MATRIX Book Series 3

David R. Wood *Editor-in-Chief*
Jan de Gier
Cheryl E. Praeger
Terence Tao *Editors*

2018 MATRIX Annals

MATRIX

Springer

MATRIX Book Series 3

MATRIX is Australia's international and residential mathematical research institute. It facilitates new collaborations and mathematical advances through intensive residential research programs, each lasting 1–4 weeks.

More information about this series at http://www.springer.com/series/15890

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Editors

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Preface

MATRIX is Australia's international and residential mathematical research institute. It was established in 2015 and launched in 2016 as a joint partnership between Monash University and The University of Melbourne, with seed funding from the ARC Centre of Excellence for Mathematical and Statistical Frontiers. The purpose of MATRIX is to facilitate new collaborations and mathematical advances through intensive residential research programs, which are currently held in Creswick, a small town nestled in the beautiful forests of the Macedon Ranges, 130km west of Melbourne.

This book is a scientific record of the eight programs held at MATRIX in 2018:

- *Non-Equilibrium Systems and Special Functions*
- *Algebraic Geometry, Approximation and Optimisation*
  Guest editors: Enrico Carlini, Jochen Garcke, James Saunderson
- *On the Frontiers of High Dimensional Computation*
  Guest Editor: Frances Kuo
- *Month of Mathematical Biology*
  Guest Editors: Mark Flegg and James Osborne
- *Dynamics, Foliations, and Geometry In Dimension 3*
  Guest Editors: Jonathan Bowden and Andy Hammerlindl
- *Recent Trends on Nonlinear PDEs of Elliptic and Parabolic Type*
  Guest Editor: Daniel Hauer
- *Functional Data Analysis and Beyond*
- *Geometric and Categorical Representation Theory*
  Guest editor: Peter McNamara

The MATRIX Scientific Committee selected these programs based on scientific excellence and the participation rate of high-profile international participants. This committee consists of: Jan de Gier (University of Melbourne, Chair), Ben Andrews (Australian National University), Peter Bühlmann (ETH Zurich), Alison Etheridge (University of Oxford), Gary Froyland (University of New South Wales), Kerrie Mengersen (Queensland University of Technology), Joshua Ross (University of Adelaide), Terence Tao (University of California, Los Angeles), Ole Warnaar (University of Queensland), Geordie Williamson (University of Sydney), and David Wood (Monash University).

These programs involved organisers from a variety of Australian universities, including Australian National University, Monash University, Queensland University of Technology, RMIT University, Swinburne University of Technology, Federation University Australia, University of Adelaide, University of New South Wales, University of Melbourne, University of Queensland, and University of Sydney, along with international organisers and participants.

Each program lasted 1–4 weeks, and included ample unstructured time to encourage collaborative research. Some of the longer programs had an embedded conference or lecture series. All participants were encouraged to submit articles to the MATRIX Annals.

The articles were grouped into refereed contributions and other contributions. Refereed articles contain original results or reviews on a topic related to the MATRIX program. The other contributions are typically lecture notes or short articles based on talks or activities at MATRIX. A guest editor organised appropriate refereeing and ensured the scientific quality of submitted articles arising from each program. The Editors (Jan de Gier, Cheryl E. Praeger, Terence Tao and myself) finally evaluated and approved the papers.

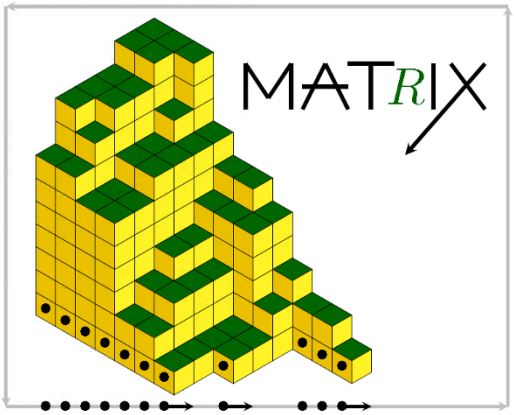
Many thanks to the authors and to the guest editors for their wonderful work.

MATRIX is hosting ten programs in 2019, with more to come in 2020; see `www.matrix-inst.org.au`. Our goal is to facilitate collaboration between researchers in universities and industry, and increase the international impact of Australian research in the mathematical sciences.

David R. Wood
MATRIX Book Series Editor-in-Chief

Non-Equilibrium Systems and Special Functions

8 January – 2 February 2018



Organisers

Vadim Gorin
MIT

Tomohiro Sasamoto
Tokyo Institute of Technology

Ole Warnaar
University of Queensland

Michael Wheeler
University of Melbourne

Participants

Patrik Ferrari (Bonn Uni), Craig Tracy (UC Davis), Vadim Gorin (MIT), Tomohiro Sasamoto (Tokyo Inst Technology), Ole Warnaar (Uni Queensland), Michael Wheeler (Uni Melbourne), Dan Betea (Universite Paris Diderot), Jrmie Bouttier (CEA Saclay, ENS de Lyon), Zeying Chen (Uni Melbourne), Evgeny Dimitrov (MIT), Victor Dotsenko (Universite Pierre et Marie Curie), Caley Finn (Universite de Savoie), Alexandr Garbali (Uni Melbourne), Jan de Gier (Uni Melbourne), Liam Hodgkinson (Uni Queensland), Takashi Imamura (Uni Tokyo), Ivan Kostov (CEA-Saclay), Atsuo Kuniba (Uni Tokyo), Vladimir Mangazeev (Australian National Uni), Masato Okado (Osaka City Uni), Vincent Pasquier (CEA Saclay), Leonid Petrov (Uni Virginia), Matthieu Vanicat (Uni Ljubljana), Mirjana Vuletić (Uni Massachusetts), Paul Zinn-Justin (Uni Melbourne), Yi Sun (Columbia Uni), Paul Pearce (Uni Melbourne), Chihiro Matsui (Uni Tokyo), Matteo Mucciconi (Tokyo Inst Technology), Iori Hiki (Tokyo Inst Technology), Xin Zhang (Uni Melbourne), Alessandra Vittorini Orgeas (Uni Melbourne)

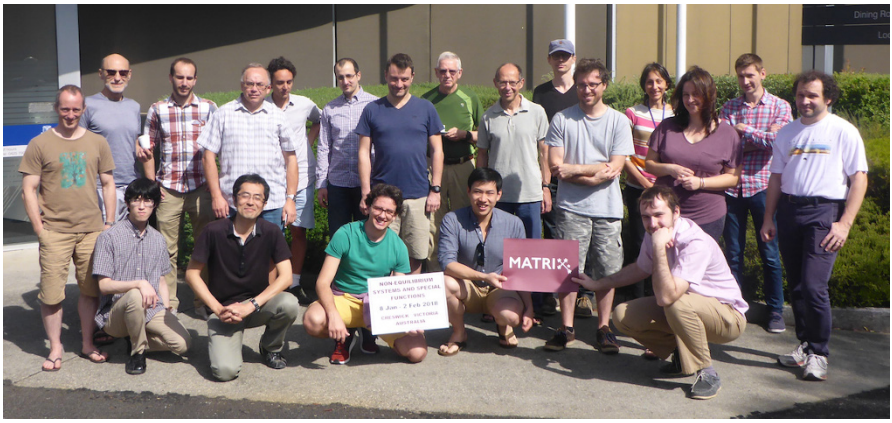
This program focused on recent advances in the study of non-equilibrium statistical mechanical systems, in particular stochastic classical particle systems in the KPZ class. These systems have surprisingly deep connections to two-dimensional lattice models with strong boundary effects and also to the theory of special functions, such as the Macdonald polynomials and elliptic functions. The program gathered leading experts in these areas and promoted discussion and collaboration on related themes.

Overall, the program drew good attendance from all over the globe. There were healthy numbers of researchers from US and European institutions, and a very strong Japanese contingent. The program received very positive feedback from attendees. Many new collaborations were formed and the atmosphere of the program

was extremely convivial. Overseas participants particularly appreciated the relaxed and stimulating environment.

Weeks 1 and 2 were primarily devoted to collaboration/research, with one talk organised per day. These weeks also saw very good attendance. Week 3 of the program featured a conference on "KPZ universality, particle processes, Macdonald processes, and special functions" This week drew the largest number of attendees during the program and had the highest density of talks.

Vadim Gorin, Tomohiro Sasamoto, Ole Warnaar, Michael Wheeler
Organisers



Algebraic Geometry, Approximation and Optimisation

5 – 16 February 2018

Organisers

Enrico Carlini
Politecnico di Torino

Jochen Garcke
University of Bonn

Wolfgang Hackbusch
Max Planck Institute

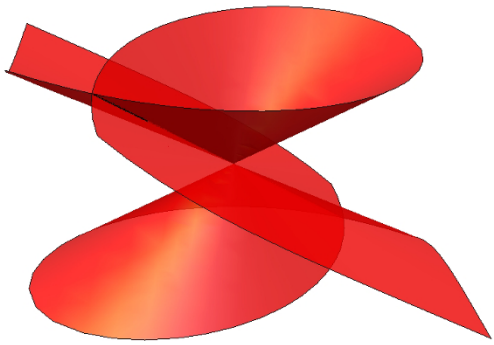
Markus Hegland
Australian National University

Vera Roshchina
RMIT University

Nadia Sukhorukova
Swinburne University of Technology

Julien Ugon
Federation University Australia

David Smyth
Australian National University



Participants

Pablo Parrilo (MIT), Levent Tuncel (Waterloo), Terry Rockafellar (Uni Washington), Ludmila Polyakova (Saint-Petersburg State University, Russia), Wolfgang Hackbusch (Max Planck Institute for Mathematics in the Sciences), Enrico Carlini (Politecnico di Torino, Italy), Andrew Eberhard (RMIT Uni), Jochen Garcke (Institut fr Numerische Simulation), Lars Grasedyck (RWTH Aachen Uni), Markus Hegland (Australian National Uni), Vera Roshchina (RMIT Uni), James Saunderson (Monash Uni), Nadezda (Nadia) Sukhorukova (Swinburne Uni Technology), Julien Ugon (Federation Uni Australia), David Yost (Federation Uni Australia), Alex Kruger (Federation Uni Australia), Fei Lu (RMIT Uni), Thi Bui Hoa (Federation Uni Australia), Scott Lindstrom (Uni Newcastle), Abhishek Bhardwaj (Australian National Uni), Sebastian Kraemer (RWTH Aachen Uni), Nguyen Duy Cuong (Federation University Australia), Anand Rajendra Deopurkar (Australian National Uni), Zari Dzalilov (Federation Uni Australia), Kyle Broder (Australian National Uni), Shilu Feng (Australian National Uni), Edda Koo (Uni Sydney)

There has been notable success in applying the tools of algebraic geometry to a selection of approximation and optimisation problems. In optimisation, a whole

new field of convex algebraic geometry has emerged based on the ideas of semidefinite programming relaxations of polynomial optimisation problems. In numerical analysis and approximation, understanding properties of, and developing algorithms for, working with tensors of low rank (and other structured tensors) naturally leads to the study of secant varieties and optimisation algorithms over such varieties.

The 2-week MATRIX workshop 'Algebraic geometry, approxmation, and optimisation' brought leading experts working at the mutual interfaces between these three areas, with the aim of strengthening the emerging connections between these fields. The morning sessions of the program consisted of a number of lecture series discussing instances of fruitful interactions between the topics of the workshop, from varying points of view.

- Enrico Carlini (Politecnico di Torino) discussed secant varieties and general notions of tensor rank;
- Wolfgang Hackbusch (Max Planck Institute) surveyed various formats for structured tensors and numerical methods for tensor approximation;
- Markus Hegland (Australian National Uni) and Anand Deopurkar (Australian National Uni) discussed connections between algebraic geometry and numerical analysis;
- Ludmila Polyakova (Saint-Petersburg State University) discussed various aspects of non-smooth analysis in approximation and optimisation;
- Pablo Parrilo (MIT) discussed convexification of secant varieties for linear inverse problems, and methods to exploit chordal sparsity in polynomial ideals; and
- Levent Tunçel (University of Waterloo) discussed optimisation algorithms for algebraically structured convex optimisation problems, and conditions for the exactness of convex relaxations.

In addition to these, there were presentations from James Saunderson (Monash University) and Sebastian Kraemer (RWTH Aachen University) related to hyperbolic programming and hierarchical tensors, respectively. Throughout the two weeks of the program, the afternoons were focused on smaller group discussions among the participants.

A number of program participants remained in the area for a third week to attend the Variational Analysis Down Under (VADU) workshop at Federation University in Ballarat. This workshop attracted leading senior researchers in variational and non-smooth analysis, including Asen Dontchev (University of Michigan and Mathematical Reviews) and Terry Rockafellar (University of Washington).

One outcome of the workshop was the preliminary version, included in this volume, of the research paper "Schur functions for approximation problems" by Nadezda Sukhorukova, Julien Ugon and David Yost. In this paper the authors propose a new approach to least squares approximation problems. The approach has a combinatorial flavour, exploiting the connection between generalized Vandermonde matrices and Schur functions.

Enrico Carlini, Jochen Garcke, James Saunderson

Guest Editors

On the Frontiers of High Dimensional Computation

4 – 15 June 2018

Organisers

Frances Kuo
University of New South Wales

Hans De Sterck
Monash University

Josef Dick
University of New South Wales

Mahadevan Ganesh
Colorado School of Mines

Mike Giles
University of Oxford

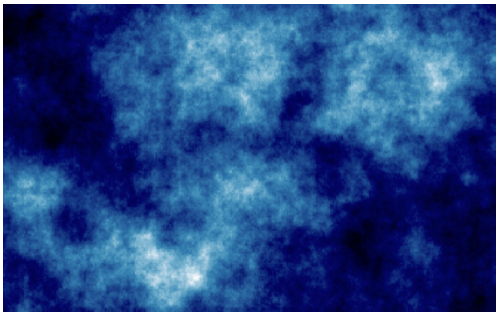
Markus Hegland
Australia National University

Dirk Nuyens
KU Leuven, Belgium

Ian Sloan
University of New South Wales

Clayton Webster
Oak Ridge National Lab, USA

Henryk Wozniakowski
University of Warsaw and
Columbia University



Participants

Christoph Aistleitner (TU Graz, Austria), Abhishek Bhardwaj (Australian National Uni), Johann Brauchart (TU Graz, Austria), Bruce Brown (UNSW Sydney), Tiangang Cui (Monash Uni), Hans de Sterck (Monash Uni), Jerome Droniou (Monash Uni), Mahadevan Ganesh (Colorado School of Mines), Alexander Gilbert (UNSW Sydney), Mike Giles (Uni Oxford), Ivan Graham (Uni Bath), Michael Griebel (Uni Bonn), Stuart Hawkins (Macquarie Uni), Markus Hegland (Australian National Uni), Stefan Heinrich (Uni Kaiserslautern), Kerstin Hesse (Uni Paderborn), Fred Hickernell (IIT Chicago), Yoshihito Kazashi (UNSW Sydney), Peter Kritzer (Austrian Academy of Sciences), Thomas Kühn (Uni Leipzig), Frances Kuo (UNSW Sydney), Bishnu Lamichhane (Uni Newcastle), Fanzi Meng (Australian National Uni), Hrushikesh Mhaskar (Claremont Graduate Uni), Giovanni Migliorati (Sorbonne Uni), James Nichols (Sorbonne Uni), Dirk Nuyens (KU Leu-

ven, Belgium), Chaitanya Oehmigara (Australian National Uni), Sergei Pereverzyev (Austrian Academy of Sciences), Leszek Plaskota (Uni Warsaw), Stanislav Polishchuk (Monash Uni), Robert Scheichl (Uni Bath), Dongwoo Sheen (Seoul National Uni), Ian Sloan (UNSW Sydney), Yuguang Wang (UNSW Sydney), Grzegorz Wasilkowski (Uni Kentucky), Clayton Webster (Oak Ridge National Laboratory), Wolfgang Wendland (Uni Stuttgart), Robert Womersley (UNSW Sydney), Henryk Wozniakowski (Uni Warsaw and Columbia Uni), Yuan Xu (Uni Oregon), Yuesheng Xu (Sun Yat-sen University, China), Guannan Zhang (Oak Ridge National Laboratory), Houying Zhu (UNSW Sydney), Yuancheng Zhou (Australian National Uni)

High dimensional computation is a new frontier in scientific computing, with applications ranging from particle physics, chemical reactions, groundwater flow, heat transport, and wave propagation, to financial mathematics, risk management, and parameter estimation. Often the difficulties come from uncertainty or randomness in the data, which presents major challenges in the areas of data science and uncertainty quantification.

This program provided a forum for interaction between Australian and international experts on the theory and application of high dimensional computation, including quasi-Monte Carlo and sparse grid methods, information based complexity, discrepancy and approximation theory, computational and Bayesian inverse problems, multi-level and multi-index techniques, energy and point configuration on spheres and manifolds, PDEs with random coefficients or boundaries, and more, with the aim to establish new collaborations.

We had a total of 45 participants, including 19 from Australia (ANU, Macquarie, Melbourne, Monash, Newcastle, and UNSW Sydney), and the remaining from Austria, Belgium, China, France, Germany, South Korea, Poland, UK, and USA. The first week of the program was devoted to research collaboration, with intentionally only one research seminar each day. We had a workshop in the second week, with a total of 34 short research talks, and this allowed time each day for research collaboration both in the mornings and afternoons.

During the program there were many groups of collaborators working on a multitude of topics, including:

- Kernel construction for machine learning; graph convolutional networks; graph-based methods for manifold learning; high dimensional data approximation.
- Probing the cosmic microwave background radiation maps; complex spherical designs; complex orthogonal polynomials on the unit disc; localized polynomial kernels; regularization parameter choice strategies for the reconstruction from noisy data on spheres; radial basis function approximation on the sphere from noisy scattered data.
- Tractability analysis for linear multivariate problems in terms of singular values; absolute value information; complexity of stochastic integration; approximation in spaces of smooth functions; sharp preasymptotics for approximation in periodic isotropic Sobolev spaces; approximation of Sobolev functions defined on high-dimensional Euclidean balls; tractability of approximation of weighted Sobolev embeddings.

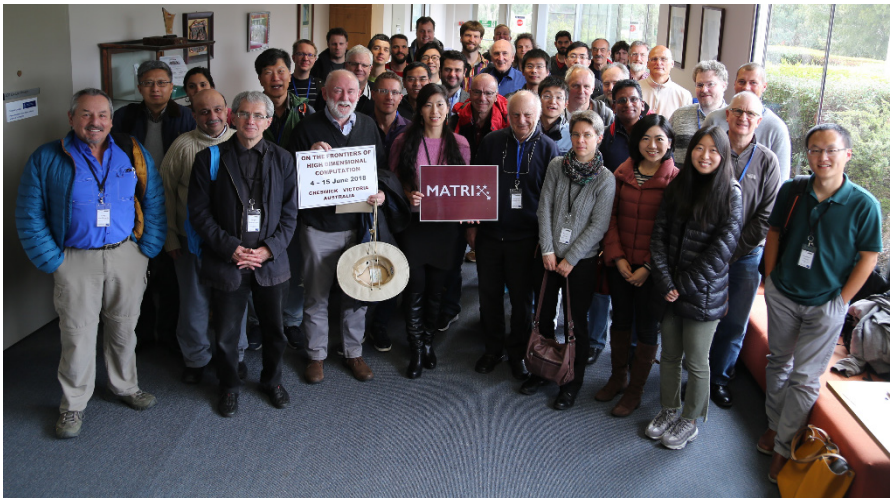
- Lattice rules for function approximation and reconstruction; lattice rules without random shifting; hyperuniformity; low-discrepancy sampling for non-uniform measures; efficient integration over unbounded domains; reduced component-by-component constructions for product and order dependent weights; quasi-Monte Carlo community software.
- Application of quasi-Monte Carlo methods to stochastic wave propagation, elliptic eigenvalue problems with stochastic coefficients, Bayesian computation; uncertainty quantification for neutron transport.
- Multi-level methods for dimension reduction and infinite dimensional Markov chain Monte Carlo; efficient implementation of multivariate decomposition methods
- Bayesian methods for wave propagation inverse problems; fully discrete spectral algorithm for dielectric media; 3D T-matrix software; analysis of wavefunction expansions in the near field; tensor train approximation for stochastic wave propagation.
- Computation of high dimensional oscillatory integrals in the high frequency case; fast solutions of boundary integral equations.
- Lévy-Ciesielski approximation of Brownian motion.

The nine refereed articles arising from this program cover a range of these topics.

Participants reported a high level of satisfaction: their words were "excellent opportunity", "interesting", "inspiring", "stimulating", "productive", "new research results and directions", "new contacts and connections", as well as "fantastic facilities and catering". After this MATRIX program, most participants joined the Conference in Honour of Ian Sloan on the Occasion of His 80th Birthday from June 17 to 19 at UNSW Sydney.

I would like to thank everyone who participated in this MATRIX program and the subsequent celebration in Sydney. I am also grateful to all authors and referees who contributed to this volume. On behalf of all participants, I would like to thank MATRIX for hosting our program and giving us the wonderful opportunity to interact and collaborate in such a stimulating environment.

Frances Kuo
Guest Editor


ON THE FRONTIERS OF
HIGH DIMENSIONAL
COMPUTATION
4 - 15 June 2018
CREMORNE VICTORIA
AUSTRALIA
MATRIX

Month of Mathematical Biology

27 June – 20 July 2018

Organisers

Ruth Baker
University of Oxford

Kevin Burrage
Queensland University of Technology

Helen Byrne
University of Oxford

Edmund Crampin
University of Melbourne

Mark Flegg
Monash University

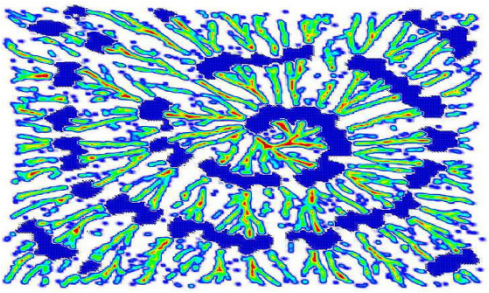
Alexander Fletcher
Sheffield University

Edward Green
University of Adelaide

Samuel Isaacson
Boston University

James Osborne
University of Melbourne

Hans Othmer
University of Minnesota



Participants

Axel Almet (Uni Oxford), Satya Arjunan (RIKEN), Steve Andrews (Fred Hutchinson Cancer Research Center), Christopher Angstmann (UNSW), Sandy Anderson (Moffit Cancer Centre), Bartosz Bartmanski (Uni Oxford), Josh Bull (Uni Oxford), Phillip Brown (Uni Adelaide), Ana Victoria Ponce Bobadilla (Uni Heidelberg), Casper Beentjes (Uni Oxford), Bartosz Bartmanski (Uni Oxford), Jess Crawshaw (Uni Melbourne), James Cavallo (Monash Uni), Edmund Crampin (Uni Melbourne), Radek Erban (Uni Oxford), Mark Flegg (Monash Uni), Edward Green (Uni Adelaide), James Glazier (Indiana Uni), Bruce Gardiner (Murdoch Uni), Guillermo Gomez (Uni South Australia), Ramon Grima (Uni Edinburgh), Daniel Hahne (Leipzig Uni), Samuel Isaacson (Boston Uni), Stuart Johnston (Uni Melbourne), Melissa Knothe-Tate (UNSW), Yangjin Kim (Konkuk Uni), Ashfaq Khan (RMIT), André Leier (UAB), Karen Lipkow (Cambridge Uni), Brodie Lawson (QUT), Kynan Lawlor (MCRI), Sharon Lubkin (North Carolina State Uni), Shev

Macnamara (UTS), Paul Macklin (Indiana Uni), Claire Miller (Uni Melbourne), Tatiana Marquez-Lago (UAB), Zoltan Neufeld (Uni Queensland), Don Newgreen (MCRI), Hans Othmer (Uni Minnesota), James Osborne (Uni Melbourne), Margriet Palm (Leiden Uni), Catherine Penington (Macquarie), Erika Tsingos (Heidelberg Uni), Chin Wee Tan (WEHI), Daniel Wilson (Uni Oxford), Ruth Williams (UCSD), Michael Watson (Uni Sydney).

This program consisted of two research workshops, "Virtual tissues: Progress and challenges in multicellular systems biology (1–7 July) and "Spatio-temporal stochastic systems in biology" (15–20 July). Between these workshops, many participants attended the Society of Mathematical Biology meeting held in Sydney.

Virtual tissues: Progress and challenges in multicellular systems biology

This workshop brought together world-leading mathematical modellers, systems biologists and experimentalists to discuss advances in all aspects of cell and tissue modelling and simulation and to define (and begin working on) a set of grand challenges in the pathway to in silico drug discovery and improved therapies using multicellular models. The goals of the workshop were to:

- produce a set of collaborative projects focusing on grand challenges in colonic crypt, kidney, and enteric nervous system development and disease;
- develop new partnerships and strengthen existing interdisciplinary collaborations;
- advance functionality of existing multicellular modelling tools;
- improve recognition by the biological community of multicellular modelling as a research tool.

The workshop included around 20 talks (each 15-45 minutes) ranging from experimental talks through to technical talks on model developments and multicellular modelling standards. The remaining time was broken into large group discussions focussing on the workshop goals led by the organisers and senior participants and also smaller group discussions using the facilities in MATRIX house.

During the program several group collaborations emerged. One looked at defining standards for multicellular modelling, and another looked at a repository for multicellular modelling benchmarks. Both of these projects have continued after the workshop. The goals of these groups are (i) to write a position paper on the necessity for a standard for multicellular model specification and (ii) to develop a set of benchmark problems for multicellular models and present these as an online resource for the community.

The workshop was discussed many times at the Society of Mathematical Biology meeting which was held in Sydney the following week. This feedback was overwhelmingly positive and it was pleasing when praise came through third parties.

Spatio-temporal stochastic systems in biology

The first day of this workshop was dedicated to the training of junior participants. Flegg and Isaacson ran group discussions, and there were software presentations

by participants Andrews (Smoldyn), Arjunan (Spatiocyte) and Coulier (URDME) showing implementations of various algorithms and mathematical frameworks.

On subsequent days, the participants worked in small groups on five research focus problems, each lead by a senior participant: nonlinear effects in spatiotemporal stochastic systems in biology (André Leier and Tatiana Marquez-Lago), classical molecular dynamics (Radek Erban), adaptation (Ruth Williams), reaction and diffusion processes (Hans Othmer), and particle-based simulation methods (Steve Andrews).

There were also four talks given by Karen Lipkow, Ramon Grima, Brodie Lawson and Shev Macnamara covering a wide spectrum of topics ranging from fundamental mathematical paradigms and curiosities to complex biological systems and applications. While the focus of the workshop was research, these talks broke up the workshop and provide some diversity to the daily schedule.

A recurring thread in all the focus problems was issues related to multiple scales, which are known as a major challenge in mathematical biology. Often multiple scales (temporal, spatial and density) lie at the heart of a mathematical analysis of stochastic systems in biology.

Results of work were presented at the end of the workshop by the junior participants. All of the focus problems were successful and most will lead to publications.

Mark Flegg and James Osborne
Guest Editors

Dynamics, Foliations, and Geometry In Dimension 3

3–14 September 2018

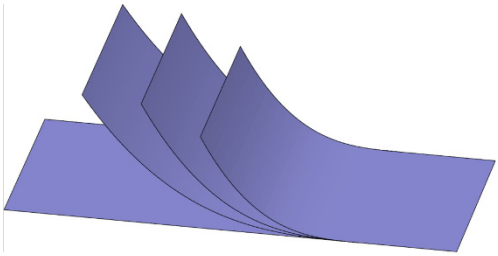
Organisers

Jonathan Bowden
Monash University

Steven Frankel
Yale University, USA

Andy Hammerlindl
Monash University

Rafael Potrie
Universidad de la República, Uruguay



Participants

Jonathan Bowden (Monash Uni), Andy Hammerlindl (Monash Uni), Steven Frankel (Washington Uni, St Louis), Rafael Potrie (Uni de la República, Uruguay), Christian Bonatti (Uni de Bourgogne), Keith Burns (Northwestern), Danny Calegari (Uni Chicago), Vincent Colin (Uni Nantes), Sergio Fenley (Florida State Uni), Thomas Vogel (LMU Munich), Katie Mann (Brown Uni), Jessica Purcell (Monash Uni), Jana Rodriguez Hertz (SUSTech), Raul Ures (SUSTech), Helene Eynard-Bontemps (Uni Jussieu), Pierre Dehornoy (Uni Grenoble), Mario Shannon (Uni de Bourgogne), Yi Shi (Peking Uni), Andre de Carvalho (Uni Sao Paolo), Santiago Martinchich (Uni de la República), Vernica De Martino (Uni de la República), Josh Howie (Monash Uni), Dan Mathews (Monash Uni), Agnieszka Zelerowicz (Pennsylvania State Uni), Layne Hall (Monash Uni)

This 2-week workshop brought together a small but focussed team of researchers from Australia, Europe, Asia, and North and South America to study the interplay of dynamical systems, foliations, and contact structures with the geometry and topology of three-dimensional manifolds.

One key focus of the event was on the construction and classification of partially hyperbolic diffeomorphisms and Anosov flows in dimension three. Associated to these dynamical systems are a pair of taut foliations in the manifold, and so the study of these foliations and the closely related concept of tight contact structures also took prominence during the workshop.

The workshop schedule was of a relaxed nature, with most days having one or two hours of scheduled lectures and the remaining time left for informal discussion.

There were four mini-courses during the event. Danny Calegari gave a lecture series describing taut foliations and their properties. Andy Hammerlindl and Rafael Potrie presented a mini-course explaining the properties of the branching foliation theory developed by Brin, Burago, and Ivanov and its application to the classification of partially hyperbolic dynamics. Stephen Frankel's mini-course explored

the relation between pseudo-Anosov and quasi-geodesic flows on hyperbolic 3-manifolds. Lastly, the mini-course of Thomas Vogel and Vincent Colin detailed the properties of tight contact structures, their approximation of taut foliations, and their relation to dynamics on the manifold.

The informal discussions pursued a number of avenues of research and we highlight a few of these here. Any Anosov flow in dimension 3 yields a pair of transverse taut foliations on the manifold. However, it is an open question whether any 3-manifold with such a pair of foliations must necessarily support an Anosov flow. This question was explored during the workshop and the article by Bonatti, Bowden, and Potrie in this volume discusses this work.

Recent years have seen huge progress in the understanding of partial hyperbolicity in dimension 3, due both to classification results in certain families of manifolds and the construction of new examples with novel properties. A research announcement of Barthelmé, Fenley, Frankel, and Potrie concerns the classification of partially hyperbolic systems homotopic to the identity map.

Finally, the classification of partially hyperbolic diffeomorphisms and Anosov flows is closely related the long-standing open problem of the classification of Anosov diffeomorphisms. An article by Andy Hammerlindl looks at the classification problem for Anosov diffeomorphisms with global product structure.

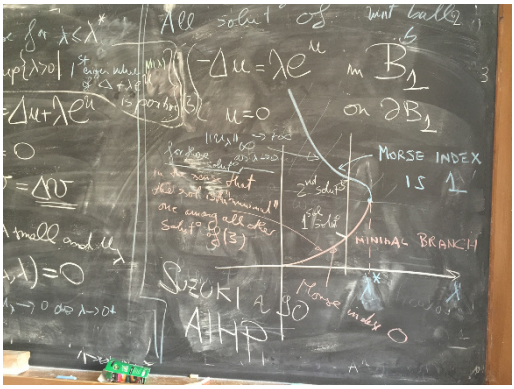
This short but productive workshop passed far too quickly, and by all accounts the visitors thoroughly enjoyed their time in Creswick. The most-asked question at the end of the workshop was when would we host such an event again.

Jonathan Bowden and Andy Hammerlindl
Guest Editors


MATRIX
DYNAMICS, FOLIATION AND GEOMETRY IN DIMENSION 3
3-14 SEPTEMBER 2018
CRESWICK
VICTORIA AUSTRALIA
MATRIX

Recent Trends on Nonlinear PDEs of Elliptic And Parabolic Type

5 - 16 November 2018



Organisers

Yihong Du
University of New England

Daniel Hauer
University of Sydney

Angela Pistoia
Sapienza Universitá di Roma

Participants

Yihong Du (Uni New England), Daniel Hauer (Uni Sydney), Angela Pistoia (Sapienza Universit di Roma), Susanna Terracini (Uni Turin), Philippe Souplet (Uni Paris 13), Changfeng Gui (Uni Texas at San Antonio), Robin Neumeyer (Northwestern Uni), Jerome Coville (INRA), Isabella Ianni (Uni Campania), Massimo Grossi (Uni Roma 1), Benedetta Pellacci (Uni Campania), Serena Dipierro (Uni Milan), Yannick Sire (Johns Hopkins Uni), Enrico Valdinoci (Uni Milan), Florica Cirstea (Uni Sydney), Bernhard Ruf (Uni Milan), Michael Winkler (Uni Paderborn), Francesca Gladiali (Uni Sassari), Gianmaria Verzini (Politecnico di Milano), Hiroshi Matano (Meiji Uni), Ben Andrews (Australian National Uni), Xu-Jia Wang (Australian National Uni), Ki-Ahm Lee (Seoul National Uni), Masaharu Taniguchi (Okayama Uni), Daniel Daners (Uni Sydney), Julie Clutterbuck (Monash Uni), Wolfgang Arendt (Uni Ulm), Paul Bryan (Macquarie Uni), Guofang Wei (Uni California at Santa Barbara), Barbara Brandolini (Uni Naples Federico II), Glen Wheeler (Uni Wollongong), James McCoy (Uni Newcastle), Timothy Collier (Uni Sydney), Yuhan Wu (Uni Wollongong), Elisa Affili (Uni Milan), Pietro Miraglio (Uni Milan)

This meeting aimed to gain a deeper understanding of several key themes in nonlinear elliptic and parabolic PDEs, where spectacular progress has been made in recent years. These include spatial segregation in nonstandard diffusion, propagation in heterogeneous media, gradient blow-up of diffusive Hamilton-Jacobi equations, and some selected topics on geometric flows. We brought to the fore the key challenges for future research in these areas. This program intertwined talks from each community of the four main themes and highlighted the most salient ideas, proofs and questions, which are important and fertile for pushing forward the research in these areas in Australia and worldwide.

Week 1 featured the following two mini-courses:

- Susanna Terracini: “Spatial segregation with non standard diffusions”

- Philippe Souplet: “An introduction to nonlinear Liouville theorems for reaction-diffusion equations and systems and their applications”

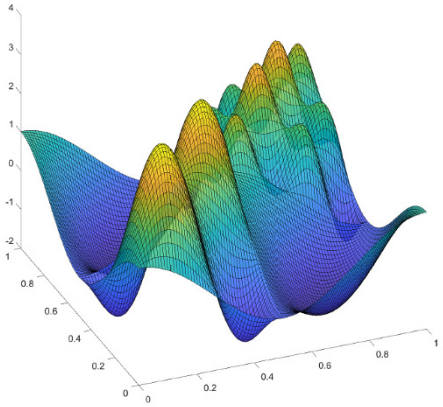
Week 2 featured the following two mini-courses:

- Hiroshi Matano: “Front propagation in the presence of obstacles”
- Ben Andrews: “Multi-point maximum principles with applications to sharp gradient estimates and travelling waves”

Daniel Hauer
Guest Editor

Functional Data Analysis and Beyond

3 – 14 December 2018



Organisers

Aurore Delaigle
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Frederic Ferraty
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Debashis Paul
University of California at Davis

Participants

Alexander Aue (Uni California at Davis), Michelle Carey (University College Dublin), Ming-Yen Cheng (Hong Kong Baptist Uni), Sophie Dabo-Niang (Uni de Lille), Aurore Delaigle (Uni Melbourne), Marie-Hlne Descary (Uni de Montreal), Idris Eckley (Lancaster Uni), Frdric Ferraty (Toulouse Jean Jaures Uni), Gery Geenens (UNSW), Rob Hyndman (Monash Uni), Ci-Ren Jiang (Academia Sinica), Pavel Krupskiy (UoM), Dominik Liebl (Bonn Uni), Eardi Lila (Cambridge Uni), Steve Marron (Uni North Carolina), James Ramsay (McGill Uni), Matthew Reimherr (Penn State Uni), Damla Senturk (Uni California at Los Angeles), Karim Seghouane (Uni Melbourne), Hanlin Shang (Australian National Uni), Jian Qing Shi (Newcastle Uni), Katharine Turner (Australian National Uni), Susan Wei (Uni Melbourne), Fang Yao (Uni Toronto), Jiajun Tang (Uni Melbourne), Zhuosong Zhang (Uni Melbourne), Wei Huang (Uni Melbourne), Ruoxu Tan (Uni Melbourne), Alessandra Vittorini Orgeas (Uni Melbourne), Andriy Olenko (La Trobe Uni), Jeng-Min Chiou (Academia Sinica), Heng Lian (City Uni Hong Kong), Jin-Tin Zhang (National Uni Singapore)

The program focused on recent developments in functional data analysis. This area of statistics has been widely used to answer science and policy questions, where the data are typically observed over time, space and other continuous variables.

During the program there were several groups of collaborators. A real highlight of the program was when the young participants were able to present their work to senior researchers. As a result, the young researchers attending the workshop interacted significantly with the two most senior and prominent participants, James Ramsay and Steve Marron.

The warm atmosphere of the program also encouraged significant interactions between young female participants and more senior female participants. Several

groups of them were invited to each others institutions to continue the discussion and collaboration initiated at the workshop.

Another highlight is that several participants are organising another similar workshop in Senegal in 2020. The whole two weeks were extremely fruitful.

Aurore Delaigle, Frederic Ferraty, Debashis Paul
Organisers

Geometric and Categorical Representation Theory

10 – 21 December 2018

Organisers

Clifton Cunningham
University of Calgary

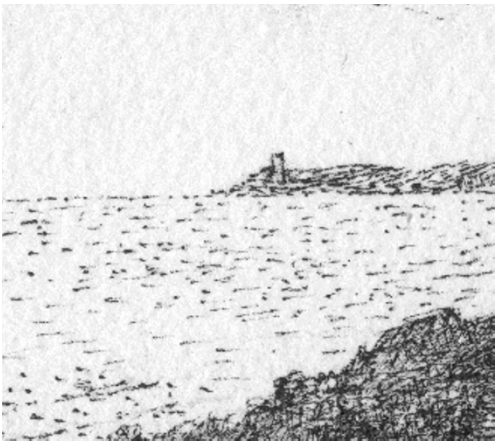
Masoud Kamgarpour
University of Queensland

Anthony Licata
Australian National University

Peter McNamara
University of Melbourne

Sarah Scherotzke
Bonn University

Oded Yacobi
University of Sydney

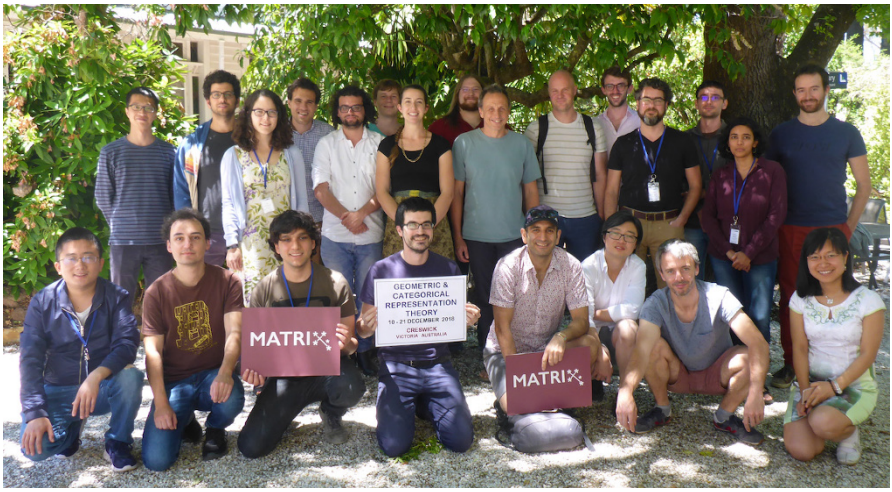


Participants

Peter McNamara (Uni Melbourne), Masoud Kamgarpour (Uni Queensland), Oded Yacobi (Uni Sydney), Tony Licata (Australian National Uni), Clifton Cunningham (Uni Calgary), Luca Migliorini (Universita di Bologna), Geordie Williamson (Uni Sydney), Valentin Buciumas (Uni Queensland), Arun Ram (Uni Melbourne), Iva Halacheva (Uni Melbourne), Anna Romanov (Uni Sydney), Asilata Bapat (Australian National Uni), Yohan Brunebarbe (Institut de Mathmatiques de Bordeaux), Joel Gibson (Uni Sydney), Giulian Wiggins (Uni Sydney), Josh Ciappara (Uni Oxford), Javier Fresan (Centre de Mathmatiques Laurent Schwartz cole Polytechnique), Arik Wilbert (Uni Melbourne), Yaping Yang (Uni Melbourne), Gufang Zhao (Uni Melbourne), Gaston Burrull (Uni Sydney), Joseph Baine (Uni Sydney), Minhua Liu (Uni Sydney), Xun Xie (Uni Sydney), Geoff Vooys (Uni Calgary)

Representation theory is a central branch of mathematics, with connections to algebraic geometry, symplectic topology and number theory. The fundamental aims of the newer branches of geometric and categorical representation theory are to uncover deeper geometric and categorical structures underpinning familiar mathematical objects. Once such structures are discovered, they are then able to be applied to resolve classical open problems. Recent years have seen significant advances made in this field, partly fuelled by the results of breakthroughs made by Australian researchers. This program brought together leading international researchers and early career researchers for an intense and productive two-week program.

Peter McNamara
Guest Editor


GEOMETRIC &
CATEGORICAL
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THEORY
MATRIX
MATRIX

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