

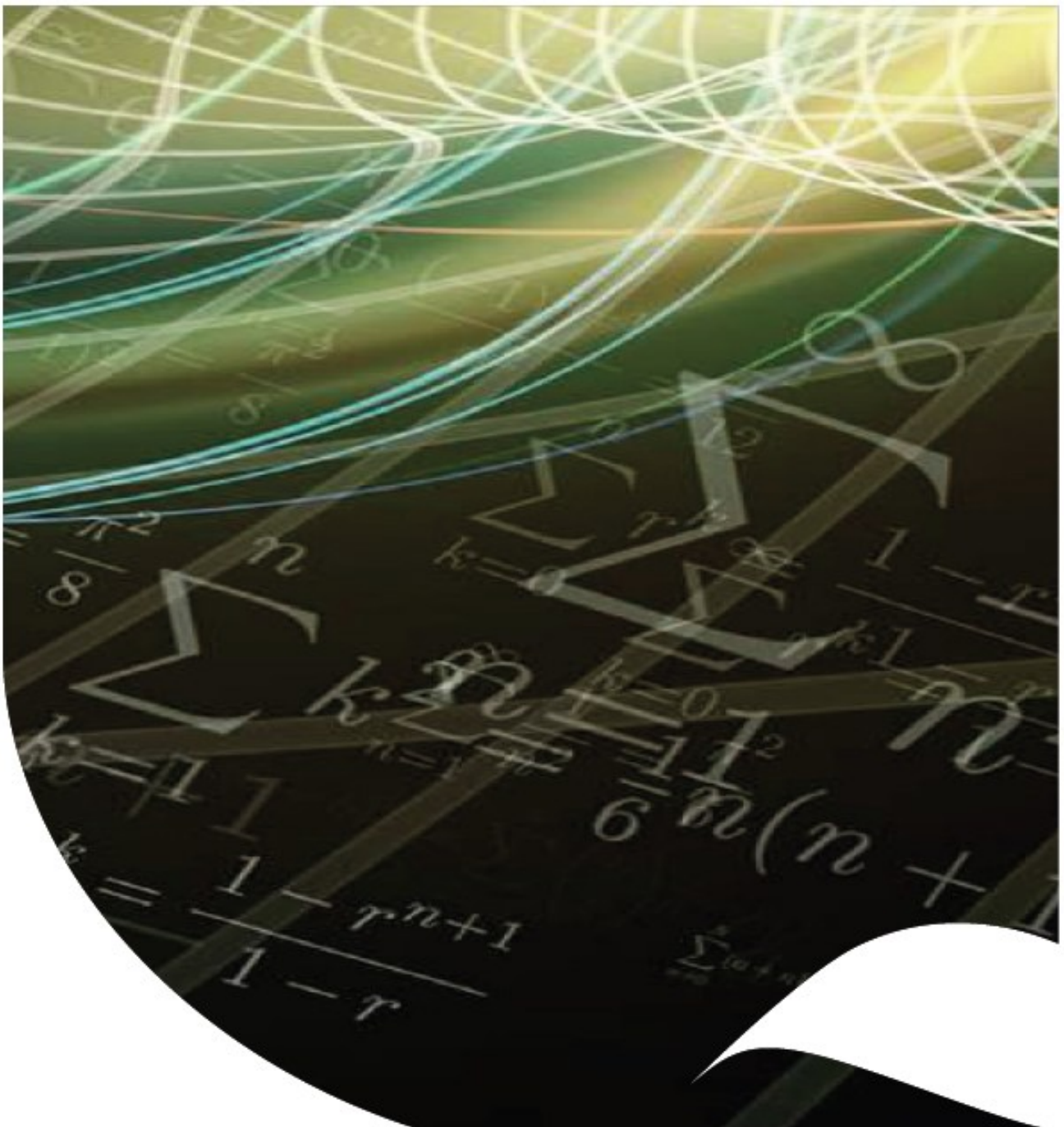


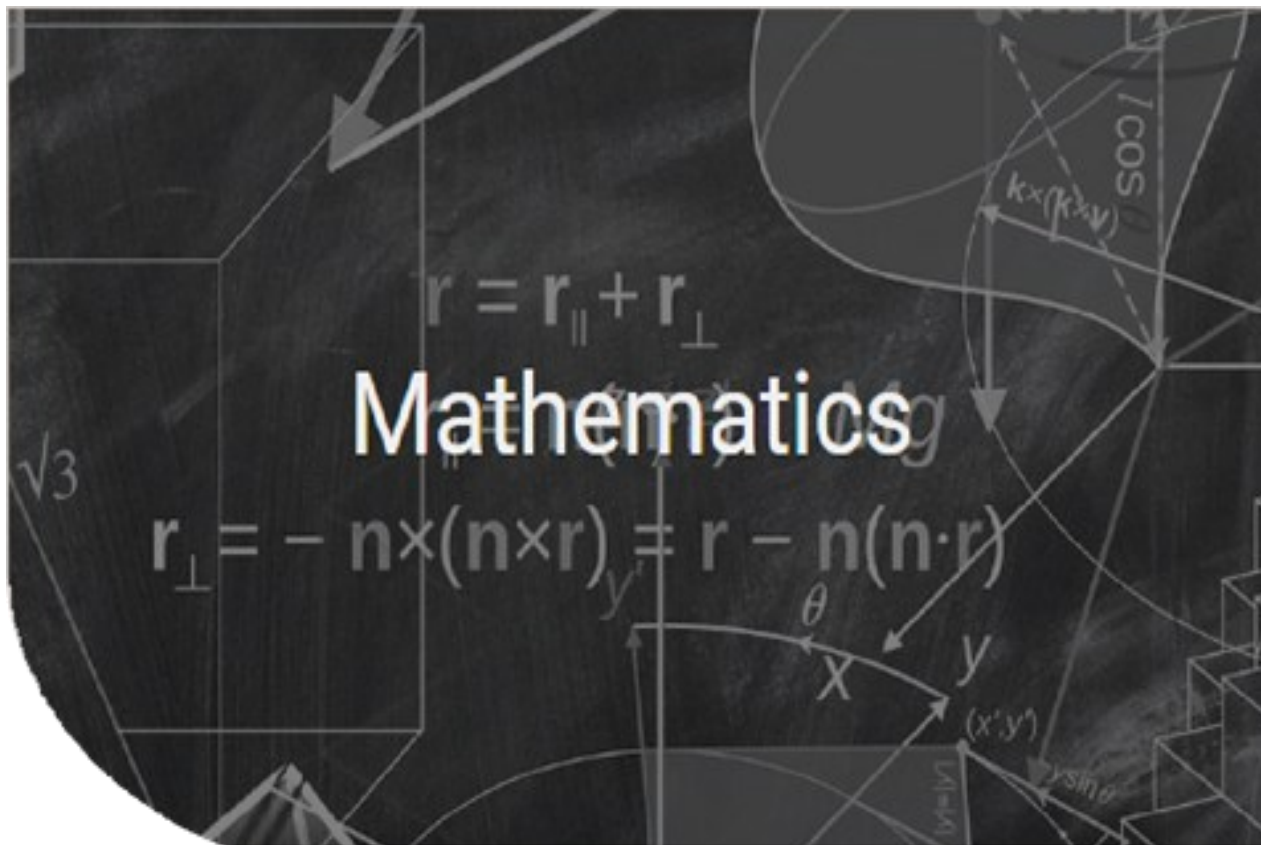
THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

SMP Poster Day 2026

Abstract Booklet





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M1. Filtering formulations for fuel freight

Candidate: **Chris O'Brien**

Advisor: **AsPr Michael Forbes**

Abstract: Have you ever wondered how petrol stations (almost) always have fuel? Does mathematics have a role to play? Fuel distribution companies must decide how they route their vehicles every day to ensure they efficiently deliver fuel to their stations. In particular, the transportation of fuel presents some additional complications: different fuels cannot be mixed, vehicles must deliver full compartments for safety reasons, deliveries may be split over multiple visits as they demand more fuel than one vehicle can carry. We present new integer programming formulations based on fragments and full routes to accommodate these rules; however, the sheer number of options can make the model impossible to solve for even moderate instances. To overcome this, we introduce formulation leveraging, a novel variable fixing technique that can be used to remove superfluous variables in the fragment formulation prior to optimisation. Our computational tests showed that more than 90% of variables could be removed in some cases while solving every instance in the benchmark to optimality (including 25 for the first time). This demonstrates the technique's utility and indicates it as a useful augmentation for fragment formulations in other vehicle routing problems.

M2. The Geometric Wall: Manifold Structure Predicts Layerwise Sparse Autoencoder Scaling Laws

Candidate: **Eslam Zaher**

Advisor: **Prof Farbod Roosta-Khorasani**

Abstract: Sparse autoencoders (SAEs) operationalise the linear representation hypothesis: they reconstruct model activations as sparse linear combinations of interpretable dictionary atoms, on the implicit assumption that activation space is well approximated by a globally linear structure. Their reconstruction error varies sharply across layers in ways that existing scaling laws, fitted at single layers, do not explain. We argue that this variation is the empirical trace of a geometric mismatch: where the activation manifold is curved and its intrinsic dimension varies across layers, no sparse linear dictionary can match it uniformly, and the SAE's width-sparsity scaling becomes a layer-dependent function of manifold structure rather than a single universal law. We conduct the first cross-layer SAE scaling study, fitting and regressing on 844 residual-stream Gemma Scope SAE checkpoints across 68 layers of Gemma 2 2B and 9B. Stage 1 fits a per-layer scaling-law surface; Stage 2 regresses the fitted parameters and the derived per-layer width exponents on four layerwise geometric summaries. We find that manifold geometry predicts the per-layer width exponent in both models, and that the same regression coefficients learnt on one model predict the other model's per-layer exponents under cross-model transfer, indicating a transferable geometric law. At the showcase layers where richer width grids permit identification of the asymptotic floor, we find that the fitted floor tracks the layerwise geometric ordering: higher curvature and intrinsic dimension correspond to higher floor, consistent with the irreducible second-order residual that any sparse linear approximation of a curved manifold must leave behind. SAEs thus encounter not a finite-resource ceiling but a geometry-dependent wall, set by the manifold they are trying to reconstruct.

M3. Ricci Flows With Symmetry

Candidate: **Henry Wood**

Advisor: Dr Ramiro Lafuente

Abstract: We study Ricci flows on principal bundles with nilpotent structure group and compact one-dimensional base. Lauret proved that homogeneous Ricci flows on simply connected manifolds with nilpotent symmetry are type-III. Recently, Gindi-Streets proved that Ricci flows on four-dimensional principal bundles with nilpotent structure groups and compact one-dimensional base are type-III. We allow the structure group to be any nilpotent Lie group and prove that the corresponding Ricci flows are type-III. To do so, we extend Lauret's bracket flow to principal bundles. The results are new for Ricci flow.

M4. Distilling small and well-performing tree policies for reinforcement learning

Candidate: **Joel Woodfiled**

Advisor: Dr Nan Ye

Abstract: Neural networks have been successfully applied to reinforcement learning to solve difficult sequential decision-making problems. However, they are generally hard to interpret, motivating recent interest in learning decision tree policies as decision trees are more interpretable. One technique for learning tree policies is distillation, where a complex neural network policy is trained first and the learned policy is projected onto the set of tree policies. However, these techniques may struggle to learn small, well-performing trees as the neural network may be too complex for projection to work effectively. We investigate a novel method for training the neural network with a regulariser that encourages the model to be close to the set of tree policies so that the projection is more effective. We test our methods on benchmark reinforcement learning problems.

M5. Theoretical Convergence Analysis of Gaussian Process MARL

Candidate: **Jonathan Mavroforas**

Advisor: Prof Farbod Roosta-Khorasani

Abstract: We develop an approach for learning how multiple decision-making agents should act when the dynamics of their environment are known. Our method learns from a single stream of experience and provides mathematical guarantees for convergence toward an approximate equilibrium.

M6. The Fino—Vezzoni conjecture

Candidate: **Joseph Kwong**

Advisor: Dr Ramiro Lafuente

Abstract: A complex manifold is a space that locally looks like C^n , but globally may look completely different. Complex manifolds admit many Hermitian metrics: different ways of measuring distances. One way of distinguishing between complex manifolds is by studying Hermitian metrics that satisfy different differential equations: the most infamous are Kahler, balanced, and pluriclosed metrics. The Fino–Vezzoni conjecture asserts that a complex manifold admitting both balanced and pluriclosed metrics must also admit a Kahler metric.

M7. Ensuring sufficient sampling effort to monitor an elusive Australian mammal

Candidate: **Kevin Foo**

Advisor: Dr Matthew Holden

Abstract: Monitoring koala populations is critical for their protection, as the species faces threats such as habitat loss and disease. It is important to ensure that surveys conducted to monitor changes in the proportion of sites used by koalas have sufficient sample sizes. If not, declines or increases in the proportion may be unlikely to be detected. Koalas are elusive, and regional surveys cover larger areas. For this reason, presence-absence surveys are often conducted using the presence of koala droppings as evidence of site usage. These surveys, however, have problems with observational error. We have created a minimum sample size formula applicable for total revisit, no revisit and partial revisit surveys, and dependent on observational error and transition probabilities. This formula, validated using Monte Carlo simulations, has broader applicability to the detection of trends of binary data where observation units may or may not be revisited.

M8. Einstein Manifolds with Symmetries

Candidate: **Marcos Martinez Wagner**

Advisor: Dr Ramiro Lafuente

Abstract: Riemannian geometry studies shapes in an intrinsic way. Among Riemannian manifolds, we study Einstein manifolds which are of importance both to physicists and geometers. The Einstein equation is not an easy PDE, but we can simplify the equation by imposing symmetry.

M9. What is a G_2 -manifold?

Candidate: **Stepan Hudecek**

Advisor: Prof Artem Pulemotov

Abstract: What are G_2 -manifolds and why you should care? What is so interesting and important about seven dimensions? In this poster, we introduce a very active geometry topic, G_2 -manifolds, a certain special type of 7-dimensional spaces. We also explore their unique mathematical properties and their connection to physics.

M10. Geckos, Grasses and Logistic Growth

Candidate: **Tapash Alister**

Advisor: Dr Matthew Holden

Abstract: Weeds are a serious threat to many species and ecosystems. While they can be removed, any gardener will tell you the biggest challenge is keeping an area weed free (since they grow back), with repeated clearing is required to maintain a habitat. However, if you clear too much area, the weed will grow back before you can re-clear and if you clear too little area, you will not have enough weed-free habitat. This leads to the natural question: how much area should we be clearing to maximise a local species population? My research aims to answer this question through analysis of sequences of solutions to ODEs and general optimisation techniques, with two distinct methods tailored to protection of the endangered Border Thick-tailed Gecko and protection of native plants generally.

M11. Existence and uniqueness of the Yang-Mills flow

Candidate: **Chak Hoi Chan**

Advisor: AsPr Min-Chun Hong

Abstract: The Yang-Mills flow equation was introduced by Atiyah and Bott in 1982. It is the gradient flow of the Yang-Mills functional. The poster will represent our works on the existence and uniqueness of the Yang-Mills flow. We proved the existence of weak solutions of the Yang-Mills flow in higher dimensions ($m \geq 4$). We proved a parabolic gauge fixing theorem and a compactness theorem for the Yang-Mills flow. By improving our parabolic gauge fixing theorem, we aim to prove uniqueness as well.

M12. A Band-Aid on Australia's Housing Crisis

Candidate: **Grace Burtenshaw**

Advisor: Dr Meagan Carney

Abstract: In recent years Australia has observed a growing, unexplained resilience of increasing house price against mortgage rate hikes. Here, we seek to understand what is driving Australia's indestructible asset using insights from market experts. We construct a differential equation model of house price to develop intuition for its historical behaviour and responsiveness to changes in mortgage rates. Using this model, we identify a point of 'decoupling' between house price and mortgage rate in the system with supply limitations found to be the main driver for this change. From there, modern extreme value techniques are implemented on real-world data to investigate how the effectiveness of mortgage rate in moderating extreme house price has changed before and after this historical decoupling. We find that without an increase in the housing supply chain, through either deregulation or reduced competition with government building, a 9% increase in mortgage rate will be needed to slow extreme housing costs.

M13. Biologically guided machine learning for Long COVID classification

Candidate: **Huan Zhou**

Advisor: **Dr Meagan Carney**

Abstract: Long COVID remains an important clinical problem, yet there is still no single validated laboratory test for it. Proteomics provides a way to look for molecular differences between people with persistent symptoms and those who have recovered. But good predictive performance alone does not show whether a classifier is using disease-related biology or other study-related structure. We asked whether prior information could guide model fitting while retaining discrimination. Using serum proteomics from 104 donors, we compared LASSO, RRR (Right for the Right Reasons) and a Continuous negative prior with donor-grouped resampling. The negative prior penalised proteins more strongly when they were associated with preparation or cohort structure. In linear models, AUC changed little while preparation and cohort reliance decreased. In a nonlinear protein-plus-clinical model, AUC was 0.831 versus 0.832 without a prior; while gradient-based cohort reliance fell from 0.226 to 0.088. The guided models showed similar discrimination while relying less on study-related protein patterns.

M14. Integer Programming for N-Fractions Puzzle

Candidate: **Ruoxuan Shi**

Advisor: **AsPr Michael Forbes**

Abstract: We present a case study in which we solve the N-fractions puzzle using a Mixed Integer Programming model. The N-fractions puzzle is problem 41 in CSPLib, a library of test problems for Constraint Programming solvers. We first propose a model which is correct assuming exact arithmetic and show how to modify the model to account for floating point rounding errors. We then reuse ideas from constraint programming approaches to the puzzle and limit the lowest common multiple (LCM) of the denominators in the solution. This massively reduces solution time and means we can finally close the remaining open case to the puzzle. The apparent simplicity of the puzzle, the novelty of the modelling techniques used and the speedups achieved through limiting the LCM make the puzzle an interesting teaching case.

M15. Deformations of QFTs for String Theory and Gravity

Candidate: **Nicola Baglioni**

Advisor: **Dr Gabriele TartaglinoMazzucchelli**

Abstract: We study deformations of two-dimensional quantum field theories that preserve integrability, with particular emphasis on stress-tensor deformations such as the TT deformation. These theories remain remarkably tractable, with controlled deformations of their Lagrangians, spectra and S-matrices, and admit connections to string theory and topological gravity. Using auxiliary fields, we construct a broader class of such deformations and show that they can be interpreted geometrically through a coupling to a Beltrami metric. This suggests a new family of solvable gravitational theories and motivates further work on curved backgrounds, non-conformal seed theories, higher-dimensional origins, renormalizability and holographic applications.

M16. Equivariant polyforms from superspace

Candidate: **Parth Raina**

Advisor: Dr Gabriele TartaglinoMazzucchelli

Abstract: Equivariant localization has proven to be a powerful technique for evaluating supergravity actions on supersymmetric backgrounds admitting a $U(1)$ isometry. The associated Killing vector defines an equivariant exterior derivative. A key step in localization is the construction of an equivariantly closed polyform whose top-degree component corresponds to the supergravity lagrangian. Although such polyforms have been identified in a wide range of supergravity theories, a general and systematic explanation for their origin has been lacking. We describe a superspace mechanism that systematically produces equivariant polyforms on supersymmetric backgrounds from closed superforms, without imposing equations of motion.



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P1. Combination of the all-order correlation potential and coupled-cluster methods in high-precision atomic theory

Candidate: Andoni Skoufris

Advisor: Dr Benjamin Roberts

Abstract: Perhaps surprisingly, low-energy atomic phenomena provide one of the strongest ways of probing high-energy physics, such as parity-violating fundamental interactions and the variation of fundamental constants over time. With higher-precision atomic theory comes the ability to more strongly constrain beyond-Standard-Model physics scenarios, and there are two main methods that are used to accurately calculate the properties of atomic systems. The all-orders correlation potential (AOCP) method makes use of Feynman diagrams to nonperturbatively, and very efficiently, account for the most important many-body effects inside atoms, but it fails to accurately describe states with strong overlap with the atomic core. The all-order coupled cluster (AOCC) method is an iterative procedure that yields similar accuracy in almost all atomic systems, but far more accurately describes strongly correlated states, albeit at the cost of substantial computing resources. While both methods achieve exceptional accuracy, each accounts for certain effects missed by the other. In my poster I will describe a programme which aims to combine the best aspects of each method, to improve the accuracy of state-of-the-art atomic structure calculations.

P2. Measuring the Hidden Motions of the Universe

Candidate: Caitlin Ross

Advisor: Dr Cullan Howlett

Abstract: Galaxies do not simply follow the expansion of the Universe. Gravitational interactions with surrounding matter induce additional motions, known as peculiar velocities, which contain valuable information about the distribution of matter and the growth of cosmic structure. Measuring these velocities is challenging and requires redshift-independent distance estimates to disentangle local galaxy motions from the recession velocity caused by cosmic expansion. My project uses the Fundamental Plane relation to measure distances and peculiar velocities for $\sim 100,000$ galaxies within the Dark Energy Spectroscopic Instrument (DESI) survey.

These measurements form the DESI DR1 Peculiar Velocity Survey, the largest homogeneous Fundamental Plane survey ever assembled and the largest peculiar velocity catalogue produced to date, more than doubling the number of available peculiar velocity measurements. By combining galaxy sizes and surface brightness measurements from imaging with stellar velocity dispersions derived from DESI spectroscopy, distances can be estimated with a typical precision of $\sim 26\%$.

The resulting catalogue provides a powerful new probe of cosmology and gravity, enabling measurements of the growth of cosmic structure, reconstruction of the matter density and velocity fields, studies of large-scale bulk flows, and tests of dark matter and cosmological models. Through mapping the hidden motions of galaxies, this work helps reveal the underlying structure of the local Universe and provides a foundation for future peculiar velocity studies.

P3. Calculating the Electronic Properties of Crystals from First Principles

Candidate: Ethan Makaresz

Advisor: Prof Benjamin Powell

Abstract: Crystals are an incredibly diverse class of materials responsible for most of modern technology, but only a small subset of them can be easily described by current theories. Those with the most interesting properties tend to be the most difficult to model, so that filling this gap in the theory would open the way to unknown technological advances. My poster introduces the current state-of-the-art method, density functional theory + dynamical mean field theory (DFT+DMFT).

P4. Atomic structure calculations for constraining new electron-electron forces

Candidate: Cameron West

Advisor: AsPr Jacinda Ginges

Abstract: Electron-electron interactions beyond the Standard Model are promising candidates for dark matter and new sources of parity violation. We present a general procedure for extracting new bounds on coupling strengths with atomic structure calculations and do so for certain parity-odd cases. Our approach includes dominant many-body effects and is valid for any parity or mediator mass. Constraints are then extracted by comparing calculations with experimental measurements, which in our case consist of atomic electric dipole moments and parity non-conserving (PNC) transitions. The most significant results arise in the spin-1 parity-violating case, where comparison with the π -PNC transition in caesium yields bounds on new physics in a previously unconstrained region of mediator masses.

P5. Can a 1D Bose gas be described by conventional fluid dynamics?

Candidate: Carsten Dittrich

Advisor: Prof Karen Kheruntsyan

Abstract: Conventional hydrodynamics (CHD) successfully describes the large-scale dynamics of ordinary fluids using only three conservation laws: particle number, momentum, and energy.

One-dimensional Bose gases with repulsive contact interactions are fundamentally different. These systems are integrable, possessing infinitely many conserved quantities that constrain their dynamics. To account for these additional conservation laws, conventional hydrodynamics has recently been extended to generalized hydrodynamics (GHD). This framework has achieved remarkable agreement with experiments on ultracold Bose gases, allowing these systems to serve as a powerful testbed for exploring finite temperature quantum many-body dynamics far from equilibrium.

Although GHD provides a more complete description, it is also substantially more complex and less intuitive than CHD. This raises a natural question: when is the simpler hydrodynamic description sufficient, and when does one truly need the full generalized theory?

By systematically comparing the predictions of CHD and GHD across a wide range of interaction strengths and temperatures, we identify the regimes in which the two approaches agree quantitatively and where their predictions begin to diverge. The results provide practical criteria for determining when an integrable quantum gas behaves effectively like an ordinary fluid.

P6. NEUROscope: Quantum Precision Meets Living Neural Networks

Candidate: **Charlie Gray**

Advisor: Prof Warwick Bowen

Abstract: Dementia and Alzheimer's Disease recently became Australia's leading cause of death where the number of Australians living with dementia is projected to exceed 1 million by 2065. Our understanding of these neurodegenerative diseases is limited in fundamental ways – what triggers neuroinflammation; what is the combined effect of various brain cells (glial, astrocytes, neurons) on symptom development and the build-up of synaptic dysfunction and interneuron communication failures. Current methods to understand these neurological processes are limited. Multielectrode arrays do not have single cell resolution; patch clamps cannot measure small networks; calcium imaging is affected by phototoxicity. We are developing NEUROscope to target these limitations with quantum limited precision and high temporal and spatial resolution. Designed to non-invasively resolve intracellular dynamics at up to 10kHz and image connections of neurons and surrounding glial cells. The NEUROscope aims to capture cytoskeletal structural dynamics involved in neuron spike signal propagation. Capturing this fundamental behaviour with subcellular precision is key to developing our understanding of disease risk factor development and aggregation in neural networks.

P7. Enzymatic Degradation of Single PET Nanoplastics with Ballistic Optical Tweezers

Candidate: **Dan Lei**

Advisor: Prof Warwick Bowen

Abstract: Poly(ethylene terephthalate) (PET) is the most widely produced polyester and a major component of plastic waste. It is highly resistant to biodegradation, persisting in the environment and fragmenting into ever smaller micro- and nanoplastic particles. PET degrading enzymes can break the polymer down into soluble products, but depolymerisation remains slow and poorly understood: the reaction proceeds at the solid-liquid interface, and conventional bulk assays average over millions of particles, obscuring how any individual particle degrades.

We use ballistic optical tweezers to track the radius of a single trapped PET nanoparticle in real time. Structured-light detection suppresses the strong trapping field while preserving the weak signal scattered by the particle, giving access to the ballistic Brownian motion regime with 10 ns temporal resolution. In this regime the momentum relaxation time of the particle appears as a corner frequency in the velocity power spectrum; because the relaxation time is set by particle size, the radius follows from the shape of the spectrum alone. The measurement is therefore calibration free, requiring neither detector calibration nor trap stiffness, and returns one radius per second of data.

Control measurements in water and in enzyme-free reaction buffer show no measurable radius drift, with the radius varying by only ~ 1 nm between consecutive measurements, a $\sim 0.2\%$ uncertainty at 1 s temporal resolution. Enzyme measurements are ongoing. This establishes a route to measuring single-particle erosion rates, degradation mechanisms and particle variability that bulk assays cannot resolve.

P8. On-surface reaction of a carbene precursor on Cu(111)

Candidate: **Gustavo Campi**

Advisor: Dr Peter Jacobson

Abstract: Carbenes are among the most reactive species in organic chemistry. In solution a carbene reacts too quickly to observe directly, so chemists read its chemistry from the products it leaves behind. On a cold metal surface, the molecules stay where they land, and the STM images them one at a time.

We sublime the carbene precursor from a Knudsen cell at 170 °C onto Cu(111) held in ultrahigh vacuum, then image the sample at 77 K. On the surface the precursor loses its tosyl group, leaving a species that can be described either as a carbene or as an allene with Möbius aromaticity. Two populations of particles cover the surface after deposition. Counting 645 particles across several areas gives 308 of one shape (T) and 292 of the other (F), a ratio of 1.05 to 1, consistent with F being the tosyl group released from the precursor. The T species assemble into one-dimensional chains of up to five units, aligned with the close-packed directions of Cu(111) and repeating about every 1.15 nm along the chain axis. Resolving the copper lattice and the molecules in the same frame gives a tentative unit cell, and with it a starting geometry for calculations.

P9. Watching sub-microsecond conformational dynamics over minutes

Candidate: **Heehun Sung**

Advisor: Prof Warwick Bowen

Abstract: Tracking heterogeneous structural dynamics in single, native-state biomolecules would provide direct insight into biological function. However, previous label-free techniques have not enabled resolution of microsecond dynamics over extended durations. Here, we overcome this limitation by engineering a slot dielectric photonic crystal cavity that achieves far-sub-wavelength optical field confinement with high optical field uniformity. We demonstrate continuous measurement of unlabelled ferritin conformational changes on timescales as short as 400 ns. The capacity for chip-scale integration facilitates a generalizable platform for probing single molecule conformational dynamics within the functionally critical microsecond-millisecond regime.

P10. Observation of Single Receptor Binding Events with Ballistic Optical Tweezers

Candidate: **Jackson Lucas**

Advisor: Prof Warwick Bowen

Abstract: Binding of molecules to receptors on the cell membrane is important for drug delivery and nutrient transport. It is also harnessed by foreign entities such as viruses to enable entry into cells. Recently, it has been shown that optical tweezers are capable of measuring single receptor binding events. However, the dynamics could only be observed at speeds of around a second – much slower than the characteristic timescale of binding. Ballistic optical tweezers provide the ability to monitor viscous damping orders of magnitude faster than is possible in the Brownian regime. We have applied this capability to observe receptor binding, allowing measurement of dynamics with several orders of magnitude higher speed. This approach may enable quantitative screening of receptor–ligand kinetics relevant to targeted drug delivery, including optimisation of lipid nanoparticle surface properties for mRNA therapeutics. More broadly, it offers a tool to investigate rapid cell–surface interactions central to infection and cellular signalling.

P11. Let's go with Exploring the Momentum Bispectrum

Candidate: **James Simpson**

Advisor: Dr Cullan Howlett

Abstract: Cosmological research relies heavily upon statistical measures in order to constrain cosmological constants and learn about the universe. Currently, the most common type of measure used is the two-point correlation function, or its Fourier transform the Power Spectrum. This tells us the correlation between pairs of galaxies. While this measure is incredibly useful for constraining cosmological information, it is becoming more common to additionally use the three-point correlation function, or the Bispectrum in Fourier space. The Bispectrum is useful as a tool because it captures non-linear interactions that the Power Spectrum cannot easily account for; specifically, the bispectrum is sensitive to cosmological initial conditions, gravitational instability, and galaxy formation physics. Peculiar velocity has long been used to overcome the limitations of the relatively low volume of low redshift analysis and it has been shown that the addition of galaxy peculiar velocities increase cosmological information contained in the power spectrum. This project aims to answer the question of whether adding momentum to the Bispectrum has a similar effect. In theory, this should improve low-redshift measurements but also provide additional probes to further constrain cosmological parameters. If we demonstrate that the momentum bispectrum is useable, this creates a new statistics that can be used to measure raw data.

P12. Characterisation of Two-Level System Loss in Superconducting Quantum Circuits

Candidate: **Lachlan Hanrahan**

Advisor: Prof Arkady Fedorov

Abstract: Two-level systems (TLS) in oxides and interfaces contribute to microwave loss in superconducting resonators. We characterise an aluminium-on-sapphire control resonator using power- and temperature-dependent transmission measurements. A joint TLS and Mattis-Bardeen fit attributes approximately 28% of the low-temperature single-photon loss to TLS. Removing this fitted contribution while retaining the background loss would ideally improve the internal quality factor by 39%. This establishes a baseline for future resonators fabricated by transferring aluminium from mica onto sapphire using UV-release tape. Matched measurements will test whether modifying the interface reduces TLS-associated loss.

P13. Geometry-Enhanced Lifetime of Bogoliubov Modes in Ring Bose-Einstein Condensates

Candidate: **Lachlan Miller**

Advisor: AsPr Tyler Neely

Abstract: We use the Gross-Pitaevskii equation to study the evolution of Bogoliubov excitations in a Bose-Einstein condensate with arbitrary one- and two-dimensional geometries. By numerically solving the time-dependent equation in experimentally relevant trapping potentials, we analyze how boundary conditions and density inhomogeneities modify the excitation spectrum and nonlinear mode dynamics. In a two-dimensional ring trap, where the azimuthal mode number is quantized to integer values, we find that azimuthal modulation of both the trap depth and the ring geometry enhances the lifetime and frequency of an imprinted azimuthal mode, thus improving the Q factor by orders of magnitude. Experimentally, we have previously observed long lifetime phonon modes in a two-dimensional Helmholtz resonator geometry [1, 2], demonstrating strong agreement with an acoustic LC resonator model. Extending this framework to a ring geometry, we observe a similar frequency dependence on geometric parameters, consistent with an inductive-capacitive description of compressible superfluid flow. By additionally introducing controlled azimuthal density modulation, we analyse the mode frequency in terms of a weak periodic perturbation. Using an undamped Gross-Pitaevskii model, we identify the dominant mechanism underlying the lifetime improvement as a reduction in nonlinear mode coupling. In particular, geometric and density modulation suppress four-wave mixing processes by reducing spatial overlap of the target mode with other azimuthal and radial modes. The resulting increase in resonator Q factor has direct implications for atomtronic applications of trapped BECs including high-precision rotation sensing in toroidal Bose-Einstein condensates [3] and cold atom phononic circuitry where long-lived modes can reduce error rates [4].

P14. Connections and memory for brain-inspired computing

Candidate: **Laxmiprasad Naik**

Advisor: Prof Andrew White

Abstract: Brain-inspired computing requires mechanisms to weight incoming signals, integrate information over time, and generate an output once a threshold is reached. Photonic platforms are promising to implement these functionalities because optical signals can be processed in parallel and transmitted with high bandwidth. However, combining optical weighting with efficient signal integration and thresholding in an integrated platform are an important challenge. Electro-optic modulators in which optical signals can be electrically regulated are used to implement tunable synaptic weights. The weighted optical signals will then be detected using superconducting nanowire single photon detectors (SNSPD) and the electrical dynamics of superconducting nanowires is used to integrate signals and demonstrate spiking behaviour of neurons.

P15. Bohr-Weisskopf Effect in Superheavy Elements

Candidate: **Maddie Davies**

Advisor: AsPr Jacinda Ginges

Abstract: The Bohr-Weisskopf effect (BW) describes the contribution to the hyperfine structure from the inclusion of finite distribution of nuclear magnetisation. Different nuclear models can be used to include this effect with varying levels of success. As experimental measurements improve in precision for heavy and superheavy systems, a more accurate understanding of the BW effect is required in these systems. In this project, we seek to quantify the contribution of this effect in different states of many-electron systems and identify systems of interest for further experimental tests.

P16. Modeling Normal Modes of Vortex Lattices in Bose Einstein Condensates

Candidate: **Mason Clarke**

Advisor: Prof Matthew Davis

Abstract: When rotated, two dimensional Bose-Einstein condensates form vortices as topological point-defects with vanishing density at their core. They behave as point particles, and in the presence of dissipative forces will settle to form a triangular lattice. Like atomic crystal structures, these lattices can sustain excitations in the form of normal modes, where the vortices execute small periodic orbits.

There are both classical and quantum models for describing these modes and their associated energies, but under what conditions do they agree? We find that, in the small vortex core, flat-trap regime, the two models coincide to a high degree of accuracy. These results will be used as the basis to decompose vortex lattice modes into smaller components. We will also search for a connection to fractional quantum Hall states, that could be realised in the lab.

P17. Indefinite Causal Order Advantage for Noisy Metrology

Candidate: **Melvie George**

Advisor: Dr Markus Rambach

Abstract: Quantum physics allows for nonclassical causal structures where the order of events is indefinite. Events in such processes are said to have an indefinite causal order (ICO) [1]. ICO provide a significant advantage in quantum metrology by increasing the precision in parameter estimation protocol—even in the presence of noise [2,3]. Here we experimentally demonstrate that using indefinite causal order to probe noisy channels and a to-be-measured channel can withstand arbitrarily more noise than any quantum system with definite causal order, even if the probe is fully mixed and one of the noisy channels erases all information [3]. We investigate indefinite causal order advantages in quantum metrology by making use of polarisation and spatial degree of freedom of single photons.

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P18. A dissipative origin of the tilted-washboard potential in superconducting junctions

Candidate: **Nic Christopher**

Advisors: Prof Thomas Stace

Abstract: In a superconducting Josephson tunnel junction, Cooper-pairs tunnel from one superconductor to another across a non-superconducting region. Experiments on Josephson junctions with a constant current flowing through them were the first to demonstrate quantum phenomena at a macroscopic scale. The theoretical model used to describe this system, while intuitively appealing and consistent with current experiments, is an effective model that does not have clear limits on its regime of validity. We demonstrate that this model, known as the tilted-washboard potential, emerges from a more general, dissipative model in a well-defined limit and we investigate situations where the behaviour predicted by the generalised model deviates from the behaviour predicted by the tilted-washboard potential.

P19. Learning and Thermodynamic Advantage in Quantum Learning Machine

Candidate: **Nilesh Pandey**

Advisors: Prof Andrew White

Abstract: Artificial intelligence is transforming every aspect of our lives, but its growing computational demand comes with a significant energy cost, placing an increasing burden on our planet and resources. To address this challenge, I am developing quantum learning machines (QLMs) that use single photons to learn about their environment. A QLM sends a stream of single photons into its surroundings to probe the world and learns from the photons that return. These returning photons carry information about the environment, which can be extracted through quantum interference between the emitted and reflected photons.

QLMs can learn information using far less energy than their classical counterparts, which use coherent light to probe and detect their surroundings. I will also discuss my efforts to miniaturise these learning machines and integrate them onto a photonic chip, paving the way toward compact, scalable, and energy-efficient intelligent hardware.

P20. Photonic Control of Rotons in Superfluid Helium

Candidate: **Sam Kirwin-Jones**

Advisor: Prof Warwick Bowen

Abstract: Rotons are a type of excitation (or sound wave) existing in superfluid that explain some of its fascinating properties. This poster outlines my plan to investigate Roton excitations using photonic devices, and to implement quantum repeaters using these excitations.

P21. Cavity-enhanced Quantum Sensors for Bio-Electrics to Detect Low Frequency Electric Field with Rydberg Atoms

Candidate: **Sandhya Bharathkumar**

Advisor: AsPr Tyler Neely

Abstract: Low-frequency electric-field detection is challenging for conventional antennas due to their large size and limited sensitivity. Rydberg vapour-cell sensors offer a promising alternative for quasi-DC electrometry, but charge accumulation on cell walls can screen the applied field and limit sensitivity. A cavity-enhanced configuration is being investigated, with modelling predicting up to 20 dB sensitivity improvement over free-space measurements. Optimised cell coatings combined with cavity enhancement could enable high-sensitivity quasi-DC electrometry.

P22. Magnet integrated trampoline optomechanical magnetometers

Candidate: **Poh Meng Yeo**

Advisor: Prof Warwick Bowen

Abstract: In recent years, chip-scale optomechanical magnetometers have demonstrated incredible sensitivity at room temperature, allowing for applications such as biomedical imaging [1] and navigation [2] to resource exploration [3]. Many preceding optomechanical magnetometers are incompatible with integrated photonics or electronics, constraining both performance and applicability.

We have developed an optomechanical magnetometer consisting of magnet bonded to silicon nitride trampoline using a pick-and-place approach. With this, we were able to achieve a chip-scale magnetometer with a theoretical thermomechanical noise limited peak sensitivity of $360\text{fT}/\sqrt{\text{Hz}}$. Currently, the first prototypes are characterized to have a sensitivity limit of $397\text{fT}/\sqrt{\text{Hz}}$.

The device demonstrated in this work should provide a reliable platform for optomechanical sensing allowing for highly sensitive optomechanical magnetometers that operate at room temperature. Future work will focus on the integration of on-chip cavity enhanced readout, improving the bandwidth of the sensor.

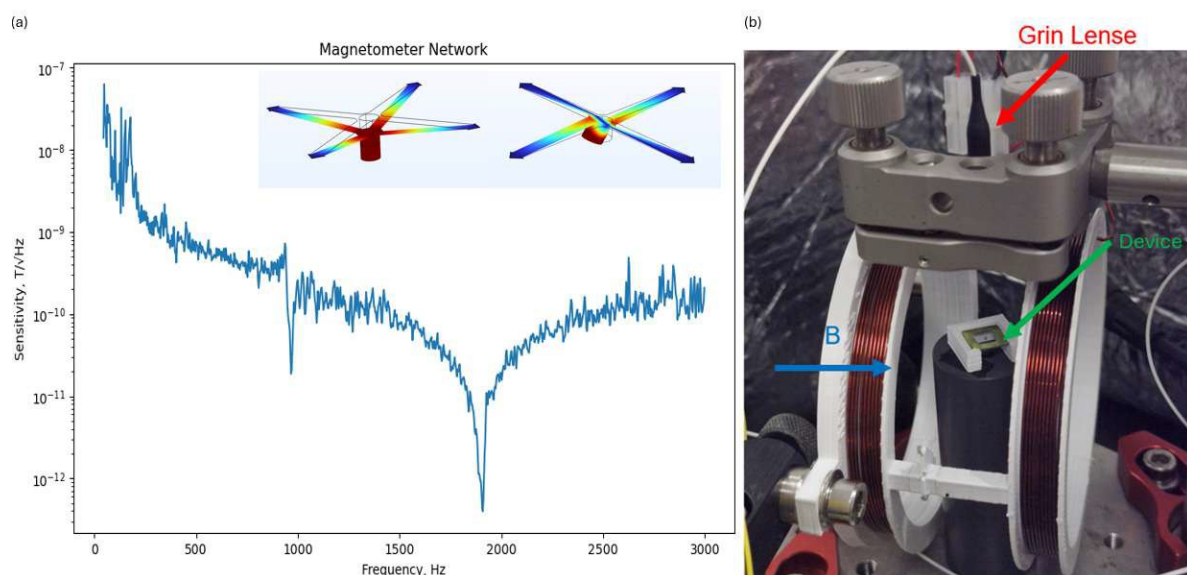


Fig.1: (a) Measured sensitivity of device (b) Silicon Nitride trampoline with a bonded magnet.

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P23. Improved quantum sampling methods for molecular simulations

Candidate: **Connor van Rossum**

Advisor: AsPr Sally Shrapnel

Abstract: Quantum-selected configuration interaction (QSCI) methods use a quantum computer to identify dominant electronic configurations in the molecular ground state, while a classical computer diagonalizes the Hamiltonian within the reduced subspace spanned by those configurations. Sample-based quantum diagonalization (SQD), a leading QSCI approach, uses iterative classical post-processing to correct noisy quantum measurement to ensure that the corresponding configurations remain physically sensible. We show that SQD performance can be strongly influenced by uncontrolled growth of the classical diagonalization subspace. When classical resources are not explicitly constrained, classical uniform random sampling can reproduce SQD benchmarks as noise increases the diversity of sampled configurations. We show any fair benchmarking protocol of SQD must explicitly control diagonalization size over unique samples. We then address the problem of efficiently discovering physically relevant, energy-lowering configurations by introducing a measurement protocol based on non-orthogonal configuration interaction (NOCI). By distributing measurements across orbital bases optimized with respect to the molecular Hamiltonian, we obtain improved sample efficiency relative to measurements performed solely in the Hartree–Fock basis. Importantly, these improvements persist even under fixed classical resource budgets, demonstrating that the resulting configurations are of higher quality rather than being more numerous. Under our proposed benchmarking procedure, we establish measurement-basis engineering as a promising route to improving quantum sampling methods for electronic structure.

P24. Studying the growth of an Intermediate Mass Black Hole in Omega Centauri

Candidate: **Arshia Anjum**

Advisor: AsPr Holger Baumgardt

Abstract: Intermediate-mass black holes (IMBHs) represent a critical link between stellar-mass and supermassive black holes (BHs), with important implications for star cluster evolution and gravitational-wave astronomy. Omega Centauri, the strongest galactic candidate to host an IMBH, provides a unique laboratory to study the growth of IMBHs, as its long-term dynamical history and present-day structure preserve clear imprints of the central dark mass. I present Monte Carlo simulations ($N \sim 10^7$ stars) of Omega Centauri-like systems that track the concurrent evolution of the cluster and its growing central IMBH. The models incorporate stellar evolution, fallback-corrected natal kicks, gravitational-wave driven black hole mergers, and tidal disruption of stars using MOCCA. Comparing simulations against observed surface-brightness, velocity-dispersion, fraction of fast-moving stars, and retained stellar-mass black-hole subsystem reveals that BH retention is the dominant factor shaping cluster kinematics, and that GW mergers with retained BHs are the primary growth channel of the central IMBH. We find that the most likely IMBH mass lies in the range $2.0\text{--}3.6 \times 10^4 M_\odot$. We also find that the cluster should retain at least $4 \times 10^4 M_\odot$ in its stellar-mass BH subsystem to match the observed equipartition trends in Omega Centauri, placing an upper limit on natal kicks that declines approximately linearly with $\log_{10}(\text{mass})$ — from ~ 300 km/s at $6 M_\odot$ to ~ 10 km/s at $20 M_\odot$. I will discuss how the final state depends sensitively on initial cluster conditions, and how these simulations connect to predicted tidal disruption and gravitational-wave inspiral rates observable with Rubin/LSST and LISA.

P25. Ion migration in mixed-halide perovskites from machine-learning-accelerated ab initio modelling

Candidate: **Connor Tweedie**

Advisors: **Dr Carla Verdi**

Abstract: Lead-halide perovskites have shown promise as one of the leading materials in emergent photovoltaic technology design. Power conversion efficiencies close to 20% were achieved over a decade ago with single-junction perovskite solar cells (PSCs), and today efficiencies above 30% are seen in various tandem cell architectures. One key advantage of these materials is the optoelectronic tunability enabled by tweaking the chemical compositions of their cation and anion components, and binary mixtures of different halides can provide even finer control of band gaps and stability. They are prone however to phase segregation into unmixed regions upon exposure to light, reversing many of their expected benefits and limiting practicality for PSC usage. Experimental evidence points towards large concentrations of mobile vacancy defects, but the exact microscopic origins of this photo-induced instability are only accessible through comparison of first-principles atomistic modelling. For the inorganic halide-alloy perovskite CsPbI₂Br, a nudged elastic band method coupled with density functional theory (DFT) calculations were used to determine energy barriers for defect-mediated ion migration pathways. Machine-learned interatomic potentials were introduced into a novel workflow to pre-converge these paths before further DFT refinement, optimising efficiency without sacrificing ab-initio accuracy. These simulations provide insight into the role that temperature and compositional disorder play on ion diffusion dynamics, leading to better understanding of factors affecting performance and stability of mixed-composition PSCs.

P26. Ionisation via scattering and absorption for dark matter, neutrino and exotic physics searches

Candidate: **Narise Williams**

Advisor: **Dr Benjamin Roberts**

Abstract: Accurate calculations of atomic ionisation cross-sections are essential for constraining dark matter–electron interactions, neutrino scattering, and precision Standard Model and beyond-Standard Model physics. We present a generalised framework for computing atomic ionisation cross-sections for scattering and absorption processes, fully incorporating relativistic effects and avoiding the use of the dipole approximation, which is not valid for scattering and breaks down for certain absorption processes. This approach is applicable to a broad class of models, including dark matter and relativistic particles such as neutrinos, and accommodates general interaction structures, including vector, axial-vector, scalar, pseudoscalar couplings, and their interference. We calculate relativistic atomic ionisation form factors for xenon and argon across an energy range spanning eV to MeV. These form factors provide essential input for the interpretation of dark matter direct-detection experiments, neutrino scattering measurements, and searches for exotic interactions, enabling model-independent constraints to be placed on a wide class of relativistic and non-relativistic new physics scenarios.

P27. SHOCK! Hubble's fork outdated after one hundred years: Stellar Specific Angular Momentum as a Physical Classifier of Galaxies

Candidate: **Pratyush kumar Das**

Advisors: Dr Sarah Margret Sweet

Abstract: The Hubble sequence has provided the traditional framework for classifying galaxies for more than a century, but increasingly large spectroscopic surveys motivate classification schemes based on physical rather than purely visual properties. I present measurements of stellar specific angular momentum, j_* , for 3068 galaxies from the SAMI Galaxy Survey using Spinny, a modular pipeline that combines galaxy geometry, stellar surface-density profiles, rotation-curve modelling and extrapolation beyond the limited integral-field spectroscopic aperture. The resulting j_* - M_* relation shows a strong dependence on galaxy morphology: disc-dominated systems have substantially higher stellar specific angular momentum than bulge-dominated systems at fixed stellar mass. Star-forming and blue galaxies similarly occupy higher-angular-momentum regions than quiescent and red systems. I also explore a two-component interpretation in which the angular momentum contributions from bulges and discs are considered separately. These results demonstrate how angular momentum can provide a physically motivated framework for understanding galaxy structure and evolution, with applications to current and upcoming integral-field surveys including Hector, MAGPI and MaNGA.

P28. Re-examining the hyperfine structure of ThO

Candidate: **Shannon Ray**

Advisor: AsPr Jacinda Ginges

Abstract: Searches for Beyond Standard Model physics in molecular systems have become an increasingly active area of research in recent decades. CP-violating interactions and hyperfine parameters are both sensitive to the behaviour of the electronic wavefunction in the nuclear region. Consequently, precise measurements and accurate calculations of molecular hyperfine structure provide an important benchmark for assessing the reliability of CP-violating interaction calculations.

To date, no experimental measurement of the magnetic hyperfine constant exists for the H^3 state of ThO – the first electronic excited state. In this talk, I present calculations of the magnetic hyperfine constants of ThO for multiple states using coupled-cluster methods implemented in DIRAC. These results are intended to guide a future nuclear Schiff moment search using ThO at Michigan State University.