2020/21 UQ Summer Research Scholarship Program

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

How to apply:

The UQ Summer Research Program is offered by the School of Mathematics and Physics (SMP) and UQ Student Employability Centre during the summer vacation period. Here is a list of the 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 Summer Research Program application.

(3) Applications open on Monday, 24 August and close by Sunday, 27 September 2020.

IMPORTANT NOTE TO APPLICANTS:

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

UQ Summer Research Project Description

Supervisor	Associate Professor Holger Baumgardt	Duration: 8 weeks
Contact Details:	Email: h.baumgardt@uq.edu.au, Telephone: 07 3365 3430 Office: Physics Annexe Building 6, Room 402	

Testing the nature of ultra-faint dwarf galaxies SMP-SRP-01-21

Ultra-faint dwarf galaxies are the tiniest known galaxies. They have sizes of only 100 pc or less and luminosities a million times smaller than that of the Milky Way. Ultra-faint dwarf galaxies have been discovered in large numbers in the halo of the Milky Way in recent years. They play a key role in testing our understanding of dark matter and small-scale structure formation. However the nature of many ultra-faint dwarf galaxies is not yet firmly established. In this project you will use the latest data from space-based satellites like Gaia and the HST to help better understand the nature of these enigmatic galaxies.

Number of student places available: 1

Delivery: No onsite attendance required

Expected outcomes: Ability to identify strengths, Develop confidence in communication, Better understanding of what a career in research entails

Suitable for: Year 3 students who have done PHYS3080 or who have comparable knowledge

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

<table>
<tr><td>Supervisor</td><td>Professor Warwick Bowen</td><td>Duration: 5-6 weeks</td></tr>
<tr><td>Contact Details:</td><td colspan="2">Email: w.bowen@uq.edu.au</td></tr>
<tr><td colspan="3">Super-resolution quantum imaging using Bayesian inference SMP-SRP-02-21

Super-resolution imaging is a critical tool for understanding living biology, since most of the molecules involved are far smaller than the wavelength of light and therefore cannot be resolved with conventional microscopes.</td></tr>
<tr><td colspan="3">Number of student places available: 1</td></tr>
<tr><td colspan="3">Delivery: Can be remote if necessary</td></tr>
<tr><td colspan="3">Expected outcomes: This project will analyse a new type of super-resolution imaging, that breaks the usually Rayleigh limit to resolving the separation of two emitters. It will first analyse the limits to the performance of this technique due to the quantisation of light, and then make explore how quantum correlations between photons can be used to improve performance.</td></tr>
<tr><td colspan="3">Suitable for: A physics student with strong computational abilities and experience with Bayesian analysis.</td></tr>
<tr><td colspan="3">Other important details: Please contact Prof Warwick Bowen by e-mail (w.bowen@uq.edu.au) if you are interested prior to applying. Evidence of supervisor support is required to be uploaded as part of the application process.</td></tr>
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UQ Summer Research Project Description

Supervisor	Professor Tim McIntyre	**Duration: 8 weeks**
Contact Details:	Email: t.mcintyre@uq.edu.au	

Schlieren imaging for supersonic and hypersonic flow fields SMP-SRP-03-21

Schlieren imaging relies on the fact that light follows a curved path when passing through a fluid with a density gradient. By using a combination of mirrors, lenses, and apertures, it is possible to design an optical system that visualises these flow gradients as changes in light intensity. This project involves developing and testing a schlieren system on a small flow facility with possible exploration of enhanced approaches such as colour schlieren or focussed schlieren techniques.

Number of student places available: 1

Delivery: The project will be conducted partially on-site. However, it can be adapted to any limitations on access to the campus.

Expected outcomes: The scholar will develop experience with an optical imaging system and its application to high speed flow facilities.

Suitable for: Any physics student with an interest in gaining experience in a research laboratory.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Professor Ben Powell	**Duration: 6-10 weeks**
Contact Details:	Email: powell@physics.uq.edu.au	

New particles in spin crossover materials SMP-SRP-04-21

I sometimes pity particle physicists, who are limited to studying a single vacuum and its excitations, the particles of the standard model. For condensed-matter physicists, every new phase of matter brings a new "'vacuum." Remarkably, the low-energy excitations of these new vacua can be very different from the individual electrons, protons, and neutrons that constitute the material. The materials multiverse contains universes where the particle-like excitations carry only a fraction of the elementary electronic charge, are magnetic monopoles, or are fermions that are their own antiparticles. None of these properties have ever been observed in the particles found in free space. Often, emergent gauge fields accompany these "fractionalized" particles, just as electromagnetic gauge fields accompany charged particles.

We have recently discovered a new phase of matter, spin-state ice, that is predicted to show both fractionalised quasiparticles and an emergent gauge field. Furthermore, the spin-state ice has a remarkably simple theoretical description. In this project you will study these materials theoretically and try to predict there properties. A range of methods from exact mathematical treatments through to models on supercomputers are possible, and can be selected to suit the interests and background of the student.

Number of student places available: 4

Delivery: This project can be carried out remotely.

Expected outcomes: Advance theoretical/mathematical modelling, advanced numerical methods, experience of comparing theoretical predictions to experimental data.

Suitable for: Should have completed at least the equivalent of 2-3 years of full time study in physics, maths and/or chemistry.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Peter Jacobson	**Duration: 8 weeks**
Contact Details:	Email: p.jacobson@uq.edu.au Office: Physics Annexe Building 6, Room 436	

Improving the fabrication of superconducting qubits SMP-SRP-05-21

High quality factor microwave resonators are critical components of quantum computer architectures. Aluminium resonators on silicon are now standard components in these architectures, but the measured quality factors in these resonators is lower than expected. Recent work suggests that the limiting factor for these devices are imperfections at the metal-substrate interface. This project focuses on preparing atomically precise interfaces for improved superconducting qubits. Using new equipment housed at SMP and CMM, the student will prepare clean substrates and develop procedures to grow high quality factor resonators.

Number of student places available: 1

Delivery: The project is experimental and includes hands on lab work. This will be carried out under UQ distancing policies.

Expected outcomes: The student will gain experience with vacuum equipment, device fabrication, cleanroom protocols, and material characterisation techniques.

Suitable for: This project is open to students with a background in physics, chemistry, or engineering. Enthusiasm for experimental work is a must.

Other important details: Discussions with applicants are encouraged, please reach me at: p.jacobson@uq.edu.au. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Itia Favre-Bulle	**Duration: 8 weeks**
Contact Details:	Email: i.favrebulle@uq.edu.au	
Virtual retinal display for zebrafish		SMP-SRP-06-21
This project aims to scan the literature in search of the newest virtual retinal displays available. This project also aims to design an appropriate virtual retinal display for zebrafish and test it.		
Number of student places available: 1		
Delivery: The project can be completed under a remote working arrangement if necessary.		
Expected outcomes: The Scholar will gain knowledge in optical physics in general, but more particularly in optical systems integration for animal research.		
Suitable for: Optical physics background is preferable.		
Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.		

UQ Summer Research Project Description

Supervisor	Professor Matthew Davis & Dr Matt Reeves	Duration: 6-10 weeks
Contact Details:	Email: mdavis@physics.uq.edu.au	

Tunnelling of supercurrents in a Bose-Einstein condensate SMP-SRP-07-21

One of the features of superfluidity is that a flow in a ring below a critical velocity will never slow down like it would in a classical fluid with friction. This project will computationally study the coupling of two rings to understand the conditions for when a supercurrent can tunnel from one ring into another. It will begin with constructing a Hamiltonian matrix for the system, and diagonalizing it to look at the properties of the eigenstates. It will move on to simulating the interacting system with the Gross-Pitaevskii equation. If successful, it is hoped that these results will lead to experiments in the UQ Bose-Einstein condensation laboratory.

Number of student places available: Up to 2

Delivery: On campus preferred but can also be performed remotely. Student should attend research group meetings.

Expected outcomes: Students will learn how to solve the linear and nonlinear Schrodinger equation computationally. If successful, it is hoped that these results will lead to experiments in the UQ Bose-Einstein condensation laboratory.

Suitable for: Self-motivated second/third year physics students who are interested in pursuing research in theoretical and computational quantum physics.

Other important details: Please get in touch with Professor Davis before applying for this project. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Professor Matthew Davis & Dr Matt Reeves	Duration: 6-10 weeks
Contact Details:	Email: mdavis@physics.uq.edu.au	

Model of an atomtronic transistor SMP-SRP-08-21

The term “atomtronics” has been coined to describe the creation of electronic circuit-like experiments using ultracold quantum gases. This project will develop a simple model of an atomtronic transistor based on kinetic theory of gases and apply it to understand an experiment performed at the University of Colorado, Boulder. Students will use knowledge of statistical mechanics and thermodynamics to develop a model of particle and energy flow in a three-terminal trap.

Number of student places available: Up to 2

Delivery: On campus preferred but can also be performed remotely. Student should attend research group meetings.

Expected outcomes: The model will validate or falsify the understanding described in the experimental paper. A successful project will lead to publishing a paper describing the model and its results.

Suitable for: Self-motivated third year physics students who are interested in pursuing research in theoretical and computational quantum physics.

Other important details: Please get in touch with Professor Davis before applying for this project. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Professor Matthew Davis & Dr Matt Reeves	**Duration: 6-10 weeks**
Contact Details:	Email: mdavis@physics.uq.edu.au	

Nonequilibrium superfluid flows SMP-SRP-09-21

The aim of this project is to make a connection between classical mechanics and quantum mechanics - looking for the signatures of classical trajectories in the quantum wave functions. This is potentially interesting for superfluids, as to some extent they behave as classical fluids. This would require adding the effects of particle interactions - an additional nonlinear term in the Schrodinger equation.

Number of student places available: Up to 2

Delivery: On campus preferred but can also be performed remotely. Student should attend research group meetings.

Expected outcomes: Students will learn how to solve the linear and nonlinear Schrodinger equation computationally with sources and sinks. The results may influence the UQ experimental program on Bose-Einstein condensates.

Suitable for: Self-motivated second/third year physics students who are interested in pursuing research in theoretical and computational quantum physics.

Other important details: Please get in touch with Professor Davis before applying for this project. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Professor Matthew Davis & Dr Matt Reeves	Duration: 6-10 weeks
Contact Details:	Email: mdavis@physics.uq.edu.au	

Superfluidity under a quench of interaction strength in a persistent current SMP-SRP-10-21

One of the key insights of Landau was to derive a phenomenological formula for the critical velocity in a superfluid. In a Bose gas this is related to the speed of sound, which is directly related to the strength of repulsive interaction between particles. By making use of something known as a "Feshbach resonance" in the scattering properties of two atoms, it is experimentally possible to tune the strength of interactions in a Bose gas. This project will look at a ring system in which there exists a persistent current that if left undisturbed will never decay. However, if the interaction strength is sufficiently reduced, the speed of sound will decrease below the speed of the current and the superflow will break down. This project will characterize the non-equilibrium dynamics as the flow breaks down and thermalizes. It should be able to be related to the well-known "Kibble-Zurek" mechanism for phase transitions.

Number of student places available: Up to 2

Delivery: On campus preferred but can also be performed remotely. Student should attend research group meetings.

Expected outcomes: The student will learn how to apply computational methods to solve the nonlinear Schrodinger equation. A complete set of results with appropriate interpretation could be turned into a publication.

Suitable for: Self-motivated second/third year physics students who are interested in pursuing research in theoretical and computational quantum physics.

Other important details: Please get in touch with Professor Davis before applying for this project. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Prof Matthew Davis & Prof Margaret Mayfield	**Duration: 6-10 weeks**
Contact Details:	Email: mdavis@physics.uq.edu.au	
Statistical physics model of abundances and interactions in plant communities SMP-SRP-11-21 This project aims to use the methods of statistical physics to help understand the equilibrium and dynamics of interacting plant communities with Prof Margie Mayfield in the School of Biological Sciences. Prof Mayfield's group has collected a significant amount of data on plant abundances, and shown that the data suggests that nonlinear interactions between the plants affect their seed production. We hope to gain a new understanding of this data using equilibrium models of statistical mechanics. See: Higher-order interactions capture unexplained complexity in diverse communities Margaret M. Mayfield & Daniel B. Stouffer Nature Ecology & Evolution 1, Article number: 0062 (2017) doi:10.1038/s41559-016-0062		
Number of student places available: 1		
Delivery: On campus preferred but can also be performed remotely. Student should attend research group meetings.		
Expected outcomes: Hopefully we will show that physics methods can be used to help understand the interactions between plants in a community.		
Suitable for: Self-motivated science students with strong quantitative skills who are interested in pursuing an interdisciplinary project covering theoretical physics and biology. Knowledge of statistical mechanics is desirable.		
Other important details: Please get in touch with Professor Davis before applying for this project. Evidence of supervisor support is required to be uploaded as part of the application process.		

UQ Summer Research Project Description

Supervisor	Dr Cecilia Gonzalez Tokman	**Duration: 10 weeks**
Contact Details:	Email: cecilia.gt@uq.edu.au	

Stability in non-autonomous dynamical systems SMP-SRP-12-21

This project aims to investigate global stability aspects of non-autonomous dynamical systems, a class of models used to describe phenomena whose evolution rule changes over time, e.g. due to random and/or seasonal effects. It will involve the analysis of finite and/or infinite-dimensional models, relying on analytical and numerical tools from modern ergodic theory.

Number of student places available: 1

Delivery: COVID-19 considerations: The project can be completed under a remote working arrangement if required.

Expected outcomes: The student will develop knowledge and practice in analytical and numerical aspects of random dynamical systems, as well as written and oral communication skills. The project may lead to the development of random dynamical systems models amenable to rigorous analysis, and/or to novel stability results in the field.

Suitable for: Background/skills:

- A strong mathematical background is essential (e.g. two years in a mathematics/quantitative degree).
- Some experience in dynamical systems is highly desirable (e.g. SCIE3011).
- Experience with mathematical software (e.g. Matlab or Mathematica) is ideal but not required.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Travis Scrimshaw	Duration: 8 weeks
Contact Details:	Email: t.scrimshaw@uq.edu.au Office: Building 69, Room 709	

Super box-ball systems SMP-SRP-13-21

The box-ball system is a dynamical system that is used to model water waves moving through a thin channel. The waves are encoded in objects called solitons, which we study using a simple discrete rule. The box-ball system can be generalised by converting ideas from representation theory into discrete objects called crystals. In this project, we are going to look at a generalisation due to Hikami and Inoue coming from the study of supersymmetry. The aim of this project is to combine their generalisation with another generalisation using recent results of Kwon and Okado on the corresponding crystals. We will be describing what a soliton is in this generalized framework. We will also explore what behaviours our new system can exhibit and contrasting them to the previous results.

Number of student places available: 2

Delivery: This project will entail regular meetings and requires the student to have access to a computer (a laptop is sufficient). Meetings can be done via Zoom if necessary.

Expected outcomes: Scholars will gain experience in using examples to develop theorems, performing experimental mathematics, and developing software (in Python) to better understand problems. Scholars will also work in the fields of combinatorics and mathematical physics, where they will also learn how to develop new definitions and write papers.

Suitable for: An interest in studying discrete systems and determining mathematical theorems from computations, examples, and computer experiments. Basic experience in programming using Python is desirable but not required.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Ben Roberts and Dr Jacinda Ginges	**Duration: 8 weeks**
Contact Details:	Email: b.roberts@uq.edu.au; j.ginges@uq.edu.au Office: Physics Annexe Building 6, Room 427	

High-accuracy atomic physics calculations for tests of fundamental physics and the standard model SMP-SRP-14-21

High-precision atomic physics experiments play an important role in testing the Standard Model of particle physics at low energy. Highly accurate atomic structure calculations are required in order to interpret the experiments in terms of fundamental physics parameters.

Atomic physics calculations involve treating the many-electron atomic Hamiltonian approximately. In order to achieve high accuracy, a number of many-body effects need to be taken into account using perturbation theory.

One such class of effects, known as "ladder diagrams", are missing from some calculations. Though small, these corrections seem to be important in some cases. The ladder-diagram method has been applied previously to energies with high success (see: Physical Review A, 78, 042502). The plan here is to extend this method to include "ladder diagram" corrections directly into atomic wavefunctions. These wavefunctions can then be used to compute relevant atomic properties (for example, hyperfine splittings, transition rates, lifetimes, etc.).

The project will involve aspects of quantum mechanics (elementary atomic theory) and numerical methods (application of existing code libraries to new problems in atomic physics). It will also involve some basic programming (in c++ and/or fortran), though no prior knowledge of programming is required.

Number of student places available: 1

Delivery: This project can be conducted remotely if need be.

Expected outcomes: The project will involve aspects of quantum mechanics (elementary atomic theory) and numerical methods (application of existing code libraries to new problems in atomic physics).

Suitable for: Reasonable (undergraduate) level of quantum mechanics required. Some basic coding ability will be helpful, but is not required.

Other important details: Interested students *must* contact the supervisor/s, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Associate Professor Arkady Fedorov	**Duration: 8 weeks**
Contact Details:	Email: a.fedorov@uq.edu.au Office: Parnell Building 7, Room 306	

Quantum control and measurement of superconducting quantum circuits SMP-SRP-15-21

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.

Number of student places available: 1

Delivery: On-site attendance is recommended but not required. The project can be also performed in a remote mode.

Expected outcomes: 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

Suitable for: Physics, engineering students with interest in quantum physics, quantum information and experiment. Knowledge of basics of quantum mechanics is required. Experience with electronics, Python programming, data processing is a plus.

Other important details: The project can be tailored to have components of measurements, design and simulation depending on candidate preferences and qualification. Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Joel Corney	**Duration: 8 weeks**
Contact Details:	Email: j.corney@uq.edu.au	

Coupled modes in whispering-gallery resonators SMP-SRP-16-21

Optical resonators formed from microspheres or microdisks support high-quality "whispering gallery modes", in which the incoupled light circulates many times in a highly confined space. This provides a way of enhancing nonlinear optical effects, leading for example to novel quantum states of light.

In this theoretical project, you will calculate the nonlinear dynamics than ensues when the resonator can support multiple simultaneous modes. In particular you will explore the impact of various competing or enhancing effects on the threshold response of the device.

Number of student places available: 1

Delivery: Project can largely be completed off-site. Weekly on-site meeting preferred, but on-line alternative can be arranged.

Expected outcomes: You will develop skills in analytic and computational approaches in theoretical physics. You will be required to produce a short report and to give an informal talk at the end of the project.

Suitable for: Some knowledge of quantum physics is essential (equivalent to a second-year course on the topic). Familiarity with ordinary differential equations would be an advantage.

Other important details: The project can be tailored to have components of measurements, design and simulation depending on candidate preferences and qualification. Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Tyler Neely	**Duration: 10 weeks**
Contact Details:	Email: t.neely@uq.edu.au Telephone: 0431 999 606 Office: Physics Annexe Building 6, Room 326	

Folded smoke rings in a 2D Bose-Einstein condensate SMP-SRP-17-21

One of the hallmarks of superfluidity is the existence of quantised vortices. In a three-dimensional fluid, these can form a vortex ring - similar to a smoke ring familiar from classical physics. Like the classical ring, the vortex ring travels, carrying linear momentum through the fluid.

By taking a slice through the vortex ring, the equivalent structure in a 2D superfluid system is recognised, known as a vortex dipole. This object consists of a vortex and antivortex pair. Similar to the smoke ring, it moves as a fixed object through the fluid.

A recent numerical study has discovered higher-order fixed vortex structures – these would appear as folded rings in 3D and would be unstable but are stable in the 2D superfluid system. However, these have not yet been observed in experiments.

The aim of this project will be to numerically simulate the experimental system, using a software package known as XMDS2. The aim will be to determine an experimental sequence that can create the initial vortex structure.

Time allowing, opportunity to implement the sequence in the experimental system may arise.

Number of student places available: 1

Delivery: The project can be delivered flexibly, as it will in the first instance consist of numerical simulations (to potentially be implemented in the lab).

Expected outcomes: Experience with numerical simulations, understanding of superfluid physics, experience with parameter optimisation.

Suitable for: Some basic coding experience is desirable, but not required. This project is more suitable to 2nd or 3rd year students.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Associate Professor Ebinazar Namdas	Duration: 8-10 weeks
Contact Details:	Email: e.namdas@uq.edu.au	

Organic light emitting diodes (OLEDs) SMP-SRP-18-21

Organic Light Emitting Diodes (OLEDs) are a class of organic electronics, which is extensively being investigated because of its potential for flat---panel display and lighting. It is an attractive area of research particularly because they are lightweight, flexible, have wider viewing angles and a faster response time. Currently, they are also used in displays of smart phones. The performance of an OLED depends on various parameters such as thickness of the light emitting layer (organic semiconductor), buffer layer between electrode and emitting layers etc.

Number of student places available: 2

Delivery:

Expected outcomes: In this project, you will gain an in-depth knowledge about the working of mechanism of OLEDs, and measurement technique and/or device modelling and simulation.

Suitable for: 3rd year students. Requirement- Strong background in Matlab, etc (1 student). Experimental Project requirement – Strong interest in applied physics, optics (1 student)

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Dietmar Oelz	Duration: 8 weeks
Contact Details:	Email: d.oelz@uq.edu.au	

Modelling and simulation in cell biology SMP-SRP-19-21

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.

Number of student places available: 1

Delivery: Remote working arrangement is possible

Expected outcomes: Experience in mathematical modelling and simulation.

Suitable for: Starting from year 3 students. Students with interest in and intuition for applications, programming skills, curiosity and self-motivation.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Dietmar Oelz	**Duration: 8 weeks**
Contact Details:	Email: d.oelz@uq.edu.au	

Applied PDEs SMP-SRP-20-21

Typically projects are available in the context of mathematical models of phenomena related to cellular morphogenesis, intra-cellular transport, (collective) cell migration and mechanical aspects of Neurobiology.

Number of student places available: 1

Delivery: Remote working arrangement is possible

Expected outcomes: Experience in using PDEs as modelling tools and in manipulating PDEs both algebraically and numerically.

Suitable for: Starting from year 3 students. Talent and interest in Applied Mathematics and PDEs, curiosity and self-motivation.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Alex Tam	Duration: 6-8 weeks
Contact Details:	Email: alex.tam@uq.edu.au Office: Building 69, Room 706	

Mathematical modelling and simulation of contractile actomyosin rings SMP-SRP-21-21

Interactions between actin filaments and myosin motor proteins in the cell cortex generate forces that enable cells to move, change shape, and divide. Of particular interest is the 'actomyosin' ring, which contracts to split the cell in two during cell division. Since actin filaments and myosin motors are distributed at random in the cortex, it is not immediately clear why this ring contracts.

With Dr Dietmar Oelz, I have been working on a mathematical model based on filament bending to understand contraction in two-dimensional actomyosin networks, and have developed Julia code to simulate our model. However, several important questions remain unanswered, including:

- Does our model predict contraction in specific ring-like geometry?
- Can our model explain long-term patterns that arise in experiments?
- How does the application of external forces affect network contraction?

We will work towards answering these questions during this summer research project.

Number of student places available: 1

Delivery: This project can be delivered either in-person or under remote working arrangements.

Expected outcomes: This project will enable a student to experience working as an applied mathematician in a relaxed environment. They will experience how the mathematics taught at UQ is being used in current research, and develop modelling and computational skills relevant to further Honours or postgraduate study in applied mathematics.

Suitable for: This project is suitable for any student with interest in applied mathematics, mathematical biology, and biophysics. A prospective student will ideally have some familiarity with scientific computing, for example in Matlab, Python, or Julia.

Other important details: Please contact Alex Tam prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Jacinda Ginges	**Duration: 8-10 weeks**
Contact Details:	Email: j.ginges@uq.edu.au	

Quantum electrodynamic contributions to the hyperfine structure in heavy atoms

SMP-SRP-22-21

Hyperfine structure refers to the small energy-level splitting in atoms that arises due to the interaction of the nuclear magnetic moment with the magnetic field created by atomic electrons. It plays an important role in both atomic and nuclear physics, and it even defines the unit for time, the second (ground state hyperfine splitting in cesium). In this project, a semi-empirical approach for the inclusion of quantum electrodynamic (QED) radiative corrections to the hyperfine structure for heavy atoms will be developed. There is currently no accurate scheme to include such effects in atoms with many electrons. Quantifying these effects is important in precision tests of fundamental physics in heavy atoms.

Number of student places available: 1

Delivery: This project may be conducted remotely.

Expected outcomes: The student will use and develop both analytical and numerical skills and deepen their understanding of (relativistic) quantum mechanics. Successful completion of the project may lead to a refereed journal publication.

Suitable for: Students with a strong background in quantum mechanics and a demonstrated high level of performance in theoretical physics subjects. Students should have completed at least 3 years of undergraduate physics study.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Terry Farrelly	**Duration: 8-10 weeks**
Contact Details:	Email: t.farrelly@uq.edu.au	

Some open problems in quantum fault tolerance SMP-SRP-23-21

Protecting quantum information from errors is crucial for emerging quantum technologies to function. To do this requires error correction and more general fault-tolerant strategies. In this project, scholars will learn about quantum error correction and fault tolerance. Then they will tackle one or a few of the 10 small open problems in quantum fault tolerance here: https://arxiv.org/abs/2008.05051

The project may involve a numerical aspect or it can be purely theoretical.

Number of student places available: 1

Delivery: Working via zoom would be possible but not ideal.

Expected outcomes: The scholar will learn about quantum error correction, fault tolerance, and possibly gain some experience with numerical simulations of quantum error correction. Other benefits include research and presentation experience.

Suitable for: Students interested in research with knowledge of quantum mechanics. Some basic knowledge of quantum information/computation would be useful but isn't completely necessary.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Travis Scrimshaw	Duration: 8 weeks
Contact Details:	Email: t.scrimshaw@uq.edu.au Office: Building 69, Room 709	

R-matrices and denominator formulas for Kirillov-Reshetikhin models SMP-SRP-24-21

Kirillov-Reshetikhin modules are an important class of affine quantum group representation that appear in many areas of mathematical physics and geometry. While we understand many things about these modules, constructing explicit examples is difficult, but it can be done by using Dorey's rule and a computer. An important component of this is computing the R-matrix, the morphism that interchanges the two factors, and a certain normalizing factor called the denominator formula. The goal of this project is to implement an algorithm for constructing the Kirillov-Reshetikhin modules and computing the denominator formulas using a computer. We will then use this code to compute important examples of the denominator formula where hand computations have currently failed.

Number of student places available: 2

Delivery: This project will entail regular meetings and requires the student to have access to a computer (a laptop is sufficient). Meetings can be done via Zoom if necessary.

Expected outcomes: Scholars will gain experience in performing experimental mathematics, developing software (in Python) to apply to mathematical problems, and conducting research in algebra. Specifically, scholars will work in the field of representation theory, where they will synthesize information, learn to write papers, and perform important computations.

Suitable for: An interest in studying algebra, and using computers to advance our knowledge in mathematics. The only requisite is an understanding of linear algebra; abstract algebra is desirable but not required. Experience in programming using Python is strongly desirable but not required.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Travis Scrimshaw	**Duration: 8 weeks**
Contact Details:	Email: t.scrimshaw@uq.edu.au Office: Building 69, Room 709	

Limits of Kirillov-Reshetikhin crystals SMP-SRP-25-21

Kirillov-Reshetikhin crystals are certain discrete structures that arose from the student of quantum systems in mathematical physics. They have been well-studied, but remain somewhat mysterious due to the lack of a uniform construction. There is a particular construction called the coherent limit that has been very useful, but is done in a case-by-case fashion. One aspect of this project is to give a uniform description of these limit crystals. There is another construction called the asymptotic limit of the corresponding algebraic structure. The other aim of this project is to develop the combinatorial interpretation of this limit, including a rigorous mathematical definition of this limit.

Number of student places available: 2

Delivery: This project will entail regular meetings and requires the student to have access to a computer (a laptop is sufficient). Meetings can be done via Zoom if necessary.

Expected outcomes: Scholars will gain experience in using examples to develop theorems, performing experimental mathematics, and developing software (in Python) to better understand problems. Scholars will work in the fields of combinatorics, mathematical physics, and representation theory, where they will also learn how to develop new definitions and write papers.

Suitable for: An interest in studying discrete structures and determining mathematical theorems from computations, examples, and computer experiments. Basic experience in programming using Python is desirable but not required.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Anna Puskas	**Duration: 8-10 weeks**
Contact Details:	Email: a.puskas@uq.edu.au Office: Building 69, Room 724	
Alcove walks and metaplectic polynomials SMP-SRP-26-21 The representation theory of algebraic groups and their metaplectic covers has led to interest in certain multivariate polynomials that satisfy functional equations governed by a Weyl group. These polynomials can be constructed in terms of combinatorial objects closely related to the representation theory of (finite dimensional) Lie algebras. This project focuses on understanding the connections between extant constructions, with a particular focus on the even orthogonal type.		
Number of student places available: 1		
Delivery: The project can be completed on campus, or under remote working arrangements.		
Expected outcomes: The Scholar will gain experience with doing collaborative and independent research, and learn about models in algebraic combinatorics relevant in representation theory.		
Suitable for: An undergraduate student interested in representation theory and algebraic combinatorics, with a working knowledge on the representation theory of finite dimensional Lie algebras.		
Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.		

UQ Summer Research Project Description

Supervisor	Dr Anna Puskas and Dr Travis Scrimshaw	**Duration: 8 weeks**
Contact Details:	Email: a.puskas@uq.edu.au and t.scrimshaw@uq.edu.au Office: Building 69, Room 724 and Building 69, Room 709	

Infinite arrays of crystals SMP-SRP-27-21

Gelfand-Tsetlin patterns are classical objects in combinatorics consisting of triangular arrays of integers satisfying certain inequality conditions. They are related to symmetries of vector spaces invariant under permutations. These have a natural symmetry which allow them to be folded and related to vector spaces invariant under signed permutations. The primary goal of this project is to take a certain limit of Gelfand-Tsetlin patterns and relate this limit to another combinatorial object called zig-zag strip bundles.

Number of student places available: 1

Delivery: This project will entail regular meetings and requires the student to have access to a computer (a laptop is sufficient). Meetings can be done via Zoom if necessary.

Expected outcomes: Scholars will gain experience in performing experimental mathematics, developing software (in Python) to apply to mathematical problems, and conducting research in combinatorics with connection to representation theory. More specifically, scholars will learn to synthesize information, write mathematical papers, and utilizing computers to aid in constructing examples.

Suitable for: An interest in studying discrete structures and using computers to advance our knowledge in mathematics. Only basic knowledge of discrete mathematics is required. Experience in programming using Python is strongly desirable but not required.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.

UQ Summer Research Project Description

Supervisor	Dr Travis Scrimshaw	**Duration: 8 weeks**
Contact Details:	Email: t.scrimshaw@uq.edu.au Office: Building 69, Room 709	

Decomposing configurations of lines SMP-SRP-28-21

An important object in algebraic geometry is the space of all the ways to build increasing dimensional vector spaces inside of n-dimensional space. This is called the flag variety. If we look at how a nilpotent matrix M and consider the subset of the flag variety satisfying certain properties coming from representation theory, a classical result describes the different pieces of this subset using combinatorial objects called standard Young tableaux. A recent variant of the flag variety was introduced by looking at the set of k (1-dimensional) lines in n-dimensional space that also has important connections to representation theory. One aim of this project is to describe the equivalent decomposition of this new variety to see if the irreducible components are parameterized using a generalization of standard Young tableaux called standard set-valued tableaux.

Number of student places available: 2

Delivery: This project will entail regular meetings and requires the student to have access to a computer (a laptop is sufficient). Meetings can be done via Zoom if necessary.

Expected outcomes: Scholars will gain experience in performing experimental mathematics, developing software (in Python) to apply to mathematical problems, and conducting research in algebraic geometry. Specifically, scholars will learn to synthesize information, read and write mathematical papers, and perform important computations using a computer and by hand.

Suitable for: An interest in studying algebra and algebraic geometry and using computers to advance our knowledge in mathematics. The only requisite is an understanding of linear algebra; abstract algebra is desirable but not required. Experience in programming using Python is strongly desirable but not required.

Other important details: Interested students *must* contact the supervisor, prior to submitting an application. Evidence of supervisor support is required to be uploaded as part of the application process.