NZIP 2025 Conference Abstract Book

Abstracts - Invited Speakers

Searching for Dark Matter, on Earth and in the Stars

Professor Nicole Bell

Keynote | Nicole Bell, PLT1 Lecture Theatre (Building 303), July 1, 2025, 9:15 AM - 10:00 AM

Biography:
Professor Nicole Bell is a theoretical physicist at the University of Melbourne. Her research lies at the interface of particle physics, astrophysics and cosmology, with particular focus on dark matter and neutrino physics. She leads the Theory Program of the ARC Centre of Excellence for Dark Matter Particle Physics and was a Chief Investigator in the ARC Centre of Excellence for Particle Physics at the Terascale. Prof Bell is a Fellow of the American Physical Society and was awarded the 2020 Nancy Millis Medal by the Australian Academy of Science. She is the Immediate Past President of the Australian Institute of Physics.

The quest to identify the cosmological dark matter is one of the foremost goals of science today. Yet the very nature of dark matter makes this a formidable task. I outline the status of dark matter direct detection searches and describe new strategies to probe dark matter interactions in terrestrial experiments. Complementary information about dark matter can be obtained by considering the capture of dark matter in stars. I describe applications of dark matter capture in the Sun, white dwarfs and neutron stars, to probe interactions that would be difficult or impossible to observe in experiments on Earth.

Rigour, relevance and reflection in physics education

Professor Manjula Sharma

Keynote | Prof. Manjula Sharma, PLT1 Lecture Theatre (Building 303), July 2, 2025, 9:15 AM - 10:00 AM

Biography:
Professor Manjula Sharma is originally from Fiji and a graduate from the University of the South Pacific. She is a leading science educator and she has deeply engaged in school and university curriculum matters for several decades. Manjula is currently Director of the STEM Teacher Enrichment Academy at The University of Sydney, prior to which she led the Sydney University Physics Education Research (SUPER) group. Her research is grounded in educational instrumentation and measurement in the areas of multimedia, inquiry based approaches and engaging teachers and students in investigative work. She has over 100 peer reviewed papers in international journals and has supervised outstanding PhD candidates, including Dr Derek Muller creator of YouTube channel Veritasium. She has led the Government funded project, Advancing Science and Engineering through Laboratory Learning, ASELL Schools and has been Chief Examiner for NSW HSC Physics. She is serving as Chair of IUPAP Commission C14 on Physics Education. Professor Sharma co-founded the premier Australian Conference on Science and Mathematics Education (ACSME) and the International Journal of Innovation in Science and Mathematics Education (IJISME). Her awards include the 2012 Australian Institute for Physics Education Medal, 2013 OLT National Teaching Fellowship and she is a Principal Fellow of the UK Higher Education Academy, Fellow of the Australian Institute of Physics and Honorary Fellow of the Teacher's Guild of New South Wales, Australia.

Physics education involves a three-fold tension in curricula, emphasizing rigour, relevance, and reflection in teaching and learning. The first aspect, 'what is physics', focuses on the pursuit of rigour, which is demonstrated through the complexity of problems students can solve, often involving equations. The second aspect, 'why do we need physics', aims to make the subject relevant for students, addressing concerns that it may be viewed as unimportant. The third aspect, 'how do we do physics', encourages personal reflection on the process of learning, an element often overlooked in the crowded curriculum. This presentation will explore the challenges of finding a balance in addressing these aspects, aiming to ensure that students not only study physics but also continue with further physics studies.

Space Weather risk to New Zealand. Collaborative response by the Solar Tsunami research team and Industry.

Dr Daniel Mac Manus[1], Professor Craig Rodger[1]
[1]University Of Otago, Dunedin, New Zealand
Physics in the Real World, PLT1 Lecture Theatre (Building 303), July 3, 2025, 9:00 AM - 10:30 AM

Biography:
Daniel Mac Manus has completed a PhD at the University of Otago in 2023 as a member of the Space Physics research group in the Physics department. He is now working as a Postdoctoral Researcher in the department. He has worked closely with Transpower to create a validated model to simulate how critical equipment in the New Zealand power grid is impacted during large space weather events. This work has created a relationship of trust with the NZ electricity industry such that a operation mitigation plan has been developed.

Space Weather refers to all environmental conditions in space that can affect Earth and its technological systems. It is primarily caused by solar activity from the Sun in the form of radiation and charged particles interacting with the Earth's magnetic field, atmosphere, and technological systems. This can negatively impact Communication and Navigation systems, Satellites, Aviation, and Power Grids. As our dependence on advanced technology grows, this field is gaining greater global significance. In New Zealand, our current focus has been on the electrical transmission and gas pipeline networks. Energy provision is vital to modern societies and our economy.

The MBIE-funded Solar Tsunamis Endeavour Programme is a global initiative spearheaded by the University of Otago, aimed at studying the potential effects of extreme space weather events on New Zealand's energy infrastructure. Our energy industry partners have pinpointed the crucial questions that must be addressed to shield New Zealanders from the most severe effects of space weather. Our research has attempted to answer these questions. The outputs include the recent development of research-informed mitigation strategies to protect the power network during severe space weather events. These strategies were implemented during a severe space weather event in May 2024, which was roughly a 1 in 10-year event. A coordinated response plan involving the New Zealand electricity Industry and government bodies is now under development to help us prepare for much large extreme space weather events. In this presentation we will provide a short overview of the programme's highlights, with more detailed information on the mitigation applied in May 2024.

Non-rocket spacelaunch research at Rocket Lab

Mr Hamish McDonald

Physics in the Real World, PLT1 Lecture Theatre (Building 303), July 3, 2025, 9:00 AM - 10:30 AM

Biography:
Hamish obtained his MSc from Otago University, experimenting in Jevon Longdell's Quantum Optics lab. He then worked as a Physicist at Buckley Systems for 5 years, where he designed ion-optical devices for particle accelerators and researched novel ion sources. Some notable customers were SLAC, Fermilab, Argonne National Lab, Toshiba, Hitachi, and ANSTO's Centre for Accelerator Science. Hamish was then hired as Senior Physicist at Rocket Lab to research non-rocket spacelaunch for the CEO Sir Peter Beck. Focusing mostly on beamed energy propulsion and the superconducting quench launcher, they present what they can at international conferences AIAA SciTech and Breakthrough Discuss. Hamish's current interest is electric propulsion.

At Rocket Lab, a small team of two physicists spent two years researching non-rocket spacelaunch at the CEO's request. They surveyed the zoo of exotic non-rocket spacelaunch schemes before focusing on two promising-looking schemes: beamed-energy propulsion and the superconducting quench launcher.

Beamed-energy propulsion is where ground-based lasers are used to heat the propellant in a launch vehicle, rather than relying on the finite chemical energy of the fuel-oxidiser reaction. If one can navigate the complexities of transmitting and transferring the energy efficiently, then beamed-energy propulsion promises efficiencies far greater than conventional chemical launch.

The superconducting quench launcher is an evacuated tunnel with solenoidal coils spaced evenly along, energised with a persistent supercurrent. Through magnetic interaction with the solenoids, a magnetic sabot pushes a launch vehicle to near orbital velocity. As the magnetic sabot passes each solenoid it inductively drives the current to zero, and then quenches the solenoid to weaken any reverse current that is induced. Because of this, the superconducting quench launcher is the only magnetic launch scheme that doesn’t require active switching of large powers, and theoretically converts magnetic stored energy to kinetic energy with nearly 100% efficiency.

Hamish will briefly talk about these ideas, and what him and his team learned about them.

OpenStar Technologies: Exploring the Levitated Dipole as a Commercial Fusion Reactor

Dr. Craig Chisholm

Physics in the Real World, PLT1 Lecture Theatre (Building 303), July 3, 2025, 9:00 AM - 10:30 AM

Biography:
Dr. Craig Chisholm obtained his MSc from the University of Otago working in the field of ultracold atoms before moving to Barcelona, Spain to complete a PhD at the Technical University of Catalonia and the Institute of Photonic Sciences employing ultracold atoms for quantum simulation of exotic states of matter. His work has been published in international journals including Nature and his thesis was recognised with an exceptional experimental doctoral thesis award. He has now returned to New Zealand to work on yet another state of matter as an experimental plasma physicist at OpenStar Technologies where he is responsible for machine operations and instrumentation of plasma diagnostics on OpenStar's first levitated dipole experiment, "Junior".

Nuclear fusion promises to provide abundant and clean energy to meet the world's growing demands but has so far remained elusive due to the extremely high plasma densities and temperatures needed to overcome the Coulomb repulsion between nuclei. OpenStar Technologies, a startup based in Wellington with roots in the high temperature superconductor (HTS) lab at the Robinson Research Institute, is developing a concept called the levitated dipole reactor for fusion energy production. The levitated dipole is a concept where plasma is magnetically confined by a by a superconducting current ring levitated in a large vacuum vessel by a secondary magnet, and is a promising technology due to it's favourable plasma physics and relatively low engineering complexity. Building on the foundational results of the Levitated Dipole eXperiment (LDX) in the early 2000's, OpenStar has manufactured a new generation of levitated dipole devices leveraging recent advances in HTS magnet technologies. OpenStar's first experiment called "Junior" achieved first plasmas in October 2024 and integrates a novel HTS power supply technology on board the dipole magnet which will pave the way to the next-generation machines.

Abstracts – Oral Presentations

Ocean monitoring using optical interferometry in subsea cables

Dr Johan Grand[1], Dr Giuseppe Marra[2], Annette Koo, Max Tamussino[2]
[1]Measurement Standards Laboratory, Wellington, New Zealand, [2]National Physical Laboratory, Teddington, UK

1A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:

Johan obtained a PhD in Near-Field Optics from the University of Technology of Troyes (France) in 2004 and was appointed Assistant Professor at Paris-Diderot University, where his research centered on Surface-Enhanced Spectroscopies. He joined MSL in 2019 to contribute his expertise to research within Time and Length standards.

Recent advances in Earth observation have increasingly adopted optical fibre sensing technologies to monitor environmental changes across vast and otherwise inaccessible regions. We present an interferometric technique that repurposes existing submarine communication cables as distributed environmental sensors. Unlike methods that integrate signals over entire cable lengths, this approach enables the detection of optical phase shifts on individual spans between optical repeaters. By effectively transforming each repeater-to-repeater section into an independent sensor, the technique offers significantly improved spatial resolution and signal localisation.

This approach uses existing subsea cable infrastructure without requiring hardware modifications, offering a scalable and cost-effective solution for global Earth monitoring. It holds particular promise for seismology, oceanography, and climate science, as it provides real-time data from the ocean floor—one of the least observed areas of the Earth system.

We report on recent deployments of this method in the Tasman Sea between New Zealand and Australia. Within the first month of operation, the system detected dozens of seismic events. The region's high seismic activity, combined with the elbow-shaped geometry of the cable, offers a unique opportunity to accelerate research into the capabilities of seafloor cable-based sensing. These early results highlight the method's sensitivity and resolution and underscore its potential to transform environmental sensing by integrating fibre-optic sensing into the global network of submarine cables.

Why your battery meter tells lies and it's hard to fix: Effect of pauses in cycling on sub-millihertz battery impedance

Dr Marcus Wilson[1], Mr Logan Cowie[2], Assoc Prof Michael Cree[2]
[1]Te Aka Mātuatua - School of Science, University of Waikato, Hamilton, New Zealand, [2]Te Kura Mata Ao - School of Engineering, University of Waikato, Hamilton, New Zealand

1A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:

Marcus Wilson is currently a senior lecturer in physics with Te Aka Mātuatua - School of Science at the University of Waikato. He has worked in numerical modelling of physics processes in industry in the UK and academia in New Zealand. His research interests include the electrical properties and dynamics of the brain, transcranial stimulation, physics education and modelling of rechargeable batteries.

Rechargeable lithium-ion batteries are an increasing part of our world, found in small devices such as medical implants and mobile phones, up to much larger applications in electric vehicles and the huge battery electric storage systems (BESS) that support the modern electricity grid. But despite the advances in design and manufacturing, your battery meter still does not tell you the truth: "75% charge remaining" most likely does not mean 75% charge remaining. On a trivial scale this means your phone battery goes flat unexpectedly; less trivially your car runs out of charge before you get home, and on a cold winter's morning the electricity grid might not actually be able to provide the peak power that its operators think it can. The reason that producing an accurate meter is so challenging is that battery history matters. A battery's response to an electrical stimulus doesn't just depend on its state now, but also on its state in the past. In mathematical terms, its behaviour is described by fractional differential equations, where the order of the equation is non-integer. In this presentation, we discuss an experiment where we have looked at the effect of a long (56 day) break in battery battery charge/discharge cycling on electrical properties of the battery. On recommencement of cycling, we can discern the effect of the pause on impedance for around 30 days after the break. To see the effect we have constructed the impedance spectrum at ultra-low frequencies (10 µHz - 10 mHz) by applying wavelet methods to time-series data of voltage and current. However, if uncontrolled, other factors such as the shape of stimulating waveforms will mask much of this history effect, and thus in practice history may only matter on the scale of a few days. Nonetheless, results show that answering a simple question "what is my battery charge" does not have a simple physical answer, and thus producing a battery meter that does not lie remains a real challenge for theoretical physicists and mathematicians.

Measuring human vision – history of the photopic response curve

Ellie Molloy[1]
[1]Measurement Standards Laboratory of New Zealand, Lower Hutt, New Zealand
1A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
Ellie is a research scientist in the Light team at MSL.

Photometric measurements, such as luminance and illuminance, quantify the amount of light perceived by a human eye. This is achieved by weighting the intensity of the source by the photopic response curve, which describes the sensitivity of the human eye to different wavelengths of light. The photopic response curve was defined by the International Commission on Illumination (CIE) in 1924 to describe the response of the human eye in good lighting levels.

Since its definition, it has been recognised that the photopic response curve underestimates the average response of the human eye at the blue end of the spectrum. Our physiological understanding of the human eye has also improved since 1924, and it is now known that it is cone cells in the retina that enable photopic vision in daylight conditions. Humans with normal vision have three types of cone cells – long, medium, and short (L, M, and S), named after the part of the spectrum for which they are most sensitive. Functions describing the spectral sensitivity of the cones have been developed, which give a more physiologically relevant description of human vision.

However, it is known that the response of the human eye is not always the same, differing both between different people and for an individual over their lifetime. For example, people with protanopia colour-blindness experience a shifting of the peak of the L-cones towards the blue end of the spectrum and have significantly reduced response at the red end. As we age, the lens in our eye yellows slightly, resulting in the peak response of our eye shifting towards the red end of the spectrum.

Therefore, even using cone fundamentals to describe the response of the human eye does not give a description of human vision that applies to everyone. This talk will discuss the history of the photopic response curve, the developments of the cone fundamentals, and the proposals for describing human vision going forward.

Development of Microfluidic Ion Pipette Aspiration (IPA) for Single-Particle Mechanical Characterization

Mr Chi Minh Truong[1,2,6], Doctor Ayelen Tayagui[1,3], Professor Volker Nock[1,3], Professor Ashley Garrill[4], Professor Frédérique Vanholsbeeck[2,6], Professor Geoff Willmott[1,2,5]
[1]The MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington, New Zealand, [2]Department of Physics, The University of Auckland, Auckland, New Zealand, [3]Department of Electrical and Computer Engineering, University of Canterbury, Christchurch, New Zealand, [4]School of Biological Sciences, University of Canterbury, Christchurch, New Zealand, [5]School of Chemical Sciences, The University of Auckland, Auckland, New Zealand, [6]The Dodd-Walls Centre for Photonic and Quantum Technologies, , New Zealand

1A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
I am a dedicated and driven PhD candidate specializing in microfluidics, lab-on-chip technology, microfabrication, and automation. Throughout my academic journey, I have actively participated in a variety of multidisciplinary research projects. My academic research background and professional qualifications have been recognized through several prestigious scholarships, awards, and prizes. Eager to make meaningful contributions, I aspire to address pressing global challenges in agriculture, biology, and medicine using my knowledge and experience.

Abstract
Research on the mechanical properties of soft microparticles, such as colloids and biological particles, has attracted significant interest from scientists and engineers across various disciplines, including physics, materials science, biomedical engineering, and microbiology [1]. One key application of measuring particles' mechanical properties is in the field of cell mechanobiology. Research has shown that the mechanical properties of a cell can be related to its functions, including development, division, motion, and adhesion [2]. Therefore, the mechanical properties of cells can be used to assess the state of cell separation, disease progression, immune status, and drug screening effects. Ion Pipette Aspiration (IPA) [3] is an advanced technique for characterizing the mechanical properties of soft particles. The IPA system integrates a traditional micropipette aspiration (MPA) setup, a resistive pulse sensing (RPS) system, and a high-resolution microscope camera. In the MPA section, a sample delivery system enables the controlled flow of particle samples through a constriction structure. A highly precise pressure control system applies negative pressure at the constriction, inducing particle deformation. During this process, the RPS system, which consists of two electrodes positioned at either end of the constriction, generates a small DC electrical signal (0.1–1V) to monitor current fluctuations as the particle deforms. This approach allows for simultaneous measurement of deformation and the influence of geometric changes on the electrical conductivity of the sample particle over time. Physical models are necessary to infer rheological properties from the measurements. This research aims to enhance the accessibility and adaptability of IPA across various laboratory environments. The method is well-suited for profiling and comparing the mechanical properties of microscale particles and holds the potential for analyzing nanoscale particles.

References
[1] D. T. N. Chen, Q. Wen, P. A. Janmey, J. C. Crocker, and A. G. Yodh, "Rheology of Soft Materials," Annual review of condensed matter physics, vol. 1, no. 1, pp. 301-322, 2010, doi: 10.1146/annurev-conmatphys-070909-104120.
[2] Y. Hao, S. Cheng, Y. Tanaka, Y. Hosokawa, Y. Yalikun, and M. Li, "Mechanical properties of single cells: Measurement methods and applications," Biotechnol Adv, vol. 45, p. 107648, Dec 2020, doi: 10.1016/j.biotechadv.2020.107648.
[3] N. Lacalendola and G. R. Willmott, "Measurement of viscoelastic particle deformation using pipette ion currents," Sensors and actuators. A. Physical., vol. 344, p. 113698, 2022, doi: 10.1016/j.sna.2022.113698.

Analysis and Segmentation of AI-Denoised Propagation-Based X-ray Phase-Contrast CT Images of the Breast

Miss Amritha Ramchandar[1], Dr Ashkan Pakzad[2], Dr T. E. Gureyev[2], Dr K. M. Pavlov[1,3,4]
[1]University Of Canterbury, Christchurch, New Zealand, [2]University of Melbourne, Melbourne, Australia, [3]Monash University, Melbourne, Australia, [4]University of New England, Armidale, Australia

1A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
Amritha Ramchandar is currently pursuing a research-based Master of Science degree in Medical Physics at University of Canterbury. Her research aims to assess the impact of AI-denoising on the segmentation of breast tissues in propagation-based X-ray phase-contrast CT images of the mastectomy samples. This work targets to improve diagnostic accuracy in medical imaging, specifically in low-dose CT imaging.

Propagation-based X-ray phase-contrast computed tomography (PB-CT) [1] provides enhanced soft-tissue contrast, making it a promising modality for breast imaging in the detection of cancers. Though PB-CT can produce less noisy images at similar ionising radiation doses compared to conventional modalities [2], noise continues to degrade image quality. This research aims to assess the impact of AI-denoising on the quality of downstream artificial intelligence (AI) models to segment breast tissues in PB-CT images of mastectomy samples. We specifically focused on the segmentation of glandular and adipose tissues, which constitute most of the breast and are of significant clinical interest.
PB-CT of 6 fresh mastectomy samples were acquired at 4 mGy and 24 mGy doses. An AI model trained on similar images was used to denoise the 4 mGy images. Images captured at different doses were rigidly registered (aligned) using Elastix [3] by minimising mean squared differences. Manual segmentations of sparse slices were generated using 3D Slicer and used to train an nnU-Net [4], a widely adopted AI model for medical image segmentation. A separate model was trained for 4 mGy original, 4 mGy denoised and 24 mGy images using 5 cases and then evaluated for the remaining case.

Segmentation accuracy was assessed using the Dice Similarity Coefficient (DSC) [5], a measure of overlap between AI-model and manual reference segmentations. Reporting preliminary results of single slice images, the original 4 mGy model achieved a DSC score of 0.935 for adipose tissue and 0.875 for glandular tissue, meanwhile the denoised 4 mGy model achieved higher DSC scores of 0.977 and 0.954, respectively. These findings demonstrate improved segmentation accuracy, as a result of AI-denoising. Evaluation is in progress, as additional image slices are assessed. This work presents a methodology to evaluate denoising through downstream AI tasks. Moreover, enhanced image segmentation accuracy can facilitate clinically significant analyses including dosimetry assessments and breast glandular-adipose tissue quantification.

References:
1. T. Taba et al., “X-Ray Phase-Contrast Technology in Breast Imaging: Principles, Options, and Clinical Application”, American Roentgen Ray Society, Vol 211, pp 1-13, 2018.
2. Jessica Tu et al., “A bibliometric and social network analysis perspective of X-ray phase-contrast imaging in medical imaging”, Journal of Medical Radiation Sciences, Vol 69, pp 37-46, 2022.
3. Klein S. et al., "elastix: A Toolbox for Intensity-Based Medical Image Registration", IEEE Transactions on Medical Imaging, Vol. 29, no. 1, pp. 196-205, Jan. 2010.
4. Ronneberger, O. et al., “U-Net: Convolutional Networks for Biomedical Image Segmentation”, Springer International Publishing, Vol. 9351, pp 234-241, 2015.
5. Mark J. Gooding et al., “Comparative evaluation of auto contouring in clinical practice: A practical method using the Turing test”, Medical Physics, Vol 45, Issue 11, pp 5105-5115, 2018.

A critical examination of generative AI technology

Mr Benny Pan

1B: Education, Studio Space G03 (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
I began my machine learning journey in 2017 when I gained the Google's TensorFlow certification. Since then, I've immersed myself in AI applications for education, developing a draft curriculum framework and implementing multi-modal assessment strategies in physics.

In collaboration with 4 overseas schools, we built and presented an AI-powered personalized learning tool at the Asian-Europe Foundation international conference. I've taken on leadership roles in several key initiatives with the AI Forum NZ, focusing on AI strategy, Te Tiriti in AI education, and AI literacy.

As a member of the national Large Language Model working group, I help organizations navigate AI strategy and implementation challenges. Currently, I'm developing a portfolio-based assessment model with AI integration as part of my master's project.

This workshop offers a critical examination of generative AI technology, exploring the underlying working mechanisms that power tools like ChatGPT and other large language models (LLM) while assessing their applications in education. We will investigate how these technologies can enhance critical thinking, problem-solving, and simulations in the classroom, while providing an overview of the current state of AI in this ever changing education landscape.

We'll address the significant ethical considerations and risks educators face when implementing AI tools, including concerns about academic integrity, misinformation, and the development of future-proof skills. You'll learn practical methods for comparing different LLMs based on their suitability for specific tasks, considering their respective risks and associated costs. The session concludes with practical strategies for mitigating implementation risks, empowering educators to make informed decisions.

Workshop objectives
- Explain the mechanisms behind generative AI and large language models (LLMs)
- Evaluate how AI tools can enhance critical thinking and problem-solving in educational settings
- Identify key ethical considerations including academic integrity concerns and misinformation
- Compare different LLM platforms based on their suitability for specific tasks
- Develop practical strategies to mitigate risks when implementing AI tools in the classroom

The Visible Spectrum of Physics Students: Promoting Diversity in Physics Classrooms

Miss Thalia Rutherfurd[1]
[1]Hobsonville Point Secondary School, Auckland, New Zealand
1B: Education, Studio Space G03 (Building 303), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
I'm a physics teacher at Hobsonville Point Secondary school. I've a background in engineering and have taught since 2020. I'm a proud member of the Rainbow Community and neurodivergent (as many an engineer is). This year, I completed a masters thesis in education looking at the experiences of gender diverse secondary school teachers in Aotearoa, and have a passion for making STEM a more welcoming/appealing place for a range of diverse peoples.

This workshop will look at diversity in physics education and some ways you can recognise the existence of diverse students in ways that align with the physics content being taught. You'll also have an opportunity to work with your peers to come up with ideas that may work in your specific context.

I'll also share some insights found through my thesis as to the benefits of having a diverse teaching staff for our students.

Why is thinking in Physics so difficult for many students? What are the issues? How can we help students learn to take the risks required?

Ms Sue Napier[1]
[1]NZIP, Christchurch, New Zealand
1C: Education, Case Room G20 (Building 302), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
Sue Napier, retired HOD Physics and Electronics at Riccarton High School. At present I am a lead facilitator for NEX / NZIP based in Christchurch and Wanaka.

My aim is to look at strategies that I have seen / used over my years of teaching Physics, and then have an open forum to discuss what other strategies people have / are using in their teaching. The goal is to have students thinking outside the square, so we will explore the issues and possible strategies to help students.

In past years I watched Paul Hewitt teach different strategies that try to make students think and use the basic Physics to solve “simple” problems.
Priscilla Laws taught the benefit of making students predict what will happen in a demonstration and then doing it and discussing the answers. The lovely “but - but” IYPT (and NZYPT) questions are open ended and the solutions need to be debated with an opponent. They are open ended questions like “Wet and Dark - Clothes can look darker or change colour when they get wet. Investigate the phenomenon.”

Learning How to Learn through Self-Assessment: A Study Skills Survey Tool for Secondary School Students

Dr Yuanyuan Hu[1]

[1]Faculty of Engineering and Design, The University of Auckland, Auckland, New Zealand

1C: Education, Case Room G20 (Building 302), July 1, 2025, 10:45 AM - 12:15 PM

Biography:

Yuanyuan is a Research and Teaching Fellow in the Faculty of Engineering and Design at the University of Auckland. She holds a PhD in Software Engineering. Her research interest is primarily in applying Artificial Intelligence to enhance teaching and learning practices in higher education. Her current work focuses on applying educational technologies to support engineering students in improving self-regulated learning habits.

Developing effective learning habits early is critical for students' long-term success. However, research shows that nearly half of university students have never received formal training in study skills. Learning habits formed in secondary school often carry into higher education, so early intervention is crucial. Secondary school teachers also report that many students appear to have 'forgotten how to learn', often leading to poor study practices and reduced academic confidence.

To improve this, we have developed a research-informed, online self-assessment survey tool adapted for secondary school students. The tool aims to help students reflect on their current learning habits, identify their strengths and areas for improvement, and access tailored learning resources to improve. It focuses on six prioritised study skills for STEM learning: time management, note-taking, memory, concentration, exam preparation, and stress/anxiety management.

This workshop will present the latest version of the tool, demonstrate how students self-diagnose and receive feedback, and share initial findings from pilot studies, including statistical results and participants' feedback. Workshop attendees will be invited to explore the tool hands-on and offer feedback on its applicability and adaptability in diverse school settings. We will discuss how such tools can help students build self-awareness and more effective study routines, preparing them for success in both secondary school and beyond.

First-Year Physics and High School Outreach at Otago

Assoc. Prof. Blair Blakie[1], Associate Professor Jonathan Squire, Professor David Hutchinson, Mr Paul Muir, Dr Emma Douma
[1]University Of Otago, Dunedin, New Zealand

1C: Education, Case Room G20 (Building 302), July 1, 2025, 10:45 AM - 12:15 PM

Biography:
Blair Blakie is a Professor of Physics at the University of Otago. His research interests include ultra-cold atomic physics theory.

In this workshop, we will present the first-year physics programme at Otago, including courses for physics and physical science majors, health science first-year students, and our general-interest astronomy course. We will showcase some of the interactive teaching methods and assessment tools developed by the Department—audience participation in problem-solving will be encouraged! Additionally, we will discuss the Otago Scholarship Physics initiative, which supports students and teachers preparing for the Scholarship Physics exam, as well as the NCEA-focused curriculum posters created by the Department. The session will conclude with ample time for general discussion.

What is driving recent changes in Antarctic sea ice?

Assoc. Prof. Inga Smith[1]
[1]University Of Otago, Dunedin, New Zealand

2A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:

Inga researches and lectures in climate change related topics: Antarctic sea ice; greenhouse gas emissions from international transport; climate change physics; fluids and thermodynamics.

She has worked on research projects funded by the Marsden Fund, Deep South National Science Challenge, and the Antarctic Science Platform. Inga has been on the World Climate Research Programme's CLIVAR (oceans and climate) Scientific Steering Group, and she is an immediate past co-director of He Kaupapa Hononga: Otago's Climate Change Network. She has been to Antarctica 12 times with the New Zealand programme, and once with the US Antarctic Programme, and when working at the University of East Anglia in the UK she conducted research on the Antarctic Circumpolar Current between the Falkland Islands and South Georgia aboard the British Antarctic Survey vessel the "James Clark Ross". Inga grew up in Queenstown, where she attended Wakatipu High School, and has had a life-long drive to understand and protect cold and mountainous places.

Antarctic sea ice extent has been undergoing rapid changes; in particular, there was a dramatic absence of sea ice during the winters of 2023 and 2024 in regions which would normally have sea ice present. By the time of the NZIP 2025 conference, we will have a strong indication of whether or not 2025 is following the same pattern. New Zealand’s nearest neighbour in winter has historically been Antarctic sea ice, which was slightly closer than Australia to us. New Zealand’s weather and climate are closely linked to what is happening in Antarctica and the Southern Ocean. What will the changes to Antarctic sea ice mean for New Zealand and our neighbours in the Pacific Ocean? The Antarctic Circumpolar Current joins all of the ocean basins together so that any changes in Antarctica are felt everywhere, but particularly at the latitudes of New Zealand. In this talk, I will give an overview of Antarctic sea ice, and how sea ice physics and climate change science are contributing to our understanding of the underlying processes.

Big Bang Matter and Neutron Stars

Dr Arno Tripolt[1]
[1]Scots College, Wellington, New Zealand

2A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:
Dr. Arno Tripolt studied physics at the University of Graz (Austria) from 2005 to 2011, which included a summer term at the Humboldt University of Berlin and a research visit at the GSI/FAIR particle accelerator in Germany. In 2015, Arno Tripolt received a PhD in Physics from the University of Darmstadt (Germany) for his work on Big Bang matter. Dr. Tripolt continued his scientific career at the ECT in Trento (Italy), the University of Frankfurt (Germany), the University of Graz (Austria), and the University of Giessen (Germany), before becoming a Teacher of Physics at Scots College in 2025.

Shortly after the Big Bang, the matter in our universe was in a very hot and dense state, often called the quark-gluon plasma (QGP). A similar form of matter may still exist at the core of neutron stars or during neutron-star mergers. Investigating the properties of these extreme forms of matter has been a key goal in high-energy particle physics for several decades now. Experimentally, such matter can be recreated in particle accelerators through collisions of heavy ions at ultra-relativistic speeds. Theoretically, the aim is to investigate the underlying quantum field theory, Quantum Chromodynamics (QCD). One theoretical framework capable of investigating QCD at finite temperature and density is the Functional Renormalisation Group (FRG). In this talk, I will present recent FRG results on the QCD phase diagram and nuclear matter at extreme densities. Most of the results will be based on effective theories such as the quark-meson model and the parity-doublet model. A particular focus will be on vector mesons, chiral symmetry, electromagnetic rates in heavy-ion collisions, identifying phase transitions and the critical endpoint, and possible insights into the properties of neutron stars. I will also refer to the possibility of using gravitational waves to learn more about the properties of matter within neutron stars.

Modelling and Analysis of Semiconductor Lasers Subject to Fiber Bragg Grating Feedback

Mr Joe Steele[1,2], Prof. Bernd Krauskopf[1,2], Prof. Neil Broderick[1,2]
[1]University Of Auckland, Auckland Central, New Zealand, [2]Dodd-Walls Centre, Dunedin, New Zealand
2A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:
Joe Steele is a PhD candidate in Applied Mathematics at the University of Auckland, specialising in nonlinear dynamical systems applied to semiconductor laser dynamics. His research develops analytical models for semiconductor lasers with fiber Bragg grating feedback, unifying numerical simulation with theoretical analysis. He holds a Master by Research from University College Cork and Tyndall National Institute, where he worked in the Advanced RF Technologies group, following his undergraduate degree in Applied Mathematics from UCC. His expertise covers computational electromagnetics, delay differential equations, and bifurcation theory, with applications to photonic systems and high-frequency components.

Semiconductor lasers are compact, efficient light sources widely used in optical communications, and their sensitivity to external feedback makes them rich systems for studying nonlinear dynamics. The Lang-Kobayashi (LK) equations are the standard tool for modelling lasers subject to external feedback from a regular mirror. A key reflective component in optical systems is the fiber Bragg grating (FBG)—a periodic optical fiber refractive index variation—leveraged for its precise spectral control and all-fiber compatibility. When the external feedback comes from an FBG, present modelling requires a computationally expensive convolution term, which provides limited analytical insight into the system's behaviour.

We present a novel modelling approach that approximates FBG feedback by a sum of discrete delay terms. Critically, this avoids the need for numerical convolution while preserving the essential physics. This enables detailed analysis of the laser's mode structure, stability regimes, and bifurcation structure in the spirit of that for the 'classic' LK equations. In this way, our work provides a foundation for deeper theoretical study of semiconductor lasers subject to technologically relevant types of FBG feedback, bridging the gap between numerical simulation and analytical understanding.

Temperature-dependent photoluminescence in rare-earth-doped $NaMgF_3$

Mr Harrison Devane[1], Dr Joe Schuyt[1], Dr Hellen Nalumaga[1], Dr Shen V Chong[1,2], Prof. Grant Williams[2]
[1]Robinson Research Institute, Lower Hutt, New Zealand, [2]MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington, New Zealand

2A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:

Dr Shen Chong is a Senior Scientist at the Robinson Research Institute, Victoria University of Wellington. He has a PhD in materials chemistry from The University of Auckland and had postdoctoral experience working under Jeff Tallon and then at University of Tsukuba, Japan, under Kazuo Kadowaki. He went to Japan as a New Zealand Ministry of Science nominated Japan Society for the Promotion of Science (JSPS) postdoctoral fellow in 2007. He has published work in superconductivity, magnetism, functional properties of nano-materials, and surface chemical reactions. He is currently a Principal Investigator at the MacDiarmid Institute for Advanced Materials and Nanotechnology (NZ).

The temperature-dependent luminescence of crystalline nanocomposites has shown promising applications for temperature sensing in systems that require high resolution and fast response times across a wide range of temperatures. Our group has focused on developing a wireless, photoluminescence-based temperature sensor for monitoring power grid assets in New Zealand. One of the compounds that we investigated was $NaMgF_3$ doped with trivalent europium (Eu^{3+}) and sensitised with 2-thenoyltrifluoroacetone (TTFA). The structural and photoluminescence properties of this compound were studied to determine an optimal europium concentration that produces reproducible and high-resolution temperature-dependent photoluminescence over a temperature range that is attractive for such electronic devices.

The photoluminescence characterisation revealed a decrease in the relative intensity of the $^5D_0 \rightarrow {}^7F_2$ transition compared to the $^5D_0 \rightarrow {}^7F_1$ Eu^{3+} transitions, along with a decrease in the photoluminescence lifetime with increasing Eu^{3+} concentration. A strong temperature-dependent Eu^{3+} emission was found over the 300 to 460 K temperature range. A kinetic model was employed to analyse the data, revealing that excitation occurs directly into the TTFA ligand, followed by energy transfer to the ^5D_J states of Eu^{3+}. This model indicates that thermal quenching results from increased back transfer between the $^5D_0$ state of Eu^{3+} and the T_1 triplet state of TTFA. Furthermore, the relative sensor sensitivity ranges from 0.2 to 2.8% K^{-1}, which is among the highest reported values in inorganic nanothermometers. The best resolution achieved is ≈ 0.1 K at 360 K, with the lowest resolution being approximately 1 K at higher temperatures. These results indicate that this compound is a promising candidate for optical based temperature sensing.

First Principles Study of Square Tin-Oxide Nanotubes and Surface Modified Derivatives

Mr Alex Barnes[1,2], Prof. Nicola Gaston[1,2]
[1]Department of Physics, University of Auckland, Auckland, New Zealand, [2]MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington , New Zealand

2A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:

Alex Barnes is an honour's student and research assistant at the University of Auckland. His honours' project is a computational investigation into metal oxides with a focus on the recently discovered square tin oxide tubes. He is supervised by Professor Nicola Gaston. Other computational work focuses on Graphullerite, a novel carbon allotrope, as well as developing graph-based machine learning methods for materials science. Previous experimental research used both benchtop and synchrotron spectroscopy methods. Alex was awarded an University of Auckland Postgraduate Honours Scholarship.

Previously our collaborators at the University of Canterbury have synthesised Tin-Oxide (SnO_2) nanotubes[1], which surprisingly have a square face. This is interesting, as nanostructures tend to have circular/cylindrical geometries as these have lower energy barriers during self-assembly. Furthermore, these nanotubes have a two-dimensional electron gas on their surface and a high surface area to volume ratio, making these materials promising for catalytic applications including conversion of CO_2, gas sensing and semiconductor devices.

Using first principles density functional theory (within VASP) we aim to computationally recreate the experimental results and further deepen our understanding of the electronic properties of the nanotubes. Specifically, we will calculate the band structure and bandgap of the nanotubes while we vary geometric parameters like size, wall thickness, and the aspect ratio of the square face. We hope to use the control that computational methods afford us, to understand how through altering the geometric parameters, the corners and edges of the square face enhance or change the electronic properties of the nanotubes. These results can then be used during the application of these materials. Next, we will modify the nanotubes by binding molecules for example hydroxyl groups to the surface of the nanotubes, and again calculate the band structure. The created interface between the nanotube and surface molecules curves the band structure at the surface (referred to as band bending) and can drastically enhance or destroy the two-dimensional electron gas on the surface. Band bending is also important for applications in semiconductor devices. We hope to investigate a wide variety of different surface modifier molecules, starting with sulfur species and hydroxyl. As band bending is so important to the application of these materials, the computational method being developed, should serve as a first port of call when considering different surface modifiers.

References:

1. Scott, J. I., et. al. (2023). Looking Outside the Square: The Growth, Structure, and Resilient Two-Dimensional Surface Electron Gas of Square SnO2 Nanotubes. Small, 19(28), 2300520.

AI in the Classroom: Enhancing Teaching and Guiding Responsible Use.

Ms Kate Jackson[1]
[1]Cashmere High School, Christchurch, New Zealand

2B: Education, Studio Space G03 (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:
I have 35 years of experience teaching Science (specializing in Physics), in both New Zealand and the UK. My career includes over a decade of teaching in Modern Learning Environments, where I have developed a deeper understanding of the evolving use of digital technologies in supporting student learning and the challenges this brings. I am currently a classroom teacher as well as a subject facilitator for NZIP.

This workshop will focus on two main questions: how we as educators can use AI to improve teaching by creating helpful resources, and we can monitor and guide students' use of AI responsibly.

As AI becomes more common in education, we have new opportunities to enhance learning and personalize resources for students. Whilst there will be some examples of current use of AI within schools, the goal is to share and evaluate as many of the AI tools available as possible, so bring your ideas with you. We'll explore how we as educators track and manage AI use in the classroom, ensuring students are using these tools ethically and appropriately.

Through hands-on activities and group discussions, participants will gain ideas and tools for using AI to enhance their teaching while promoting responsible use among students.

There will be no "silver bullet" revelations, more an open dialogue on the current state of the use of AI in school, what is currently in play and how can we best be ahead of the game?

Lighting Up Physics: Hands-On Electricity and Electromagnetism for Secondary School Students

Dr Dulsha Kularatna-Abeywardana[1,2], Dr Rajith Abeywardana[2]
[1]The University of Auckland, Auckland, New Zealand, [2]Little Engineers, Auckland, New Zealand
2B: Education, Studio Space G03 (Building 303), July 1, 2025, 1:15 PM - 2:45 PM

Biography:
Dr Dulsha Kularatna-Abeywardana

Dulsha is an electronics engineer, educator, and co-founder of Little Engineers, with a strong commitment to excellence and a passion for inspiring future generations. She holds a PhD in Electrical and Electronics Engineering from the University of Auckland and currently a Senior Lecturer at the same institution. Dulsha combines technical expertise with creativity to drive meaningful change in engineering education. She is a passionate advocate for diversity in STEM. As a member of IEEE Region 10 Women in Engineering committee, she champions inclusion and empowers female students to thrive in a traditionally male-dominated field, leaving a lasting impact on the profession.

Dr Rajith Abeywardana

Rajith, co-founder and director of Little Engineers, brings a powerful blend of academic excellence and practical expertise in electrical and electronics engineering. He holds a PhD from the University of Auckland, in Electrical and Electronics Engineering and previously served as a Research Fellow, contributing to cutting-edge projects in wireless power transfer and fast-charging technologies. With a holistic background that bridges research and real-world application, Rajith plays a pivotal role in shaping the vision of Little Engineers—igniting curiosity and empowering the next generation of STEM innovators through engaging, hands-on learning experiences in physics and engineering.

Engaging secondary school students in physics through real-world, hands-on exploration builds confidence, deepens understanding, and can lay the foundation for a lifelong interest in science and engineering. Electricity and electromagnetism are core concepts in the secondary school physics curriculum, yet they often feel abstract and inaccessible to many students.

This interactive workshop introduces educators to innovative, classroom-tested activities that make these principles both tangible and exciting. Using the Little Engineers STEM kits, participants will explore key physics concepts such as current, voltage, resistance, series and parallel circuits, electrical measurements, home electrical circuits, magnetic fields, induction, and electromagnetic forces.

Teachers will have the opportunity to build and experiment with physical components, gaining first-hand experience of how these concepts can be made tangible and exciting for their students. Educators will build circuits, experiment with magnetic interactions, and construct simple motors and generators—making invisible forces visible and understandable.

All activities are aligned with the New Zealand curriculum and include opportunities for inquiry-based learning, student-led investigation, and links to other learning areas such as mathematics, digital technologies, and environmental science. The session will also highlight inclusive strategies to support a diverse range of learners and show how to embed real-world engineering examples into physics teaching.

Whether you’re looking to enhance your students’ understanding or bring a fresh approach to a familiar topic, this session provides practical, engaging ways to light up your classroom with physics.

Physics courses in NZ High schools; different pathways in a selection of schools.

Mr Jeffery Yang[1], Mr David Thrasher, Mr David Housden, Mr Mark Standley, Mr Chris Currie
[1]Macleans College, Manukau, New Zealand

2C: Education, Case Room G20 (Building 302), July 1, 2025, 1:15 PM - 2:45 PM

Biography:
A handful of teachers in New Zealand who are also NZIP facilitators.

NCEA is not the only high school qualification available in New Zealand. Alternative qualifications like Cambridge A level and International Baccalaureate (IB) are also available. Some schools also offer students the option of choosing a qualification.

What are the pros and cons of these qualifications when it comes to Physics?

What do some schools do to prepare students for these alternative qualifications in year 11 when it comes to Physics?

Practicals. Why do we do practicals.

Mr Chris Currie[1], Mr Mark Standley[2]
[1]Palmerston North Boys High School, [2] Whanganui Collegiate School

2C: Education, Case Room G20 (Building 302), July 1, 2025, 1:15 PM - 2:45 PM

Possible (cheap) equipment and simple experiments for seniors. Will take teachers/students through simple measuring activities, determining uncertainties and how to reduce them, equipment needed for activities, graphing techniques (log-log graphs). While these activities are not all suitable for 2.1 and 3.1 they will build student capabilities and confidence, as well as teach a couple of concepts and tricks of the trade.

Galactic Archaeology in the Southern Sky

Dr Clare Worley[1]
[1]University of Canterbury, Christchurch, New Zealand

3A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:
Dr Worley undertook her science studies at the University of Canterbury, including a PhD in Astronomy. She then went to the Observatoire de la Cote d'Azur for a three year postdoctoral fellowship in Galactic Archaeology. This led to a research associate role at the Institute of Astonomy at the University of Cambridge, UK, working on the large scale spectroscopic surveys of WEAVE and 4MOST. In 2022, Dr Worley returned to the University of Canterbury to take up a senior lecturership role.

Galactic Archaeology is the study of the Milky Way for its formation and evolutionary history. In particular, kinematic and chemical information of stars in the Milky Way are used to disentangle the evolutionary events that resulted in the stellar populations that we see today.
The southern sky offers the most spectacular view of the Milky Way, in particular of the galactic centre and plane in which most stars reside. When observed with large scale surveys on large diameter telescopes using high resolution spectrographs, detailed chemical abundance patterns within the stellar populations are revealed.

However, as these large surveys reach deep and far into the MIlky Way, our local neighbourhood of bright and nearby stars are often neglected as not observable by these large telescopes. But our region of the Milky Way shows a transition between in the inner and outer regimes of our galaxy with potentially different evolutionary histories. Detailed analysis of our neighbourhood is required and the ideal facilities are high resolution instruments on small to medium telescopes. The University of Canterbury Ōtehiwai Mt John Observatory offers such a facility with the High Efficiency and Resolution Canterbury University Large Échelle Spectrograph (HERCULES) currently operating on the 1 metre McLellan Telescope. I will present the unique contribution to Galactic Archaeology using this facility with a first look at results from the bright star survey of the solar neighbourhood being undertaken with HERCULES.

An analogy between chemical and magnetic nozzles from the perspective of numerical simulations

Mr Sashin Leuke Bandara Karunaratne[1], Dr Jakub Glowacki[1], Dr Tulasi Parashar[1]
[1]Victoria University of Wellington, Wellington, New Zealand

3A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:

Sashin Leuke Bandara Karunaratne is an aerospace engineer, who is currently a PhD candidate in engineering at the Robinson Research Institute of Victoria University of Wellington, New Zealand. He obtained his bachelor's and master's degrees in aerospace engineering from Mississippi State University and Purdue University respectively. His current research involves plasma instabilities in magnetic nozzles under high magnetic field regimes.

Chemical and magnetic nozzles represent two frequently utilized spacecraft thruster types relying on distinct mechanisms to convert stored energy in propellants to directed momentum. Chemical thrusters equip combustion, thermodynamic expansion and acceleration to generate thrust, often at high propellant mass flow rates producing high thrust. Contrarily, magnetic nozzles mainly rely on electromagnetic acceleration at much lower mass flow rates, resulting in significantly higher exhaust velocities. Despite the contrasting operational principles and regimes between these thrusters, they share some similarities between the underlying physics of thrust generation. For example, the process of expansion and acceleration of hot gases through a converging-diverging De Laval nozzle in a chemical thruster is mathematically analogous to that of a magnetic nozzle in an electromagnetic thruster. This analogy provides a framework capable of simplifying the numerical simulation of magnetic nozzles, shortening the computational time without compromising the underlying physics. In this study, a numerical analysis is performed using a hydrodynamic approach in OpenFOAM, drawing conclusions on the validity and limitations of this simplified approach to study magnetic nozzles. Accordingly, a comprehensive analysis between chemical and magnetic nozzles incorporating aspects of energy conversion, thrust generation mechanisms, and performance parameters such as thrust and specific impulse are conducted. This study through its detailed analogies, not only aims to aid in enhancing the fundamental conceptual understanding of these nozzles, but also improve upon their numerical modeling and simulation strategies.

Controlling the activity of intrinsic and extrinsic defects in doped SnO2 by ion implantation and annealing

Mr Abubakar Sadiq Yusuf[1,2,3], Dr Martin Markwitz[2,4,5], Professor Zhan Chen[1], Professor Maziar Ramezani[1], Professor John Kennedy[2], Dr Holger Fiedler[2]
[1]School of Engineering, Computer and Mathematical Sciences, Auckland University of Technology, PO Box 92006, Auckland 1142, New Zealand[2]National Isotope Centre, GNS Science, PO Box 30368, Lower Hutt 5010, New Zealand, [3]School of Physical Sciences, Department of Physics, Federal University of Technology, PMB 65, Minna, Niger State, Nigeria, [4]School of Chemical and Physical Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand, [5] The MacDiarmid Institute for Advanced Materials and Nanotechnology, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

3A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:

Mr. Abubakar Sadiq Yusuf is a dedicated academic and researcher with expertise in solid-state physics and perovskite solar cell technology. He is pursuing a PhD at Auckland University of Technology, New Zealand, where he also lectures in the Department of Physics and Astronomy. Abubakar holds a Master of Technology in Solid-State Physics in 2016 and a Bachelor of Technology in Physics/Telecommunication in 2010 from the Federal University of Technology Minna, Nigeria.

His career spans multiple academic and administrative roles, rising to Lecturer I at the Federal University of Technology Minna and Academic Lecturer at Auckland University of Technology. His research focuses on developing and modifying advanced materials for solar energy applications, and he has contributed extensively to international journals and conferences.

In addition to his teaching and research, he actively participates in student mentorship, departmental administration, and manuscript review for international journals. He holds memberships in professional bodies such as the New Zealand Association of Scientists, the United Kingdom Institute of Physics, and the Nigerian Society of Physical Sciences. He has also received commendations for his dedication to academic excellence and community service.

Abstract:

Advancements in perovskite solar cell (PSC) technology highlight the crucial role of electron transport layers (ETLs) in enhancing device performance by ensuring efficient charge transfer and minimizing energy losses. Tin dioxide (SnO2), with its high optical transmittance and inherent n-type conductivity, is a promising ETL material. In this work, we have demonstrated that ion implantation in conjunction with a tailored annealing temperature significantly improves the electrical conductivity and thermal stability of colloidal SnO2 thin films, enhancing their application as charge-transporting layers in PSC applications. Antimony (Sb^+) implantation reduced film resistivity to 149.3 ± 4.3 μΩ cm after annealing at 300 °C, while xenon (Xe^+) implantation achieved a resistivity of 150.2 ± 8.7 μΩ cm after annealing at 200 °C. Xe^+-implanted films exhibited poor thermal stability, with resistivity doubling to 313.0 ± 9.1 μΩ cm after annealing at 300 °C, highlighting the doping effect of antimony in SnO2. Optical transparency decreased for both implantations in the 400–500 nm range, with a more pronounced reduction for Xe^+. Hall effect measurements reveal that Sb^+ implantation enhances electrical conductivity by increasing carrier concentration and reducing resistivity, particularly at higher annealing temperatures, due to Sb dopant activation and defect repair. In contrast, Xe^+ implantation primarily induces defect formation, the beneficial defects which are annealed out at 300 °C leading to an increased resistivity. Structural and compositional measurements are used to investigate the doping and damage effects of ion implantation, with SnO2 showing highly tunable electrical and optical properties. These findings underscore Sb^+ implantation and annealing as an effective strategy for optimizing SnO2 ETLs, supporting its potential for high-performance PSC applications.

The Effects of Non-hydrostatic Pressure and Shear on Silicon Carbide

Mr Samuel Case[1], Prof Jodie Bradby[1]
[1]Australian National University, Acton, Australia
3A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:
I am a PhD student at the Australian National University, where I study the effects of high pressure and shear on materials using diamond anvil cells and DFT. I hold a BSc(Hons) in Physics from the University of Auckland, where I developed a strong interest in condensed matter physics.

Silicon carbide (SiC) is a widely used material with exceptional mechanical, thermal, and electronic properties, used in high-temperature electronics and extreme-environment applications. It is also widely believed to make up the cores of some exoplanets. Despite some study under hydrostatic compression, the combined effects of high pressure and deviatoric stress remain poorly understood, particularly regarding phase transformations, deformation mechanisms, and potential synthesis of novel polymorphs.

We investigated the behaviour of several common SiC polymorphs by subjecting to both hydrostatic and non-hydrostatic conditions using diamond anvil cells (DAC) and rotational diamond anvil cells (RDAC). We combine in situ Raman spectroscopy post compression TEM to investigate stress-induced phase changes and mechanical responses at pressures up to 50 GPa. Application of controlled shear through the RDAC enables systematic exploration of deformation pathways not accessible through hydrostatic compression alone. Our results reveal a broadening of Raman peaks consistent with possible stress-induced amorphisation. These findings offer new insight into the deformation mechanisms of SiC at extreme conditions and point to potential routes for accessing new high-pressure phases through tailored stress environments.

This work contributes to a growing body of research on the role of shear in high-pressure physics, with implications for material synthesis and planetary science.

Bound Excited States of Fröhlich Polarons in One Dimension

Ms Jamie Taylor[1,5], Mr Matija Cufar[2,4], Dr David Mitrouskas[3], Prof Robert Seiringer[3], Dr Elke Pahl[1,5], Prof Joachim Brand[2,4]
[1]University Of Auckland, Auckland, New Zealand, [2]Massey University, Auckland, New Zealand, [3]Institute of Science and Technology Austria, Klosterneuburg, Austria, [4]Dodd-Walls Centre for Photonic and Quantum Technologies, Auckland, New Zealand, [5]McDiarmid Institute for Advanced Materials and Nanotechnology, Auckland, New Zealand

3A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:

Jamie Taylor is an MSc student in physics at the University of Auckland, supervised by Elke Pahl, and co-supervised by Joachim Brand of Massey University. Her research area is computational quantum many-body physics.

The Fröhlich polaron is a model of an electron interacting with a polarisable medium. It describes a quasiparticle, created by the 'dressing' of the electron with a cloud of lattice distortion. Despite the model's long history, excited states with energies below the previously known continuum of scattering states have only recently been proven to exist, and only in the limit of strong electron-phonon coupling. We provide the first numerical evidence of these states in the intermediate coupling regime, using the full configuration interaction quantum Monte Carlo method to calculate the energies and properties of excited states in the one dimensional model.

Much of the previously known information about the Fröhlich polaron model is exact only in the limits of weak or strong coupling, with variational approximations used in between. Recent exact studies using diagrammatic Monte Carlo have successfully profiled the ground state at a range of coupling strengths, but did not find excited states below the continuum. Our method stochastically samples the eigenstates, allowing for calculation of the low-lying energy spectrum and distribution of phonons in the eigenstates to arbitrary precision, for any coupling strength.

Odd-frequency superfluidity from a particle-number-conserving perspective

Dr. Kadin Thompson[3,4], Professor Uli Zülicke[2,3,4], Professor Michele Governale[2,3,4], Professor Joachim Brand[1,2]
[1]Massey University, Auckland, New Zealand, [2]Te Whai Ao - Dodd Walls Centre for Photonic and Quantum Technologies, New Zealand, [3]Victoria University of Wellington, Wellington, New Zealand, [4]MacDiarmid Institute for Advanced Materials, New Zealand

3A: General, PLT1 Lecture Theatre (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:
Professor Brand hails from Germany and first came to Aotearoa to ride his bike around the country. After receiving a PhD from the University of Heidelberg he spent postdoctoral years at the University of Washington in Seattle and the Max Planck Instityte for the Physics of Complex Systems in Dresden. Since 2006 he has been an academic at Massey University in Auckland where he is now a Professor of Physics.

We investigate odd-in-time—or odd-frequency—pairing of fermions in equilibrium systems within the particle-number-conserving framework of Penrose, Onsager, and Yang, where superfluid order is defined by macroscopic eigenvalues of reduced density matrices. We show that odd-frequency pair correlations are synonymous with even fermion-exchange symmetry in a time-dependent correlation function that generalises the two-body reduced density matrix. Macroscopic even-under-fermion-exchange pairing is found to emerge from conventional Penrose-Onsager-Yang condensation in two-body or higher-order reduced density matrices through the symmetry-mixing properties of the Hamiltonian. We identify and characterize a transformer matrix responsible for producing macroscopic even fermion-exchange correlations that coexist with a conventional Cooper-pair condensate, while a generator matrix is shown to be responsible for creating macroscopic even fermion-exchange correlations from hidden orders such as a multiparticle condensate. The transformer scenario is illustrated using the spin-balanced s-wave superfluid with Zeeman splitting as an example. The generator scenario is demonstrated by the composite-boson condensate arising for itinerant electrons coupled to magnetic excitations. Structural analysis of the transformer and generator matrices is shown to provide general conditions for odd-frequency pairing order to arise in a given system. Our formalism facilitates a fully general derivation of the Meissner effect for odd-frequency superconductors that holds also beyond the regime of validity for mean-field theory.

Teaching L2 Mechanics and Electricity with a Potpourri of Experiments, Demonstrations, Applets and Videos, etc

Mrs Brenda MacKechnie[1], Mrs Sue Napier[2]
[1]NZIP/NEX, Upper Hutt, New Zealand, [2]NZIP/NEX, Christchurch, New Zealand
3B: Education, Studio Space G03 (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

Biography:
Biography1:
I am a recently retired Senior Physics teacher and HOD Science at Hutt International Boys' School. At present I am the NZIP/NEX Lead Facilitator for the North Island (based in Wellington)

Biography2:
I am a recently retired HOD Physics and Electronics teacher at Riccarton High School. At present I am the NZIP/NEX Lead Facilitator for the South Island (based in Christchurch and Wanaka).

This workshop is intended to share engaging experiments, demonstrations, animations and videos suitable for teaching L2 Mechanics and Electricity using our combined experience of about 75 years teaching!!

NCEA External Assessment – an NZQA perspective

Mr Ian Phillips[1]
[1]National Assessment Facilitator - NZQA
3B: Education, Studio Space G03 (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

In what ways are candidates not achieving in level 2 and level 3 Physics External Assessments? NZQA's observations of candidate performance during marking.

An update - Curriculum, NCEA and NEX

Mr David Housden[1], Dave Thrasher[2]
[1]St Cuthbert's College, [2]NZIP-Ed & St Bernard's College

3B: Education, Studio Space G03 (Building 303), July 1, 2025, 3:15 PM - 5:00 PM

A short summary of NZ curriculum refresh, NCEA updates & planned changes & NeX information (Networks of Expertise). David Housden (NZIP-Ed & St Bernard's College) and Dave Thrasher (St Cuthbert's College) will cover the main topics. Opportunity for Q&A if time allows.

Rheostats, Eclipses, Planks, Surprises and Non-Sequiturs. A collection of small things that are useful and fun for teachers and students.

Mr Haggis Henderson[1]
[1]TKKMO Te Rāwhitiroa, Whangārei, New Zealand
3C: Education, Case Room G20 (Building 302), July 1, 2025, 3:15 PM - 5:00 PM

Biography:
Haggis is "of the four winds". Born on an army base, he has moved extensively around the North Island and settled in Mangapai, where he is fulfilling his dream of growing his own firewood. He teaches Physics at Whangarei Boys' High and he enjoys teaching kids, playing the accordion, tinkering in his shed, patting his cat, walking his dog and looking at the night sky. He loves his family, folk music and the quest to understand the rules that govern the universe – Physics, in other words. He is particularly fond of the smell of macrocarpa firewood and dark ale – often at the same time.

Rheostats, Eclipses, Planks, Surprises and Non-Sequiturs. Each of these things is interesting, useful and fun but none of them are long enough to warrant a full session. I have glued together some small snippets of useful contexts and ideas for reaching and teaching students.

Rheostats are useful for teaching the link between bench equipment and circuit diagrams. Eclipses are useful to include in the 2.6 Waves unit - and I travelled to the USA in April 2024 to see my first one. Planks are terrific for teaching levers, moments, torques and equilibrium plus they provide a great opportunity to practise for 2.1 (find the equation of non-linear data). Surprises come from messing around with the units that we teach - and some we don't ("barns", anyone?). None of these things follows on from the one before but they make for an interesting group of experiences that both boost and round out the knowledge that students need for success.

Search for Chaos in the Quantum Three-Body Problem

Dr Alex Kerin[1,2], Professor Joachim Brand[1,2]
[1]University Of Massey, Auckland, New Zealand, [2]Te Whai Ao - Dodd-Walls Centre, New Zealand
4A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Alex completed his PhD at the University of Melbourne under the supervision of Andy Martin and Andrew Melatos in 2023. He primarily investigated the far-from-equilibrium dynamics of interacting quantum few-body problems but also developed a novel model describing the stochastic formation of mountains on neutron stars. Alex has since begun his first postdoctoral position at the University of Massey where his research currently focuses on quantum chaos and few body systems.

In classical mechanics the concept of chaos has proven very powerful. The chaotic nature of a system will affect, among other things, the types of path it takes through phase space. The concept of chaos has been extended to the quantum realm with random matrix theory and level-spacing statistics. Quantum regular systems display Poissonian statistics, where quantum chaotic systems display Wigner-Dyson statistics, i.e. energy levels repelling one another. Quantum chaos is deeply tied to how (or if) quantum systems thermalise, with phenomena such as correlations holes, and it is related to fundamental principles of quantum thermodynamics such as the ergodic hypothesis.

One or two-body problems are rarely chaotic. However, as more and more interacting bodies are added to a system the system tends to display signatures of chaos. For example, the hydrogen atom has no chaotic signatures, unlike the helium atom which displays level repulsion. Interacting three-body problems are an archetypal chaotic system. Here we consider three bodies in a three-dimensional isotropic harmonic trap interacting with zero-range contact interactions. We make use of analytic and semi-analytic techniques to calculate the energy spectra for arbitrary interaction strength and species mass ratios and compare the level spacing statistics to the predictions of random matrix theory. Curiously, we observe power-law level spacing statistics which do not conform to the predictions of random matrix theory and are more typical of systems with fractal geometries.

How to make a p-wave superfluid with ultracold molecules?

Mr Satyanand Kuwar[1,2], Mr Matija Cufar[1,2], Dr. Alex Kerin[1,2], Prof. Joachim Brand[1,2]
[1]Massey University, Auckland, New Zealand, [2]e Whai Ao – Dodd-Walls Centre for Photonic and Quantum Technologies, New Zealand

4A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:

He is currently a research scholar at Massey University, Auckland Campus. He completed his Bachelor of Science in physics from SRM University, Chennai, India, and his master of Science in physics from the Indian Institute of Technology, Mandi, India. His core interest is solving the quantum many-body problem using numerics and analytics.

It has recently become possible to cool heteronuclear molecules to ultracold temperatures. This is exciting because these molecules possess a permanent dipole moment, enabling them to interact over extended distances through dipole-dipole interaction. Microwave shielding and laser cooling techniques cool these molecules to ultracold temperatures in the micro to nano-Kelvin range. These molecules can be transferred into a one-dimensional lattice built using standing-wave laser interference patterns. This configuration may allow us to experimentally achieve the one-dimensional tight-binding regime with extended-range interactions and thus realise an extended Hubbard model. Here, we study the one-dimensional extended Hubbard model with spinless (spin-polarised) fermions and investigate the available many-body phases. Besides phases relating to the formation of droplets and density wave patterns, the model supports p-wave superconductivity at not-too-strong attractive interactions. At the precise point of a quantum phase transition to the droplet phase, the ground state exhibits true off-diagonal long-range order. Thus the largest eigenvalue of the two-particle reduced density matrix, which gives the number of p-wave Cooper pairs, is proportional to the number of fermions in the system in the thermodynamic limit, a property that is rare in interacting one-dimensional systems. Furthermore, we establish a mapping between the extended Fermi-Hubbard model and a quantum gas model with contact interaction in one dimension. This mapping further corroborates the existence of true off-diagonal long-range order in the extended Fermi-Hubbard model.

Pulsed Squeezed Driving of a Two-Level Atom as a Source of Wigner Negative Light

Rory Robertson[1]

[1]The University of Auckland, Auckland, New Zealand

4A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:

Rory Robertson is a PhD candidate at The University of Auckland, researching theoretical quantum optics with supervisor Scott Parkins. Their work focuses on modelling and simulating open quantum systems to discover and characterise new uniquely quantum states of light.

Wigner-negative states of light are a type of non-classical state of great interest in quantum optics, having key roles in the development of quantum computing and other quantum technologies. However, the generation of propagating Wigner-negative states is a historically difficult task, generally requiring complicated and probabilistic methods to achieve any result. Within our work we have theoretically demonstrated, through the application of a cascaded systems model, a scheme for producing novel and highly-negative states of light. We achieve this by cascading a pulse of squeezed light through a two-level atom, and capturing specific temporal modes of the output field. This is an entirely deterministic process, producing propagating Wigner-negative states at a higher efficacy than previous methods, and without reliance on inconsistent and inherently probabilistic techniques used in other schemes. This process can also be readily extended to driving more complicated systems or using different initial states of light, producing a wide variety of unique states. This transformation of the Gaussian, non-negative Wigner distribution of a squeezed state into a non-Gaussian distribution displaying strong Wigner-negativity is already a striking discovery. What's more, the similarities between our generated states and so called "squeezed cat" states -- superpositions of displaced squeezed states of opposite amplitudes -- suggest the potential for further applications, and a greater understanding of how Wigner-negativity can be generated in open quantum systems.

Multimode photon correlations from a single atom

Mr Alexander Elliott[1,2], Scott Parkins[1,2]
[1]The University of Auckland, Auckland, New Zealand, [2]Te Whai Ao -- Dodd-Walls Centre, Auckland, New Zealand
4A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Alex Elliott has recently submitted his PhD thesis at the University of Auckland, studying theoretical quantum optics.

Stable transmission of light signals over long distances requires low-loss waveguides and associated technologies optimised for the carrier wavelength. Sources of nonclassical light in the telecommunication band are particularly sought after, given the multitude of existing advanced technologies for transmitting and processing these wavelengths. In the context of atomic light sources, it is therefore crucial to find transitions that are resonant at the desired frequencies. We theoretically examine the photon correlations from a single alkali atom coupled to modes of a nanofibre resonator. In particular, we explore the photon emissions in transitions from the 7S excited state of a caesium atom, which are resonant at telecommunication-band wavelengths.

Photon correlations provide insights into the quantum nature of light and its interactions with matter, and are exploited for developing sources of single photons and highly correlated states of light. The coupling imprints unique signatures of the atomic transitions onto photon emissions from the respective cavity modes, which are directly channelled into optical fibre. By appropriately configuring the systems, steady-state correlations are established within each mode, as well as between modes. We demonstrate violations of classical inequalities for both single-mode and multi-mode photon statistics using just a single atom.

Lattice Bose polarons near a quantum phase transition

Matija Cufar[1]
[1]Massey University, Auckland, New Zealand
4A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Matija is a PhD student studying under Joachim Brand at Massey University. He's interested in the physics of ultra-cold quantum gases with a focus on lattice systems, as well as numerical methods, particularly quantum Monte Carlo.

When a mobile impurity is immersed in a quantum bath, it gets dressed by excitations and forms a quasiparticle known as a polaron. In recent years, polaron physics has been of considerable interest, since these systems recently became experimentally realisable, and because polaron-like physics might be the mechanism behind certain exotic materials such as unconventional superconductors.
In this talk, we present our recent theoretical and numerical work that focuses on a single mobile impurity immersed in a strongly-interacting Bose-Hubbard model. In particular, we are interested in the regime where the underlying bath undergoes a quantum phase transition from a Mott insulator to a superfluid, and where the impurity-boson interactions are strong.
We find that the nature of the polaron formed between the impurity and the bath strongly depends on the underlying phase of the bath, as well as the impurity-boson interactions. We also find that near the transition point, the polaron appears to become scale invariant. These properties indicate that that the polaron is sensitive to the conditions in the bath and may be useful as a probe in both experimental and numerical settings.

Materials for magnonics - optimised spin-wave propagation in magnetic Heusler alloys Co2MnGa1-xGex

Dr Simon Granville[1,2], Prof. Haiming Yu[3], Mr Jinlong Wang[3], Dr Yao Zhang[1], Dr Yuefeng Yin[4], Prof. Nikhil Medhekar[4]
[1]Victoria University of Wellington, Wellington, New Zealand, [2]MacDiarmid Institute for Advanced Materials and Nanotechnology, New Zealand, [3]Beihang University, Beijing, China, [4]Monash University, Clayton, Australia

4B: General, MLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Dr Simon Granville is a Principal Scientist at Victoria University of Wellington's Paihau-Robinson Research Institute, and the Programme Leader for Future Computing in the MacDiarmid Institute for Advanced Materials and Nanotechnology. Simon is an experimental materials physicist and NZ expert in thin film magnetic materials. He is most active in developing an understanding of the magneto-electronic and magneto-optical properties of ferromagnetic materials and applying them towards next-generation computing technologies. He is also an investigator of Quantum Technologies Aotearoa and co-leads a NZ government-funded programme to develop magnetic memory for superconducting and quantum computing.

Today's computing technologies rely on controlling the movement of electrons around circuits made of semiconductors. Moving electrons scatter and lose energy in the process. This generates lots of heat, which needs be removed so devices don't melt. Magnonics, which completely removes electrical current flow, could be a way to solve the heat problem. Instead of moving electrons, information is transmitted and processed using excitations in magnetic materials, called spin waves. However, this potentially fast and energy-efficient new form of computing needs magnetic materials with the right characteristics to allow advances towards feasible devices.

In this talk I will show our results from GHz-frequency magnetic measurements that characterise the magnonic properties of thin films of ferromagnetic metallic Heusler alloys. By changing the composition of the films during growth, we optimise two of the major characteristics of suitable materials: the magnetic damping and spin wave propagation distance. We explain how it is the common crystal structure but distinct electronic band structures of the Heusler alloys, ranging from half-metallic to Weyl semi-metallic, that allow the optimisation of these characteristics, marking these materials as great choices for developing magnonic devices to replace electronics.

Dynamics of Brownian Janus Spheres

Mr Stephen Chung[1,2], Prof. Geoff R. Willmott[1,2,3]
[1]The MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington, New Zealand, [2]Department of Physics, The University of Auckland, Wellington, New Zealand, [3]School of Chemical Sciences, The University of Auckland, Auckland, New Zealand

4B: General, MLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:

A 3rd year PhD student studying colloidal interactions using microfluidics

The motion of spherical, asymmetric Janus colloids driven only by hydrodynamics and thermal motion is an important aspect of possible applications using these particles. Relevant applications include biomedical diagnostics and therapeutics, providing stability and functionality at phase boundaries, and (especially) self-assembly into higher-order structures. Despite this, there has been relatively little rigorous experimentation focused on Janus spheres in solution, either as individual particles or interacting in small clusters [1]. For interacting particles, simulations have shown that it is important to include hydrodynamic effects (such as shear flows) and kinetics into any analysis.

This presentation will describe the challenges relating to experimental studies of Janus dynamics. One experimental approach is to use microfluidics to precisely handle Janus colloids so that they can be observed moving and/or interacting freely. Tumbling of individual particles in shear is of interest, while two-particle interactions away from channel walls may be achieved through a sheath-flow design. To observe the orientational dynamics of ~10 mm colloids, a customised 3D microscopy setup and image analysis tools are required. It is expected that interaction dynamics can be modulated by changing particle surface geometry, surface chemistries (e.g. charged, hydrophilic/phobic, specific recognition via DNA), and solution conditions, for example. Development of this work should allow for design of Janus spheres for specific applications in future.

[1] Chung, S., Safaei, S., Willmott, G. R., 3D assembly of Janus Spheres: Potentials, Dynamics and Experiments, Adv. Phys.: X 9, 1-29 (2024).

AC voltage standard

Dr Vladimir Bubanja[1]
[1]Measurement Standards Laboratory Of New Zealand, Lower Hutt, New Zealand
4B: General, MLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Vladimir Bubanja obtained PhD in Physics at the Delft University of Technology, the Netherlands. He works in the Electrical Standards team of the Measurement Standards Laboratory of New Zealand in Lower Hutt.

We derive the analytic solution of the heat flow equation of a single-junction thermal converter (SJTC). The heat is generated by the flow of an electric current through the heater wire, while the thermocouple attached via a ceramic bead to the middle of the heater wire acts as a heat sink. We consider the nonlinearities caused by the Thomson and radiation effects, as well as the temperature dependence of the physical properties of the heater material. The results are used to obtain the expression for the ac–dc transfer difference as a function of the device geometry and material parameters. We report on the very good agreement between the analytical, numerical, and experimental results of the ac–dc difference of the SJTC in the frequency range from 10 Hz to 1 kHz. The results are used for the design of thermal converts and their further use in the ac voltage metrology.

Akaike's Information Criterion for Linearly Separable Clusters

Dr Maria Eda Arado

4B: General, MLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Maria Eda Arado is Programme Manager in Built Environment and Engineering at the School of Innovation, Design and Technology, Wellington Institute of Technology. She is also an engineering tutor in tertiary education, where physics forms a core part of the foundational curriculum. Maria has developed a mathematical theorem applying the Akaike Information Criterion (AIC) in cluster analysis with linearly separable components. Her work demonstrates the superiority of using vectors of slopes as inputs to the k-Means algorithm, rather than raw data, for accurately determining the number of clusters. This research has important applications in engineering and environmental data analysis.

Using the Akaike Information Criterion (AIC) in cluster analysis with linearly separable components, the paper demonstrates the superiority of using the vector of slopes as inputs to the K-Means algorithm over using the raw data in determining the number of clusters. This approach was applied to the marine reserves data, where AIC consistently identified the optimal number of clusters more accurately and reliably than other indices.

Melting of noble gas systems under extreme conditions

Miss Diana Yu[1]
[1]Miss. Diana Yu, Auckland, New Zealand

4B: General, MLT1 Lecture Theatre (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Diana Yu is a PhD student at the University of Auckland. She graduated from The University of Science and Technology in China, and moved to New Zealand. She studies condensed matter physics, quantum chemistry and astrophysics. Her main project is to analyse the phase transitions of condensed matter systems under different conditions using computer simulations.

The discovery of strong magnetic fields on magnetic white dwarf stars has led to great interest in the study of matter under such conditions. Under such conditions, the physics and chemistry changes drastically: atoms take on elliptical shape, high-spin states become new electronic ground states, and a new binding mechanism called perpendicular paramagnetic bonding is found. The latter leads to a stabilisation of the feeble bonds of noble gas compounds found under standard conditions. As a consequence, melting points are known to increase and the occurance of new solid phases is probable.

Adding the high pressure environment of white dwarfs, melting temperatures might be drastically different from the no-magnetic field case, thus impacting the cooling behaviour of magnetic white dwarfs.

We study the thermodynamic of noble gases under such extreme conditions as found on white dwarfs using Parallel Tempering Monte Carlo (PTMC) techniques.

In order to accommodate fcc, hcp and bcc structures, we adopt two types of boundary conditions: 1. a right rhombic prism-shaped box where the layers of atoms are arranged along the direction of the magnetic field, for fcc and hcp. 2. a rectangular prism-shaped box for fcc and bcc.
Due to the influence of perpendicular paramagnetic bonding, the length/height ratio of the box is allowed to change during the simulations.

Two types of dimer potentials are used: one calculated at MP2 level and one at CCSD(T) level, the results are compared. We have also developed a sorting algorithm for these configurations based on common neighbour analysis (CNA) to determine the types of structures each configuration correspond to.

Harnessing AI to Revolutionize Physics Education: Planning, Teaching, and Assessment

Dr Kris Bhatt[1]
[1]Nps International School, Singapore, Singapore, [2]NZIP, New Zealand, [3]International Baccalaureate, Switzerland, [4]Cambridge, U K

4C: Education, Studio Space G03 (Building 303), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Dr. Kris Bhatt, Senior Principal at NPS International School, Singapore, teaches IB Diploma Physics and integrates technology to enhance learning. A mentor for STEM competitions, he has led teams to the NASA Human Exploration Rover Challenge for three consecutive years (2023-2025), the only team from Southeast Asia. His NPSI team is among 25 selected for the Global Finals of the Conrad Challenge at Kennedy Space Center, Houston. Previously, Dr. Bhatt taught physics at Rotorua Girl's High School and served as principal at Reporoa College in New Zealand before moving abroad.

Artificial Intelligence (AI) has transformed the way educators plan, teach, and assess students. With a wealth of free resources and tools available, teachers can now leverage AI to enhance their teaching practices and improve student outcomes. This interactive workshop will provide physics educators with practical strategies to integrate AI tools into their classrooms, making lessons more engaging, assessments more efficient, and feedback more impactful.

Workshop Objectives:
Learn how to use AI tools to design interactive and dynamic lesson plans tailored to different learning levels.
Explore AI-generated resources to create engaging and personalized learning experiences.

Delivery Stage:
Discover how AI can identify and recommend activities to enhance student engagement.
Generate well-graded worksheets and tasks to "check for understanding" during lessons.

Assessment Stage:
Design self-marking assessments to save time and provide instant feedback to students.
Use AI to generate detailed feedback on student work and create extension tasks for homework.

Lab Tasks and Experiments:
Learn how AI tools can simplify the creation of physics experiments and lab tasks, making them accessible and safe for students.

Student Self-Assessment and Feedback:
Explore how AI can help students mark their own work and receive constructive feedback to improve their understanding.

Enhancing Performance:
Use AI to generate model answers and the "best physics response" to questions, helping students refine their problem-solving skills and improve performance.

Workshop Highlights:
Hands-on demonstrations of AI tools and platforms.
Interactive sessions to practice designing lesson plans, worksheets, and assessments.
Strategies to improve time management and productivity using AI.
Tips to become a more effective and innovative physics teacher.

Outcome:
By the end of the workshop, participants will be equipped with the knowledge and skills to integrate AI tools into their teaching practices, making physics education more interactive, efficient, and impactful. Teachers will leave with actionable strategies to save time, enhance student engagement, and improve learning outcomes.

Target Audience:
Physics teachers at all levels (middle school, high school, and beyond) who are interested in leveraging AI to transform their teaching practices.

Takeaways:
Access to a curated list of free AI tools and resources for physics education.
Sample lesson plans, worksheets, and assessments created during the workshop.

Folk Music Physics. Songs that boost retention of key ideas.

Mr Haggis Henderson[1]
[1]TKKMO Te Rāwhitiroa, Whangārei, New Zealand
4D: Education, Case Room G20 (Building 302), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Haggis is "of the four winds". Born on an army base, he has moved extensively around the North Island and settled in Mangapai, where he is fulfilling his dream of growing his own firewood. He teaches Physics at Whangarei Boys' High and he enjoys teaching kids, playing the accordion, tinkering in his shed, patting his cat, walking his dog and looking at the night sky. He loves his family, folk music and the quest to understand the rules that govern the universe – Physics, in other words. He is particularly fond of the smell of macrocarpa firewood and dark ale – often at the same time.

At past conferences I have presented some Physics songs. Many of our students have an artistic inclination and they quite like the idea of learning Physics concepts by way of song, dance or some other artistic endeavour. This presentation will be a participatory workshop on singing Physics songs with some time spent on how to write them too. I will present some of my work and I hope to be able to include some other musicians and their work too – depending on who steps forward.

From the takoto to the qubit – the story of measurement in New Zealand

Ellie Molloy[1], Annette Koo[1]
[1]Measurement Standards Laboratory of New Zealand, Lower Hutt, New Zealand
4D: Education, Case Room G20 (Building 302), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
Ellie is a research scientist in the Light team and Annette is the Director and Chief Metrologist of MSL.

An important part of science education is an introduction to measurements and the International System of Units (the SI). In New Zealand, the Measurement Standards Laboratory (MSL) is responsible for ensuring that we have measurements that are traceable to the SI. This ensures that the measurements in New Zealand are being made on the same measurement scale as around the world.

In this workshop, we will introduce the role of MSL in New Zealand and explain how we fit into the international measurement infrastructure. Then, we will demonstrate some activities that can be used to help illustrate the importance of measurement. We will also demonstrate a resource on our website that looks at how measurement is used in our daily lives, in ways that are not initially obvious, and provide some material about the history of measurements in New Zealand, including pre-European standard measures used by Māori.

Physics Scholarship Workshop

Dr Matthew McGovern[1]
[1]Havelock North High School, Hastings, New Zealand

4D: Education, Case Room G20 (Building 302), July 2, 2025, 10:30 AM - 12:00 PM

Biography:
I am a high school physics teacher, with 14 years experience teaching in Australia and New Zealand. As well as a PhD in experimental physics, I have recently completed a MA, investigating a novel method of measuring how well a teacher can identify difficulties that students have with fundamental concepts in mechanics.

Workshop on a scholarship program for the busy physics teacher.

The aim with this program is to scaffold your top students from L3 NCEA physics, to being able to study independently for the scholarship exam.

This is based upon the 1 Term program I have refined over the last decade that I use with my school and other Hawkes Bay students.

Entangled photon-pair emission in waveguide circuit QED from a Cooper pair splitter

Professor Michele Governale[1], Professor Christian Schönenberger[2], Dr Pasquale Scarlino[3], Dr Gianluca Rastelli[4]

[1]Victoria University of Wellington, Wellington, New Zealand, [2]Department of Physics, University of Basel, Basel, Switzerland, [3]Institute of Physics and Center for Quantum Science and Engineering, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, [4]Pitaevskii Center on Bose-Einstein Condensation, CNR-INO and Dipartimento di Fisica dell'Università di Trento, Trento, Italy

5A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 2:00 PM - 3:00 PM

Biography:

Michele Governale is Professor of Physics at Victoria University of Wellington and a Principal Investigator at the MacDiarmid Institute for Advanced Materials and Nanotechnology. Michele was awarded his PhD in 2001 from the University of Pisa. After that, he held research positions in Germany and Italy before moving to New Zealand in 2009. Michele is a theoretical condensed-matter physicist and his research focusses on nanoscale systems, novel materials, superconductivity and topological phases of matter.

Entanglement, the non-classical correlations possible in multipartite quantum systems, is an important physical resource for quantum technologies. Here, we propose a setup for transferring entanglement from electrons in a superconducting nanodevice to microwave photons in transmission lines within a waveguide circuit QED architecture. The setup consists of two double quantum dots, each coupled to a microwave transmission line. We find that this system can generate frequency-entangled photon pairs in the left and right transmission lines - specifically, a superposition of two photon wavepackets at different frequencies. The frequency entanglement of the photons arises from the particle-hole coherent superposition (i.e., Andreev bound states) involving the delocalized entangled spin singlet. We also estimate a lower bound for the efficiency of entangled photon-pair generation, accounting for non-radiative processes such as phonon emission. Our proposal is realistic and achievable with state-of-the-art techniques in quantum microwave engineering using electrostatically defined semiconducting quantum dots.

Beyond the fundamental interest in extracting entanglement from a quantum many-body condensate (e.g., a BCS superconductor), having a deterministic, on-demand source of frequency-entangled photon pairs is crucial for photonic quantum information applications.

Inserting magnetic semiconductors into superconducting Josephson junctions

Professor Ben Ruck

5A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 2:00 PM - 3:00 PM

Biography:
Ben is a condensed matter physics experimentalist who researches the electronic and magnetic properties of novel materials, both for their fundamental interest and for their potential application in electronic devices. He enjoys collaboration with a wide range of researchers from across New Zealand and around the world, including theorists and experimentalists, and he makes use of numerous synchrotron facilities. His research approach is founded on supervision of research students.

Ben is a principal investigator in the MacDiarmid Institute for Advanced Materials and Nanotechnology, and he has held leadership roles within Te Herenga Waka - Victoria University of Wellington. He greatly enjoys teaching physics whether in a lecture, lab, or tutorial environment, and he places great value on building relationships with secondary school physics teachers.

The ever-increasing role of large-scale computing in our lives is creating competing demands for greater computational power and lower energy consumption. This necessitates the development of next-generation computing, where conventional hardware based on silicon is replaced by exotic new materials. One of the most promising paradigms is superconducting computing, with transistors giving way to Josephson junctions (JJs) consisting of two superconducting layers separated by a very thin non-superconducting layer. Josephson junction logic devices already exist: the qubits in the quantum computers of Google and IBM are the most striking examples. However, key components to enable large-scale uptake of this technology are missing, including memory solutions that operate quickly enough while consuming sufficiently low power.

Using a magnetic material as the non-superconducting layer offers additional functionality to JJs, as the superconducting phase must behave differently passing through a magnetised barrier layer. Metallic ferromagnetic materials have been used to form proof-of-concept memory and logic devices, but these function at speeds orders of magnitude lower than conventional JJ devices due to their low normal-state resistances. To this end we are incorporating a class of novel magnetic semiconductors, the rare earth nitrides, as the non-superconducting layer in JJs. These materials offer both controllable resistivity and a rich variety of magnetic properties, giving scope to explore the fundamental physics of magnetic Josephson junctions. Here we present experimental results from a collaboration with researchers at Nagoya University, where JJs with rare earth nitride magnetic barrier layers are fabricated and characterised both as un-shunted junctions and as part of larger superconducting devices, such as DC SQUIDs.

Rural Physics - Contexts for reaching students from rural backgrounds

Mr Haggis Henderson[1]
[1]TKKMO Te Rāwhitiroa, Whangārei, New Zealand

5B: Education, Studio Space G03 (Building 303), July 2, 2025, 2:00 PM - 3:00 PM

Biography:

Haggis is "of the four winds". Born on an army base, he has moved extensively around the North Island and settled in Mangapai, where he is fulfilling his dream of growing his own firewood. He teaches Physics at Whangarei Boys' High and he enjoys teaching kids, playing the accordion, tinkering in his shed, patting his cat, walking his dog and looking at the night sky. He loves his family, folk music and the quest to understand the rules that govern the universe – Physics, in other words. He is particularly fond of the smell of macrocarpa firewood and dark ale – often at the same time.

Many students come from rural backgrounds and many teachers come from urban backgrounds. This workshop combines two contexts to help students understand Physics ideas by using experiences that they might be familiar with - such as tractor use, fencing, tree felling, farm water management and tool use.

There will be a practical component in the presentation.

Simple Harmonic Motion guided teaching with simulations, quizzes and graphing programs

Mr Jeffery Yang[1]
[1]Macleans College, Manukau, New Zealand

5B: Education, Studio Space G03 (Building 303), July 2, 2025, 2:00 PM - 3:00 PM

Biography:
Ex-engineer, current Physics teacher and NZIP facilitator.

Simple Harmonic Motion is generally thought of as the hardest topic for students to grasp in Level 3 NCEA Physics. This workshop uses recommendation from Physics education research and ideas from teachers to set up a sequential approach to deliver SHM to students.

The approach is heavily guided using simulation which allow vector directions to be shown and phase difference to be compared. This allows student to build up the relationship between displacement, velocity and acceleration.

An online repetitive quiz then helps cements these ideas into students minds to built a qualitative model. Finally, a graphing program is used to put the equations to the test where students compare their calculations to the graphs from the equation.

This final step then completes the linking from concept to equations.

Quantum – What is the Hype?

Mrs Brenda MacKechnie[1]
[1]NZIP/NEX Lead PLD Facilitator - North Island, Upper Hutt, New Zealand

5C: Education, Case Room G20 (Building 302), July 2, 2025, 2:00 PM - 3:00 PM

Biography:
Brenda MacKechnie, retired Physics teacher and HOD Science at Hutt International Boys' School and Lead PLD facilitator (NZIP/NEX) for North Island

As 2025 is the International Year of Quantum, more attention is focused on this branch of science. But what is quantum? This session introduces the Perimeter Institute resources for secondary school students, focussing on the core phenomenon of quantum science through a series of activities. This new knowledge will then allow participants to determine which products marketed today are actual quantum or quantum hype.

What I learned from doing Master's research in physics education

Dr Matthew McGovern[1]
[1]Havelock North High School, Hastings, New Zealand
5C: Education, Case Room G20 (Building 302), July 2, 2025, 2:00 PM - 3:00 PM

Biography:
I am a high school physics teacher, with 14 years experience teaching in Australia and New Zealand. As well as a PhD in experimental physics, I have recently completed a MA, investigating a novel method of measuring how well a teacher can identify difficulties that students have with fundamental concepts in mechanics.

In 2023 I was fortunate enough to receive a teacher's study award which gave me 3 school terms off teaching to pursue my Master's research project and thesis. This talk is in two parts:

1) How I got the study award, what papers I studied, and why you should also look into this career path, both from a professional, and personal point of view.

2) The results of my Master's research, including investigating a method to measure how well a physics teacher can predict what difficulties their students have; and what I learnt from some in-depth interviews with these physics teachers.

Interfacing cold atoms with an optical nanofiber

Dr Wayne Crump[1], Mr Mohammad Sadeghi[1], Associate Professor Maarten Hoogerland[1]
[1]University Of Auckland, Auckland, New Zealand

6A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

Biography:

Wayne Crump is a research fellow at the University of Auckland working in the cold atom lab of Associate Professor Maarten Hoogerland. He is building a cavity QED system using a fiber cavity and cold atoms and looking to use it to generate multiphoton states. Previously he worked at Aalto University in Finland coupling superconducting qubits with mechanical resonators. He completed his PhD at Victoria University of Wellington in 2019 on superconductivity.

The generation and control of sensitive quantum states is a fundamental challenge for the design of quantum technologies. Low frequency states such as those used in superconducting circuits are generally confined to the dilution refrigerators they have been created in. This is due to the decoherence caused by higher temperatures. The optical regime is therefore a desirable operation point, as states can be transmitted via optical fibers at room temperature. The challenge is now working at terahertz frequencies and coupling optical photons with a nonlinear element to generate these non-classical quantum states.

In our experimental system, we couple cold atoms to guided modes of an optical fiber. A portion of the fiber has been drawn out to have around a 400 nm diameter, which means the atoms couple to the evanescent field. The fiber sits in a vacuum chamber where we also use a Magneto Optical Trap to confine Caesium atoms near the nanofiber for interactions. We show the results of experiments with the nanofiber as well as progress towards our goal of creating a cavity QED system to generate multiphoton states of light.

Progress towards coherent transduction in a monolitihic triple resonant electro-optic device

Dr Nicholas Lambert[1,2], Mr Linjie Shao[1,2], Mr Pablo Paulson[1,2], Dr Chengcai Tian[1,2], Dr Florian Sedlmeir[1,2], Dr Mallika Suresh[1,2], Professor Harald Schwefel[1,2]
[1]Department of Physics, University of Otago, Dunedin, New Zealand, [2]Dodd Walls Centre, University of Otago, Dunedin, New Zealand

6A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

Biography:
Nicholas Lambert is a Research Fellow in the Physics Department at the University of Otago. He studies the interaction of microwaves with other systems, including superconducting devices, magnetic resonances and optical fields in non-linear materials. The aim of this research is to develop new techniques and platforms for future quantum technologies.

We describe our progress towards fabricating an efficient platform for coherent transduction between microwave and optical frequencies. Our device is based on a lithium tantalate whispering gallery mode resonator, which supports telecoms frequency optical modes with low losses. We combine this with a microwave resonant structure. The material has a second order non-linearity which allows frequency conversion using the electro-optic effect. The geometry of the fields in our device, and the nature of the electro-optic tensor of lithium tantalate, are such that the pump mode and signal mode have orthogonal polarisations, allowing single sideband operation and straightforward separation of pump and signal.

We aim here to make a device with a high number efficiency; in other words, most input microwave photos result in an output optical photon. To do this, we need to maximise the overlap between input, pump and signal modes. We will do this with a periodically modulated microwave ring resonator, which allows phase matching despite the difference in m number between TE and TM modes of similar frequency. The ring resonator will be fabricated directly on the rim of the WGM resonator, ensuring the highest possible fields at the optical mode volume. Furthermore, the resulting device will be monolithic and robust, allowing use in cryogenic environments.

Maximum likelihood estimations for analysing photon counts in few atom experiments

Dr Marvin Weyland[1], Dr Lucile Sanchez[1], Dr Poramaporn Ruksasakchai[1], Assoc Prof Mikkel Andersen[1]
[1]University of Otago, Dunedin, New Zealand
6A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

Biography:
Dr Weyland studied physics in Magdeburg, Germany and did his PhD in experimental physics at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany in 2016. After working in a private engineering company for a short time, he came to New Zealand to work on single atom experiments at the University of Otago, where he investigates few atom interactions in optical tweezers.

Measuring a distribution of random events and fitting a model to it in order to understand some underlying properties is common throughout science. Choosing the right way to fit your data is a crucial basic step. Here, we use the example of fluorescence distributions from few atoms in a tight optical tweezer and show different approaches to determine the atom number distribution from it. In the tight tweezer regime, the detection light causes rapid atom loss due to light-assisted collisions. This in turn leads to non-Poissonian and overlapping fluorescence distributions for different initial atom numbers. We use maximum likelihood estimation algorithms to fit model distributions that account for the atom loss.

This gives accurate atom number distributions for relatively few experimental runs to sample a photon number distribution.

We show that the method can be extended to situations when the photon number distributions for known initial atom numbers cannot be modeled, at the cost of requiring a higher number of experimental runs. This method can be used for quantum computers based on individual atoms in optical tweezers as well as for basic research in atomic physics.

Long optical coherence times in a rare-earth-doped antiferromagnet

Mr Masaya Hiraishi[1], Mr Zachary Roberts, Dr Gavin King, Dr Luke Trainor, Associate Professor Jevon Longdell
[1]University Of Otago, Dunedin, New Zealand
6A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

Biography:
I completed my Bachelor's and Master's degrees at the Tokyo University of Science in Japan. I am currently a PhD student at the University of Otago. My research focuses on microwave and optical spectroscopy of rare-earth ions in magnetic materials. Specifically, I am investigating collective excitations of electronic spins in crystals and the optical transitions that couple to these collective excitations.

Even in solid state crystals, exceedingly long coherence times have been observed for the spin and optical transitions of rare-earth-ion dopants. The limiting factor for further improvements is the influence of electronic and nuclear spins in the host crystal. While it is in principle possible to have a host crystal that is free of either electron or nuclear spin hosts, a low strain crystal host for rare earths that is completely free of host spins look unlikely. Here, we show that dephasing effects of electron spins can be avoided in magnetically ordered hosts at sufficiently low temperatures. Providing an exciting new direction for improved rare earth host crystals. The system we investigated is erbium ions doped in gadolinium vanadate. The host material, gadolinium vanadate, is antiferromagnetically ordered at 2.4 K, resulting in two magnetically inequivalent sites for doped erbium ions. We also observed strong coherent coupling between the erbium ions and collective magnetic resonances of the spins in the host (magnons). Because the magnons couple much more strongly to microwave photons that the erbium dopants, this might be a route to microwave-to-optical frequency conversion of quantum signals with much higher bandwidths than is currently possible.

Quantum properties of parametrically driven cavity solitons in a bichromatically driven Kerr resonator

Dr Sophie Shamailov[1,2], Dr Gregory Moille[3,4], Miss Miriam Leonhardt[1,2,5], Mr David Paligora[1,2], Dr Nicolas Englebert[6], Dr François Leo[6], Dr Julien Fatome[7], Dr Kartik Srinivasan[3,4], Prof Miro Erkintalo[1,2]
[1]Department of Physics, University of Auckland, Auckland 1010, New Zealand, [2]The Dodd-Walls Centre for Photonic and Quantum Technologies, Dunedin 9016, New Zealand, [3]Joint Quantum Institute, NIST/University of Maryland, College Park, USA, [4]Microsystems and Nanotechnology Division, National Institute of Standards and Technology, Gaithersburg, USA, [5]Atomic and Laser Physics, Pembroke College, University of Oxford, Oxford, UK, [6]Service OPERA-Photonique, Université libre de Bruxelles, Brussels, Belgium, [7]Laboratoire Interdisciplinaire Carnot de Bourgogne, UMR 6303 CNRS Université de Bourgogne, Dijon, France

6A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

Biography:

Sophie Shamailov obtained her Bachelors at the University of Auckland, majoring in Physics and Pure Mathematics. She went on to do an Honours and Masters degree in Physics at the University of Auckland, and a PhD in Physics at Massey University, graduating in 2018. She has worked as a research assistant in Applied Mathematics and in Physics at both universities, and is currently in the middle of her third Research Fellow position at the University of Auckland.

Temporal solitons are stable localised solutions in driven-dissipative resonators which exist due to the careful balance between dispersion and nonlinearity. Classically, cavity solitons are very well understood and have found many practical applications. More recently, the effects of quantum fluctuations on these solitons have been studied, in particular in the form of two-mode squeezing, as well as spontaneous emission and two-photon correlations for classically empty modes in a soliton lattice state. Furthermore, the phase noise spectrum of the cavity soliton arising from timing jitter induced by interactions with the quantised vacuum has been computed.

Cavity solitons have the potential to constitute the next mile-stone -- building on top of the large body of work centred on the vacuum state -- in terms of creating high-dimensional, strongly entangled and squeezed states. Such continuous-variable cluster states have many potential applications as a "quantum resource", and progress in this direction would contribute to the field of quantum computation and information, metrology, sensing and communications.

Here we compute the quantum properties of a new kind of cavity soliton: the parametrically driven cavity soliton, which has recently been predicted and experimentally demonstrated in a bichromatically driven pure-Kerr resonator. We repeat calculations previously done for ordinary cavity solitons. One key result is that the parametrically driven cavity soliton exhibits stronger two-mode squeezing than comparable ordinary cavity solitons across a wide range of parameters, which implies that the entanglement is stronger as well by virtue of the connection between these two phenomena. This suggests that the parametrically driven Kerr cavity soliton would be an even better quantum resource for various applications which require squeezing and entanglement, and thus has the potential to advance photonics-based quantum technology, especially if an integrated, scalable chip architecture is achieved.

Testing Student-Focused STEM Workshops with Teachers: A Hands-On Electronics and Computing Experience

Miss Wesley Key[1], Miss Neha Desu[1]
[1]The University of Auckland, Auckland, New Zealand

6B: Education, Studio Space G03 (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

Biography:

Wesley Key is a final-year student at the University of Auckland specialising in Computer Systems Engineering and is a Kupe Leadership Scholar. Her honours research investigates the relationship between secondary school students' interest in STEM and hands-on computing and electronics activities. She oversees outreach initiatives that encourage diversity in STEM and assists high school students as the Initiatives Director of WEN. Wesley firmly commits to educational equity and developing meaningful, hands-on learning opportunities, especially for marginalised groups. She is dedicated to increasing the accessibility and inclusivity of STEM education and has led seminars and activities through several STEM programs.

Neha is in her final year of studying Computer Systems Engineering at the University of Auckland. Her part 4 research project focuses on the relationship between secondary school students' interest in STEM and hands-on computing and electronics activities. As a former maths tutor at Kumon, she saw firsthand how foundational support can shape students' confidence in STEM. Neha is committed to using both her technical background and leadership experience to inspire young women and minorities to pursue careers in engineering and technology, aiming to create a more inclusive and innovative future in STEM.

The potential of hands-on computing and electronics activities to spark students' interest and foster positive perceptions of STEM careers has been demonstrated. However, it is equally important to understand the perspectives of educators. Originally designed and intended for secondary school students, these activities will be trialled with teachers in this workshop to get critical feedback. Participants will gain hands-on experience with interactive, project-based STEM activities that their students might encounter, such as designing digital counters, emulating sections of datapaths, and breadboarding circuits, which foster curiosity, problem-solving, and a basic technical understanding.

This workshop is a component of our senior engineering research project, which looks closely at how well these activities engage secondary school pupils. We intend to obtain important insights from instructors' professional viewpoints by first testing the activities on them. During this experiential workshop, teachers will examine how they teach, think about ways to include these activities in their curriculum, and assess the exercises from the student's perspective. Participants' opinions on the usefulness of each assignment and its impact on student involvement will be recorded through a questionnaire during organized discussions and feedback sessions that will follow each activity.

The Human Ethics Committee has accepted our ongoing study, which attempts to pinpoint important elements impacting secondary students' interest in STEM, especially regarding hands-on learning. Our goal in getting teachers engaged is to gather insightful, qualitative input that will help us improve our activities and make them more valuable and appealing in different school environments.

DC Circuits L2

Mr Chris Currie[1], Mr Mark Standley[2]
[1]Palmerston North Boys High School, [2] Whanganui Collegiate School

6B: Education, Studio Space G03 (Building 303), July 2, 2025, 3:30 PM - 5:00 PM

An introduction to circuit concepts and an investigative approach to introducing students to DC Circuits. Specifically current and potential difference behaviour in various circuit setups. It will also look at the relationships that can be derived from current and potential difference. Primarily aimed at L2 but could be used at a variety of levels.

Dark Matter and Gravitational Wave Detection: From the Lab to the Classroom

Jackie Bondell[1,2,3,4], Laura Burn[4,5]
[1]School of Physics, University of Melbourne, Melbourne, Australia, [2]Centre of Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, Australia, [3]ARC Centre of Excellence for Dark Matter Particle Physics, Melbourne, Australia, [4]ARC Centre of Excellence for Gravitational Wave Discovery [OzGrav], Hawthorn, Australia, [5]Department of Physics, University of Auckland, Auckland, New Zealand

6C: Education, Case Room G20 (Building 302), July 2, 2025, 3:30 PM - 5:00 PM

Biography:

Jackie Bondell (she/her) is the Senior Education and Outreach Manager for the ARC Centre of Excellence for Dark Matter Particle Physics and the Centre of Excellence for Gravitational Wave Discovery. She focuses on connecting teachers, students, and researchers, playing a pivotal role in crafting educational content for outreach programs and tailoring curricula for enhanced school engagement. At the core of Jackie's strategy is the seamless integration of cutting-edge scientific content into curriculum-aligned education opportunities for students and teachers. With 15 years as a Physics instructor in the US, earning multiple teaching awards, Jackie brings extensive experience to the field.

Laura Burn (she/they) is a physics PhD candidate at the University of Auckland, passionate about science communication and physics education. Her research focuses on gravitational waves from merging supermassive black holes for the future Laser Interferometer Space Antenna (LISA). Alongside her research, she works as a planetarium presenter, engages in school outreach, and is a research assistant in science education. Laura advocates for inclusive, equity-focused teaching and loves helping the public engage with cutting-edge science.

In shaping tomorrow's science education landscape, we ponder: How can we uncover the invisible? How do scientists engineer experiments and instruments to explore the Universe's most elusive phenomena, detectable at the smallest scales? Scientists at the forefront of research in cutting-edge topics in modern physics and astronomy, such as dark matter and gravitational waves, are discovering creative solutions to make detecting the unseen possible. This interactive session will introduce the engineering and science behind next-generation dark matter and gravitational wave detectors, such as the SABRE (Sodium Iodide Active Background Rejection) dark matter direct detection experiment in Australia and the LIGO (Laser Interferometer Gravitational Wave Observatory) experiments in the United States. These engineering marvels serve as inspiration for a series of low-cost, hands-on activities to engage students in the nature of science and scientific inquiry, as well as in content areas such as gravitation, waves, interference, orbits, stellar evolution, and particle physics. Teachers will engage in a subset of these lessons and receive kits to take back to their schools, including lesson plans and curriculum links. The objective is to equip educators with a toolkit of accessible and curriculum-linked Physics activities that cultivate students' creativity and critical thinking, inspiring continued study in STEM and engagement in future scientific discourse.

Names of colleagues, students, places and concepts in Te Reo. A revisit from 2021.

Mr Haggis Henderson[1]
[1]TKKMO Te Rāwhitiroa, Whangārei, New Zealand

6C: Education, Case Room G20 (Building 302), July 2, 2025, 3:30 PM - 5:00 PM

Biography:
Haggis is "of the four winds". Born on an army base, he has moved extensively around the North Island and settled in Mangapai, where he is fulfilling his dream of growing his own firewood. He teaches Physics at Whangarei Boys' High and he enjoys teaching kids, playing the accordion, tinkering in his shed, patting his cat, walking his dog and looking at the night sky. He loves his family, folk music and the quest to understand the rules that govern the universe – Physics, in other words. He is particularly fond of the smell of macrocarpa firewood and dark ale – often at the same time.

Many Physics teachers have come from backgrounds that are different from some of their students and colleagues. In the past, respect for diversity has not been given the value that it is given now and it is not acceptable to mispronounce names. Pronunciation of Te Reo is often taught by first-language speakers, many of whom are so comfortable in the language that they can find it hard to unpack things from a non-Maori point of view. Having come from a Pakeha background and having learned how to speak Te Reo as a second language, I have some pointers and tips that might be of use to those who would like to improve their pronunciation. This talk will have laughter, noise, participation and a song to close.

Please note, this presentation will be mostly a repeat of the presentation from 2021. These need for these skills has not diminished with time.

Mātauranga Māori and Physics: Some examples and contexts

Mr Mat Synge[2], Mr Haggis Henderson[1]
[1]TKKMO Te Rāwhitiroa, Whangārei, New Zealand, [2]Aquinas College, Tauranga, New Zealand
6C: Education, Case Room G20 (Building 302), July 2, 2025, 3:30 PM - 5:00 PM

Biography:
Mat lives in Tauranga with his wife Jess and their two young boys, Ollie and Lachie. Together, they enjoy life on a lifestyle block, where whānau time is a top priority. Mat teaches Physics, Chemistry, and Te Reo Māori at Aquinas College in Tauranga. He has found his journey learning Te Reo Māori and exploring aspects of Te Ao Māori to be both challenging and deeply fulfilling.

Haggis is "of the four winds". Born on an army base, he has moved extensively around the North Island and settled in Mangapai, where he is fulfilling his dream of growing his own firewood. He teaches Pāngarau at TKKMO Te Rāwhitiroa and he enjoys teaching kids, playing the accordion, tinkering in his shed, patting his cat, walking his dog and looking at the night sky. He loves his family, folk music and the quest to understand the rules that govern the universe – Physics, in other words. He is particularly fond of the smell of macrocarpa firewood and dark ale – often at the same time.

There is increasing recognition of knowledge that is sourced from indigenous cultures. Here, in Aotearoa, the indigenous culture's knowledge is called Matauranga and this presentation introduces some aspects that overlap with Physics. Some of the ideas to be presented and discussed include:

Te Reo Māori words for key ideas in Ahupūngao/Physics.

Contexts from Te Ao Māori that can be used in Ahupūngao/Physics lessons.

Te Reo Māori words for key ideas in Pāngarau/Mathematics.

Instructions and other classroom words that can be used in lessons.

A shorter introduction to Quantum-computing Aided Composition (QAC)

Dr Omar Costa Hamido

7A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 11:00 AM - 12:30 PM

Biography:
OCH is a performer, composer, and technologist, working and teaching on music and quantum computing, telematics, multimedia, and improvisation. He earned his PhD at UC Irvine (USA) with the pioneering work in Music and Quantum Computing "Adventures in Quantumland" (quantumland.art). He also earned his MA at ESMAE-IPP (PT) with his research on the relations between music and painting, and currently he is a Marie-Curie Fellow with the project IIMPAQCT at University of Coimbra (PT). OCH has numerous software tools and relevant academic publications, and he has presented his music and research at international venues such as NYCEMF, NIME, IRCAM, Splice, Audio Mostly, and MCM. In recent years, his work has been recognized with grants and awards from MSCA, Fulbright, FCT, Medici, Beall Center for Art+Technology, and IBM. omarcostahamido.com

In this talk I will present a brief overview of my research and creative work on Music and Quantum Computing. In particular, I will explain the quest for defining Quantum-computing Aided Composition (QAC) and the emergence of the field of Quantum Computer Music. I’ll include a live demonstration of what it looks like to compose with quantum circuits and address previous and upcoming events that are shaping the field and the Community.

Rare-Earth ions in CaF_2 nanoparticles for scalable quantum technologies

Professor Michael Reid, Michael Moull, Professor Jon-Paul Wells
[1]University of Canterbury, Ilam, New Zealand

7A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 11:00 AM - 12:30 PM

Biography:

Michael Moull completed an MSc in Physics at University of Canterbury in 2024 and is currently working on a QTA PhD project entitled Rare-Earth ions for scalable quantum technologies.

Rare-earth doped materials are strong candidates for quantum information technologies that provide an interface between light and matter, such as quantum memories, repeaters and transducers. Coherent storage with a six-hour time-scale has been demonstrated in electron-nuclear hyperfine states of Europium ions in yttrium silicate [1]. Erbium is of particular interest due to its compatibility with existing fibre-optic technologies [2]. A limitation of rare-earth optical technology is the low transition intensities between the 4f levels. Trigonal sites for rare-earth ions in CaF_2 may be created by oxygenation of the crystals, where the substitution of an oxygen ion adjacent to the rare-earth ion gives extremely large dipole moments [3].

Our recent spectroscopic studies of erbium [4] and europium ions in oxygenated CaF_2 have demonstrated accurate modelling of the electronic and hyperfine energy level structure with a crystal-field model. Crucially, we show that we can also model the optical transition intensities. Such detailed understanding of how the local environment affects the optical properties of rare-earth ions, combined with advanced fabrication techniques, has the potential to optimise performance for quantum technology applications.

We are now investigating these centres in nanoparticles of CaF_2, with the aim of demonstrating single-ion detection in fibre cavities [5], in collaboration with groups in France and Germany.

[1] M Zhong, MP Hedges, RL Ahlefeldt, JG Bartholomew, SE Beavan, SM Wittig, JJ Longdell, MJ Sellars, Optically addressable nuclear spins in a solid with a six-hour coherence time, Nature 517:177, 2015
[2] MT Uysal, Ł. Dusanowski, H Xu, SP Horvath, S Ourari, RJ Cava, NP de Leon, and J D Thompson. Spin-photon entanglement of a single Er3+ ion in the telecom band (arXiv:2406.06515), June 2024.
[3] AJ Silversmith and AP Radlinski. Zeeman spectroscopy of the G1 centre in CaF2 :Eu3+ . Journal of Physics C: Solid State Physics, 18:4385, 1985
[4] MD Moull, JBL Martin, TGM Newman, AL Jeffery, JG Bartholomew, J-PR Wells, and MF Reid. Spectroscopy, Crystal-Field, and Transition Intensity Analyses of the C3v(O2−) Centre in Er3+ Doped CaF2 Crystals. Optical Materials: X 24, 100365, 2024.
[5] C Deshmukh, E Beattie, B Casabone, D Serrano, A Ferrier, P Goldner, D Hunger, H de Riedmatten. Detection of single ions in a nanoparticle coupled to a fiber cavity. Optica 10, 1339, 2023.

Three, Four and More Body Spinor Interactions via Nanofibre Cavity QED

Mr Thomas Clarkson[1,2], Assoc. Prof. Scott Parkins[1,2]
[1]The University of Auckland, Auckland, New Zealand, [2]Te Whai Ao, The Dodd Walls Centre for Photonic and Quantum Technologies, New Zealand

7A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 11:00 AM - 12:30 PM

Biography:
Thomas Clarkson is a PhD student studying at the University of Auckland under the supervision of Scott Parkins. His thesis topic is on using multimode fibre cavities for engineering Hamiltonians in alkali atoms.

In many models of physical systems, pairwise interactions are usually sufficient to describe most phenomena, for instance, in quantum optics the interactions between atomic dipoles and photons. However, there are many fields in physics, such as in quantum metrology[1], where higher order descriptions are needed. This many-body behaviour can be engineered in various settings via using an intermediate system to mediate the interactions between the particles, resulting in the desired many-body behaviour in the original system. Here we adapt a recent scheme [2] engineered within momentum states of atoms to the context of internal spin states in cavity QED. Due to being an all fibre based system, this would allow for easy integration into fibre based quantum communication setups, where it has been shown that many-body interactions can lead to rapid creation of GHZ-like states[3].

In this work, we show that three-body and higher-order interactions can be described between internal spin states of an ensemble of alkali atoms. Interactions between the atoms are mediated via a multi-photon process in a nanofibre cavity, which can support multiple frequency-distinct cavity modes due to having a small free spectral range. This system can then be studied as an open quantum system, where we investigate the system in the limit of either dispersive or dissipative mediating cavities.

References:
1. Munoz-Arias, M. H., Deutsch, I. H. & Poggi, P. M. Phase-Space Geometry and Optimal State Preparation in Quantum Metrology with Collective Spins. PRX Quantum 4, 020314 (2 Apr. 2023).
2. Luo, C. et al. Realization of three and four-body interactions between momentum states in a cavity through optical dressing. arXiv preprint (Oct. 2024).
3. Zhang, X., Hu, Z. & Liu, Y.-C. Fast Generation of GHZ-like States Using Collective-Spin XYZ Model. Phys. Rev. Lett. 132, 113402 (11 Mar. 2024).

Nonlinear Dynamics of Coupled Light-Matter Systems

Ofri Adiv[1,2,3], Professor Bernd Krauskopf[1,3], Professor Neil Broderick[2,3], Assoc. Professor Scott Parkins[2,3]

[1]Department of Mathematics, The University of Auckland, Auckland, New Zealand, [2]Department of Physics, The University of Auckland, Auckland, New Zealand, [3]Dodd-Walls Centre for Photonic and Quantum Technologies, New Zealand

7A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 11:00 AM - 12:30 PM

Biography:

I am a PhD student at the University of Auckland under the supervision of Bernd Krauskopf, Neil Broderick, and Scott Parkins. My project is centered around dynamics of light-matter systems.

Interactions between many-body atomic systems and light have received much attention, both recently and in the past, due in part to advances in quantum technologies. More specifically, within models of such light-matter systems, the Dicke model has long been a focus of research for its applicability to a range of scenarios, and for the quantum phase transitions it exhibits. Originally proposed by Hepp and Lieb, it describes the interaction between an ensemble of atoms and light in an optical cavity. At a critical value of the light-matter coupling the system undergoes a quantum phase transition to superradiance, where the ensemble emits coherently into the cavity.

We continue this line of research by investigating a pair of atomic ensembles confined to two separate optical cavities, which couple to one another through the exchange of photons. We do so with a view towards quantum information processing, where networks of coupled quantum subsystems, such as atomic ensembles, can influence each other so that their interactions can be tailored. Our analysis is rooted in dynamical systems theory and centers around the differential equations that govern the evolution of quantum-mechanical expectations. In this framework behaviours of the quantum system correspond to different dynamical objects, and their bifurcations to quantum phase transitions. This translation allows us to paint a detailed dynamical picture, revealing periodic behaviour, quasiperiodic oscillations, chaotic dynamics, and their organisation in phase space.

Reflection in linear videos

Professor Manjula Sharma

7B: Education, Studio Space G03 (Building 303), July 3, 2025, 11:00 AM - 12:30 PM

Biography:
Professor Manjula Sharma is originally from Fiji and a graduate from the University of the South Pacific. She is a leading science educator and she has deeply engaged in school and university curriculum matters for several decades. Manjula is currently Director of the STEM Teacher Enrichment Academy at The University of Sydney, prior to which she led the Sydney University Physics Education Research (SUPER) group. Her research is grounded in educational instrumentation and measurement in the areas of multimedia, inquiry based approaches and engaging teachers and students in investigative work. She has over 100 peer reviewed papers in international journals and has supervised outstanding PhD candidates, including Dr Derek Muller creator of YouTube channel Veritasium. She has led the Government funded project, Advancing Science and Engineering through Laboratory Learning, ASELL Schools and has been Chief Examiner for NSW HSC Physics. She is serving as Chair of IUPAP Commission C14 on Physics Education. Professor Sharma co-founded the premier Australian Conference on Science and Mathematics Education (ACSME) and the International Journal of Innovation in Science and Mathematics Education (IJISME). Her awards include the 2012 Australian Institute for Physics Education Medal, 2013 OLT National Teaching Fellowship and she is a Principal Fellow of the UK Higher Education Academy, Fellow of the Australian Institute of Physics and Honorary Fellow of the Teacher's Guild of New South Wales, Australia.

Interactive multimedia is often promoted as highly beneficial for student learning, but linear videos have established a widespread and lasting presence. One key reason for this is that interactive multimedia requires specific usage to be beneficial, while linear videos can be utilized in almost any manner. Somewhere in the middle is the concept of integrating interactivity into linear videos, which will be explored in this workshop. The workshop will delve into the idea of reflective thinking [1] using Veritasium videos, as well as examining reflective thinking and assessing social media [2]. It is based on the PhD thesis of Petr Lebedev, who authored the script and starred in a video on Japanese Swords, showcasing the potential trajectory for physics students. This workshop provides an opportunity to understand the potential benefits of incorporating reflective thinking into linear videos and the impact it can have on student learning.

NCEA Internal Assessment – an NZQA perspective

Mr Raymond Neal[1]
[1] National Assessment Moderator - Physics, NZQA

7C: Education, Case Room G20 (Building 302), July 3, 2025, 11:00 AM - 12:30 PM

Investigating in Physics.
Insights for assessing PESS 1.2 (92045).
Comparing Physics 2.1 and3.1.

Showcasing our Smart Carts: Co-design an outreach activity with us!

Ms Ashleigh Fox[1], Ms Jenny Nguyen[1]
[1]Faculty of Engineering and Design, University of Auckland, Auckland, New Zealand
7C: Education, Case Room G20 (Building 302), July 3, 2025, 11:00 AM - 12:30 PM

Biography:
I’m Jenny, a fourth year student at the University of Auckland. I am currently studying a BE(Hons) in Civil Engineering and BSc in Chemistry. I became a WEN Outreach Ambassador over two years ago to influence and impact students just as I was in high school by the team back then. Thanks to my degree, I've developed a passion for the engineering industry because of its accessibility, flexibility, and practical application of my one-true-love, science!

Since 2019, the University of Auckland Women in Engineering team have been working to encourage more women to consider engineering as a viable career path. One part of our programme is visiting school classes around New Zealand with a range of hands-on activities design to showcase a range of aspects of engineering and address some of the barriers that women school students face.

One of our activities uses Pasco Smart Carts to demonstrate the application of kinematics equations, and this is a popular choice for Physics teachers when they invite us into their senior classes.

Our new vision for the Women in Engineering strategy incorporates some key themes into all our initiatives to make engaging aspects of engineering more visible, namely innovation, creative problem solving, sustainability and community impact. We have redeveloped some of our activities to ensure these aspects are more explicit, and that students can see both the goal for the activity and how what they do can be applied in the real world.

Join us in this workshop to learn more about the activities and events we offer, and help us update our Smart Carts activity to better portray one or more of the above aspects of engineering.
We hope to leave the workshop with your fantastic suggestions for narratives to tie the activity components together and some great real-world examples of these concepts and equations in action!

Progress towards simplified measurement schemes for optomechanical quantum-correlation thermometers

Dr Ana Rakonjac[1], Dr Biswarap Guha[2], Dr Thomas P Purdy[3], Dr Kartik Srinivasan[2], Dr Nikolai N Klimov[2], Dr Daniel S Barker[2]

[1]Measurement Standards Laboratory of New Zealand, Lower Hutt, New Zealand, [2]National Institute of Standards and Technology, Gaithersburg, United States of America, [3]University of Pittsburgh, Pittsburgh, United States of America

8A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 1:30 PM - 3:00 PM

Biography:

Ana Rakonjac is a senior research scientist at the Measurement Standards Laboratory of New Zealand. She has a background in experimental cold atom physics and quantum sensing. Her work at MSL involves maintaining and disseminating the temperature scale to New Zealand industry, and her current research interests are focused on developing quantum sensors for measuring thermodynamic temperature.

Optomechanical thermometry is a promising route to portable primary thermometry from room temperature down to a few kelvin. Quantum noise arising from the zero-point motion of a mechanical oscillator can provide in situ calibration of the oscillator's thermal motion. In an optomechanical system, the resonator undergoes thermal Brownian motion, driven motion from the light in the cavity, and optomechanical backaction. Noise correlators can be employed to separate thermal and quantum signals, thereby forming a quantum-correlation thermometer and enabling primary temperature measurements. The optomechanical cavity is chip-scale, which allows for integration with other chip-scale sensors. Fiber-optic readout makes optomechanical thermometers suitable for a variety of applications, including those in which conductive sensor leads cannot be used. However, the measurement precision of quantum-correlation thermometers is not presently competitive with existing secondary thermometers, and reducing systematic uncertainties is an ongoing challenge.

We use a waveguide-coupled GaAs nanobeam resonator with an optical resonance in the telecom wavelength range and a mechanical resonance around 2.6 GHz as our optomechanical thermometer. The optomechanical resonator is installed in a low-vibration cryostat along with a resistive cryogenic thermometer that independently monitors the temperature. Our detection scheme utilises a double-mix-down technique, where optical carrier sidebands generated by an electro-optic modulator mix with the mechanical signal in the resonator and are then combined with a local oscillator in a heterodyne measurement. This method requires only a single channel for data acquisition, with subsequent phase-sensitive signal processing performed entirely in software. We report on progress towards primary thermometry using this simplified measurement scheme and provide an outlook for future work.

Analysis of frequency-dependent coupling for Josephson parametric devices

Waltraut Wustmann[1,2], Rui Yang[3,4], Zheng Shi[3]
[1]University Of Otago, Dunedin, New Zealand, [2]Quantum Technologies Aotearoa, [3]University of Waterloo, Waterloo, Canada, [4]Shanghai Institute of Microsystem and Information Technology, Shanghai, China

8A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 1:30 PM - 3:00 PM

Biography:

WW studied physics at Technical University Dresden, Germany, where she also completed her PhD on the topic of time-periodic open quantum systems. Postdoctoral stays brought her to Chalmers University in Gothenburg, Sweden and to University of Maryland, USA where she did research on superconducting electronics for quantum and digital computing. This line of research is ongoing, now at the University of Otago.

Resonators with flux-pumped SQUIDs are widely used in superconducting quantum computing research, where they have applications to e.g. amplify signals, read out qubits, achieve noise squeezing or frequency conversion. In its simplest form, the resonator is coupled weakly to a transmission line (TL) which carries the in- and output signals. Weak coupling ensures a high quality factor and results in a large amplifier gain at only moderate pump power. Since the TL is a frequency-independent environment and the coupling is non-resonant, the bandwidth of the parametric devices is small and decreases with increasing gain.

An auxiliary coupling circuit can render the coupling frequency-dependent and helps to overcome the gain-bandwidth limitation, i.e. to widen the bandwidth at undiminished gain. Here we analyze the quantum Langevin dynamics of the parametric device for a frequency-dependent coupling circuit. The assumption of frequency-independent coupling coefficients (First Markov approximation) is no longer appropriate here. As a result, the usually constant, real-valued damping rate in the quantum Langevin equation is replaced by a frequency-dependent, complex-valued self energy, which characterizes the damping and frequency shifts of the resonator amplitude. The input-output relations which relate the TL amplitudes and the resonator amplitude are generalized consistently, such that quantum commutation relations are preserved under unitary evolution (i.e. if there are no other losses apart from the coupling to the TL).

For simple auxiliary coupling networks, such as serial and parallel LC-circuits, we analytically derive the frequency-dependent self energy and its approximate resonant form. Using these results, we analyze the parametric gain and the broadening of the amplifier bandwidth. Our results provide insight for the bandwidth engineering of Josephson parametric devices, using simple coupling networks realizable with limited resources. This contrasts the daunting fabrication demands of traveling-wave parametric-amplifiers containing hundreds of Josephson junctions.

Storing single photons in a rare-earth doped crystal

Dr Luke Trainor[1,2], Helen Chrzanowski[3,4], Xavier Barcons Planas[3,5,4], Masaya Hiraishi[1,2], Gavin King[1,2], Janik Wolters[3,5], Jevon Longdell[1,2]
[1]Department of Physics, University of Otago, Dunedin, New Zealand, [2]Dodd-Walls Centre for Photonic and Quantum Technologies, New Zealand, [3]Institute of Optical Sensor Systems, German Aerospace Centre (DLR), Berlin, Germany, [4]Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany, [5]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany

8A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 1:30 PM - 3:00 PM

Biography:

Luke Trainor did his PhD at the University of Otago in the group of Harald Schwefel, studying nonlinear optics in whispering-gallery resonators. He took up a postdoc in Jevon Longdell's group in 2021 and since then he has been working closely with Janik Wolters at the German Aerospace Centre (DLR) to store single photons in a rare-earth doped crystal, among other work focusing on rare earths in crystals.

Rare earth ions are well known for having narrow spectral lines they absorb and emit. When they are doped into a crystal at low concentration and cooled to cryogenic temperatures these lines narrow even further and the time the ions can stay in a quantum superposition state, their “coherence time” greatly increases.

We use erbium-167 ions doped in yttrium orthosilicate, which are cooled in a dilution refrigerator to about 25 mK. The erbium ions have narrow absorption features near 1550 nm, which is where optical fibres work best. If we can store single photons at this wavelength in such a way that the quantum information that they store is not lost, then we could use the resulting quantum memory as part of a wider network connected by optical fibres, and use that network, e.g. to send incredibly secure messages.

The erbium-167 ions have nuclear spin, which means we can alter the frequencies they absorb by changing their nuclear spin level. We use laser pulses to pump the ions away from certain frequency regions, meaning they only absorb the frequencies we want them to. The “spectral holes” we create last for about three days. We create a comb shape of regular holes, which acts like a frequency grating and stores the light for a time chosen with the comb-tooth spacing.

This "atomic frequency comb" memory is effective at storing both bright classical pulses of light as well as single photons. We create pairs of photons at different frequencies. These pairs of photons are generated in the same process and are correlated in time. When we store a photon from this pair, the time correlation is shifted, which we measure by counting the photons on single-photon detectors and determining the delay between the two detectors clicking.

Trapping Dysprosium in a Magnetic Optical Trap Directly from a Thermal Beam

Mr Liam Domett-Potts[1], Dr Lucile Sanchez[1], Dr Marvin Weyland[1], Mr Charlotte Hayton[1], Associate Professor Mikkel F.Andersen[1]

[1]The University of Otago, Dunedin, New Zealand

8A: Quantum Technologies Aotearoa, PLT1 Lecture Theatre (Building 303), July 3, 2025, 1:30 PM - 3:00 PM

Biography:

Liam Domett-Potts is a PhD student at the University of Otago, studying under Associate Professor Mikkel F. Andersen in the Otago Atomic Physics Laboratory. He completed his Honours degree working on an individually addressing atoms in optical tweezers. This talk covers the work done during his Master's degree, during which he designed and built a Dysprosium magnetic optical trap.

Dysprosium is the most magnetic element on the periodic table, which gives it the potential to display exotic physics. To study magnetic interacting atoms, we plan to capture single atoms of Dysprosium in optical tweezers, similarly to [1]. The first step is a 3-D magneto-optical trap (MOT), which combines the optical molasses technique [2] and spatial-dependent Zeeman splitting [3] to trap a cloud of Dysprosium atoms. The MOT is inside an ultra-high vacuum (UHV) chamber and an effusion cell produces a hot beam of Dysprosium atoms, from which it loads. An amplified external cavity diode laser, locked to an optical reference cavity, generates the 421nm light that forms the optical molasses. Water-cooled coils in an anti-Helmholtz configuration generate the magnetic fields. Our experiment is the first to load the MOT directly in the hot beam, prioritising simplicity over a large MOT population by going without a 2-D MOT or Zeeman slower, used in [4] and [5]. This talk presents our design and implementation of a simpler Dysprosium MOT. We also show the characteristics of the MOT, including how dark states play a critical role in its dynamics. We have greatly simplified the Dysprosium MOT by going without frequency doubling setups to generate the laser light [5], [6] and pre-cooling stages [5], [7]. Simplifying this process allows more laboratories worldwide to implement Dysprosium trapping and further our understanding of its exotic physics.

References

[1] Matthew McGovern. Isolating and manipulating single atoms. PhD thesis, The University of Otago, 2012.

[2] Harold J. Metcalf and Peter. Van der Straten. Laser cooling and trapping. Graduate texts in contem- porary physics. Springer, New York, 1999.

[3] B. H. Bransden and C. J. (Charles Jean) Joachain. Physics of atoms and molecules. Prentice Hall/Pearson Education, Harlow, 2nd ed. edition, 2003.

[4] Jianshun Gao. A First Two-Dimensional Optical Trap For Dysprosium. PhD thesis, University of Heidelberg, 2022.

[5] Mingwu Lu. Quantum bose and Fermi gases of dysprosium [electronic resource] : production and initial study. PhD thesis, Stanford University, 2014.

[6] Leonardo Del Bino. Development of an experimental apparatus for the realization of dipolar quantum gases of Dysprosium atoms. PhD thesis, University of Florence, 2015.

[7] Davide Dreon. Designing and building an ultracold Dysprosium experiment: a new framework for light-spin interaction. Theses, Universite´ Paris sciences et lettres, July 2017.

NCEA Internal Assessment – an NZQA perspective

Mr Raymond Neal[1]
[1] National Assessment Moderator - Physics, NZQA
8B: Education, Studio Space G03 (Building 303), July 3, 2025, 1:30 PM - 3:00 PM

Investigating in Physics.
Insights for assessing PESS 1.2 (92045).
Comparing Physics 2.1 and3.1.

Astronomy – Stars & Exoplanets

Mr Chris Currie[1], Mr Mark Standley[2]
[1]Palmerston North Boys High School, [2] Whanganui Collegiate School

8B: Education, Studio Space G03 (Building 303), July 3, 2025, 1:30 PM - 3:00 PM

Astronomy is one of the most fascinating topics in all of science. This session will discuss a junior high school classroom resource on stars, stellar evolution, black holes and exoplanets. We will explore hands-on activities you can use in your classroom.

Python notebook for illustrating electrodynamics concepts like AC current/voltage, phasors and resonances (year 13 NCEA content)

Dr Elke Pahl[1], Mr Tristan O'Hanlon[1]
[1]University Of Auckland, Auckland, New Zealand

8C: Education, Case Room G20 (Building 302), July 3, 2025, 1:30 PM - 3:00 PM

Biography:
Tristan is lecturing at the University of Auckland. He began his career as a secondary school physics teacher and has been the Head of Department and has extensive experience with the NCEA and CIE (Cambridge International Examinations) curricula. Tristan has organised national physics events: the International Young Physicists Tournament, CERN Masterclass and the ChipSAT Hackathon. Tristan works alongside Auckland secondary school physics teachers in organising the annual Physics Teacher's Day held at the University of Auckland and is involved in science teacher training though the Faculty of Education. He has implemented programming skills sessions in the training of beginning science and physics teachers.

Elke has studied chemistry and maths at the university of Heidelberg and got a PhD in theoretical and computational chemistry. During postdocs in Seattle, Dresden and at Massey University, Albany campus, she changed more and more into physics and became lecturer at Massey before moving to the university of Auckland in 2019. She has created a number of Programming in Python (PiP) labs used in first year physics courses and several Python and Julia notebooks for stage 2-4 students.

In this workshop we will be working with you through the beginning of a set of three Python notebooks, developed to introduce year 13 electrodynamics material. We guide you through interactive numerical programming activities, suitable for senior secondary students. The notebooks carefully introduce oscillating AC currents and voltages and the concept of phasors for capacitor/inductor circuits culminating in the explanation and visualization of resonances. Python skills delivered in the notebooks build on the set of three mechanics notebooks delivered last year as a 3-weeks professional NZIP development module.

This workshop is facilitated by Tristan O'Hanlon and Dr Elke Pahl from the University of Auckland. The set of notebooks has been developed during a summer project at the University of Auckland by year 2-physics student Nat Ruang guided by Dr Ben Pollard, Tristan O'Hanlon and Elke Pahl. Elke Pahl has created a number of Programming in Python (PiP) labs used in first year physics course and Tristan O'Hanlon has implemented programming skills sessions in the training of beginning science and physics teachers.

Abstracts – Poster Presentations

Measuring 6Li(n,3H)4He Reaction Cross-Sections in the 1970's for Today's Requirements

Dr Murray Bartle[1]
[1]Penguin Scientific And Medical Ltd, Rangitikei, New Zealand

Poster Networking Session, Exhibition Area (Building 302 Foyer), July 1, 2025, 5:00 PM - 6:30 PM

Biography:

After overseas postdocs/lecturing, Murray returned to NZ in 1980 joining DSIR/INS/GNS-Science until 2010. Created with partners fat-measuring production speed meat scanners used internationally 1990/2010. Consultant to NZ Customs in assessing/purchasing security scanners 2003/2006. VUW materials group contract/co-supervised 2 PhD students 2005/2013. VUW contracted lecturer 3rd year applied physics 2011/2015. IAEA expert Asia/Pacific 2010/2013; in Vietnam (2010), Malaysia (2010/2013) and China (2012). Contributed to NZ Royal Society Factsheet on Radiation (2022).

This poster outlines the author and co-workers 1970's measurements of 'cross sections' for the ^{6}Li(n,^{3}H)^{4}He reaction (reaction: ^{6}Li + neutron → ^{3}H + ^{4}He). Most fusion power reactor concepts are based on the ^{2}H(^{3}H,n)^{4}He (deuterium-tritium fusion) reaction and 'call on' the ^{6}Li(n,^{3}H)^{4}He reaction as a source of tritium (^{3}H). In 1971-74, ^{6}Li(n,^{3}H)^{4}He cross sections were measured in the 2 to 10 MeV (million electron volts) energy range using the University of Wisconsin's (Madison, USA) EN Tandem Van de Graaff accelerator. A neutron beam generated from the ^{2}H(^{2}H,n)^{3}He reaction was utilized. Briefly, deuterons (ionized deuterium) bombarded a deuterated polyethylene foil. In the associated particle technique (APT) method, detected ^{3}He ions identified associated neutrons in a neutron beam (via reaction kinematics) which was encompassed with a ^{6}Lithium Iodide scintillator detector/target. The APT provided precise timing between the neutrons and ^{3}He ions giving accurate neutron counting (absolute neutron flux measurement) and a low background count-rate. Results were presented March 3-7, 1975, at the Conference on Nuclear Cross Sections and Technology at Washington D.C. USA and published in the literature. Later in the 1975-77 period, the author and co-workers at the Australian National University (ANU), made measurements at higher neutron energies in the 12 to 18 MeV range. Higher neutron energies were achievable because the EN Tandem accelerator at ANU could be injected with a deuteron beam from a cyclotron. In summary, research work at two laboratories during 1971-1977, provided accurate ^{6}Li(n,^{3}H)^{4}He cross sections that have contributed to evaluated nuclear data files (ENDF's) and fusion reactor fuel predictions. For example, the data contributes to the 2018 ENDF/B VIII.0 files (Brookhaven National Lab., USA). Also supports 2017 theoretical calculations by the Chinese Institute of Atomic Energy (CIAE), Beijing.

Tracking a Space Mission: Engaging Classrooms with the Hēki Mission Aboard the International Space Station

Mr Tane Butler[1], Dr Betina Pavri[1], Dr Randy Pollock[1], Mr Reweti Arapere, Mr Max Goddard-Winchester[1], Mr Cameron Shellard[1], Ms Celine Jane[1], Mrs Lynn Young[1], Mr Joseph Bailey[1]
[1]Paihau-Robinson Research Institute, Wellington, New Zealand

Poster Networking Session, Exhibition Area (Building 302 Foyer), July 1, 2025, 5:00 PM - 6:30 PM

Biography:

Tane Butler is a Materials Science Researcher and Outreach Coordinator at Paihau-Robinson Institute. His background is in Semiconductor Physics and micro-fabrication of Spintronic devices. His research interests are in Quantum Computing, Spintronics, and STEM Communication. Tane holds a Masters degree in Physics.

Betina Pavri is currently a Senior Principal Engineer at Paihau-Robinson Research Institute, supporting development of superconducting magnet technologies for space applications. Previously, she worked as a senior operations/systems engineer at NASA's Jet Propulsion Laboratory as part of the development and operations team for the Mars Science Laboratory Rover, the Dawn Mission to asteroids Vesta and Ceres, and the Mars Reconnaissance Orbiter, among others.

Randy Pollock received his B.S. from the California Institute of Technology. He is currently the Chief Scientist/Engineer - Space at the Paihau -Robinson Research Institute. His current research involves the application of high temperature superconductors in space. Previously, he worked at NASA's Jet Propulsion Laboratory playing key roles in science instrument development -primarily spectrometers for Earth science missions used for climate research. He also served as Chief Engineer for the SHERLOC instrument for the Perseverance Mars rover.

Reweti Arapare is an illustrator, sculptor, and painter of Māori descent (Ngāti Raukawa ki te Tonga, Ngāti Porou, Ngāti Tūwharetoa). He studied at Massey University's Toioho ki Āpiti, earning his master's in 2009. His art, influenced by te reo, Te Ao Māori, and graffiti culture, reflects his bilingual upbringing. Arapare has exhibited widely, including at Auckland Art Gallery and the New Zealand Maritime Museum. His work honors Māori heritage and explores contemporary expressions of identity and language.

Max Goddard-Winchester Max Goddard-Winchester received his B.E (Hons) in Mechanical Engineering from the Canterbury University. He is a technician, where he leads the mechanical design and manufacture of superconducting systems for space applications including the development and integration of a superconducting magnet with a terrestrially tested plasma thruster, and development of a space-bound superconducting magnet system.

Cameron Shellard holds a B.E (Hons) in Mecha-tronics from Canterbury University and a Masters in Engineering from Victoria University of Wellington. His masters research involved simulating the electrification of aircraft in New Zealand. Since then, he has continued to work on experimental hybrid rocket technology and superconducting magnets for space applications.

Celine is an engineer in the space team at the Paihau—Robinson Research Institute. She has a Masters of Engineering from Victoria University of Wellington focusing on control system design for spacecraft using electromagnetic propulsion. Celine has previous industry experience in the NZ aerospace start-up scene, in addition to being award the NZ Space Scholarship in 2023 where she undertook an internship at NASA's Jet Propulsion Lab in California. Celine spends her time developing spaceflight software and avionics, orbital and thermal models of spacecraft, and electromagnetic thruster instrumentation.

Lynn Young - Lynn received her B.E (Hons) in Electrical and Electronics Engineering from the University of Canterbury. She is a Space technician at Paihau-Robinson Research Institute. Lynn was responsible for cryogenic wiring harnesses and was involved in testing and the assembly of Heki.

The Hēki mission, scheduled to launch to the International Space Station (ISS) in 2025, provides a unique opportunity to bring space research into classrooms. Developed in New Zealand, Hēki is designed to explore advanced propulsion technology and engage students in real-world physics and engineering challenges.

Hēki will test how powerful magnets can enhance ion engine efficiency, a critical factor for making long-duration space missions operate more sustainably. By improving propulsion technology, spacecraft could carry larger payloads and operate longer in space. The mission will follow key phases—development, launch, ISS installation, in-orbit operation, and post-flight assessment—offering insights into space technology and problem-solving.

Educational engagement is at the heart of Hēki. Over the past two years, team members have shared their work via public talks and student events. As Hēki approaches its launch date. The team plans a mission blog, real-time updates, and interactive tools to allow students to follow progress, analyze data, and participate in hands-on activities. Teachers can integrate mission concepts into the NCEA Physics curriculum, linking topics such as mechanics, electromagnetism, and ionization. Engineering challenges, such as solving the heat dissipation issue in space, can serve as classroom problem-solving exercises.

The mission also highlights career pathways in space science. Students can learn from young engineers and scientists, explore aerospace education and internship opportunities, and discover the importance of diverse perspectives in STEM through Maori artwork.

Hēki is more than a space experiment—it's an invitation for students to engage with cutting-edge science, think critically, and envision their future in space research. Educators are encouraged to integrate mission resources into their lessons and inspire the next generation of space scientists and engineers.

Events:

Talks for students at 2024 TechStep event at Taiohi Tūrama - Rotorua Centre for YouthTalk and site tour for students from Hutt Valley and Wellington Schools.

Public talk and Q&A associated with showing of "Good Night Oppy" documentary at Te Papa Tongarewa, Wellington

Science Wairarapa public talk on Hēki mission and Mars Curiosity Rover

AeroSpaceNZ news article on Hēki and Kōkako

https://www.aerospace.org.nz/news/efficient-satellite-thrusters-at-paihau-robinson-research-institute

RNZ interview: "Our Changing World – Superconducting magnets and plasma rockets"

https://www.rnz.co.nz/national/programmes/afternoons/audio/2018915182/our-changing-world-superconducting-magnets-and-plasma-rockets

RNZ story: "Superconductor destined for space mission being built in Lower Hutt shed" https://www.rnz.co.nz/news/top/528504/superconductor-destined-for-space-mission-being-built-in-lower-hutt-shed

LinkedIn post on Hēki testing & completion of final NASA safety reviews

https://www.linkedin.com/posts/robinson-research-institute_spaceresearch-nasa-activity-7266952524715188225-q9Iz/

LinkedIn post on Hēki completing final NASA safety inspections and packing for launch

https://www.linkedin.com/posts/robinson-research-institute_the-h%C4%93ki-team-and-colleagues-at-voyager-activity-7294519272435761152-FwSm/

An in-depth Study of Phase-Shifted EPR-Bell States

J. J. Joshua Davis, Maarten Hoogerland, Carey L. Jackman, Rainer Leonhardt, Paul J. Werbos
[1]Dodd-Walls Centre for Photonics and Quantum Technologies, Maarten Hoogerland's Lab, Department of Physics, UOA, Auckland, New Zealand, [2]Dodd-Walls Centre for Photonics and Quantum Technologies, Department of Physics, UOA, Auckland, New Zealand, [3]Missouri University of Science and Technology, Rolla, The United States of America

Poster Networking Session, Exhibition Area (Building 302 Foyer), July 1, 2025, 5:00 PM - 6:30 PM

Biography:
Since 1998, Joshua has worked in cognition and consciousness research and published his master thesis in Cognitive Science, "The Brain of Melchizedek: A Cognitive Neuroscience Approach to Spirituality" (2009). From 2011 he has conducted research and published in the areas of Cognitive Neuroscience, Neurotheology, Philosophy, Semiotics and the Biophysics of Inner Peace. After 2018 Joshua has been doing experiments to study different cognitive and brain states via EEG measurements at Ian Kirk's Lab, Centre for Brain Research. In parallel he has been conducting a Bell experiment in Maarten Hoogerland's Lab at the Department of Physics, University of Auckland.

We will present novel findings from an extensive EPR-Bell experiment using photons generated by spontaneous parametric down conversion (SPDC) Type II. A distinctive aspect of the experiment is the introduction of a deliberate phase shift accompanied with a change from linear to circular (or elliptical) polarisation in one of the entangled photons using a quarter wave plate (QWP) at varying angles, creating Phase-Shifted EPR-Bell states (PSEBs). By setting the QWP angle at 22.5° or 45° for example, we modify the wave function whereby variations of "entangled" states are prepared and analysed. Some of the results are surprising and raise intriguing questions about the nature of "entangled" states, considering that experimental coincidence counts match the theoretical coincidence counts with significant accuracy, when measured using a pair of polarisers at different angles in each path, together with a pair of single photon counting modules (SPCMs), one in each path, and the aid of a coincidence detector.

The results confirm a range of quantum mechanical predictions but also reveal unexpected outcomes: certain PSEBs fail the Clauser, Horne, Shimony, and Holt (CHSH) inequality test, a fundamental benchmark for quantum entanglement.
However, the findings challenge conventional interpretations of "entanglement", suggesting that phase-shifted EPR-Bell States produce measurable quantum correlations in ways never considered before.

A deeper review of these intriguing results is necessary to understand their implications. Possible explanations for the lack of violations are discussed, offering insights into how "entanglement" is affected by phase and polarisation modifications. These observations open new avenues for exploring quantum mechanics, potentially refining our understanding of nonlocal correlations and the meaning of "entangled" states in experimental quantum optics.

Dynamics of Multiple Fields in Ultra-Light Dark Matter Models

Mr Leon Ge[1]

[1]Department of Physics, University of Auckland, Auckland, New Zealand

Poster Networking Session, Exhibition Area (Building 302 Foyer), July 1, 2025, 5:00 PM - 6:30 PM

Biography:

I am a master's student in physics at the University of Auckland. My research focuses on the theoretical and computational modeling of ultra-light dark matter (ULDM), especially the dynamics of multiple interacting fields and solitons. I am interested in cosmology, quantum theory, and numerical simulations, and I'm currently working on extending ULDM models using generalized Schrödinger–Poisson equations.

Ultra-light dark matter (ULDM) has attracted increasing attention due to its wave-like behavior on astrophysical scales, offering a compelling alternative to cold dark matter (CDM) in addressing small-scale structure problems. In particular, ULDM provides possible resolutions to longstanding CDM challenges such as the core-cusp problem and the missing satellites problem, which stem from discrepancies between theoretical predictions and observations of dwarf galaxies and halo substructures. While most studies have focused on single-field ULDM models, multiple interacting scalar fields naturally arise in extensions of high-energy physics, and deserve detailed investigation due to their rich phenomenology and strong theoretical motivation.

In this work, we study the nonlinear dynamics of multi-field ULDM systems, focusing on the time evolution and interactions of localized solitonic structures formed by different fields. Using a generalized Schrödinger–Poisson framework, we perform numerical simulations to examine the behavior of solitons with varying field masses and initial conditions. Our simulation framework enables us to accurately and efficiently track the independent evolution of each field while capturing their mutual gravitational influence with high spatial and temporal resolution. The results reveal complex dynamical patterns and energy transfer mechanisms that depend sensitively on the mass hierarchy, initial configurations, and spatial separations of the fields involved.

Microwave to Optical Frequency Conversion in Rare Earth Ions

Dr Gavin King[1,2], Luke Trainor[1,2], Jevon Longdell[1,2]
[1]University Of Otago, Dunedin, New Zealand, [2]Dodd-Walls Centre for Quantum and Photonic Technologies, Dunedin, New Zealand

Poster Networking Session, Exhibition Area (Building 302 Foyer), July 1, 2025, 5:00 PM - 6:30 PM

Biography:
Gavin King has dealt mostly with the optical and microwave properties of the rare earth ions in crystals, especially for microwave-to-optical frequency conversion.

He has also been involved in developing optical spectroscopy of gases for industrial safety devices.

Superconducting qubits are a particularly promising technology for practical quantum computing, but suffer from being microwave devices that couple naturally to microwave photons. Single microwave photons are all too readily lost at room temperature, so are not suitable for long-distance transfer of quantum states. In comparison, optical photons have a high characteristic energy and are not easily lost at room temperature, either in free space or guided through optical fibres.

The rare earth ions are particularly well suited to converting these microwave photons into optical photons using a three-level scheme, having readily accessible microwave transitions and narrow optical transitions; in particular, erbium has optical transitions around the lowest-loss window in silica fibre.

Raman heterodyne spectroscopy of erbium in yttrium orthosilicate (Er:YSO) has in the past shown number conversion efficiencies of around 10 ppm, using a sample with natural isotopic abundance of erbium at 4 K. The efficiency was limited by thermal populations in the 5 GHz microwave excited state, and by parasitic re-absorption by isotopic impurities.

With isotopically purified erbium-170 in YSO, it was shown that strong coupling could be seen between the erbium ions and a microwave resonator: a necessary prerequisite for efficient frequency conversion. Using this isotopically enhanced crystal, strong coupling was also shown between an optical cavity and the erbium ions, and microwave-to-optical frequency conversion was shown with efficiencies of around 1 ppm. Unlike the previous measurements with natural isotopic abundance, the efficiency was not limited by saturation of the system, but by thermal and mechanical control of the sample, and by the detection apparatus, suggesting that it is possible to easily increase the conversion efficiency.

Sea ice GPS trackers confirm the existence of the Victoria Land Coastal Current

Antonia Radlwimmer[1], Assoc. Prof. Inga Smith[1], Greg Leonard[1], Fabien Montiel[1], Christian Haas, Ruzica Dadic, Pauline Barras, Sean Chua, Andrea Foley, Chris Pooley, Adrian Eng-Choon, Wolfgang Rack
[1]University Of Otago, Dunedin, New Zealand

Poster Networking Session, Exhibition Area (Building 302 Foyer), July 1, 2025, 5:00 PM - 6:30 PM

Biography:

Inga researches and lectures in climate change related topics: Antarctic sea ice; greenhouse gas emissions from international transport; climate change physics; fluids and thermodynamics.

She has worked on research projects funded by the Marsden Fund, Deep South National Science Challenge, and the Antarctic Science Platform. Inga has been on the World Climate Research Programme's CLIVAR (oceans and climate) Scientific Steering Group, and she is an immediate past co-director of He Kaupapa Hononga: Otago's Climate Change Network. She has been to Antarctica 12 times with the New Zealand programme, and once with the US Antarctic Programme, and when working at the University of East Anglia in the UK she conducted research on the Antarctic Circumpolar Current between the Falkland Islands and South Georgia aboard the British Antarctic Survey vessel the "James Clark Ross". Inga grew up in Queenstown, where she attended Wakatipu High School, and has had a life-long drive to understand and protect cold and mountainous places.

During summer, when the pack ice decays in the Ross Sea, the sea ice on the western side of the Ross Sea will drift northward towards Cape Adare and finally out of the Ross Sea. When the fast ice breaks out later in the season, ice floes breaking free from the coast follow a similar path. Though satellite-based tracking algorithms have been developed and used successfully on this area for selected winter months, the remote tracking of ice floes with satellite imagery remains difficult. Coverage is intermittent due to the lack of coverage from geostationary satellites and frequent obstruction of polar orbiting satellites' line of sight by cloud cover. The ice floe landscape is highly dynamic: ice floes will break up, change shape or consolidate between two satellite passings. These factors make the tracking of single features extremely difficult. In the summers of 2022/2023 – 2024/2025, however, sea ice GPS trackers in the form of location tracking buoys were successfully placed on fast ice in McMurdo Sound. This ice subsequently broke out, following the trail of decaying pack ice northward along the western edge of the Ross Sea. The buoys transmit their locations as regularly as every ten minutes, making it possible to accurately track the movement of the ice floes. This enables the investigation of the drivers of the northward drift through collocation with local environmental factors such as winds and ocean currents. A preliminary comparison between the movement of the ice floes and wind and ocean current data from reanalysis has been undertaken and is presented here. From this comparison it is seen that the buoy tracks may observationally confirm the presence of the Victoria Land Coastal Current (VLCC) along the full stretch of the western coast of the Ross Sea. The existence of this current has previously been theorized and small portions of it have been observed via immersed drifters. But the 2022/2023 – 2024/2025 buoy track dataset is the first to document the surface current in its entirety, verifying both theory and localized observations.

Can we have Newtonian Solitons in the Early Universe?

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Biography:

I am Chiara and I am interested in early universe cosmology and the potential of gravitational waves to probe the first stages of cosmic evolution.

I graduated in 2022 from the University of Padova, in Italy, where I worked on a particular background of primordial gravitational waves known as scalar-induced gravitational waves.

Currently, I am studying structure formation in the post-inflationary epoch under the supervision of Professor Richard Easther, aiming to model the generated stochastic background of gravitational waves.

In typical inflationary scenarios, the inflaton field oscillates around its minimum after the accelerated expansion completes. In some cases, inhomogeneities can grow explosively, while in others, the universe is effectively matter-dominated and inhomogeneities grow gravitationally. The dynamics in the latter case resemble structure formation in the present epoch, leading to the formation of "inflaton halos" that host localized overdensities, or "solitons", at their centers. To first approximation, this epoch is described by the Schrödinger-Poisson equation, but inflaton self-interactions and relativistic gravitational corrections eventually become significant as the overdensities grow. Working with two representative inflationary potentials, we determine the extent to which the Schrödinger-Poisson description remains valid as inhomogeneities evolve in the early universe and assess the likelihood that this formalism becomes inconsistent prior to the completion of thermalization.