# SKA PhD Scholarship Scheme
# 2018 Projects

**Program Contact:** Kate Gunn (kate.gunn@sydney.edu.au) or Robert Shen (robert.shen@astronomyaustralia.org.au)

## Project List

Below is a list of the projects available in 2018. Project abstracts are available further down.

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- The HII Region Population in the Milky Way, University of Tasmania
- The Motion of the Magellanic Clouds, University of Tasmania

## University of Sydney

**Primary contact:** Elaine Sadler (elaine.sadler@sydney.edu.au)

**Supervisor:** Tara Murphy
**Project Title:** Exploring the transient universe with the MWA and ASKAP

**Project Abstract:** Some of the most extreme events in the Universe occur when black holes form, or merge with each other, or when stars move too close to a black hole and get sucked in. In each of these cases strong bursts of electromagnetic radiation are released, which we detect on Earth as 'transient' radio emission. Not only are these events interesting in their own right, they also serve as an astronomical laboratory for exploring physics in extreme conditions. Until now we have had a limited ability to find and study these objects as they appear and disappear on short timescales. Radio astronomy is undergoing a revolution, with new telescopes able to conduct massive all-sky surveys on a regular basis, allowing us to discover 'transient' radio sources.

In this project you will conduct major surveys with the Murchison Widefield Array (MWA) and the Australian Square Kilometre Array pathfinder (ASKAP) two telescopes located in Western Australia. You will have first prime access to these unique (and completely unexplored) dataset to look for transient and highly variable radio sources, and then draw on multi-wavelength data and observations from other telescopes to identify what these sources are. Your project could focus on developing intelligent algorithms to search for rare objects, or on the scientific interpretation of any objects we find, or a combination of both. There is scope for working on a range of research areas, from exoplanets and flare stars through to gamma-ray bursts and gravitational wave events.

**Supervisor:** Scott Croom
**Project title:** Connecting gas content to the location of star formation

**Project Abstract:** The fundamental fuel for star formation is hydrogen gas that accretes onto galaxies, cools and forms stars. How and where the accretion of gas is modulated, and how this influences star formation is poorly understood. In this project we will aim to combine radio observations that measure the gas content in local galaxies (via 21cm emission line measurements) with spatially resolved maps of star formation from the new SAMI Galaxy Survey (http://sami-survey.org/). This survey, that contains thousands of galaxies across all environments (from voids to dense clusters) gives us the opportunity to understand how a galaxy's environment influences gas accretion onto it, and in turn how that modulates star formation.

**Supervisor:** Elaine Sadler
**Project title:** Tracing fuelling and feedback in powerful radio galaxies with 21cm HI absorption

**Project abstract:** One of the main goals of the SKA is to trace the neutral phase of hydrogen, the most abundant element in the Universe, out to high redshift and connect this to the formation and evolution of galaxies across cosmic time. Observations of the 21cm line of neutral hydrogen (HI), seen in absorption against strong radio continuum sources, provide us with unique information about the flow of gas into and out of galaxies at different stages in their evolution. In particular, recent observations show that radio jets in massive galaxies can drive powerful outflows of neutral gas that rapidly deplete the gas reservoir - meaning that new generations of stars can no longer form.

So far, these studies have mainly been confined to galaxies in the nearby Universe. In this project you will use the Australian SKA Pathfinder (ASKAP) radio telescope to search for redshifted HI absorption lines in distant galaxies and investigate both the infall of neutral gas and the prevalence of jet-driven outflows in radio galaxies over the past 8 billion years of cosmic time. In combination with models and simulations, these ASKAP observations will help us understand the role of galaxy mergers, gas infall and radio jets in shaping the largest and most massive galaxies we see around us today.

**More information on Sydney:**
www.sydney.edu.au (The University of Sydney)
www.sydney.com.au
www.cityofsydney.nsw.gov.au/learn/about-sydney/tourist-information

# Australian National University

**Primary contact:** Naomi McClure-Griffiths (naomi.mclure-griffiths@anu.edu.au)

**Supervisor:** Naomi McClure-Griffiths
**Project title:** Magnetic fields in the Magellanic system

**Project abstract:** Magnetic fields affect the evolution of the Universe on all scales from the Sun to galaxy clusters. They provide nearly as much energy into the interstellar medium as gas motions or thermal heating, are essential to star formation and contribute enormously to the total pressure of interstellar gas. And yet, we know very little about the origin of magnetic fields within galaxies or indeed the nature of magnetised gas in galaxies. This project will work with new radio interferometric data from the Australia Telescope Compact Array of polarized extragalactic sources to probe the magnetised, ionised medium throughout the nearest galaxies, the Large and Small Magellanic

Clouds. This project will carry on into the Australian SKA Pathfinder Polarization survey of the Universe’s Magnetism (POSSUM) and will involve collaboration with Dr Ann Mao at the Max Planck Institute for Radioastronomy in Bonn, Germany and Prof Bryan Gaensler at the University of Toronto, Canada.

**Supervisor:** Christian Wolf
**Project title:** High-redshift QSOs in the Southern sky

**Project abstract:** The SkyMapper Southern Survey covers the entire Southern hemisphere in six bands to 22 mag. Based on its first data release, two bright QSOs at redshift ~5 were already found. In this project, we want to identify the complete list of luminous high-redshift QSOs, measure their black-hole masses, and determine their radio properties. This will prepare the ground for multi-wavelength follow-up including the Australian SKA Pathfinders and in the SKA era.

**Supervisor:** Geoff Bicknell
**Project title:** Determination of radio spectrum, Stokes parameters and rotation measure from magnetohydrodynamic simulations of high redshift radio galaxies

**Project abstract:** The interaction of relativistic jets with the interstellar medium of evolving galaxies is a form of black hole feedback, which is believed to have an important influence on the evolution of galaxies. The spectrum and polarization of radio emission is an important diagnostic of the interaction informing us about the turbulence and density of the interaction region and the role of magnetic fields in both dynamics and emission. In this project the student will use magnetohydrodynamic simulations incorporating the evolution of the relativistic electron distribution to produce synthetic images of total intensity, polarization and rotation measure relating to jet-ISM interactions at high redshifts.

**More information on Canberra:**
www.anu.edu.au (Australian National University)
http://visitcanberra.com.au
www.canberratourism.com.au

# University of Western Australia

**Primary contact:** Lister Staveley-Smith (lister.staveley-smith@uwa.edu.au)

**Supervisor:** Richard Dodson
**Project title:** Delivering the goods - Data-intensive SKA-scale astronomy

**Project abstract:** Science is becoming increasingly data-intensive and this requires a new data focused approach. The prime example is the Square Kilometre Array (SKA) project, one of the world’s latest large- scale global scientific endeavours, which will be co-hosted in Australia and is set to produce orders of magnitude more data than all of mankind’s past accomplishments. Just one of the SKA phase-1 science projects (e.g. the HI survey) will produce derived data in the order of several terabytes per second, and the second phase of the SKA project will be at least an order of magnitude greater. This project will work on some of the most extreme datasets observed in Radio Astronomy to date, and provide a perfect test bed for the data-driven paradigm. The data will will come from the Australian SKA Pathfinder, and from a Deep HI pathfinder project called CHILES. The student will investigate the ideas and methods, demonstrating new approaches on frontier data products. We are interested to hear from potential candidates from any STEM background, as the range of skill sets required (and to be developed) can not be limited to one traditional field of study. The candidate would join an active multi-disciplinary group with many scientific and commercial cross fertilisation possibilities. Similar PhD projects in this field and related science can be found at http://www.icrar.org/study-with-icrar/postgraduate-opportunities/postgraduate-research-projects/ .

**Supervisor:** Barbara Catinella
**Project title:** Exploiting the next-generation radio surveys with spectral stacking

**Project abstract:** Atomic hydrogen gas is the raw material out of which stars are formed, and thus it is clearly of key importance for galaxy formation and evolution. Due to limitations of existing radio telescopes, our current knowledge of this crucial galaxy component is still limited to the local Universe, but this is about to change. The next-generation radio surveys planned for the Square Kilometre Array and its precursor facilities, such as the Australian Square Kilometre Array Pathfinder (ASKAP) in Western Australia, will usher in a new era for extragalactic studies, allowing us to measure the gas content of galaxies at cosmological distances. Although a large number of galaxies will be individually detected, the most stringent constraints on gas content of galaxies across cosmic time will come from spectral stacking of undetected sources. Briefly, this technique requires to co-add (i.e. “stack”) the radio spectra of faint, undetected sources, for which accurate positions and redshifts are known from optical surveys, and yields an estimate of the average gas content of the ensemble. The student will build a flexible, modular, user-friendly software package to be used by the next-generation extragalactic radio surveys. The software will be tested on both available and upcoming data sets, as well as on mock catalogs generated by numerical simulations of galaxy formation and evolution. The emphasis of the first part of this project is on the computational aspect; hence a strong background in programming (especially parallel computing) is required. The second part will focus on the scientific applications, such as the determination of gas scaling relations as a function of redshift. Similar PhD projects in this field and related science can be found at http://www.icrar.org/study-with-icrar/postgraduate-opportunities/postgraduate-research-projects/ .

**Supervisor:** Lister Staveley-Smith
**Project title:** Galaxy formation and evolution

**Project abstract:** The new Australian Square Kilometre Array Pathfinder (ASKAP) in Western Australia will be the most powerful survey instrument in the world for the study of the gaseous properties of galaxies at moderate angular resolution. It will transform our understanding of the relationship of the cool gas in galaxies with other components such as stars, ionised gas and molecular gas. It will also explore the distribution of dark matter in galaxies and in the nearby Universe. This project will use the early science phase of ASKAP (ASKAP-12) to undertake a study of the environmental properties of galaxies. In particular, we know that there are gravitational and hydrodynamic forces that will remove gas from galaxies located in massive galaxy clusters. But these forces also seem to operate in an efficient manner in smaller groups of galaxies, giving rise to a strong density dependence in the gaseous properties of galaxies that is not understood. Part of the problem is the lack of understanding of the location of the diffuse ionised ‘cosmic web’ where about 50% of the normal ‘baryonic’ material in the Universe is supposed to reside. Part is due to lack of understanding of the early radiation conditions in dense environments. Observations with ASKAP-12 will help answer these problems by detecting and measuring the detailed properties of thousands of galaxies in a range of environments, thereby gathering sufficient information and statistical accuracy to unequivocally separate out the various physical processes and work, and helping build a fuller picture of galaxy formation and evolution. The project involves gathering 21cm ASKAP data in several early science fields, reducing and analysing the data, extracting kinematic information from the data cubes and examining systematic trends of the data with overall galaxy density as determined from optical red- shift surveys. Similar PhD projects in this field and related science can be found at http://www.icrar.org/study-with-icrar/postgraduate-opportunities/postgraduate-research-projects/ .

## More information on Perth:

www.uwa.edu.au (University of Western Australia)
http://www.westernaustralia.com/en/Destinations/Experience_Perth/Pages/Experience_Perth.aspx
http://www.experienceperth.com

# University of Melbourne

**Primary contact:** Rachel Webster (r.webster@unimelb.edu.au)

**Supervisor:** Rachel Webster
**Project title:** Epoch of Re-ionisation: Foreground removal

**Project abstract:** The signal from the first stars responsible for the Epoch of Re-ionisation (EoR) in the early universe is dwarfed by radio emission from our galaxy and other radio sources along the line-of-sight. This project will develop techniques to improve the removal of foreground signals to reveal the underlying signal from the EoR. The PhD student will use the massive EoR datasets obtained from the upgraded Murchison Widefield Array, which is located on the site in Western Australia that will house the new SKA-low telescope. PhD students working on this project will be members of the MWA EoR Collaboration and the Astro-3D Centre of Excellence, working with international collaborators in the USA, Japan and China as well as the Australian EoR group. PhD students working in this area develop strong computational skills as well as deep experience in handling massive datasets. In addition, they develop a deep understanding of radio astronomy signals and signal path through a radio telescope. Opportunities will also be available to undertake theoretical subprojects related to EoR science.

**More information on Melbourne:**
www.unimelb.edu.au (University of Melbourne)
www.visitmelbourne.com

# Swinburne University

**Primary contact:** Ned Taylor (entaylor@swin.edu.au)

**Supervisor: Darren Croton**
**Project title:** The distribution of gas and metals around galaxies, from low to high redshift

**Project abstract:** The hydrogen gas content of a galaxy, from which new stars form, is an excellent probe of its future, while the metal content within that gas, produced in supernova during the death of old stars, is a similarly valuable probe of its past. The goal of this project is to make predictions for the distribution of gas and metals around galaxies from low to high redshift, for different galaxy types and in different environments, and compare these against observations. The project has the following objectives: (1) undertake a literature review of our current understanding of gas and metals in and outside of galaxies; (2) to review the theory of how galaxies form and evolve across cosmic time, with a focus on the relevant physical processes, and how these are modelled using supercomputer simulations; (3) to construct a suite of mock universes with the SAGE galaxy formation model on the OzStar supercomputer at Swinburne; (4) using this model, to reproduce the current observations of gas and metals in and outside of galaxies out to the redshifts for which it's been measured; and (5) explore the model beyond this baseline to make predictions for future observational surveys, including the upcoming SKA telescope.

**Supervisor: Christopher Fluke**
**Project title:** Astronomical knowledge discovery beyond the petascale

**Project abstract:** As astronomy moves ever closer to the Square Kilometre Array's exascale data era, an increasing number of existing desktop-based workflows will fail. Instead, astronomers will turn to automated processing using dedicated high-performance computing resources coupled with advanced data archives. Yet the ability to look at the most important data is crucial. In this project, you will research, design, implement and evaluate new visualisation-based knowledge discovery approaches. The goal is to support interactive, multi-dimensional analysis of data from observations, simulations, model fits and empirical relationships. The research will require an investigation into methods for combining visualisation-directed model-fitting with emerging machine learning techniques - such as Deep Learning - to enhance and accelerate the path to discovery. A key focus will the WALLABY survey of extragalactic neutral hydrogen with the Australian Square Kilometre Array Pathfinder (ASKAP), however, the techniques developed will be suitable for a range of current and future data intensive programs - within and beyond astronomy. All stages of the project will utilise Graphics Processing Units (GPUs) as computational accelerators. The student will also have access to Swinburne University's Advanced Visualisation facilities: the Enhanced Virtual Reality Theatre and the Swinburne Discovery Wall. This project will suit a student with existing strong programming skills, and interests in GPU-computing and/or data-intensive discovery.

**Supervisor: David Fisher**
**Project Title:** An up-close view of extremely gas rich, turbulent disk galaxies

**Project abstract:** Over 80% of stars in the Universe were formed in galaxies 10 billion years ago. These galaxies were marked by drastically high densities of star formation, were super rich in gas, and show evidence of widespread turbulence. Because these galaxies are so different from those galaxies in the local Universe, we cannot assume that local theories of star formation robustly explain such extreme environments. However, these galaxies are also very distant from us. We therefore cannot resolve the star forming regions. This situation has created a very large problem for galaxy evolution: We do not currently understand star formation processes in the most important epoch of galaxy evolution in the history of the Universe.

Our group has mined datasets of hundreds of thousands of galaxies to find a set of rare galaxies in the local Universe which are very closely matched to conditions in galaxies 10 billion years ago. This PhD project will study the properties of these galaxies to determine the stellar mass, stellar populations, star formation rates and gas masses of these massive complexes of star formation found inside nearby turbulent, gas rich galaxies (called the DYNAMO sample). This project has recently been awarded time on Hubble Space Telescope, the Atacama Large Millimeter Array (ALMA), as well as having data from programs with Hubble, NOEMA and Keck. In the future we will use SKA data to determine the amount of HI gas in these interesting galaxies (through the atomic hydrogen 21 cm line), as well as probe embedded star formation using radio continuum.

**Supervisor: Adam Deller**
**Project Title:** Pinpointing pulsars with VLBI astrometry

**Project abstract:** Our galaxy is strewn with natural clocks: rotating neutron stars whose predictable spin periods let us time their pulses of radio emission like clock ticks. These radio pulsars can be used test theories of gravitation or models of stellar evolution, or to probe the ionised medium of our galaxy. However, the models of pulse arrival times that facilitates these tests are complicated, comprising many parameters, and are dependent on an accurate model of the solar system ephemeris. By providing independent measurements of some model parameters via direct observation with Very Long Baseline Interferometry, we can test the trustworthiness of pulsar timing and highlight model deficiencies. The discrepancies uncovered in this way can, for instance, be used to improve the solar system ephemeris and facilitate improved tests of general relativity and the first detection of nanohertz gravitational waves. While already of value today, such improvements will be particularly critical in the era of SKA and FAST as the precision of pulsar timing jumps further. Fortunately, these sensitive new telescopes will themselves facilitate improved VLBI astrometry by participating in SKA-VLBI observations. This project will focus on both improving the techniques used for VLBI astrometry to maximise astrometric precision (particularly with highly sensitive telescopes), and using these techniques to uncover subtle errors in current pulsar timing models.

### More information on Melbourne:

www.swinburne.edu.au (Swinburne University of Technology)
www.visitmelbourne.com

# Curtin University

**Primary contact:** Carole Jackson (carole.jackson@curtin.edu.au)

**Supervisor:** Natasha Hurley-Walker
**Project title:** Advanced calibration and imaging with the MWA

**Project abstract:** The Murchison Widefield Array (MWA) is a low frequency (80 — 300 MHz) radio telescope operating in Western Australia and the only SKA_Low precursor telescope. Its design has many small antennas rather than fewer larger antennas as is typical for radio telescopes working at higher frequencies.

Forming high-fidelity images with the MWA can be challenging. The issues include: the very wide field of view of the MWA, the large data volume due to having many antennas, the corrupting effect of the ionosphere, the unusual reception pattern of the antennas (they are fixed on the ground), among others. Processing MWA data can often violate assumptions inherent in conventional radio astronomy data processing software. More accurate techniques are available but often come at a huge computational cost. Because of this, supercomputers are required to process large quantities of MWA data.

This project aims to investigate and develop novel techniques in radio astronomy data processing to improve the performance and/or fidelity of calibration and imaging algorithms, with a focus on MWA and future SKA_Low data. The application of these techniques has the potential to impact the Epoch of Reionisation (EoR) and GLEAM survey science programs of the MWA, which have each collected several PB of raw data.

This project is suited to a student with a strong interest in the fundamentals of radio astronomy and a solid background in computer science, maths and/or physics.

**Supervisor:** Nick Seymour (nick.seymour@curtin.edu.au)
**Project title:** Finding the most massive clusters with the Murchison Widefield Array

**Project abstract:** Clusters of galaxies are the most massive bound structures in the Universe lying at the crossroads of the large scale structure. In the nearby Universe they dominated by giant elliptical galaxies with very low star formation rates, but in past they must have been forming stars at a prodigious rate. However, finding young proto-clusters in the distant Universe is difficult as typical search methods (e.g. X-ray emission from hot gas, Sunyaev–Zel'dovich, SZ, effect) become much less sensitive. High redshift radio galaxies are known to lie in over-dense, proto-cluster environments and be beacons to pockets of extreme star formation. This is because the radio galaxy is powered by a massive and rapidly growing black hole and scaling relations suggest that this will be in the most massive host galaxy and dark matter halo. This project will take advantage of a new all sky low frequency radio survey with the Murchison Widefield Array (MWA) and combine it with NASA's mid-infrared WISE mission to find and characterise new distance proto-clusters in particular looking for the most massive ones.

This project will comprise three parts:

(i) Calibrating how well the WISE survey traces known clusters found in X-ray, millimetre (via the SZ effect) and radio surveys as a function of mass and redshift. Then the WISE data can be used to investigate the build-up of the red sequence statistically. For the radio-loud sample the potential dependence on radio jet orientation and size of the over-density of proto-cluster members can be investigated

(ii) Using this technique to search for new high redshift clusters around MWA sources. Once the best candidates are chosen, they can be followed-up with deep optical and near-infrared imaging and spectroscopy in order to confirm their redshift and nature.

(iii) Using the Australian Telescope Compact Array to observe high redshift (above redshift=1) proto-clusters at high frequencies to measure their mass distribution via the SZ effect. This technique has only been applied to lower redshift clusters to date, but can provide unique insights in the dark matter content of clusters.
The Spiderweb Galaxy. Deep Hubble image of the core of the MRC 1138-262 protocluster at z = 2.2 obtained with the Advanced Camera for Surveys.(Miley et al., 2006). Superimposed on the HST image are contours of Lyα (blue) obtained with ESO's very Large Telescope (VLT), delineating the gaseous nebula and radio 8GHz contours (red) obtained with NRAO's VLA, delineating the non-thermal radio emission.

**Supervisor:** Jean-Pierre Macquart
**Project title:** Resolving pulsar magnetospheres with picoarcsecond resolution scintellometry

**Project abstract:** The radio emission of pulsars remains, more than 40 years since their discovery, a poorly understood phenomenon. The single most important unconstrained component of pulsar emission theories is the site of the emission in relation to the surface of the neutron star, with the three major classes of models predicting particle acceleration at wildly different locations: the polar gap, the slot gap or the outer gap in the pulsar magnetosphere. The predicted emission height is tiny, ranging from ~10km (for inner gap models; 13 pico-arcseconds at a distance of 500pc) to ~5000km (for outer gap models; the size of the light cylinder for a 0.1s period pulsar). The angular resolution necessary to resolve such structure remains well beyond the capabilities of modern instrumentation.

Fortunately, the scattering of pulsar radiation by the interstellar medium (ISM) presents a means to directly measure the emission height. Pulsar radiation is subject to strong interference effects as it propagates through the turbulent ISM; interstellar scattering causes the point-like image of the pulsar to break up into thousands of sub-images or speckles that all interfere with each other. The ISM effectively operates as a giant interferometer — albeit with imperfect optics — whose diameter is comparable to the ~10AU transverse distance of speckles across the scattering region.

The technique of pulsar scintellometry uses the scintillation as an interferometer to detect a relative astrometric shift in the location of the emission region as the pulsar beam rotates through our line of sight. At its most basic, the principle behind the astrometric measurement is shown in the Figure below (see Pen et al. 2014 & Brisken et al. 2010 for full details). An angular displacement in the emission site causes a lateral displacement in the scintillation pattern at Earth. An angular difference in the emission site between different regions of the pulse would therefore cause a time lag between the scintillation patterns associated with different parts of the pulse profile. This technique (see Pen et al. 2014) improves on this principle by applying holographic phase-retrieval techniques to partially descatter the pulsar radiation in order to boost the pulsar S/N by a factor of several thousand over the raw scattered signal, and thus attain an additional ~103 increase in astrometric precision. This enables us to achieve pico-arcsecond relative astrometry on the location of the pulsar emission between time channels spread across the pulse profile.

In this project you would undertake low-frequency VLBI observations with FAST and the MWA to make speckle images of scintillating pulsars and apply the techniques of scintellometry to resolve the structure of pulsar emission regions.

A displacement in the emission site results in a lateral displacement of the scintillation pattern. Measurement of this shift enables high precision relative astrometry. This will be a project involving research across the Curtin University's Institute of Radio Astronomy and the Institute for Computation: it will develop cutting-edge computational techniques with access to expertise and supercomputing resources.

**More information on Perth:**
www.curtin.edu.au (Curtin University)
http://www.westernaustralia.com/en/Destinations/Experience_Perth/Pages/Experience_Perth.aspx
http://www.experienceperth.com

# University of Tasmania

**Primary contact:** John Dickey (john.dickey@utas.edu.au)

**Supervisor:** Stanislav Shabala
**Project title:** Cosmological Evolution of Radio Galaxies and Feedback from Supermassive Black Holes

**Project abstract:** Accretion onto supermassive black holes at the centres of galaxies powers relativistic jets of radio-emitting plasma, which in turn significantly affect the fate of galactic gas - the raw material from which stars are made. In this way, these objects (known as Active Galactic Nuclei; AGN) regulate the growth of galaxies through the process of AGN feedback.
AGN feedback is a major science goal for both the recently constructed Australian Square Kilometre Array Pathfinder (ASKAP) and the future SKA. However, the physics of how AGN jet energy couples to the surrounding gas is still poorly understood. This PhD project will combine analytical models and numerical simulations to quantify the efficiency of AGN feedback for a wide range of jet and galaxy parameters, and how the feedback mechanisms have evolved over cosmic time. A unique feature of this project is in the ability to model the AGN and galaxy populations together for the first time. This is made possible by a self-consistent treatment of gaseous environments through which AGN jets propagate. The successful candidate will use the UTAS-developed RAiSE analytical model for AGN jet propagation, complemented by simulations with the PLUTO numerical hydrodynamics code run on a distributed grid.

**Supervisor:** John Dickey
**Project title:** The HII Region Population in the Milky Way

**Project abstract:** The Southern HII Region Discovery Survey (SHRDS) is a radio frequency survey of the Milky Way Galactic plane, using the Australia Telescope Compact Array telescope. Coupled with a similar survey in the Northern Hemisphere, the SHRDS has detected radio recombination line emission from some 200 new HII regions in the inner Galaxy. The challenge now is to determine the distances, chemical compositions, masses and temperatures of these regions. Using the existing data, plus new observations from telescopes at UTAS and CSIRO, the Ph.D. student will map the structure and motions of our Galaxy. In particular, HII regions trace spiral arms, and the SHRDS will allow a more complete picture of the spiral structure of the Milky Way to be drawn. The project combines technical expertise working with telescopes and radio astronomy data calibration, with numerical modelling and radiative transfer astrophysics to interpret the data in the context of the interstellar medium.

**Supervisor:** Simon Ellingsen
**Project title:** The Motion of the Magellanic Clouds

**Project abstract:** Interactions between galaxies are known to play a key role in their evolution throughout cosmic history. Studies of past and current interactions between Local Group galaxies provide us with a unique opportunity to investigate the key factors and effects of such interactions at high resolution and sensitivity. The Large and Small Magellanic Clouds (LMC & SMC), at distances of ~50 kpc and ~62 kpc respectively, are two of the closest galaxies to the MW. Because of their proximity, they are a benchmark for studies of a variety of topics, including stellar populations, the interstellar medium, and the cosmological distance scale. Observations of the MCs can be compared with cosmological simulations to determine how interactions may have led to the triggering of star formation and how infall into the MW's halo may have led to quenching of star formation in the MCs due to gas stripping.
Our understanding of the interaction of the LMC & SMC with each other and with the Milky Way (MW) have changed dramatically in the last decade due to new measurements of the proper motions of the LMC and SMC. This project will utilise the three orders of magnitude improvement in resolution of very long baseline interferometry (VLBI) over optical observations and avoid the substantial systematic effects inherent in proper motion determination from the stellar population. LBA observations with a time baseline of 18-24 months have been undertaken and will be able to provide an independent estimate of the proper motions of both Magellanic Clouds accurate to ~50 µas/yr (corresponding to an uncertainty in velocity of ~13 kms-1 and thus giving stronger constraints on their past orbits than any previous measurements.

**More information on Hobart:**
www.utas.edu.au (University of Tasmania)
www.discovertasmania.com.au