New Zealand Mathematical Society Colloquium

3-5 December 2019
Massey University, Palmerston North

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Document history

This document is **version 2** of the programme, posted 13:30 Monday 2nd December 2019. It co-incides with the printed copy distributed to those who ordered one.

Major changes since version 1 (posted Friday 29th November 2019):

- Talks by Roberts and van Brunt swapped in schedule:
  - Roberts now *Wednesday 16:30, AH4*
  - van Brunt now *Thursday 14:30, AH4*

Welcome

We welcome you to Palmerston North for the 2019 New Zealand Mathematics Colloquium. This is the ninth time it has been held here on the Massey Palmerston North campus, and we are excited to have you joining us here once again for an excellent programme of lectures and events. We hope you enjoy the conference and your time with us here in Palmerston North.

Meeting overview

Venue

The main venue for the colloquium is the AgHort Lecture Block (AHLB; F10 on the campus map on page 7, or see `https://tinyurl.com/2019NZMSmap`).

Registration

The registration reception will be held on Monday 2nd December, 17:00–19:00 in the Riddet Atrium. See page 14 for more information.

The registration desk will be open from 8:15 on Tuesday and Wednesday in the AHLB foyer, for those who are unable to attend the reception.

Wireless

On campus you can connect to the following wireless networks:

- `eduroam`
- `MUGuests`
- `inspirefreewifi`

Morning and afternoon tea and lunch

Morning and afternoon tea and lunch will be provided on all three days (Tuesday–Thursday). These will be served in the AgHort Lecture Block Foyer.

Note on this programme booklet

The programme booklet is intended to be easy to navigate in both electronic and printed forms. Page references in the PDF are live links that will take you to the page in question; and at the top of each page there are page references to the daily schedules, so that you can quickly navigate to the schedule for any day.

Plenary Speakers

This year's plenary speakers are:

- Lisa Clark, Victoria University of Wellington;
- Steven Galbraith, University of Auckland;
- Bronwyn Hajek (ANZIAM lecturer), University of South Australia;
- Pedram Hekmati (Butcher-Kalman lecturer), University of Auckland;
- Jeanette McLeod (NZMS speaker), University of Canterbury;
- David Simpson, Massey University;
- Kerri Spooner, Auckland University of Technology.

Their abstracts can be found starting on page 16.

List of events

The following events will take place during the colloquium:

- Registration reception, Monday 17:00–19:00 in the Riddet Atrium (p14)
- Poster session, Tuesday 10:00–10:30 in the AHLB foyer (p14)
- Early career researchers discussion, Tuesday 12:30 in AH3 (p14).
- HoDs' meeting, Tuesday 12:30 at Wharerata (p14)
- Diversity panel discussion, Tuesday 18:00–19:00 in AHA1.01 (p14)
- NZMS AGM, Tuesday 17:00–18:00 in AH1 (p14)
- Mathematics Teachers' Day, Wednesday in AH1 and AH2 (p15)
- ANZIAM NZ branch AGM, Wednesday 12:45 in AH1 (p15)
- Colloquium dinner, Wednesday 19:00 at Wharerata (p15)
- Workshop on university mathematics teaching, Thursday 14:30 in AH3 (p15)

NZMS Colloquium code of conduct

Our conference is dedicated to providing a harassment-free conference experience for everyone, regardless of gender, gender identity and expression, age, sexual orientation, disability, physical appearance, body size, race, ethnicity or religion (or lack thereof). We do not tolerate harassment of conference participants in any form. Sexual language and imagery is not appropriate for any conference venue, including talks, workshops, parties, Twitter and other online media. A participant who experiences harassment or hostile behaviour may contact the following representatives:

- Vivien Kirk (NZMS President), v.kirk@auckland.ac.nz
- Dion O'Neale (ANZIAM NZ branch President), d.oneale@auckland.ac.nz
- Tammy Lynch, t.a.lynch@massey.ac.nz
- Richard Brown, r.g.brown@massey.ac.nz
- Christine Burr, c.a.burr@massey.ac.nz

These representatives will be available in person and via e-mail. Be assured that if you approach them your concerns will be kept in strict confidence and they will consult with you on any actions taken. In case of a formal complaint they will speak to all parties involved to try to resolve the issue without presupposition of guilt.

Organising Committee

The organising committee consists of

Tammy Lynch (chair)	Luke Fullard	David Simpson
Richard Brown	Robert McLachlan	Chris Tuffley
Christine Burr	Cami Sawyer	Bruce van Brunt
		Nicholas Witte

If you have any questions during the colloquium, ask any of the committee members who will be glad to assist.

Assistance

If you need any assistance during the colloquium, our School administrators Cynthia Cresswell and Ann Truter will be available from 8:30–16:00. They are located on the 4th floor of Science Tower B, Rm ScB4.11 (E9 on the campus map on page 7, or see https://tinyurl.com/2019NZMSmap). They can be reached by phone at 06 951 7600 or 06 356 9099 ext 84600.

Sponsorship

We are grateful to the following organisations for their generous support:

- School of Fundamental Sciences, Massey University
- New Zealand Mathematical Society (Inc.)
- ANZIAM (Australia and New Zealand Industrial and Applied Mathematics)

Campus information

Campus Map

The important venues for the colloquium are marked on the map on page 7, and on a Google map at https://tinyurl.com/2019NZMSmap

Parking

You can park your car in the Orchard Road car park (E12 on the campus map (p7), or see https://tinyurl.com/2019NZMSmap).

Coffee and shops

The nearest place to AHLB to get coffee is the student dining hall, located on the Concourse (far side of the Science Towers; grid square E8 on the campus map on page 7). Another option, with a lovely garden setting, is Wharerata (grid square F7 on the map).

The Concourse also has a small convenience store (the MUSA shop, next to the dining hall) and a bookshop (Bennett's), which also provides postal services.

Lost and Found / Campus Security

Massey has an on-campus security service available 24 hours, 7 days a week. If you have any concerns or problems relating to personal safety, property theft, suspicious activity, or require assistance for any reason, please contact Campus security, 06 350 5030.

Local Information

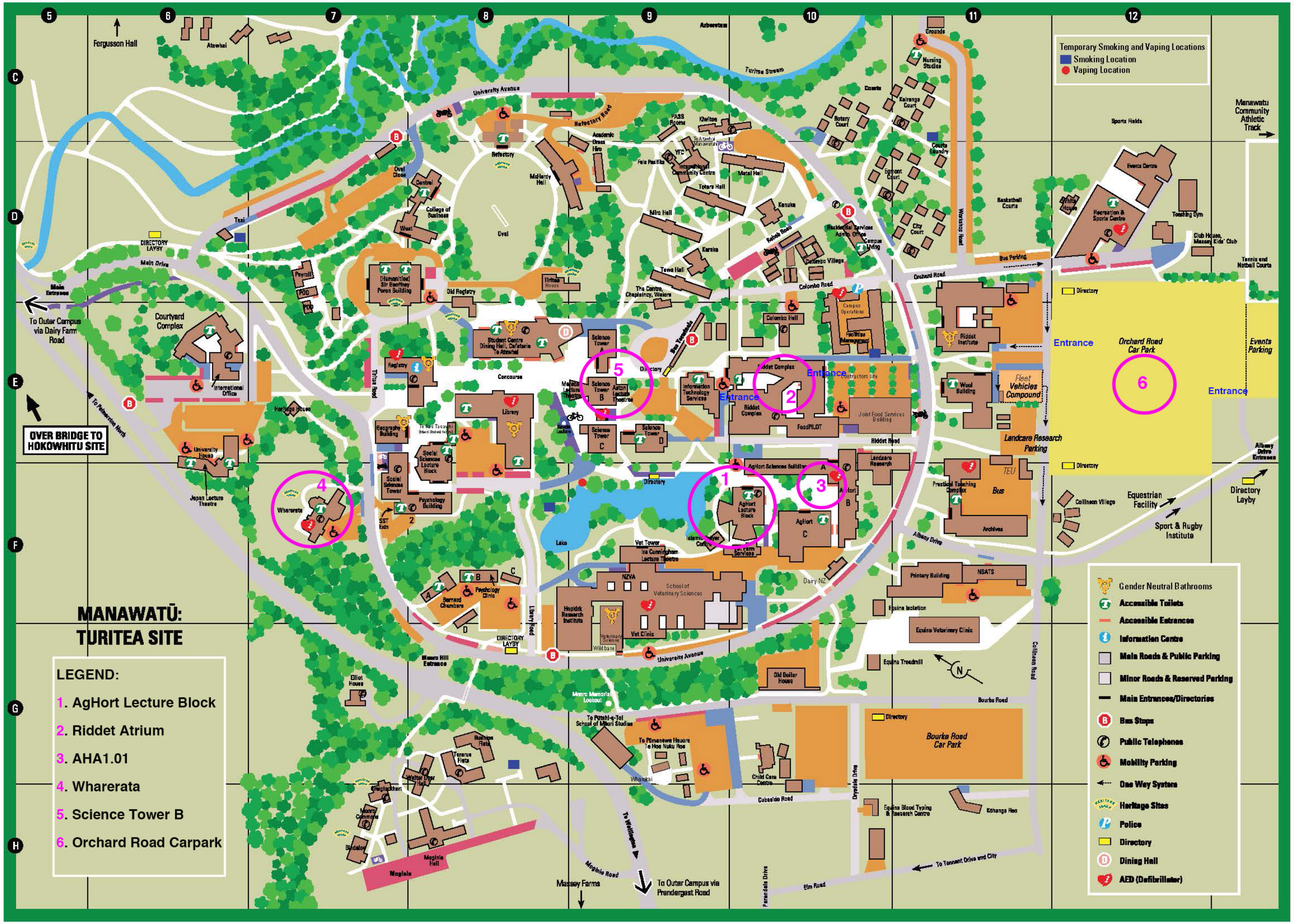
Transport

Taxis Taxis Palmerston North, 06 355 5333.

Buses A timetable for the bus service between the city and campus can be found at

https://tinyurl.com/nzms2019bus

Note that the buses will be running to the Non-Semester timetable, and as a result the last bus is quite early.


MANAWATŪ:
TURITEA SITE
LEGEND:
1. AgHort Lecture Block
2. Riddet Atrium
3. AHA1.01
4. Wharerata
5. Science Tower B
6. Orchard Road Carpark
Temporary Smoking and Vaping Locations
Smoking Location
Vaping Location
Gender Neutral Bathrooms
Accessible Toilets
Accessible Entrances
Information Centre
Main Roads & Public Parking
Minor Roads & Reserved Parking
Main Entrances/Directories
Bus Stops
Public Telephones
Mobility Parking
One Way System
Heritage Sites
Police
Directory
Dining Hall
AED (Defibrillator)
OVER BRIDGE TO HOKOWHITU SITE
Entrance
Orchard Road Car Park
Events Parking
Landcare Research Parking
Bourke Road Car Park
Fleet Vehicles Compound
To Outer Campus via Dairy Farm Road
To Outer Campus via Prendergast Road
Massey Farms
University Avenue
Library
Lake
Oval
Sports Fields
Equestrian Facility
Sport & Rugby Institute
Directory Layby
Manawatu Community Athletic Track

Eating out

The two main areas to find good restaurants in town are George Street and Broadway Avenue, both near the square.

Medical Emergencies / First-Aid

- The Palms (https://palmsmedical.co.nz), 445 Ferguson St, 06 354 7737.
- Emergency Department, Palmerston North Hospital, 50 Ruahine Street.

In an emergency dial 111.

Programme information

Venue

The main colloquium venue is the AgHort Lecture Block (AHLB; F10 on the campus map on page 7, or see https://tinyurl.com/2019NZMSmap). All plenary talks will be held in AH1, and parallel sessions will be held in AH1, AH2, AH3 and AH4. Morning and afternoon tea and lunch will be served in the AHLB Foyer.

Talks

Contributed talks are 20 minutes long, followed by 5 minutes for questions and another 5 minutes for movement between rooms. Plenary talks are 50 minutes long, followed by 5 minutes for questions.

To ensure the smooth running of sessions please upload your talk to the lecture theatre computer during the break prior to your session. Be aware that talks saved to the computers won't persist between logins, so it would be advisable not to load your talk too far in advance.

To help talks run to time, session chairs will be given yellow and red cards to indicate the time remaining:

- Yellow card: 5 minutes remaining.
- Red card: 1 minute remaining, please wind up and finish now.

Session chairs

Session chairs are listed on page 13. If you are chairing a session please check the time and room number. Please note the guidance on the coloured card system above, and ensure that sessions keep to time to enable movement between rooms.

There will be a box in each room containing the timing cards, a laser pointer, and a card with instructions. The instruction card has the login details for the guest user account to be used for the talks.

Notices

Any notices, including any changes to the programme, will be posted in the foyer of the AgHort Lecture Block Foyer (F10 on the campus map, page 7), the main colloquium venue.

Aitken Prize

The New Zealand Mathematical Society offers a $500 prize for the best contributed talk by a student at the New Zealand Mathematics Colloquium. This prize is known as the Aitken Prize, in honour of the New Zealand born mathematician Alexander Craig Aitken, and was offered for the first time at the 1995 Colloquium held in conjunction with the Aitken Centenary Conference at the University of Otago. Entrants for the prize must be enrolled (or have been enrolled) for a degree in Mathematics at a university or other tertiary institution in New Zealand in the year of the award.

Aitken prize speakers are marked with a star in the schedules.

ANZIAM poster prize

The ANZIAM poster prize is awarded for the best poster by an early career researcher. The first author of the paper must either be a student, or be within 5 years of the completion of their highest degree.

Schedules

Daily schedules and the list of session chairs follow on the next four pages.

Monday 2nd December 2019

17:00–19:00	Registration reception (p14), Riddet Atrium.

Tuesday 3rd December 2019

	AH1		AH3		AH4	
08:45	Welcome (AH1)					
09:00	*Plenary:* Clark (p16)					
10:00	Morning tea and poster session (p14), AHLB foyer. Abstracts page 43.					
10:30	Muni* (p31)	DS	Tennakoon* (p36)	MB	Toniazzi (p37)	A
11:00	Osinga (p33)	DS	Irvine* (p27)	MM	Yao* (p40)	A
11:30	Zafar* (p41)	DS	Hendy (p26)	MM	Hashemi* (p25)	A
12:00	Jeong* (p27)	DS	Witte (p40)	O	Wong* (p40)	A
12:30	Lunch, AHLB foyer		Early career discussion (p14), AH3		HoDs' meeting (p14), Wharerata	
13:30	*Plenary:* Hekmati (p17)					
14:30	Fok (p24)	GT	Mark* (p35)	C	Al-Sultani* (p19)	NA
15:00	Baeumer (p20)	NA	McVeagh* (p30)	C	McLachlan (p30)	NA
15:30	Afternoon tea, AHLB foyer					
16:00	*Plenary:* Hajek (p16)					
17:00	NZMS AGM (p14), AH1					
18:00	Diversity panel discussion (p14), AHA1.01					
19:00	*Day concludes*					

Key:

A: Analysis
ANT: Algebra and number theory
C: Combinatorics
DS: Dynamical systems
E: Education
GT: Geometry and topology
MB: Mathematical biology
MP: Mathematical physics
MM: Mathematical Modelling
NA: Numerical analysis
O: Other
* Aitken prize speaker

Wednesday 4th December 2019

	AH1	AH2	AH3	AH4
08:45	Mathematics teachers' day welcome (AH1; page 15)			
09:00	*Plenary:* McLeod (p17)			
10:00	Morning tea, AHLB foyer			
10:30	Cameron, part 1 (p23) E	Ah Sam (p19) E	Bachraty* (p20) C	Archer* (p20) MB
11:00	Cameron, part 2 (p23) E	Rattenbury (p33) E	Baykalov* (p21) ANT	Merry* (p31) MB
11:30	Sadat (p34) E	Klymchuk (p28) E	Conder (p24) C	Fatoyinbo* (p24) MB
12:00	Te Maro (p36) E	Locke (p29) E	Tuffley (p37) GT	Zaidi* (p41) MB
12:30	Lunch, AHLB foyer			
12:45	ANZIAM NZ branch AGM (p15), AH1			
13:30	*Plenary:* Spooner (p18)			
14:30	Ward (p38) E		Zhang (p41) MM	Krauskopf (p29) DS
15:00	NZMS Ed. Grp (p32) E		Cao (p23) MM	Ben-Tal (p22) DS
15:30	Afternoon tea, AHLB foyer			
16:00	O'Neale (p32) E		Lockyer (p30) GT	Laing (p29) DS
16:30	Sawyer (p34) E		Greenwood (p25) GT	Roberts (p33) MB
17:00	*Talks conclude*			
19:00	Colloquium dinner and NZMS awards (p15), Wharerata. Arrive from 19:00 for 19:30 dinner.			

Key:

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C: Combinatorics
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MP: Mathematical physics
MM: Mathematical Modelling
NA: Numerical analysis
O: Other
* Aitken prize speaker

Thursday 5th December 2019

	AH1		AH3		AH4	
09:00	*Plenary:* Galbraith (p16)					
10:00	Morning tea, AHLB foyer					
10:30	Bartlett (p21)	E	Chung (p23)	MP	Butcher (p22)	NA
11:00	Stephenson (p35)	E	Lim (p38)	MP	Graff (p25)	NA
11:30	Spooner (p35)	E	Weir (p39)	MP	Boglaev (p22)	NA
12:00	Novak (p32)	E	Sweatman (p36)	O	Joe (p27)	NA
12:30	Lunch, AHLB foyer					
13:30	*Plenary:* Simpson (p18)					
14:30			Teaching workshop (p15)		van Brunt (p38)	MB
15:00			*Workshop continues*		Hassell Sweatman (p26)	MB
15:30	Afternoon tea, AHLB foyer					
16:00			*Workshop continues*		Wilson (p39)	O
16:30			*Workshop continues*			
17:00	*Day concludes*					

Key:

A: Analysis
ANT: Algebra and number theory
C: Combinatorics
DS: Dynamical systems
E: Education
GT: Geometry and topology
MB: Mathematical biology
MP: Mathematical physics
MM: Mathematical Modelling
NA: Numerical analysis
O: Other
* Aitken prize speaker

Session chairs

		AH1	AH2	AH3	AH4
Tuesday	09:00–10:00	Bryant			
	10:30–12:30	Krauskopf		Fullard	McLachlan
	13:30–14:30	Butcher			
	14:30–15:30	Sweatman		Tuffley	Boglaev
	16:00–17:00	O'Neale			
Wednesday	09:00–10:00	Kirk			
	10:30–12:30	Leader	Murray	Mayhew	Brown
	13:30–14:30	Sawyer			
	14:30–15:30	Lawrence		Weir	Osinga
	16:00–17:00	Lawrence		Tuffley	Simpson
Thursday	09:00–10:00	Hendy			
	10:30–12:30	Rattenbury		van Brunt	Baeumer
	13:30–14:30	McLachlan			
	14:30–15:30				Ben-Tal
	16:00–17:00				Tuffley

Campus map: page 7

Schedules: Tues, page 10; Wed, page 11; Thurs, page 12

Events

Registration reception

Monday 17:00–19:00, Riddet Atrium

Drinks and pizza will be served. We have also organised a tour of the Riddet Brewery which will include beer tastings. The tour will start at 17:30.

The Riddet Atrium is located in grid square E10 on the campus map (page 7), or use the Google maps link: https://tinyurl.com/2019NZMSmap

Posters

Tuesday 10:00–10:30, AHLB foyer

The poster session will be held during morning tea on Tuesday 3rd December, 10:00–10:30 in the AHLB foyer. Presenters are asked to remain by their posters during this time.

Posters can be mounted from 8:30 on Tuesday, and can remain up throughout the colloquium. Please collect your poster by 17:00 Thursday.

HoDs' meeting

Tuesday 12:30, Wharerata

Wharerata is located in grid square F7 on the campus map (page 7), or use the Google maps link: https://tinyurl.com/2019NZMSmap

Early career researchers discussion

Tuesday 12:30, AH3

An informal gathering for early career researchers to get together and discuss ways NZMS might assist us as we develop our careers. Get yourself some lunch from the AHLB foyer and then join us in AH3.

Facilitated by David Simpson and Luke Fullard (Massey University).

NZMS AGM

Tuesday 17:00, AH1

Documents for the meeting can be found at https://nzmathsoc.org.nz/?agmthisyear

Diversity panel discussion

Tuesday 18:00, AHA1.01

The benefits that result from having diversity amongst the people who engage with and succeed in mathematics are many, including more equitable access to the many activities and careers that require mathematical thinking and the availability of a much larger pool of talented people to work in the mathematical sciences.

As a community we have known this for a long time but progress towards increased diversity has been extraordinarily slow; in NZ and internationally there is very uneven participation in mathematics in all its guises relative to socio-economic status, ethnicity and gender, as well as a range of other identity factors.

This session will look at some of the factors that contribute to the current situation in NZ, and may identify some concrete actions we can individually and collectively take to tackle the underlying issues. The focus will be particularly on factors related to ethnic

diversity.

Panel: Naomi Manu (Massey University and Pūhoro STEM Academy), Sina Greenwood (University of Auckland) and Ielyaas Cloete (University of Auckland)

Chair: Vivien Kirk (University of Auckland)

Gettting there: AHA1.01 (AgHort Building A, room 1.01) is a short walk from AHLB, where AgHort A and B meet in grid square E10 on the campus map (page 7). To get there follow someone who knows where they're going from the NZMS AGM, or use the Google maps link: https://tinyurl.com/2019NZMSmap

Mathematics teachers' day

Wednesday, AH1 and AH2

On Wednesday we will be joined by local mathematics and statistics teachers for a day of talks and discussions relating to the teaching of mathematics and statistics at the secondary and tertiary levels. Talks associated with the teachers' day, as well as some contributed talks of relevant interest, will take place in AH1 and AH2. All colloquium participants are of course welcome and encouraged to attend any of these sessions.

ANZIAM NZ branch AGM

Wednesday 12:45, AH1

Documents for the meeting can be found at https://tinyurl.com/ANZIAM2019yi3hpkb

Colloquium dinner

Wednesday 19:00, Wharerata

As usual, the colloquium dinner will include the NZMS awards presentation. Arrive from 19:00 for dinner at 19:30.

Wharerata is located in grid square F7 on the campus map (page 7), or use the Google maps link: https://tinyurl.com/2019NZMSmap

Workshop on university mathematics teaching

Thursday 14:30, AH3

Igor' Kontorovich (University of Auckland, i.kontorovich@auckland.ac.nz)
Ian Jones (Loughborough University, i.jones@lboro.ac.uk)

From undergraduates' systematic errors to tacit models that govern their thinking

This two hour workshop is for all university teachers who are interested in refining their mathematics teaching. In a discursive and collaborative environment, we will engage with contemporary research in mathematics education and put it in use to construct models of students' ways of thinking based on data from thousands of undergraduates.

The workshop is partially funded by the International Group of Mathematics Education and fully supported by NZMS.

Plenary talk abstracts

Lisa Clark

Tuesday 09:00, AH1

(Victoria University of Wellington, lisa.clark@vuw.ac.nz)

Equivalence relations, topology and C^*-algebras

C^*-algebras provide the mathematical underpinnings of quantum physics and they have a rich theory that has been developed over the last century. In 1943, Gelfand and Naimark showed that every C^*-algebra is isomorphic to a subalgebra of operators on a Hilbert space. So, in the finite dimensional setting, the study of C^*-algebras is essentially the study of matrices. Yet even with this powerful theorem, an abstract C^*-algebra can be a complicated beast and understanding basic properties can be difficult. In this talk we describe how to build a C^*-algebra from an equivalence relation so that one can see properties of the algebra by looking at properties of the equivalence relation. To get a robust class of C^*-algebras in this way, we will consider equivalence relations on topological spaces. This talk will include several examples and assumes no C^*-algebraic background.

Steven Galbraith

Thursday 09:00, AH1

(University of Auckland, s.galbraith@auckland.ac.nz)

From linear algebra to post quantum cryptography

Cryptography is a tool to protect information and to provide authentication. However, many of the systems that are currently in use are based on computational problems in number theory that can potentially be solved efficiently by a quantum computer.

After a brief introduction to how cryptography is used in practice, the talk will explain how some basic linear algebra and probability theory can be used to build cryptosystems that are conjectured to be secure against quantum computers. The talk will also contain opinions.

Bronwyn Hajek

Tuesday 16:00, AH1

(University of South Australia, bronwyn.hajek@unisa.edu.au)

Analytic solutions of nonlinear reaction-diffusion equations with applications in biology

Nonlinear reaction-diffusion equations are used widely to model many different systems and processes, particularly in biology, for example cell proliferation, population dynamics, and transmission of nerve impulses, but also in other areas such as heat transfer, flow through porous media, and chemical reactions. While exact analytic solutions are often extremely useful, they can be particularly difficult and sometimes impossible to construct for nonlinear PDEs.

In this talk, I'll show how the nonclassical symmetry method can be used to construct exact analytic solutions to nonlinear reaction-diffusion equations. Like other symmetry techniques, the nonclassical symmetry method provides a systematic way to search for transformations that allow a reduction in the number of independent variables. In this way, we hope to transform our equation so that it has one fewer independent variable, or perhaps even transform it from a PDE to an ODE that is exactly solvable.

In particular, I'll describe a special nonclassical symmetry which, under certain conditions, is valid in any number of dimensions and in any coordinate system. I'll discuss two biological problems where this symmetry has proved useful in constructing an exact solution. In the first problem, a Gompertz-like growth term is used to model the population of cells in a tumor. In this case, compactly supported solutions can be constructed, producing a tumour with a well-defined size. The second problem describes the evolution of the wave of calcium ions that travels around the surface of an amphibian egg after fertilisation. These solutions exhibit various phenomena that can be observed in experiment, including spirals.

This is joint work with Phil Broadbridge.

Pedram Hekmati *Tuesday 13:30, AH1*

(University of Auckland, p.hekmati@auckland.ac.nz)

A quantum invariant for group actions

Equivariant cohomology is an invariant that encodes information about topological spaces equipped with a group action. In this talk I will review its construction and explain how it can be refined, using ideas from quantum theory, to yield an even stronger invariant. When the space is a point, this leads to a highly interesting result in Lie theory.

Jeanette McLeod *Wednesday 09:00, AH1*

(University of Canterbury, jeanette.mcleod@canterbury.ac.nz)

Maths Craft: bringing maths to the masses

Maths Craft New Zealand is a non-profit initiative founded in 2016 and run by mathematicians Dr Jeanette McLeod and Dr Phil Wilson from the University of Canterbury. Together with the rest of the Maths Craft Team, we bring maths to the masses by celebrating the links between mathematics and craft. Our aim is to show young and old alike the fun, creativity, and beauty in mathematics through the medium of craft, demonstrate just how much mathematics there is in craft, and enable people to experience what it means to think like a mathematician.

Since our inception, Maths Craft have run numerous festivals and workshops across New Zealand, and have reached almost 13,000 people, making us the largest maths outreach programme in the country. We have secured $300,000 in grants, sponsorship, and in-kind support; written dozens of freely-available instructional handouts; trained and mentored many volunteers and team members; run professional development for teachers; and collaborated with other researchers to investigate the efficacy of our approach. In this talk we explain who Maths Craft are and what we do, discuss the nuts and bolts of running a maths outreach programme, and explore some examples of mathematical crafts. We'll also reveal some of our exciting plans for 2020 and beyond.

David Simpson

Thursday 13:30, AH1

(Massey University, d.j.w.simpson@massey.ac.nz)

Border-collision bifurcations of switched dynamical systems: from fixed points to robust chaos.

Dynamical systems with switches (such as control systems with relays, economics systems with decisions, and mechanical systems with impacts) often exhibit bifurcations that are markedly different from those of smooth systems (such as period-adding structures instead of period-doubling cascades). This talk aims to give an introduction to bifurcations of switched systems in the context of maps, $x \mapsto f(x)$. Periodic solutions typically occur on parameter sets that form a curious chain structure, akin to a string of sausages, and this can be explained through a combination of asymptotics, symbolics, and linear algebra. Chaotic dynamics typically occurs robustly (unlike for smooth maps) and this can be explained geometrically through the construction of invariant expanding cones.

Kerri Spooner

Wednesday 13:30, AH1

(Auckland University of Technology, kspooner@aut.ac.nz)

Mathematical Modelling in Education

Gaining useful insight into real world problems through mathematical modelling is a valued attribute across many disciplines including mathematics, biology and engineering. Alongside this, international educational policy makers are recognising that mathematical modelling education activities can be one way to prepare students for future professional and everyday life use of mathematics. This being the case, in what ways can mathematical modelling be included in education within New Zealand? The current situation for modelling in New Zealand schools will be discussed, followed by what could be possible for first time modellers within both secondary and tertiary education. Recommendations from experienced mathematical modellers for preparing students for mathematical modelling will be shared. Ideas as to how modelling behaviors could be incorporated into teaching practice, along with recommendations for curriculum developers are some of the intended outcomes of this talk.

Contributed talk abstracts

Josephina Ah Sam

Wednesday 10:30, AH2

(University of Auckland, j.ahsam@auckland.ac.nz)

The PIMP Project: Designing culturally- AND mathematically-rich activities — can we have both?

The Pasifika Inspired Mathematics Problems project was founded on the belief that culture and context can have a significant impact on Māori and Pacific Island (MPI) students' interest, investment, and engagement in learning mathematics. We argue that by situating problems in genuine contexts which are more culturally- and socially-relevant to our MPI students, educators have a greater chance of sparking students' motivation as well as building more meaningful conceptual understanding of what may sometimes appear to be menial and irrelevant concepts and procedures. In our project, we drew on our own pedagogical considerations for how to support students who may have greater difficulty accessing mathematical ideas and combined this with principles for designing model-eliciting activities. As the project has progressed over the year, we have continued to ask ourselves, can we have culturally- AND mathematically-rich activities that will not only increase students' engagement but also do justice to the mathematics? And how (and when) do we decide to balance the two?

In this talk, I will give a brief overview of our project so far and highlight some of the issues we have faced with juggling our responsibility to the mathematics while foregrounding its application to genuine MPI contexts. I will introduce a task which has been designed by the project team and MPI students from the study, and discuss some of the responses students had about the tasks, their conflicts with designing their tasks, and what they hope to see in mathematics classrooms in the future.

Mohamed Al-Sultani

Tuesday 14:30, AH4

(Massey University, m.al-sultani@massey.ac.nz)

Numerical solution of nonlinear parabolic systems by block iterative methods

This talk deals with investigating numerical methods for solving coupled system of nonlinear parabolic problems

$$\begin{aligned}
&\frac{\partial u_s}{\partial t} - \mathcal{A}_s u_s(x,y,t) + f_s(x,y,t,u) = 0, \quad (x,y,t) \in Q_T = \omega \times (0,T],\\
&\omega = \{(x,y) : 0 < x < l_1, \quad 0 < y < l_2\},\\
&u_s(x,y,t) = g_s(x,y,t), \quad (x,y,t) \in \partial Q_T,\\
&u_s(x,y,0) = \psi_s(x,y), \quad (x,y) \in \overline{\omega}, \quad s = 1,2,\ldots,S,
\end{aligned}$$

where $u = (u_1, u_2, \ldots, u_S)$. For numerical solution of this nonlinear system, we employ block monotone iterative methods based on the Jacobi and Gauss–Seidel methods to solve nonlinear difference schemes which approximate the coupled system of nonlinear parabolic problems, where reaction functions are quasi-monotone nondecreasing. In the view of the method of upper and lower solutions, on each time level, two monotone upper and lower sequences of solutions are constructed, where the monotone property ensures the theorems

on existence and uniqueness of solutions to problems with quasi-monotone nondecreasing reaction functions.

Constructions of initial upper and lower solutions are presented. Error estimates between the computed approximation and the solutions of the nonlinear discrete problems are obtained. The monotone convergence property is used to prove the convergence of the nonlinear discrete problems to the corresponding differential problems as mesh size decreases to zero. Numerical experiments on some applied problems are presented.

Jason Archer

Wednesday 10:30, AH4

(Massey University, jasonla1994@hotmail.com)

The ecology of emerging infectious diseases

More than 60% of emerging infectious diseases are zoonotic, meaning that they have their origins in other species before being transmitted to human hosts. Examples of such diseases include influenza, Ebola, and rabies, all of which present a significant threat to public health. As such, ecological factors can play an important role in determining the risk of novel infections in humans. One hotly debated potential factor influencing this risk is the dilution effect, a hypothesis which posits that biodiversity can reduce the likelihood of disease outbreaks. Using ecoepidemiological models composed of first-order Ordinary Differential Equations (ODEs), we suggest ways to quantify the dilution effect in various ecosystems by defining mathematically what is meant by the terms "biodiversity" and "risk of infection." Analysis of these models lends insight into the contexts in which one might expect a dilution effect to be observed. In particular, we present an example describing toxoplasmosis, a disease with cats as a primary host which spreads via their faeces to warm-blooded intermediate hosts such as mice, which when consumed transmit the disease to cats. Studies have shown that mice exposed to the pathogen lose their aversion to the scent of cat urine and are therefore more likely to become prey; we use our mathematical framework to examine how this and similar relationships between predation and infection can affect the spread of the disease and bring about a dilution effect.

Martin Bachraty

Wednesday 10:30, AH3

(University of Auckland, mbac631@aucklanduni.ac.nz)

Skew morphisms of finite groups

Skew morphisms, which generalise automorphisms for groups, are related to regular Cayley maps, and also to finite groups with a complementary factorisation $G = BC$, where C is cyclic and core-free in G. In this talk, I will outline the connections between these three concepts, and then focus on the case when B is monolithic (meaning that it has a unique minimal normal subgroup, and that subgroup is not abelian). In particular, we will give a complete classification when B is simple.

Boris Baeumer

Tuesday 15:00, AH1

(University of Otago, bbaeumer@maths.otago.ac.nz)

A conjecture: Higher order Grunwald formula

The dominant eigenfunction of solutions to the fractional Dirichlet problem on a bounded interval behaves like $x^{\alpha-1}$ near the boundary, destroying higher order convergence ($1 < \alpha < 2$). We found a numerical algorithm that is consistent of order α and appears to be positivity preserving. However, in order to prove stability we need to prove positivity and for that we might need the help of number theorists to solve an easily accessible problem.

Padraic Bartlett

Thursday 10:30, AH1

(University of Auckland, padraic.bartlett@auckland.ac.nz)

Creating Communities for Distance Students

At the University of Auckland, we have a programme (MAX) for high-achieving secondary school students. Students are able to enrol in the paper either as local students or as distance-based learners. While both cohorts have traditionally performed "well" in the course on an absolute basis, the distance group has historically been much more likely to get a mark of a C or below, as well as to disengage with the class.

To address these concerns, we secured a Learning Enhancement Grant to improve the learning outcomes of our distance students. By using a number of technological resources (livestreaming, online forums, Skype), we were able to foster a sense of shared community between our distance students and in-class students. This led to a marked uptick in communications between these two groups, and erased the gap in performance between these cohorts in our end-of year assessments.

In this talk, we will describe some best practices for using technology to create and support mixed communities of local/distance students.

Anton Baykalov

Wednesday 11:00, AH3

(University of Auckland, a.baykalov@auckland.ac.nz)

Intersection of conjugate solvable subgroups in $GL_n(q)$ and $GU_n(q)$

Assume that a finite group G acts on a set Ω. A point $\alpha \in \Omega$ is **G-regular** if the stabilizer of α is trivial. Define the action of the group G on Ω^k by

$$g : (\alpha_1, \dots, \alpha_k) \mapsto (\alpha_1 g, \dots, \alpha_k g).$$

Let G act faithfully and transitively on Ω, and for a positive integer m denote the number of G-regular orbits on Ω^m by $Reg(G, m)$. If H is a subgroup of G and G acts by right multiplication on the set Ω of right cosets of H then G/H_G acts faithfully and transitively on Ω. (Here $H_G = \cap_{g \in G} H^g$.) In this case, we denote $Reg(G/H_G, m)$ by $Reg_H(G, m)$.

In this work we consider Problem 17.41 b) from the "Kourovka notebook":

> *Let H be a solvable subgroup of a finite group G that has no nontrivial solvable normal subgroups. Do there always exist five conjugates of H whose intersection is trivial?*

The problem is reduced to the case when G is almost simple by E. P. Vdovin (2012). In particular it sufficient to show that $Reg_H(G, 5) \geq 5$ for every solvable subgroup $H < G$ for all almost simple groups G. In the talk we present the following result:

Theorem. *Let $G \in \{GL_n(q), GU_n(q)\}$ and let (n, q) be such that G is not solvable. If S is a maximal solvable subgroup of G then $Reg_S(G, 5) \geq 5$.*

Alona Ben-Tal

Wednesday 15:00, AH4

(Massey University, a.ben-tal@massey.ac.nz)

New Boolean representation of neural networks

We have developed a new framework for studying neural networks based on Boolean representation. The new framework enables us to predict the behaviour of neural networks based on properties of neurons, not their values. We used the new framework to form a network architecture that mimics many features seen in the respiratory neural network. In particular, we show how selective control of inspiration and expiration times can be achieved. Our network can easily be scaled to represent breathing rates of different species. It provides novel insights and new testable predictions. Co-authors: Yunjiao Wang and Maria C.A. Leite

Igor Boglaev

Thursday 11:30, AH4

(Massey University, i.boglaev@massey.ac.nz)

Numerical solution of nonlinear integro-elliptic systems

This talk deals with numerical treatments of systems of nonlinear integro-elliptic equations. Monotone iterative methods based on the method of upper and lower solutions are constructed. These iterative methods yield two sequences which converge monotonically from above and below, respectively, to a solution of a nonlinear difference scheme. The monotone methods solve only linear discrete systems at each iterative step and simplify considerably the search for initial guesses as is often required in the Newton iterative method. Convergence of the monotone iterative methods are proved in the cases of quasi-monotone nondecreasing and quasi-monotone nonincreasing reaction functions. Some basic techniques for construction of initial upper and lower iterates are discussed. Numerical experiments are presented.

John Butcher

Thursday 10:30, AH4

(University of Auckland, butcher@math.auckland.ac.nz)

The order of general linear methods

For a general linear method, defined by $y^{[n]} = M_h y^{[n-1]}$, with starting values defined by $y^{[0]} = S_h y(x_0)$, the numerical order is p, if $M_h S_h y(x_0) = S_h y(x_0 + h) + O(h^{p+1})$. For a specific method, the evaluation of the order has required the identification of an appropriate starting method. We present a new algorithm for determining the order, which avoids direct reference to the starting method but focusses on evaluating the B-series for a representative of the conjugacy class known as the "underlying one-step method".

Angela Cameron

Wednesday 10:30, AH1

(Manawatū Maths Teachers Association, A.Cameron1@massey.ac.nz)

The other *Maths Craft: 'a chance for students in years 6–11 to Do Maths like a Research Mathematician'*

This talk is in two parts, with the opportunity to attend either part or the full session.

Part 1 (10:30): Maths Craft problem solving is a free-style approach that is learner centred, curriculum linked but free of the rigour of rules. It is about showing students that maths is not just about getting a right answer, but about exploring, noticing patterns, making conjectures, proving or disproving those conjectures, figuring out "why", and thinking of ways to extend the problem. During this session we will work through a mathematical problem that is accessible to students of all ages. Maths Craft problem solving is a project developed by Anthony Harradine and Dr. Anita Ponsaing. For more information see www.mathscraft.org.

Part 2 (11:00): Evaluating and discussing the use Maths Craft or similar activities in your classroom. A stated goal is that you and your students should experience the joy of exploring a problem. We argue that Mathematics and Statistics are a way of thinking, not just a toolkit of skills. If this is true how are we teaching these ways of thinking in school? What are the processes that research mathematicians and statisticians use when they approach a problem?

Jiling Cao

Wednesday 15:00, AH3

(Auckland University of Technology, jiling.cao@aut.ac.nz)

Rough stochastic elasticity of variance and option pricing

This study is concerned with the elasticity of variance for risky assets. We show that the elasticity of variance for S&P500 exhibits short-range correlations. By using asymptotic and martingale methods, we obtain a semi-analytical expression for the option price in the two-scale regime where the constant elasticity of variance is perturbed by a smooth and bounded function of a rapid fractional Ornstein-Uhlenbeck process with Hurst exponent within $(0, 1/2)$. The associated implied volatility is presented and discussed. As a result, the scope of Markov stochastic elasticity of variance model is extended to a non-Markov case.

Hyuck Chung

Thursday 10:30, AH3

(AUT, hchung@aut.ac.nz)

Bending motion of an inhomogeous floating plate

The topic of the talk is the motion of a thin elastic plate floating on water. I will present an analytical method of computing the bending wave field across an elastic floating plate that has inhomogeneities. The fully coupled system between the plate and the water makes this problem more difficult than decoupled ones such as spring-loaded plates or shallow-water problems. A method using a Green's function of the floating plate will be presented. Scattered flexural waves by a finite region of irregular features are computed.

Marston Conder *Wednesday 11:30, AH3*
(University of Auckland, m.conder@auckland.ac.nz)

Observations and answers to questions about edge-transitive maps

A *map* is an embedding (or drawing) of a connected graph or multigraph on a closed surface, dividing the surface into simply-connected regions called the *faces* of the map. Any bijection from a map M to itself, preserving the vertices, the edges and the faces of M, and incidence between them, is called an *automorphism* (or symmetry) of M. The most highly symmetric maps are those for which the automorphism group $\mathrm{Aut}(M)$ acts transitively and hence regularly on the *flags* of M, which are essentially incident vertex-edge-face triples. These *regular maps* have been studied for decades, dating back to the late 1800s. Lately, attention has shifted to *edge-transitive* maps, for which $\mathrm{Aut}(M)$ acts transitively on the edges of M. There are 14 distinct classes of edge-transitive maps, determined by the effect of the automorphism group 'locally', around an edge. In this talk I will make some observations about these 14 classes, and describe the recent answers to some open questions about them, posed in a 2001 paper by Širán, Tucker and Watkins. One of these answers was found in joint work with Isabel Holm, an Honours student at Auckland in 2018.

Hammed Olawale Fatoyinbo *Wednesday 11:30, AH4*
(Massey University, h.fatoyinbo@massey.ac.nz)

Spatiotemporal pattern formation in a model of electrically coupled smooth muscle cells

Electro-mechanical coupling (EMC) is a physiological process that involves the generation of signal and contraction of muscle cells. It may arise under the influence of external sources (such as agonists) or spontaneous activity of the ion channels. The spontaneous EMC activity in muscle cells is known as pacemaker dynamics. Motivated by this cellular behaviour, we investigate the formation of spatiotemporal patterns in a model of electrically coupled smooth muscle cells. Modulating model parameters, we identify transitions between types of excitability in the parameter space. The numerical simulations of our model in one spatial dimension showed that the patterns can bifurcate from a stable pattern to spatiotemporal chaos.

Alex Fok *Tuesday 14:30, AH1*
(University of Auckland, alex.fok@auckland.ac.nz)

Extended Verlinde algebra

The Verlinde algebra is an algebra related to a compact Lie group G, which has rich connections to diverse contexts. It appears in mathematical physics as the Frobenius algebra of a certain topological quantum field theory, and in algebraic geometry as the algebra encoding information of moduli spaces of G-bundles over Riemann surfaces. The Verlinde algebra for G with nice connectedness properties have been well-known. However, explicit descriptions of such for disconnected G are lacking. In this talk, I will discuss partial results on an extension of the Verlinde algebra arising from a disconnected G. The talk is based on work in progress joint with David Baraglia and Varghese Mathai.

Marie Graff

Thursday 11:00, AH4

(University of Auckland, marie.graff@auckland.ac.nz)

On the role of numerical viscosity in the study of the local limit of nonlocal conservation laws

We deal with the numerical investigation of the local limit of nonlocal conservation laws. Previous numerical experiments suggest convergence in the local limit. However, recent analytic results state that (i) in general convergence does not hold because one can exhibit counterexamples; (ii) convergence can be recovered provided viscosity is added to both the local and the nonlocal equations. Motivated by these analytic results, we investigate the role of numerical viscosity in the numerical study of the local limit of nonlocal conservation laws. In particular, we show that the numerical viscosity of Lax-Friedrichs type schemes jeopardizes the reliability of the numerical scheme and erroneously detects convergence in cases where convergence is ruled out by analytic results. We also test Godunov type schemes, less affected by numerical viscosity, and show that in some cases they provide more reliable results.

This is a joint work with M. Colombo (EPFL, Switzerland), G. Crippa (Univ. of Basel, Switzerland) and L.V. Spinolo (IMATI-CNR, Pavia, Italy).

Sina Greenwood

Wednesday 16:30, AH3

(University of Auckland, sina@math.auckland.ac.nz)

Trees and inverse limits of set-valued functions on intervals

We consider inverse limits of sequences of upper semicontinuous set-valued functions $f_{i+1} : \mathbb{I}_{i+1} \to 2^{\mathbb{I}_i}$ (where $\mathbb{I}_i = [0, 1]$ for each $i \in \mathbb{N}$), for which the graph of each bonding function is an arc. We show that any finite tree can be obtained as such an inverse limit, and one for which each bonding function is one of two specified functions. In addition, we discuss trees of height $\omega + 1$ that can be obtained as the inverse limit of such a sequence.

Seyed Mohsen Hashemi

Tuesday 11:30, AH4

(Massey University, S.M.Hashemi@massey.ac.nz)

Convexity and Linear Distortion

This talk is primarily concerned with the convexity properties of distortion functionals (particularly the linear distortion) defined on quasiconformal homeomorphisms of domains in Euclidean n-spaces, though we will mainly stick to three-dimensions. The principal application is in identifying the lower semi-continuity of distortion on uniformly convergent limits of sequences of quasiconformal mappings. For example, given the curve family or analytic definitions of quasiconformality — discussed in my research — it is known that if $\{\mathbf{f_n}\}_{n=1}^{\infty}$ is a sequence of K-quasiconformal mappings (and here K depends on the particular distortion but is the same for every element of the sequence) which converges to a function $\mathbf{f}$, then the limit function is also K-quasiconformal.

Despite a widespread belief that this was also true for the geometric definition of quasiconformality (via the linear distortion $H(\mathbf{f})$ defined below) Tadeusz Iwaniec gave a specific surprising example to show that the linear distortion function is not lower semi-continuous. The main aim of my talk is to show that this failure of lower semicontinuity

is actually far more common, perhaps even generic in the sense that it might be true that under mild restrictions on a quasiconformal $\mathbf{f}$, there may be a sequence $\{\mathbf{f_n}\}_{n=1}^{\infty}$ with $\mathbf{f_n} \to \mathbf{f}$ uniformly and with $\limsup_{n\to\infty} H(\mathbf{f_n}) < H(\mathbf{f})$. The main result of my research is to show this is true for a wide class of linear mappings.

Catherine Hassell Sweatman *Thursday 15:00, AH4*
(Auckland University of Technology, catherine.sweatman@aut.ac.nz)

Mathematical model of diabetes and lipid metabolism linked to diet, leptin sensitivity, insulin sensitivity and VLDLTG clearance predicts paths to health and type II diabetes

An original model of diabetes linked to carbohydrate and lipid intake is presented and applied to predict the effects on biomarkers of various diets. The variables (biomarkers) are concentrations of fasting plasma glucose, insulin, leptin, glucagon, non-esterified fatty acids (NEFA) and very low density lipoprotein triglyceride (VLDLTG), as well as muscle lipids, hepatic lipids, pancreatic lipids, fat mass and mass of β-cells.

The model predicts isocaloric high carbohydrate low fat (HCLF) diet and low carbohydrate high fat (LCHF) diet trajectories to health which vary little in fat mass at steady state. The LCHF trajectories to health are faster than isocaloric HCLF trajectories with respect to fat mass loss, although these trajectories may be slower initially if parameters are adjusting from HCLF values. On LC diets, leptin sensitivity and VLDLTG clearance are thought to increase. Increasing leptin sensitivity and VLDLTG clearance is predicted to lower lipids including fat mass and VLDLTG. The model predicts that changes in VLDLTG due to a change in diet happen rapidly, approaching steady state values after a few weeks, reflecting leptin sensitivity and VLDLTG clearance which are much harder to measure. The model predicts that if only insulin sensitivity increases on a LC diet, steady state fat mass would increase slightly. If leptin and insulin sensitivities increase concurrently, the combined effect could be a decrease in fat mass, consistent with the fact that increasing insulin sensitivity is often associated with fat mass loss in trials.

Trajectories to type II diabetes are investigated.

Shaun Hendy *Tuesday 11:30, AH3*
(University of Auckland, shaun.hendy@auckland.ac.nz)

The motion of droplets on textured superhydrophobic surfaces

Droplets on superhydrophobic surfaces will bead if their radius is below the capillary length, leading to an almost dissipationless rolling motion if the surface is tilted. In practise the motion is limited by viscous dissipation near the zone of contact with the surface or, if the surface is high slip, dissipation by contact line friction at the perimeter of that contact zone. Here we study the motion of droplets on high slip surfaces with texture by using molecular dynamics simulations and by extending a model developed for isotropic surfaces. This model introduces a contact line friction tensor to capture the texturing of the surface. We find that there is excellent agreement between the model and the theory.

Samuel Irvine *Tuesday 11:00, AH3*
(Massey University, s.k.irvine@massey.ac.nz)

Modelling granular flow in a two opening silo

Granular material, such as sand, soil, and grain, is of vast importance to many industrial endeavours. Many models have been developed to aid our understanding of the behaviour of these materials, with the $\mu(I)$ rheology being the basis for many recent developments. While some situations can be adequately understood, models of dense granular flow struggle to capture all relevant effects. In particular, silos are widely used in many industrial applications, yet no continuum model exists which accurately predicts flow rate. A two-opening silo also displays a dip in flow rate for small separation between orifices.

The flow rate dip in two-opening silos can be modelled with the local $\mu(I)$ model. For low friction values, the $\mu(I)$ model predicts a monotonic decrease in flow rate, however for higher values the flow rate dip is recovered. Extensions have been made to the $\mu(I)$ model to account for factors such as non-local effects, dilatancy, and wall friction; accounting for these factors could improve the prediction for flow rates in both the one-opening and two-opening silos.

Valerie Jeong *Tuesday 12:00, AH1*
(University of Auckland, valerie.jeong@auckland.ac.nz)

A Heteroclinic Cycle and Evolutionary Robotics

Evolutionary Robotics is a methodology for a machine learning type problem, where we evolve the brain of a robot so that the robot can complete a given task. Often, the robot receives some inputs from the environment and these play a key role when evolving the brain of the robot. One way to model the brain (the controller) of a robot is to use a dynamical structure called a heteroclinic network. A heteroclinic network arises from a variety of physical applications, and there have been many contributions to understanding the dynamics. However, the effect of perturbations and noise to a heteroclinic network is still not well understood.

External inputs that a robot receives are similar to perturbations to a heteroclinic network. Noise can also be added, since any physical application is never free from noise. This raises the need for a dynamical analysis of a heteroclinic network with perturbations and noise. In this talk, I will illustrate a general setting for an Evolutionary Robotics task, and discuss the dynamics of a heteroclinic cycle called the Guckenheimer-Holmes cycle with perturbations and/or noise.

Stephen Joe *Thursday 12:00, AH4*
(University of Waikato, stephen.joe@waikato.ac.nz)

Eigenvalues of a particular non-symmetric matrix arising from the collocation method

The collocation method can be used to solve the integral equation

$$-\frac{1}{\pi}\int_0^\pi \log|\cos(t)-\cos(s)|v(s)\,\mathrm{d}s = f(t), \qquad t\in[0,\pi],$$

where f is known and v is the function to be found. If n is a positive integer and $h = \pi/n$, then suppose that piecewise constant functions are used and the collocation is done at $(i - 1/2)h$ for $i \le i \le n$.

Then one gets a linear system of equations with the symmetric coefficient matrix A having elements

$$A_{ij} = -\frac{1}{\pi} \int_{(j-1)h}^{jh} \log |\cos((i - 1/2)h) - \cos(w)| \, \mathrm{d}w, \qquad 1 \le i, j \le n.$$

In an analysis of the method, one can make use of the eigenvalues and eigenvectors of A.

In a related collocation method, one gets a linear system of equations with the coefficient matrix B having elements

$$B_{ij} = -\frac{1}{\pi} \int_{(j-1)h}^{jh} \log |\cos((i - 1/2)h) - \cos(w)| \frac{\sin(w)}{\sin((j - 1/2)h)} \, \mathrm{d}w, \qquad 1 \le i, j \le n.$$

For $w \in [(j - 1)h, jh]$, we might expect $\sin(w)/\sin((j - 1/2)h) \approx 1$ so that the matrix B would not be too different from A. Despite B not being symmetric, it turns out that the eigenvalues and eigenvectors of B can be explicitly worked out. The eigenvalues of A and B have the same asymptotic behaviour as $n \to \infty$.

Sergiy Klymchuk

Wednesday 11:30, AH2

(AUT, sergiy.klymchuk@aut.ac.nz)

A new type of questions for teaching and assessing critical thinking in mathematics

Typical assessment in mathematics consists of the following three types of questions and problems: procedural, conceptual and applications. In the vast majority of such questions, all conditions of theorems/formulas/rules are satisfied. Therefore, students might develop a habit of applying formulas and rules without checking the conditions/constraints. In real life, not everything behaves so nicely and ignoring conditions/constraints might lead to significant and costly errors. We suggest including so-called provocative or 'impossible' mathematics questions in teaching and assessment. Such questions look like typical routine procedural questions but in fact they have a catch — they are deliberately designed to mislead the solver. The intention is to prepare students for real life by enhancing their critical thinking that includes the abilities to analyse questions and recognize mistakes. These abilities can be transferred outside mathematics classroom into everyday life so students become better-informed citizens and critical thinkers.

As a pedagogical strategy, provocative mathematics questions demonstrate the importance of being alert and ready to analyse everything. They enhance a habit of questioning the question and not to take anything for granted which is an essential part of a mathematical way of thinking. We believe that practice in solving and posing provocative questions should be an integral part of training of prospective mathematics teachers, and is included into professional development of in-service mathematics teachers. Taking into account a solid professional background of mathematics teachers, the investment in training them in using provocative questions in a classroom and assessment might be very small

— attending just 1–2 seminars or workshops — however the benefits for their students and society is enormous. These benefits include but are not limited to recognising mistakes and fake news, identifying contradictory information, eliminating impossible cases, using sceptical and unbiased analysis, making rational judgements and decisions based on factual evidence, and other traits of critical thinking.

Bernd Krauskopf

Wednesday 14:30, AH4

(University of Auckland, b.krauskopf@auckland.ac.nz)

Signatures of multi-frequency tipping in climate systems

A well-known scenario of tipping is that of approaching and then passing a fold (or saddle-node bifurcation) of a stable equilibrium or periodic orbit, after which the system suddenly transitions to another attractor. We discuss the next step up: 'a fold of an invariant torus', which creates what we refer to as multi-frequency tipping. This phenomenon involves the break-up of the torus via additional bifurcations, which may act as precursors of the tipping to come. Examples from the climate systems literature will be discussed, where yet unexplained precursors may be interpreted as manifestations of multifrequency tipping.

This is joint work with Andrew Keane (University College Cork).

Carlo Laing

Wednesday 16:00, AH4

(Massey University, Albany, c.r.laing@massey.ac.nz)

Degree assortativity in networks of spiking neurons

Degree assortativity refers to the increased or decreased probability of connecting two neurons based on their in- or out-degrees, relative to what would be expected by chance. We investigate the effects of such assortativity in a network of theta neurons. The Ott/Antonsen ansatz is used to derive equations for the expected state of each neuron, and these equations are then coarse-grained in degree space. We generate families of effective connectivity matrices parametrised by assortativity coefficient and use SVD decompositions of these to efficiently perform numerical bifurcation analysis of the coarse-grained equations. We find that of the four possible types of degree assortativity, two have no effect on the networks' dynamics, while the other two can have a significant effect.

Kim Locke

Wednesday 12:00, AH2

(University of Auckland, kim.locke@auckland.ac.nz)

My year as a Mathematics Teacher Fellow – Teaching in a Secondary vs. Tertiary environment

A year away from the secondary school classroom to work as a mathematics teaching fellow at the University of Auckland has shown me how far apart these two worlds actually are. Yet we expect our students to move seamlessly from one to the other within the space of a Christmas holiday.

In this talk I will share my observations on some of these differences, as I have experienced them from a teacher's perspective. Arising from these observations, I reflect on

how I might adapt my practice in either environment so as to better prepare students for this change or support them through the change. I also look at how I have personally benefited from the experience of learning and how this, in turn, will benefit my students.

Michael Lockyer *Wednesday 16:00, AH3*
(Auckland University of Technology, michael.lockyer@aut.ac.nz)

Extending bonding functions in generalised inverse sequences.

We consider the following problem: given a generalised inverse limit $\varprojlim\{Y_i, g_i\}$, and a sequence of spaces $(X_i \supset Y_i)$, does there exist a sequence of functions $(f_i : X_{i+1} \to 2^{X_i})$ such that $\varprojlim\{X_i, f_i\} = \varprojlim\{Y_i, g_i\}$?

We answer this question in the affirmative. During this talk I will introduce the problem (including the notion of a generalised inverse limit), and give an overview of the construction of the sequence (f_i). This is joint work with Iztok Banič and Simon Goodwin.

Robert McLachlan *Tuesday 15:00, AH4*
(Massey University, r.mclachlan@massey.ac.nz)

Divergence-free aromatic series

Divergence-free vector fields form a fundamental class of vector fields on a vector space. Their flows are volume-preserving and have their own characteristic dynamics. But the possible existence of a basis-independent volume-preserving integrator is unknown. Recently it has been discovered that a generalisation of Butcher series, called "aromatic series", can be divergence-free. Therefore, a first step towards understanding this area is to understand the divergence-free aromatic series. The progress in this area will be described.

Michael McVeagh *Tuesday 15:00, AH3*
(Massey University, m.mcveagh@massey.ac.nz)

Lattice Bases for Polytope Sampling

Statistical linear inverse problems occur when we are interested in fitting a statistical model to a random process that may only be observed indirectly. The relationship between the observed data and the data to be modelled is given by an underdetermined linear system, $\mathbf{y} = A\mathbf{x}$, where $\mathbf{y}$ and $\mathbf{x}$ are count data vectors of non-negative integers. The likelihood function for such models requires a summation over the set $\mathcal{X}_{|\mathbf{y}} = \{\mathbf{x} \in \mathbb{Z}^r : A\mathbf{x} = \mathbf{y}, \mathbf{x} \geq \mathbf{0}\}$. This set can be represented geometrically as a lattice polytope, the set of integer-valued points inside a convex region of $\mathbb{R}^N$ bounded by hyperplanes. Unfortunately, this summation can be computationally infeasible when $\mathcal{X}_{|\mathbf{y}}$ is large.

One approach to addressing this problem involves sampling from $\mathcal{X}_{|\mathbf{y}}$ using Markov Chain Monte Carlo algorithms, which amounts to taking a random walk through the solution space. This requires a Markov basis: a set of moves that can be used to construct such a walk, which is therefore a subset of $\ker_{\mathbb{Z}}(A)$. However, not every set that contains

a basis for $\ker_{\mathbb{Z}}(A)$ is guaranteed to produce a random walk that can access every element of $\mathcal{X}_{|\mathbf{y}}$. The challenge is to be able to efficiently compute a set of moves that ensures the random walk can visit every element of $\mathcal{X}_{|\mathbf{y}}$, and that it can do so economically.

My research focuses on using lattice bases as Markov bases, and aims to combine algebraic results on connectivity of bases with consideration of the geometry of lattice polytope representations of any particular $\mathcal{X}_{|\mathbf{y}}$, to develop methods for finding lattice polytope samplers that are efficient to run, computationally feasible to find, and capable of exploring the entire polytope.

Stephen Merry *Wednesday 11:00, AH4*
(University of Canterbury, stephen.merry@pg.canterbury.ac.nz)

Epidemic modelling of Bovine Tuberculosis transmission in Common Brushtail Possums

The Common Brushtail Possum is an introduced species that, over the last 150 years, has caused significant damage to New Zealand's native flora and fauna. Moreover, Brushtail Possums are one of the major wildlife reservoirs of Bovine Tuberculosis, and are thought to be one of the main vectors of the disease to cows. Motivating the research is a set of data, collected by Dr Dan Tompkins and his team at Landcare Research. For a 6 month period, contacts between individuals in 4 groups of possums, each of approximately 40 individuals, were recorded. Further, a strain of Bovine TB was deliberately introduced into the population, and the occurrence of secondary infections were observed. From the contact data, we construct networks representing these possum populations, weighted with the frequency of contact between individuals. We then simulate the transmission of Bovine Tuberculosis through this network using an SEIR compartmental model, with parameters drawn from literature, and compare the number of susceptible and infectious individuals with those in the data.

Sishu Shankar Muni *Tuesday 10:30, AH1*
(Massey University, Palmerston North, s.muni@massey.ac.nz)

A new geometric mechanism for multistability in smooth dynamical systems

Multistability refers to the coexistence of a large number of stable states (coexisting attractors) in a dynamical system for a fixed set of parameter values. It is a common feature in, for example, neuroscience, coupled oscillators, climate dynamics, social systems, and ecosystems. In this talk, we will discuss the necessary conditions for a new geometric mechanism by which multistability occurs in smooth dynamical systems. We will present a minimal example and outline the challenges ahead to observe this phenomenon in prototypical maps such as the generalised Henon map.

Julia Novak

Thursday 12:00, AH1

(University of Auckland, j.novak@auckland.ac.nz)

Improving Student Engagement — Policy and Practice

I will cast a critical eye over policies and practices aimed at improving student engagement and highlight some of the unintended consequences. As academics it is important that we honestly assess the impact of our own innovations and give students the opportunity to engage, without being over prescriptive about how, when and why they engage. I shall conclude by sharing data from a TLRI funded project on the impact of non-routine problems on the engagement of undergraduate STEM students.

NZMS Education Group

Wednesday 15:00, AH1

The secondary-tertiary transition

An active discussion connecting secondary and tertiary educators around issues our students face in transitioning from secondary to tertiary education.

Dion O'Neale

Wednesday 16:00, AH1

(University of Auckland, d.oneale@auckland.ac.nz)

Using network science to understand student pathways in and through STEM education.

High-school education in New Zealand uses a standards based assessment framework (NCEA) where students select to take skills or competency based standards in order to gain credits in particular disciplinary fields. The resulting assessment system is, at the surface, remarkable in the flexibility it offers to both students and schools. However, high-schools are far from equal, in terms of both their resourcing and their student intake; and the effect of subtle biases, along with factors like socio-economic status have been well documented to be correlated with students' learning outcomes. We make use of administrative data related to all students took a NCEA standard in their final year of high-school in the period 2010–2016. We use this data to construct a bipartite network connecting students to standards. Students are linked to demographic information such as ethnicity, gender, and school socio-demographic status. We project this network on to the standards and use community detection to reveal clusters of standards that tend to be taken together, independently of disciplinary classification. Within STEM, we find that standards broadly cluster into communities of Science-for-Careers and communities related to Careers-in-Science. We then overlay the network with demographic information related to the students linked to each community of standards. Doing so reveals clear differences in student participation, linked to gender and ethnicity. Specifically, we find that Māori and Pacific Island students are less likely to be enrolled in externally assessed standards (linked to university study), relative to their European and Asian peers. Similarly, they were more likely to be enrolled in vocationally linked standards. This raises the questions of whether the flexibility provided by the NCEA framework is being used in students' best interests, or whether it encourages schools to push students down particular pathways, based on their background rather than their abilities or aspirations.

Hinke Osinga

Tuesday 11:00, AH1

(University of Auckland, h.m.osinga@auckland.ac.nz)

Robust chaos: Geometric insights from manifold computations

Dynamical systems theory relies heavily on the knowledge of global invariant manifolds of equilibria and periodic orbits, which form the backbone of the organisation of phase space and, hence, of observed behaviour. We study a new type of chaos that arises robustly in higher-dimensional systems. We explain how global invariant manifolds organise the geometric complexity arising in a 3D Hénon-like map and discuss how to address the discrepancy between theoretical results and their manifestations in explicit examples.

This is joint work with Stephanie Hittmeyer and Bernd Krauskopf (University of Auckland) and Katsutoshi Shinohara (Hitotsubashi University).

Nicolette Rattenbury

Wednesday 11:00, AH2

(University of Auckland, nicolette.rattenbury@auckland.ac.nz)

Peer-Marked Presentations in Large-Scale Classes

Maths 108 is a large service course, with approximately 2000 enrolments per year. Although the course has been very good at assessing the content taught we have struggled to help students build communication skills.

This year we introduced peer-reviewed video presentations, where students have to create a short video explaining their working for a question, from a given list of questions. This list is created from questions that have been answered particularly badly in previous tests and exams. The students then peer-review a handful of other videos.

In this talk I will discuss the implementation of this assessment, along with feedback from all the parties involved, including the students.

Mick Roberts

Wednesday 16:30, AH4

(Massey University, m.g.roberts@massey.ac.nz)

The dynamics of antimicrobial resistance

Antibiotics are used extensively to control infections in humans and animals, usually by injection or a course of oral tablets. There are several methods by which bacteria can develop resistance, including mutation during DNA replication and horizontal gene transfer. We present a model for the development of antimicrobial resistance within a single host animal, motivated by the use of antibiotics in companion (pet) animals. We derive criteria for a resistant mutant strain to replace the existing wild-type bacteria, and for co-existence of the wild-type and mutant. Where resistance develops through horizontal gene transfer, we derive criteria for the resistant strain to be excluded or co-exist with the wild-type. We show how resistance may develop during antibiotic treatment when either or both mechanisms operate.The results show that it is possible that applying and then relaxing antibiotic control may lead to the bacterial load returning to pre-control levels, but with an altered structure with regard to the variants that comprise the population.

Misbah Sadat

Wednesday 11:30, AH1

(Horowhenua College, msadat@horowhenua.school.nz)

Effect of no streaming on Māori and Pasifika student achievement in NCEA Level 1 Mathematics and Statistics

Horowhenua College is a decile 3 college with a substantial percentage of Māori and Pasifika students. This talk follows the journey of the Mathematics Faculty over the past 3 years. In response to student achievement in 2017, the faculty decided to remove all streaming from their Level 1 mathematics classes so that all classes were mixed ability. I discuss the effect this change had on the achievement of the priority learners and overall classroom behaviour, along with discussing teachers' shift in pedagogy. I will also discuss the faculty's 'next steps'.

More information can be found at http://gazette.education.govt.nz/articles/no-streaming-of-mathematics-students/

Cami Sawyer

Wednesday 16:30, AH1

(Massey University, C.Sawyer@massey.ac.nz)

The future of NCEA: what we know and what we don't

After wide consultation in 2018 the Ministry of Education has decided to make changes to NCEA. Two of the stated reasons for this are because of (1) broad consensus that NCEA is becoming increasingly disconnected and (2) workload issues for students and teachers. It is a stated goal that the changes will refocus students on learning. This is not a curriculum change. It is a change in the standards, which are the guidelines for how the curriculum is assessed. The standards will be rebuilt within each subject so that there are fewer of them (4 per subject at each level), and each standard will cover a broader range of knowledge, skills and capabilities. The intended result is to empower the design of quality programmes of learning, focusing on coherent blocks of the most important learning. This year, the NZMS Education Group along with the NZ Statistics Association (NZSA) and NZ Association of Mathematics Teachers (NZAMT) formed a small reference group to keep informed with the ministry review process as well as discuss across the different groups. In July, the NZMS Education Group met to discuss what advice we would share with the Ministry of Education in implementing these changes. I will share some of our thoughts and concerns and lead a discussion where you can help us feed forward into this process.

Sarah Mark

Tuesday 14:30, AH3

(University of Canterbury, sarah.mark@pg.canterbury.ac.nz)

The intersection of three longest paths in a graph

In 1966, Gallai asked whether all of the longest paths in a connected graph share a vertex. It is known that every pair of longest paths share a vertex, and it has been conjectured that any three longest paths in a connected graph share a vertex. We prove that the conjecture is true for all connected graphs in which we can delete six edges to produce a tree.

Kerri Spooner

Thursday 11:30, AH1

(Auckland University of Technology, kspooner@aut.ac.nz)

Insights into possible mathematical modelling teaching practices within tertiary education

Gaining understanding into real world problems through mathematical modelling is a valued attribute across many disciplines including mathematics, biology and engineering. This being the case, in what ways can mathematical modelling be taught to first time modellers? A New Zealand study was carried out involving three case studies. Each case study comprised of a mathematical modelling course, lecturer participant and student participants. For student participants, it was the first time they had taken a mathematical modelling course during their tertiary study. Data was collected through participant interviews and classroom observations to address the question "How do your lecturers create student learning experiences in mathematical modelling?" Lecturer participants all had a different approach to teaching modelling. For the first case study, the lecturer taught modelling techniques and processes during lectures, followed by an open-ended modelling day. For the second case study, modelling techniques, including mathematical tools, where taught during lectures, with students experiencing the modelling process through modelling case studies. For the final case study, modelling techniques were taught during lectures and popular culture contexts were used to apply these modelling techniques. Reflective thematic data analysis was used to reveal insights into the student experience for these three different approaches. Preliminary results show that providing opportunities for students to discover their own process for modelling allows for the learning of modelling to occur. Due to the change in culture experienced by the students, ways of providing reassurance need to be explored.

Jonny Stephenson

Thursday 11:00, AH1

(University of Auckland, jonny.stephenson@auckland.ac.nz)

Daily in-lecture warm-up problems in a general mathematics course

Regular warm-up problems offered during a course's lectures may be used to build a routine of engagement in the course content through a fast feedback cycle, and provide a structured opportunity for students to explore problems in a low-stakes environment, as well as to interact with their peers.

In the past semester, warm-up problems were incorporated into the stage II general mathematics course at the University of Auckland, which covers three main topics:

differential calculus of several variables, linear algebra, and differential equations. The problems were made an official part of every lecture after the first, and each consisted of an exercise based on the previous lecture's content. We will discuss the implementation of these problems, as well as the student response to them.

Winston Sweatman *Thursday 12:00, AH3*
(Massey University, w.sweatman@massey.ac.nz)

Some periodic orbits of the four-body problem

The gravitational few-body problem is beautiful but challenging. It concerns a number of point masses moving under their mutual gravitational attraction. I will present some symmetrical periodic orbits. I will start with a very low number of masses and build up to four masses.

Pania Te Maro *Wednesday 12:00, AH1*
(Massey University, P.Temaro@massey.ac.nz)

What do pipi tell us about mathematics and statistics in schools?

An activity that year 7–9 ākonga (students) in a kura kaupapa Māori (total immersion school under the Te Aho Matua Act) completed, led to exploring the similarities and differences of Māori world views and maths world views. The overall focus is to examine equitable privileging of mātauranga Māori (Māori knowledge) with mātauranga mathematics (mathematical knowledge) and the possibilities for allowing each body of knowledge the space, time and activity to thrive without trying to make one the other. This session is for anyone who is intrigued by what is happening in some kura for mathematics, as well as those who want to take a political look at equitable privileging of knowledge systems in schools and what impacts on ensuring this state.

Gayani Tennakoon *Tuesday 10:30, AH3*
(University of Auckland, gten341@aucklanduni.ac.nz)

Collective Motion with Excluded-Volume Effects

Many physical and biological systems consist of individuals with collective behaviour. In reality, these individuals have a finite size, and many living organisms tend to keep others at a distance; hence, they exclude a volume in space. Volume exclusion can be considered as the simplest possible interaction within a population. From small-scale systems such as interior cell motion or ion channels to large-scale systems such as pedestrian motion or animal swarms, it plays a significant role in determining transport properties in the diffusion of particles through crowded environments. Stochastic models describe how interacting individuals give rise to collective behaviour. For large systems, particle-based models become computationally intractable. This difficulty can be avoided by replacing these high dimensional stochastic models with continuum population-level models based on partial differential equations for the population density. The goal of our research is to develop mathematical models that involve volume excluded by sizes of particles. The method is based on developing a matched asymptotic expansion to establish the link

between the stochastic model and the population-level model. We begin by considering finite-sized particles travelling at a constant speed in one dimension and later extend the model at a finite set of velocities in higher dimensions. The result is a coupled system of partial differential equations (PDE) for the distribution function of position, velocity and time. Due to size exclusion, the PDEs are nonlinear in the transport term.

Lorenzo Toniazzi

Tuesday 10:30, AH4

(Otago University, ltoniazzi@maths.otago.ac.nz)

Censored Lévy processes, relaxation and hitting times

It is well-known that fractional derivatives relate to Lévy processes in similar ways as the Laplace operator relates to a Brownian motion. In [3], we initiated the study of the initial value problem $D_x^\beta u(x) = f(u,x)$, $x > 0$, where the fractional derivative $-D_x^\beta$ is the generator of a censored β-stable Lévy subordinator, $\beta \in (0,1)$. This results in a natural alternative to the popular Caputo derivative of order β [1,4,5]. After a gentle introduction about the probabilistic interpretation of fractional calculus, we present our main findings: (i) the Mittag-Leffler-type solution to the relaxation equation $D_x^\beta u = -\lambda u$ decays faster than comparable models, at the polynomial rate $x^{-1-\beta}$, and (ii) the censored Lévy β-stable subordinator hits the barrier in finite time, in contrast with the symmetric version of the process [2].

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Christopher Tuffley

Wednesday 12:00, AH3

(Massey University, c.tuffley@massey.ac.nz)

Weakly linked embeddings of complete graphs

Given two complete graphs $G \cong K_m$ and $H \cong K_n$ disjointly embedded in $\mathbb{R}^3$, we say that G and H are *weakly linked* if some cycle in G links some cycle in H, but no cycle in either graph links a cycle in the other with linking number greater than 1 in absolute value. I'll give a complete algebraic classification of weakly linked embeddings. In particular, we'll see that there is either a vertex of G common to all triangles in G that link H, or there is a triangle T^* in G such that a triangle T of G links H if and only if it shares an edge with T^*, with the possible exception of T^* itself.

Bruce van Brunt

Thursday 14:30, AH4

(Massey University, b.vanbrunt@massey.ac.nz)

The Balanced Pantograph Equation

The balanced pantograph equation is a functional differential equation of the form

$$y'(x) + y(x) = p_1 y(\alpha x) + p_2 y(\beta x),$$

where α, β, p_1 and p_2 are positive numbers such that $\alpha \neq 1$, $\beta \neq 1$ and $p_1 + p_2 = 1$. If $\alpha = \beta > 1$, then this equation models cell division, where a cell produces α daughter cells of the same size. If $\alpha > \beta > 1$ and $1/\alpha + 1/\beta = 1$, then the equation models asymmetric cell division, where a cell divides into two daughter cells of unequal size. In this talk we depart from cell division models and look at the relatively unexplored case when $0 < \beta < 1 < \alpha$ and show that one can derive very detailed information about the asymptotic behaviour of solutions as $x \to \infty$.

Rebekah Ward

Wednesday 14:30, AH1

(Massey University, rebekah.ward.nz@gmail.com)

Mathematical modelling framework and Desmos activity for senior secondary

Mathematical modelling is an approach to solving problems using mathematics and creative thinking, making mathematics more relevant to students. Following the progressive stages of modelling encourages students to put all of their mathematics skills together. Through the process, students also learn important twenty-first century skills such as problem solving and critical thinking. We will consider a possible modelling framework that you could use with your students along with a Desmos activity to guide through parts of the process. We will also share a marking rubric based on SOLO taxonomy that you could use to assess your students' modelling.

Woei Chet Lim

Thursday 11:00, AH3

(University of Waikato, wclim@waikato.ac.nz)

Demonstration of the spike phenomenon using the LTB models

Spikes, originally found in the context of vacuum orthogonally transitive G_2 cosmological models, describe a dynamic and spatially inhomogeneous gravitational distortion. We demonstrate the occurrence of permanent spikes using the Lemaître-Tolman-Bondi models, chosen because the solutions are exact and can be analysed by qualitative dynamical systems methods. Three examples are given and illustrated numerically. The third example demonstrates that spikes can form directly in the matter density, as opposed to indirectly in previous studies of spikes in the Kasner regime. Spikes provide an alternative general relativistic mechanism for generating exceptionally large structures observed in the Universe.

Graham Weir

Thursday 11:30, AH3

(Massey University, grahamweir@xtra.co.nz)

The magnetic field about neodymium magnets

Neodymium magnets were independently discovered in 1984 by General Motors and Sumitomo. Today they are the strongest type of permanent magnet commercially available. They are the most widely used industrial magnet, with many applications, including in hard disk drives, cordless tools and magnetic fasteners. We discuss the magnetic field from the most common geometries of blocks and cylinders. The solution for the block geometry is given in terms of elementary functions, involving twenty four non-dimensional quantities, arising from the eight vertex positions of the magnet, and the three components of the magnetic field. In cylindrical coordinates, the exact solution for the cylinder has the components of the magnetic field in the axial (radial) direction involving complete elliptic integrals of the first and third (second) kind. In all cases, the longitudinal magnetic field component in the direction of magnetisation is bounded everywhere, but the transverse magnetic field contains logarithmic divergences. Most commercially available neodymium magnets have heights somewhat smaller than their other dimensions. Then the magnetic field is zero around a path just outside of the magnet, and lying in the symmetry plane. The magnetic field is locally sensitive to spatial variations in magnetisation, which will typically produce a chaotic surface magnetic field, over the length scale of the magnetic domains.

Phillip Wilson

Thursday 16:00, AH4

(University of Canterbury, phillip.wilson@canterbury.ac.nz)

Constructive proof that William Shakespeare probably was not a dactylographic monkey

A popular modern demonstration that multiplying a very small number by a very large number can yield an order one number is the tale of a troop of monkeys hitting typewriter keys at random until one of them accidentally reproduces the complete works of William Shakespeare. Though the probability of an individual monkey reproducing Shakespeare is vanishingly small, success is nevertheless guaranteed in the limit as the number of monkeys typing randomly tends to infinity. In this talk, we highlight the tension between classical probability and its constructive counterpart by showing that, surprisingly, within a constructive model of computation it is possible to assign to an infinite number of monkeys probabilities of reproducing Shakespeare in such a way that while it is impossible that no monkey reproduces the collected works, the probability of any finite number of monkeys doing so is arbitrarily small. The surprising aspect is that the method of assigning probabilities depends only on the desired probability of success and not on the size of any finite subset of monkeys. Moreover, the result extends to reproducing all possible texts of any finite length. The good news for fans of monkey-based generation of iambic pentameter — or indeed of any probabilistic computational simulation — is that the fraction among all possible probability distributions of such pathological distributions is vanishingly small provided sufficiently large samples are taken.

Nicholas Witte

Tuesday 12:00, AH3

(Massey University, n.s.witte@massey.ac.nz)

The distribution of zeros of the derivative of the Riemann Zeta function via random unitary matrices

In 1935 Speiser formulated an equivalent statement of the Riemann hypothesis in terms of the zeros of the derivative of the Riemann zeta function: that $\zeta'(s)$ has no zeros to the left of the critical line, $\mathrm{Re}(s) = 1/2$, located far up the imaginary axis. To do this we model $\zeta'(s)$ by the derivative of the characteristic polynomial of a random matrix from $U(N)$, and deduce the radial distribution of its zeros within the unit circle, which corresponds to the region on the right-hand side of the critical line. The correspondence of our distribution with data from the Riemann zeta function is remarkable and predicts the curious features observed in the latter.

Chris Wong

Tuesday 12:00, AH4

(University of Auckland, mwon535@aucklanduni.ac.nz)

Differentiability and kernel estimates for elliptic operators

Consider the operator $A = -\sum_{k,l=1}^{d} \partial_k c_{kl} \partial_l$ on a bounded connected open set with $C^{1+\kappa}$ boundary, where the coefficients c_{kl} are Holder continuous, subject to Neumann boundary conditions. We show that the kernel of the semigroup generated by $-A$ is differentiable in each variable and the derivatives are Holder continuous. Moreover, we prove Gaussian kernel bounds and Holder Gaussian bounds for the derivatives of the kernel.

Cong Yao

Tuesday 11:00, AH4

(Massey University, c.yao@massey.ac.nz)

Minimisation of Mean Exponential Distortions and Teichmüller Theory

In deformations of material objects physical laws give the final state minimising an energy functional and solving a (typically non-linear) PDE (minimising L^2-norm of the gradient gives harmonic maps and Laplace's equation — linear case). This project seeks to exploit novel connections identified by Martin et al. between minimisation of distortion functionals (scale invariant measures of energy and distortion) and harmonic mappings. Surprisingly, minimisers for highly non-linear distortion functionals often have inverses which are minimisers of convex functionals. This discovery led to a partial solution of the 1962 Nitsche conjecture (since completely solved) and other connections, including modelling heart function and diagnostics and the deformations of cellular structures. This circle of ideas finds applications to theoretical materials science and critical phase phenomena, as distortion functionals are natural measures of change in a system and address fundamental questions relating microstructure and length scales. This project will investigate the explicit duality between the harmonic maps approach to Teichmüller theory and the classical theory via minimisers of mean distortion, and posits interpolation between these cases via $\exp(p)$-minimisers. In particular, the existence and regularities of $\exp(p)$-minimisers are investigated.

Sidra Zafar

Tuesday 11:30, AH1

(Massey University, Auckland, s.zafar@massey.ac.nz)

Coarse-graining a network of coupled phase oscillators

Previous research shows that in the Kuramoto model (with uniform frequencies for all-to-all-coupled system) when the coupling strength between the oscillators exceeds certain threshold, fraction of oscillators in the network becomes synchronized. We utilized the idea of varying coupling strength for a spatially extended network of oscillators with uniform frequencies, in two different approaches. The first one is by utilizing the numerical continuation technique and varying coupling strength as its parameter. In second one, we used 'equation free approach' as an additional method to the numerical continuation technique. The equation free approach is used to approximate the coarse scale behaviour of the exact solution by using low dimensional description of variables for which no governing equations are available in closed form. Moreover, the system of spatially extended networks supports twisted waves; we compare both approaches by varying coupling strength and study stability and bifurcation. As a result, we would show that by using a small number of variables we are able to reproduce the behaviour for full system.

Faheem Zaidi

Wednesday 12:00, AH4

(Massey University, f.zaidi@massey.ac.nz)

Is our breathing optimal?

The amplitude and frequency of breathing vary in response to changes in the blood levels of oxygen and carbon dioxide, but exactly how the respiratory control system makes these adjustments is still unknown. We explored the hypothesis that a particular combination of amplitude and frequency of breathing realized is optimal with respect to some objective function. Several objective functions have been suggested in the literature; all were studied using 1D models and all provided physiologically acceptable minima under normal conditions. We investigated optimal solutions of mathematical models that describe more accurately lung mechanics and gas exchange. We first reduced published 6D and 5D models to 3D and 2D models. The simplest 2D model consists of two piecewise linear differential equations. For this model, the optimal problem can be solved analytically. The analytical solution was used to verify a numerical algorithm that was then utilized to solve the optimal problem of the more complex models. In all the optimal solutions we found, the durations of inhalation and exhalation are equal. This is different from observations under normal conditions where the duration of inhalation is shorter than that of exhalation.

Co-authors: Alona Ben-Tal and Mick Roberts

Wenjun Zhang

Wednesday 14:30, AH3

(AUT, wenjun.zhang@aut.ac.nz)

Pricing VIX Derivatives with Infinite-Activity Jumps

In this talk, we investigate a two-factor VIX model with infinite-activity jumps, which is a more realistic way to reduce errors in pricing VIX derivatives, compared with Mencia and Sentana (2013). Our two-factor model features central tendency, stochastic volatility and

infinite-activity pure jump Levy processes which include the variance gamma (VG) and the normal inverse Gaussian (NIG) processes as special cases. We find empirical evidence that the model with infinite-activity jumps is superior to the models with finite-activity jumps, particularly in pricing VIX options. As a result, infinite-activity jumps should not be ignored in pricing VIX derivatives.

Poster abstracts

Ravindra Bandara

(University of Auckland, ravindra.bandara@auckland.ac.nz)

Existence of infinitely many multipulse solitons in a quartic fibre

The generalized nonlinear Schrödinger equation (GNLSE) is a nonlinear partial differential equation (PDE) that describes many diverse physical phenomena, e.g., the propagation of light in optical waveguides, the dynamics of Bose-Einstein condensates and small-amplitude gravity waves in the ocean. In general, analytical solutions for the GNLSE are hard to find, especially, when considering higher-order dispersion. We are concerned with pulse propagation in a nonlinear optical waveguide which has been designed so that the dispersion is dominated by the fourth-order term. Surprisingly in this regime pulses have been observed to propagate stably over multiple dispersion lengths in experiments despite there being no known analytic solution to the GNLSE. Further numerical investigations revealed that such pulses have unique and attractive features worthy of further study. We consider a stationary wave solution ansatz, where the optical pulse does not undergo a change in shape while propagating. This allows us to transform the PDE into a fourth-order nonlinear ordinary differential equation (ODE). In particular, we use the ODE to find bi-asymptotic trajectories, known as homoclinic solutions, which correspond to soliton solutions of the PDE. We take advantage of the mathematical property (reversibility) of the ODE to show the existence of infinitely many symmetric homoclinic solutions in a certain parameter regime. Specifically, we employ numerical continuation techniques to compute a representative number of them. Moreover, we show the existence of infinitely many non-symmetric soliton solutions that arise in the ODE as connecting orbits between periodic orbits and equilibrium solutions.

Ielyaas Cloete

(University of Auckland, i.cloete@auckland.ac.nz)

Dual mechanism of Ca^{2+} oscillations in hepatocytes

Variation of calcium concentration in hepatocytes (liver cells) is known to modulate diverse cellular functions, including bile secretion, glucose, and energy metabolism, and vesicular trafficking. A major question in the study of calcium signalling in hepatocytes is how these distinct cellular processes are controlled and organised via coordinated spatial and temporal calcium signals.

Downstream cellular responses are controlled via intracellular calcium oscillations, but the underlying mechanisms which shape these oscillations have yet to be elucidated. We are interested in determining the effects of the calcium feedback on Phospholipase C (PLC) have on the whole-cell calcium signal. Recent experimental data suggest that hormone-induced calcium oscillations require positive calcium feedback on PLC to generate inositol trisphosphate oscillations, yielding cross-coupling between calcium and inositol trisphosphate.

We discuss recent progress in construction and analysis of a model of calcium oscillations that incorporates the new experimental results about likely feedback mechanisms in hepatocytes.

Hammed Olawale Fatoyinbo
(Massey University, h.fatoyinbo@massey.ac.nz)

Spatiotemporal pattern formation in a model of electrically coupled smooth muscle cells

Electro-mechanical coupling (EMC) is a physiological process that involves the generation of signal and contraction of muscle cells. It may arise under the influence of external sources (such as agonists) or spontaneous activity of the ion channels. The spontaneous EMC activity in muscle cells is known as pacemaker dynamics. Motivated by this cellular behaviour, we investigate the formation of spatiotemporal patterns in a model of electrically coupled smooth muscle cells. Modulating model parameters, we identify transitions between types of excitability in the parameter space. The numerical simulations of our model in one spatial dimension showed that the patterns can bifurcate from a stable pattern to spatiotemporal chaos.

Seyed Mohsen Hashemi
(Massey University, S.M.Hashemi@massey.ac.nz)

Linear distortion and its application in material science

One of the most studied phase transitions in nonlinear material science is the Martensitic transition. The diffusionless structural transition from a high symmetry to a lower symmetry crystallographic phase. My poster reviews some mathematical contributions to the study of Martensitic microstructures via continuum models based on nonlinear elasticity. These contributions have used techniques from branches of mathematics such as nonlinear analysis, the calculus of variations, linear algebra, partial differential equations and geometry. By using quasiconformal mappings, we can study about rank-one connected interface of metals. Distortion can occur during welding as a result of the non-uniform expansion and contraction of the weld and base metal during the heating and cooling cycle.

Robert McLachlan
(Massey University, r.mclachlan@massey.ac.nz)

Boundary value problems and symplectic integration

This poster describes joint research for which Christian Offen won the 2019 Hatherton Award. Which bifurcations occur in boundary value problems for a Hamiltonian system? Which role do symmetries play? How can bifurcations be preserved in numerical computations? In this research Christian overturned the conventional wisdom, which said that symplectic integrators play no special role in boundary value problems, by showing that they are essential in preserving certain bifurcations of codimension 3 and higher.

Dion O'Neale
(University of Auckland, d.oneale@auckland.ac.nz)

Historical Correspondence Networks.

Correspondence records are a rich source of historical data — one that is becoming in-

creasingly amenable to computational analysis as records such as hand-written letters are converted to machine readable formats.

William Colenso (1811–1899) was a printer, missionary, explorer, naturalist, and politician in the early period of the colonisation of New Zealand. We have used the addressee and location-of-writing meta-data from Colenso's letters to construct a co-location correspondence network. The network links recipients of Colenso's letters when he tended to write to them from the same set of locations. The network reveals several significant communities. This suggests that it could provide a naive way to identify themes or topics in the corpus of Colenso's letters. The dual network connects geographic locations where Colenso tended to write to the same particular sets of people. Again, clusters of locations within the network suggest themes in Colenso's work at these different locations. It is also possible to study how the network changes over time. In addition to giving an interesting visualisation of Colenso's correspondence, this gives us a potential way to look at whether themes in the correspondence were more strongly associated with where Colenso was or when he wrote.

The construction of the networks is completely agnostic of the content of the letters. We will use digital methods such as text mining, as well as more traditional historical techniques, such as narrative analysis, to compare and contrast themes suggested by the network structure, with those from the content of the letters. We suggest that interesting liminality between naive networks and known historiography might emerge, and that gaps revealed by this mixed methodological approach would create novel opportunities for understanding and contextualising the past.

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Ten Years of Posters at the Colloquium

Posters are an important way of presenting research. They offer different opportunities for communication, sometimes more effective than spoken presentation. We celebrate ten years since the introduction of the poster session at the NZMS Colloquium. This is time to reflect on this milestone and the use of posters.

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Connections between saddle periodic orbits as organising centres of complicated dynamics

Recent theory states that connecting cycles between two saddle periodic orbits generate highly complicated dynamics when the periodic orbits have unstable manifolds of different dimensions. These heterodimensional cycles give rise to interesting nearby dynamics, including infinitely many periodic and/or homoclinic orbits as well as further such cycles. Results in the literature concern a neighbourhood of an abstract cycle. We compute heterodimensional cycles for a concrete four-dimensional vector field, by using advanced numerical methods based on continuation of two-point boundary value problems. In this poster presentation, we show that both orientable and non-orientable cycles exist, and we discuss the nearby bifurcation structure in a parameter plane.

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