AMSI SUMMERSCHOOL 19
IN THE MATHEMATICAL SCIENCES

7 JAN – 1 FEB 2019

THE UNIVERSITY OF NEW SOUTH WALES

EVENT REPORT

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

UNSW SYDNEY

Australian Government
Department of Education and Training

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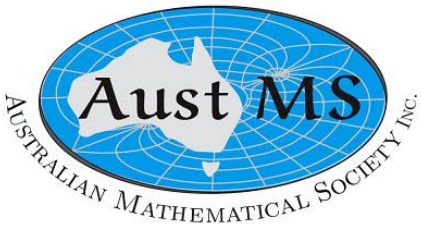
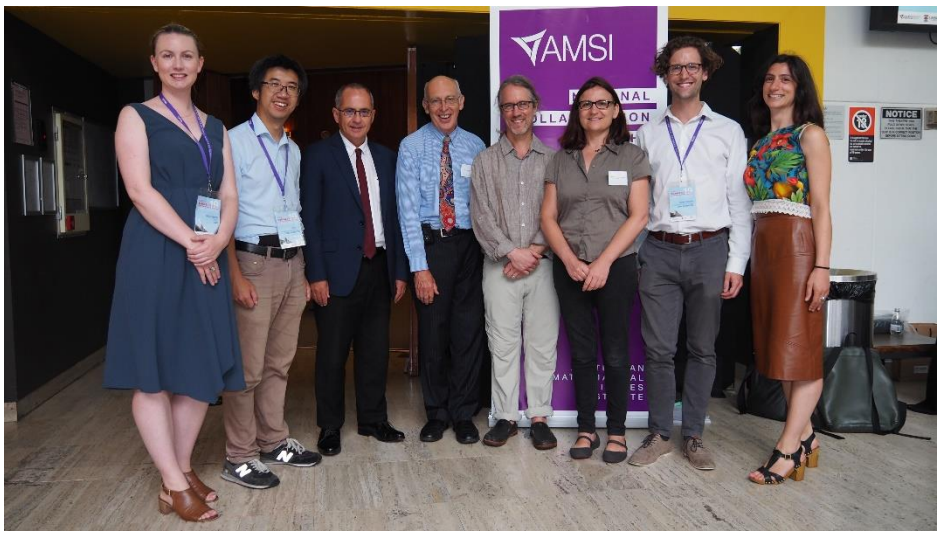


AMSI Summer School 2019

in the Mathematical Sciences

University of New South Wales

7 January to 1 February 2019


AMSI
NOTICE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FOREWORD

The AMSI Summer School is one of five premier flagship events hosted each year around Australia and forms part of the Securing Australia's Mathematical Workforce: 2016-2020 agreement between AMSI and the Department of Education and Training. Now in its 17th year, this key program has become of the most important calendar events for honours and postgraduate students in the mathematical sciences and cognate disciplines.

Hosted over four weeks, this program offers eight distinct subjects and gives students the opportunity to learn from highly experienced lecturers from all around Australia.

The complete program, comprising course content and extra activities, is designed to align with the project objectives of the agreement to:

- Strengthen research training and the work-readiness of advanced mathematical sciences graduates;
- Promote university-industry collaborations that will encourage the private sector employment of mathematical sciences graduates;
- Attract and improve the retention of senior undergraduate students in the mathematical sciences, with particular attention to women and Aboriginal and Torres Strait Islander students.

AMSI Summer School 2019 was jointly funded by the Australian Mathematical Sciences Institute (AMSI) and the Australian Government's Department of Education and Training, with support from the University of New South Wales (UNSW), the Australian Mathematical Society (AustMS), the Australian New Zealand Industrial and Applied Mathematics (ANZIAM), the Statistical Society of Australia (SSA), the Australian Signals Directorate, Optiver, the Commonwealth Bank and the BHP Foundation through the Choose Maths program.

"I can't adequately express how grateful I am for the consideration and kindness you all showed me, and the supportive environment you created. This event has made a difference in my life and maybe the trajectory of my future."

Chelsea Just, The University of Queensland

DIRECTOR'S REPORT

The AMSI Summer School is an exciting and unique event on the AMSI Research and Higher Education calendar and is one of the most anticipated events for Honours, Masters and PhD students studying mathematics nationally. As one of AMSI's flagship higher-education events, the Summer School features honours-level courses delivered by leading mathematical researchers and educators. The four-week program, designed for honours and postgraduate students, also attracted undergraduates, early-career researchers and industry professionals in the mathematical sciences and cognate disciplines.

A record 171 students from around Australia attended the 2019 AMSI Summer School, which was held at UNSW's Sydney campus from January 7 to February 1, 2019. Support to attend the Summer School was provided to 55 students through Travel Grants and 33 students through Choose Maths Grants. Students participated in eight intensive courses covering all aspects of mathematical research, from pure and applied mathematics to statistics and cognate quantitative disciplines such as mathematical biology and earth science. The courses, which incorporated lectures, tutorials, and computer labs, were delivered by 11 renowned experts from around Australia. All the courses were well-attended throughout the four weeks, with 85 students sitting the final exam for a course for credit and one student sitting an exam for interest.

In addition to the eight intensive honours-level courses, the Summer School program includes several diversity, career and outreach events. These included a Choose Maths evening, which featured dinner and a presentation by Dr Julia Collins (Choose Maths—Women in Maths Network Coordinator), attended by female students and staff members. The Summer School also held a Careers Event in Leighton Hall which showcased stall-holders from industry, and a series of panel discussions including one entitled "This Is What a Scientist Looks Like" chaired by Professor Catherine Greenhill. A public lecture by esteemed oceanographer Dr Stephen Griffies from Princeton University was held during the last week of Summer School. The public lecturer was very well-received, and drew around 120 attendees.

One of the key highlights of the Summer School is the engagement with the students. The program featured a vibrant social events calendar, with bi-weekly picnics and BBQs, weekly movie nights, networking events, virtual reality experiences and weekend excursions, which were well-attended by students. The Summer School was capped off with a closing dinner, where students and lecturers shared their experiences from the past four weeks. Guests were also treated to a viewing of the AMSI Summer School promotional video, which was directed and created by our videographer.

Finally, we would like to acknowledge the generous support from the sponsors, without whom this event would not be possible, and to the many people who worked tirelessly in the year-long planning leading to the 2019 Summer School. The Program Standing Committee provide insightful suggestions in choosing a broad range of topics and lecturers, which were relevant, appealing and would complement the programs at students' home institutions. In the latter part of 2019 the local organising committee work almost full-time on the preparation of the Summer School. Particular thanks go to Bruce Henry, Suzie Scandurra, Beatta Zarrabi, Susannah Waters, Diana Combe, Vito Scandurra and Altaf Syed at UNSW, and Tim Brown, Geoff Prince, Chloe Pearse and Anna Muscara at AMSI.

Associate Professor Guoyin Li and Dr Shane Keating—Event Co-Directors

Associate Professor Guoyin Li
Australian Future Fellow and lecturer
School of Mathematics and Statistics
The University of New South Wales

Dr Shane Keating
Researcher and lecturer
School of Mathematics and Statistics
The University of New South Wales

COURSE PROGRAM

The academic program consisted of eight courses throughout the intensive four-week timetable. Students were given the opportunity to enrol in up to two courses and had the option to take one course for credit, completing assessment tasks including a final examination, and obtaining a passing grade.

Courses offered could be roughly categorised as follows:

An Introduction to Non-Commutative Functional Analysis: Quantised Calculus

Professor Fedor Sukochev, The University of New South Wales
Dr Galina Levitina, The University of New South Wales

Analytic Number Theory

Dr Michael Coons, The University of Newcastle

Dynamical Systems: Models of Chaotic Dynamics

Dr Andy Hammerlindl, Monash University

Optimisation

Associate Professor Regina Burachik, The University of South Australia

Mathematics of Planet Earth

Dr Shane Keating, The University of New South Wales
Associate Professor Lisa Alexander, The University of New South Wales

PDE Methods and Models in Mathematical Biology

Associate Professor Peter Kim, The University of Sydney
Dr Justin Tzou, Macquarie University

Mathematical Methods for Machine Learning *(Sponsored by SSA)*

Dr Zdravko Botev, The University of New South Wales

Stochastic Modelling

Dr Giang Nguyen, The University of Adelaide

"I enjoyed the opportunity to learn maths at a higher level and really push myself. It just ignited my curiosity and passion for maths. I loved the opportunity to live in the residential college and form meaningful connections with people from so many different places and different areas of study. It really was just a brilliant experience."

Storm Logan, RMIT University

An Introduction to Non-Commutative Functional Analysis: Quantised Calculus

Professor Fedor Sukochev and Dr Galina Levitina, UNSW

Synopsis: Functional analysis, a central pillar of modern analysis and its foundations, was covered in this course with an emphasis on the study of compact linear maps on Hilbert spaces. This course provided the basic tools for the development of such areas as quantum mechanics, harmonic analysis and stochastic calculus. Special attention was given to applications in noncommutative geometry, specifically quantised calculus. The quantised calculus was introduced by Alain Connes in his 1994 book Noncommutative Geometry. This is a means of doing calculus which makes sense in a high degree of generality and has many properties analogous to the classical notion of "infinitesimal calculus". We gave a brief overview of applications to Julia sets.

Course Overview:

- Review of general Functional Analysis (measure and integration, Banach spaces and their duals, Hilbert spaces, bounded linear operators on Hilbert spaces)
- Compact operators (spectral theory of compact operators and singular value decomposition)
- Ideals of compact operators: Calkin theorem for two-sided ideals, Schatten and weak Schatten ideals
- Traces on ideals of compact operators: the classical trace and singular traces
- Applications: quantised calculus on the circle and an overview of quantised calculus for fractals, Connes trace theorem

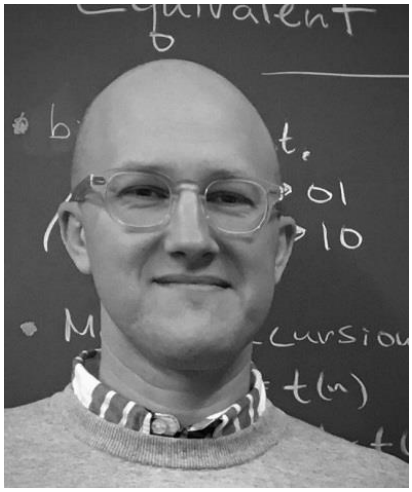
Number of students who completed the course:	**19**
Number of students who passed the course for credit:	**14**
Feedback: agreed the course was of a high standard:	**93%**

"The Functional Analysis course was one of the best run courses I've ever taken… Galina was a terrific lecturer and very helpful during consultation hours."

Anonymous

Analytic Number Theory

Dr Michael Coons, The University of Newcastle



Synopsis: Questions in number theory have driven the main stream of mathematical research for millennia, producing avenues leading to significant advancement in several other areas of mathematics. Stemming from the interest in the arithmetic of the integers one encounters the basic operations of 'plus' and 'times'. While 'plus' is easy enough, the intricacies of 'times' continue to be an object of rigorous mathematical study. The first important result in this vein is the proof of the infinitude of the primes—the multiplicative building blocks of the integers—recorded by Euclid in his Elements.

In this course, we studied the distribution of primes in its classical development before moving onto other important functions in the context of the multiplicative properties of integers.

Course Overview:

- Infinitude of primes
- Chebyshev's functions
- Bertrand's theorem
- Partial summation
- Riemann's zeta function
- Prime number theorem
- Newman's theorem
- Dirichlet L-functions
- Primes in arithmetic progressions

We also covered:

- Primitive roots and quadratic reciprocity
- Sums of multiplicative functions and density
- Roth's theorem and the circle method
- Vinogradov's three-prime theorem

Number of students who completed the course:	**13**
Number of students who passed the course for credit:	**7**
Feedback: agreed the course was of a high standard:	**89%**

"The lecturer was pretty funny and ran a well-structured course where we knew what was expected of us."

Daniel Johnston, The University of Melbourne

Dynamical Systems: Models of Chaotic Dynamics

Dr Andy Hammerlindl, Monash University

Course Overview: Dynamics is the study of systems that change in time. In some cases, the long-term behaviour is simple, such as a system settling down to an equilibrium or a regular periodic motion. In other cases, the system is chaotic. This does not mean, however, that we cannot analyse the system or determine its properties. In fact, many highly chaotic dynamical systems are very well understood.

In this course, we covered dynamical systems theory, starting with Poincaré's foundational work showing that no chaos is possible for flows on the plane, and going up to recent advances and discoveries. A large focus of the course was on known models of chaotic dynamics and the geometric and topological objects associated with their behaviour. This included horseshoes, geometric Lorenz attractors, Anosov systems, homoclinic tangencies, heterodimensional cycles and blenders. We also covered classification results that showed how well these models relate to dynamical systems that arise in the physical world.

Number of students who completed the course:	**17**
Number of students who passed the course for credit:	**6**
Feedback: agreed the course was of a high standard:	**88%**

"The lecturer Andy was really nice and willing to help. It's also great to meet all these brilliant students."

Shuai Tan, Australian National University

"Andy is a very enthusiastic lecturer, and I found his lecturers to be very engaging."

Anonymous

"I really appreciated the opportunity to meet new people, especially those with a different specialisation in mathematics. I am incredibly glad I had the opportunity to attend the Summer School because now I have contacts and friends in every capital city of Australia. It also opened my eyes to new possibilities and areas of mathematics that I hadn't even considered."

Guo Feng Anders Yeo, RMIT University

Optimisation

Associate Professor Regina Burachik, The University of South Australia

Synopsis: Optimisation training including (i) theoretical analysis and algorithms, (ii) their relation to practical problems, and (iii) the ability to apply the theory and algorithms to these 'real-life' problems.

Hence, we covered the following general areas:

- Modelling: formulation of a given problem as an optimisation problem
- Theory: study of the existence and uniqueness of solutions, and characterisation of the solutions of optimisation problems
- Methods: development and convergence analysis of algorithms for solving optimisation problems

Implementation: transcription of the algorithm to the medium of a suitable technical device (e.g. a digital computer). For instance, on a digital computer, the implementation of a method consists of writing a code corresponding to the method and running it on the computer.

All these four stages were part of this optimisation course. To implement the methods, we used MATLAB (or a similar language, such as octave).

Many topics were demonstrated by MATLAB programs, and students found satisfaction in the ability of solving problems on their own!

Course objectives: at the end of this course, students were able to:

- Identify the main features of a given optimisation problem (i.e. whether the problem was constrained or not, differentiable or not, convex or not, etc.)
- Decide whether the problem had solutions, and whether these solutions could be found analytically
- Become acquainted with numerical algorithms able to compute/approximate the solutions
- Analyse the convergence of optimisation techniques
- model and solve optimisation problems using MATLAB

Course Overview:

- Week 1: Review of mathematical tools: inner product and norms. Matrices, eigenvectors and eigenvalues. Topology concepts, open/closed balls, open/closed sets. Optimality conditions for unconstrained optimisation: global and local optima, first-order optimality conditions, second-order optimality conditions. Conditions for existence of solutions. Global optimality conditions. The quadratic case. (Chapters 1 and 2 of textbook).

- Week 2: Least squares problem (Chapter 3). The gradient method, scaled gradient method, Gauss-Newton Method. Newton's method, damped Newton method, Cholesky factorisation. (Chapters 4 and 5).
- Week 3: Hybrid Gradient-Newton (Chapter 5). Convex sets and their topological properties (Chapter 6). Convex functions. Connection with global optimality conditions. Continuity and differentiability of convex functions, and other related properties (Chapter 7, up to 7.9).
- Week 4: Convex optimisation: important examples: linear programming, convex quadratic problems. Examples of use of CVX software for solving convex optimisation problems (Chapter 8). Optimality for problems with continuously differentiable objective over a convex constraint set:
- Optimality conditions for some special cases (Chapter 9). KKT conditions for inequality constrained problems (Chapter 11, up to 11.7).

Number of students who completed the course:	**26**
Number of students who passed the course for credit:	**11**
Feedback: agreed the course was of a high standard:	**94%**

"I think what most attracted me were the teaching methods. The slides and lecture materials were very clear and I could quickly grasp the key points. Professor Regina [Burachik] was very nice and patient enough to answer our questions."

Dongpei Bian, The University of Melbourne

"I thoroughly enjoyed the optimisation course! When Guoyin took it for the first week the joy and energy he had were infectious and it was so much fun. When Regina returned, she also was incredibly enthusiastic about teaching and taught in a really good and concise way."

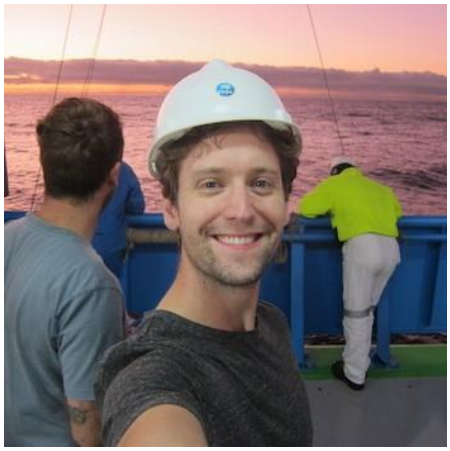
Guo Feng Anders Yeo, RMIT University

"I enjoyed the courses and the people that I met during the courses. I made friends who live in different cities and had a very fun time socialising with mathematics students in an intense college environment. I also really enjoyed the social events organised by the coordinators. Overall, the Summer School was a place where I could study subjects I'm interested in and socialise with like-minded individuals."

Geoffrey Liu, Australian National University

Mathematics of Planet Earth

Dr Shane Keating and Associate Professor Lisa Alexander, UNSW



Synopsis: This course aimed to introduce key concepts and mathematical methods for understanding our planet and the dynamical processes that shape it. We introduced the fundamental equations of motion and conservation laws that govern the fluid dynamics of the atmosphere and ocean. These equations are systematically simplified to develop the elegant and powerful theory of geophysical fluid dynamics, which is then used to quantitatively model a rich variety of atmospheric and oceanic phenomena and their interaction with Earth's climate.

Students also developed an understanding of how climate models are built, executed and evaluated. We examined statistical methods for interrogating large climate datasets, including model evaluation metrics, uncertainty quantification and extreme value theory. Theoretical understanding gained in lectures was explored in practical sessions and hands-on activities using a coupled climate model (CSIRO Mk3L) to simulate a range of climate scenarios such as double-CO2, Snowball Earth or the Last Glacial Maximum.

Course Overview:

1: Fundamental concepts
Eulerian and Lagrangian frames, continuity, Navier-Stokes equation, vorticity, frozen-in law, Kelvin's theorem, equation of state, energy conservation

2: Geophysical fluid dynamics
Stratification, Boussinesq approximation, internal gravity waves, rotating coordinate systems, Coriolis force, geostrophic balance, f-plane and beta-plane approximations, Rossby waves

3. Atmospheric circulation
Overview of atmospheric circulation, thermal wind balance, baroclinic instability, wave-mean interaction, zonal jets

4. Ocean circulation
Overview of ocean circulation, planetary geostrophic equations, wind-driven circulation, Ekman layer, Sverdrup balance, abyssal flow, Stommel-Arons model, buoyancy-driven circulation

5. Climate models
Model hierarchies from conceptual to comprehensive, chaos and initial conditions, climate models, energy budgets, fluxes

6. Climate data science and statistics
Model evaluation metrics, uncertainty estimation, interpreting ensembles, bias correction, weighting, statistical methods for climate date, extreme value theory

Number of students who completed the course:	**15**
Number of students who passed the course for credit:	**6**
Feedback: agreed the course was of a high standard:	**91%**

"Watching a physicist using maths was very enjoyable—quite different to how maths had been presented to me at my home institution. The subject material was engrossing; in fact, it made me wonder how I might move toward studying oceanography."

Cormac Scanlon, La Trobe University

"Learning about oceanography and meteorology, getting to apply fluid dynamics to those contexts was truly magnificent: as a friend once said, there's almost a poetry about that."

Khaya Mpehle, The University of Melbourne

"I had to do a subject of my interest, but not offered at my home institution, and the lecturer was amazing. I've also made friends who have similar career interests as I do, who helped me understand my career goals better."

Shidan Liu, RMIT University

"I have made friends who I think will be my future co-authors and collaborators."

Neil Dizon, The University of Newcastle

PDE Methods and Models in Mathematical Biology

Associate Professor Peter Kim, The University of Sydney

Dr Justin Tzou, Macquarie University

Synopsis: Mathematics can be useful for studying biological systems. In this course, we showed how to utilise partial differential equations (PDEs) to model and analyse a range of biological systems. PDE models capture a wide range of biological phenomena, including spatial and age-structured interactions. Particular topics included age-/maturity-structured models, diffusion and reaction-diffusion models for predator-prey dynamics, chemotaxis, pattern formation and mean first-passage time models for applications such as intracellular transport. We also discussed a recently developing area of mathematical modelling, that of bridging agent-based (or individual) models and differential equations.

Course Overview:

- Age-structured models
- Diffusion
- PDE approach for mean first-passage time problems in 1-D and 2-D
- Chemotaxis
- Fisher's equation
- Travelling waves/fronts
- Reaction-diffusion systems
- Turing stability analysis
- Weakly nonlinear analysis for small amplitude patterns
- Asymptotic methods for large amplitude patterns in 1-D and 2-D
- Connecting PDEs to agent-based models

Number of students who completed the course:	**12**
Number of students who passed the course for credit:	**8**
Feedback: agreed the course was of a high standard:	**90%**

"I found a new and interesting subject, and mathematical biology may become my future learning area."

Yazheng Kang, Australian National University

Mathematical Methods for Machine Learning

Dr Zdravko Botev, The University of New South Wales

Synopsis: To someone starting to learn data science, the multitude of computational techniques and mathematical ideas may seem overwhelming. Some may be satisfied with only learning how to use off-the-shelf recipes to apply to practical situations. But what if the assumptions of the black-box recipe are violated? Can we still trust the results? How should the algorithms be adapted?

The purpose of this short course was to provide an accessible introduction to the basic ideas in data science and machine learning. It was intended for anyone interested in gaining a better understanding of the mathematics and statistics that underpin the rich variety of ideas and machine learning algorithms in data science. This understanding is needed, because computer implementations come and go, but the underlying key ideas and algorithms will remain, and will form the basis for ongoing research and future practice.

Course Overview:

- Handling Data
- Fundamentals of Supervised Learning and Regression
- Monte Carlo Methods for Bayesian Learning
- Unsupervised Learning (Clustering and Mixture Modelling)
- Kernel Methods and Support Vector Machines for Classification
- Deep Learning and Neural Networks

Number of students who completed the course:	**47**
Number of students who passed the course for credit:	**20**
Feedback: agreed the course was of a high standard:	**45%**

Sponsored by the Statistical Society of Australia

Statistical Society of Australia

"I found the content very interesting as much of it was new to me. The material inspired me to write a blog post sharing some of what I learnt."

Michael Howes, Australian National University

Stochastic Modelling

Dr Giang Nguyen, The University of Adelaide

Synopsis: Randomness is an important factor in modelling and analysing various real-life situations. This course covered some key aspects in stochastic modelling, including the theory underlying Brownian motions and diffusion processes, as well as techniques for numerical simulations.

Course Overview:

- Preliminaries from measure-theoretic probability
- Modes of convergence
- Brownian motion
- Simulation algorithms
- Filtration, martingales and stopping times
- Basics of Ito calculus

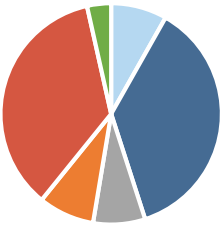
Number of students who completed the course:	**33**
Number of students who passed the course for credit:	**6**
Feedback: agreed the course was of a high standard:	**96%**

"The lecturer, Giang Nguyen, was extremely engaging. She made the subject really interesting and fun, and definitely knew her stuff and was able to answer anyone and everyone's questions appropriately."

Mabel Chen, RMIT University

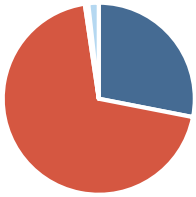
PARTICIPATION BREAKDOWN

Enrolments by Institution	
Australian National University	15
Curtin University of Technology	2
La Trobe University	2
Macquarie University	3
Monash University	17
Ernst & Young (Industry)	1
RMIT University	6
Swinburne University of Technology	1
The University of Adelaide	12
The University of Melbourne	34
The University of New South Wales	27
The University of Newcastle	5
The University of Queensland	12
The University of Sydney	22
The University of Western Australia	4
The University of South Australia	2
The University of Southern Queensland	1
The University of Technology Sydney	5
TOTAL	171



STATE/TERRITORY

ACT	14	8%
NSW	63	37%
QLD	13	7%
SA	14	8%
VIC	61	36%
WA	6	4%
TAS	0	0%
INTERNATIONAL	0	0%



GENDER

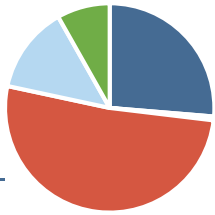
Male	119	70%
Female	48	28%
Other	1	1%
Prefer not to disclose	3	2%

ATSI STATUS

Yes	1	1%
No	169	98%
Prefer not to disclose	1	1%

RESIDENCY STATUS

Australian Citizen	82	48%
Permanent Resident	6	3%
Student Visa	81	47%
Other	1	1%
Prefer not to disclose	1	1%



ACADEMIC STATUS

Undergraduate	14	8%
Honours	45	26%
Masters	88	52%
PhD	23	13%
Early-Career Researcher	0	0%
Other	1	1%

GRANTS

AMSI Travel Grants

AMSI Travel Grants are offered to support AMSI Member students attending flagship higher-education events by funding their travel and accommodation. AMSI Summer School 2019 grants were funded by AMSI, University of New South Wales and the Australian Government's Department of Education and Training, and were determined on a competitive basis. In 2019, AMSI Travel Grants were awarded to 55 students from 11 AMSI Member universities:

- Michael Howes, Australian National University
- Geoffrey Liu, Australian National University
- Shih Ching Fu, Curtin University of Technology
- Timothy Gummer, Curtin University of Technology
- Robert Hickingbotham, Monash University
- Siyuan Lin, Monash University
- Sean Malcolm, Monash University
- Nicholas Pennell, RMIT University
- Guo Feng Yeo, RMIT University
- Jordan Orchard, Swinburne University of Technology
- Joshua Bean, The University of Adelaide
- Tobin South, The University of Adelaide
- Neil Dizon, The University of Newcastle
- Chao Ye, The University of Queensland
- James Evans, The University of Western Australia
- Richard Steele, The University of Southern Queensland
- Shuai Tan, Australian National University
- Andrew Tanggara, Australian National University
- Kenny Wiratama, Australian National University
- Andrew Cook, Monash University
- Tarik Pecaninovic, Monash University
- Callum Scott, Monash University
- Luke Thompson, Monash University
- Ryan Dye, The University of Adelaide
- Timothy Moy, The University of Adelaide
- Kieran O'Loughlin, The University of Adelaide
- Stuart Teisseire, The University of Adelaide
- Connor Duffin, The University of Western Australia
- Michael Dymock, The University of Western Australia
- Jiangrong Ouyang, The University of Melbourne
- Daniel Johnston, The University of Melbourne
- Khaya Mpehle, The University of Melbourne
- Shichang Pan, The University of Melbourne
- Brian Waxmann, The University of Melbourne

- Chengrui Wu, The University of Melbourne
- Manu Yadav, The University of Melbourne
- Xu Huang, The University of Melbourne
- Paul Nguyen, The University of Melbourne
- Yinda Wang, The University of Melbourne
- Lijun Zhang, The University of Melbourne
- Anubhav Kaphle, The University of Melbourne
- Peter Olanipekun, Monash University
- Oscar Rodriguez Trujillo, Monash University
- Shiqiu Qiu, Australian National University
- Peizheng Ni, Monash University
- Jingwei Qiu, Monash University
- Darren Low, Monash University
- Mabel Chen, RMIT University
- Shidan Liu, RMIT University
- Cassandra Llorente Canon, Australian National University
- Shingyan Kwong, The University of Adelaide
- David Quarel, Australian National University
- Yaozhong Qiu, The University of Melbourne
- Dewei Zhuang, The University of Queensland
- Jiahao Wu, The University of Melbourne

Choose Maths Grants

Choose Maths Grants are designed to offer full and partial support for Australian female mathematical sciences students and early-career researchers to participate in the AMSI higher-education programs and/or assist with caring responsibilities. The BHP Billiton Foundation, as an initiative of the Choose Maths program, funded these grants to help women build and extend their mathematical skills and professional networks. In 2019, Choose Maths Grants were awarded to 33 female students from nine AMSI Member universities:

- Yazheng Kang, Australian National University
- Storm Logan, RMIT University
- Yao Tang, La Trobe University
- Siksha Sivaramakrishnan, Monash University
- Saritha Kodikara, RMIT University
- Rose Crocker, The University of Adelaide
- Ashley Dennis-Henderson, The University of Adelaide
- Miriam Slattery, The University of Adelaide
- Haripriya Sridharan, The University of Adelaide
- Xuemei Liu, The University of South Australia
- Anita Sugo, The University of Newcastle
- Chelsea Just, The University of Queensland

- Shenzhengyi Kuang, The University of Queensland
- Jiayi Li, The University of Queensland
- Cherish Chen Huay Lo, The University of Queensland
- Chengcheng Wang, The University of Queensland
- Zhiwang Wen, The University of Queensland
- Rachael McCullough, The University of Melbourne
- Bing Liu, The University of Melbourne
- Madhurima Biswas, The University of Melbourne
- Dongpei Bian, The University of Melbourne
- Peijing Li, The University of Melbourne
- Ziwei Liu, The University of Melbourne
- Wenfei Shi, The University of Melbourne
- Youxin Tan, The University of Melbourne
- Shiyu Tian, The University of Melbourne
- Yahang Wang, The University of Melbourne
- Yi Xing, The University of Melbourne
- Qin Xu, The University of Melbourne
- Zhu Yao, The University of Melbourne
- Hangfei Zheng, The University of Melbourne
- Qi Zhuang, The University of Melbourne
- Jiayi Wu, The University of Melbourne

"It was really helpful to be surrounded by other students in similar positions to my own, i.e. passionate about maths, and interested in having a mathematical career. That doesn't happen very often."

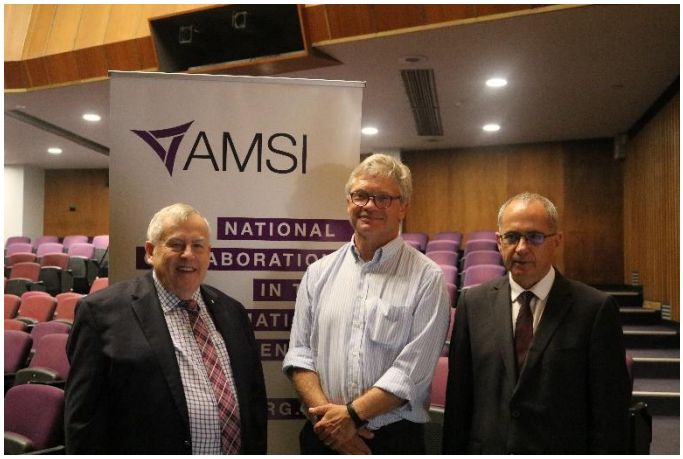
Mabel Chen, RMIT University

"I most enjoyed the networking opportunities provided by the Summer School. The number and variety of social events provided was fantastic and allowed me to meet like-minded people from all over the country. Living with the majority of them really consolidated the friendships and connections made."

Michael Dymock, The University of Western Australia

EVENT HIGHLIGHTS

Opening Ceremony



The Summer School was officially opened by NSW Chief Scientist & Engineer Professor Hugh Durrant-Whyte. Students and attendees were also warmly welcomed by Professor Simon Kilcross (Deputy Dean (Strategy), Faculty of Science, UNSW), Professor Bruce Henry (Head of Mathematics and Statistics, UNSW) and Professor Ron Sandland (Chairman of AMSI Board). Event Co-Directors Associate Professor Guoyin Li and Dr Shane Keating introduced the local event team and made everyone feel more at home at UNSW. The ceremony was attended by approximately 171 students, the Summer School lecturers and members of the UNSW School of Mathematics and Statistics. This was followed by a morning tea, a group photograph and tours of the campus.

Diversity in STEM Event

The Diversity in STEM event was a panel discussion which was hosted in conjunction with the Careers Day Fair. With the event theme 'This is What a Scientist Looks Like', the session was hosted by Professor Catherine Greenhill (UNSW) and invited guest panellists Dr Giang Nguyen (University of Adelaide, WIMSIG), Dr Thomas Morrill (UNSW Canberra) and Kirsten Banks (astronomer and science communicator, UNSW). Each panel member spoke about their experience and barriers that hinder diversity in academia and the wider STEM community. Attendees were encouraged to participate in lively and informative discussions around these barriers and experiences. Approximately 30 people attended, 22 of whom were Summer School attendees.

"I met lots of new friends during the Summer School, which is the part that I enjoyed the most. Although I already have lots of friends in my home institution, talking to students from other universities was still one of the most enjoyable parts of this event."

Chengrui Wu, The University of Melbourne

Careers Day Fair

The Careers Day Fair is always a highlight for students attending Summer School, providing valuable information and contacts for student careers pathways. This year, the event was hosted by AMSI Director Professor Tim Brown. Presentations about career pathways in mathematics were given by:

- Bureau of Meteorology
- Alpha Beta
- Australian Signals Directorate
- Optiver
- Commonwealth Bank

This was followed by three different panel sessions about the APR.Intern program, the Diversity in STEM topic "This is What a Scientist Looks Like", and career pathways in academia and industry. These panel sessions gave students the opportunity to find out more about different career paths available to them, exposure to different career experiences and a chance to engage in deeper discussion with members of academia and industry. AMSI would like to thank the following panel members for their time:

APR Internship Panel Session
Mark Ovens, APR.Intern, AMSI
Cassius Coombs, APR.Intern, The University of Sydney
Loic Brisrobert, industry partner, Rapiscan Systems
Brian Arnott, industry partner, Dolby
Lucian Gonzalez, academic, The University of Sydney

Diversity in STEM—This is What a Scientist Looks Like
Professor Catherine Greenhill, UNSW
Dr Giang Nguyen, University of Adelaide, WIMSIG
Dr Thomas Morrill, UNSW Canberra
Kirsten Banks, astronomer and science communicator

Academia and Industry Career Pathways
Adrianne Harris, UNSW Careers Team
Richard Finlay, Reserve Bank of Australia
Dr Genevieve Mortiss, DST Group
Associate Professor Regina Burachik, The University of South Australia
Dr Michelle Dunbar, The University of Sydney

The Careers Day Fair also included an expo where students were able to talk with presenters and stall holders individually about career paths and graduate employment opportunities. 120 students participated in the event with very positive feedback from both presenters and students. In particular, students found the day very informative, discovering career pathways they did not realise were available to them.

Stall holders included:

- Bureau of Meteorology
- Australian Signals Directorate
- Optiver
- Commonwealth Bank
- APR.Intern
- Alpha Beta
- Reserve Bank of Australia
- Department of Defence
- UNSW Careers
- Statistical Society of Australia

SOCIAL EVENTS

Welcome Reception

On the evening of the first day of the program, a Welcome Reception was hosted to give students the opportunity to meet each other over dinner in an informal setting. The event was hosted in the mathematics and statistics department common room. Approximately 150 students attended.

Choose Maths Networking Event

A Choose Maths dinner was hosted in the first week of the program. This specialised event gave female staff and students the chance to meet over dinner and share their experiences studying and working within the mathematics fields. Attendees also learned more about the AMSI Choose Maths program, the kind of support it offers and its importance within the community. Feedback from both staff and students was positive. The event attracted approximately 50 guests.

"The extra programs were all very well organised and presented. The careers day in particular allowed those who had not thought about a job outside research to be exposed to some of the possibilities that they have if they do not wish to continue in academia."

Kieran O'Loughlin, The University of Adelaide

Weekly BBQs and Picnics

Mid-week barbeques and picnics were held at lunchtime on alternating Wednesdays each week of the Summer School. The barbeques were hosted at the UNSW Round House, and the picnics on the Physics Lawn. These were well-attended and were enjoyed by all students.

VR Experience

The team at UNSW arranged a series of virtual-reality immersive experiences for students to participate in. Experiences included a virtual tour of Sydney and a Minecraft experience. These were offered at sessional times throughout the Summer School program. These experiences were highly popular among Summer School attendees and provided some light-hearted respite between intense classes.

Excursions

Two weekend excursions were organised specially for students visiting from outside Sydney. On the first weekend, the group completed the Coogee to Bondi coastal walk to take in the views of the beautiful and internationally-renowned coastline. On the second week, students travelled to the Royal National Park to explore the natural beauty of the bushland, forest and cliff-faces. It was agreed that this was a highlight for all students who attended.

Movie Maths

The team at UNSW organised a weekly movie night for the first three weeks of Summer School, enabling students and lecturers to relax in the evening after intensive coursework. Movie snacks and state-of-the-art theatres made for a truly authentic cinematic experience.

Closing Dinner

The closing dinner was hosted on a cruise ship that toured around the Sydney Harbour, so that students could take in the splendour of one of the most iconic sights in Australia. The dinner was attended by 145 guests including 125 students. The dinner included short speeches and presentations from participants, lecturers and organising staff. Guests were also treated to a video presentation of their time at UNSW and Summer School. It was noted by many that this was a particularly memorable way to conclude the Summer School.

"I have met other PhD students who are doing similar research to me. I have learned a lot of useful information from them. I have also learned how to handle the stress of my research and study from those who have completed their PhDs."

Xuemei Liu, The University of South Australia

"The subject I took (Mathematics of Planet Earth) was fascinating, the lecturer was clearly an expert, and it was very enjoyable getting to meet other students with interests similar to mine. The university partner (UNSW) seemed hospitable and welcoming, and its location—10 minutes from Coogee Beach—was very pleasant indeed!"

Cormac Scanlon, La Trobe University

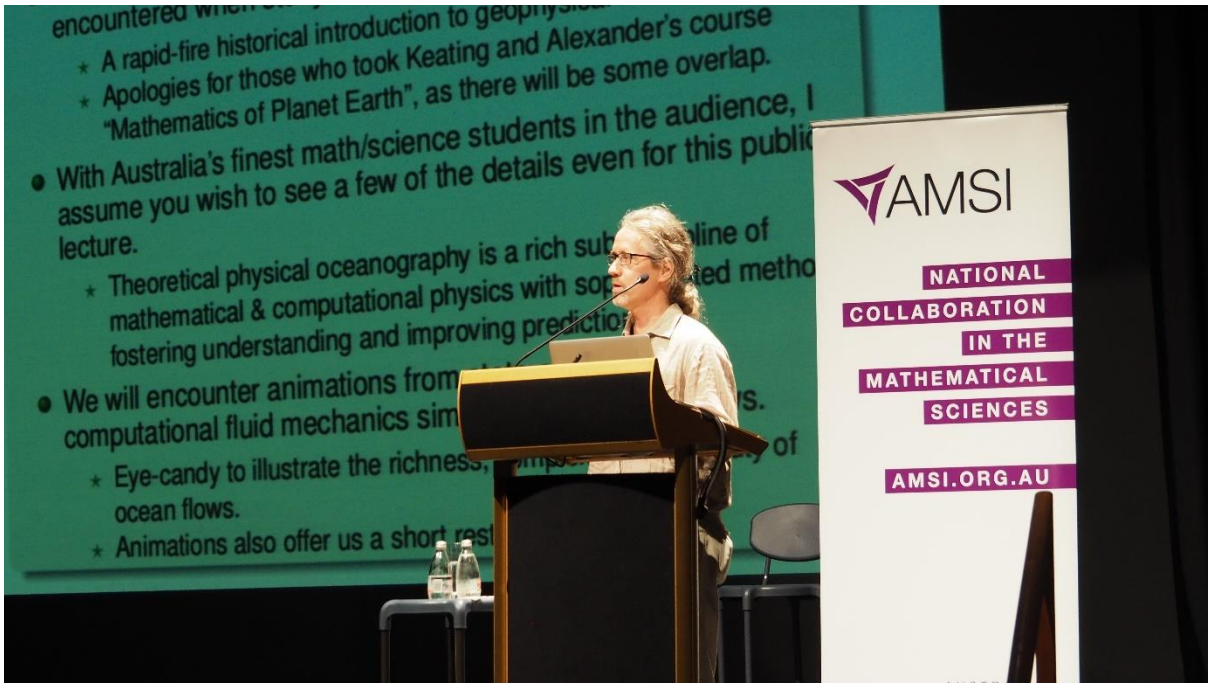
"[I enjoyed] the opportunity to be around so many fantastic students, develop relationships with peers, and get excited about the future of our careers."

Tobin South, The University of Adelaide

"[I enjoyed] the courses and the events because the Summer School's life was wonderful. Not only learning the knowledge but also making a lot of new friends."

Jiayi Li, The University of Queensland

PUBLIC LECTURE



We were very fortunate to have Dr Stephen Griffies (NOAA Geophysical Fluid Dynamics Laboratory and Princeton University) present the Public Lecture for the 2019 Summer School. Dr Griffies is a leading expert on ocean circulation and ocean fluid dynamics. His presentation, 'A Math/Physics View of Ocean Circulation', focused on some of the mechanisms of ocean circulation and the questions confronting ocean scientists today. This lecture was hosted at UNSW's Science Theatre and was well-received with over 114 people attending the event, including 30 students of the Summer School. Dr Griffies' presentation was followed by a rigorous Q&A discussion with the audience.

"Networking is something which I typically have no interest in. However… I soon realised that there was great potential to meet other students who are both ambitious with their mathematics education and have some novel ideas of their own."

Jordan Orchard, Swinburne University of Technology

STUDENT PROFILE

Grant Adds Up to Summer of Maths

For as long as she can remember, Storm Logan has been captivated by the beauty of maths. In Year Four, she even begged her mother to let her attend Saturday Maths School.

"I love seeing maths used, watching the way it applies in the real world. As far as I'm concerned, the more maths experience you get, the better," she says.

Now an RMIT Masters of Statistics and Operations Research student, the same passion spills over as she talks about attending the 2019 Australian Mathematical Sciences Institute (AMSI) Summer School.

"Many universities can offer subjects, but AMSI Summer School gave me access to people I may have never met. It fuelled my interest in operations research and has prepared me for the maths I'm likely to encounter in coming years," enthuses Storm.

Without the support of a CHOOSEMATHS grant, she may never have had her summer of mathematics. Storm believes she would have been one step further from her dream of being the operations researcher who uses analytical methods and mathematical algorithms to optimise management, logistics and scheduling.

"Receiving my grant was essential to my attending, without this support I highly doubt I would have been able to afford accommodation for the month."

Storm believes grants and networking opportunities for women open a world of opportunities. They benefit not only the women themselves, but the wider community as they are able to hone and apply their skills.

"These grants and the networking opportunities they provide are extremely important. They give women the chance to participate in programs and training that they may have otherwise missed out on."

With her eye on an industry career, it was the chance to network that Storm believes was the most valuable part of the AMSI Summer School 2019 for her.

"[Networking] is just as important as the actual courses you study," says Storm. "It is important to reach out to the other students—they're the ones you can turn to during assignment times."

Her advice to anyone thinking of going to Summer School is simple—apply!

"You could spend your whole life thinking that someone else will get it. But that 'someone else' could very well be you. There's no harm in trying and everything to gain if you succeed."

The little girl excited to do more mathematics on a Saturday would no doubt agree. Not that Storm was always so certain about her path.

“I came from a very maths- and science-oriented family. I don’t think I knew I would pursue maths as a career but when I look back, it should have been obvious.”

About the Choose Maths Grants

Funded by BHP Foundation as an initiative of the Choose Maths project, the Choose Maths grants are designed to provide full or partial support for Australian female mathematical sciences students and early-career researchers to participate in the AMSI Flagship programs.

Awarded on a competitive basis by the Choose Maths Grant Committee, this funding supports women to build and extend their skills and professional networks by providing financial support to attend and/or assist with caring responsibilities.

“I just wanted to say thank you to everyone. You guys not only made the program run smoothly and did so much work and preparation in the background. You guys also made it a point to be approachable and chat to us. I'm really glad that my first ever AMSI Summer School was this one, I wouldn't have it any other way. The people and the experience were just fantastic. Thank you!”

Storm Logan, RMIT University

FEEDBACK ANALYSIS

Sixty-four percent of attendees completed the post event feedback form commenting on their experiences at the 2019 Summer School. On the whole, the survey data suggests that this program continues to be integral to the mathematical sciences landscape in the higher education sector, giving students a platform to make valuable networks, broaden their knowledge and open up possibilities for future study and career paths in mathematics and statistics. In rating their overall experience where 1 signalled poor performance and 10 excellent, the average rating for the 2019 program was 8.7.

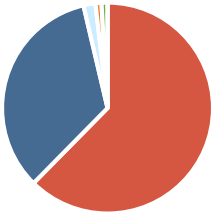
Of those that completed the survey, 49 per cent of students cited that their motivation for attending was to gain credit towards their degree. An additional 37 per cent attended to broaden their knowledge and 7 per cent attended to learn from a specific lecturer.

Once again, the AMSI Summer School program demonstrated to participants the importance of mathematical sciences qualifications and its wide and varied application in industry. Forty per cent of survey respondents noted that participating in the program strengthened their resolve to pursue a PhD in mathematics (20 per cent agreed; 20 per cent strongly agreed), while 68 per cent of students felt the Careers Day Fair event provided good information and advice about careers and job opportunities (32 per cent agreed; 36 per cent strongly agreed).

Below is a further breakdown of thoughts and comments regarding the 2019 program.

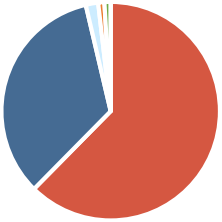
OVERALL, THE SCHOOL WAS OF A HIGH STANDARD

Strongly Agree	62%
Agree	34%
Neutral	2%
Disagree	1%
Strongly Disagree	1%

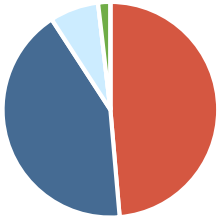


OVERALL, THE SCHOOL WAS WELL-ORGANISED

Strongly Agree	69%
Agree	29%
Neutral	1%
Disagree	0%
Strongly Disagree	1%

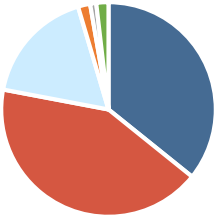


THE COURSES OFFERED PROVIDED A GOOD VARIETY OF SUBJECTS



Strongly Agree	49%
Agree	42%
Neutral	7%
Disagree	0%
Strongly Disagree	2%

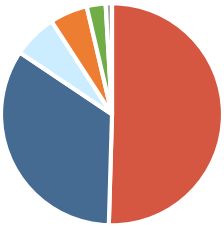
I MADE USEFUL CONTACTS AND NETWORKS AT SUMMER SCHOOL



Strongly Agree	36%
Agree	42%
Neutral	17%
Disagree	2%
Strongly Disagree	1%
Prefer not to say	2%

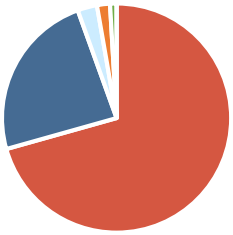
I WILL APPLY KNOWLEDGE GAINED FROM THE SCHOOL TO MY CURRENT AND FUTURE STUDIES/ACTIVITIES

Strongly Agree	50%
Agree	34%
Neutral	6%
Disagree	5%
Strongly Disagree	3%
Prefer not to say	1%



I WOULD RECOMMEND SUMMER SCHOOL TO OTHERS

Strongly Agree	71%
Agree	24%
Neutral	3%
Disagree	2%
Strongly Disagree	1%



"This was an amazing event which surpassed all my expectations. I really commend the generosity of the sponsors and the organising skill of the support staff in putting everything together so smoothly."

Shih Ching Fu, Curtin University of Technology

"The AMSI Summer School experience was a fantastic way for me to start my honours year at Monash because it helped me with my confidence, as well as being a fantastic way of bonding with classmates with whom I will be spending the remainder of the year."

Andrew Cook, Monash University

COMMITTEES

Program Committee

- Guoyin Li (Event Co-Director), UNSW (Co-Chair)
- Shane Keating (Event Co-Director), UNSW (Co-Chair)
- Bruce Henry, (Head of School, Mathematics and Statistics), UNSW
- Geoff Prince (Director), Australian Mathematical Sciences Institute
- Simon Clarke (AMSI Summer School 2018 Director), Monash University
- Anthony Henderson (AMSI Summer School 2017 Director), The University of Sydney
- Chloe Pearse (Program Manager, Research and Higher Education), Australian Mathematical Sciences Institute
- Vanessa Robins, Australian National University
- Ivan Guo, Monash University
- Murray Elder, Monash University
- Bronwyn Hajek, University of South Australia
- Pierre Portal, Australian National University
- Anna Muscara (Committee Secretary), Australian Mathematical Sciences Institute

Organising Committee

- Guoyin Li (AMSI Summer School 2019 Co-Director), UNSW
- Shane Keating, (AMSI Summer School 2019 Co-Director), UNSW
- Bruce Henry (Head of School, Mathematics and Statistics), UNSW
- Suzie Scandurra, UNSW
- Susannah Waters, UNSW
- Beatta Zarrabi, UNSW
- Diana Combe, UNSW
- Altaf Syed, UNSW
- Josephene Isaacs, UNSW
- Vito Scandurra, UNSW
- Chloe Pearse, Australian Mathematical Sciences Institute
- Anna Muscara, Australian Mathematical Sciences Institute

"I would just like to say thank you to all the organisers and staff that made this Summer School so great. I had a wonderful time and would highly recommend this program to anyone interested in mathematics."

Ashley Dennis-Henderson, The University of Adelaide

AMSI 19 SUMMER SCHOOL

IN THE MATHEMATICAL SCIENCES

7 JAN – 1 FEB 2019
THE UNIVERSITY OF NEW SOUTH WALES

AN INTRODUCTION ON NON-COMMUTATIVE FUNCTIONAL ANALYSIS: QUANTISED CALCULUS
PROF. FEDOR SUKOCHEV (UNSW)
DR GALINA LEVITINA (UNSW)

ANALYTIC NUMBER THEORY
DR MICHAEL COONS (UON)

DYNAMICAL SYSTEMS: MODELS OF CHAOTIC DYNAMICS
DR ANDY HAMMERLINDL (MONASH)

OPTIMISATION
ASSOC. PROF. REGINA BURACHIK (UNISA)

MATHEMATICS OF PLANET EARTH
DR SHANE KEATING (UNSW)
ASSOC. PROF. LISA ALEXANDER (UNSW)

MODELS IN MATHEMATICAL BIOLOGY
ASSOC. PROF. PETER KIM (USYD)
DR JUSTIN TZOU (MACQ)

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AMSI RESEARCH

Australian Mathematical Sciences Institute

Research and Higher Education
Building 161 C/- The University of Melbourne
VIC 3010 Australia

events@amsi.org.au
www.amsi.org.au