CONFERENCE BOOKLET

NZMASP - Christchurch 2024

Please consider the environment before printing this booklet.

Contents

Chapter 1

Important information

1.1 Contact numbers

For general, non-urgent enquiries, please contact us via our email: admin@nzmasp.org.nz

The conference organisers may be contacted using the details below:

- Liam MacDonald: 027 942 6239 or liam.macdonald@pg.canterbury.ac.nz
- Kate Truman: 021 265 0850 or kate.truman@pg.canterbury.ac.nz

Other important contacts are:

- Christchurch police station: 105 (111 for emergencies)
- Riccarton Clinic Urgent Care: 03 343 3661 (111 for emergencies)
- Corporate Cabs Christchurch: 0800 789 789
- Blue Star Taxis: 03 379 9799
- ‘Safe to talk’ national sexual harm helpline: 0800 044 334 (or text 4334)

See Chapter 5 on our Code of Conduct for an anonymous reporting form link.

1.2 Accommodation

The accommodation we have organised is at Arcady Hall from Sunday 24th to the morning of Thursday 28th November.

The accommodation is at
90 Waimairi Road, Ilam, Christchurch 8041
03 364 2747

Check-in is from 4pm on Sunday. We expect most check-ins by 8pm, however Arcady can allow late check-ins which are known in advance. If you have not already done so, please provide us with your arrival time here. You will need to check-in at reception when you arrive, which can be accessed via the wheelchair ramp on Waimairi Road.

1.3 Transport

If you are arriving into Christchurch via the airport, we recommend catching bus number 3 to the UC campus outside the Student’s Association. From this stop, head down Homestead Lane on the opposite side of Ilam Road to reach Arcady. You can find information about the airport bus stop here. Bus number 3 will also take you into the Christchurch Bus Interchange if you want to head into the CBD.

Bus fares can be paid using cash or a MetroCard. We highly recommend that you order a MetroCard online for $10. You will need to allow a week or two for this to be posted to you. This gives you access to cheaper individual fares and daily and weekly fare caps, and if you’re under 25 years old, it only takes 4 trips to be the cheapest option.

1.4 Venue

The conference will be held in Rātā (formerly called Engineering Core) at UC's Ilam Campus (69 Creyke Road, Ilam, Christchurch 8041). From the accommodation, it is a 15 – 20 minute walk if you cut through campus. If you wish to catch a bus (this will take longer than walking!), we suggest:

- The Orbiter Anti-clockwise from the *Waimairi Road near Athol Tce* stop to the *Riccarton Road near Newnham Tce* stop. The Orbiter runs in both directions — exiting Arcady Hall onto Waimairi Road you want the bus running **left** towards Riccarton and Barrington.
- Next, catch the number 100 / The Palms bus from the *Riccarton Road near Newnham Tce* stop to the *University — Creyke Road* stop.

We recommend checking the Metro website for up to date information about delays/cancellations.

In Christchurch Lime and Neuron e-scooters are able to be rented.

Rātā E5, located on the ground floor, will be the main room for conference talks. Nearby room Rātā 128 will be available as a quiet space for those needing a break from talks, and E7 will be used as an additional lecture theatre on Tuesday.

1.5 Information for presenters

Most attendees at NZMASP 2024 will be giving a presentation. Talks will be 15 minutes in length, followed by 5 minutes question time. Presentations by the plenary speakers will be 60 minutes in length (including question time). Refer to the programme in chapter 2 of this booklet to see when we have scheduled for your talk.

Tips for your presentation

- Keep it simple. Most of the audience will not be experts in your particular field. In fact, a large portion of your audience won't know more about your field beyond an undergraduate level, so please keep these people in mind.
- Less is more. You have limited time and your audience have limited attention; you may want to focus on a small aspect of your research and explain it well.
- Ensure that slides will be readable from the back of the room. Equations can take effort to read; use them when appropriate but don't go overboard.
- If you use videos or any non-standard tech, have them open and ready to go and have a back-up plan if it doesn't work.
- Practise your talk. Know what you are going to say, and how long it will take.
- Look at the audience, and make eye contact. Pause and take a breath between paragraphs or slides. Try to have fun :)
- Taking questions after the talk is important, but it is okay to not know all the answers. If you're stuck for an answer, say you don't know off the top of your head and follow up later.
- Acknowledge the people and organisations which have contributed to the work you present; supervisors, collaborators, funding etc.

Slides

We encourage presenters to upload their slides to the google drive folder using this link. (Please put your talk in the folder labeled with the day of your presentation.) If possible, please format your slides as a pdf and include animation files separately.

Presenters may also:

- bring their slides on a USB drive
- bring their own device if they want to use a specific program.

If presenters are bringing their slides on a USB or using their own device then please get in touch with a member of the committee in the break before the session with your talk.

Recording

We will not be recording any of the presentations. Participants are welcome to film/record their own talk if they so desire. Please do not make a recording of someone else's talk without their enthusiastic permission.

1.6 Information for session chairs

The conference organisers wish to thank all of the volunteer session chairs, as they greatly help with the running of the conference.

Role description

Session chairs are each in charge of a session involving 3-4 student speakers. Their main job is to introduce each speaker and let them know if they are running out of time. After each talk, they should ask the audience if there are any questions and have a question prepared themselves in case nobody from the audience asks one. The question can be something general, such as "how did you become interested in this topic" if a speaker's talk is outside the chair's expertise.

When introducing a speaker, please be mindful of their pronouns. If you are unaware of a person's pronouns, please use gender-neutral language when referring to them.
Chairs will be provided with a warning card to show speakers when they have five minutes and one minute remaining of their speaking time. The chair will ring a bell if a speaker has gone overtime.

1.7 Prizes

The NZMASP conference will award prizes to recognise the most outstanding student speakers. The prizes are voted for by the audience and a voting form will be made available at the end of the conference. While listening to the presentations, please keep a note of any talks you may wish to vote for. Towards the end of the conference, we will post a Google form to allow you to allocate your votes for each different category.

The winner of each prize will receive a monetary reward, excluding our '*most entertaining prize* which come with a mystery gift.

Rules and criteria

- You may not vote for yourself (please be impartial)
- When calculating the subject prize winners, your first preference vote is worth two points, whereas your second preference vote is worth one point.

Prizes available

Overall prizes

- The Reserve Bank of New Zealand (RBNZ) prize for the best overall student presentation
- Second place overall student presentation
- Third place overall student presentation

As well as a monetary prize, our top three awards include a year of Wolfram | One Professional Edition, courtesy of our generous sponsor Wolfram Research and valued at $1,660.

Study level prizes

- The Maths Craft New Zealand Prize for excellence at Masters Level
- The Harmonic Analytics Prize for excellence at Honours level

Subject prizes for pure mathematics

- The New Zealand Mathematical Society Prize

Subject prizes for applied mathematics and mathematical physics

- The Australian and New Zealand Industrial and Applied Mathematics (ANZIAM) prize

Subject prizes for pure and applied statistics

- The New Zealand Statistical Association (NZSA) prize

Subject prizes for data science

- The Dragonfly Data Science Prize in Computer & Data Science

Presentation, style and entertainment prize

- The NZMASP most entertaining prize

1.8 Social events

Tuesday 26th: NZMASP roundtable

A roundtable discussion on the future of the NZMASP conference will be held at 7:00 pm on Tuesday in E5.

Wednesday 27th: Jane Street social event at Dice & Slice

Jane Street®

A complementary social event will be held at Dice & Slice on Wednesday 27th from 6pm to 9pm. Dice & Slice is a board game bar and pizzeria at 5/181 High Street. It is a 5 minute walk from the Bus Interchange in the CBD. Food will be provided at this event, however, any drinks must be purchased by attendees. This event is exclusively sponsored by Jane Street, who are generously also providing their own board games.

Thursday 28th: Prize-giving

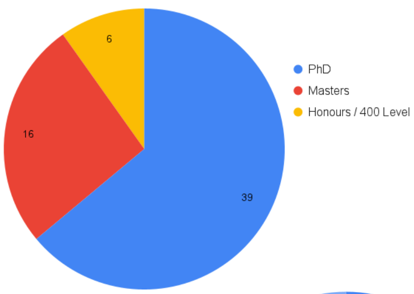
Will feature the awards ceremony, in which the conference organisers will thank the sponsors and plenary speakers and the committee and sponsors will present prizes for outstanding student presentations. We will also hand over the reigns of the NZMASP conference to next year's University of Auckland based committee.

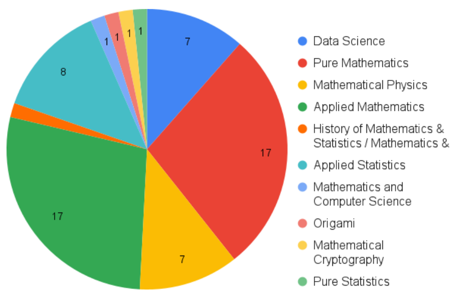
1.9 Photos

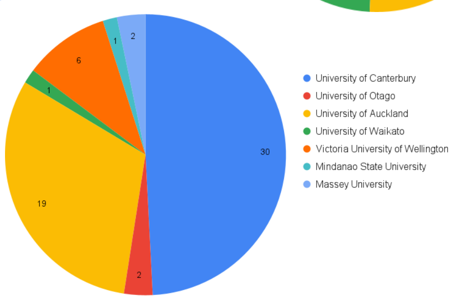
Feel free to add any photos of your time at NZMASP 2024 to our shared Google Photos album available at this link.

A conference group photo will be taken on Thursday 28th at 11:15 am.

1.10 Stats







Chapter 2

Programme

For the latest version of the programme, please visit our website.

2.1 Monday 25th

Start	End	Presenter	Title	Chair
8:40	9:00		Welcome + nametags	
9:00	9:20	Committee	Opening remarks & safety etc.	
9:20	9:40	Nathan Hartmann	History of the Tangent: al-Bīrūnī and his Shadows	Kate Truman
9:40	10:00	Daniel Wrench	Rejecting the Dull Hypothesis: learning to love statistics	
10:00	10:20		Morning tea	
10:20	11:20	Tilman Davies	NZSA Plenary Talk	Kate Truman
11:20	11:30		Break	
11:30	11:50	Jyotsna Garg	Investigating the Influence of Government Policies on Electric Vehicle Adoption in New Zealand	Evelyn Wen
11:50	12:10	Miranda Xu	Dyadic branching Brownian motion on a strip	
12:10	12:50		Lunch	
12:50	13:10	Sophia Witham	Arithmetic is hard, but some Inuit middle schoolers fixed it	Nathan Hartmann
13:10	13:30	Samuel Bastida	Friendship & Colouring In	
13:30	13:50	Merlyn Barrer	The Mathematics of Origami Design	
13:50	14:00		Break	
14:00	15:00	Maths Craft	Plenary Talk / Activity	Abigail Edwards
15:00	15:20		Afternoon tea	
15:20	15:40	Amin Boumerdassi	Investigating the inmpact of gravitational wave glitches on the parameter estimation of extreme mass ratio inspirals	Mitchell Cameron
15:40	16:00	Kang Wang	Galaxy Cluster Gas Pressure Profile Modelling with Reversible Jump MCMC	
16:00	16:20	Angeline Xiao	Evaluating the impact of timely access to concussion services on patient outcomes in Aotearoa	
16:20	16:30	Committee	Daily closing announcements	

2.2 Tuesday 26th

2.2.1 Room 1

Start	End	Presenter	Title	Chair
9:00	9:10	Committee	Welcome back	
9:10	9:30	Sebastian Petit	Codes From Generalised Polygons	Sophia Witham
9:30	9:50	John McLachlan	Intersections of three longest paths in polyhedral graphs	
9:50	10:10	Lynnel Naingue	On Graded Twisted Steinberg Algebras	
10:10	10:30		Morning tea	
10:30	11:30	Tessa Walker-Barrett	Plenary Talk	Liam Gibson
11:30	11:40		Break	
11:40	12:00	Michael Kelly	Generalised Twisted Groupoids and their C*-Algebras	Timotheus Keanu
12:00	12:20	Lander Verlinde	Nearly orthogonal sets over finite fields	
12:20	13:00		Lunch	
13:00	13:20	Zachary Buckley	A Deeper Dive into Cohen's Finite Quaternionic Reflection Groups	Lander Verlinde
13:20	13:40	Caitlin Mitchell	A Characterisation of Free Spikes	
13:40	14:00	Shai Levin	Bruhat-Tits Trees: Unfolding of the Supersingular Isogeny Graph	
14:00	14:10		Break	
14:10	14:30	Victor Lu	16-Descent on Elliptic Curves	Samuel Bastida
14:30	14:50	Pabasara Athukorala	Wagner's Algorithm for $\{-1,1\}^n$ vectors	
14:50	15:10	Timotheus Keanu	The p-adic Numbers: A Brief Introduction	
15:10	15:30		Afternoon tea	
15:30	15:50	Derek Perrin	Leveling Up Volcanoes	Sebastian Petit
15:50	16:10	Laurane Marco	Modular Polynomials and Isogeny Volcanoes	
16:10	16:30	Logan McDonald	Cardinal Characteristics and Computability	
16:30	16:40	Committee	Daily closing announcements	
19:00	20:00	Nathan Hartmann	Open roundtable discussion	

2.2.2 Room 2

Start	End	Presenter	Title	Chair
9:00	9:10	Committee	Welcome back - E5	
9:10	9:30	Breanna Camden	The Physical interpretation of the Newman-Penrose constants and Newman's H-space in Numerical Relativity	Merlyn Barrer
9:30	9:50	Sebenele Thwala	Towards non-linear scattering of gravitational waves	
9:50	10:10	Areeba Merriam	Numerical Implementation of the Friedrich-Nagy Initial Boundary Value Problem	
10:10	10:30		Morning tea	
10:30	11:30	Tessa Walker-Barrett	Plenary Talk - E5	Liam Gibson
11:30	11:40		Break	
11:40	12:00	Sam Doak	OK, but what is wild chaos? (Part 1)	Zac Isaac
12:00	12:20	Juan Patino Echeverria	OK, but what is wild chaos? (Part 2)	
12:20	13:00		Lunch	
13:00	13:20	Matthew Gibb	The mathematics of magnets and magnet-like systems on novel topologies	Bruna Caveion
13:20	13:40	Lachlan Campion	Numerically extending the Generalised Conformal Field Equations to include energy and momentum.	
13:40	14:00	Mark Bishop	My journey into the rabbit hole of turbulence	
14:00	14:10		Break	
14:10	14:30	Keetley Rate	Simulation of Two-Phase flows with the Conservative Level Set Method	Seigan Hayashi
14:30	14:50	Vincent Lomas	Modelling spread of an infectious disease between different ethnicities in NZ	
14:50	15:10	Davide Papapicco	Slowly, then all at once: uncovering the dynamics of a catastrophe	
15:10	15:30		Afternoon tea	
15:30	15:50	Samuel Bolduc-St-Aubin	Feedback with implicit state-dependent delay: a case study of ENSO	Mark Bishop
15:50	16:10	John Bailie	The role of conceptual models of the Atlantic Meridional Overturning Circulation	
16:10	16:30	Madeleine Barber-Wilson	Going Rogue Rogue waves arising from symmetry breaking in coupled oscillators	
16:30	16:40	Committee	Daily closing announcements - E5	
19:00	20:00	Nathan Hartmann	Open roundtable discussion - E5	

2.3 Wednesday 27th

Start	End	Presenter	Title	Chair
9:00	9:10	Committee	Welcome back	
9:10	9:30	Kate Truman	Implementing the Skyline Stratigraphic Ranges Fossilized Birth-Death Model in BEAST	Md. Azmir Ibne Islam
9:30	9:50	Bruna Caveion	Inferring Cancer Phylogenies from Single-Cell RNA and Multi-Omics Data	
9:50	10:10	Lilin Zhang	Kolmogorov-Arnold Networks for learning non-additive fitness landscapes	
10:10	10:30		Morning tea	
10:30	10:50	Abigail Edawrds	Wang Tiles, Aperiodicity and Computation	Shai Levin
10:50	11:10	Md. Azmir Ibne Islam	Dynamics induced by a heteroclinic network comprising five nodes	
11:10	11:30	Megan van Zyl	Post-Quantum Computing Applications in Cyber Security	
11:30	11:40		Break	
11:40	12:10	Vita Sudirham & Cameron Grubb	Opportunities at the RBNZ	Sebastian Petit
12:10	12:50		Networking with RBNZ / lunch	
12:50	13:10	George Robinson	Advantages of spatio-temporal early warning signals	Nasrin Nikbakht
13:10	13:30	Nic Lam	Evolving Improved Sampling Protocols for Dose Response Modelling Using Genetic Algorithms with a Profile-Likelihood Metric	
13:30	13:50	Evelyn Wen	State Space Modelling of Railway Operational Incidents: A Case Study in Wellington, New Zealand	
13:50	14:00		Break	
14:00	15:00	Rachael Tappenden	Plenary Talk	Liam MacDonald
15:00	15:20		Afternoon tea	
15:20	15:40	Liam MacDonald	A Generic Scheme for Quadratic Minimization	Nic Lam
15:40	16:00	Seigan Hayashi	Control-Based Continuation - Investigations in Macro to Micro Applications	
16:00	16:20	Nasrin Nikbakht	Numerical study of Chernoff approximations for parabolic heat-type equations with variable coefficients	
16:20	16:30	Committee	Daily closing announcements	
18:00	21:00		Dice & Slice	

2.4 Thursday 28th

Start	End	Presenter	Title	Chair
9:00	9:10	Committee	Welcome back	
9:10	9:30	Yvonne Li	Optimising Healthcare Pathways for Elderly Patients: wellbeing, equity and efficiency	Liam MacDonald
9:30	9:50	Pooja Baburaj	Data and Metadata Model Inspired by SDMX to Enhance Causal Inference with Urban Data	
9:50	10:10		Morning tea	
10:10	11:10	Finlay Thompson	Plenary Talk	Kate Truman
11:10	11:20		Break + group picture	
11:20	11:40	Mitchell Cameron	Probabilistic Machine Learning What Model Works Best?	Daniel Wrench
11:40	12:00	George Smith-Kolff	Sound Generation with Variational Autoencoders	
12:00	12:20	Committee	Voting for prizes	
12:20	13:00		Lunch	
13:00	13:20	Liam Gibson	How to teleport and kill dragons	Liam MacDonald
13:20	13:50	Committee	Prize-giving	
13:50	14:00		Concluding remarks	

Chapter 3

Speakers

3.1 Plenary Speakers

Tessa Barrett-Walker - Oranga Tamariki

Nō Ingarani ōku tīpuna. Ko Tessa Barrett-Walker tōku ingoa. I graduated from the University of Canterbury with a BSc(Hons) in mathematics and a BA in Te Reo Māori and Māori and Indigenous Studies in 2021. I currently work for Oranga Tamariki as a Senior Business Analyst in the Māori, Partnerships and Communities team. I am interested in multi- and interdisciplinary research, and exploring how maths, stats, and data can be utilised to meaningfully contribute to tino rangatiratanga.

Tilman Davies - University of Otago, NZSA speaker

I am a statistician originally from Perth, Western Australia. I completed my doctoral degree at Massey University in 2011 before joining Otago, where I am now a senior lecturer. My research — which deals with methods and applications in spatial statistics — has been supported by Marsden Fund grants and involves collaborators in industry and academia both here in New Zealand and internationally. In my spare time, I am an avid PC gamer, 3D printer, piano learner, and hazy-pale-ale-sampler. In his spare time, Tilman is an avid PC gamer, 3D printer, piano learner, and hazy-pale-ale-sampler.

Rachael Tappenden - University of Canterbury

Rachael Tappenden is an applied mathematician. Her primary research interests lie in optimization and numerical linear algebra, and applications in machine learning. Her research focuses on the development, theory, and implementation of algorithms for large scale problems. She was awarded her PhD from the University of Canterbury in 2011. In 2012, she took up a postdoctoral position at the University of Edinburgh, UK, followed by a postdoctoral position at The Johns Hopkins University, USA, in 2014, and in 2016 she became a lecturer at the University of Canterbury.

Finlay Thompson - Dragonfly Data Science

Finlay has extensive experience as a database and software developer. He leads the technical direction of Dragonfly's work, with a strong focus on open source technologies. He enjoys the challenge of making analytical and statistical solutions work in practice. Finlay researched four-dimensional algebra and geometry for his PhD in mathematics at SISSA, Italy. He completed post-docs at CIMAT in Mexico and Victoria University of Wellington, then worked in Wellington's IT industry before joining Dragonfly in 2008. Finlay is Adjunct Professor at University of Canterbury and chair of the Advisory Board for the Master of Applied Data Science programme at UoC.

3.2 Industry Speakers

Cameron Grubb - RBNZ

I am a Graduate Analyst at Te Pūtea Matua – The Reserve Bank of New Zealand, working in the Deposit Takers Statistics Team. A core part of my role involves working with residential mortgage statistics; specifically, we produce key data that supports monitoring and supervising higher-risk mortgage lending. Additionally, I've had the chance to work with other teams, like Data Development and Data Science Systems, on various projects.

I'm relatively new to the bank (and Wellington), having joined in February after completing my Master's in Economics (just three days before starting at the bank) at the University of Otago. Outside of work, I enjoy socializing with friends, exploring New Zealand's outdoors, and competitive target shooting.

Vita Sudirham - RBNZ

I have a background in computational mathematics with MSc and PhD degrees from University of Twente, Netherlands. I have several years of teaching experience, including as a lecturer at Bandung Institute of Technology in Indonesia and as a teaching fellow at Victoria University of Wellington. Currently, I am working as a Senior Statistical Analyst in the Deposit Takers Statistics Team at the Reserve Bank of New Zealand. My primary role includes producing statistical data on banks' financial statements and profitability. I also had the opportunity to work on several projects involving our database system. I am fond of working with numbers as well as learning about central banking and economics. Outside of work, I spend most of my time with my family, either watching movies at home or having lunch at one of our favourite restaurants.

3.3 Guest Speakers

Jeanette McLeod & Phil Wilson - Maths Craft New Zealand

Maths Craft New Zealand brings maths to the masses by celebrating the links between mathematics and craft. Maths Craft is a non-profit initiative founded in 2016 and run by mathematicians Dr Jeanette McLeod and Dr Phil Wilson. Jeanette and Phil are passionate about engaging the public with mathematics through craft. Their aim is to show young and old alike the fun, creativity, and beauty in mathematics through the medium of craft, and to demonstrate just how much mathematics there is in craft. By doing all of this, they help people to experience what it means to think like a mathematician.

Maths Craft New Zealand is Aotearoa's largest maths outreach initiative, having reached over 37,000 people so far. Along with Festivals and workshops across the country, Maths Craft ships Maths Craft in a Box to schools, runs teacher professional development, and more besides. For their work on Maths Craft, Jeanette and Phil were awarded the 2019 Cranwell Medal for Science Communication by the New Zealand Association of Scientists, were finalists for the 2019 Excellence in Science Communication Award from the Science Communicators Association of New Zealand, were elected as Fellows of the New Zealand Mathematical Society in 2020, and in 2022 won the NZMS Gillian Thornley Award for outstanding contribution to the cause or profession of mathematics.

Jeanette is Co-founder and Director of Maths Craft New Zealand. She has a PhD in pure mathematics from the Australian National University, and is currently a Senior Lecturer Above the Bar at the University of Canterbury, and a Principal Investigator in the New Zealand Centre for Research Excellence, Te Pūnaha Matatini. Jeanette carries out research in the areas of pure and applied graph theory. Phil is Co-founder and Deputy Director of Maths Craft New Zealand. He has a PhD in mathematics from University College London, and is a Senior Lecturer Above the Bar in the School of Mathematics & Statistics at the University of Canterbury, and a Principal Investigator in Te Pūnaha Matatini. He does research in fluid dynamics, mathematical modelling, and the philosophy of mathematics.

3.4 Student abstracts

3.4.1 Pure Mathematics

Pabasara Athukorala: *Wagner's Algorithm for $\{-1,1\}^n$ vectors*
Wagner's algorithm is an elegant approach for solving a k-dimensional extension of the classic birthday problem. Given k lists of n-bit values, the goal is to select one element from each list so that the XOR of the selected k values equals zero. For the case where $k = 2$, this reduces to the well-known birthday problem, which can be solved in square-root time. Wagner's algorithm extends this result, providing a cube-root time algorithm for $k = 4$ and more optimisations for $k > 2$. Due to its effectiveness and simplicity, Wagner's algorithm has become a widely used tool in cryptography and related fields. In this talk, we explore how Wagner's algorithm can be applied to a new problem: given k lists $L_1, \dots, L_k$ of n-dimensional vectors uniformly and independently sampled from $\{-1,1\}^n$, identify vectors $v_1 \in L_1, \dots, v_k \in L_k$ such that their sum, $v_1 + v_2 + \cdots + v_k = 0$.

Samuel Bastida: *Friendship and Colouring In*
In 1941, R.L. Brooks investigated one of the most important problems that had been vexing preschoolers for centuries: "How many colours are required to colour something in?". As it turns out, answering this question in general is (to use a technical term here) "hard", however, Brooks was able to characterise when a graph with maximum degree k is k-colourable. In 2016, Stiebitz and Toft were able to expand Brooks' Theorem to characterise when a graph with maximum friendship k (sometimes called maximum local edge-connectivity k) is k-colourable. It is known that Brooks' Theorem extends to list-colouring (a more general form of colouring that is even "harder" than the original) and so we determine whether or not Stiebitz and Toft's Theorem also extends to list-colouring and obtain some

rather surprising results.

Zachary Buckley: *A Deeper Dive into Cohen's Finite Quaternionic Reflection Groups*
The Finite Quaternionic Reflection Groups (and their root systems) were classified by Cohen in 1980. These groups can be understood with the help of the computer algebra package magma; by creating the root systems of the reflection groups as matrix groups in magma, we can determine their irreducible subgroups and also achieve a more comprehensive understanding of Cohen's Finite Quaternionic Reflection Groups. This presentation will detail some key preliminaries, such as complex/symplectic reflection groups and irreducible subgroups, before delving into some calculations we have made, some results we have found with magma, and what we hope to accomplish in this research project.

Abigail Edwards: *Wang Tiles, Aperiodicity and Computation*
Wang tiles are a type of theoretical domino proposed by Hao Wang in 1961. In 1966 Robert Berger found a set of Wang tiles which tile the plane only aperiodically. This proof used Wang tiles to simulate Turing machines, demonstrating that Wang tiles are capable of computation. In this talk we will examine the history of Wang tiles and aperiodic tilings, and methods of using Wang tiles for computation.

Timotheus Keanu: *The p-adic Numbers: A Brief Introduction*
As we learn more mathematics, we discover many kinds of numbers: Starting with the intuitive integers, we then deal with the fractions (the rationals Q). Slightly more advanced is the analytical completion of Q, the real numbers R. There is another type of completion of Q, which is distinct from the reals, but regardless has some similar properties: The p-adic numbers.

In this talk, we will discuss how to construct the p-adic numbers, and some basic results related to them. I will then explain how the p-adic numbers are applied to solve some problems.

Michael Kelly: *Generalised Twisted Groupoids and their C*-Algebras*
Twisted groupoids are a central object of study to C*-algebraists; twisted groupoid C*-algebras were introduced even before the usual groupoid C*-algebras in the thesis of Renault, and large classes of C*-algebras have been shown to arise from twisted groupoids.

A twisted groupoid is defined via a group bundle with fibres T, where T is the complex unit circle. My research extends this idea from T to any locally compact Hausdorff group; in this talk we will discuss different possible ways to construct a groupoid from this and in turn a C*-algebra, as well as how these constructions relate to each other. I will also discuss the possible generalisation to this setting of some useful theorems relating to twisted groupoids.

Shai Levin: *Bruhat-Tits Trees: Unfolding of the Supersingular Isogeny Graph*
The ℓ-Supersingular Isogeny Graph ("the graph") over characteristic p is a $(\ell + 1)$-regular, expander graph with approximately p/12 vertices. We may view this graph via it's universal covering graph, the Bruhat-Tits tree ("the tree"), which is an infinite, rooted, $(\ell + 1)$-regular tree.

When p is exponentially large (think larger than the number of atoms in the earth), computing neighbours of vertices in the graph is highly efficient, but finding paths between arbitrary vertices in the isogeny graph is believed to be computationally infeasible. Curiously this is not the case "upstairs" in the tree, where finding paths are easy.

In this talk I will give a very high level overview of quaternion algebras, and how they connect these two objects in a mysterious way.

Victor Lu: *16-Descent on Elliptic Curves*
The method of descent for Diophantine equations involves deriving auxiliary equations which may contain information on the solutions of the original equation. In modern number theory descent is used to find potential rational points of Abelian varieties. For elliptic curves over number fields K, algorithms for explicit p^n-descent for $p = 2$ and $n = 1, 2, 3$ has been developed. We aim to extend it to n = 4 case, which would allow us to find better bounds for the group of rational points E(K) when the Tate-Shafarevich group of E/K has nontrivial 2-primary part. In this talk we describe the general theory behind descent, and some of the work we've done so far for 16-descent on elliptic curves over number fields. Please note that this research is still ongoing.

Laurane Marco: *Modular Polynomials and Isogeny Volcanoes*
Modular polynomials are bivariate polynomials such that the kth modular polynomial captures the existence of a k-isogeny between two elliptic curves E, E'. Their main application is in a point-counting algorithm for elliptic curves due to Schoof, but they can also be used to compute the Hilbert class polynomial as well as endomorphism ring of elliptic curves over finite fields. In this talk, we will introduce an algorithm by Bröker, Lauter and Sutherland to compute modular polynomials using the volcano structure of isogenies of ordinary elliptic curves and give an illustrative overview.

Logan McDonald: *Cardinal Characteristics and Computability*
Cardinal characteristics of the continuum are the boundaries between countable sets and the reals with respect to specific properties. Where these cardinal characteristics provide an interesting structure of uncountable cardinals, we can find analogues in computability theory and obtain a rich structure of uncomputable objects. Analogues of a cardinal characteristic for maximal ideal independent families had not yet been studied, and it turns out they have properties similar to those previously studied in terms of maximal independent families and ultrafilter bases.

John McLachlan: *Intersections of three longest paths in polyhedral graphs*
In 1966, Gallai asked the question of whether all longest paths of a connected graph intersect. This question was answered negatively by Walther, and since then, mathematicians have discovered many graphs for which all longest paths do not intersect. In this talk, we will investigate the related conjecture that every three longest paths of a connected graph intersect. We will consider a class of graphs for which this conjecture remains open, and proceed by briefly outlining some known results. In pursuit of proving the conjecture for this class, we will then provide a series of preliminary results, in particular, properties of a theoretical counterexample.

Caitlin Mitchell: *A Characterisation of Free Spikes*
Matroids abstract the notion of independence, and naturally arise as the linearly independent subsets of the columns of a matrix or as the subsets of the edges of a graph that contain no cycles. A fundamental problem is to decide which matroids arise as the columns of a matrix. Such matroids are said to be representable. Spike matroids are a barrier to proving representability results. In this talk we give a characterisation of free spikes.

Lynnel Naingue: *On Graded Twisted Steinberg Algebras*
In this talk, we determine when large classes of algebras can be realized as twisted Steinberg algebras, which are built from topological groupoids. We generalize recent results in this area by introducing the notion of a graded algebraic Cartan pair. This was done for C*-algebras in 2019 by Brown, Fuller, Pitts and Reznikoff, which motivates our study. Their arguments are highly analytic and do not apply in our setting so we needed to develop new purely algebraic techniques. In this study, we show that there is a correspondence between the graded algebraic Cartan pair and the graded twisted Steinberg algebras. This is a joint work with Dr. Lisa Orloff Clark and Dr. Jocelyn P. Vilela.

Derek Perrin: *Leveling Up Volcanoes*
The components of an ordinary ℓ-isogeny graph of elliptic curves over a finite field $\mathbb{F}_q$ have a "nice" volcano structure. Given an integer N prime to ℓ and the characteristic of $\mathbb{F}_q$, we may "level up" these graphs by adding a $\Gamma_0(N)$, $\Gamma_1(N)$, or $\Gamma(N)$-level structure to its vertices. In this talk, we will discuss the structure of these graphs and show how their size and number of components is determined by the choice of parameters.

Sebastian Petit: *Generalised polygons and codes*
We all know polygons but you know what's even cooler? Generalised polygons! In this presentation, we give a brief introduction to this amazing theory. Prepare for some finite incidence geometry and graph theory while we explore these very regular structures which form the 'building blocks' of more complicated geometries. As a bonus, we also make a connection to coding theory. Generalised polygons can generate some codes for us. Using the geometry, we can then prove intriguing properties of these codes. In particular, we focus on the minimum weight.

This is based on research under the supervision of Geertrui Van de Voorde.

Lander Verlinde: *Nearly orthogonal sets over finite fields*
For a field $\mathbb{F}$ and integers d, k and ℓ, a set $A \subseteq \mathbb{F}^d$ is called (k, ℓ)-nearly orthogonal if all vectors in A are non-self-orthogonal and every $k+1$ vectors in A contain $\ell+1$ pairwise orthogonal vectors. Determining the maximal size of such sets has been studied extensively for different fields, showing some interesting differences depending on its characteristic. Recently, Haviv, Mattheus, Milojević and Wigderson have improved the lower bound on nearly orthogonal sets over finite fields, using counting arguments and a hypergraph container lemma. We generalise this by showing the existence of a set $A \subseteq \mathbb{F}^d$ of essentially the same size, with a stronger property that given any family of subsets $A_1, \ldots, A_{\ell+1} \subset A$, each of size $k+1$, we can find a vector in each A_i such that they are all pairwise orthogonal. This was previously known only for $\ell = 1$. Joint work with Rajko Nenadov.

3.4.2 Applied Mathematics

John Bailie: *The role of conceptual models of the Atlantic Meridional Overturning Circulation*
The Atlantic Meridional Overturning Circulation (AMOC) is a large-scale ocean circulation that transports warm surface waters from the topics to the sub-polar North Atlantic. Traditionally, mathematicians and climate scientists have used low-order climate models to explain variability in the strength of the AMOC. This talk aims is to describe

the role of conceptual climate models have played in the basic physical understanding of AMOC, its variability, and its potential for triggering tipping cascades within the larger climate system.

Madeleine Barber-Wilson: *Going Rogue: Rogue waves arising from symmetry breaking in coupled oscillators*
Spoken of for centuries in sailors' tales, rogue waves are a phenomenon of freakishly tall waves arising from nowhere in otherwise calm seas. Could the genesis of such waves be modelled mathematically, and if so, what kind of model should be used? This talk will discuss modelling rogue waves arising in a ring of coupled, D4-symmetric oscillators when we break their symmetry.

Samuel Bolduc-St-Aubin: *Feedback with implicit state-dependent delay: a case study of ENSO*
The El Niño-Southern Oscillation, or ENSO, manifests itself as periodic fluctuations in sea surface temperature and atmospheric conditions across the equatorial Pacific Ocean, which are notoriously hard to predict even with sophisticated global climate models. This motivates simpler representations of ENSO by considering the underlying feedback mechanisms only. We are interested in delay differential equation (DDE) models for ENSO, that portray the interaction between delayed feedback and seasonal forcing. More specifically, delays are introduced due to the finite velocities of the oceanic waves that transport warmer and cooler water across the Pacific Ocean, while a non-autonomous periodic forcing represents the seasonal variation.

In conceptual climate models, delayed processes are generally assumed to be constant. However, it is important to note that the use of constant delays is a modelling assumption. Delays in climate models are inherently non-constant and depend on the state of the system, and this makes state-dependence an appealing consideration from a modelling perspective. Building upon prior research, we extend our investigation of an established ENSO DDE model by incorporating implicitly defined state-dependent delays. We study here an idealised model where the delayed negative feedback is modelled by a step function. This enables us to construct solutions analytically and we prove that, for a large range of parameters, implicit state-dependent delay does not give different dynamics compared to the constant-delay case. These findings provide insight into why the introduction of implicit time delays may not significantly affect the dynamics, as when observed in a prior investigation.

Sam Doak: *OK, but what is wild chaos? (part 1)*
This is the first of two talks about wild chaos; here, we focus on discrete-time systems. Chaotic dynamics are characterised by deterministic unpredictability: similar initial conditions can lead to vastly different outcomes. Despite its apparent disorder, chaos can be understood through the regular geometric interactions that underlie it. Wild chaos builds upon classical chaos by introducing strange geometries that can only occur in discrete-time systems of dimension at least three. In this talk, I'll give a gentle introduction to wild chaos and how it manifests in a specific example. Furthermore, we will explore the geometric origins of wild chaos and highlight what makes it different from classical chaos.

Seigan Hayashi: *Control-Based Continuation - Investigations in Macro to Micro Applications*
Control-based continuation (CBC) broadly refers to a collection of methodologies that enables investigation directly on a physical system to trace out a bifurcation diagram of the nonlinear system. CBC embraces the essence of numerical continuation by identifying solutions incrementally to create a curve of solutions that describes the dynamical landscape of the system. The key distinction with CBC is that it is applied in a physical setting, without requiring a mathematical model.

We apply CBC on two experiments. First, a periodically forced mechanical dual-beam experiment, best described as a macro-scale with a sufficiently slow timescale. Second, and of particular focus, on an externally excited active micro-cantilever, with relatively fast timescale - demonstrating the fastest timescales in CBC literature. In both experiments, we conduct an experimental bifurcation analysis, thereby revealing the bifurcation landscape of its dynamic response.

Md. Azmir Ibn Islam: *Dynamics induced by a heteroclinic network comprising five nodes*
Intransitivity plays an important role in ecological models of competition where no single species dominates. The behaviour of such models is organised by a heteroclinic network. In simple terms, a heteroclinic orbit is a solution that connects two equilibria of a system. A heteroclinic network is a union of several heteroclinic cycles, which are closed loops of heteroclinic orbits. The classic Rock-Paper-Scissors game is one example that serves as a basic model for competition between three species. When the game is translated into a system of differential equations in continuous time, it gives rise to a heteroclinic cycle that connects three equilibria, each of which represents the dominance of a single species. In this talk, we consider a spatially extended model of intransitive competition between not three, but five species; the dynamics can be viewed as an expansion of the Rock-Paper-Scissors game with two additional strategies. In this game of Rock-Paper-Scissors-Lizard-Spock, each strategy beats two of the strategies and loses to the remaining two. The system contains more equilibria, which represent dominance of only a subset of the species; the resulting heteroclinic network contains several different heteroclinic cycles. We will introduce the model and convey the richness of possible dynamics close to the heteroclinic network. We will present examples of new peri-

odic orbits that bifurcate from specific cycles in the heteroclinic network and show how they change as parameters vary.

Nic Lam: *Evolving Improved Sampling Protocols for Dose–Response Modelling Using Genetic Algorithms with a Profile-Likelihood Metric*
Practical limitations of quality and quantity of data can limit the precision of parameter identification in mathematical models. Model-based experimental design approaches have been developed to minimise parameter uncertainty, but the majority of these approaches have relied on first-order approximations of model sensitivity at a local point in parameter space. Practical identifiability approaches such as profile-likelihood have shown potential for quantifying parameter uncertainty beyond linear approximations. This research presents a genetic algorithm approach to optimise sample timing across various parameterisations of a demonstrative PK-PD model with the goal of aiding experimental design. The optimisation relies on a chosen metric of parameter uncertainty that is based on the profile-likelihood method. Additionally, the approach considers cases where multiple parameter scenarios may require simultaneous optimisation. The genetic algorithm approach was able to locate near-optimal sampling protocols for a wide range of sample number ($n = 3 - 20$), and it reduced the parameter variance metric by 33–37% on average. The profile-likelihood metric also correlated well with an existing Monte Carlo-based metric (with a worst-case $r > 0.89$), while reducing computational cost by an order of magnitude. The combination of the new profile-likelihood metric and the genetic algorithm demonstrate the feasibility of considering the nonlinear nature of models in optimal experimental design at a reasonable computational cost. The outputs of such a process could allow for experimenters to either improve parameter certainty given a fixed number of samples, or reduce sample quantity while retaining the same level of parameter certainty.

Vincent Lomas: *Modelling spread of an infectious disease between different ethnicities in NZ*
This project aims to identify and investigate the spread of diseases within and between ethnic groups of New Zealand. Starting with the first COVID-19 Omicron wave and looking at interaction between Maori, Pacific Peoples, Asian, and European/Other, an SEIR model was developed. This compartmental model tracked each population's Susceptible, Exposed, Infected, and Recovered separately. It considered each ethnicity having different contact rates with a bias to contact their own ethnicity. This was able to be fitted to the attack rates of COVID RAT testing data to get information on how diseases spread through different ethnicities within NZ. This is an important area of research as ethnicity-stratified models are able to explicitly quantify the effect of diseases on individual ethnicities, which has not been considered much in the past.

Liam MacDonald: *A Generic Scheme for Quadratic Minimization*
Minimizing the strongly convex quadratic function is equivalent to solving a system of equations. Among iterative methods for this problem there is always a trade-off between convergence rate and the cost per iteration. We will look at some of the common and state-of-the-art iterative methods for solving this problem, such as the Steepest Descent method and the Conjugate Gradient method. Under the Generic Scheme, these methods appear when choosing the appropriate search directions. The Generic Scheme allows for many different iterative methods to fit under a more general framework that directly establishes convergence.

Nasrin Nikbakht: *Numerical study of Chernoff approximations for parabolic heat-type equations with variable coefficient*
The method of Chernoff approximation was discovered by Paul Chernoff in 1968 and now is a powerful and flexible tool of contemporary functional analysis, see overview by Ya.A.Butko . This method helps to solve numerically the Cauchy problem for evolution equations, e.g., for heat-type equations and for more general parabolic second-order partial differential equations with variable coefficients. Solutions of the classical heat equation are already known and do not require any approximations; but for more complicated equations exact solutions are unknown, so numerical approximation are often requested by researchers dealing with PDEs. Chernoff approximations are functions defined by explicit expressions that contain variable coefficients of the equation and initial conditions as parameters. The rate of convergence of Chernoff approximations were studied theoretically by O.E.Galkin and I.D.Remizov in a general setting for arbitrary C0-semigroup. In the case where exact solutions are unknown, these solutions were numerically found by using Finite Differences method and general method of solving PDEs by MATLAB PDE Solver called "pdepesolve". We also provide graphical illustrations of convergence and its rate.

Davide Papapicco: *Slowly, then all at once: uncovering the dynamics of a catastrophe*
Many natural and human complex systems evolve on a slow timescale and are stable with respect to external perturbations. However, these systems can experience sudden rapid departures from their natural equilibrium, known as tipping events, which often bring catastrophic, unrecoverable repercussions.

Extreme paleoclimate events, ecosystems' collapse and economic crises are some examples of dynamical systems evolving slowly around an equilibrium until a tipping point causes a fast critical transition outside the basin of attraction and onto a new, unhealthy state. Given the disruption of natural equilibria and the potential unrecoverability of certain states past the critical transitions, forewarning of these tipping points has been the subject of extensive research for the past 30 years. Characterisation of these events and their early-warning signals starts with a dynamical interpretation of these different regimes and further develops into the realm of stochastic processes and transitional states.

Numerous precursors have been hypothesized and statistical measures have been derived as leading indicators of tipping events for simplified and low-dimensional dynamical systems. Despite these efforts several fundamental issues still plague the practical application of early-warning signals in natural timeseries, with their lack of consistency across a broad spectrum of real-world tipping points posing a major shortcoming in their reliability.

The purpose of this talk is twofold. In the first part we will address the challenges facing the generalisation of frameworks of tipping events to spatially-extended (high-dimensional) models. Subsequentially we will show how a novel, prototypical approach based on the finite-states probabilistic interpretation of critical transitions can potentially address the fallacies of previously proposed, model-based indicators.

Juan Patino-Echeverria: *OK, but what is wild chaos? (part 2)*
This talk follows up on part one about wild chaos; this part explores it in vector fields. Wild chaos is a form of higher-dimensional chaotic dynamics that can only arise in vector fields of dimension at least four. I will explain the concept of the Lyapunov spectrum, which helps to understand the need for the minimum dimension and how it relates to attracting chaotic dynamics. Moreover, I will explain the relationship between the geometric origins of a wild chaotic attractor in a four-dimensional Lorenz-like vector field and the corresponding Lyapunov exponents. Central to this talk is the concept of a Poincaré map, which allows us to apply the results concerning maps to differential equations.

Keetley Rate: *Simulation of Two-Phase flows with the Conservative Level Set Method*
Two-phase flows are complex fluid phenomena, occurring when two immiscible fluids with distinct properties interact within the same system. Studying such flows can help us understand many natural fluid processes such as raindrops, cloud formation and volcanic processes, as well as man-made systems such as emulsion production and water filtration. Simulating two-phase flows with surface tension is challenging as we are required to solve the Navier-Stokes equations in both fluids, as well as the free-surface problem at the moving interface between them. This work explores how a mass conserving level set method is used to solve the multi-phase flow problem, and how it can be extended to accommodate non-Newtonian dynamics.

George Robinson: *Advantages of spatio-temporal early warning signals*
Critical transitions occur when a system undergoes a sudden shift from one state to another. Early warning signals (EWS) are indicators which may be used to anticipate abrupt critical transitions in time-varying systems; these systems may be either temporal or spatio-temporal. EWS have been proposed for both classes of system, furthermore temporal EWS can be applied to spatio-temporal systems by averaging over the spatial domain. Spatially-informed EWS should, in principle, be able to outperform temporal EWS for spatio-temporal systems by making use of the additional spatial information. We describe methods and present a MATLAB software package for computing and comparing EWS for spatial systems. In this methodology, we highlight important factors to be considered for informing practical EWS use for empirical spatio-temporal data sets. This assessment of EWS based on these factors allows for an informed decision as to which EWS to apply to different systems in order to provide an indication of an impending critical transition. We also find that the results of our analysis of the EWS for the commonly used reaction-diffusion type model does not extend to other spatial models with similar dynamics. Therefore, it is important not to be overly reliant on reaction-diffusion type models when developing results regarding the practical use of EWS.

Evelyn Wen: *State Space Modelling of Railway Operational Incidents: A Case Study in Wellington, New Zealand*
The Wellington Metro Railway Network is crucial for connecting Wellington city to its surrounding areas. However, given its scale, complexity, and the region's unique geography, disruptions are not uncommon. In this study, we obtain the significant rail operational incidents in Wellington for the past seven years, classify the disruption causes, assign a severity level for each incident based on industrial knowledge, and aggregate to monthly level for time series analysis. The states in State Space Model refer to the unobserved dynamic evolution of observations (Commandeur & Koopman, 2007). Incorporating this concept, this study aims to examine the states of past operational incidents, predict future disruptions, and inform strategic decision making for preventive safety measures.

3.4.3 Statistics

Amin Boumerdassi: *Investigating the impact of gravitational wave glitches on the parameter estimation of extreme mass ratio inspirals*
Extreme mass ratio inspirals (EMRI) are a type of astrophysical event in which a compact and massive object such as two black holes of highly non-equal masses merge into each other. These result in the emission of gravitational

waves (GW) – the ripples in spacetime famously observed in 2015 by the LIGO collaboration. Many types of GW events can be parameterised by known astrophysical models, which permits estimation with Bayesian inference and MCMC. EMRIs are no exception to this, however parameter estimation of EMRIs is faced with numerous difficulties. These include things such as the 14-dimensional parameterisation of EMRIs, years-long observation times and highly multimodal likelihoods. One possible challenge for EMRI parameter estimation is the presence of GW glitches – a type of frequent, short-duration, high-amplitude noise event present in GW detectors. They are not true GW events, rather coming from local and often unexplained disturbances to the detector. For many types of GW sources, glitches are known to induce biases in the posterior distribution – however to date, no study has been conducted on the impact of glitches on EMRI parameter estimation. This project aims to investigate whether glitches result in biased EMRI posteriors, and to what degree this may be the case.

Mitchell Cameron: *Probabilistic Machine Learning: What Model Works Best?*
This presentation explores the application of machine learning algorithms for accurate probability estimation. Traditional approaches to probability estimation often face limitations in handling complex patterns in data. Common machine learning methods are typically used for regression and classification tasks with little regard for probabilities. Thus, giving rise to a nuanced approach to machine learning called "Probability Machines". The presentation begins with a theoretical overview of probability estimation, discussing challenges in conventional methods and the advantages of machine learning models. Special focus is given to gradient boosting machines, which provide strong theoretical and practical benefits. The presentation concludes with a replication study examining the impact of Fair Trade certification on the income of Ethiopian farmers. By employing advanced probability estimation techniques in the context of observational causal inference, this study revisits previous analyses and offers new insights into certification's economic outcomes.

Jyotsna Garg: *Investigating the Influence of Government Policies on Electric Vehicle Adoption in New Zealand: An Analysis Study on Consumer Behavior and Market Dynamics in 2024*
Electric vehicles (EVs) are proving to be an increasingly reliable way of reducing emissions from transportation. In this study, we explore the changes in consumer behavior that stemmed from two major government policies—the Clean Car Discount (CCD) and Road User Charges (RUC)—influencing potential electric vehicle (EV) purchasers in the New Zealand market. Arriving in 2024, after these policy interventions, our study wants to find out how financial incentives, environmental awareness, and changing vehicle costs will affect consumer choices. Through a combination of time series analysis and econometric modeling, this research aims to investigate changes in electric vehicle (EV) adoption patterns, specifically concerning the identification of structural breaks at the introduction of the Clean Car Discount (CCD) and Road User Charges (RUC). Second, the study will use the Berry-Levinsohn-Pakes (BLP) model to investigate how price differences and marginal cost affect consumers' electric vehicle (EV) demand. In the nascent stages, this research is intended to uncover what drives consumer choices and buying behavior. The expected results are a better understanding of EV uptake from these policies, general and specific behavioral mechanisms in the market that may drive electric vehicle (EV) uptake, as well as to what extent these may contribute to emissions reduction in New Zealand's move to more sustainable transport systems. This study will serve as a valuable resource offering a systematic evaluation of the government's impact on consumer behavior and environmental outcomes in New Zealand over time, supporting the achievement of New Zealand's climate objectives.

Yvonne Li: *Optimising Healthcare Pathways for Elderly Patients: Wellbeing, Equity, and Efficiency*
Healthcare systems face significant challenges as the population ages, with growing demand for resources and increasing pressure on healthcare facilities. This talk explores mathematical models designed to optimize healthcare pathways for elderly patients by balancing patient wellbeing, equitable access to care, and operational efficiency.

Three distinct models are presented. The first is a compartmental model, which addresses delays and queues in the emergency department and wards by analyzing the impact of routing probabilities on patient flow. The equilibrium distribution of patients is derived, and an optimal proportion of patients routed to elderly care is determined to minimize waiting times.

The second model, a beds-focused migration process, investigates the availability of beds in a hospital system by modeling patient movement and bed occupancy. A fixed-point approach is applied to compute the equilibrium distribution of bed usage, with the aim of minimizing the number of vacant or occupied beds and ensuring efficient resource use.

Finally, the third model introduces a static priority system for hospital admissions, where patients are classified by priority levels. The focus here is on how the allocation of medium-priority patients impacts the overall system's capacity, especially in high-demand areas like operating rooms. This model provides insights into managing patient queues and the conditional expected exceedance of bed capacity.

Together, these models offer some insights for managing hospital resources more effectively and ensuring patients receive timely care.

Kang Wang: *Galaxy Cluster Gas Pressure Profile Modelling with Reversible Jump MCMC*
This study introduces an innovative approach to modelling galaxy cluster gas profiles by combining Reversible Jump Markov Chain Monte Carlo (RJMCMC) with Nested Sampling. Traditional parametric methods, such as the generalised Navarro-Frenk-White (gNFW) profile, often face challenges like parameter degeneracy. In contrast, our method uses a flexible, semi-parametric nodal model to accurately define the gas pressure profile of galaxy clusters. This node-based model allows for automatic trans-dimensional model selection within a single program execution, eliminating the need to run multiple models and compare Bayes factors. Using data from the Coma, A2255, and A85 clusters observed by the Planck space telescope, our approach significantly improves the ability to describe the pressure-radius relationship compared to conventional parametric models.

Daniel Wrench: *Rejecting the Dull Hypothesis: learning to love statistics*
Maths has long been one of the most dreaded school subjects (present company notwithstanding). But even amongst mathematicians, statistics occupies a special place in hell for many. What if this aversion is merely a sampling error of experience? In this talk, we'll first examine the widespread reputation of statistics as boring and difficult - even dangerous. Then, armed with evidence spanning physics, coin flips, AI, and some classic probability riddles, I hope to update your prior belief, and - depending on your significance level - maybe just reject the Dull Hypothesis.

Angeline Xiao: *Evaluating the impact of timely access to concussion services on patient outcomes in Aotearoa*
The Aotearoa Concussion Cost-Effectiveness Services Study examined the cost-effectiveness of ACC-funded interdisciplinary concussion services for patients who have persistent symptoms after sustaining a mild traumatic brain injury. The study aimed to assess the impacts of timely access (the exposure of interest: early vs late presentation) to such services on symptom reduction, patient self-management, quality of life, functioning, and resource use. This longitudinal study followed participants over a period of 12 months after presentation. Mixed-effects regression models were used to determine the effects of presentation time on the outcomes. The assumed causal structure required the use of two-stage regression and inverse probability weighting to yield unbiased estimates of the exposure effects.

Miranda Xu: *Dyadic branching Brownian motion on a strip*
Brownian motion is the continuous-time analogue of a scaled simple random walk, widely used to approximate random motion. Let this be affected by a downward drift. Suppose that each Brownian path branches into two identical 'children' at some constant rate. We restrict the process to a finite length strip on the reals, and study the process under the assumption paths are killed on reaching the boundaries. The process can be decomposed into a "blue tree" of immortal paths bound to stay in the strip, and 'red sub-trees' branching off the main immortal process. It is then possible, using a martingale change of measure and Doob's h-transform, to study the immortal sub-process. It is possible to prove the existence of a critical strip width under certain conditions on the drift, for which the process almost surely becomes extinct (and a blue sub-tree is not possible). We use asymptotic arguments to study the probability of survival near criticality, and find a quasi-stationary limiting process at the critical width (using limits from above). Motivations include nuclear safety and study of combustion rates - we may for instance decompose the motion by dimension and independently analyse the motion on each axis.

3.4.4 Mathematical Physics

Mark Bishop: *My journey into the rabbit hole of turbulence*
Energy spectral densities are popular tools in the study of statistical properties, particularly for the analysis of turbulent flows. The spectral density contains information not only on the intensity, but also on the scale dependence of the turbulent fluctuations. Structure functions are a similar tool and provides similar information but in lag-space rather than Fourier-space. Unfortunately, in the strict sense, the structure function at a fixed scale is more appropriately thought of as the turbulent energy of all scales $\leq$ that scale. This presentation covers my journey into the rabbit hole of describing turbulent energy densities in scale-space, so called "signature functions", and their relations to Fourier-space spectral densities.

Breanna Camden: *The Physical interpretation of the Newman-Penrose constants and Newman's H-space in Numerical Relativity*
The Newman Penrose (NP) constants are five complex absolutely-conserved quantities defined on null infinity (scri+) for asymptotically flat space-times. Owing to a recent construction of an initial boundary value problem for the generalised conformal field equations, scri+ has been made accessible by numerical methods allowing the NP constants to be numerically determined for the first time. However, the NP constants have only been explicitly calculated for limiting cases such as stationary, time-symmetric or small deviations from axi-symmetric space-times which have limited relevance to physically-meaningful space-times.

We generalise this framework to include a wider selection of initial asymptotically flat space-times. By varying the initial physically-motivated parameters of these numerical evolutions, we determine how the NP constants depend on such parameters, and thus motivate an explicit physical interpretation of the NP constants. We also explore potential relationships between the NP constants, H-space and twistor theory as recently hinted at by Penrose.

Lachlan Campion: *Numerically extending the Generalised Conformal Field Equations to include energy and momentum.*
The best model we currently have to describe gravity is that of Einstein's field theory of general relativity (GR) which allows us to relate geometry to mass and energy. A novel prediction that was made using Einstein's theory was that of gravitational waves, which were first measured in 2015. Gravitational waves and phenomena such as energy and momentum are not well defined locally. but do have a well defined description at 'infinity', One method that is particularly well suited to study these phenomena, is that of conformal compactification, which allows "infinity" to be described by local differential geometry.

In the 1990's, Helmut Friedrich developed an extension of Einstein's field equations to include infinity, now known as the Generalised Conformal Field Equations (GCFE). The GCFE comprise a system of PDEs that can be reduced to a system of ODES in all components except the curvature components by a judicious choice of gauge (Conformal Gauss Gauge). The GCFE in this gauge has been used for numerical simulations, as undertaken by Frauendiener, Stevens et al., to calculate the propagation of gravitational waves in vacuum, namely with vanishing energy momentum tensor.

By using theoretical work undertaken by Juan Kroon, we generalize the existing framework to include energy momentum. This unlocks the ability to study phenomena, fully coupled to gravity, such as electromagnetic waves, charged black holes and various scalar fields. This talk showcases how this has been done.

Matthew Gibb: *The mathematics of magnets and magnet-like systems on novel topologies*
The Ising model is a simplified model of a magnet. Mathematically, the Ising model is a stochastic process which describes "spins" that are embedded in a discrete network, which represent tiny magnetic dipoles in a magnet. Many magnetic materials are well-modelled by the Ising model on a network generated by a regular tiling of Euclidean space, for which there (typically) are known exact solutions. However, there are a vast array of magnet-like systems called "cooperative phenomena" which may have more general, and often irregular, network structures. The limiting behaviours of irregular Ising models are not exactly known for large networks. In this presentation, we use enumerative and Monte Carlo methods to solve or approximate the limiting behaviour of irregular Ising models. Some of the irregular networks considered are new to the literature. Solution heuristics are identified, which support conjectures in the literature, and inspire some new conjectures.

Areeba Merriam: *Numerical Implementation of the Friedrich-Nagy Initial Boundary Value Problem*
Gravitational waves, first predicted by Albert Einstein in 1916, are ripples in spacetime that travel at the speed of light. They were only recently detected directly by observatories like LIGO and are generated when massive objects, such as black holes or neutron stars, collide. They are important because they are able to tell us information that electromagnetic radiation from surrounding matter can't provide. However, studying their non-linear behavior is extremely limited due to the complexity of the Einstein field equations.

The initial boundary value problem (IBVP) for the Einstein equations is a fundamental tool for most numerical studies of these equations. The first well-posed IBVP was introduced by Friedrich and Nagy in 1999. Although having many advantages over commonly used numerical formulations of the Einstein equations, it has only been numerically implemented in simple cases.

This talk discusses a numerical formulation of the Friedrich-Nagy IBVP as a means to explore the non-linear properties of gravitational waves.

Sebenele Thwala: *Towards non-linear scattering of gravitational waves*
Gravitational waves are ripples in the fabric of space-time that propagate at the speed of light. First proposed in 1916, they are produced by extremely compact objects such as neutron stars or black holes. These waves are governed by non-linear equations,namely the Einstein equations, and hence self-interact. In recent years, due to the pioneering work by the LIGO/VIRGO collaborations, we are now able to detect gravitational waves here on earth. To properly decode the information contained in these gravitational waves, a rigorous understanding of their self-interaction properties is necessary.

In this talk two things will be discussed:

The scattering problem for gravitational waves. The process of scattering is arguably the most important tool in fundamental physics for understanding interactions, with nearly everything known about nuclear and atomic physics coming from scattering experiments. This process includes an initial state, an interaction, and a final state. We will introduce what this process looks like for gravitational and the mathematics required to set up such a problem.

We will then present the numerical framework, that utilises a system called the Generalised Conformal field equations (GCFE). This is a system of equations obtained by conformally rescaling the Einstein equations to represent infinity in a finite manner. With this framework, we relate, in the fully non-linear regime, the gravitational in states to the gravitational out states.

3.4.5 Data Science

Pooja Baburaj: *Data and Metadata Model Inspired by SDMX to Enhance Causal Inference with Urban Data*
The application of the concepts in the Statistical Data and Metadata Exchange(SDMX) to data management provides a robust framework that adds to the performance of the causal analysis. This paper customizes an SDMX model and applies the result to tabular data with the aim of assisting researchers in organizing and analysing the complex urban data for establishing the causal links. This adaptation tackles the broad range of multivariate information and several types of data, which is frequently faced in urban studies. Moreover, richness and variability of such data are kept intact. Therefore, employing a robust SDMX structure for data structuration and standardization would bring added values about interoperability and coherence. Using such a framework inspired by SDMX with a simple template for defining concepts will shift the attention to the data itself, allowing it to support domain knowledge acquisition, automation, and integration. This paper illustrates how the modified version of the SDMX structures contributes to curing some common data problems, such as the lack of metadata, incompleteness, and complexity. This paper does not compare the results of causal inference but underlines a strategic approach to data management as a critical passage toward the unlocking of full potential in causal analytics, hence toward better decision-making and policy development. It also emphasizes the application of SDMX conceptual ideas for users to differentiate between attribute, dimensions, and primary values.

Bruna Caveion: *Inferring Cancer Phylogenies from Single-Cell RNA and Multi-Omics Data*
Understanding how cancer evolves within individual patients is crucial for developing targeted and effective treatments. Tumors develop diverse cellular subpopulations due to dynamic molecular changes, including mutations and epigenetic variations. Reconstructing cancer cell evolutionary histories, or phylogenies, can illuminate these developmental patterns, contributing to a more nuanced understanding of tumor growth and metastasis. Recent technological advancements, such as single-cell RNA sequencing (scRNA-seq) and multi-omics approaches, have opened the door to exploring these complex processes in unprecedented detail.

This project aims to leverage scRNA-seq and multi-omics data for constructing cancer cell phylogenies. A core focus will be to determine how these data sources, particularly gene expression, single nucleotide variants (SNVs), and methylation patterns, can provide additional evolutionary insights that DNA alone cannot capture. Initially, I will develop a simulation framework to generate synthetic datasets that mirror the biological and technical characteristics of scRNA-seq and multi-omics data. These simulations will help validate phylogenetic models by providing known evolutionary histories, against which I can assess the accuracy and robustness of various phylogenetic inference tools.

Following validation, I will refine evolutionary models to capture correlations between data types, thereby improving the models' applicability to real-world datasets. Ultimately, these models will be applied to actual glioblastoma and pancreatic cancer datasets to analyze tumor evolution in a biological context.

By addressing the challenges in scRNA-seq phylogenetic analysis—such as dropout events and amplification bias—this research hopes to advance the methodology for reconstructing cancer cell lineages accurately. The ultimate goal is to contribute to a framework that can enhance our understanding of tumor evolution, supporting more personalized and informed treatment strategies.

George Smith-Kolff: *Sound Generation with Variational Autoencoders*
In addressing the challenge of AI-generated audio synthesis, we adopt a focused methodology by training a Variational Autoencoder on snare one-shot sounds. This strategic decision is informed by an analysis of the existing landscape within generative AI for music composition, revealing notable deficiencies. Rather than grappling with the intricacies inherent in generating comprehensive musical compositions, this research concentrates on the synthesis of succinct one-shot audio samples. This deliberate restriction seeks to redefine the problem space, with the anticipation that the brevity of these samples may yield enhanced quality compared to current generative AI models. Our research posits this approach as a methodological refinement, steering away from the broader scope prevalent in current research, while aiming to contribute to a nuanced and elevated quality in AI-generated audio output.

Kate Truman: *Implementing the Skyline Stratigraphic Ranges Fossilized Birth-Death Model in BEAST*
BEAST (Bayesian Evolutionary Analysis Sampling Trees) is a software used in phylogenetics to infer evolutionary histories. Given molecular sequences or morphological data (factors describing the appearance of an organism), BEAST utilises Markov Chain Monte Carlo to infer how closely related different species are, and how long ago lineages diverged. The software supports many models which make different assumptions about evolutionary processes, such as whether the birth and extinction rates of species are constant or change over time, the inclusion of fossils to provide extra information, and whether species alive at the same time period evolve at the same rate.

A popular class of models are the Fossilised Birth-Death (FBD) models, which allow fossil data to be included without assuming that lineages go extinct at fossilisation. The Stratigraphic Ranges Fossilised Birth-Death (SRFBD) model includes additional information by explicitly including stratigraphic ranges, that is, multiple fossils of the same species with different ages. The SRFBD model, which has recently been implemented in BEAST, would be expected to produce less biased results than a general FBD model with the same diversification rates, but which does not allow multiple samples of the same species.

However, the SRFBD model does have a drawback, in that it only allows for constant diversification rates (birth, extinction and sampling). We thus focus on an extension, the skyline SRFBD model, in which diversification rates take piecewise-constant forms, and discuss considerations for its implementation in BEAST, so that it can be used to infer evolutionary histories.

Lilin Zhang: *Kolmogorov-Arnold Networks for learning non-additive fitness landscapes*
Learning non-additive fitness landscapes is crucial for understanding gene interactions and their complex effects on fitness. Kolmogorov-Arnold Networks (KAN) is a pioneering model proposed by a team at MIT. Inspired by the Kolmogorov-Arnold theorem, it replaces traditional linear weights with spline-parameterized univariate functions. As a powerful alternative to multilayer perceptrons (MLPs), it has quickly attracted the attention of the global AI community. This paper explores the application of KAN in learning non-additive fitness landscapes. To this end, we simulated experimental data based on real SNV data and conducted experiments. Experimental results show that KAN is comparable to the best existing methods in terms of accuracy and shows greater advantages in robustness, especially in noisy data that is closer to the actual situation.

3.4.6 Other

Merlyn Barrer: *The Mathematics of Origami Design*
In the past 50 years or so, origami design has undergone a revolution with modern designs becoming incredibly intricate or realistic, to the point where most laypeople are surprised it is even possible to fold modern designs from a single square of paper without cuts. In this talk, we will explore the fundamentals of the modern theory of origami design, and show how the problem of designing a model to represent a given subject can be reduced to packing circles in a square.

Nathan Hartmann: *History of the Tangent: al-Bīrūnī and his Shadows*
The history behind the tangent is extensive. Long belong it was known as a trigonometric function, shadows found from sundials were used in its place for astronomical purposes, relying on differing lengths to determine time of day and the time of year. This talk focuses on one minute episode in the story behind the tangent, focusing on Medieval Islamicate polymath al-Bīrūnī (973CE - c. 1050) and his comprehensive work on shadows. We examine the shadow table found in the 12th Chapter of The Exhaustive Treatise on Shadows.

Sophia Witham: *Arithmetic is hard, but some Inuit middle schoolers fixed it*
How we do and perceive arithmetic is largely influenced by our culture the numerals we use. We will learn about one of the newest numeral systems, Kaktovik numerals, as well as some ancient systems if we have time, to learn about how our cultures and numeral systems effect the way we do mathematics.

Megan van Zyl: *Post-Quantum Computing Applications in Cyber Security*
This project is dedicated to developing a proof of concept for online security frameworks in a post-quantum computing era, focusing on password authentication schemes and cloud-based private key usage. By leveraging the no-cloning property of qubits, it extends existing research to introduce storing private keys in quantum form on the cloud, mitigating quantum attacks. Strategies include task allocation between quantum and classical computers to optimise efficiency and accuracy while addressing quantum computing inaccuracies caused by noise. Evaluation methods include the challenger method for accuracy assessment and cryptanalysis to identify mathematical security weaknesses. The goal of the project is to conduct further research into practical solutions to facilitate the security of asymmetric cryptography in a post-quantum era.

Liam Gibson: *How to teleport and kill dragons*
The main goal in Minecraft is to kill the Ender Dragon. With over 140,000,000 monthly players, efficiently killing the Ender Dragon is a strong candidate for a Millennium Prize Problem of the 31th century, and beyond. As Confucius said "before one can fight the Dragon, one must find the Dragon". Thus, in this talk, I will discuss how best to find the Ender Dragon using triangulation and Bayesian inference.

Chapter 4

Sponsors

The conference organisers wish to acknowledge the sponsors of NZMASP 2024, as without their generosity this conference would be impossible.

The Reserve Bank of New Zealand

The Reserve Bank of New Zealand is New Zealand's central bank. They are primarily a policy organization and exist to promote a sound and dynamic monetary and financial system. For graduate opportunities, see their website.

Wolfram Research

Founded by Stephen Wolfram in 1987, Wolfram Research is one of the world's most respected computer, web and cloud software companies—as well as a powerhouse of scientific and technical innovation. As a pioneer in computation and computational knowledge, they have pursued a long-term vision to develop the science, technology and tools to make computation an ever-more-potent force in today's and tomorrow's world. Visit their website to find out more.

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Jane Street is a research-driven trading firm where curious people work together on deep problems. Jane Street has offices in some of the world's most dynamic cities, including a presence in Amsterdam, Chicago, Hong Kong, London, New York and Singapore. Discover graduate roles with Jane Street on their website.

The School of Mathematics and Statistics, University of Canterbury

Studying at Te Whare Wānanga o Waitaha | University of Canterbury prepares you to find your path, live your dreams, and change the world. Visit their website to find out more.

The New Zealand Mathematical Society

The New Zealand Mathematical Society (Inc.) is the representative body of professional mathematicians in New Zealand, and was founded in 1974. Its aims include promotion of research in the mathematical sciences, the development, application and dissemination of mathematical knowledge within New Zealand, and effective cooperation and collaboration between mathematicians and their colleagues in New Zealand and in other countries. Find out more at their website.

The New Zealand Statistical Association

The NZ Statistical Association, founded in 1948, is New Zealand's only association for professional statisticians. For a fuller description of the aims and activities of the NZSA, and background to this page, visit their aims and activities page.

Australia and New Zealand Industrial and Applied Mathematics

ANZIAM (Australia and New Zealand Industrial and Applied Mathematics) is a division of The Australian Mathematical Society (AustMS). Their members are interested in applied mathematical research, mathematical applications in industry and business, and mathematics education at tertiary level. The New Zealand Branch of ANZIAM aims to promote Applied and Industrial Mathematics in New Zealand. See their website.

Dragonfly Data Science

Dragonfly Data Science are a team of scientists and dreamers based in Aotearoa New Zealand, with a shared purpose of doing good with data. Visit their website to find out more.

Te Pūnaha Matatini

Te Pūnaha Matatini – the meeting place of many faces – is the Aotearoa New Zealand Centre of Research Excellence for complex systems. Visit their website to find out more.

Maths Craft New Zealand

Maths Craft brings maths to the masses by celebrating the links between mathematics and craft. They are passionate about engaging the public with mathematics through craft. Their aim is to show young and old alike the fun, creativity, and beauty in mathematics through the medium of craft, and to demonstrate just how much mathematics there is in craft. Find out more here.

Harmonic Analytics

Harmonic Analytics is a leading data science company based in New Zealand. Visit their website to find out more.

Chapter 5

Code of Conduct

The following Code of Conduct is designed for the NZMASP conference, however the same principles detailed below also apply to our Discord server. We want the server to be a safe and friendly environment for New Zealand Postgraduate Mathematics and Statistics students to connect, socialise and support each other.
The current committee reserves the right to issue warnings or remove any messages we view to be discriminatory, harassment, or in poor taste. Failure to head warnings may result in being banned from the server.

All participants in the NZMASP 2024 conference are required to agree to the code of conduct as a condition of registration.

The NZMASP organising committee is committed to a professional, open, productive, and respectful exchange of ideas. These aims require a community and environment that fosters inclusion, provides mutual respect, and embraces diversity.

The NZMASP conference is dedicated to providing a harassment-free conference experience for everyone, regardless of gender, gender identity and expression, sexual orientation, disability, physical appearance, body size, race, age or religion. We do not tolerate harassment of conference participants or staff in any form.

Conference participants violating these rules may be sanctioned or expelled from the conference without a refund at the discretion of the conference organisers.

Harassment includes, but is not limited to:

- Verbal comments that reinforce social structures of domination related to gender, gender identity and expression, sexual orientation, disability, physical appearance, body size, race, age or religion.
- Sexual images in public spaces
- Deliberate intimidation, stalking, or following
- Harassing photography or recording
- Sustained disruption of presentations or other events
- Inappropriate physical contact
- Unwelcome sexual attention
- Advocating for, or encouraging, any of the above behaviour

5.1 Enforcement

Participants asked to stop any harassing behaviour are expected to comply immediately. If a participant engages in harassing behaviour, event organisers retain the right to take any actions to keep the event a welcoming environment for all participants. This includes warning the offender or expulsion from the conference with no refund. Event organisers may take action to redress anything designed to, or with the clear intention of, disrupting the event or making the environment hostile for any participants. We expect participants to follow these rules for the duration of the conference, including at the conference venue, accommodation and all conference-related social activities.

5.2 Reporting

If someone makes you or anyone else feel unsafe or unwelcome, please report it as soon as possible. Harassment and other code of conduct violations reduce the value of our event for everyone. We want you to be happy at our event. People like you make our event a better place.

If you're not sure if something you have seen or experienced should be reported, please contact a member of the organising committee for an informal discussion on the issue using the contact details in the contact information section below. You can make a report either personally or anonymously.

5.2.1 Anonymous Report

You can make an anonymous report here. We can't follow up an anonymous report with you directly, but we will fully investigate it and take appropriate action.

5.2.2 Personal Report

You can make a personal report by contacting a member of the organising committee in person or via the contact details listed in the programme.

Messages can also be sent to admin@nzmasp.org.nz, please be aware that this is a communal committee address which all of the committee have access to.

When making a personal report, our committee members will ensure you are safe and cannot be overheard. They may involve other committee members to ensure your report is managed properly. Once safe, we'll ask you to tell us about what happened. This can be upsetting, but we'll handle it as respectfully as possible, and you can bring someone to support you. You won't be asked to confront anyone and we won't tell anyone who you are. We will consult you before taking any action based on your report. Our team will be happy to help you contact local law enforcement, local support services, provide escorts, or otherwise assist you to feel safe for the duration of the event. We value your attendance.

Chapter 6

Statement on diversity and equity

The New Zealand Mathematics and Statistics Postgraduate (NZMASP) conference intends to provide an open platform for all postgraduate students in mathematics and statistics to present their research and grow their collaborative networks; however, we recognize that these fields exhibit some of the lowest levels of diversity of gender, race and culture in academia. The organising committee for the 2023 NZMASP conference will seek to address these inequities based on the following guiding principles:

- While an ideal goal would be for the level of attendance of women, people with marginalised gender identities, people with disabilities and people from racial or cultural minorities to be representative of the New Zealand population as a whole, we acknowledge that this is currently unrealistic due to the historic and ongoing inequity in our field.
- Since we can't control who comes to the conference, our mission is to make the conference welcoming to all attendees, particularly if they identify with or belong to under-represented groups.

With this in mind, the NZMASP organising committee is addressing, and will address, these issues by:

- Establishing a good process for handling all forms of discrimination and harassment – please refer to our code of conduct for details,
- Regularly having discussions about cultural inclusion,
- Incorporating Maori language into conference addresses,
- Promoting the normalisation of women in STEM fields through the gender diversity of our invited speakers list,
- Bringing disabled access to the forefront of our planning efforts, particularly with regards to the conference venue and accommodation provider,
- Meeting the needs of attendees with disabilities that are not already catered for (such as the hearing impaired) on a flexible basis,
- Offering a variety of accommodation options which take people's preferences into account. In particular, while the primary mode of accommodation provided by the conference is shared, this can be adjusted to cater for different group and individual requirements,
- Offering support and flexible options for attendees travelling with children,
- Catering to a variety of dietary requirements including Kosher, Halal, vegan, vegetarian and food allergies.