2024 Space & Astronomy Undergraduate Studentship Projects

PROJECT TITLE	PROJECT DESCRIPTION	Duties/Tasks	Relevant fields of study
Radar characterisation of near-Earth asteroids using NASA's Deep Space Network stations	Most asteroids orbit the Sun between Mars and Jupiter in the "asteroid belt", but some have orbits than bring them close to Earth. These Near-Earth Asteroids provide a chance to study their physical characteristics at relatively small distances, and also assess whether there is any chance they may collide with the Earth in the future. This project uses the powerful transmitters at the NASA Canberra Deep Space Communication Complex to bounce radio waves off near-Earth asteroids (NEAs) during their passage close to Earth. The reflected radio signals are detected at the Australia Telescope Compact Array (ATCA) near Narrabri, providing information on the asteroid's motion, rotation, shape and composition.	Observation assists from scheduling to data analysis, improving programs to characterise target asteroids, and investigating possible applications of wave-form modulation for radar imaging.	Astronomy/ Planetary Science/ Physics/ numerical Sciences. Knowledge of Matlab/Python computing would be advantageous
Listening to Breakthrough Listen on Murriyang	This project will utilise data taken with the Breakthrough Listen project with Murriyang, the CSIRO Parkes radio telescope. It will explore the potential to perform highly sensitive spectral line stuidies of the Galactic Centre by piggybacking on existing SETI searches of the centre of the Milky Way.	Conduct detailed surveys of spectral lines in the Galactic Centre, focusing on identifying known molecular and atomic signatures; Explore calibration potential of high-resoluiton spectral line data, and/or develop future requirements for such a survey; Catalog and analyze detected spectral lines to study the physical and chemical conditions of the region.	Astrophysics and/or data science
Weighing Supermassive Black Holes in the Early Universe	The search for supermassive black holes in the earliest epochs of the Universe has been remarkably fruitful, surprising many astronomers by their sheer abundance, size, and level of activity. According to our best estimates, supermassive black holes in the early Universe are more massive than we can presently explain. To gain deeper insights into their demographics, growth mechanisms, and origins, our group has collected high-quality spectroscopic data from actively accreting supermassive black holes within the first billion years of the Universe. Our comprehensive spectral coverage reveals a wealth of information about their accretion discs. This dataset holds the potential to develop more reliable calibrations for determining the black hole mass with implications for the ongoing research on active galactic nuclei (AGN) using the James Webb Space Telescope. As part of this project, the student would have the opportunity to gain hands-on experience in the analysis and classification of AGN spectra. They will work on modelling spectral components, fitting spectral energy distributions, and utilising multivariate analysis techniques to enhance the reliability of black hole mass estimations. Requirements for this project include prior experience with Python, as it will be an integral tool for data analysis and modelling.		Astronomy, Physics, Computer Science
New array configurations for the Australia Telescope Compact Array	The Australia Telescope Compact Array (ATCA) is a radio-telescope consisting of six 22m antennas, five of which are able to be moved along an east-west rail track with a short north-south spur. There are currently 17 standard array configurations which astronomers can choose from when they submit observing proposals. This project will consider options for new array configurations that may be better suited to a number of the telescope's scientific goals, and that make optimal use of the capabilities of the soon-to-be-installed BIGCAT system.	The student will develop an understanding of how radio interferometer arrays work, and use existing software packages to consider new array configurations for the ATCA, and develop a figure-of-merit to determine which arrays might be offered to the international astronomical community in the future.	Some background in mathematics (and familiarity with Foruier Transforms), computing (espcially unix systems), and astronomy would be helpful, though not all are required.
Searching for a 'radio ephemeris' for CU Vir	CU Vir is probably the most famous and most well-studied magnetic early-type star. This is the first magnetic hot star from which pulsed radio emission was detected in the year 2000. These pulses were found to be persistent and periodic with the stellar rotation period. However, observations at multiple epochs showed that the pulse arrival phases slowly evolve with time. A sinusoidal variation in the rotational period was predicted primarily based on optical data, but the corresponding ephemeris still cannot align the radio pulses from widely separated epochs. In this project, the student will collectively study the radio pulses observed from this star with the ATCA between 1999-2024, and attempt to come up with a model for the variable rotation period solely based on radio data. This work has the potential to provide insights on the cause behind the evolution of the pulse-arrival phases and also possibility of differential rotation in these exotic objects.	ATCA radio data analysis, writing python codes, interpretation	Physics, Astronomy

Hyperfine structure of methanol masers	The hyperfine structure is a well-known effect in spectroscopy arising from various interactions with the nuclear spin in an atom or molecule. However, it is still not well understood for complex molecules like methanol, especially in the astrophysical context, despite the fact that the appropriate theoretical models and laboratory measurements have become available in the last decade. The predicted split is comparable to the spectral resolution of the modern radio telescopes. Therefore, the effect is expected to leave a detectable footprint on the measured spectral profiles of some astrophysical masers, rather narrow emission lines naturally occurring in the regions of high-mass star formation. Such high-precision measurements have an impact for a wider range of science areas from quantum chemistry to the attempts to understand the nature of dark matter. In the present day, there is a growing evidence that masers form preferentially in just one hyperfine component. This project is about testing this hypothesis using the data from the Australia Telescope Compact Array (ATCA).	Data analysis	Astrophysics, data science, statistics, molecular spectroscopy
Using wiggly radio waves to understand the Universe's strongest magnets	Pulsars are a type of spinning neutron star that blast beams of radio waves from their magnetic poles. When one (or both) of these beams sweep across the Earth, then we can detect the pulsar as a source of periodic and often highly polarised radio pulses. By looking at how the polarisation state changes across these pulses at different radio frequencies, we can learn an enormous amount of information about these exotic stars. However, these effects can be difficult to disentangle from changes in pulse shapes and variations in the Galactic magnetic fields located between us and distant pulsars. In this project you will explore techniques to mitigate against these detrimental effects and apply them to the more than 250 pulsars that are currently being monitored with the 64-m Murriyang radio telescope as part of the Parkes Young Pulsar Array. You will then use the improved polarisation measurements to study the pulsar magnetic fields and investigate where their radio emission originates.	Learn how to analyse polarisation data collected by single-dish radio telescopes. Develop Python-based software for analysing these data sets and determine how they relate to theoretical models of neutron star magnetic fields and the pulsar emission mechanism. Engage with fellow students and ATNF staff.	Astronomy and physics. Knwoledge of coding in Python is a requirement. Prior experience with using UNIX terminals is advantageous.
AI-Powered Astronomy: Unveiling the Cosmos	This project aims to leverage Machine Learning (ML) and Artificial Intelligence (AI) algorithms to identify special patterns in astronomical data, such as Fast Radio Bursts (FRBs), Radio Frequency Interference (RFI), and other unknown signals. A key aspect of the project is to ensure that the techniques used are explainable and transparent, rather than relying on black box methods. By combining advanced technology with a focus on transparency, this project will contribute to the understanding of astronomical phenomena and the development of interpretable AI methods, fostering trust and insight in automated pattern recognition.		Physics, Astronomy, Computer Science. Coding skills in Pyhton or MatLab
Hunting for exotic astrophysical events in a decade of VLITE data	The VLA Low-band Ionosphere and Transient Experiment (VLITE) is a commensal system capable of continuously accessing 64 MHz of bandwidth from the 236-492 MHz Low Band system deployed on the VLA. Over the last 10 years, it has accumulated about 60,000 hours of data covering over 80% of the celestial sphere in multiple epochs. Thus, it is a treasure trove of information on variable and transient objects that arise from exotic propagation and explosive phenomena such as tidal disruption events and variability around supermassive black holes, counterparts to gravitational waves emitted from binary compact object merger events, afterglows from gamma ray bursts, fast radio bursts, relativistic outflows from radio galaxies, pulsars, supernovae, flaring stars, interstellar medium, and many hitherto unknown phenomena ripe for discovery. This project will mine a portion of the data for such exotic events, place constraints on their occurrence rates, characterise and classify the diversity of time-domain phenomena, and advance towards understanding the fundamental physics of their origins. The project will be supervised by Dr. Nithyanandan Thyagarajan and Dr. Tracy Clarke.	The student will be tasked with analysing VLITE catalogs and images from a limited but statistically large portion of the sky and conducting search for transient and variable objects, whose time-domain behaviour will be classified and characterised. The student will place constraints on the occurrence rates of such time-domain phenomena from the initial limited data. If sufficient and quick progress is made, the student will be provided with a larger data set to expand the search for more discoveries. The supervisors and the student also have the freedom to choose a subset of certain objects for a more specialised search and follow up. High level of comfort in Python programming is required. Experience with Machine Learning and statistical techniques is desired but optional.	Physics, Astronomy, Data Science
Functional Performance Specification, and design and development guide, for satellite earth observation aquatic calibration and validation instrumented site	In-situ environmental observation data is critical for the calibration and validation of imagery and data from earth observing satellites. Using documentation produced for a recently implemented aquatic site at the Googong Dam near Canberra, this project will develop a Functional Performance Specification and guide for the design and build of future, similar observation sites. This includes consideration of floating pontoon infrastructure, scientific instrumentation, power systems, control systems, data management & communications and application of relevant regulatory or best practice technical standards. This project is suitable for an engineering or science student with an interest in scientific instrumentation, satellite earth observation and systems engineering design and development practices.	i) Review design documentation for the Googong Dark-water Inland Observatory Network site and develop a Functional Performance Specification to be used for future sites in this network ii) Develop a design and development guide for the specification of system components, interfaces and their scaling for different site functionality.	Engineering, Systems Engineering, Satellite Earth Observation, calibration and validation
Validating satellite-derived water height data using in-situ GPS	The SWOT satellite is a new innovative NASA-CNES mission that uses SAR interferometry to instantaneously map ocean and in-land water heights. In this project the student will use in-situ water height measurements made at the Googong reservoir near Canberra to validate measurements made by the SWOT satellite. This project is suitable for a data or application scientist with experience in scientific coding (preferably in python). Knowledge of satellite Earth observation and/or hydrology is desirable but not essential.	i) Review the SWOT data product types and make recommendations on which are most useful for in-land water applications ii) Download and organise relevant SWOT data and in-situ data for Googong validation site iii) Develop python code in jupyter notebook to conduct data inter-comparison iv) Make an assessment of the accuracy of SWOT measurements with respect to the in-situ data.	Satellite Earth observation, calibration and validation, hydrology

Understanding the unidentified moving objects (UMOs) in radio images of the sky	Astronomers are conducting a large sky survey using the ASKAP radio telescope to search for rapidly changing astronomicaly signals such as Fast Radio Bursts (FRBs) and pulsars. However, they are also discovering a large number of mysterious sources, including ones that seem to move across the sky at a very rapid pace! We suspect these sources to be of human origin - likely coming from objects in earth orbit or reflections of other moving objects in the sky (such as aeroplanes), however, the signal we're seeing is unlike anything seen before from satellites or other known sources of human generated intereference. The project involves searching for a larger sample of these Unidentifed Moving Objects (UMOs) in our survey images, and try to correlate their properties and position with the publicly available satellite and aeroplane telemetery information to establish the origin of such emission, and solve the UMO mystery.	Space science, astronomy, computing, problem solving	Physics, astronomy, computer science
Identifying extreme objects in radio scintillation data	Just as stars twinkle in the night sky, radio sources twinkle due to turbulence in the solar wind, a phenomenon known as interplanetary scintillation (IPS). Using a modern radio telescope, such as the Murchison Widefield Array (MWA), we can observe IPS from hundreds of sources simultaneously. Over several years we have built up a database which now contains several million IPS measurements. We have used these to create a catalogue containing thousands of previously unknown compact radio sources, and we can also use this data to track space weather events as they travel out from the Sun. So far, however, we have reduced each of these measurements to a single number: the strength of scintillation. However, our observations contain much richer information. The aim of this project will be to explore other metrics of our observations, such as the scintillation timescale or the skew of the distribution of brightness measurements. This will allow us to identify the most extreme radio sources and space weather events. This project would suit a student who is interested in dealing with finding outliers in very large datasets, and/or has an interest in Space Weather or the astrophysics of compact objects.		Physics, astronomy, mathematics, computer science, statistics
Searching the ATCA calibrator database for candidate compact symmetric objects	Compact symmetric objects (CSOs) are bright double radio sources straddling an active galactic nucleus (AGN), with a total linear size smaller than 1 kiloparsec. Despite being first identified many decades ago, their lifetimes and fuelling mechanisms remain something of a mystery. Recently it has been suggested that most CSOs are relatively short-lived objects, that their jets may be powered by stellar tidal disruption events, and that these objects are of great importance to our understanding of supermassive black holes, their accretion disks, and the birth of relativistic jets. To test these ideas, a comprehensive catalog of "bona fide" CSOs is needed. While steps have been made to identify such sources from observations in the northern hemisphere, there is a lack of such a catalog of southern hemisphere CSOs. Notably, CSO candidates are characterised by peaked radio spectra and low variability on timescales of years. The Australia Telescope Compact Array calibrator database contains long-term monitoring data for hundreds of compact objects across the gigahertz frequency range. This project will involve analysing the database, and potentially other archival radio observations, to identify a southern sample of CSO candidates.		Physics, astronomy
The Future of Radio Astronomy is Collaborative	The joint rise of machine learning and automation across society is changing the way we work, collaborate and conduct research. Astronomy is rich with complex, multi-dimensional data of the sky, our telescopes and the surrounding environment, which is increasingly challenging to draw meaningful inference from in a timely way. What is the role of human scientists in the modern era, and how best do we make use of both human expertise and machine intelligence in managing telescopes and scientific data? How do we easily distinguish between black holes, radio galaxies, solar interference and hardware issues in our data? This project will contribute to our Collaborative Intelligence Future Science Platform (CINTEL) work, which aims to explore and characterise how CINTEL evolves within the Australia Telescope National Facility (ATNF).	Study the ASKAP telescope system, monitoring data and output raw/science data to understand the current workflow. Determine relevant focus questions on where and how collaboration can combine the unique strengths of human scientists and AI automation. Use scientific, analytic, technical and/or programming skills to explore and answer project questions. Prepare, summarise and present conclusions on project work. Place outcomes in context of broader CINTEL work across CSIRO and the future of radio telescope facilities.	astronomy, human-computer interaction, machine learning, large language models, big data, physics, computer science, psychology
Analysing asteroid radar delay-Doppler data	The project would involve Analysing asteroid radar delay-Doppler data. This work will inform future waveform – generator deployment in the system. The student will have the opportunity to learn both the function of the asteroid radar tracking and post processing techniques.		• Radar • Antennas, Electrical / Electronic • Engineering, Coding
Unveiling the population of mysterious long period radio sources	Recently, astronomers have discovered a handful of mysterious radio sources with ultra long periodicities of many minutes. These sources defy decades old understanding on the radio emission of neutron stars - therefore requiring significant revision to emission models, or representing an entirely new radio source class. Discovery of further examples will therefore prove essential to unravelling this Galactic mystery.	This project will involve development of new techniques for discovery of long period sources in radio astronomy data. You will compare results derived from different radio astronomy datasets recorded with our Murriyang, ATCA, and ASKAP telescopes, and assess the feasibility of these techniques for potential upcoming surveys. Candidates should have skills in programming languages such as Python or C and working with UNIX based systems.	physics, astronomy, mathematics, computer science

Awesome Antennas Verifying SKA-Low	The world's largest radio telescope, SKA, is coming! The SKA Observatory is made up of two telescopes, SKA-MID in South Africa and SKA-LOW in Australia. SKA-LOW, which will eventually be 512 stations, each with 256 antennas, begins in earnest in 2024, with the first Array Assembly release comprising 4 stations to come online in time for summer 2024-2025. The SKA-LOW Science Operations Team has to date been working in collaboration with the various teams developing the second and third generation of proof-of-concept systems, the Aperture Array Verification Systems ('AAVS2' and 'AAVS3'). Over the 2024-2025 summer, we will be reviewing data captured with the proof-of-concept systems and transitioning to running observations with the 4-station telescope. The student will learn how to operate this telescope and produce basic data products, contributing to the effort of verifying the telescope and establishing SKAO Science Operations. One avenue to follow may be to explore how SKA Low data can be used to identify sub-arcsecond scale objects using a phenomenon similar to twinkling of stars but in radio frequencies called Interplanetary scintillation.	Duties and tasks can be scaled to the skillset of the student, but may include: setting up observations with Aperture Array 0.5 (4 stations of the SKA-LOW telescope); Observing commissioning targets; and learning to produce basic interferometric images. These observations will be used in combination with commissioning efforts for future SKA-LOW work.	Physics, Astronomy; basic computer science
Making the first SKA-Low stations science-ready	The construction of SKA-Low is well underway and is poised to deliver the first four operational stations. This exciting milestone means that we are able to start testing the world's largest radio telescope and ensure that it is capable of delivering transformational astronomical science. The SKA-Low Science Commissioning team will be working with engineers, operations scientists, and astronomers to understand the telescope performance. This involves defining observational tests, inspecting the corresponding data products, and consulting with colleagues to understand the results. Commissioning scientists develop a deep understanding of the telescope systems and data analysis software. At this stage of the SKA project, all of this commissioning activity will lead to the first images produced with SKA-Low!	Duties and tasks can be adapted to the interest and skills of the student. This will involve inspection and analysis of observational data sets from SKA-Low, and may include close collaboration with operations scientists, engineers, and/or software developers. The student may be involved in defining observational tests.	Physics, Astronomy, Engineering, computer science
MiniXRF Systems Engineering Support	The MiniXRF is a miniaturized X-Ray fluorescence instrument specifically designed for lunar applications. We are seeking someone to support the systems engineering effort. The project's focus can be tailored to match the core qualifications and interests of the successful applicant. Potential focus areas include: Software/Firmware Development (SmartFusion 2 based space-rated computer), Planetary Science, In-Situ Resource Utilisation (ISRU) Objectives.	Assist with the following tasks: 1. Requirements Management and Traceability: Assist in managing and tracing system requirements to ensure they align with mission goals and scientific objectives. 2. Translation of Objectives: Convert application and science objectives into detailed instrument requirements, ensuring the MiniXRF meets all mission-critical needs. 3. Defining Qualification Needs: Identify and define qualification and testing requirements to ensure the MiniXRF is ready for deployment in lunar conditions. 4.Literature Review: Conduct comprehensive reviews of existing similar payloads to inform design decisions and identify best practices.	Aerospace engineering / Systems engineering / Computer Science / Planetary Sciences / In-Situ Resource Uilisation