, built with SAGE (the Semi-Analytic Galaxy Evolution). These models will be applied to the interpretation of the vast amounts of data ASTRO 3D astronomers will have on hand across the Centre.

Darren will also assist the Data Intensive Astronomy team to create a single, cohesive interface where astronomers can query both the Genesis Simulations and the observational data simultaneously.

PROF KARL GLAZEBROOK

Institution: Swinburne University of Technology

Project Lead: Galaxy Evolution

Professor Karl Glazebrook is the Director of the Centre for Astrophysics and Supercomputing at Swinburne University of Technology. He brings extensive expertise in the galaxy formation and evolution field, as well as substantial scientific and leadership experience to ASTRO 3D.

Karl is leading the Galaxy Evolution project, coordinating Keck observations, analysis and outputs for both the Origin of the Ionised Universe Theme and the Origin of Matter and the Periodic Table Theme.

He is also leading senior academics in large inter-University research collaborations, matching resources to skills and expertise across ASTRO 3D programs.

PROF LISA KEWLEY

Institution: ANU

Centre Director

Theme Leader: Origin of the Ionised Universe

Centre Director Lisa Kewley is an established world leader in the theoretical modelling and observation of star-forming and active galaxies. Her recent research combines stellar evolution and photoionization models with cosmological hydrodynamic simulations to predict how the ionising radiation changes in galaxies over the last 6 billion years, and has shown that the ionising radiation in galaxies changed dramatically with time.

Lisa's expertise covers both optical and radio astronomy, observation and theory, as well as understanding local and distant galaxies. She will bring this expertise into her Theme Leader role that connects the MWA Epoch of Reionisation survey with the ionizing radiation seen in the first galaxies to understanding how the ionizing radiation evolved across cosmic time to understanding the ionizing radiation in nearby galaxies with SAMI.

A/PROF CHRISTOPHER POWER

Institution: University of Western Australia

Project Lead: Genesis Simulations

Associate Professor Chris Power is a leading computational astronomer who is having a major impact in his field.

Chris is leading the development of Genesis Simulations that will track the birth, growth and the ultimate fate of galaxies from the earliest epoch of galaxy assembly, through the Epoch of Reionisation to the present day.

Chris models large N-body simulations (comprising of ~100 billion particles) to construct the most detailed and sophisticated prescriptions for galaxy formation that we have.

A/PROF EMMA RYAN-WEBER

Institution: Swinburne University of Technology

Project Lead: Galaxy Evolution

Associate Professor Emma Ryan-Weber is an ARC QEII Fellow. She is an international leader in the observation of metals in the Intergalactic Medium at high redshifts. Her pioneering near-infrared spectroscopic observation was the first to demonstrate the viability of detecting intergalactic metals towards the end of the Epoch of Reionisation.

Emma is overseeing the data mining of the SkyMapper survey to uncover new high redshift ($z>6$) quasars. She is also directly measuring the ionising radiation from galaxies at $z\sim3$–4.

PROF ELAINE SADLER

Institution: University of Sydney

Theme Leader: Origin of Matter and the Periodic Table

Survey Lead: ASKAP

Professor Elaine Sadler has extensive expertise in leading large radio astronomy surveys with extremely high international impact.

Elaine's research expertise covers both optical and radio astronomy, and she brings extensive science management experience, including the leadership of major galaxy surveys with significant international impact.

Elaine is also leader of the ASKAP FLASH survey.

PROF LISTER STAVELEY-SMITH

Institution: University of Western Australia

Thread Leader: Data Intensive Astronomy

Professor Lister Staveley-Smith is the Science Director at ICRAR/UWA and has over two decades of experience in leading major surveys on new radio telescope facilities and in developing and applying new software and computation techniques.

Lister is coordinating and leading the Data Intensive Astronomy observational teams at UWA, Curtin, AAO and the University of Sydney to ensure a cohesive Data Intensive Astronomy structure that facilitates the analysis of our Petabyte-scale datasets.

He is also co-leader of WALLABY, one of three ASKAP surveys which provide a critical, complementary suite of wide and deep coverage of galaxies through space and time.

A/PROF MICHELE TRENTI

Institution: University of Melbourne

Project Lead: First Galaxies

Associate Professor Michele Trenti is an ARC Future Fellow who has built a strong international reputation for combining theoretical simulations and observations to understand the first galaxies in the Universe.

Michele is using the current Hubble Space Telescope and will use the future James Webb Space Telescope to observe the chemical elements within the First Galaxies of the Universe. This involves understanding how much of the elements were produced in the first galaxies and whether they are blown out of these galaxies by massive galactic-scale winds from stars or supermassive black holes.

He is also connecting theorists with observers to understand galaxy formation from both a theoretical and observational practice, aiding in linking the First Galaxies observations with the deep understanding of galaxy evolution that ASTRO 3D will provide.

A/PROF CATHRYN TROTT

Institution: Curtin University

Project Lead: MWA EoR

Associate Professor Cathryn Trott is using the current and expanded MWA and in the future, the SKA to explore the evolution of ionised hydrogen in the early Universe.

Cath is leading the ICRAR MWA Epoch of Reionisation (EoR) project for the Origin of the Ionised Universe Theme. Cath will also use the supercomputing facilities at the Pawsey Centre for EoR data storage, triage and analysis, augmented by existing and future-developed sophisticated signal processing algorithms.

She is also assessing the scientific progress of the Centre against goals as part of the Science Management Committee, and developing her team with leadership and mentoring skills.

PROF RACHEL WEBSTER

Institution: University of Melbourne

Project Lead: MWA EoR

Professor Rachel Webster is a world expert in the field of reionisation and is currently the chair of the Board of Directors for Australian Astronomy Limited (AAL). She brings extensive leadership expertise to ASTRO 3D.

Rachel is leading the data reduction and analysis of the Epoch of Reionisation signals observed with the MWA. The extension of the MWA will break open the veil on the Epoch of Reionisation, allowing fundamental parameters of the Early Universe to be constrained.

She is also leading the Equity and Diversity Committee for ASTRO 3D.

PROF STUART WYITHE

Institution: University of Melbourne

Centre Deputy Director

Thread Leader: Genesis Simulations

Professor Stuart Wyithe is an international leading authority in the theoretical simulation of the Epoch of Reionisation and Gravitational Lensing.

Stuart's theoretical expertise spans the Epoch of Reionisation to first star and galaxy formation and evolution, and he also brings important strategic planning experience to ASTRO 3D.

Stuart is working closely with Lister Stavely-Smith to ensure the Genesis Simulations are incorporated into the Data Intensive Astronomy infrastructure, and mock data are produced for the Centre surveys.

PARTNER INVESTIGATORS

NAME	ORGANISATION	PROJECT/S
Roberto Abraham	University of Toronto	Galaxy Evolution
Douglas Bock	CSIRO	First Stars
Andrew Bunker	University of Oxford	First Galaxies, Galaxy Evolution
Warrick Couch	AAO	SAMI
Julianne Dalcanton	University of Washington	ASKAP, Galaxy Evolution
Roger Davies	University of Oxford	SAMI
Bryan Gaensler	University of Toronto	MWA EoR, ASKAP
Andrew Hopkins	AAO	SAMI, HECTOR
Evan Kirby	California Institute of Technology	First Stars, GALAH
Bärbel Koribalski	CSIRO	ASKAP
Di Li	Chinese Academy of Sciences	ASKAP
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Volker Springel	Heidelberg Institute for Theoretical Studies	Genesis
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Continued

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Continued

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Yisheng Qui	University of Melbourne	Genesis
Keven Ren	University of Melbourne	First Galaxies

Continued

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Clare Peter	University of Western Australia
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SCIENCE HIGHLIGHT

PUTTING THE '3D' IN ASTRO 3D

The ASTRO 3D flagship telescopes (AAT, ASKAP, MWA and Skymapper) are collecting unprecedented volumes of multi-dimensional datasets.

For each pixel received by the telescopes — whether it is visible light from the Optical Telescopes (AAT and Skymapper) or radio frequencies from ASKAP and MWA — we are also collecting detailed spectra, using instruments such as SAMI, to compile a "datacube". For the first time, ASTRO 3D astronomers will have a 3D understanding of the shape and composition of stars and galaxies in the Universe and how they have changed since the Big Bang.

These petabytes scale volumes of observational data being collected from our current cutting-edge telescopes (and our future next-generation telescopes like SKA and JWST) are also being fed into computer simulations. Using the super-computing facilities at NCI and Pawsey centre, our theoretical astronomers are developing data management systems and visualisation tools that produce models of Universe, star and galaxy formation, unlike anything we've been able to see before.

As a consequence of this cutting-edge 3D data and modelling, ASTRO 3D will be able to utilise tools such as Virtual Reality, Augmented Reality, 3D movies and planetarium shows, 3D printed models and files, coupled with links to school curriculum to help both the general public and students understand and appreciate the new era of discovery in astrophysics.

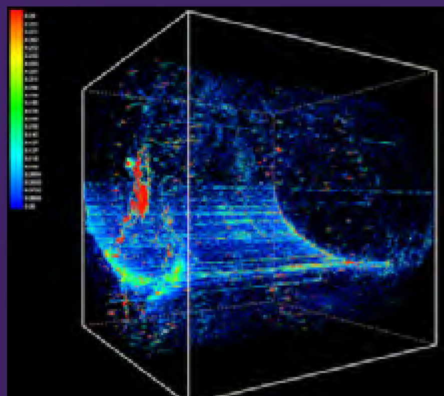


IMAGE CREDIT: Amr Hassan

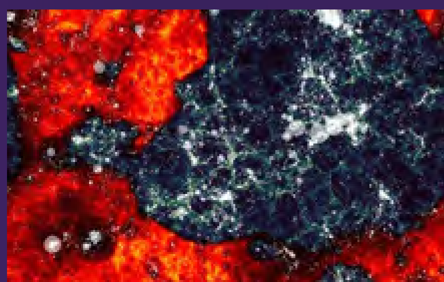


IMAGE CREDIT: Paul Geil

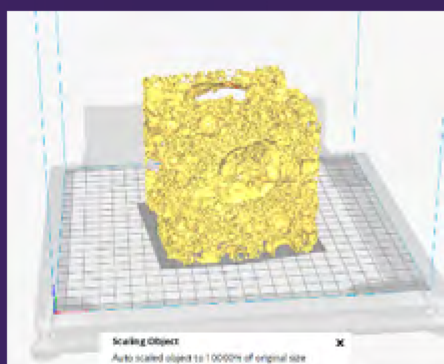


IMAGE CREDIT: Ingrid McCarthy and Simon Mutch

RESEARCH

RESEARCH THEMES

1. THE ORIGIN OF MATTER AND THE PERIODIC TABLE

Tracing the distribution of matter and chemical elements back to the earliest times in the Universe allows us to understand the birth of the first stars, the formation of the first galaxies, and the evolution of galaxies like our Milky Way. The *Origin of Matter and the Periodic Table* theme links ASTRO 3D researchers across many of our projects and surveys, allowing us to build a 3D picture of the formation and evolution of the universe that we see today. The questions that motivate our work include:

- How did structures in the Universe grow out of matter, forming the building blocks of galaxies like our Milky Way?
- What forces have shaped the accumulation and motion of matter in the Universe across space and time?
- How were the elements of the periodic table forged across space and time, and how were they assembled into galaxies like our Milky Way?

The oldest stars in our own Milky Way Galaxy provide a unique and detailed ‘fossil record’ of the buildup of the chemical elements over time. The GALAH survey led by CI Joss Bland-Hawthorn (University of Sydney) and CI Martin Asplund (ANU) will use the Hermes spectrograph on the 4m Anglo-Australian Telescope to measure the abundance of a range of chemical elements in a million individual stars. The project is off to a flying start, with chemical abundances already measured for over 400,000 stars, and a very active group working on analysis and interpretation of the data. These local measurements complement the observations of young galaxies in the very early Universe, which are being carried out by CI Michele Trenti (University of Melbourne) and colleagues with the Hubble Space Telescope as part of the ‘First Galaxies’ project.

Several ASTRO 3D projects are working together to understand how these first galaxies grow over cosmic time and are chemically enriched by multiple generations of stars. The Galaxy Evolution project led by CI Karl Glazebrook (Swinburne) tracks both the growth of galaxy mass and the changing star-formation rate in galaxies across a broad span of time, from the early Universe to the galaxies we see around us today. These researchers use some of the world’s largest and most powerful optical telescopes to probe faint and distant galaxies.

Their work is complemented by the ASKAP Surveys project led by CI Lister Staveley-Smith (UWA) and CI Elaine Sadler (University of Sydney), using the new wide-field Australian SKA Pathfinder (ASKAP) radio telescope to trace the neutral hydrogen gas within galaxies (the raw material from which new generations of stars can form) across almost eight billion years of cosmic time. AI Naomi McClure-Griffiths (ANU) and colleagues are investigating how galaxies grow through the accretion of gas from their surroundings and will use the Chinese FAST radio telescope to advance this work in the near future. All these projects are closely linked to the Genesis Simulations thread, led by CI Stu Wyithe (University of Melbourne), CI Chris Power (UWA) and CI Darren Croton (Swinburne University), which will develop *synthetic multi-wavelength datasets* that can be used to directly interpret the observations from our major 3D surveys.

Tracing the distribution of matter and chemical elements back to the earliest times in the Universe allows us to understand the birth of the first stars, the formation of the first galaxies, and the evolution of galaxies like our Milky Way.

2. THE ORIGIN OF THE IONISED UNIVERSE

During the infancy of the Universe, a watershed event dramatically changed the Universe from neutral and dark, to being almost completely ionized. This period is when the very first structures in the Universe formed. Despite its pivotal role, the Epoch of Reionisation is one of the least understood phases in the history of the Universe. The Epoch of Reionisation set the initial conditions for the formation and evolution of the galaxies that surround us today. The aims of this theme are to characterise the beginning and end of reionisation, identify the sources of reionisation, and track how these sources evolve across the subsequent 13 billion years of cosmic time.

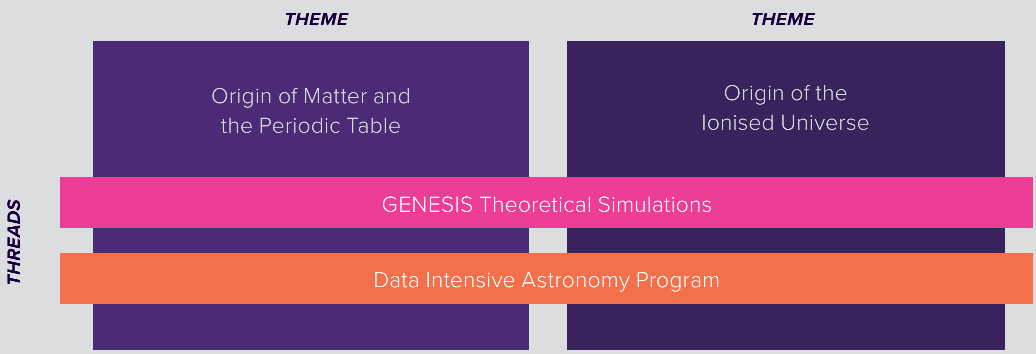
To reach these aims, we have brought together radio experts in 21cm tomography of the Epoch of Reionisation, experts in the optical observations of the first stars and the first galaxies in the Universe, and experts in the theory and observations of galaxy formation and evolution.

The beginning and end of reionisation are being probed for the first time with 21cm tomography with the Murchison Widefield Array in Western Australia. In November 2017, the Murchison Widefield Array (MWA) completed the building and deployment of equipment for its Phase Two expansion, funded by a $1M Australian Research Council (ARC) Linkage Infrastructure, Equipment and Facilities (LIEF) grant, and $1.2 million from partner institutions. The Phase Two array adds 128 new antenna stations, bringing the total number of antenna stations onsite in Western Australia, to 256.

The telescope array is now ten times more powerful in probing the Epoch of Reionisation. This project will formally become part of ASTRO 3D in March 2018, when we will begin processing two years of data, collected to test the pipelines and analysis required to detect the Epoch of Reionisation. Under ASTRO 3D, CIs Cath Trott and Rachel Webster and their teams will collect MWA data over a 5-year period, culminating in the deepest ever dataset with which to search for signals from the Epoch of Reionisation. Centre Deputy Director Stu Wyithe and his group at the University of Melbourne have begun preparing detailed theoretical predictions of the types of data cubes that one might see from the Epoch of Reionisation, as part of the ASTRO 3D Genesis thread.

CI Martin Asplund and his group aim to detect the First Stars in the Universe. He is using the Skymapper telescope at Siding Springs in Coonabarabran to detect first stars candidates, which will then be followed up using 8–10m telescopes such as the Very Large Telescopes at the European Southern Observatory.

As the first galaxies formed and evolved, the Hubble Space Telescope and the future James Webb Space Telescope will characterize the properties of the first galaxies in their natal environment. CI Michele Trenti and his survey team are leading this program. In 2017, Michele's team at the University of Melbourne began collaborating with Genesis theorists at the University of Western Australia to model the evolution of the first galaxies to understand what these galaxies might look like in surveys today.



SPOTLIGHT ON DR ROB BASSETT

FROM SWINBURNE UNIVERSITY OF TECHNOLOGY

"I watched the Hubble Space Telescope being launched when I was only four years old and the images from that continue to grab my imagination. I studied physics at high school and uni, but it was my long-time lab partner who convinced me to sign up for astrophysics towards the end of my studies."

"Now I'm researching understanding how high-energy radiation produced in galaxies escapes and reionised the neutral hydrogen gas in the Universe. My team at Swinburne has recently begun to uncover a sample of very distant, highly star-forming galaxies that we believe are the most likely candidates for ionizing the Universe. We are now collecting data to confirm our hypothesis about the high-energy radiation escaping from these galaxies."

"I think ASTRO 3D is an exciting new opportunity to bring together a number of groups trying to crack the burning questions facing astrophysics today and I'm looking forward to establishing a shared research framework that allows us to attack these questions from different points of view and using very different data and methods, together"

The ionizing radiation from distant galaxies is being analysed by Swinburne CI Emma Ryan-Weber and her team using data from the Keck Telescope in Hawaii. They are using absorption-lines from background quasars to provide a signpost for the conditions for early galaxy formation. The ionizing radiation in galaxies over the subsequent 12 billion years will be mapped across space and time by observing emission-lines with new sensitive NIR instruments on current 8–10m telescopes, followed by the GMT.

In 2017, the ANU Galaxy Evolution team, led by Centre Director Lisa Kewley developed new diagnostics to estimate the amount of ionizing radiation produced in galaxies over the past 12 billion years using optical and ultraviolet emission lines. These diagnostics are now ready to be applied to UV and optical data currently being collected from the Keck and VLT telescopes by the Galaxy Evolution team at ANU and Swinburne. In 2017, the Swinburne and ANU Galaxy Evolution teams collaborated through visits by ASTRO 3D postdocs and through discussion and strategic planning at the Annual Retreat in November. In 2018, the ANU team will train the Swinburne team in applying their theoretical models and diagnostics to their Keck data.

The SAMI team is mapping the ionizing radiation in 3-dimensions across nearby galaxies, providing a crucial local benchmark for the high redshift universe. In 2017, ASTRO 3D PhD student Henry Poetrodojo analysed the ionizing radiation in 25 SAMI galaxies. Henry will extend this work to the full SAMI dataset in 2018. The SAMI project formally becomes part of ASTRO 3D in March 2018.

In ASTRO 3D, these observational studies will be cemented with the Genesis cosmological hydrodynamic simulations and semi-analytic models that span the Epoch of Reionisation to the present day. By combining Australia's theoretical and multi-wavelength observational expertise with key instruments and telescopes available on the 2018–2025 timescale, Australia is primed to make a broad and major impact on our understanding of the ionized universe.

RESEARCH THREADS

1. GENESIS THEORETICAL SIMULATIONS

The ASTRO 3D Genesis Simulation program focuses on three key science areas:

- Simulating the birth of the first stars and their impact on early universe chemical enrichment, proto-galaxy formation, reionisation and the evolution of the IGM.
- Tracking galaxy growth through star formation and mergers, and the build-up of angular momentum at all galactic scales, leading to the emergence and evolution of large-scale structure and the epoch of quasars.
- Uncovering the history of the local galaxy population, including radio galaxies and AGN, by following the dynamical, stellar and chemical evolution of the galaxies across cosmic time to the present day.

These questions will be addressed through the concurrent development of a new generation of integrated N-body/hydrodynamical galaxy formation simulations coupled to sophisticated semi-analytic galaxy models, the "Genesis Suite". Genesis will be available to both the ASTRO 3D and wider astronomical community through an update to the Theoretical Astrophysical Observatory (TAO++), opening up Genesis to be easily usable to address all the key ASTRO 3D science goals.

The initial phase of the Genesis Simulations thread has focused on generating a suite of large N-body simulations that will be coupled to semi-analytical models to produce synthetic galaxy populations across cosmic time.

The first set of runs consist of volumes of between 100 Mpc/h and 300 Mpc/h on a side, with between approximately 10 and 200 billion particles, allowing us to reliably resolve low-mass dark matter halos of approximately 109 solar masses.

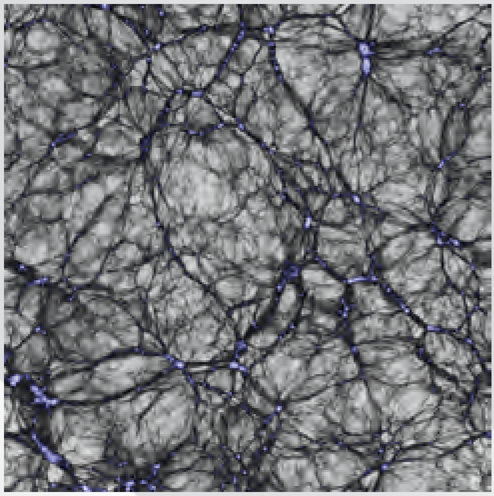


IMAGE CREDIT: Simulation run by the Genesis Team on NCI Raijin supercomputer

The runs have been designed to cater for a range of projects, from the Epoch of Reionisation to galaxy evolution with the HI and optical 3D surveys in the present-day Universe. An example of the hydrogen density field at z=15 is shown in the figure, colour coded according to projected hydrogen density. The white spheres are the first stars which ionise the surrounding hydrogen gas, making the universe transparent for the first time.

A key component of the initial phase has been to ensure that we have robust dark matter halo catalogues and assembly histories and that these couple properly to semi-analytical models. In particular, Genesis postdocs Pascal Elahi and Simon Mutch have worked closely together to ensure that results from Elahi's 6D phase space structure finder, VELOCIraptor, properly integrate into Mutch's semi-analytical model, MERAXES. MERAXES has been developed to predict self-consistently the structure of the neutral and ionized hydrogen density field produced by the sources of reionisation, and early results based on our test simulations suggest that we are now ready to exploit our science runs. One of the first theory projects we will tackle is to understand the relationship between the earliest sources of reionisation and the spatial distribution of their descendants in the present-day Universe.

In parallel to the N-body programme, the Genesis team has been preparing for the hydrodynamical zoom simulations of individual systems, ranging in mass from dwarf galaxies to galaxy clusters. The initial phase has focused on identifying interesting candidates and running dark matter only versions of approximately 10 systems spanning a range of masses.

Early in 2018, hydrodynamical versions of these will be run, including cooling, star formation, stellar feedback, AGN growth and AGN feedback, with a mass and force resolution that is comparable to recent studies in the literature. These zooms will form the foundations for improved treatments of chemical evolution and mixing.

SPOTLIGHT ON ASSOC. PROF CHRIS POWER

FROM THE UNIVERSITY OF WESTERN AUSTRALIA

"Growing up outside of Dublin, some of my earliest memories are of being very excited by the dark night skies, enchanted by the Moon and stars, rather than mundane fields and cows. I wolfed down books about the planets and stars, and I would freeze for hours during long, winter nights with my trusty binoculars. Shows like 'The Sky at Night', the Gitto mission to Halley's comet, Voyager and the launch of Hubble all sparked my love of exploring the great unknown of the Universe."

"My ASTRO 3D research uses powerful supercomputer models to understand the physical processes that govern the growth of galaxies over the lifetime of the Universe. I use these supercomputers as virtual laboratories, running numerical experiments to explore the changing rate at which stars are born out of cold gas and subsequently die in violent supernovae."

"We can build more accurate theories of galaxy formation and compare observations with realistic and testable predictions."

"My work on how X-ray binary stars interact with galaxy formation has been really interesting. We found that when the more massive star dies and forms a neutron star or black hole, it can gravitationally capture or pull in gas from its companion — and this turns out to be potentially how most small-mass galaxies (like our Milky Way) have formed."

"While ASTRO 3D has a broad and diverse set of science programmes, we are rapidly discovering the range of demands on the kind of theory and simulations support required."

"So we are developing tailored suites of simulations to match the needs of specific science programmes, which is challenging but rewarding!"

2. DATA INTENSIVE ASTRONOMY (DIA) PROGRAM

The Data Intensive Astronomy Program (DIAP) facilitates better access to tools, technology, infrastructure and training for ASTRO 3D researchers working with large datasets and in High-Performance Computing (HPC) environments. It does this by working with national infrastructure providers, and by the sharing of expertise between ASTRO 3D researchers. As much of the ASTRO 3D science involves world-leading surveys and large data sets, our ability to process our data in a timely and efficient manner is critical to our success.

The DIA Program is managing two key projects:

- **Data Flow and Process Management**
  This project aims to analyse data flow requirements of ASTRO 3D surveys and provide support for the implementation of optimized data transfer and storage paths. It will develop the Data Activated Flow Graph Engine (DALiuGE) and provide integration with existing pipelines for ASTRO 3D surveys.
- **Virtual Observatory (VO) and Theoretical Astrophysical Observatory (TAO)**
  The VO project aims to promote interoperability between the ASTRO 3D data sets that will exist on ASVO nodes, especially those of most interest to ASTRO 3D (ADC, CASDA, MWA, TAO). One of these nodes, TAO, is an online eResearch laboratory that allows ASTRO 3D researchers to construct their own mock light cones from a range of different simulation and galaxy formation model data, including Genesis, filter the output through virtual telescopes and download the results for their own scientific use.

The DIA program welcomed Manodeep Sinha as a simulations and data expert, based at Swinburne. Manodeep is an experienced astronomer in the areas of cosmology, galaxy evolution and statistics and is leading the use of TAO for ASTRO 3D and the Genesis simulations. Vitaliy Ogarko was appointed as ASTRO 3D Data Intensive Scientist to work on data flow and process management, based at UWA. Vitaliy is a computation physicist, with a background in condensed matter and geoscience.

The SAGE semi-analytic model was modified to accept the Genesis data format and tested on the halo merger trees to produce an initial set of mock predictions. PhD student Dian (Pipit) Triana has begun initial work on modelling the composite spectral energy distribution from SAGE galaxies that will include galaxy light, dust, gas and supermassive black holes.

To interactively analyse and visualise merger trees, an MPI-parallel utility was created. An MPI-parallel converter enables faster conversion into TAO-friendly formats of bigger datasets. New interfaces and connectivity were developed across codes to allow astronomers to make graphing their data and models in a cloud-style environment. To enable better transparency, higher collaboration and cross-talk across the team, an ASTRO 3D Github (**github.com/astro3d**) was organised with unlimited private repositories where all the codes and documents can be hosted, and teams are assigned tasks.

In 2018, the DIA program team will complete their survey of the ASTRO 3D survey and project data needs, and focus on the requirements of each project, as well as cross-matching and querying data across the different data centres.

SCIENCE HIGHLIGHT

THE FIRST BILLION YEARS OF THE UNIVERSE

IMAGE CREDIT: Natasha Hurley-Walker

ASTRO 3D astronomers are studying the process by which the structures in the Universe first formed, using low-frequency radio waves.

The Epoch of Reionisation refers to the period in the history of the Universe during which the neutral hydrogen gas was ionised (electrons removed from atoms) and the smooth matter distribution become the highly structured galaxies and clusters of galaxies we have today.

The observational Epoch of Reionisation project explores the first billion years of the Universe, as probed through the redshifted emission line of neutral hydrogen gas. Studying the spatial and temperature distribution of the neutral hydrogen gas between the first galaxies provides key insights into the growth of structure at Cosmic Dawn and the first sources of ionising radiation in the Universe. In ASTRO 3D, we are exploring this signal with the Murchison Widefield Array (MWA), and in future Square Kilometre Array (SKA-Low), both of which will be located in the remote Western Australian desert.

The MWA EoR project is an international collaboration, with major contributions from ASTRO 3D nodes at the University of Melbourne and Curtin University, and partner institutions CSIRO and the University of Washington. The collaboration has been collecting data from 2013 onwards towards three regions of the sky, and across a wide period in the first billion years of the Universe. The team collect, calibrate, process and analyse these thousands of hours of data to extract the weak cosmological signal from all of the sources of extragalactic, Galactic and terrestrial contamination that blanket it. In ASTRO 3D, the primary science aims are improvements in our signal processing and signal extraction, leading to first detection and exploration of this era. The MWA observational data will be combined with the theoretical predictions of the Genesis Simulations and the processing efficiency aims of the Data Intensive Astronomy thread.

RESEARCH PROJECTS AND SURVEYS

1. THE MWA EOR

The observational Epoch of Reionisation (EoR) project using the Murchison Widefield Array will transition from the ARC Centre of Excellence for All-Sky Astrophysics (CAASTRO) in January 2018. CAASTRO's support of this project over the past seven years has provided the platform from which the ASTRO 3D program can yield world-leading science in the coming seven years.

The Murchison Widefield Array (MWA) is a low-frequency radio telescope in the Western Australian desert. Operating between 80 and 300 MHz, it explores many scientific questions. Principal among these is the search for signals from neutral hydrogen that resides between galaxies in the first billion years of the Universe. During this crucial evolutionary period, entitled the Epoch of Reionisation, the first stars and galaxies in our Universe were born, completing our understanding of the full history of the Universe. The hydrogen signal encodes key information about the spatial location and evolution of these first astrophysical objects, but its detection remains elusive due to the weakness of the signal compared with the foreground radio sky, and the complexity of the instrumental measurement.

The ASTRO 3D EoR program will provide new measurements of this period of the Universe. Utilising the upgraded MWA, in which additional receiving stations have been added to enhance EoR science, and building on our growing knowledge of our instrument and foreground sky, we will firstly re-process the existing four years of MWA data, building a quality database to triage the cleanest data from the most contaminated. In 2018, we will use this quality database to analyse the cleanest data and publish the lowest EoR signal detection limits from the MWA.

To achieve an EoR signal detection, we will also further refine our understanding of the telescope. We will improve the measurement of the telescope's response to the sky, which is known to cause substantial contamination in our data. In tandem with this, we are developing new tools to calibrate the telescope and remove the foreground sky, taking advantage of the new receiving stations optimised for EoR science. As we address the systematic contamination associated with both the telescope and foregrounds, we will probe deeper into our data, yielding the best possibility of a signal detection with the MWA.

Finally, ASTRO 3D creates key connections between the EoR theorists at the University of Melbourne, and the Genesis Simulation Thread members at Melbourne, the University of Western Australia and Swinburne University. With joint student projects, we will use the sophisticated Genesis simulations to guide our observational program, stimulating targeted experiments that enhance the science achievable.

A panorama of one of the MWA compact hexes at dawn. ***IMAGE CREDIT:*** mwatelescope.org

2. THE FIRST STARS

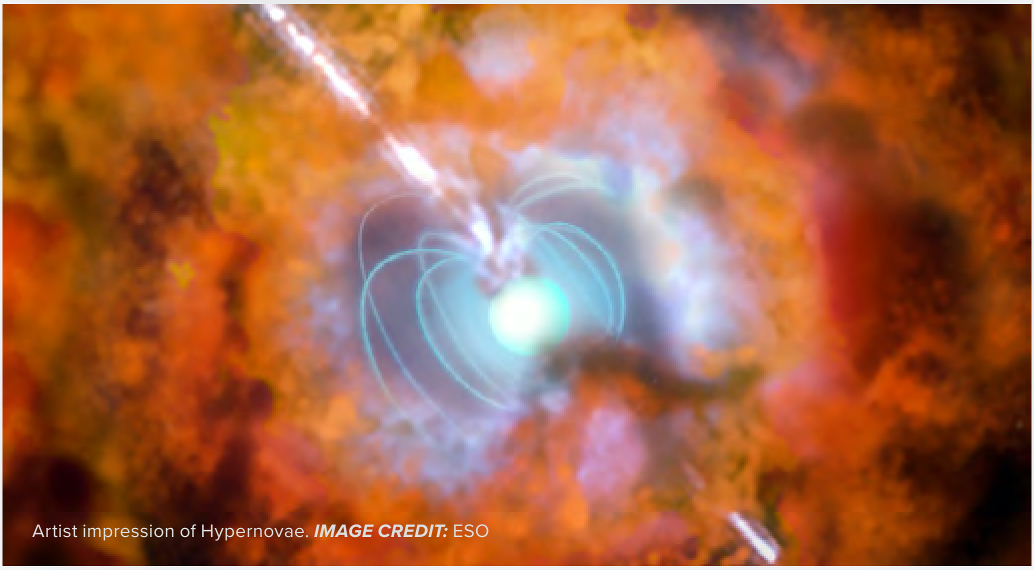
The First Stars team are searching for the oldest stars in the Universe, some of which are currently located in and around the Milky Way galaxy. These stars contain crucial clues to the earliest cosmic epochs, having formed within a few hundred million years after the Big Bang. By measuring the chemical compositions of stars with extremely low content of heavy elements (carbon and heavier elements) one can infer the nature of the very first generations of stars, the conditions during the formation of the first galaxies, and even about the Big Bang itself.

The First Stars team has been mining the SkyMapper Data Release 1 to identify candidate Milky Way halo stars with extremely low metallic content, some of which herald from the Epoch of Reionisation and thus complement studies of distant galaxies. Such stars have little UV metal line-blanketing which can be detected thanks to the photometric filters used by ANU's SkyMapper telescope.

In order to confirm their metal-poor star nature, medium resolution spectra are being obtained of thousands of these candidate stars with the WiFES spectrograph on the ANU 2.3m telescope using some 60 nights per year.

The First Stars contain crucial clues to the earliest cosmic epochs, having formed within a few hundred million years after the Big Bang.

The photometric pre-selection is working very well with the majority of the spectroscopic targets having extremely low metallicities ([Fe/H]<-2.50). High-resolution spectra of the most interesting, metal-poor stars are then being obtained with 6–10m telescopes to determine their detailed chemical composition. During 2017 the team was awarded six nights with the Magellan telescope in Chile to observe several exciting halo stars with an iron content less than 1/10,000th of the solar value. The team is planning to submit an ESO Large Program proposal in 2018 with UVES/VLT to observe a large sample identified from SkyMapper of these exceptionally rare objects to learn about the nature of the first stars and the earliest cosmic epochs.



Artist impression of Hypernovae. ***IMAGE CREDIT:*** ESO

Artist impression of the Milky Way bulge. ***IMAGE CREDIT:*** ESOA/NASA/JPL-Calt ech/M. Kornmesser/R. Hunt

The ANU First Stars team has been joined by postdoc Thomas Nordlander. Thomas completed his PhD at Uppsala University, Sweden, and has very broad expertise in stellar physics and Galactic archaeology. He will perform the most sophisticated and accurate chemical analysis of the most metal-poor stars by means of 3D non-local Thermodynamic Equilibrium (non-LTE) spectral line formation calculations. Thomas recently performed a complete 3D non-LTE-based re-analysis of SMSS0313-6708, the most iron poor star known which was discovered by the team as part of SkyMapper commissioning (Keller et al. 2014, Nature, 506, 463). Thomas found an upper limit on [Fe/H] which is 10x higher than previously estimated. The abundance pattern is consistent with massive progenitors (10–60 Msun) exploding as low-energy core-collapse supernovae and rules out nucleosynthesis in hypernovae or pair-instability supernovae (Nordlander et al. 2017, A&A, 597, A6).

The First Stars team is also continuing the analysis of the most metal-poor stars in the Milky Way bulge, which have been identified with SkyMapper and the Anglo-Australian Telescope. Some of these stars are believed to have formed in the very early universe, when it was less than one-tenth of its current age, an otherwise inaccessible cosmic epoch by other means with today's telescopes (Howes et al. 2015, Nature, 527, 484).

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SPOTLIGHT ON ASSOC. PROF MICHELE TRENTI

FROM THE UNIVERSITY OF MELBOURNE

"I grew up at the foothills of the Italian Alps and for my 11th birthday, I got a book on the properties of the stars and galaxies. The title translates as "Star by Start — A touristic guide to the Universe" and I still have the book in my office as a reminder of how I started on my path toward professional astrophysics."

"My research is studying the formation and evolution of stars and galaxies during the infancy of the Universe in the first billion years after the Big Bang (we are now at about 13.8 billion years). So I am studying objects as they existed more than 13 billion years in the past. This is possible, because light takes a long time to travel the incredible distance from the edge of the observable Universe to us on Earth. I primarily use the Hubble Space Telescope, which is orbiting above the Earth's atmosphere to give us the sharpest view of the most distant galaxies. So for me, Hubble is a time machine to look in the past!"

"My most exciting moment in my career was the first observations I made with Hubble's most advanced infrared camera, installed by the astronauts servicing the telescope in 2009."

"I had been awarded time to use that camera to search for the brightest galaxies more than 13 billion years in the past and getting that first data and discovering that some galaxies as bright as our own Milky Way were already present at such early times was personally very exciting."

"I think that astronomers are changing the way they do research. Traditionally, small teams (even just a student plus their supervisor) could tackle big problems and make significant progress with relatively small telescopes or modest computational resources. Now the field is evolving into one progressively more and more dominated by research carried out in big teams, analysing big datasets from large telescopes that require sophisticated statistical techniques, or carrying out complex supercomputing simulations to model formation of galaxies, black holes, stars and planets. Such shift requires us to think about how we organize collaborations and provide effective mentoring for early career researchers to become productive members of large teams, but at the same time retain opportunities to demonstrate leadership and independence in research. ASTRO 3D gives us the chance to do that."

Hubble BoRG 58 Survey Field. ***IMAGE CREDIT:*** NASA/ESA/M Trenti/L. Bradley/BoRG

3. THE FIRST GALAXIES

The First Galaxies project is focussed on discovering galaxies during the first billion years after the Big Bang and characterizing their properties. These goals are achieved through a combination of observations by some of the most powerful telescopes (space and ground-based) with theoretical and numerical modelling of the expected properties of these galaxies.

The project had a very strong start thanks to the award in June 2017 of 500 Hubble Space Telescope Orbits (about one month of time): ASTRO 3D CI Michele Trenti and his international Brightest of Reionizing Galaxies (BoRG) survey team will carry out a new multi-colour imaging search for galaxies within the first 700 million years after the Big Bang. This program was the largest approved by the Hubble Time Allocation Committee this year, and data will be acquired over the next 18 months.

The node at the University of Melbourne is exploiting the new dataset, with the first data already acquired by Hubble. In October, the team welcomed Dr Rachael Livermore (previously at UT Austin) as ASTRO 3D First Galaxies postdoc. Rachael is an expert in Hubble observations of galaxies during the Epoch of Reionisation, bringing to Australia a unique set of data analysis and modelling skills to identify and characterize faint sources in deep near-IR images. Shortly after arriving in Melbourne, Dr Livermore has been awarded an ARC DECRA fellowship for her work within ASTRO 3D, and a new postdoc is being recruited to further strengthen the team.

While waiting for the acquisition of the new Hubble data, the project has focused on fully exploiting data from previous Hubble programs with ASTRO 3D PhD student Alex Cameron. Modelling of first galaxies clustering is also underway with ASTRO 3D PhD student Keven Ren, with the long-term goal of investigating the connection between dark matter halo assembly and galaxy luminosity function evolution, in collaboration with ASTRO 3D Genesis postdoc Simon Mutch. Finally, synergic investigations are being carried out at UWA to start a new cosmological simulation in the Genesis program to investigate how the First Galaxies evolve in time and where their remnants can be found in the local Universe.

4. GALAXY EVOLUTION

Galaxy Evolution has the unifying theme of understanding the structural and chemical evolution of galaxies and how this relates to their interaction with the Inter-Galactic Medium (IGM).

This had been a year of hiring, since the Centre launch in July. We are delighted to welcome ASTRO 3D fellows Emily Wisnioski and Trevor Mendel, who have joined the galaxy evolution team at ANU, and Tiantian Yuan, who joins the galaxy evolution team at Swinburne. Emily's research focuses on a multi-wavelength analysis of star-forming galaxies from ($0.1<z<4$) to understand how galaxies evolve at the peak epoch of star formation through the study of their resolved kinematics, morphologies, and chemical properties using cutting-edge instrumentation. She will be combining her 3D high-redshift data with SAMI data to connect the galaxies at high redshift and in the local universe. Trevor models massive galaxy stellar populations, as well as understanding the role of environment in driving galaxy evolution, and the quenching of star formation in active galaxies. He will be combining his models with high-z data from the VLT and local SAMI data. Tiantian will be observing high redshift spiral galaxy candidates to determine when and how spiral-arm structures form in the universe, using a combination of Keck and the VLT.

At Swinburne, new postdoc Robert Bassett has started analysing MOSFIRE spectra of Lyman Continuum in distant galaxies, working with CI Emma Ryan-Weber. The measured optical emission lines will provide a critical measure of the ionization properties of these galaxies, whose more distant counterparts are responsible for reionizing the Universe. The Galaxy Evolution team at Swinburne has been busy submitting proposals to Keck and ESO/VLT to further pursue these Lyman-continuum galaxies and extreme emission-line galaxies in collaboration with ASTRO 3D Fellow Tiantian Yuan. PhD student Colin Jacobs, working with CI Karl Glazebrook, has begun developing a pipeline to find strong lens systems in the *Dark Energy Survey* (DES) using the Convolutional Neural Network methods he used very successfully on the CFHT Legacy Survey. These will provide probes of high-redshift galaxy mass distributions and highly magnified views of background sources for future proposals. Dr Tom Collett visited from Portsmouth to work with Colin and Karl on developing his *LensPop* simulation code for the training of neural networks on DES data. An ESO proposal has been submitted to obtain confirmation of the first Einstein Ring candidates, with the ultimate goal of using Einstein rings to constrain the nature of cold dark matter via substructure.

PhD student James Esdaile has commenced work with Karl and Ned Taylor on massive distant galaxies. He will be observing with new medium band *KbKr* filters on Gemini to find the first examples of massive, quiescent galaxies in the early universe. Karl presented an invited talk on this topic at the Florence meeting "Challenges in Galaxy Evolution: from Black Holes to the cosmic web".

The ANU galaxy evolution team has been focusing on developing UV chemical abundance, ionisation and pressure diagnostics. These diagnostics will be used to measure the chemical abundances in the most distant galaxies possible ($3.5<z<6$) using rest-frame UV spectroscopy with the VLT and JWST. The first diagnostics were presented by PhD student Ayan Acharya at the annual GMT Science Meeting in New York in September, and also by Centre Director Lisa Kewley at the "Characterising galaxies with a view for JWST" meeting at the Lorentz Centre in Leiden in October.

Galaxy Evolution has the unifying theme of understanding the structural and chemical evolution of galaxies and how this relates to their interaction with the Inter-Galactic Medium.

SPOTLIGHT ON DR KIM-VY TRAN

AN AFFILIATE OF THE CENTRE FROM THE UNIVERSITY OF NSW

“Coming from a Vietnamese family, the focus was very much on education and although I was good at maths and science, I was going to major in Humanities or Creative Arts. I actually did Classical Ballet and at one point considered a dance major! But in my first year, I did a super-interesting Astronomy class, and that was it for me!”

“I use powerful telescopes to piece together the history of the Milky Way. Because we can’t look back in time at its formation, it’s like compiling a photo album — from baby photos, through the teenage years to adulthood and old age — you get an overall picture of the Milky Way from looking at close relatives and seeing how they grew up.”

“My most exciting discovery was also the one I thought I’d totally screwed up! I had published a paper and was using spectroscope data from the Keck Telescope in Hawai’I to confirm the fingerprint of that cluster of galaxies. But I found a Hydrogen fingerprint that I didn’t understand — it was too far away to be my galaxies and I was so worried that what we had published was completely incorrect! I showed the data to some of my collaborators, and one of them said ‘oh, that’s gravitational lensing!’ — so what we were seeing was a really old galaxy that only showed up because of the pull of gravity around my cluster of galaxies! We used the Hubble high-resolution telescope to confirm that yes, what we were seeing was, in fact, two separate galaxies separated by huge distances and time.”

“I came to the University of NSW from the US to work on developing new exciting astrophysics. The opportunity to work with ASTRO 3D on further collaboration with Australian and international researcher something that could only further strengthen the network of astronomers.

SCIENCE HIGHLIGHT

THE OLDEST SPIRAL GALAXY SEEN THROUGH GRAVITATIONAL LENSING

Large galaxy clusters are the most massive structures in the Universe, comprising 10,000's of galaxies.

As predicted by Einstein, their large mass causes them to act as efficient "cosmic telescopes" (called gravitational lenses), amplifying and boosting the size and brightness of distant galaxies which serendipitously lie behind them. The gains can be up to 50x, allowing us to study the processes of galaxy formation in galaxies at a level of detail that would otherwise have to wait a decade.

ASTRO 3D researchers have been able, for the first time, to look back 11 billion years, to directly witness the formation of the first, primitive spiral arms of a galaxy. Dr Tian Tian Yuan and collaborators observed a gravitationally lensed spiral galaxy at redshift $z = 2.54$.

It is the most ancient spiral galaxy discovered and the second kinematically confirmed spiral at $z > 2$.

The galaxy, known as A1689B11, existing 11 billion years in the past, just 2.6 billion years after the Big Bang. At this time in the Universe formation, spiral galaxies are exceptionally rare and this one is forming stars 20 times faster than galaxies today — as fast as other young galaxies of similar masses in the early Universe. However, unlike other galaxies of the same epoch, A1689B11 has a very cool and thin disc, rotating with very little turbulence, which has never been seen before at this stage of the Universe.

The ASTRO 3D researchers used a powerful technique that combines gravitational lensing with the Near-infrared Integral Field Spectrography (NIFS) on the Gemini North telescope in Hawai'I to verify the vintage and spiral nature of the galaxy.

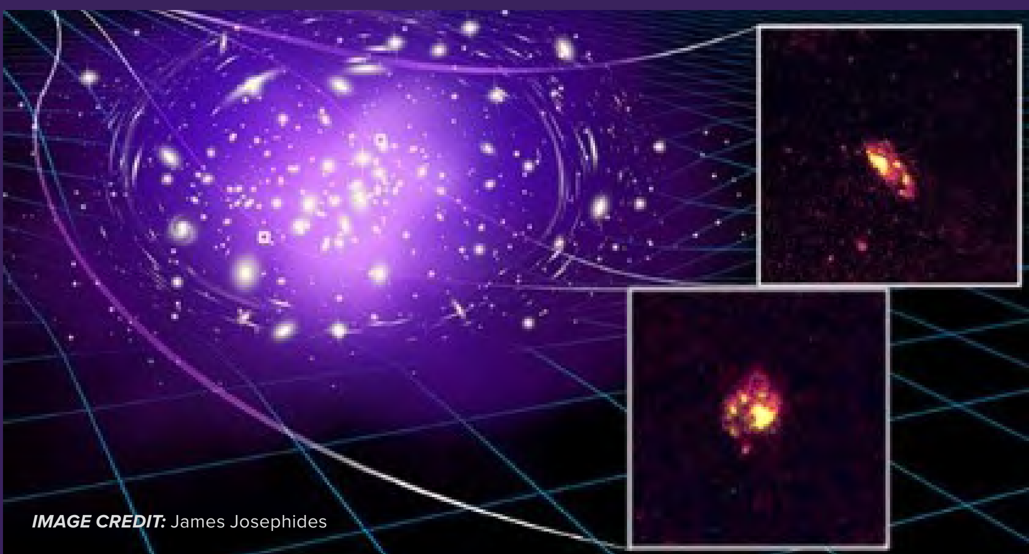


IMAGE CREDIT: James Josephides

The ASKAP radio telescope in Western Australia. This 36-disk radio interferometer uses novel phased-array feed technology that makes it possible to detect and image the 21cm line of neutral hydrogen in multiple galaxies across a 30 square-degree region of the sky. ***IMAGE CREDIT:*** CSIRO

5. THE ASKAP SURVEYS

The ASKAP Surveys project will track the evolution and buildup of neutral hydrogen in galaxies over the past 7–8 billion years. Neutral hydrogen gas provides the reservoir of material from which new stars can form in galaxies, and so is key to understanding how galaxies evolve over cosmic time. ASTRO 3D researchers are using the new Australian SKA Pathfinder to map out the cosmic distribution of neutral hydrogen (HI) in unprecedented detail via three different but interlinked ASKAP surveys.

- The WALLABY survey (led by CI Lister Staveley-Smith and PI Bärbel Koribalski) will cover two-thirds of the sky and is expected to detect the 21cm HI emission line from up to 600,000 galaxies, looking back 2 billion years in cosmic time.
- The DINGO survey (led by AI Martin Meyer) focuses on the evolution of galaxies and the gas-rich universe out to 4 billion years ago and expects to detect up to 100,000 galaxies through deep ASKAP observations spanning 60 square degrees of sky.
- The FLASH survey (led by CI Elaine Sadler) will search for the 21cm HI line in absorption against bright continuum sources across the whole southern sky, and will probe the neutral gas content of several hundred individual galaxies between 4 and 8 billion years ago, where the HI emission line is too weak to be detectable in even the deepest ASKAP surveys.

In 2017, the Wallaby and Dingo teams began Early Science observations with a 12-antenna ASKAP array. The FLASH project will transition from CAASTRO to ASTRO 3D in 2018.

WALLABY

The ASKAP Early Science program delivered data for four complete Wallaby fields in 2017. These fields (see Table below) were observed with a smaller number of antennas than will be available for full ASKAP, but with much greater integration time. Since the sensitivity and resolution are similar to the final Wallaby survey, the data has given the team a chance to test the ASKAP software pipeline, to implement post-processing pipelines, and to start doing science.

Wallaby is a large team of over 100 Australian and international scientists, led by PI Bärbel Koribalski and CI Lister Staveley-Smith, but the dedication of key individuals has been the key to the rapid progress achieved in 2017. ASTRO 3D research scientist, Bi-Qing For, was appointed mid-year and is leading the validation and data control effort. PhD students Tristan Reynolds and Ahmed Agali have also joined ASTRO 3D, and have been involved in successfully reducing data from the NGC 7232 and M83 fields, respectively (see below).

Velocity fields for (top) the galaxy pair NGC 7162, NGC 7162A, and (bottom) NGC 1566, extracted from Wallaby early science data by PhD students Tristan Reynolds and Ahmed Egali.

DINGO

DINGO began its Early Science program in 2017, with the project taking eight nights of data with the ASKAP-12 and ASKAP-16 arrays. These observations targeted the GAMA 23 hour field (the future location of the DINGO ultradeep survey) in two different frequency configurations eventually looking back more than 4 billion years. These data are being used to develop and test the DINGO data reduction pipelines, characterise the radio frequency emission in the field, and also carry out early HI emission-line stacking experiments.

ASKAP is ideally suited to HI stacking experiments — its large field of view and frequency coverage allow the faint HI signals from many thousands of galaxies to be combined over multiple epochs, giving a statistical measure of how the neutral atomic gas content of the Universe has evolved over cosmic time. Complementing this ASKAP Early Science data, PhD student Qingxiang Chen finished his initial processing of the DINGO VLA data in the GAMA 09 hour field, and is now carrying out a $z < 0.1$ HI stacking analysis.

The DINGO team also continued to grow in 2017, welcoming new PhD student Kristóf Rozgonyi to the project. Kristóf's work on gridding and deep imaging techniques is now well underway. The project also looks forward to the arrival of the first DINGO ASTRO3D research scientist in 2018, with the initial selection process for this position now completed.

The ASKAP Surveys project will track the evolution and buildup of neutral hydrogen in galaxies over the past 7–8 billion years.

FLASH

The FLASH team will accelerate the analysis of ASKAP Early Science data for HI absorption from January 2018. Netherlands-based ASTRO 3D PI Raffaella Morganti visited Australia in December 2017 to discuss coordination between FLASH and the ASTRON-led Apertif HI absorption survey.

The ASKAP Wallaby, DINGO and FLASH surveys cover complementary ranges in looking back in time, and together will be able to map neutral hydrogen over the past 8 billion years of the Universe. In combination with our optical 3D spectroscopy of survey galaxies in the same volumes, these surveys allow us to separate the key components of galaxy mass: neutral gas, ionised gas, stellar mass, and dark matter.

ASKAP radio telescope. ***IMAGE CREDIT:*** Pete Wheeler ICRAR

SPOTLIGHT ON DR BÄRBEL KORIBALSKI

FROM OUR PARTNER INSTITUTION, CSIRO

"I remember my granny giving me an astronomy book in primary school, but I don't think it sparked any interest in astronomy at the time. Close to the completion of my physics degree at the University of Bonn in Germany, I looked for a project on upper atmospheric physics, but without success as the leading professor had retired. Instead, I bumped into the director of the Radio Astronomy department, Prof. Mebold, who was very enthusiastic to recruit me, offering me a project, office and fantastic environment to work in."

“I study the distribution of dark matter in galaxies. To do this I use radio interferometers to map the 21cm line of neutral hydrogen (HI) gas in galaxies which typically extends well beyond their bright stellar disk. From the gas kinematics, I can work out how fast galaxies are rotating and then deduce their total mass, incl. the amount of dark matter as a function of radius.”

“I get super-excited when I find new galaxies! These are either optically very faint, compact (mistaken for stars) or hidden behind the dusty disk of the Milky Way, but rich in neutral hydrogen. Occasionally, I discover hydrogen where there are no stars — for example tidal tails, plumes and bridges ripped out by the gravitational dance between two galaxies colliding. One of the key goals for WALLABY Early Science, currently under way with ASKAP, is the study of tidal interactions in galaxy groups and clusters.”

“For me, ASTRO 3D is both exciting and challenging for the same reason - communication. This Centre of Excellence is not ~50 people working together on the same project in the same building. We are a geographically dispersed, diverse group, doing a huge range of scientific projects and we need to find ways to do the best science by collaborating in new and innovative ways.”

SCIENCE HIGHLIGHT

WALLABY SURVEYS TWO-THIRDS OF THE SKY FOR HYDROGEN

ASTRO 3D astronomers have begun using CSIRO's $188 million Australian Square Kilometre Array Pathfinder (ASKAP) in a major science survey project — WALLABY (Widefield ASKAP L-band Legacy All-sky Blind surveY) — in the first step in observing 75% of the sky, sampling approximately 500 000 galaxies.

The project, led by Dr Bärbel Koribalski from CSIRO and Dr Lister Staveley-Smith from the The University of Western Australia, has begun processing vast amounts of data to look for neutral hydrogen gas (HI). The data will be sifted through by astronomers with the help of supercomputers at the Pawsey Centre in Perth, Western Australia.

Neutral hydrogen — individual hydrogen atoms, comprised of a proton and an electron, floating around — is the most common form of normal matter in the universe and the building block of stars and galaxies. In the nearby Universe, most of the HI is found in galaxies, so mapping HI actually maps galaxies and produces much more information about them and their formation, than just visible light alone.

The team have spent the second half of 2017 reducing data from four 30 sq. degree fields (the angular area viewed by the telescope), and have started producing images of individual galaxies.

The images below show the HI in one ASKAP beam (out of 36) after combining seven nights of ASKAP data. They discovered two gas-rich dwarf galaxies in the vicinity of a nearby spiral galaxy (IC 5201).

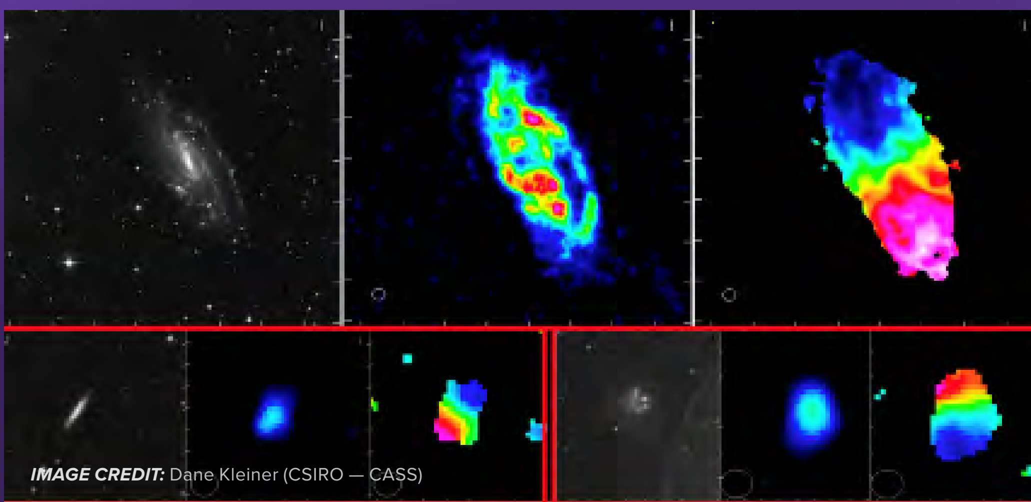


IMAGE CREDIT: Dane Kleiner (CSIRO — CASS)

The collage shows IC 5201 on the top row — the optical image (left), the HI distribution (middle) and the HI velocity field — which shows how fast the gas is moving (right). The bottom row shows the same thing for the two dwarf galaxies.

This research will help scientists better understand the interplay between hydrogen gas and the processes that lead to star formation in galaxies, and therefore how they form and evolve.

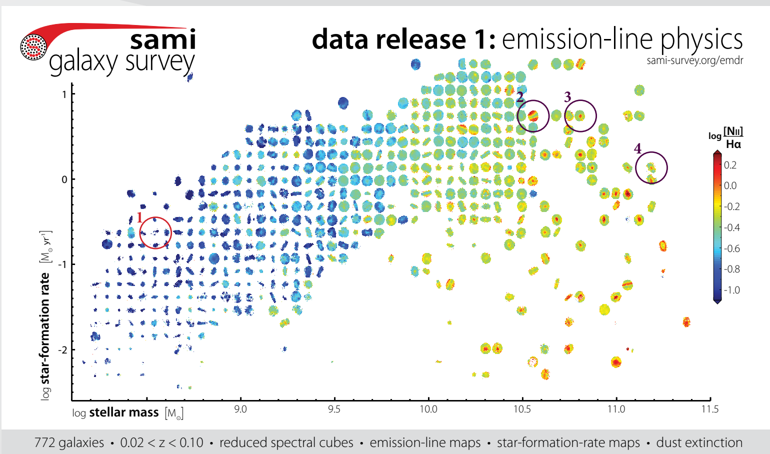
6. SAMI/HECTOR SURVEYS

The SAMI survey is currently obtaining 3D data cubes for 3600 galaxies in the nearby Universe. Integral field spectroscopy with SAMI allows the measurement of a huge range of galaxy properties that are impossible to obtain from single fibre surveys and allows direct tests of the latest galaxy formation simulations. SAMI observables include gas and stellar internal and bulk kinematics, the spatial distribution of star formation, stellar metal content and age gradients, gas oxygen abundance distributions, resolved ionization diagnostics and many others. This is the first IFU sample that is sufficiently large to disentangle the competing roles of galaxy mass and environment. As a result, we can address the following three key questions:

1. What is the physical role of environment in galaxy evolution?
2. What is the interplay between gas flows and galaxy evolution?
3. How are mass and angular momentum built up in galaxies?

Observations are currently ongoing and will be complete by mid-2018. When SAMI transitions from CAASTRO to ASTRO 3D at the end of March 2018 the core focus will be on final science analysis of the complete survey data. This will include connecting the distribution of stellar ages and metallicities to the formation of galaxies, using the motion of gas in galaxies to understand the fueling of star formation and decomposing the 3D SAMI data into separate morphological components (i.e. bulges and disks). As well as this, we will be releasing new data and derived products to the wider astronomical community as a catalyst for further science.

SAMI is already making major contributions to galaxy evolution science with a number of papers published in the last year. This includes studies on galaxy shapes connecting the dynamics of galaxies at high and low redshift, the distribution of star formation in galaxies, how stellar age and metal content vary with galaxy properties, the connection between dynamical disturbances and internal physical properties, the formation of slow rotating galaxies, and much more.



Data Release 1 galaxies are arrayed by stellar mass and star-formation rate. 1) intense star-formation activity is detected on the edge of a dwarf galaxy, responsible for 70% of the galaxy's Hα luminosity. 2) Evidence for galactic winds in the extraplanar gas in main-sequence edge-on disc galaxy 593680. Enhanced HδA indicates that bursts of star formation are necessary for driving large-scale galactic winds. 3) A small, intensely bright nucleus which show strong, broad emission lines and AGN-like [N11]/Hα line ratios is detected in galaxy 238358. The spiral arms are weak in the optical but clearly detected in Hα and from the gas velocity dispersion. 4) Galaxy 272831 shows a strong discrepancy between the kinematic properties of the ionised gas and those of the stars. This galaxy is more consistent with a recent merger or gas accretion event with possible shock heating of the accreted gas in the central region. ***IMAGE CREDIT:*** Jesse van de Sande, Andy Green, Scott Croom

In parallel, effort is focused on the replacement for SAMI, the HECTOR instrument. HECTOR will increase the power of SAMI in terms of spectral resolution, spatial sampling and galaxy number. HECTOR will be commissioned on the Anglo-Australian Telescope in 2019. There is a substantial effort currently committed to instrument development, including finalising spectrograph design so that orders can be placed for components at the start of 2018. Development of improved fibre imaging bundles is also ongoing at the University of Sydney. At the same time, the HECTOR Galaxy Survey team is defining the parameters of the major survey that will take place with the instrument.

7. GALAH SURVEY

The GALactic Archaeology with HERMES (GALAH) survey is aiming to unravel the assembly, star formation, dynamical and chemical history of the Milky Way through the nucleosynthetic fingerprints encoded into the chemical compositions of a million stars. The survey uses the AAT and the HERMES spectrograph, with which 400 stars can be observed simultaneously at high spectral resolution.

To date, almost half a million stars have been observed, already the largest spectroscopic survey at high-resolution ever undertaken. The GALAH observations and data reduction work is led out of Sydney (Sarah Martell, UNSW, Gayandhi De Silva, AAO, Joss Bland-Hawthorn, Sanjib Sharma, Janez Kos, USydney among others) while the spectrum analysis pipelines to determine stellar parameters and elemental abundances are developed at ANU (Martin Asplund, Ly Duong et al.) and MPIA, Germany (Sven Buder, Karin Lind et al.). In addition, there are important complementary observations of almost 100,000 stars in the K2 (extended Kepler mission) fields, as well as preparatory observations for NASA's TESS satellite, the next major exoplanet and asteroseismology mission after Kepler (programs led by Sanjib Sharma and Dennis Stello, University of Sydney). Many of these many stars will thus have asteroseismic information on stellar masses and ages, which will be a gold-mine for Galactic archaeology.

SPOTLIGHT ON DR CAROLINE FOSTER

FROM THE UNIVERSITY OF SYDNEY

"I was studying mostly physics and maths in Quebec, Canada until one of my Master's supervisors introduced me to the large-scale Universe, which really ignited my interest in astrophysics. I've always liked to understand how things work!"

"So now I'm working as an ASTRO 3D Fellow at the University of Sydney and I'm working on discovering the 3D shape of galaxies. We only get a 2D snapshot of them from optical telescopes and we can't send probes out to see their three-dimensional shape, so I'm using a tool called Integral Field Spectroscopy which gives us an idea of the dynamics of galaxies, which we combine with the images to give us the third dimension."

"I think my most exciting discovery was the dynamics of the stream substructures of the 'Umbrella Galaxy' (NGC 4651) which showed that actually, it was the remnants of a smaller system which had shredded. We were even able to show where the remnant nucleus of the smaller galaxy was."

"The opportunity to work on such large-scale astronomy is so exciting and I hope that we are able to have a secure future; funding of such things as HECTOR and a career progression after the Centre of Excellence are important challenges we need to solve."

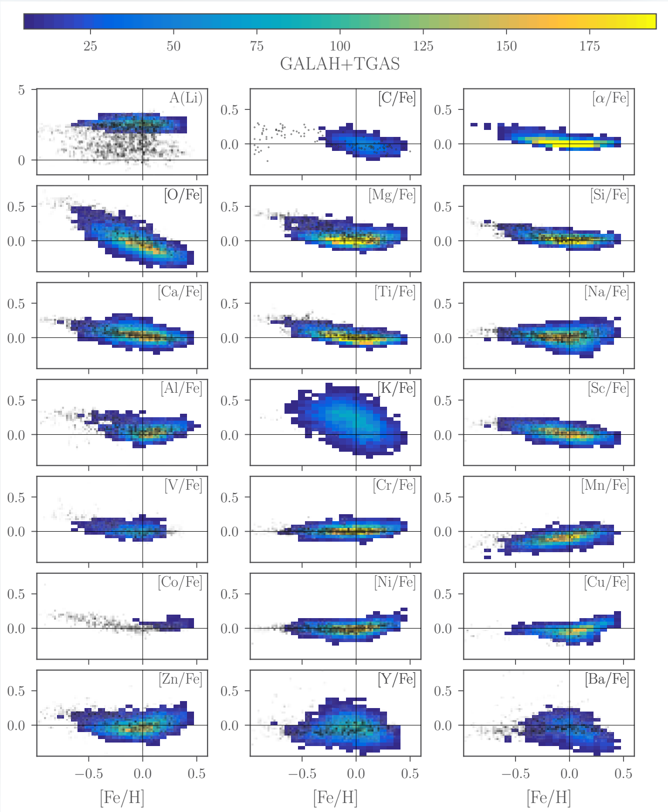
In late 2017, the GALAH team completed the second internal data release, containing accurate stellar parameters and detailed abundances for more than 20 elements for more than 450,000 stars, an unprecedented dataset. The second data release will become public world-wide in April 2018, timed to coincide with Gaia DR2, which will include parallaxes and thus distances to all GALAH stars. A rich bounty of exciting science papers can be expected from these data.

ANU student Ly Duong has studied the division of the Milky Way disk into thin and thick components, quantifying the vertical abundance gradients. To better characterise the instrumental signatures of spectrographs, CI Joss Bland-Hawthorn's instrumentation group have developed a photonic comb that allows more precise measurements of spectral features and thus stellar abundances; all GALAH observations will be re-reduced with this crucial information.

GALAH postdoc Janez Kos has recently published a new multi-dimensional method for grouping stars with very similar chemical compositions that were likely born together although now dispersed across the Galaxy, so-called "chemical tagging." Janez is able to recover stellar clusters and in the process find new members of the Pleiades star cluster.

PhD student Sven Buder is leading a detailed study of the chemo-dynamical history of the solar neighbourhood using overlap stars with Gaia DR1, finding surprisingly old (>10Gyr) thin disk stars.

The GALAH team has been joined by ASTRO 3D postdoctoral fellow Michael Hayden. He has previously worked extensively on other international Milky Way surveys like APOGEE and Gaia-ESO. His expertise in data mining and Galactic archaeology will be invaluable for the exploitation and interpretation of the very rich GALAH dataset in 2018.



GALAH abundance exploration — the panels show the abundances of 20 different elements measured from GALAH data for 7,626 stars for which distances, ages and Galactic orbits are known quite precisely. This data allows us to study the production of elements over time in the Milky Way. The top right panel, showing so-called "alpha elements" versus iron abundance, is a key indicator of element production in supernova explosions. The colour scale represents the density of stars in each panel and black dots show abundances for dwarf stars from previous higher-resolution studies with samples of fewer than 1,000 stars.' ***IMAGE CREDIT:*** Sarah Martell

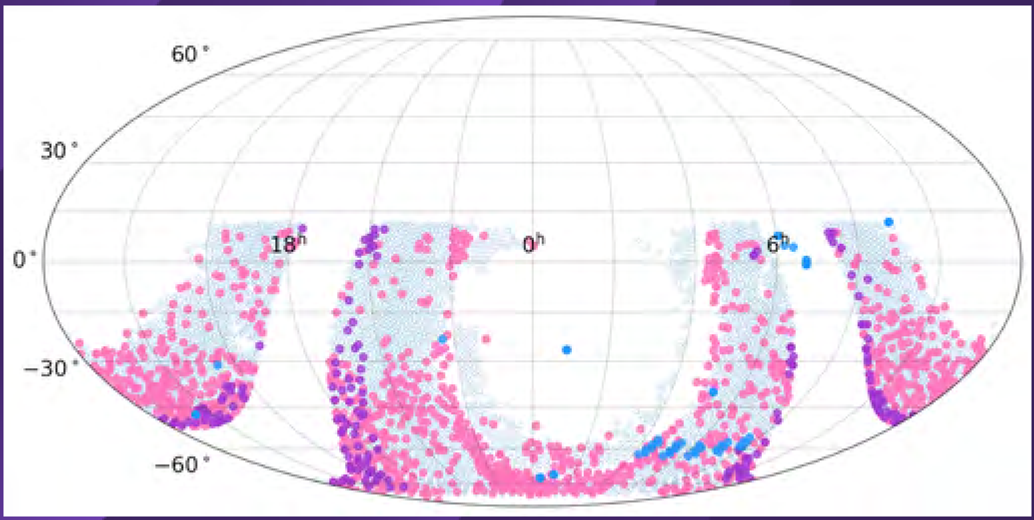
SCIENCE HIGHLIGHT

HALF A MILLION STARS DOWN, HALF A MILLION TO GO

ASTRO 3D scientists from the University of Sydney and the Australian National University are using the $13 million HERMES instrument to sample the spectra of up to 400 stars at a time, with the goal of collecting data from one million stars in the next five years.

HERMES (High Efficiency and Resolution Multi-Element Spectrograph) is an instrument attached to the Anglo-Australian Telescope (AAT) at Siding Spring Observatory. It allows researchers to take detailed spectra of 392 objects at a time, over degrees of sky. So far researchers have collected data from nearly 500,000 stars.

The researchers are trying to understand how our galaxy formed by measuring the breakup of light from 400 stars in one go, so they can measure the chemical content from the stars, like iron, sodium and calcium. Measuring how much of those elements in the star itself is kind of like a DNA trace, and you can extrapolate that information to the star's formation history. original behaviour. The GALAH project will help to understand to what extent the Milky Way's galactic disk's composition is from stars that originated in other galaxies and later merged with the Milky Way Galaxy, and what drove the major episodes of star formation the Galaxy's disk.



Map of GALAH survey progress through to October 2017. Clear circles are unobserved survey fields, pink are regular survey fields that have been observed, cyan are field observed during the Pilot Survey, blue are fields observed by the K2-HERMES programme, and purple are fields observed for the targeted Tycho-2 bright-star subproject.
IMAGE CREDIT: Sarah Martell

ACTIVITY PLAN 2018

ACTIVITY		ACTION
RESEARCH PROJECTS AND SURVEYS	**Genesis**	• Incorporate parallel capabilities into the models • Include bulge formation and angular momentum tracking into the models • Incorporate more detailed chemical evolution models • Include templates for calculating the spectral energy distribution of galaxies, suitable for making predictions for multiple ASTRO 3D surveys • Discuss updated models and project needs with ASTRO 3D observers • Run a low-resolution pilot simulation and integration, and check synthetic data sets • Compare observations with theoretical models, including abundance matching, gas accretion, satellite quenching, and environmental processing
	Data Intensive Astronomy (DIA)	• Survey ASTRO 3D membership to map out existing data resources and immediate/future requirements of each team and project. This survey will focus on the requirements of each project the capabilities of each team, and how they expect the data intensive astronomy group will help them achieve their goals • Form the DIA technical group and executive • Obtain and document data flow requirements for HI surveys • Investigate possible DIA role in future visualization/VR projects • Pilot cross-matching and querying of ASTRO 3D datasets across the different data centres
	MWA EoR Survey	• Process and publish the first 50-100 hr data set • Define and implement a data quality database • Obtain a census of the ionospheric conditions in the EoR fields with MWA • Analyse the impact of the ionosphere power spectrum on the EoR observations • Measure and characterise the first MWA beam data set • Develop an end-to-end simulation to explore instrumental parameters

Continued

	ACTIVITY	ACTION
RESEARCH PROJECTS AND SURVEYS	**First Stars Project**	• Optimize photometric selection of extremely metal-poor star candidates from SkyMapper Data Release 1 • Analyse AAO spectra of bulge extremely metal-poor star candidates • Observe extremely metal-poor star candidates with Magellan • Perform 3D spectral line formation calculations for each element, such as H, Li, C, Na, Mg, and Al
	First Galaxies Project	• Develop pipeline for processing Hubble Space Telescope BoRG survey data • Begin analysing Hubble Space Telescope Frontier Fields data • Determine the environment around the most distant galaxies and quasars • Analyse the clustering of the most distant galaxies using number counts • Derive the chemical elemental abundances of the most distant galaxies using gravitationally lensed galaxies and Keck data • Design observations and conduct modelling for James Webb Space Telescope observations of the most distant quasars
	Galaxy Evolution Project	• Search the Dark Energy Survey images for strongly lensed galaxies to observe on Keck and the VLT • Develop Mappings photoionization models to apply to distant galaxy spectra for measuring the amount of carbon, nitrogen, and oxygen • Apply for telescope time on Keck and the VLT to begin obtaining data for distant galaxies, including star-forming galaxies, massive galaxies, and candidate spiral galaxies • Analyse Lyman continuum galaxy spectra with MAPPINGS models
	ASKAP FLASH Survey	• Develop detailed plan and timeline with Genesis team for Genesis simulations of FLASH data • Deliver and verify FLASH end-to-end data processing pipeline • Apply pipeline to ASKAP-12 test field • Present first FLASH results
	ASKAP DINGO Survey	• Select target fields for commencement of full-survey operations • Deliver initial pipeline for ASKAP DINGO data processing

Continued

	ACTIVITY	ACTION
RESEARCH PROJECTS AND SURVEYS	**ASKAP WALLABY Survey**	• Prepare the ASKAP WALLABY pipeline • Prepare observations for WALLABY survey • Obtain and analyse WALLABY early science data of HI observations in nearby galaxies • Submit WALLABY early science data publication with science highlights
	SAMI/HECTOR Survey	• Prepare SAMI Data Release 2, including data products, quality control and publications • Fit the emission-line data and analyse the distribution of chemical elements in SAMI face on or inclined galaxies • Analyse the stellar populations in SAMI galaxies • Analyse the kinematics, spin, and angular momentum in SAMI galaxies • Manufacture HECTOR fibre cable and hexabundles • Design HECTOR pilot survey and prepare input catalogue
	GALAH	• Update GALAH data calibration using photonic comb • Use GAIA parallax data to improve GALAH stellar parameter and chemistry analysis method • Complete chemo-dynamical study of the solar neighbourhood, open clusters, and the Milky Way thin/thick disk • Complete GALAH public data release 2, and complete internal team data release 3
EDUCATION	**ASTRO 3D in the Classroom**	• Continue to deliver the program under the current funding model • Engage with practising science educators to review the program (previously delivered by CAASTRO) to meet the changing needs of schools
	Telescopes in Schools	• Support the program run by the University of Melbourne and develop a plan to fund and roll the program out nationally
	Teacher Training and Resources	• Engage with practising science teachers to develop a suite of products to support the astronomy component of the Australian curriculum
	Space Squad	• In partnership with YMCA, develop an ASTRO 3D activity to complement the existing program

Continued

ACTIVITY		ACTION
OUTREACH AND COMMUNICATIONS	**Uluru Programs**	• In partnership with Voyages Indigenous Tourism, coordinate and deliver the Uluru Astronomer in Residence program (previously delivered by CAASTRO) from April to November and the Astronomy Weekend in September 2018
	Public Outreach	• Participate in science events and develop public outreach activities for National Science Week in August 2018 • Participate in major astronomy festivals around Australia where there is a strategic benefit to the Centre • Deliver public talks on the research work of the Centre and astronomy in general as well as ASTRO 3D gender equity programs
	Public Relations and Media	• Ensure that the research outcomes of the Centre are communicated through the media to reach the broadest possible audience • Share discoveries and promote discussion and comment on the activities of the Centre and astronomy in general via social media platforms such as Facebook, Twitter, Instagram, YouTube
	Innovation	• Develop the concept and production plan for the new 3D planetarium production to be released in 2019 • Investigate innovative, high- quality forms of media including 3D and VR to inform and educate the broader community about the work of the Centre
	Website	• Launch the ASTRO 3D website and intranet

Continued

	ACTIVITY	ACTION
RESEARCH AND LEADERSHIP TRAINING	**Professional Development**	Deliver the following professional development training: • Professional Astronomical Skills Training Workshop • Diversity Training Workshops at every node • Early Career Researcher Training Day • Science Communication Workshop • Transferable Skills Workshop • Writing Workshops and Project Busy Weeks Develop and implement the following ongoing programs: • Centre-wide Mentoring Program • Emerging Leaders Program • Women's Career Advancement Program
	Workshops and Conferences	Deliver a workshop and conference program that includes: • 2 international conferences • 2 national conferences/workshops • At least 40 professional conferences and workshops
	Visitor Program	• Deliver a Visitor Program promoting effective collaboration and development
GOVERNANCE	**Advisory Boards**	• Finalise membership of the International Advisory Board and National Advisory Board and organise meetings as per the terms of reference
	Committees	• Ensure the Executive Management, Science Management and Equity and Diversity Committees contribute effectively to the work of the Centre • Develop Terms of Reference and form the following new Committees — Education and Outreach Committee, Intellectual Property Committee, Post-Doctoral Committee and Student Committee
	Equity and Diversity	• Develop and Implement an ASTRO 3D Gender Action Plan
	Financial Management	• Revise the ASTRO 3D budget and ensure that proper controls are implemented to ensure sound financial management practices
	Reporting	• Ensure that ASTRO 3D meets all its financial and KPI reporting obligations

COMMERCIALISATION AND TECHNOLOGY TRANSFER

Over the seven-year life of ASTRO 3D, there will be significant instrument and technology developments made for the next generation of telescopes, including the Square Kilometre Array and the Giant Magellan Telescope.

In addition to the investment opportunities, the technology transfer benefits to Australia of constructing of new, innovative instrumentation and facilities are enormous. The construction of a Mega-scale facility, as well as its associated energy and data processing needs, requires significant technological advances in many fields from optics, electronics, computing and alternative energy. The opportunity to transfer of these technologies to other industries produces fundamental advances in a wide range of areas. For this reason, astronomy technology has led to fundamental advances in optics, electronics, advanced computing, communications, medicine, and alternative energy. For example, film used for solar astronomy is now used by industrial photographers, medical and industrial spectroscopy specialists and has been used to check for forgery, detect diseased crops and forests, as well as being used in dentistry and medical diagnosis. Charge Coupled Devices were first developed for astronomy to electronically capture astronomical image, replacing film.

There are a number of specific examples of technology transfer, which directly involve ASTRO 3D projects or resources.

- As part of its astronomy fibre development for the Anglo-Australian Telescope OH-suppression spectrographs, including HECTOR, CI Joss Bland-Hawthorn's research team at the Sydney Astrophotonic Instrumentation Laboratory (SAIL) developed a ground-breaking photonic device called the "photonic lantern" that allows single-mode action in a multimode fibre. Single-mode fibres underlie all telecommunications and only allow light to propagate in one way. The lantern converts the multimode signal to parallel single-mode tracks in which complex gratings can be installed to block unwanted noise signals in many narrow frequency bands. This technology is now used by Alcatel-Lucent, AT&T Bell Labs, USA for their new local area network systems. The SAIL labs also developed a compact diffraction-limited Raman spectrograph, which is now used by Horticulture Australia Ltd in robotic food safety sensors on farms.

Astronomy technology has led to fundamental advances in optics, electronics, advanced computing, communications, medicine and alternative energy.

- Astronomical datasets are complex and the processing of these datasets has required collaboration between astronomy, computer science and statistics. Many techniques to tackle spatial data were pioneered in astronomy and subsequently transferred to other fields including geosciences and ecology. Prior to joining ASTRO 3D, CI Karl Glazebrook created specialized software for astronomy, called the Perl Data Language, which has been used in over 100 applications ranging from linguistics to genome research. AI Tobias Westmeier lead the development of the Busy Function, an analytic function designed to describe the spectral profile of galaxies in radio data. The associated code has been accessed a thousand times for applications in industry, universities and government world-wide.
- The ANU Research School for Astronomy and Astrophysics Advanced Instrumentation Centre (AITC) specialises in an adaptive optics technique that uses lasers to correct astronomical images from distortions introduced by our atmosphere. The ASTRO 3D galaxy evolution program relies heavily on this technology, which is now used in Antarctic Broadband, the VIPAC Greenhouse Gas Monitor, the Australian Plasma Thruster, and in Space Debris Detection and Monitoring by EOS-Space Systems.
- CSIRO has developed innovative Phased-Array Feeds for the Australian Square Kilometre Array Pathfinder (ASKAP), which is used in the three ASTRO 3D surveys — FLASH, DINGO, and WALLABY.
- Industry participation in ASKAP has created strong collaborations with a variety of organisations, among them niche R&D companies. These partnerships have resulted in commercial contracts with high-volume manufacturers, technology systems vendors, site services, installation firms and energy and data transmission specialists. Solutions for the nonastronomy challenges for ASKAP, including hybrid solar-diesel power, remote access and operations, and high-tech infrastructure will also have applications elsewhere in Australia and around the world.

The Centre will adhere to the IP requirements of the organisations where the IP was developed, guided by the ARC “National Principles of Intellectual Property Management for Publicly Funded Research” document. Although ownership of the IP remains with the relevant partners, the ASTRO 3D Executive Management Committee and National Advisory Committee will make recommendations regarding commercialisation. During 2018, we will form the ASTRO 3D Intellectual Property Committee to provide expert guidance for researchers with IP issues and provide the framework for technology transfer and commercialization of IP developed in the Centre instrumentation and Data Intensive Astronomy programs.

The technology transfer benefits to Australia of constructing of new, innovative instrumentation and facilities are enormous.

INDUSTRY AND COMMUNITY LINKAGES

ASTRO 3D has three main industry and community stakeholders — the National Computational Infrastructure (NCI) supercomputing facility, the Australian Astronomical Observatory and CSIRO Astronomy and Space Science (CASS).

NATIONAL COMPUTATIONAL INFRASTRUCTURE

The ASTRO 3D Genesis Simulations thread has benefitted greatly in 2017 from the support of NCI, which has provided both HPC facilities and expertise. Core to our research programme is the running of very large N-body simulations and physics-rich hydrodynamical simulations, generating tens to hundreds of terabytes of data and requiring hundreds of thousands to millions of CPU hours. NCI has provided the computing time to allow the Centre to carry out these simulations and to store the resulting datasets, as well as providing expert assistance to ensure that our codes are running optimally, and exploiting fully the NCI architectures.

In mid-to-late 2017, Dr Dale Roberts from NCI analysed the Genesis codes for generating cosmological initial conditions and for running simulations, and assessed how these codes might scale to the large problem sizes we will tackle in the coming years. This NCI input was invaluable for assessing the size and scope of simulations that could feasibly be run in the short to medium term, and guided our science planning at the ASTRO 3D retreat in November 2017.

From late 2017, the Genesis team have been running a suite of large cosmological N-body simulations — of up to a few tens of billions of particles — on the NCI to support our research programmes on the Epoch of Reionisation, the first galaxies, and galaxy evolution. These runs have so far required hundreds of thousands of CPU hours and have generated of order 100TBs of raw simulation data, and the results are already being used to carry out galaxy formation modelling, which is supporting the first set of ASTRO 3D theory papers.

The Genesis Simulations research programme will benefit enormously from the planned upgrade of the NCI peak HPC facility in 2018/19 and we look forward to tackling the full suite of ambitious Genesis simulations with the new facility.

CSIRO ASTRONOMY AND SPACE SCIENCE

ASTRO 3D has been operating a successful partnership with CSIRO Astronomy and Space Science, with partner investigator Bärbel Koribalski (Office of the Chief Executive Science Leader, CSIRO) leading the WALLABY survey in collaboration with researchers at the University of Western Australia and the University of Sydney. In addition, CSIRO Program Director and SKA Project Scientist Phil Edwards has agreed to serve on the ASTRO 3D Science Management Committee. This appointment will help to ensure a strong scientific collaboration between university and CSIRO researchers, and to identify new opportunities for CSIRO and university linkages.

AUSTRALIAN ASTRONOMICAL OBSERVATORY

ASTRO 3D utilises the SAMI and GALAH instruments operated by the Australian Astronomical Observatory at the Anglo Australian Telescope. The surveys conducted with these instruments are proving tremendously successful, with the first science results coming out in 2017 and many more to come in 2018.

The ASTRO 3D nodes have been collaborating closely with researchers based at and affiliated with the Australian Astronomical Observatory, including PIs Andrew Hopkins and Warrick Couch, as well as AIs Angel Lopez-Sanchez, Richard McDermid, Gayandi de Silva, Lee Spitler, and Dan Zucker. These PIs and AIs are working within the SAMI, GALAH and the Galaxy Evolution projects in ASTRO 3D.

In June 2018, the Anglo Australian Telescope and telescope staff will transition to a new arrangement managed by the Australian Astronomical University, while the Australian Astronomical Observatory technical and research program transition from the Department of Industry, Innovation and Science to an independent national entity, with headquarters at Macquarie University. The new AAO entity is a collaboration between Macquarie University, the University of Sydney and the Australian National University. ASTRO 3D wishes the telescope staff, research staff, and technical program staff all the best during this transition period and we look forward to continuing our fruitful collaboration under these new arrangements in 2018. With the transition of several research staff to Macquarie University, the ASTRO 3D executive, Science Management Committee, and Advisory Boards will consider the addition of Macquarie University as a potential additional node, once the transition is complete and the new entity's management team is in place.

The Anglo-Australian Telescope Dome. ***IMAGE CREDIT:*** AAO

SPOTLIGHT ON DILYAR BARAT FROM ANU

FROM ASTRONOMY TO INDUSTRY

Dilyar is an ANU PhD student working on distribution of galaxies but has been able to utilise his astronomy skills and experience in data reduction and data management to deliver Artificial Intelligence and Machine Learning solutions to one of Australia's leading tech startups.

Intelledox, a global Canberra-based tech startup who design customer-friendly digital experiences, were looking for interns to help them develop their next generation Form Builder. Dilyar, who freely admits he is "not an AI expert" was, however, excellently placed to help Intelledox out. "I can Google 'properly' and am excellent at bringing together software packages and databases to make them talk to each", he said. "I am trained to find solutions that put the raw data in and spit out the information other scientists need — they are my customers." It was this focus on the customer's needs that he feels got him the internship. "I was able to show them how existing AI and Machine Learning work to make their product more intuitive and better for their customers, because in the end, if they can't sell it to their customers, they can't make money."

Dilyar also felt his outreach experience in astronomy helped him in the internship interview and in his presentation to the global team. "Being able to translate complex terms and ideas into everyday language is definitely something that Intelledox valued."

He found working for industry an "eye-opener" and can recommend the experience to other PhD students and Post-Docs.

"The commercial skills I picked up will help in my post-PhD job searching. Whether I continue in academia or go sideways into the industry, this experience will be invaluable."

So much so, that Intelledox continues to want to employ him and he now finds himself juggling a full-time PhD with part-time work — like he wasn't busy enough already!

EDUCATION PROGRAMS

ASTRO 3D IN THE CLASSROOM

ASTRO 3D will take over the CAASTRO in the Classroom program in early 2018. The program, which has been coordinated from the University of Sydney as part of the CAASTRO Centre of Excellence, has successfully engaged Australian school students with research scientists and PhD students in a virtual meeting room through live streamed curriculum-focused lectures, short research presentations and discussions of a particular aspect of astronomy or physics, or a forum on life as a scientist.

The renamed ASTRO 3D in the Classroom has been funded by the Federal Government's Women in STEM & Entrepreneurship grants until December 2018. Over the next 12 months we will undertake a review of the content and delivery of the program to ensure that it continues to be relevant, have national impact and provide a platform for alternate funding opportunities.

TELESCOPES IN SCHOOLS

ASTRO 3D will be rolling out the Telescopes in Schools program to all states represented in the Centre during our first three years. Currently run out of the University of Melbourne and privately funded, the program is targeted at high school students in Years 7 to 9 and provides selected schools with a 12 inch computerised telescope and all the necessary gear to observe the night sky, image the objects in the night sky and conduct small research projects. These telescopes are large enough to view deep sky objects such as nebulae and far away galaxies or zoom in on a crater on the moon. Students engage with an astrophysicist about their research and then learn how to set up and drive the telescope to conduct their own research projects.

As part of our Indigenous Engagement activities, we will engage indigenous schools in our Telescopes in Schools program. For these schools, we will include a new program to explore how different cultures view the night sky.

The LX 200 -ACF Meade Telescope that each school uses in the Telescopes in Schools program.

TEACHER TRAINING AND RESOURCES

The 2016–2025 Australian Astronomy Decadal Plan identifies a significant need for effective training of teachers and for implementation of astronomy materials within the new Australian F–10 Science Curriculum. Teacher-training programs, including high-quality astronomy teaching materials, can significantly impact the quality of school education.

ASTRO 3D will ensure that STEM teachers around the country have access to the best teaching resources available by developing a program that includes large-scale engagement of astronomers in teacher-training and curriculum development at the primary and secondary levels (K-12). This program will begin with the teachers from our CitC and Telescopes in Schools networks, and expand to schools in each node state. We will provide movies, tutorials and Q&A sessions (both on-line and in-person) to train teachers to use astronomy educational materials in their classrooms.

Australian Curriculum-linked activities, units of work and registration for Professional Development for teachers will all be available on our website. We will ensure that our resources link cutting-edge astrophysics research to the Australian Science, Mathematics and Digital Technologies curriculum.

We will have teaching and learning resources linked to:

- Science understanding
- Science as a human endeavour
- Science inquiry skills
- Data representation and interpretation
- Problem solving and reasoning
- Data modelling and visualisation

OUTREACH AND ENGAGEMENT

The future of our country rests on inspiring and training the next generation of scientists and citizens. Communicating astronomical discoveries and achievements to the broadest possible audience engages the general public in astronomy and inspires students to consider a career in STEM research areas.

Over the next decade, greater collaboration and partnership among astronomy research organisations and astronomy outreach providers is essential for expanding the public impact of astronomy.

ASTRO 3D is bringing together outreach experts to build state and nation-wide campaigns under our Centre's outreach program. The program will include a broad range of public outreach activities including events such as National Science Week and Space Camp, the Uluru Astronomer in Residence and annual Astronomy Weekend (see more on these below), planetarium productions, public lectures, TV and radio appearances, popular magazine and newspaper articles, as well as maintaining a strong website and social media presence.

ULURU ASTRONOMER IN RESIDENCE

ASTRO 3D will be working in partnership with Voyages Indigenous Tourism Australia to deliver this well-regarded program from 2018. Astronomers from our team will be in residence at Uluru for nine months of the year on a fortnightly roster, engaging with tourists and the indigenous community, sharing knowledge of the night sky as viewed by different cultures, as well as the latest Centre discoveries. Guests at the resort gain valuable insight to the work of professional astronomers and the astronomers involved develop their science communication skills as well as adding scientific knowledge to the night sky discussion.

The Indigenous Land Corporation operates Voyages on behalf of the Indigenous community, and all profits support Indigenous programs across Australia.

ULURU ASTRONOMY WEEKEND

In addition to the Astronomer in Residence Program, ASTRO 3D and Voyages Indigenous Tourism Australia will be hosting a very special event, the Uluru Astronomy Weekend from 2018. Over three days our ASTRO 3D researchers and affiliates will present astronomy talks to the general public, participate in panel discussions and join resort guests for trivia lunches and the spectacular Stellar Starlight dinner.

PLANETARIUM PRODUCTIONS

ASTRO 3D is developing a new Planetarium show for release in 2019, building on the wonderful work done by the CAASTRO team with their full length production, *Capturing the Cosmos*, which was produced in conjunction with Museum Victoria. The ASTRO 3D show will be distributed free to all planetariums in Australian and New Zealand and sold to overseas planetariums. We will develop this planetarium program into a major commercial initiative, with proceeds used to support our Telescopes in Schools and Teacher Training programs. These planetarium productions have an extremely broad reach, with an anticipated viewership of 1 million people per production.

MEDIA AND SOCIAL MEDIA

ASTRO 3D has a team of top researchers whose scientific achievements often attract significant local, national and international media coverage.

To ensure that we reach the maximum possible audience we are using a range of external communications channels including press releases, our newly launched website and social media.

Our ASTRO 3D Twitter account (@ARC_ASTRO3D) was opened in November 2017 and after only three months has 241 followers with just under 500 “tweets” on our work and to share astronomical information. Our Facebook Page was launched at the same time and now has 56 likes with the level of interest growing every day. We will be expanding our social media reach in 2018 through Instagram and YouTube accounts.

ASTRO 3D has a team of top researchers whose scientific achievements often attract significant local, national and international media coverage.

ANNUAL RETREAT 2017

The first annual ASTRO 3D retreat was held over three days in November 2017 at Peppers Craigieburn, located at Bowral in the beautiful NSW Southern Highlands. It was the first opportunity for 85 of our ASTRO 3D members from all over the country to get together, share knowledge and develop the relationships that will help us build a collaborative and successful Centre.

The retreat agenda included a mix of governance and strategic planning, science discussion and networking opportunities, making the retreat a valuable experience for those who attended. Members discussed the Centre's science strategic and annual work plans at both theme and project level, including the workshops and conferences needed to help meet our Science Goals for 2018, as well as which international visitors will help facilitate science progress for each survey or project. Science highlights were presented by some of the ASTRO 3D early career researchers and discussion panels were convened on both the theoretical supercomputing and telescope facilities, as well as opportunities to facilitate collaborations across the Centre and our equity and diversity planning. Many great ideas were raised that we are building into our planning for future years.

There was plenty of time in the agenda allowed for breakout sessions including survey/project groups, cross-project discussions, and a session for faculty, junior faculty, postdocs and students to each get together and discuss their needs within the Centre environment.

Feedback received after the retreat was very positive with attendees having particularly enjoyed the breakout sessions and panel discussions. We will continue these sessions during our next retreat in Western Australia in November 2018 and build on the great experience that we had in Bowral.

RESEARCH AND LEADERSHIP TRAINING

The ASTRO 3D Research and Leadership training programs will commence from 2018 as we build our exceptional team of researchers and students.

CENTRE-WIDE MENTORING PROGRAM

During 2018, ASTRO 3D will develop and deliver a vibrant and successful individual and group mentoring program that benefits all Centre participants, utilising our team's extensive experience and diversity to build a sense of collegiality, satisfaction, confidence and achievement across the Centre.

The program will group early career researchers with networks of multiple "mentoring partners" in non-hierarchical, collaborative partnerships with a trained facilitator to address specific areas such as research, career paths, time management and work-life balance.

The success of the mentoring program will be measured through annual Centre climate surveys that will track self-confidence, career satisfaction, leadership capabilities, communication skills, and achievement of development goals amongst Centre participants.

PROFESSIONAL ASTRONOMICAL SKILLS TRAINING WORKSHOPS

Astronomy students require a range of professional and personal skills to successfully conduct and lead research on the international stage. Capitalising on the existing experience of the ASTRO 3D team, from 2018 we will offer annual workshops in skills such as scientific writing, writing postdoctoral, ARC grant and DECRA applications, professional presentations and time management skills to all students and early career researchers nationwide, both within and outside ASTRO 3D.

TRANSFERRABLE SKILLS PROGRAM

The Australian Astronomy Decadal Plan identified a critical mismatch between supply and demand in Australian astronomy, with the cohort of Australian astronomy PhD students having grown by 70% over the past decade. With the large rise in the number of PhD students, training for careers both within and outside astronomy is essential. Astrophysics PhD students typically finish their studies having gained substantial problem-solving and statistical skills so we will ensure that those skills are transferrable, providing highly skilled graduates for roles in the wider community.

The Centre has partnered with the Sydney Astrophotonic Instrumentation Laboratory (SAIL) and the Advanced Instrumentation Technology Centre to provide three month internships for our PhD students, beginning in 2018. Students will work on projects that are contracted to the laboratories, including fibre technology and development, optical design, prototyping and 3D printing. We will also operate an annual "Beyond Astronomy" workshop in collaboration with SAIL, beginning in Dec 2018. These workshops will include talks and discussions by former astronomers who are now working in other disciplines, followed by hands-on prototyping sessions in the SAIL Astrophotonics laboratory. The speakers will provide insight into their new occupations and how they made their transition from astronomy, giving our astronomy PhD students tangible examples and role models who can demonstrate successful transition from astronomy into other fields.

Data intensive science is a rapid growth field. Training students to manage massive datasets opens an array of new career paths including population statistics, medical science, bioinformatics, banking, media science, and genomics, yielding lasting benefits to the Australian community. From 2018 ASTRO 3D will offer transferrable skills courses in managing large data sets, programming in languages in demand by industry, training in industry practices and professional project management skills. These workshops will bring in industry and cross-disciplinary experts to train astronomy students and early career researchers with the lateral skills needed to transition to alternative careers.

The Centre will also sponsor additional workshops and conferences such as Dotastronomy, which brings together an international community of astronomy researchers, developers, educators and communicators to showcase and build upon web-based projects, from outreach and education to research tools and data analysis.

The usefulness and success of the transferrable skills program will be measured through workshop exit surveys, through Centre exit surveys and by tracking the careers of former Centre participants. Providing highly skilled scientists with outstanding problem solving and data management experience for the Australian economy is a significant achievement of the ASTRO 3D transferrable skills program.

EMERGING LEADERS PROGRAM

In the era of mega-scale telescope facilities, astrophysics will shift from relatively small teams and networks (typically a few to a few tens of active researchers) to significantly larger teams and global networks of researchers. ASTRO 3D will offer workshops specifically aimed at developing the skills to work and lead in the mega-scale telescope environment, including large project management, effective team building, risk management, negotiation and conflict resolution, collaborating planning and strategizing, and time management. The Centre will utilise partner organisations, AAO and CSIRO, as well as university-industry partners to bring in experts from each of these areas.

ASTRO 3D will also provide leadership coaching to our most promising young researchers to help them confidently and successfully transition from researcher to team leader. The Centre's CI/PI team contains many of Australia's most talented scientific leaders who will be matched up one-on-one with young emerging leaders for individual coaching sessions.

The success of the emerging leaders program will be measured through workshop exit surveys and by tracking the careers of participants throughout the course of the Centre.

SUCCESSION PLANNING

ASTRO 3D will incorporate succession planning into our Centre to ensure that there is a clear career progression for the best young researchers as well as a renewal of the scientific drive in the latter half of the Centre.

EQUITY AND DIVERSITY PROGRAM

Women's participation in Australian Science, Technology, Engineering, and Mathematical (STEM) fields remains low from high school through to the academic levels. Research shows that women require a safe workplace environment in which they can practice new leadership skills and share personal stories of challenge and vulnerability without having to hold up the role model position as the "first" or "only" woman leader. Being among a community of other accomplished women leaders enhances the sense that "If she can do that, so can I".

ASTRO 3D will develop a Gender Action Plan in 2018 which will include initiatives aimed at creating a supportive and family-friendly environment as well as improving and sustaining the advancement of women to senior levels. These include family-friendly core meeting times, child care at conferences, support for travel to conferences with children, part-time options for every position, the nomination of women for prizes and awards and a target of science outreach programs to girls.

As part of the Action Plan we will introduce Equity and Diversity Mentoring Groups that bring together women in the Centre, as well as additional mentoring groups to cover the range of types of diversity in the Centre including racial minorities, sexual minorities (gay, lesbian, bisexual, and transgender), and people with challenges that affect their ability to conduct full time research, such as illness or disabilities. These mentoring groups will be professionally facilitated and will address research, career paths, time management, work-life balance, as well as specific topics relevant to the diverse group such as combining children and an academic career, and how to successfully manage a research career part-time.

ASTRO 3D will also introduce a Women's Career Advancement Program to further improve the academic environment and advancement of women to senior levels. Women continue to be underrepresented in the higher levels of astrophysics, despite the fact that they have been entering the field in increasing numbers, and have made up approximately 50% of the PhD student cohort for over a decade. Research shows that advancing women into leadership positions requires both a cultural change in the workplace and persistent efforts to sustain the career advancement of women early career researchers. We will offer specific women career advancement seminars and workshops including CV preparation, self-assessment, job application preparation, interview practice, and academic level promotion application and interview advice. We will use our university and participating organization gender centres and networks to source experts for these seminars and workshops.

We will strive to ensure that the Centre as a whole plus every node and Australian partner organization achieve Gold status through the Pleiades Program. This program recognises and rewards astronomical organisations that have taken active steps to advance the careers of women through focused programs and that are striving for sustained improvement in opportunities for women to achieve positions of seniority, influence and recognition. Gold status recognises a truly outstanding sustained commitment to best practice and requires demonstrated best practices, novel or high-profile new initiatives, and monitoring of the organization conduct over a period of at least four years, among other requirements.

The success of our equity and diversity program will be measured through Centre climate surveys and through the Centre gender equity KPIs. Over the course of this Centre, we seek to achieve a fraction of 50% females at all levels including the executive, the Advisory Committee and at all Centre sponsored events (including speakers), as well as equity in salaries and opportunities.

PRESENTATIONS IN 2017

INVITED TALKS (includes conferences, workshops, colloquia, collaborations)

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
Galaxy Formation and Evolution in 3D	Lisa Kewley	Princeton/IAS Colloquium	Princeton, USA	Mar 2017
Galaxy Formation and Evolution in 3D	Lisa Kewley	Colloquium — Macquarie University	Sydney, Australia	May 2017
Observational Evidence of Gas Flow	Glenn Kacprzak	In & Out. What Rules the Galaxy Baryon Cycle	Garching, Germany	Jun / Jul 2017
Galaxy Formation and Evolution in 3D	Lisa Kewley	13th Asian-Pacific Regional IAU meeting	Taipei, Taiwan	Jul 2017
Gravitational Instability in Galaxy Formation	Mark Krumholz	Sexton Conference — Gravitational Instability Across Cosmic Scales	Sexton, Italy	Jul 2017
Chemical abundances in metal-poor stars & High precision chemical abundances	David Yong	27th TRIUMF Summer Institute (TSI 2017)	Vancouver, Canada	Jul 2017
Stellar population studies with solar like oscillators: what we have learnt so far and the promise of TESS	Luca Casagrande	TESSting Stellar Astrophysics	Birmingham, UK	Jul 2017
The Evolution of the Milky Way	Naomi McClure-Griffiths	ISM-in-3D Conference	Orsay, France	Jul 2017
Resolving Galaxies	Brent Groves	JWST: The Resolved Universe of Galaxies	Hirschhorn, Germany	Jul 2017
Local galaxy counterparts of high-redshift clumps	Karl Glazebrook	Linking Observations and Theory Across the Scales of Star Formation in Galaxies	Sesto, Italy	Jul 2017
Cold gas in galaxies	Barbara Catinella	In & Out. What Rules the Galaxy Baryon Cycle	Munich, Germany	Jul 2017

Continued

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
Ram pressure vs. Starvation: an ill-defined dicothomy?	Luca Cortese	In & Out. What Rules the Galaxy Baryon Cycle	Munich, Germany	Jul 2017
Star Formation, Fuelling and Feedback in Galactic Centres	Mark Krumholz	CAASTRO Science Conference	Canberra, Australia	Aug 2017
The Origin of Stellar Masses	Mark Krumholz	Colloquium — University of Sydney	Sydney, Australia	Aug 2017
GMT Science, Galaxy Evolution	Brent Groves	GMT Science Book Writing Workshop	Pasadena, USA	Aug 2017
The Role of Turbulence, Magnetic Fields, and Feedback for Star Formation	Christoph Federrath	Magnetic17 — Stars with a stable magnetic field	Brno — Czech Republic	Aug 2017
The Role of Turbulence, Magnetic Fields, and Feedback for Star Formation	Christoph Federrath	SFDE17 — From Local Clouds to Distant Galaxies	Quy Nhon, Vietnam	Aug 2017
Present MWA and EDA digital systems overview and how CASPER can be incorporated into MWA Phase III design.	Wayth, Randall	CASPER Workshop	Los Angeles, USA	Aug 2017
The kinematic connection between highly ionized circumgalactic gas and their host galaxies	Glenn Kacprzak	The Circle of Life: IGM, CGM, and ISM	Kruger Park, South Africa	Aug 2017
Massive galaxies — quenching vs time and environment	Karl Glazebrook	Challenges in Galaxy Evolution from black holes to the cosmic web	Florence, Italy	Aug 2017
The ASTRO 3D Data Intensive Astronomy Program	Lister Staveley-Smith	ADACS Data Intensive Astronomy workshop	Melbourne, Australia	Aug 2017
The Role of AGN Feedback in Galaxy Formation	Chris Power	From Black Holes to Environments	Canberra, Australia	Aug 2017
First Stars: Progress & Prospects	David Yong	Fifth Annual GMT Community Science Meeting: Chemical Evolution of the Universe	Tarrytown, USA	Sept 2017
Epoch of Reionisation with the Murchison Widefield Array, and looking toward SKA	Trott, Cathryn	ACAMAR 3 — 3rd Australia China Workshop on Astrphysics	Hobart, Australia	Sept 2017

Continued

INVITED TALKS (includes conferences, workshops, colloquia, collaborations)

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
SKA-CD/EoR Project	Trott, Cathryn	IAUS333 — Peering Towards Cosmic Dawn	Croatia, Dubrovnik	Sept 2017
Stellar populations and dynamics from resolved spectroscopy of galaxies	Matthew Colless	5th Annual GMTO Meeting	New York, USA	Sept 2017
Lessons from ASKAP, ATCA and Parkes	Lister Staveley-Smith	Radio Astronomy Forum	Pingtang, China	Sept 2017
Between Window and Wedge: An Improved Statistical Point-Source Foreground Model for the EoR	Murray, Steven	IAUS333 — Peering Towards Cosmic Dawn	Dubrovnik, Croatia	Sept 2017
The population of quiescent (or not?) galaxies at z~4.	Karl Glazebrook	Caltech—Swinburne workshop in galaxy evolution	Pasadena, USA	Sept 2017
HI absorption science overview	James Allison	MIGHTEE Survey workshop	Oxford, UK	Sept 2017
Stellar populations & dynamics from resolved spectroscopy of galaxies	Matthew Colless	GMT Community Science Meeting	Tarrytown, New York	Sept 2017
Redundant Calibration: Breaking the constraints of limited sky information	Joseph, Ronniy	IAUS333 — Peering Towards Cosmic Dawn	Dubrovnik, Croatia	Sept / Oct 2017
Measuring the Global EoR Signal using the Moon and the MWA	McKinley, Ben	IAUS333 — Peering Towards Cosmic Dawn	Dubrovnik, Croatia	Sept / Oct 2017
Emission line diagnostics for JWST	Lisa Kewley	Lorentz Centre Workshop — Characterising galaxies with a view for JWST	Leiden, The Netherlands	Oct 2017
GALAH Science	Martin Asplund	Know thy star Conference	Pasadena, USA	Oct 2017
The history of cold gas in the Universe using SKA	James Allison	School of Physics Seminar, The University of Sydney	Sydney, Australia	Oct 2017

Continued

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
Cosmology in the Near Field	Joss Bland-Hawthorn	John Lattanzio's 60th birthday conference	Port Douglas, Australia	Oct 2017
The large-scale accretion of gas onto galaxies	Joss Bland-Hawthorn	The role of gas in galaxy dynamics	Malta	Oct 2017
Questions & Answers — Galaxy Evolution	Joss Bland-Hawthorn	The role of gas in galaxy dynamics Conference	Valletta, Malta	Oct 2017
Dust and extinction corrections	Brent Groves	Star formation Rates in the Age of JWST	College Station, TX, USA	Oct / Nov 2017
Heavy element variations in globular clusters	David Yong	With One Hand Waving Free	Australia, Port Douglas	Oct / Nov 2017
SED Modelling Challenges	Elisabete da Cunha	Workshop on "Plumbing Star Formation Rates in the Era of JWST"	College Station, TX, USA	Oct / Nov 2017
GALAH Science	Martin Asplund	Stars in Sydney Workshop	Sydney, Australia	Nov 2017
Galaxy-Absorber Pairs at Redshift 4 to 6	Emma Ryan-Weber	The 3rd Swinburne—Caltech Workshop: Galaxies and their Halos'	Pasadena, USA	Nov 2017
Chemical Tagging and CEMPs in ultra faint dwarfs	Joss Bland-Hawthorn	Tim Beers 60th birthday conference, Melbourne	Melbourne, Australia	Nov 2017
HECTOR: A massive new integral field spectroscopic instrument for the AAT	Julia Bryant	Gama: Final Data Release, Legacy, And Future Galaxy Evolution Surveys, Icrar	Perth, Australia	Nov 2017
Astronomy Colloquium	Elisabete Lima da Cunha	Colloquium — University of Texas at Austin	Austin, TX, USA	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

Continued

INVITED TALKS (includes conferences, workshops, colloquia, collaborations)

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
The kinematics and star-formation histories of high-z quenched galaxies	Trevor Mendel	Lorenz Center Workshop — The Physics of Quenching Massive Galaxies at High Redshift	Leiden, The Netherlands	Nov 2017
The Stellar Initial Mass Function	Mark Krumholz	Hunstead Workshop — Galaxian Processes	Sydney, Australia	Dec 2017
Redundant Calibration: Breaking the constraints of limited sky information	Joseph, Ronniy	Science at Low Frequencies IV	Sydney, Australia	Dec 2017
Building models for extended radio sources: implications for Epoch of Reionisation science	Trott, Cathryn	Science at Low Frequencies IV	Sydney, Australia	Dec 2017
A census of ionospheric activity above the MRO with MWA EoR	Jordan, Chris	Science at Low Frequencies IV	Sydney, Australia	Dec 2017
MWA Phase II Status	Wayth, Randall	Science at Low Frequencies IV	Sydney, Australia	Dec 2017
The brightest galaxies at cosmic dawn	Michele Trenti	Distant Galaxies from the Far South	Bariloche, Argentina	Dec 2017
The ASKAP FLASH galaxy survey	James Allison	2017 Hunstead workshop on Galaxian Processes	Sydney, Australia	Dec 2017
The history of cold gas in the Universe using SKA	James Allison	Macquarie University Seminar	Sydney, Australia	Dec 2017
HECTOR: Galaxy Survey	Julia Bryant	Hunstead Workshop, University of Sydney	Sydney, Australia	Dec 2017
Cold gas scaling relations in galaxies	Barbara Catinella	2017 Hunstead Workshop on Galaxian Processes	Sydney, Australia	Dec 2017
Cold gas stripping in galaxy groups	Luca Cortese	Galaxy Evolution in Groups and Clusters at low redshift: Theory and Observations	Ringberg, Germany	Dec 2017

Continued

INVITED TALKS (includes conferences, workshops, colloquia, collaborations)

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
Review on observations of groups and clusters	Luca Cortese	Galaxy Evolution in Groups and Clusters at low redshift: Theory and Observations	Ringberg, Germany	Dec 2017
The connection between mass, environment and slow rotation in galaxies	Claudia Lagos	Galaxy Evolution in Groups and Clusters at low redshift: Theory and Observations	Ringberg, Germany	Dec 2017
The connection between mass, environment and slow rotation in galaxies	Claudia Lagos	Virgo workshop	Munich, Germany	Dec 2017
The Gaseous Outskirts of Galaxy Clusters	Chris Power	Hunstead Lectures	Sydney, Australia	Dec 2017
The Birth of Suns	Mark Krumholz	Invited seminar — Australian Institute of Physics	Hobart, Australia	Dec 2017
Star Formation Chronology of the Solar System	Mark Krumholz	Invited lecture — France-Australia Exobiology School	Canberra, Australia	Dec 2017
Probing ISM conditions at cosmic noon with REST-FRAME UV Diagnostics	Ayan Acharyya	Colloquium — National Centre for Radio Astronomy (NCRA)	Pune, India	Dec 2017
Determining effects of telescope resolution on metallicity gradient with synthetic observations of galaxy simulations	Ayan Acharyya	Colloquium — Indian Institute of Technology (IIT) Kharagpur	Kharagpur, India	Dec 2017

PUBLIC LECTURES

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
The true shape of galaxies	Caroline Foster	Astronomical Society of NSW	Sydney, Australia	Aug 2017
The true shape of galaxies	Caroline Foster	Penrith Observatory, Astronomy Night	Sydney, Australia	Aug 2017
Astronomy in Antarctica and Cosmology	Christian Reichardt	Melbourne High School	Melbourne, Australia	Sept 2017

OTHER PRESENTATIONS

SUBJECT	SPEAKER	EVENT	LOCATION	WHEN
ASTRO 3D Centre of Excellence	Lisa Kewley	Italian Science Bilateral Space & Astronomy Discussion	Canberra, Australia	Apr 2017
ASTRO 3D Gender Equity Program	Lisa Kewley	ARC Directors Forum	Canberra, Australia	Apr 2017
ASTRO 3D Centre of Excellence and ASTRO 3D Gender Equity Program	Lisa Kewley	Australian Research Council Staff Forum	Canberra, Australia	May 2017
ASTRO 3D DIA program	Lister Staveley- Smith	ASA Roundtable	Canberra, Australia	Jul 2017
ASTRO 3D Centre of Excellence	Lisa Kewley	Briefing with the Minister for Industry, Innovation & Science and incoming CEO of the Australian Research Council	Canberra, Australia	Jul 2017
ASTRO 3D Centre of Excellence	Lisa Kewley	IAC 2017 Panel Discussion	Adelaide, Australia	Sept 2017
ASTRO 3D Centre of Excellence	Lisa Kewley	ARC Centres of Excellence Research Showcase at Parliament House	Canberra, Australia	Sept 2017
Space Astronomy Capabilities in Victoria	Michele Trenti/Karl Glazebrook	Briefing with the Victorian Government Lead Scientist Dr. Amanda Caple	Melbourne, Australia	Nov 2017
ASTRO 3D Centre of Excellence	Lisa Kewley	ANU Year in Review	Canberra, Australia	Dec 2017

INTERNATIONAL VISITORS AND VISITS

WHO	INSTITUTION/AFFILIATION	WHEN
VISITORS TO ANU		
Sven Buder	Max Planck Institute for Astronomy, Germany	September – December 2017
Tadafumi Matsuno	National Astronomical Observatory of Japan, Japan	September – December 2017
Tim de Zeeuw	European Southern Observatory, Netherlands (Retired), ASTRO 3D International Advisory Board	November 2017
Julianne Dalcanton	University of Washington, USA	November 2017
Raffaella Morganti	ASTRON, Netherlands	December 2017
VISITORS TO UNIVERSITY OF MELBOURNE		
Miguel Morales	University of Washington, USA	December 2017
VISITORS TO SWINBURNE UNIVERSITY OF TECHNOLOGY		
Tom Collett	University of Portsmouth, UK	September – November 2017
Frederic Vogt	European Southern Observatory, Netherlands (Retired)	November 2017
VISITORS TO UNIVERSITY OF SYDNEY		
Raffaella Morganti	ASTRON, Netherlands	December 2017
Lars Hernquiest	Harvard University, USA	December 2017
VISITORS TO UNIVERSITY OF WESTERN AUSTRALIA		
Lilian Garratt-Smithson	University of Leicester, UK	August 2017
Jacinta Delhaize	University of Zagreb, Croatia	September 2017
Jens Niemeyer	Institute for Astrophysics, Gottingen, Denmark	October – November 2017
Peder Norberg	Durham University, UK	October – November 2017
Natasha Maddox	ASTRON, Netherlands	November 2017
Anna Frebel	Massachusetts Institute of Technology, USA	November – December 2017
Tom Jarrett	University of Cape Town, South Africa	December 2017
VISITORS TO CURTIN UNIVERSITY		
Nichole Barry	University of Washington, USA	November 2017

VISITS TO INTERNATIONAL INSTITUTIONS AND ASTRONOMY FACILITIES

WHO	WHERE	WHEN
Lisa Kewley	Princeton University, USA	Mar 2017
Joss Bland-Hawthorn	Keck Observatory, Hawaii, USA	Jun 2017
Ayan Acharyya	NASA Space Flight Centre, USA	Aug 2017
Darren Croton	University of California, Santa Cruz, USA	Aug 2017
Darren Croton	California Institute of Technology, USA	Aug 2017
Stuart Wyithe	Geneva Observatory, Switzerland	Sept 2017
Michele Trenti	University of Colorado, USA	Sept 2017
Michele Trenti	University of California, USA	Sept 2017
Michele Trenti	Space Telescope Science Institute, Baltimore, USA	Sept 2017
Michele Trenti	University of Michigan, USA	Sept 2017
Karl Glazebrook	Durham University, UK	Sept 2017
Karl Glazebrook	California Institute of Technology, USA	Sept 2017
Thomas Nordlander	Uppsala Observatory, Sweden	Oct 2017
James Allison	University of Oxford, UK	Oct 2017
David Yong	Las Campanas Observatory, Chile	Nov 2017
Michele Trenti	Kapetyn Astronomical Institute, The Netherlands	Dec 2017
Ayan Acharyya	National Centre for Radio Astronomy (NCRA), India	Dec 2017
Ayan Acharyya	Indian Institute of Technology (IIT), India	Dec 2017

PUBLICATIONS

REFEREED JOURNAL ARTICLES

1. Abbott, B. P.; Abbott, R.; Abbott, T. D.; Acernese, F.; Ackley, K.; Adams, C.; Adams, T.; Addesso, P.; Adhikari, R. X.; Adya, V. B.; and 3667 co-authors.

   Multi-messenger Observations of a Binary Neutron Star Merger
   The Astrophysical Journal Letters, 848, L12 (2017)

2. Andreoni, I.; Ackley, K.; Cooke, J.; Acharyya, A.; Allison, J. R.; Anderson, G. E.; Ashley, M. C. B.; Baade, D.; Bailes, M.; Bannister, K.; and 115 co-authors

   Follow Up of GW170817 and Its Electromagnetic Counterpart by Australian-Led Observing Programmes
   Publications of the Astronomical Society of Australia, 34, 69 (2017)

3. Bland-Hawthorn, Joss; Maloney, Philip R.; Stephens, Alex; Zovaro, Anna; Popping, Attila.

   In Search of Cool Flow Accretion onto Galaxies: Where Does the Disk Gas End?
   The Astrophysical Journal, 849, 51 (2017)

4. Calderon, Victor F.; Berlind, Andreas A.; Sinha, Manodeep.

   Small- and Large-Scale Galactic Conformity in SDSS DR7
   Mon.Not.R.Astron.Soc., arXiv:1712.02797 (2017)

5. Elahi, Pascal J.; Power, Chris; Lagos, Claudia del P.; Poulton, Rhys; Robotham, Aaron S. G.

   Using Velocity Dispersion to Estimate Halo Mass: Is the Local Group in Tension with Lambda CDM?
   Mon.Not.R.Astron.Soc., arXiv:1712.01989 (2017)

6. Glowacki, M.; Allison, J. R.; Sadler, E. M.; Moss, V. A.; Jarrett, T. H.

   WISE data as a photometric redshift indicator for radio AGN
   Mon.Not.R.Astron.Soc., arXiv:1709.08634 (2017)

7. Hallinan, G.; Corsi, A.; Mooley, K. P.; Hotokezaka, K.; Nakar, E.; Kasliwal, M. M.; Kaplan, D. L.; Frail, D. A.; Myers, S. T.; Murphy, T.; and 23 co-authors

   A radio counterpart to a neutron star merger
   Science, 358, 1579 (2017)

8. Hu, Lei; Wu, Xuefeng; Andreoni, I.; Ashley, Michael C. B.; Cooke, J.; Cui, Xiangqun; Du, Fujia; Dai, Zigao; Gu, Bozhong; Hu, Yi; and 23 co-authors

   Optical Observations of LIGO Source GW 170817 by the Antarctic Survey Telescopes at Dome A, Antarctica Science Bulletin
   62, 1433 (2017)

9. Kasliwal, M. M.; Nakar, E.; Singer, L. P.; Kaplan, D. L.; Cook, D. O.; Van Sistine, A.; Lau, R. M.; Fremling, C.; Gottlieb, O.; Jencson, J. E.; and 71 co-authors

   Illuminating gravitational waves: A concordant picture of photons from a neutron star merger
   Science, 358, 1559 (2017)

10. Trott, Cathryn M.; Wayth, Randall B.

    Building Models for Extended Radio Sources: Implications for Epoch of Reionisation Science
    Publications of the Astronomical Society of Australia (PASA), 34, 61 (2017)

11. Yuan, Tiantian; Richard, Johan; Gupta, Anshu; Federrath, Christoph; Sharma, Soniya; Groves, Brent A.; Kewley, Lisa J.; Cen, Renyue; Birnboim, Yuval; Fisher, David B.

    The Most Ancient Spiral Galaxy: A 2.6-Gyr-old Disk with a Tranquil Velocity Field
    The Astrophysical Journal, 850, 61 (2017)

PERFORMANCE INDICATORS

PERFOMANCE MEASURE		2017 TARGET	2017 ACTUAL
Number of research outputs	Papers in refereed journals	15	**11**
	Media releases	4	**1**
Quality of research outputs	% of refereed papers in journals with impact factor > 2.5	80%	**100%**
Number of training courses held/offered by the Centre	Professional skills workshop	1	**1**
	Diversity training workshops (one at each node)	6	**0**
	ECR training day	1	**1**
	Writing workshops	2	**2**
Number of workshops/ conferences held/ offered by the Centre	International conference	1	**0**
	National conference/ workshop	1	**1**
Number of additional researchers working on Centre research	Postdoctoral researchers	20	**16**
	Honours students	2	**2**
	Masters by coursework	2	**0**
	PhD students	6	**28**
	Associate Investigators	5	**9**
Number of mentoring programs offered by the Centre	Centre-wide mentoring program	1	**0**
	Women's career advancement program	1	**0**
Number of presentations/ briefings	Public briefings	20	**3**
	Government briefings	4	**5**
	Industry briefings	2	**0**
	Non-government organisation briefings	6	**0**
	Briefings to professional organisations & bodies	4	**4**
	Professional conferences/ workshops	20	**68**

Continued

PERFOMANCE MEASURE		*2017 TARGET*	*2017 ACTUAL*
Number of new organisations collaborating with, or involved in, the Centre	New collaborative relationships	2	**5**
Maintain a collaborative and cohesive structure	Cross-node authorship of publications	50%	**36%**
	% cross-node supervised PhD & ECRs	50%	**26%**
	Project team meetings with cross-node participation	6	**4**
	Centre-wide climate survey	1	**0**
Create a diverse Centre	Females at all levels	30%	**38%**
	At least 30% travel funds to females	30%	**28%**
	Female visitors & speakers	50%	**44%**
	Child care at all Centre supported conferences	YES	**YES**
Build the expertise for the next generation telescopes	Students working on optical GMT pathfinder instruments	20%	**13%**
	Students working on radio SKA pathfinder instruments	20%	**10%**
	Students working on space telescope data	10%	**13%**
	Students with data intensive research experience	20%	**19%**

NOTE: 2017 Actuals have been impacted by the later than anticipated 1 July start date for the Centre. Where appropriate, any shortfall in 2017 will be picked up in future years and be reflected in the cumulative performance of the Centre over time.

FINANCIAL STATEMENT

	2017 ACTUAL ($)
INCOME	
ARC Grant	4,466,000
State Government Grants	0
Other Grants	0
University Contributions	1,190,554
Partner Contributions	0
Other Income	200
TOTAL INCOME	**5,656,754**
EXPENSES	
Salaries	926,197
Travel and Visitor Support	102,470
Equipment	27,674
Workshops and Conferences	55,020
Management and Administration	46,477
Education, Outreach and Communications	32,652
PHD Support	14,983
TOTAL EXPENSES	**1,205,473**
NET SURPLUS (DEFICIT)	**4,451,281**
CARRY FORWARD BALANCE	**4,451,281**

NOTES TO FINANCIAL STATEMENTS

1. ARC CONTRACT & GOVERNANCE

a) ASTRO 3D involves six Australian Universities and a further ten Australian and international partner organisations. Funding was approved by the ARC for seven years, subject to review after four years. The centre commenced operation on the 1 July 2017, a six-month delay on the original 1 January commencement.

b) From an operational and financial perspective, the centre operates as a single body, and all funding provided by the ARC is disseminated by the Australian National University as the administering organisation.

c) The Centre's operational and financial affairs are governed under defined policies and procedures.

d) Financial reporting provides institutional expenditure per Node, with the Business Manager for the centre providing Consolidated Financial Reports for review by the Chief Operating Officer and Director.

2. INCOME

a) Income received from the ARC was $917k above the originally budgeted $3.5m. This included an amount relating to indexation of $66k.

b) University contributions reflects all funds provided at Node level. The variance against budget reflects an error at an individual Node, which will be rectified in 2018.

c) Partner Contributions refers to monies not yet received from the Chinese Academy of Science. This occurred due to the late start of Centre staff and will be invoiced in 2018.

3. EXPENDITURE

a) Due to the late start of the Centre, expenditure was well under budget (64%). This is primarily due to the deferred recruitment of both professional staff and researchers across the Centre. This has impacted on salaries and staff related costs such as travel, conferences and workshops, computer equipment and telecommunications as well as activity based project costs.

b) A financial reforecast will be conducted early in 2018 to reflect the revised timing of expenditure and allocation of funds.