2021 UQ Winter Research Scholarship Program

Research Projects
offered by the
School of Mathematics and Physics (SMP)

How to apply:

The UQ Winter Research Program is offered by the School of Mathematics and Physics (SMP) and UQ Student Employability Centre during the winter vacation period (late June to late July). Here is the list of available SMP projects for students undertaking mathematics, statistics and physics. It is open to undergraduate (including Honours) and masters by coursework students.

(1) Browse the list of projects.

(2) Contact the supervisor in the area of your interest, or the contact person listed, to discuss your interest and eligibility to undertake their research project. Gain the research project supervisor's tentative approval, and include this with your full UQ Winter Research Program application.

(3) Applications open on **Monday 22nd March** and close by **11.59pm, Sunday 18th April 2021**.

IMPORTANT NOTE TO APPLICANTS:

- Check your eligibility for the program.
- Read the Conditions of Participation before applying.
- Late applications will not be accepted.

UQ Winter Research Project Description

Project title: SMP-WRP-01-21	**Exotic Einstein Geometries on Spheres**
Project duration:	4 weeks
Description:	The round sphere has the highly desirable property that it is Einstein, meaning its curvature is constant everywhere. The aim of this project is to investigate exotic Einstein spheres, which are Einstein spaces that are topologically identical to the round sphere, but behave very differently from the geometric point of view. In this project, the student will gain a comprehensive understanding of why there are no exotic Einstein spheres if the sphere has dimension three or less. The student will then use symmetry methods to explore the interesting examples of exotic Einstein spheres that have been constructed in higher dimensions.
Expected outcomes and deliverables:	The student will gain an appreciation for the significance of several important open questions in geometry and topology, as well as a hands-on experience in solving algebraic equations, ODEs and PDEs. Essential research skills will be improved through the writing of a short report at the conclusion of the project.
Suitable for:	This project would be suitable for a mathematics student in their 3rd or 4th year of study who has taken several courses in mathematical analysis. It will be important for the student to have an understanding of basic concepts in topology, functional analysis and differential geometry before starting the project
Primary Supervisor:	Dr Timothy Buttsworth
Further info:	If you are interested in participating, or would like more information about the required background for this project, please send an email to t.buttsworth@uq.edu.au

UQ Winter Research Project Description

Project title: SMP-WRP-02-21	**Applied PDEs**
Project duration:	4-5 weeks
Description:	Typically, projects are available in the mathematical/computational modelling and simulation of cell biology. Areas of particular interest are cellular morphogenesis, intra-cellular transport, (collective) cell migration and mechanical aspects of Neurobiology. This project – depending on interest – might involve 3D agent based simulations and 3D visualization in Julia
Expected outcomes and deliverables:	Experience in using PDEs as modelling tools and in manipulating PDEs both algebraically and numerically.
Suitable for:	Talent and interest in Applied Mathematics and PDEs, curiosity and self-motivation. Starting from 3rd year
Primary Supervisor:	Dr Dietmar Oelz
Further info:	Please contact Dr Dietmar Oelz by email (d.oelz@uq.edu.au)

UQ Winter Research Project Description

Project title: SMP-WRP-03-21	**Modelling and simulation in cell biology**
Project duration:	4-5 weeks
Description:	Typically projects are available in the mathematical/computational modelling and simulation of cell biology. Areas of particular interest are cellular morphogenesis, intra-cellular transport, (collective) cell migration and mechanical aspects of Neurobiology. This project – depending on interest – might involve 3D agent based simulations and 3D visualization in Julia
Expected outcomes and deliverables:	Experience in mathematical modelling and simulation
Suitable for:	Students with interest in and intuition for applications, programming skills, curiosity and self-motivation. Starting from 3rd year
Primary Supervisor:	Dr Dietmar Oelz
Further info:	Please contact Dr Dietmar Oelz by email (d.oelz@uq.edu.au)

UQ Winter Research Project Description

Project title: SMP-WRP-04-21	**Modelling and simulation of the L-arginine – NO (nitric oxide) pathway**
Project duration:	4-5 weeks
Description:	Modelling and ssimulation of the L-arginine – NO (nitric oxide) pathway. This might involve 3D agent based simulations (in Julia, visualisation using Makie) of intracellular L-arginine kinetics
Expected outcomes and deliverables:	Experience in modelling and simulation techniques. Quantitative understanding of the effect of CAT (amino-acid transporters) on NO synthesis.
Suitable for:	This project is open to students with a background in physics, chemistry, or Talent and interest in Applied Mathematics and simulation, curiosity and self-motivation. Starting from 3rd year
Primary Supervisor:	Dr Dietmar Oelz
Further info:	Please contact Dr Dietmar Oelz by email (d.oelz@uq.edu.au)

UQ Winter Research Project Description

Project title: SMP-WRP-05-21	**Graphical user interface design for visual stimuli**
Project duration:	4-5 weeks
Description:	We aim to understand the computational principles by which stimuli in the world are represented by patterns of neural activity, and how these representations emerge during development. To do this we are recording the activity of thousands of neurons simultaneously, at single-cell resolution, in the brain of the larval zebrafish, and also recording zebrafish behaviour. While recording neural activity, we present visual stimuli to the fish by playing movies of artificially generated spots and shapes designed to mimic prey and other environmental cues that the fish might encounter in its natural environment. We are seeking a skilled software engineer, computer scientist or programmer to develop a new user-friendly graphical user interface for fast and flexible generation of a wide range of these artificial visual stimuli using Python.
Expected outcomes and deliverables:	You will be embedded in an interdisciplinary team of neuroscientists, engineers, mathematicians and physicists. While in the lab you will gain exposure to cutting edge experimental neuroscience and state-of-the-art computational analysis techniques from machine learning, applied mathematics and statistical physics. Project aims: • Develop an extensible modular package for the generation of movies of artificial visual stimuli in Python. • Develop a graphical user interface for users to specify the design of the stimuli (i.e. shape, size, position, speed, direction etc.) and various optical corrections. Project deliverables are source code and comprehensive package documentation.
Suitable for:	• Strong skills in coding in Python and demonstrated experience in GUI design are essential. • Experince with version control (GitHub) and creation of software documentation is required. • A background in mathematics and experience with standard Python scientific packages such as numpy and scipy are also highly desirable. • Previous knowledge of neuroscience is not essential.
Primary Supervisor:	Professor Geoff Goodhill
Further info:	Please contact Professor Goodhill (g.goodhill@uq.edu.au) prior to submitting an application. Further background can be obtained from the following article: goodhill.org/pub/avitan20.pdf

UQ Winter Research Project Description

Project title: SMP-WRP-06-21	**Studying Stellar Flares and Cosmic Explosions - using Tree Rings!**
Project duration:	5 weeks
Description:	Radiocarbon dating is used by archaeologists to determine the ages of wooden artefacts and remains of living things, by measuring how much carbon-13 has decayed to carbon-12 since the material last took in fresh carbon from the air. The amount of carbon-13 in the atmosphere has slowly varied over time due to solar activity and volcanic eruptions, so to calibrate their radiocarbon dates, archaeologists use precise measurements of tree rings of known age. With alternating patterns of slow and fast growth, tree rings form a barcode pattern that can be matched to libraries stretching back millennia, giving us precise radiocarbon references for almost any year since the last Ice Age. In 2012, a remarkable discovery was made by Fusa Miyake: in 774 AD, there was a huge spike in radiocarbon all over the world, that decayed over the course of a year or two, and may have been associated with powerful aurorae noted by mediaeval monks. It was almost certainly astrophysical in origin. Now several 'Miyake events' have been discovered, and astronomers wonder: was this a powerful solar flare? A supernova? Or the result of a 'magnetar burst', the powerful blast of a magnetised neutron star rearranging itself. New radiocarbon data in the IntCal20 record are ripe for analysis, by statistically digging into the vast new dataset to find new Miyake events hiding in the noise. We can then determine the true rate of their occurrence, their amplitude and timing, and help narrow down their astrophysical origin. This is an ideal project for a student with strong computer skills and an interest in statistics and interdisciplinary studies. *Guardian* article about our work: https://www.theguardian.com/science/2016/aug/17/traces-of-sun-storms-locked-in-tree-rings-could-confirm-ancient-historical-dates-astrochronology
Expected outcomes and deliverables:	Scholars will gain skills in time-series analysis and machine learning, and a successful project will lead to opportunities for publishing this research in journals. The main deliverable will be a statistical model of the IntCal20 time series, identifying or ruling out possible previously-unknown Miyake events.
Suitable for:	This project is open to applications from students with a good working knowledge of Python, Julia, or R, and an interest in machine learning or statistics.
Primary Supervisor:	Dr Benjamin Pope
Further info:	Students applying for this project are advised to contact the supervisor Dr Benjamin Pope at b.pope@uq.edu.au.

UQ Winter Research Project Description

Project title: SMP-WRP-07-21	**Measures in Number Theory**
Project duration, hours of engagement & delivery mode	The duration will be 5 weeks and hours will 36 hrs/wk. This project can be completed online if campus is shut down. Otherwise, it will be done on-site. *For example, 4 weeks and applicant will be required on-site for the project.*
Description:	This is a project about measures on algebraic groups over number fields. This plays an important role in many areas, such as the Langlands program.
Expected outcomes and deliverables:	The students will gain skills in deep aspects of number theory.
Suitable for:	*Pre-requisites are advanced algebra, advanced analysis, and measure theory courses with top grades. This is a project for Honours students or higher.*
Primary Supervisor:	Masoud Kamgarpour
Further info:	Please contact me if you want to apply.

UQ Winter Research Project Description

Project title: SMP-WRP-08-21	**Machine Learning of Biological Swimmers**
Project duration, hours of engagement & delivery mode	*4 weeks and applicant can perform the project work from home*
Description:	This project is concerned with developing machine learning codes for image recognition and tracking of swimming and trapped cells.
Expected outcomes and deliverables:	The scholar may gain skills in cutting edge machine learning and processing of simulated and experimental data. The scholar will be asked to present her/his work to the other members of the Optical Micromanipulation Group.
Suitable for:	This project is open to application from students from 2nd to 4th year of study with some computational experience.
Primary Supervisor:	Alexander Stilgoe *stilgoe@physics.uq.edu.au*
Further info:	If you are interested in this project please contact me to arrange a meeting to provide you with more information

UQ Winter Research Project Description

Project title: SMP-WRP-09-21	**Study of deformation of emulsion droplets with Optical Tweezers.**
Project duration, hours of engagement & delivery mode	*4 weeks and applicant will be required on-site for the project.*
Description:	This project is concerned with studies of how oil droplets in an oil-water emulsion deform when trapped and manipulated by multiple optical traps. The project will involve production of emulsion droplets with a low surface tension and deforming them using optical tweezers. Furthermore, measuring the force required to deform a droplet would aid in the understanding of emulsions and their stabilizing process.
Expected outcomes and deliverables:	The scholar may gain skills in laboratory work concerning optics and understanding of laser micromanipulation process. The results of the work could lead to publication giving the scholar opportunity to generate a publication. The scholar will be asked to present her/his work to the other members of the Optical Micromanipulation Group.
Suitable for:	This project is open to application from students from 1st to 4th year of study.
Primary Supervisor:	Halina Rubinsztein-Dunlop
Further info:	If you are interested in this project please contact me to arrange a meeting to provide you with more information

UQ Winter Research Project Description

Project title: SMP-WRP-10-21	**The Bach flow**
Project duration, hours of engagement & delivery mode	Duration: 4 weeks, 20hs per week, it is expected (but not essential) that the applicant will be able to meet in person if restrictions permit this.
Description:	The Bach flow is a fourth-order geometric evolution equation for Riemannian metrics on a 4-manifold, defined in terms of the Bach tensor, a conformal invariant object that is of particular importance in the study of 4-dimensional conformal geometry. The project consists in studying the literature for this flow in the context of locally homogeneous 4-manifolds, and to obtain the equations for some cases which have not been previously considered. If time permits, an analysis of the resulting system of ODEs will be carried out.
Expected outcomes and deliverables:	The student will gain experience in dealing with cutting-edge research in pure mathematics. They will learn important techniques for studying geometric flows under symmetry assumptions. There is also the possibility that this might lead to a publication later on.
Suitable for:	It is expected that the applicant will be a 3rd or 4th year student with a solid background in Analysis and Differential Geometry. Some knowledge in Lie groups and algebras would be ideal.
Primary Supervisor:	Ramiro Lafuente
Further info:	Please refer any questions to r.lafuente@uq.edu.au

UQ Winter Research Project Description

Project title: SMP-WRP-11-21	**Tensor-network quantum error correcting codes**
Project duration, hours of engagement & delivery mode	*Project duration: 5 weeks. On-site attendance is not essential for the project, but face-to-face meetings twice a week would be ideal if possible.*
Description:	*Background: Quantum error correction will be vital for quantum computers to be useful in the future. While there are many proposed error correcting codes and decoders, which codes will be most useful in practice is still unknown.* *Project: This project will involve analysing new quantum error correcting codes based on tensor networks and doing simulations to test their ability to protect quantum information from errors.*
Expected outcomes and deliverables:	*Scholars will learn about quantum error correction, tensor networks, and will perform numerical simulations in python. They will get experience in basic research and some programming experience. Students will have to give a small presentation at the end of their project and write a short report.*
Suitable for:	*Suitable for students with a good grasp of quantum mechanics and, ideally, some quantum computation/quantum information.*
Primary Supervisor:	*Terry Farrelly.*
Further info:	*Email for info: t.farrelly@uq.edu.au. (Please email before applying.)*

UQ Winter Research Project Description

Project title: SMP-WRP-12-21	Superconducting quantum circuits - Arkady Fedorov
Project duration, hours of engagement & delivery mode	5 weeks. Can be done in remote mode.
Description:	Superconducting quantum circuits are nanostructures fabricated on a chip, operated at milliKelvin temperatures and controlled by electrical signals. Due to unique physical properties of superconductors and Josephson junctions these systems have recently become one of the most promising platforms for building quantum computers and is an attractive testbed for fundamentals of quantum mechanics. The project is dedicated to learning, practicing as well as developing new techniques to control and measurement of superconducting circuits which may find use both in academia and in quantum industry.
Expected outcomes and deliverables:	The scholar will learn: • Underlying physical principles of operation of superconducting quantum circuits including resonators and qubits. • Basics of microwave measurements at cryogenic temperatures. • Skills of numerical simulation of open quantum systems in application to superconducting devices Students are asked to produce a final report and may be asked make an oral presentation of their results at the group meeting.
Suitable for:	Physics, engineering students with interest in quantum physics, quantum information and some aspects of experiment. Knowledge of basics of quantum mechanics is encouraged. Experience with electronics, Python programming, data processing is welcome too. Most suitable for students at later stages (3d year and above) but 2d year student will be considered too. The project can be tailored to have components of measurements, design and simulation depending on candidate preferences and qualification.
Primary Supervisor:	Assoc Prof Arkady Fedorov
Further info:	Contact me before applying a.fedorov@uq.edu.au, Parnell Bld. #306, sqd.equs.org

UQ Winter Research Project Description

Project title: SMP-WRP-12-21	**Sonification of Dark Energy Survey data**
Project duration, hours of engagement & delivery mode	This is a 4 to 5-week project for between 20-36 hours per week, depending on applicant's availability.
Description:	The aim of this project is to investigate and implement ways to display the data from the Dark Energy Survey (DES) using sound. That is, to sonify the data. The motivation is two-fold. Firstly, to make this accessible to people without sight; and secondly, to provide a new method by which to analyse the data. We propose to work with the astreos.space project, who have already developed the platform on which to host such data, and have already sonified other astronomical data sets. https://astreos.space/
Expected outcomes and deliverables:	The participant will develop their software skills and learn how to encode different types of data into sound. They will also learn about dark energy and dark matter, and how we can map the distribution of dark matter in the universe using weak lensing (the bending of light paths by gravitational fields). The expected output will be either an app or program that DES scientists and the general public can use to "view" the dark matter maps we have made using sound as an alternative medium to convey the information.
Suitable for:	Experience with data analysis and computer programming will be essential. Past experience with sonification will be extremely valuable.
Primary Supervisor:	Tamara Davis
Further info:	Please contact Tamara Davis if interested, on tamarad@physics.uq.edu.au.

UQ Winter Research Project Description

Project title: SMP-WRP-12-21	**Virtual retinal display for zebrafish**
Project duration, hours of engagement & delivery mode	4 weeks, 25hours per week. COVID-19 considerations: The project can be completed under a remote working arrangement or if on-site attendance is required.
Description:	This project aims to design an appropriate virtual retinal display for zebrafish and test it. This project will involve research in the literature of the newest virtual retinal displays available and how they can be applied to zebrafish.
Expected outcomes and deliverables:	The Scholar will gain knowledge in optical physics in general, but more particularly in optical systems integration for animal research. If time permits, the scholar would have the opportunity to generate a publication from their research.
Suitable for:	Optical physics background is preferable.
Primary Supervisor:	Itia Favre-Bulle
Further info:	i.favrebulle@uq.edu.au