Welcome to SAMBa
2023-24

EPSRC Centre for Doctoral Training
Statistical Applied Mathematics at Bath

Contents

1. Statistical Applied Mathematics

Across mathematics, statistics and industry, the problems of turning huge datasets into useful knowledge, of making predictions of complex systems based on the combination of data and state-of-the-art process modelling, and of modelling processes on complex stochastic domains are prevalent. The range of applications, and subsequent socio-economic impact is very broad: insurance risk, medical genetics, energy management, communication networks, pharmaceutical development, safety management of physical systems, ecological and population monitoring and retail analytics to name but a few.

Historically, deterministic applied mathematics and statistics have taken different approaches to modelling observed phenomena, one based primarily on mathematical description of mechanism, and the other on the mathematical representation of data. What is needed now is a large pool of researchers whose expertise genuinely spans the interface between these approaches, while also having confidence in cross-disciplinary approaches and industrial collaboration. We call the continuum between these two approaches statistical applied mathematics. In joining this centre for doctoral training, students have the opportunity to be part of a future generation of interdisciplinary mathematicians, with careers in both university and industry, whose primary strengths will be their problem-solving ability, a world-view that sees no separation between applied mathematics and statistics, and their preparation to work in the emerging world of big models and big data.

Training during the first year of SAMBa gives you a broad range of mathematical, computational and statistical tools. You will experience interaction with industrial partners and gain the ability to distil industrially relevant problems into a mathematical approach and formulation. At the end of the first year's taught component, you choose a supervisor and thesis topic. SAMBa offers breadth and flexibility at this stage: the focus of the thesis research may range from industrially focused research in collaboration with an external partner, to progressing the theoretical underpinnings of statistical or stochastic processes. You will have gained an important skill set in industrial mathematics in your first year, even if the choice of your Ph.D. research does not involve industry directly.

Each year we aim to enrol at least 10 new students into our four-year SAMBa training programme, thanks to generous funding from EPSRC and the University of Bath. SAMBa promotes intellectual independence, flexibility, and ownership of knowledge that is essential for international research competitiveness. The key aspects of the programme are described in the following sections.

2. Useful reading

An up-to-date reading list can be found at:
http://people.bath.ac.uk/man54/SAMBa/misc/SAMBaReadingList.pdf.

This summarises material that is important to the main areas within the statistical applied mathematics remit. Copies of the books listed are available in the SAMBa student offices. The University of Bath's library and website hold many more resources.

3. The first year of SAMBa

Mentoring

You have been assigned a first year supervisor and a co-factor. The former is an academic who will help advise you on your studies and the latter is an existing Ph.D. student who will support you upon joining SAMBa and hopefully throughout your time in the programme.

M.Res. in Statistical Applied Mathematics

The academic year has two teaching semesters and a summer period. Academic year dates can be found here: **Academic year dates (bath.ac.uk)**. You will take compulsory, core and optional units during the first two semesters, giving you a total of 60 credits. Over the summer, you will write a thesis formulation report (TFR) worth 30 credits with your chosen supervisory team. This will set the goals and context for your Ph.D. research. Successful completion (at least 60% average in taught units, and for the TFR) of the first year programme will lead to an M.Res. qualification, awarded when you exit SAMBa.

Core units

During the teaching semesters, you must take 6 units across a cross-disciplinary syllabus with two units from each of three streams: Statistics and Data Science, Applied and Probabilistic Analysis and Modelling, and Computation and Numerical Mathematics. The exact choice of units will depend on your background and experience, but at least four units are expected to come from a core list, reflecting the SAMBa remit of deep interactions between different mathematical disciplines:

- Numerical solution of evolutionary equations (MA40171, Semester 1)
- Applied statistical inference (MA40198, Semester 1)
- Generalised linear models (MA50084, Semester 1)
- Topics in applied computation (MA50174, Semester 1)
- Numerical linear algebra (MA50178, Semester 1)
- Bayesian and large scale methods (MA50247, Semester 1)
- Scientific computing (MA40177, Semester 2)
- Numerical solution of elliptic PDEs (MA50170, Semester 2)
- Inverse problems, data assimilation and filtering (MA50250, Semester 2)
- Applied stochastic differential equations (MA50251, Semester 2)
- Mathematics of machine learning (MA50263, Semester 2)

Optional units

Outside of the core units, you can select courses to meet individual needs and interests, a list is included in section 4. Reading courses (including Taught Course Centre (TCC)[1] units, and APTS[2] courses) are available across the SAMBa remit, and you are encouraged to take at least one of these during your first year.

More information on TCC: http://www.maths.ox.ac.uk/groups/tcc
More information on APTS: http://www2.warwick.ac.uk/fac/sci/statistics/apts

Compulsory units

Alongside these taught courses, you will work in small groups on two-semester, 12 credit Inter-disciplinary Research Projects, which will bring together elements of the core streams into a short research project, led by one or more academic members of staff. You will also take the two-semester long unit Student-led symposia and Integrative Think Tanks.

[1] The EPSRC-funded TCC is a collaboration between the Mathematics Departments at the Universities of Bath, Bristol, Imperial, Oxford and Warwick and offers graduate-level courses over the academic year using Access Grid technology.

[2] Academy for Ph.D. Training in Statistics is an EPSRC-funded collaboration between UK statistics groups. It offers four one-week residential courses each year (with assessment) to first (research) year Ph.D. students in statistics and applied probability.

Integrative think tanks (ITTs)

After each end-of-semester examination period, there is a week-long ITT. These are focal points in SAMBa, and central to our goals. ITTs are facilitated workshops in which academic, industrial, and other external partners present challenges requiring the formulation of research ideas. You will work in small groups with other participants to define routes to the solution of the challenges, identifying new research ideas. ITT problem formulations lead to Ph.D. projects, reading courses, and other collaborative research with external partners. The environment is designed to be supportive and gives all participants a chance to explore new ideas and research directions. Above all, it is an opportunity for you to experience the process of formulating research and presenting your work to both experts and non-experts. During each ITT, you will give a presentation on the topic that your group worked on and following each event, you will write a report in the style of a short research grant proposal. You will be assessed on both of these and given feedback.

Student-led symposia

With guidance from academics, you will decide on training topics and reading group activities, as well as inviting speakers to give seminars or short courses from a self-managed budget. Material will be steered to relate to upcoming ITTs with academic staff and industrial partners attending the ITTs involved in the symposia series immediately before. A goal of these symposia is to foster research independence. Each semester, you will be expected to prepare and deliver a presentation, which will be formally assessed.

Thesis formulation report (TFR)

You will spend three months over the summer writing your TFR, working with your chosen supervisory team to outline your motivation, objectives and methodology for your proposed Ph.D. Following the second ITT (early June) you will be required to have a definitive thesis supervisory team in place. There are a large number of potential supervisors and co-supervisors within SAMBa and a summary of the research interests of those already affiliated with SAMBa is at the back of this booklet, but this is not an exhaustive list. You will be exposed to potential supervisors throughout your first year and are encouraged to engage widely with opportunities to identify research interests. Under the supervisory team's guidance, you will prepare a 25-35 page document, which outlines, in depth and breadth, the motivation, objectives and methodology for the proposed Ph.D. problem(s) you will tackle in years 2-4. Assessment of these reports will be on the written report and an oral presentation and you must receive at least 60% to progress to the SAMBa Ph.D.

End of first year transfer day

The first year officially ends for students with the arrival of the next cohort. This will be marked by a transfer day where you will present your TFR to the SAMBa cohort and interested parties from the Department and wider University.

4. Summary of first year

Compulsory units

Study period	Unit code	Unit title	Credits
All year	MA50246	Student-led symposia and Integrative Think Tanks	12
All year	MA50264	Interdisciplinary research projects	12

Optional units – List A

Students must select a minimum of 4 'core' units from this list

Study period	Unit code	Unit title	Credits
Semester 1	MA40171	Numerical solution of evolutionary equations	6
Semester 1	MA40198	Applied statistical inference	6
Semester 1	MA50084	Generalised linear models	6
Semester 1	MA50174	Topics in applied computation	6
Semester 1	MA50178	Numerical linear algebra	6
Semester 1	MA50247	Bayesian and large scale methods	6
Semester 2	MA40177	Scientific computing	6
Semester 2	MA50170	Numerical solution of elliptic PDEs	6
Semester 2	MA50250	Inverse problems, data assimilation and filtering	6
Semester 2	MA50251	Applied stochastic differential equations	6
Semester 2	MA50263	Mathematics of machine learning	6

Optional units – List B

Students can select a maximum of 2 units from this list

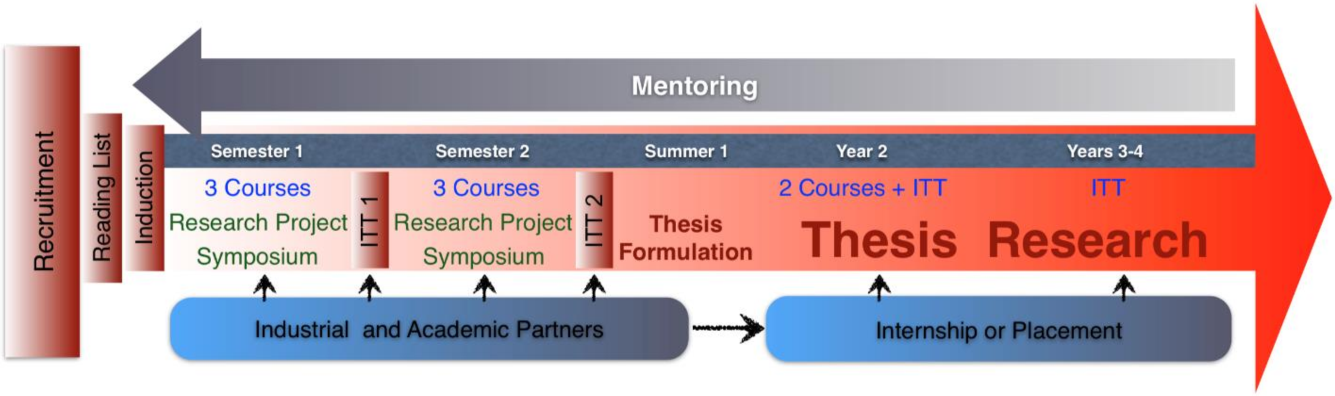
Study period	Unit code	Unit title	Credits
Semester 1	MA40042	Measure theory & integration	6
Semester 1	MA40045	Dynamical systems	6
Semester 1	MA40092	Classical statistical inference	6
Semester 1	MA40254	Differential and geometric analysis	6
Semester 1	MA50087	Optimisation methods of operational research	6
Semester 1	MA50125	Markov processes and applications	6
Semester 1	MA50179	Mathematical biology 1	6
Semester 1	MA50181	Mathematical methods 1	6
Semester 1	MA50183	Specialist reading course	6
Semester 1	MA50205	Advanced mathematical study 1	6
Semester 1	MA50257	Methods for stochastic systems	6
Semester 2	MA40048	Analytical & geometrical theory of differential equations	6
Semester 2	MA40049	Elasticity	6
Semester 2	MA40050	Numerical optimisation and large-scale systems	6
Semester 2	MA40057	Functional analysis (alternate years, will run 2024/25)	6
Semester 2	MA40058	Probability with martingales	6
Semester 2	MA40090	Multivariate data analysis	6
Semester 2	MA40189	Topics in Bayesian statistics	6
Semester 2	MA40203	Theory of partial differential equations	6
Semester 2	MA40239	Discrete probability	6
Semester 2	MA40255	Viscous fluid dynamics	6
Semester 2	MA40256	Analysis in Hilbert spaces (alternate years, running 2023/24)	6

Semester 2	MA50059	Mathematical methods 2	6
Semester 2	MA50061	Control theory	6
Semester 2	MA50063	Mathematical biology 2	6
Semester 2	MA50085	Time series	6
Semester 2	MA50089	Stochastic processes and finance	6
Semester 2	MA50206	Advanced mathematical study 2	6
Semester 2	MA50215	Specialist reading course	6
Semester 2	PH40073	Mathematical physics	6
Semester 2	PH40084	Advanced quantum theory	6

Dissertation period

Unit code	Unit title	Credits	Notes
MA50248	Thesis formulation report (MRes and Integrated PhD)	30	Compulsory for MRes and PhD progression
MA50187	Project (MSc)	30	Compulsory for students working towards MSc

5. Years two to four



Ph.D. research

You will have research, and the preparation of a thesis, as your main focus. A Ph.D. thesis should be submitted within four years of joining SAMBa.

Progress reports on Ph.D.

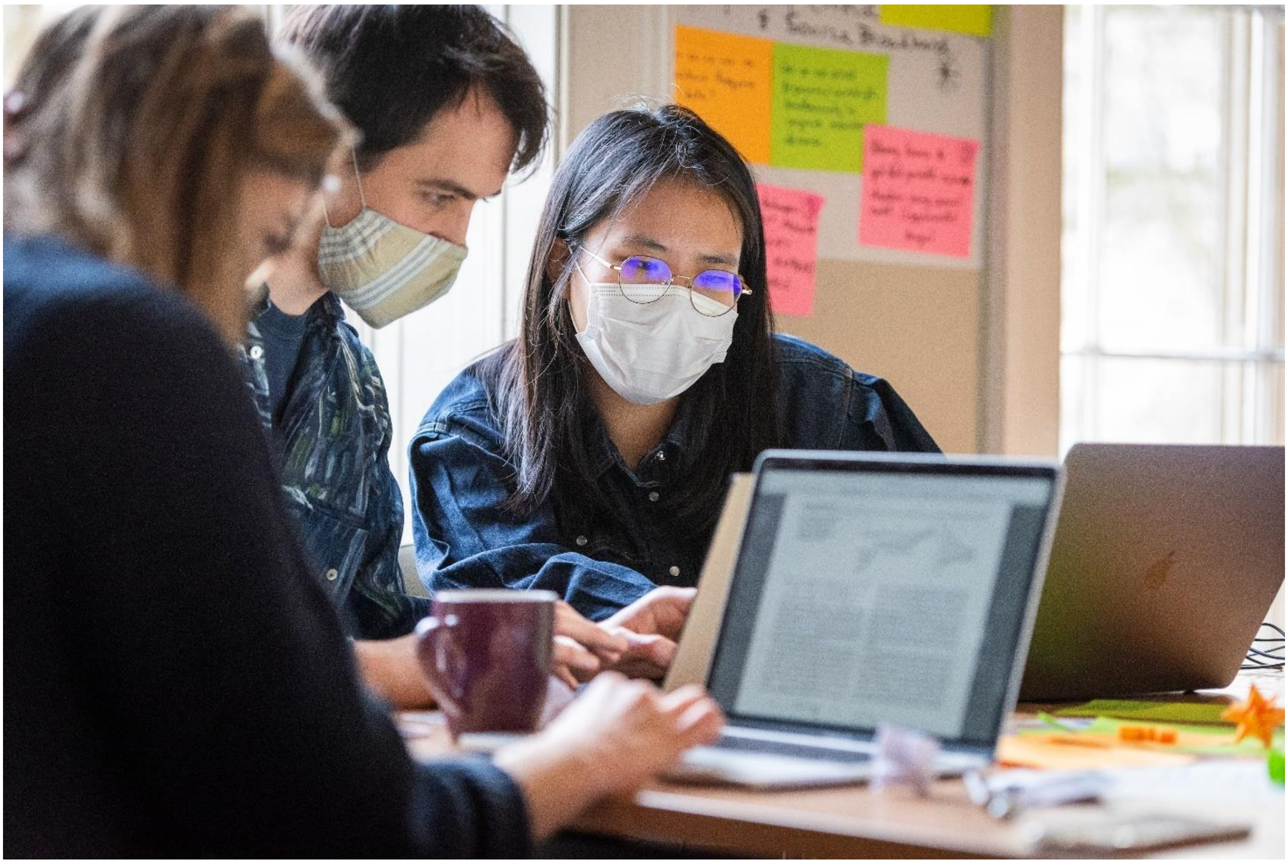
You are required to submit a progress report 30 months after you join SAMBa (i.e. 18 months into the Ph.D. stage) and will be interviewed (at a confirmation viva) by two assessors who are not members of the supervisory team. If this assessment is satisfactory, you will be confirmed as a Ph.D. candidate. If confirmation of Ph.D. candidature is not recommended at this stage, you may progress to submit a thesis for an M.Phil. only. In addition, you are expected to submit 6-monthly progress reports describing your work to date. These reports will be presented, and their research in general discussed, with your supervisor(s) and potentially an additional assessor.

Taught courses

In the second year, you will be expected to take two further courses, which should come from the core modules or as a reading course. Further reading courses should also be considered as a valuable addition to your research during the rest of your time in SAMBa.

Student-led symposia and ITTs

You will continue to be involved in student-led symposia throughout your remaining years at SAMBa. Students from later years are expected to present developing research, including open research problems for discussion. You are also expected to attend one ITT in year 2, and a further one in the remaining 2 years.



Placements and secondments

You are strongly encouraged to undertake an academic or industrial placement (related to your Ph.D. research) or secondment (unrelated to your Ph.D. research) during your research project. Placements and secondments can be extremely varied in nature.

Placements are organised by you and your supervisory team, with the approval of the SAMBa Management Team. Depending on the project, you may do an academic placement (i.e. a research visit to another university or department), or an industrial placement. Examples include spending three months on-site with an industrial partner involved with your Ph.D. research, visiting a research institute overseas 3 or 4 times for 2- or 3-week stints, or working somewhere else on the Bath campus, within a research group with expertise in the field in which you are developing your research project.

Secondments are short-term mathematically-driven projects but will be outside the remit of your Ph.D. research. These necessitate a suspension from Ph.D. studies and will therefore result in your Ph.D end date being extended by the length of the secondment. Secondments will be fully funded by the host partner, including salary and expenses. The emphasis is on you to identify opportunities, as well as make the necessary arrangements. The SAMBa Management Team will be available for consultation and assistance in this process, and will ultimately approve the secondment, in consultation with your supervisory team.

Join the SAMBa Internships site (MS Teams) for information and opportunities.

6. Fostering independence

Students of SAMBa are expected to cultivate a strong sense of independence in preparing themselves as mathematical scientists and, more broadly, as researchers.

Student-led symposia and ITTs

The student-led symposia and ITTs are a golden opportunity for you to explore your interests and respond to the challenges of the open-ended questions that will arise during ITTs. Students should approach academic staff within the department and across campus to ask them for input into the student-led symposia, or invite them to ITTs, if their expertise is desired. The budget that accompanies the symposia and ITTs means you can invite specialists from outside of the University to participate (pending approval from the Management Team).

Conferences and workshops

You are encouraged to attend conferences and workshops to network with people who have similar interests; to gain different perspectives, ideas or advice; to develop your skills and expertise in presenting a poster or talk, sharing your research and receiving and responding to feedback.

Training Support Fund (TSF)

Each SAMBa studentship is accompanied by a Training Support Fund (TSF) of £4,000 which provides funding to support your research. TSFs are intended to cover research-related costs such as travel and conference attendance, fieldwork, industrial and work placements, meetings with collaborators or volunteers, printing and small equipment including laptops. TSFs should not be used to supplement your living costs. Any equipment purchased as from your TSF remains the property of the University and should be returned when you leave.

You will have an individual TSF project account code set up in your name, with your primary supervisor named as the Principal Investigator (PI). If you would like to check the balance of your TSF, please email samba@bath.ac.uk or call in to the SAMBa Office, 4W 1.16.

Primary supervisors have responsibility for managing the TSF codes of their students, on behalf of the sponsor. They are accountable for the appropriate use of the funds, for ensuring that they are used for the purposes given/stipulated by the funder and in accordance with the University's Financial Regulations.

Key things to note:

- Expenditure from your TSF must be approved by your primary supervisor.
- University financial regulations and processes should be followed, and purchases made via approved suppliers. If you are unsure, please speak to the SAMBa team, samba@bath.ac.uk, or the Faculty Finance team, fac-sci-finance-admin@bath.ac.uk, to find out more about what you need to do to make purchases.
- Travel and accommodation
    - Expenditure should be in line with the University's travel and expenses policy
    - Travel/accommodation should be booked via Clarity, the University travel agent
- Conferences and workshops
    - The Faculty Finance team fac-sci-finance-admin@bath.ac.uk can help with booking for conferences and workshops. You will need to contact them with the details and your TSF Project code.
- Expense claims
    - Expenditure claims should be made via the Agresso Finance system with relevant receipts and/or accompanying documentation attached.

Department culture

Whilst you are obliged to take courses in your first and second year of study, you are encouraged to continue taking graduate courses right through your Ph.D. This is common practice with other Ph.D. students in the Department, with students often forming small discussion or reading groups. With 80 - 100 Ph.D. students in the department (including SAMBa) and around 20 postdocs, there is plenty of opportunity for collaborative learning groups and other self-organised activities.

Seminars

The Department hosts many different weekly seminar series with internationally renowned speakers coming from all over the world. This includes the Landscapes Seminars, which are held every few weeks during semester time and consist of world-class speakers who deliver overview lectures on specialist research fields. Full information on all seminar series can be found on the departmental web pages: **Seminars in the Department of Mathematical Sciences (bath.ac.uk)**.

7. Exploring the Department and the University

The Department of Mathematical Sciences

A defining quality of the department's distinctive research character is the conscious blurring of boundaries between different named research groups. The groups are:

- Algebra, geometry and number theory
- Analysis
- Applied and interdisciplinary mathematics
- Numerical analysis and data science
- Probability
- Statistics

Institute for Mathematical Innovation (IMI)

The Institute for Mathematical Innovation at the University of Bath has been created to address key challenges in mathematics and its applications and translate fundamental insight into economic and societal impact. IMI brings together disciplines across the University's remit and works with companies in every sector. The IMI may generate opportunities for SAMBa students through their industrial interactions.

Cross-disciplinary research centres

The Department of Mathematical Sciences hosts a number of cross-disciplinary research centres on themes relevant to SAMBa, each of which has structural support from the University. The Centres for Mathematical Biology, Nonlinear Mechanics, and Networks and Collective Behaviour provide established links with academics across the University. Bath is also home to the Probability Laboratory at Bath (Prob-L@B), one of the leading international research centres in the field. Details of all these can be found on the departmental web pages. There are also research links across campus between individual academics which you can exploit in finding opportunities for research and activities.

Dedicated space for postgraduate taught and doctoral students

The Graduate Commons building, 10 West, has dedicated spaces for independent study and one-to-one meetings for postgraduate students (plus kitchen facilities). This shared accommodation provides an excellent opportunity to meet students from across the University and provides an opportunity for cross-disciplinary working. For more details please visit:
https://www.bath.ac.uk/locations/10-west-graduate-commons/

8. Administration

Core Management

Name	SAMBa role	Email address
Alex Cox	Co-Director	mapamgc@bath.ac.uk
Susie Douglas	Co-Director	chpsrd@bath.ac.uk
Lou Adkin	Centre Coordinator	la642@bath.ac.uk
Lindsay Melling	Operations Officer	lam99@bath.ac.uk

Executive Team

Responsibility for the executive management and operation of the programme lies with the Executive Team consisting of a selection of key SAMBa academics together with the core management. The Executive Team meets on a regular basis (several times a month). They oversee management processes, such as student recruitment, approval of supervisors, management of budgets and preparation of taught courses. They also are responsible for the resolution of possible conflicts within the student body.

Name	SAMBa role	Email address
Silvia Gazzola	Executive team	sg968@bath.ac.uk
Matt Nunes	Executive team	man54@bath.ac.uk
Marcel Ortgiese	Executive team	ma2mo@bath.ac.uk
Theresa Smith	Executive team	trs35@bath.ac.uk
Phil Trinh	Executive team	hppt20@bath.ac.uk

Departmental contacts

Name	Department role	Email address
Gunnar Traustason	Head of Department	gt223@bath.ac.uk
Kate Remington	Department Coordinator	maths-enquiries@bath.ac.uk
Niamh Brady	Department Coordinator	maths-enquiries@bath.ac.uk

Directors of Studies

Overall coordination of all postgraduate students in the Department is formally carried out by two Directors of Studies (DoS): one for students on postgraduate taught courses (PGT) and one for postgraduates studying for research degrees (PGR). Directors of Studies liaise between the Department of Mathematical Sciences and the Doctoral College. SAMBa students will be formally overseen by the PGT DoS in their first year and the PGR DoS after that. We recommend, however, that you initially discuss all personal and course-related issues with a member of the Core Management team. For reference the Directors of Studies are as follows:

Name	Department role	Email address
Ben Adams	PGT Director of Studies	ba224@bath.ac.uk
Karsten Matthies	PGR Director of Studies	km230@bath.ac.uk

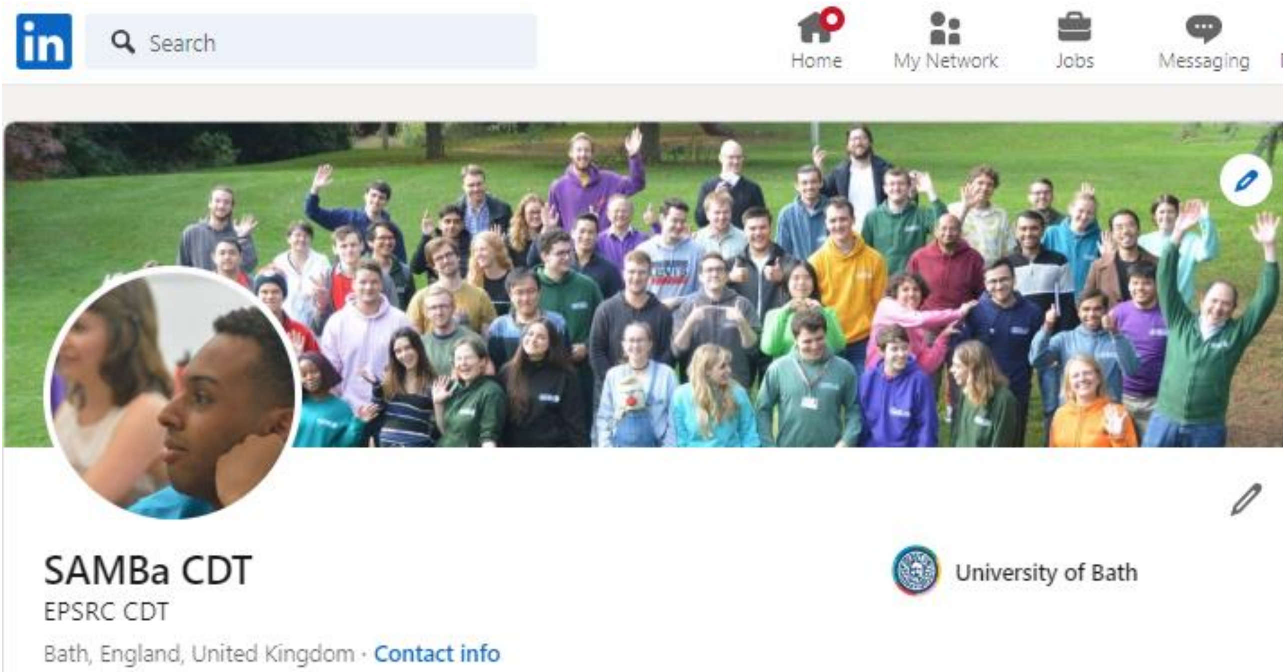
Strategic Advisory and Monitoring Board

SAMBa is monitored by an external board made up of non-Bath academics as well senior government and industrial scientists. Representatives from EPSRC are present at the meeting of the Board, which typically takes place once a year and which advises on the CDT's strategic direction as well as monitoring the performance measures and the degree of adherence to the vision of SAMBa. The current membership of the Advisory Board, and its terms of reference, can be found on the Advisory Board page of the SAMBa website.

Electronic media

SAMBa uses various electronic media for internal and external communications, as well as having a number of official contact addresses:

- SAMBa webpage: https://samba.ac.uk/
- SAMBa email address: samba@bath.ac.uk
- SAMBa on LinkedIn: https://www.linkedin.com/in/sambacdt
- SAMBa on X/Twitter: @SAMBa CDT
- SAMBa on Facebook: https://www.facebook.com/groups/725115514220752/



9. University support and complaints procedures

Support during your Ph.D.

Completing a Ph.D. is a challenging experience and can be difficult at times. There is a lot of support around you in SAMBa, from the rest of the cohort, the staff, and the department and we hope that we will be able to accommodate individual circumstances as much as possible in order to make sure you are able to fulfil your potential. The University has a wide range of support mechanisms and you are encouraged to take advantage of these services as and when you require them.

Where to go for guidance, advice and support:

Student Support Advice Service	Help and advice on all welfare and wellbeing issues: drop-in, phone and online. Phone: **01225 383838** Email: studentsupport@bath.ac.uk
Be Well Talk Now	24-hour advice and support. Phone: **0808 196 8046** (from the UK), **+44 3 307771499** (from outside the UK).
Student money advice	Practical advice on managing money, funding and sourcing additional income. Drop-in sessions and appointments.
Disability Service	Specialist advice throughout your studies, including liaising with your department to recommend study adjustments and applying for specialist one to one support and equipment.
Therapeutic Services and Mental Health	Provide talking therapies, mental health support and courses and workshops. Can also help you find the right support outside the University.
Independent Advisor Service for PGRs	Independent advice service available for doctoral students to access throughout their studies.
Support for doctoral students	Advice and support for those undertaking a research degree.
Sexual assault or harassment	Advice, help and support if you have been affected by sexual assault, harassment or rape. Report and support tool.
Urgent or emergency wellbeing support	In an emergency, if you are worried about your own, or another person's health or welfare, you should call security on **01225 383 999** if you are on campus or ring the emergency services on **999**.
NHS health information service	UK national service for health support and advice, available 24/7 Phone: **111** if you need help/advice but it's not an emergency
Samaritans	National charity, available day or night, for anyone who's struggling to cope, who needs someone to listen without judgement or pressure Phone: **116 123** (free, confidential support)
Support Directory	This page has links to the support provided by the University, SU and external support organisations.

Independent Advice

Sometimes you might want to seek independent, confidential advice or occasionally, you may encounter problems in connection with supervision or other issues. Where these cannot be resolved at department or School level, or where you consider this route inappropriate, you should contact **The University Independent Advisor Service**. Advisors provide independent and confidential advice to postgraduate research students. Consultations are treated in strict confidence. They will never disclose your details or do anything on your behalf without your permission.

The **Doctoral College** provides a useful summary of the support and support services available and how to access them: **Support for doctoral students (bath.ac.uk)**

The **SU Advice and Support Centre** provides independent and confidential advice on academic issues where you may need individual representation such as complaints, mitigating circumstances, appeals and disciplinary procedures including academic misconduct: **Advice and Support (thesubath.com)**

The **Chaplaincy** offers counsel and advice to both staff and students of all faiths and no faiths: **Chaplaincy (bath.ac.uk)**

What to do if….

At times during your PhD you'll have various questions or concerns and it may not be clear where you can get advice or support. The 'What to do if….' guides (accessed via Moodle) contain advice on a variety of topics such as ***What to do if***….

- my PhD supervisor is unresponsive/disengaged
- someone in the department has said/done something I find offensive
- I am worried about a fellow PhD student
- I have an illness or disability
- I need specific skills support during my PhD
- I’m being overworked/pressured into additional responsibilities unrelated to my PhD
- I experience a lack of motivation/imposter syndrome/handling rejection during my PhD
- my PhD supervisor and I have different expectations, or disagree on the direction of my project

International students

The student immigration service: **Student Immigration Service (bath.ac.uk)** can help with enquiries about visas, residency, and settling in the UK.

Complaints

We aim to engage students in SAMBa and welcome feedback and suggestions for improvement, as well as letting us know when things are working. We will give you opportunities for providing feedback and suggestions on various aspects of SAMBa, including operation and delivery. If you have any complaints about SAMBa, please approach one of the Co-Directors in the first instance, or a member of the Executive Team.

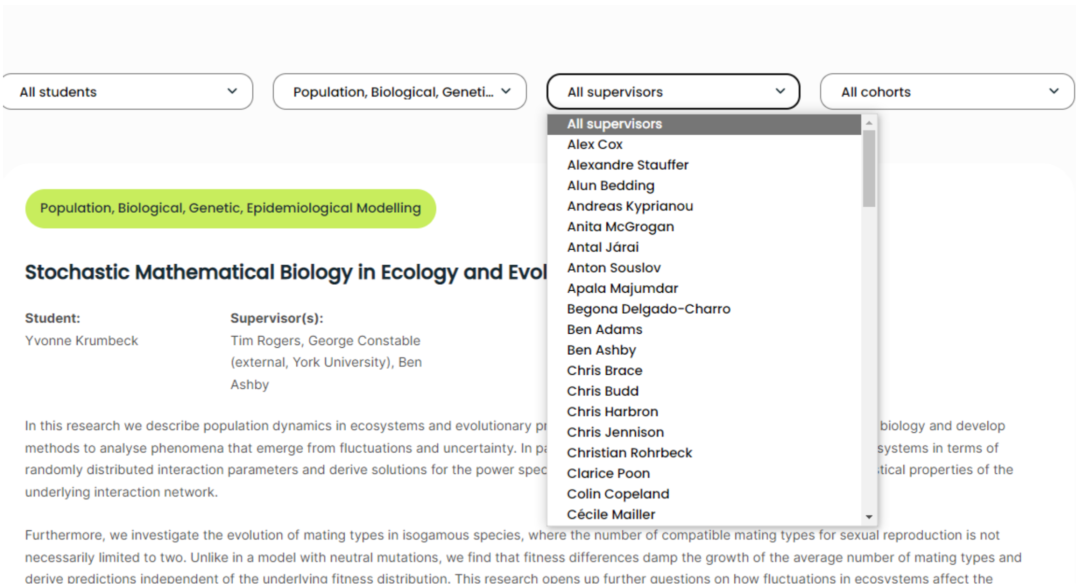
If you would like to make a more formal complaint, you can do this through the University's Doctoral College at the following link: **Appealing against an academic decision (bath.ac.uk)**.

10. SAMBa student projects

SAMBa Ph.D. projects cover a broad range of research within the department and more details of past and current research is given below.

Explore student research projects on the SAMBa website

Details of current and previous student research projects are given below. Please visit the [Student Research Projects] area of the [SAMBa website] to search for projects by student, topic, supervisor or cohort.



10.1 Current projects

Novel methods for network-structured time series modelling – Chiara Boetti

Supervisor(s): Matt Nunes

There has been an explosion in the availability of data observed on networks / graphs over time, from neuroscience to telecommunications and transport. Whilst there is a well-established literature on analysing multicomponent time series, tools which adequately account for the connections in such network-structured time series setting are relatively uncommon. The aim of this project is to develop new models and associated tools for these time series objects in different scenarios, such as data which exhibit long memory, nonstationarity or changing structure over time.

Accessibility percolation – Diana De Armas Bellon

Supervisor(s): Matt Roberts, Daniel Kious

Accessibility percolation was introduced by Nowak and Krug as a model for evolution. In this model, a graph represents possible genotypes or phenotypes, with each vertex assigned a fitness value. The objective is to identify paths of vertices whose fitness values increase, signifying viable evolutionary pathways. In the 'House of Cards' model, fitness values are independently and identically distributed. In the 'Rough Mount Fuji' model, fitness values exhibit some form of drift as well as an independent and identically distributed component. The primary aim is to obtain theoretical insights into the asymptotic behaviour of the House of Cards and Rough Mount Fuji models across various settings, including on trees, the hypercube, random graphs, or even the integer lattice.

Learning to optimise in inverse problems – Patrick Fahy

Supervisor(s): Matthias Ehrhardt, Mohammad Golbabaee

Inverse Problems focus on recovering information from potentially noisy data. Many such examples exist due to modern imaging modalities, such as MRI and PET. Commonly, inverse problems are tackled by considering variational regularisation. Often, the solution to such minimisation problems is found using iterative methods, such as PDHG and ADMM. This PhD will focus on learning to optimise, which seeks to leverage data to speed up this optimisation process. There are many potential areas for research, from learning hyperparameters in an iterative procedure, to learning how to sample in Stochastic optimisation methods.

Stochastic Control Problems of Measure-Valued Martingales and Applications – Chaorui Wang

Supervisor(s): Alex Cox, Tony Shardlow

In this project, we will study the construction and extension of the measure-valued martingales (MVMs), and the solution to relevant control problems via viscosity theory. In particular, we want to clarify the admissible control set of the problems as much as possible. Moreover, we will try to study its applications, for instance, the Bayesian search problem, the differential game problems etc. We are also interested in the use of machine learning algorithms to solve stochastic control problems via BSDE formulation, with a focus on finite-dimensional versions of MVM control problems.

Asymptotics beyond-all-orders for free surface flow – Henry Writer

Supervisor(s): Philippe Trinh

The project aims to explore the beyond-all-orders behaviour of free surface fluid flow created when a liquid flows over a variable bottom topology. We employ various techniques, including spectral and physical-plane methods, to gain insights. Our goal is to understand the distinctions between these methods and determine the situations where one method is preferable over the other. Furthermore, we aim to extend these methods and ultimately develop the capability to analyse gravity-capillary wave systems in three dimensions.

Optimising Psychological Treatment in the NHS – Adeeb Mahmood

Supervisor(s): Thomas Burnett, Theresa Smith, Özgür Şimşek

This thesis will work towards the optimisation of psychological treatment within the IAPT service, IAPT stands for Improving Access to Psychological Therapies also commonly known as NHS Talking Therapies and it was developed to improve the delivery of, and access to, evidence-based, psychological therapies for depression and anxiety disorders within the NHS. We are interested in two key objectives. The first is to predict which patients are likely to dropout and not attend their therapy sessions, this is known as a Leave Without Being Seen (LWBS) problem in the literature. Our second goal in this thesis is to form a real-time sequential decision maker within IAPT, this will take the form of reinforcement learning.

Reinforced random walk models and biologically inspired network design – Wilfred Armfield

Supervisor(s): Cécile Mailler, Daniel Kious

The slime Physarum Polycephalum (aka the blob) has been the subject of extensive research over the past decade as it is able to construct optimal transport networks in multiple scenarios. In particular, it does so without centralised control or global knowledge of the system. The aim of this PhD project is to develop a reinforced random walk model that emulates the behaviour of the blob, make rigorous the notion of optimality of a network and prove that this model indeed exhibits this optimality.

Solving Dynamics Inverse Problems with Physics-Informed Neural Networks - Pablo Arratia Lopez

Supervisor(s): Matthias Ehrhardt, Lisa Kreusser

In inverse problems, image reconstruction from noisy measurements is one of the classical tasks to be solved. Many imaging techniques take measurements throughout the time of some dynamic process and then a sequence of frames needs to be retrieved (such as a heart beating imaged with magnetic resonance). The underlying physical behaviour can be incorporated into the formulation as a regulariser that may endorse the reconstruction of images by modelling an additional variable (a velocity field for instance) satisfying some PDE. The goal of this PhD project is to solve this problem with the so-called Physics-Informed Neural Networks (PINN), a new paradigm introduced in 2019 where a neural network is trained while respecting physical constraints by taking advantage of automatic differentiation.

Quantum algorithms for Hamiltonian simulation - Guannan Chen

Supervisor(s): Pranav Singh, Chris Budd

The Hamiltonian of a quantum system dictates its dynamics completely. The computation of these dynamics under a particular Hamiltonian is called the Hamiltonian simulation problem, and it allows the prediction of the system behavior. Despite significant progress in Hamiltonian simulation on classical computers over the past century, the Hamiltonian simulation problem has remained an extremely challenging task over the past century due to the curse of dimensionality as the computation costs grow exponentially with system size. One of the motivations for Feynman's 1982 proposal for the design of quantum computers was in response to this problem. The aim of this PhD project is to develop quantum algorithms for Hamiltonian simulation. These include algorithms inspired by classical splitting methods, as well as variational quantum algorithms involving anstaz- based quantum circuit optimization.

Expanding Populations and Fitness - João Luiz de Oliveira Madeira

Supervisors: Sarah Penington and Marcel Ortgiese

Random mutations that occur near the colonisation front in an expanding population can survive in the population by 'surfing' on the population expansion, even if the mutations themselves are deleterious. In this project, we will work towards rigorously determining the large-scale behaviour in a model of this phenomenon introduced in a recent non-rigorous biology paper by Etheridge and Foutel-Rodier (Theor Pop Biol, 2020).

Viscoelastic Flows of White-Metzner Type Fluids - Christian Jones

Supervisor(s): Jonathan Evans

Polymer melts and solutions are highly important materials in industry, and display characteristics of both viscous fluids and elastic solids. Due to this, these viscoelastic fluids can be quite complicated to model, and require a constitutive relation in order to relate any material deformation to the internal stresses. Moreover, in many polymer processing applications, geometries are encountered in which singularities arise in the stress, such as re-entrant corners, and flow out of a die. Understanding these singularities; therefore, is a crucial task, as failure to do so can have negative implications on the quality of the processed product.

However, it is only fairly recently that asymptotic analysis has been utilised to quantify these stress singularities for a range of models, largely based on the upper convected Maxwell (UCM) model. This is usually combined with formulating the problem in a natural stress basis, where the stress variables are aligned with the flow direction. In many geometries, this is vital for producing a full description of the fluid flow. Thus, the main goal of this PhD project is to continue and expand the use of these techniques through application to other viscoelastic models.

Data driven numerical integrators - Henry Lockyer

Supervisor(s): Pranav Singh, Lisa Kreusser, Eike Müller

Numerical integration, specifically multistep methods are currently solved using truncated Taylor series that have nice analytical properties for small timesteps. Sadly, practical users want large timesteps (greater than 1) where Taylor analysis breaks down (even for high order methods). Therefor in this PhD we seek to find practical, powerful, usable methods that go beyond asymptotics and are optimal for larger time steps.

Developing new tools in graph-based signal analysis - Sinyoung Park

Supervisor(s): Matt Nunes, Sandipan Roy

In many settings, data naturally arise as connections between individual nodes in a graph. Alternatively, data arising in other spaces (such as images) can be coerced into a graph-like structure for analysis, the suggested advantage being that one can unlock alternative information such as dependency structure not apparent in the original domain, or that network sparsity can be exploited for more straightforward analysis. The aim of this project is to look at methods that analyse graph-based data using signal analysis, especially wavelet transform and expand on these further.

Bilevel Learning - Mohammad Sadegh Salehi

Supervisor(s): Matthias Ehrhardt, Subhadip Mukherjee

Inverse problems are the process of estimating parameters of interest from indirect, potentially noisy, measurements. They are ubiquitous in many areas of science and engineering, including virtually every modern medical imaging modality. The standard approach to inverse problems and specifically image reconstruction is variational regularisation. Although hugely successful, typically, it is dependent on a range of parameters that have to be set manually. State-of-the-art image reconstruction methods learn these parameters from training data using a variety of machine learning techniques, such as bilevel methods. Bilevel learning can be seen as a method to learn parameters best suited to a specific task. From the mathematical point of view, this strategy leads to a nested optimisation problem which is computationally very difficult to handle. This PhD project lies in algorithms for bilevel learning used in the mathematical imaging literature. In particular, derivative-free and first-order methods tailored for the mentioned type of problems and their challenges are investigated, as well as their convergence theorems. Alongside these algorithms the usage of data-adaptive input-convex neural networks as the regulariser, will be explored. Applications of this PhD project include undersampled MRI reconstruction; image denoising, deblurring and segmentation; and data clustering. Also, other sorts of applications in the general category of supervised learning are desirable.

Within-host Individual-based model for diabetic tuberculosis patients - Aminat Yetunde Saula

Supervisor(s): Ruth Bowness, Jane White

For several decades, Tuberculosis (TB) has been preventable and curable. However, someone still dies from tuberculosis across the world every 15-20 seconds, and 50 percent of those deaths are children. In addition to this, patients with diabetes have a higher mortality rate when infected with TB and have an increased likelihood of TB relapse. The aim of this PhD project is to use individual-based modelling (or agent-based modelling) to develop a within-host model of TB infection within a human lung, building on previous models (Bowness et al. 2018) to focus on patients with type 2 diabetes. The goal would be to understand the differences in immune responses in these patients to TB infection and simulate improved treatment strategies. We will work with experimentalists, using laboratory data to calibrate the model, and clinicians who have access to clinical data to validate model findings. Specifically, this project will benefit from a collaboration with Dr Muge Cevik (University of St Andrews/NHS Lothian), who is an expert on treating diabetic TB patients and is currently involved in a clinical trial in this area of research.

Collective Motion Under Non-Reciprocal Pairwise Interactions – Beth Stokes

Supervisor(s): Richard James, Tim Rogers

Preliminary experimental work and mathematical modelling suggest that sexual conflict can give rise to non-reciprocal interactions and anomalously fast diffusion of pairs of Trinidadian Guppies (Poecilia reticulata). In the long-term, their behaviour also results in key ecological and evolutionary processes such as population dispersal and invasion of alien species. To combine the biology of pairwise interactions through to population level consequences will require mathematical models of processes at different time, spatial and social scales. In biological terms, such problems lie at the intersection of movement ecology and collective behaviour. Using mathematical techniques from agent-based modelling, mean-field and coarse-grained approximations and continuous time PDE modelling, the aim of the project is to develop a general framework, or suite of mathematical models, to interpolate between and extrapolate from one social, spatial and temporal scale to the next, modelling the effect on non-reciprocal social forces in Trinidadian Guppies on large-scale population structure and the ecological and evolutionary consequences of their behaviour.

Mathematical and statistical analysis of physical activity data to create new models for predicting health risks and benefits - Melina Del Angel Martinez

Supervisor(s): Prof. Dylan Thompson, Matthew Nunes

Wearable monitors have been recently introduced as a new technology for monitoring energy expenditure more objectively and reliably than the usual self-reported methods. The overall goal of the research is to find mathematical and statistical models for analyzing longitudinal data gathered using wearable technology, and to draw meaningful conclusions in the physiological context based on these models. The external partner of the project is KiActiv®, a digital health company that has minute-by-minute resolution data coming from more than 2000 patients that took their 12-week KiActiv® Health programme.

Mathematical methods for differential privacy in clinical research - Ruchen Liu

Supervisor(s): Matthew Nunes and Sandipan Roy

Differential Privacy (DP) is a novel probabilistic framework to provide provable guarantees of data privacy when individual participants submit data for analysis. Generative (deep learning) models are useful to analyze and generate data but are still prone to adversarial attacks. An open research question is whether generative (deep learning) models can be used in a differentially private framework to either (i) produce private synthetic image and tabular data, which could then be shared safely or (ii) trained in a differentially private manner so that the model itself can be shared. Since our application of interest is clinical trials data, another goal of the project will be to develop DP counterparts of clinical trial methods and quantifying the reliability of analysis results using these methods.

Development of Sparse Statistical Modelling for Neurological Applications - Xinle Tian

Supervisor(s): Sandipan Roy, Matthew Nunes

The aim of many neurological studies, for example using fMRI data, is to derive the areas of the brain and connections between them which are the principal contributors to brain activity. Current techniques often focus on latent variable models to quantify the main features of process dynamics, but can often produce negative weightings for components, contrary to scientific belief and resulting in models which are difficult to interpret. This project aims to develop new models for functional activity which don't enforce restrictive model assumptions, with associated estimation theory and fitting based on constrained optimization to ensure clinically-relevant parameter values. In addition, we will develop inference methods in which structure can be included as a graph prior for sparse graphical models. Subsequent research will then focus on algorithms for detecting changes in such settings. With the potential new models, it serves to both improve interpretability and predictive performance in neurological studies and allow us to investigate a better understanding of functional connectivity which occurs in neurological studies.

Multiscale Rational Krylov Methods - Mark Tennyson

Supervisor(s): Pranav Singh and Sergey Dolgov

Hybrid asymptotic-numerical schemes for exponentially small selection mechanisms - Cecilie Andersen

Supervisor: Phil Trinh

There are a number of problems in fluid mechanics and the wider physical sciences that involve the asymptotic analysis of nonlinear ordinary or partial differential equations studied in some singular limit, say $\varepsilon \to 0$, and where an eigenvalue, say λ, exhibits a selection mechanism. In some cases, this yields a countably infinite sequence, $\lambda 1 < \lambda 2 < \lambda 3 < \ldots$. However, within a number of such open problems, the mechanism determining the sequence as $\varepsilon \to 0$ is governed by exponentially small terms beyond-all-orders. Cecilie will study and provide a review of existing theory of such selection mechanisms as encountered in problems such as Saffman-Taylor viscous fingering, vortex reconnection, resonant oscillations in shallow-water flows, and similar problems. Cecilie will also study an open problem related to selection mechanism found in rising bubble flow in a channel (or equivalently, separating flow from the nozzle of a jet). This work will initiate a wider PhD in studying such selection mechanisms for several related open challenges in fluid and continuum mechanics.

Epidemiological dynamics in populations with spatial and demographic structure - Abby Barlow

Supervisor: Ben Adams

Abby's research lies in the field of epidemiology. In particular, she is concerned with further developing and applying the theory of spatially and demographically structured epidemiological models. In her thesis formulation report, she developed and analysed an age-structured model for COVID-19 epidemiology in Mongolia. The model incorporates age-related transmission rates to account for the country's specific demographic structure. In her future PhD research she plans to develop spatially-structured epidemiological models under metapopulation and household frameworks. Under these frameworks, the population is divided into subpopulations based on their spatial separation or designated households. This allows for a distinction between the stronger and more frequent contacts we expect between individuals who reside closer to each other and the weaker contacts between those further apart.

A priori bounds for fractional SPDEs - Salvador Esquivel

Supervisors: Hendrik Weber, Andris Gerasimovics

Salvador's project belongs to the theory of Singular Stochastic Partial Differential Equations with the main focus on what is known as the $\mathbf{\Phi^4_d}$ model. This theory heavily relies on both theory of Schochastic Process and theory of PDE. The aim of this work is to understand the use of regularity structures to develop small scale theory for some class of Singular SPDE and the use of a priori bounds to extend them to global solutions.

The symbiotic contact process on non-lattice structures - Carmen van-de-l'Isle

Supervisors: Marcel Ortgiese, Sarah Penington

The symbiotic contact process is a two particle type extension of the contact process. We can think of the process as two contact processes which help each other to survive, hence the symbiotic name. The process can be motivated by both disease modelling, where a patient is less likely to recover as quickly from two illnesses versus one, or modelling animal species which live longer in close contact. The process has been studied on lattices where a phase transition has been proved between survival and extinction given the infection rate of the process. We aim to extend on this work by providing results for the phase transitions and critical values for the infection parameter on non-lattice structures such as Galton-Watson trees and random graphs.

Excursions from Hyperplanes for Isotropic Stable Processes - Sonny Medina Jimenez

Supervisors: Andreas Kyprianou, Juan Carlos Pardo Millan

Breaking the paths of isotropic Lévy processes in R^d in radial excursions from the origin is a technique that has been used to understand the behaviour of processes when they approach the origin or the unit sphere $S = \{x \in R^d : |x| = 1\}$. We aim to build on these ideas and techniques and consider related behaviour in relation to the hyperplane $H = \{x \in R^d: <x, v> =0 \}$, with $v \in S$, and use the associated path decomposition to address questions such as how to condition the process to stay on one side of the hyperplane, examining the point of closest reach to H, conditioning to never touch the hyperplane or the relationship between this and the spherical case via conformal transformations of Riemannian manifolds.

Multivariate Regression on High-Dimensional Networks - Daniel Miles

Supervisors: Sandipan Roy and Vangelis Evangelou

A crucial feature of many modern data sets is their inherent graphical (network) structure embedded in them. Gaussian Graphical Models, known by various other names, are commonly used in Statistics to encode a graphical conditional relationship onto a multivariate Gaussian distribution. Many scientific applications manifest a high dimensionality combined with a sparse graph structure, which can hinder inference and high-level interpretation when fitting graphical models onto relevant data. However, as exemplified through geospatial crime data, the implementation of a regression-based transformation through a penalty term in the log-likelihood function can efficiently and informatively infer a covariate relationship between a high number of connected nodes (crime rates for different regions) with a smaller number of secondary variables (socioeconomic factors). Daniel's project aims to establish tractability conditions for parameter estimation under a generalised expression of this new Gaussian graphical model, through an iterative algorithmic procedure. Where a graph structure is not known, a Lasso-like penalty must be employed in tandem with the regression penalty. Further considerations include the extension of the single graph case to that of an evolving graph, mainly in a temporal sense.

Problems for self-similar Markov processes - Mehar Motala

Supervisors: Andreas Kyprianou, Alex Cox

The ultimate aim of the PhD will be to consider a number of problems from the theory of self-similar Markov processes. The thesis formulation report will outline problems surrounding conditioned Lévy processes, self-similar Markov processes, and Markov Additive Processes. In particular, Mehar will look at extending results concerning the Markov Additive Process conditioned to continuously hit the unit sphere in d dimensions.

Statistical learning methods for dimension reduction in multivariate extremes - Matthew Pawley

Supervisors: Christian Rohrbeck, Evangelos Evangelou

In many application areas, such as climate science and finance, it is important to assess the risk of rare, extreme events. Mathematically, this involves modelling the tail behaviour of a multivariate random variable using techniques from a field of statistics called multivariate extreme value theory. However, the tail dependence between the components is characterised by a measure that must be estimated using only a small number of observations. Traditional methods for modelling this measure are limited to small or moderate dimensions. Recently, methods from unsupervised learning, such as clustering and principal components analysis, have been adapted to extreme; these methods are better-equipped to handle high-dimensional settings. Matthew's project aims to advance existing techniques and develop new methodology in this area.

Flow-based statistical-shape models - Allen Paul

Supervisor: Tony Shardlow

The project will develop flow-based methods for understanding and categorizing medical images, with a long-term goal of describing shape variation of bones in psoriatic arthritis. Two key areas to be explored are: i) large-deformation diffeomorphic metric mapping: deterministic techniques for warping two images via a diffeomorphism to identify areas of similarity and difference, and ii) statistical techniques for working with uncertain deformation fields and Bayesian techniques for describing shape variation.

Modelling of ice crystal icing in engines - Timothy Peters

Supervisors: Hui Tang, Phil Trinh

In 2006 a new phenomenon was recorded to have caused repeated reports of engine failure. This was coined ice crystal icing and occurred at altitudes previously thought benign. Ice crystals would be ingested into airplane engines where they would partially melt, leading to the accretion and breaking off of ice, causing engine damage. Timothy is exploring this accretion problem, with the aim to develop a full accretion model for an arbitrary engine geometry. This accretion problem lends itself to a few different long-term projects. The first is the development of the accretion models and a large-scale analysis of key physical quantities. The second involves studying the dynamics of ice break off in the engine.

Tumour and Treatment Modelling - Jenny Power

Supervisors: Tristan Pryer, Silvia Gazzola

This project is concerned with brachytherapy treatment for cancer patients. Brachytherapy is a type of radiation treatment that consists of placing sealed, radioactive sources directly into or next to the tumour to be treated. These sources emit radiation which kills the tumour. It has proven to be an efficient form of treatment as the radiation dose delivered can be focused on the tumour, and can be quite high, while limiting dose exposure of the surrounding normal tissue. However, a disadvantage of brachytherapy occurs when the tumour is close to a critical organ. In this instance, the radiation emitted from the sources may damage these critical organs, which could cause further health problems and complications. A challenge lies in positioning the sources such that the tumour is exposed to the required amount of radiation to kill it, but the critical organ is not exposed to excessive toxicity. The main question this project will address is "Where should these radioactive seeds be placed (and how many of them), such that the dose on the critical organs is minimised?". This project spans the mathematical topics of partial differential equations, numerical analysis, inverse problems and PDE constrained optimisation, as well as the physical and biological processes behind radiation transport. The aim of this work is to develop a numerical model which will determine the optimal placements of these radioactive sources such that the damage on the critical organs and surrounding tissue is minimal, but the dose on the tumour is still high enough to eradicate it. This problem is formulated as a PDE constrained optimisation problem.

Once-reinforced random walks on tree-like graphs - Pawel Rudnicki

Supervisors: Daniel Kious and Hendrik Weber

Once reinforced random walk (ORRW) is an example of a self-interacting random walk, which is not Markovian, and hence, the study of it often proves to be rather nontrivial. It has been studied mainly on trees, and the existence of a phase transition for recurrence/transience has been established on those graphs. There have only been a few results obtained for ORRW on non-simple graphs, exclusively on ‘ladder graphs’, which are essentially one-dimensional. Pawel is investigating ORRW on tree-like graphs, that is, graphs with loops which additionally possess a useful tree structure. In particular, Pawel’s research concerns learning about the phase transition on that class of graphs.

Learning the Regulariser for Inverse Problems - Seb Scott

Supervisors: Matthias Ehrhardt, Silvia Gazzola

Solving inverse problems, such as those that arise in imaging applications, like computed tomography, is a challenging task due to their inherent ill-posedness and high dimensionality. Traditionally, one solves them using model-based methods, with variational regularisation models [2] being the most popular - where the choice of regulariser is usually a fixed, ad hoc decision. Recently, more data-driven approaches for determining regularisation operators and regularisation parameters have been considered [1]. This project is an exploratory study into these semi-data-driven methods for solving inverse problems, with a focus on the bi-level learning framework, and how one may use a neural network to learn, with mathematical guarantees, an appropriate regulariser.

[1] S. Arridge et al. “Solving inverse problems using data-driven models”. eng. In: Acta numerica 28 (2019), pp. 1–174. issn: 0962-4929.
[2] J. Chung, S. Knepper, and J. G. Nagy. “Large-Scale Inverse Problems in Imaging”. eng. In: Handbook of Mathematical Methods in Imaging. New York, NY: Springer New York, pp. 43–86. isbn: 0387929193.

Exploring information spread and stochastic systems in biology - Andrei Sontag

Supervisors: Tim Rogers, Christian Yates

Mathematical modelling of biological systems has been of paramount importance in aiding policy-making aimed to curb the spread of diseases or rumours, save endangered species, and control plagues of locusts. This project will concern the exploration of intriguing and exciting topics in mathematical biology. Three research topics are of particular interest. First, the study of the complex dynamics arising from the feedback between the behavioural reactions of individuals to an ongoing epidemic. Second, the investigation of information and misinformation spread in populations, particularly on networks. And third, the study of the collective motion of locusts, focusing mainly on the extension of existing models to account for halting movement.

Robust Adaptive Dynamic Programming for the Newsvendor Problem - Marcel Stozir

Supervisor: Alex Cox

In data-driven stochastic optimisation problems that account for model uncertainty, the decision maker can either act myopically based on the knowledge that has been acquired so far or exploratory by choosing a sub-optimal action that may gather more information about the system to improve future decisions. This exploration-exploitation trade-off is most prominently encountered in the newsvendor problem where a retailer can only observe the number of products sold but not the excess demand, and is encouraged to learn about the unknown demand distribution to make more informed inventory decisions. Marcel’s work focuses on approximating the optimal solution in this planning problem in such a way that the decision maker can learn the true characteristics of the demand robustly under model misspecifications. Based on concepts from optimal transport theory he plans to develop a method aimed at adaptively reducing the infinite space of attainable future models to a finite number of distinct forms; which allows for an effective computation of the intractable Bellman equation. He intends to extend this method to a broader range of uncertain stochastic optimisation problems which may also allow for a scenario reduction technique in algorithm planning for Reinforcement Learning applications.

Justification of kinetic equations using graph structures - Theodora Syntaka

Supervisor: Karsten Matthies

The derivation of continuum equations from a discrete deterministic system of particles is of major interest. This is an area of research in mathematical physics originating from Hilbert's Sixth Problem in 1900. This problem has been approached in two steps using the Boltzmann equation as a mesoscopic description. The first one is to derive kinetic equations, such as the Boltzmann equation, from a system of particles and the second is to derive continuum equations, such as Navier-Stokes and Euler equations, from the Boltzmann equation. Kinetic equations such as the Boltzmann equation are iconic because they illustrate the phenomenon that irreversible dynamics can be the result of reversible microscopic motion. My project focuses on developing a novel approach which combines tools from Probability theory and Analysis to systematically approximate the particle dynamics with simpler evolutions.

Adaptive Undersampling in Spectromicroscopy - Oliver Townsend

Supervisors: Silvia Gazzola, Sergey Dolgov, Paul Quinn

My project is focussed on making the spectromicroscopy experiment more efficient through the use of undersampling. The spectromicroscopy experiment is a key tool used by material scientists to determine the chemical speciation of a specimen at the microscopic level; the issue is that even relatively small samples take a long time to complete, causing a bottleneck in services. By taking fewer measurements and recovering the missing data entries (one method is through the use of Low Rank Matrix Completion Algorithms), we can reduce the time each experiment takes, and allow a significant increase in the number and quality of scans taking place.

Stochastic Pattern Formation - Fraser Waters

Supervisors: Kit Yates, Jonathan Dawes

First proposed as an explanatory model for morphogenesis, the paradigm of a 'Turing pattern' has been used to analyse the spontaneous emergence of coherent spatio-temporal structures in reaction-diffusion systems across a wide range of applications, from mathematical biology to nonlinear optics. In continuous deterministic models, this instability mechanism is well understood, and typical analysis can predict the leading order spatial characteristics and growth rates of these emerging patterns, as well as the parameter regimes in which they may be observed. Stochastic models have been shown to exhibit such patterns far outside the parameter regimes predicted by their deterministic counterparts. Fraser is exploring the analysis of these 'Turing pattern'-like instabilities in lattice-based stochastic jump process reaction-diffusion models, in particular the effects of stochasticity on the susceptibility of the system to this spontaneous patterning, and the characteristics of the emergent structures.

Mathematical and statistical analysis of time series data to quantify trends and events in ocean noise - Gianluca Audone

Supervisors: Matt Nunes, Philippe Blondel, Chris Budd, Peter Harris, Stephen Robinson

Variation in the ambient sound levels in the deep ocean has been the subject of recent studies, with particular interest in the identification of trends, features and events in the data. Many early studies demonstrated the effect of shipping on low frequency sound dynamics in the deep-ocean. However, it is now recognised that there is a variety of other sound sources, both natural and man-made, contributing to the soundscapes. In addition, climatic variations like warmer oceans or sea ice cover can influence sound propagation over large distances. Given the high-dimensional and complex nature of the dataset, Gianluca is developing a modelling framework to reveal intersource and intersensor dependencies in the data, i.e. to extract quantitative information about sound levels in the deep ocean from the data. The analysis methodology developed includes aspects of signal processing, statistical characterisation of 23dynamics and machine learning techniques. Being able to separate and efficiently analyse sources of noise in this complex environment will lead to improved understanding of the local and global causes of fluctuations in ocean acoustics, and have potential impact in short- / long-term environmental planning and marine conservation. Gianluca is working in collaboration with the National Physical Laboratory (NPL).

Limit Theorems for generalised urn schemes - Chris Dean

Supervisors: Cécile Mailler, Sarah Penington

Generalised urn schemes are a classical discrete-time probabilistic model that describe the contents of an urn that contains balls of different colours. At each time step, a ball is chosen uniformly at random in the urn, and replaced into the urn together with a set of new balls whose number and colours depend on the colour of the selected ball and on a replacement rule, which is encoded in a matrix R. The cases of R being either the identity matrix or irreducible are well-studied in the literature and limiting theorems show how the composition of the urn behaves when time goes to infinity. In the case of the identity matrix, recent developments by Borovkov have been made on the convergence of the composition of the urn as the number of initial balls goes to infinity together with time; different behaviours have been observed, depending on the scaling of these two factors. Chris' project will begin by looking at Borovkov's results and see if similar results can be shown in the case when R is irreducible. Chris will generalise these results to infinitely-many-colour urns, which leads to the natural and interesting open problem of making the number of colours go to infinity together with time.

Developing efficient statistical tools for problems arising in spatio-temporal modelling - Josh Inoue

Supervisors: Matt Nunes, Sandipan Roy

When analysing spatio-temporal data in applications such as in environmental, ecological, or epidemiological settings, detecting abrupt changes over space and or time gives insight into the underlying mechanics of a system and can have a significant impact in the interpretation of the evolution and future state of the process. Alternatively identifying anomalies is of equal importance to not misinterpret trends in the data. The aims of the project include looking at methods that analyse spatio-temporal data and expand on these further, where gaps in the literature exist, developing a set of robust statistical tools to interpret these data sets. Josh also considers more complex situations potentially involving non-stationarity, missing or censored data, non-linearity and causality. In particular, considering how the space and time elements of the data interact, and when it is possible to detect change points or anomalies, how easily can they can be classified and if the stationarity is separable between the space and time elements.

Euler-Poincare equations for nonconservative action principles - Rosa Kowaleski

Supervisors: David Tsang, Karsten Matthies

The non-Hamiltonian action principle developed by Galley (2012), was developed to capture the dynamics of non-conservative systems by extremising an action with a doubling of the degrees of freedom. Such an action principle allows for the development of non-conservative classical field theories, including dissipative fluid dynamics. The Euler-Poincare equations are the analogue of the Lie-Poisson equations for a Lagrangian system. They are equivalent to the Euler-Lagrange equations for the action on the (infinite-dimensional) Lie group (and algebra) that describes the geodesic evolution of a system. Rosa's project focuses on developing the Euler-Poincare equations for the non-Hamiltonian action principle, in particular capturing the dissipative behaviour of a viscous fluid.

Localization of waves in random media with resonant inclusions - Yi Sheng Lim

Supervisors: Kirill Cherednichenko, Hendrik Weber

Consider waves travelling through a domain with two key features: (1) that it has numerous tiny regions of high contrast ("resonant inclusions"), and (2) a random landscape outside these microscopic inclusions. Physically, we may think of this media as a composite material with disorder; mathematically, a wave equation where the coefficients are very large at (1) and random at (2). The goal of Yi Sheng's project is then to show that waves are "caught" by the environment, with probability one. This is in contrast with the classical picture of waves travelling through a non-resonant and ordered environment (e.g. sound waves propagate through air over large distances). The fact that this is possible in a random environment is one of the most important discoveries of physics in the late fifties. However, a mathematically rigorous study of this "Anderson localisation" phenomena is only available for a few specific models, so work is far from complete. Considering the inclusions (1) and the disorder (2) separately, we also know that (1) has strikingly similar spectral properties to (2). Since the goal of proving that waves are localised may be formulated in terms of the spectrum, Yi Sheng asks if the resonant inclusions may "assist" in trapping waves. This will be made rigorous using multiscale analysis as the primary tool, accompanied by ideas from the theory of random operators.

Unifying different approaches for flood estimation - Piotr Morawiecki

Supervisors: Philippe Trinh, Paul Milewski

The development of accurate models for flood prediction is a key challenge in the modern era. Piotr's research is motivated by the inability of current methods to predict flooding in small catchments or areas with limited data. Currently used methods include physical, conceptual, and statistical models; often, the underlying assumptions within these approaches are not assessed and the model limitations are unknown. The aim of the PhD is to deeply understand the limitations of these flood models and sources of their inaccuracy. As a part of this analysis, an asymptotic framework is developed to provide scaling laws and analytical predictions over a range of scenarios. This analysis will allow a more direct comparison of the many disparate approaches used in industry. Finally, the project will seek the development of specific computational models that will better handle catchments for which the standard methods are inaccurate.

Stochastic Modelling of Migration and Proliferation of Melanoblast Neural Crest Cells in Mammals - Shahzeb Raja Noureen

Supervisors: Kit Yates, Tim Rogers

Piebaldism is a condition which occurs when an animal's fur, hair or skin lacks pigmentation in patches, typically at the ventral (front) side of the body, due to the absence of 17pigment-producing cells (melanocytes). The process responsible for this discolouration happens during the early stages of embryonic development. Early melanocyte precursors known as melanoblasts (one sub-type of a whole family of cells of developmental origin known as neural crest cells) which originate towards the dorsal (back) end of the embryo are responsible for giving the skin its colour. During the development of the embryo, these cells travel from the back towards the front of the body and as they do so, they divide to create daughter cells which themselves can migrate and divide. Research suggests that a piebald phenotype in mice is a result of the melanoblast neural crests cells failing to reach the dorsal epidermis (front region of the skin). It was originally assumed that this happens due to slow diffusion of melanoblasts but recent evidence suggests that in fact, the reason is the slower proliferation of these cells rather than the decreased rate of migration. The slow proliferation has been linked to mutations in the kit gene. Other types of neural crests cells are responsible for other essential developmental processes in mammals and erroneous proliferation or migration in these cells can result in developmental defects such as deafness, heart problems and even cancer. Shahzeb is exploring the proliferation and movement of the melanoblast neural crest cells using agent-based methods, both on- and off-lattice and on a uniformly growing domain. He aims to develop multistage models that can relate the cell-cycle stages to other migratory parameters and generate more realistic cell-cycle time distributions. The multistage models, developed on- and off-lattice, will allow him to examine the effects of relatedness between cells and build models where individual cell properties are inherited by daughter cells. He is investigating the importance of distinct melanoblast sub-populations during epidermal colonisation and develop methods of modelling clonal behaviour.

Fluid dynamical analysis of drops on fluid baths - Kat Phillips

Supervisors: Paul Milewski, Jonathan Evans

When a small droplet impacts on a bath of the same fluid it usually coalesces. In certain regimes, however, a thin layer of air remains between the droplet and the bath acting as a barrier, and as such it is possible for the droplet to be propelled upwards due to the restorative capillary force of the bath, before this air layer is depleted. If the bath is vibrated at a suitable vibration frequency, this rebounding mechanism can repeat periodically causing the droplet to bounce indefinitely off the surface of the bath. In addition, for a vibrating bath, Faraday waves are generated radiating outwards from the impact site on the surface of the bath. As the vibration amplitude is increased, the rebounds are higher and the resulting Faraday waves increase in amplitude, eventually destabilising the droplet causing it to ‘walk’ across the surface of the bath. These phenomena provide motivation for the problem at hand, as the main topic of study will be the role of the lubrication air layer that allows for this droplet, and also similar solid-fluid impacts at the capillary scale, to exhibit rebound. Using a combination of theoretical and numerical methods we aim to elucidate the phenomena of such bouncing droplets.

Computational Optimal Transport - Fengpei Wang

Supervisors: Clarice Poon, Tony Shardlow

Optimal transport seeks the best way of transforming one probability distribution into another. It provides a natural, elegant framework for comparing probability distributions while respecting the underlying geometry. Within machine learning and related fields, optimal transport distances (in particular the Wasserstein metric) have found successful application in things like image registration and interpolation and adversarial neural networks. However, computing optimal transport distances between arbitrary (i.e. not necessarily discrete) probability distributions remains a challenging problem. Fengpei is studying the use of the Sinkhorn algorithm for computing the optimal transport between continuous measures, given point samples. She is interested to explore how to combine optimal transport with several different methods. These include stochastic algorithms and acceleration techniques by screening out variables.

Hybrid numerical-asymptotic analysis of snaking bifurcations - Edwin Watson-Miller

Supervisors: Philippe Trinh, Jonathan Dawes

There is a great deal of interest in nonlinear differential and difference equations that exhibit homoclinic snaking, in which solution curves of localised patterns 'snake' back and forth across a bifurcation diagram in a narrow region of parameter space. These snaking bifurcations arise in many experimental and theoretical contexts, including optics, convection, ferrofluids, Couette flow, buckling problems, neuroscience, and so forth. In recent years, a methodology using beyond-all-orders asymptotics has been developed to describe snaking bifurcations. However, this approach has not yet enjoyed wide adoption on account of the significant technical theory and machinery required. Edwin is making this more accessible by using numerical methods to replace certain analytical steps. This would also enable generalising this method to systems where we cannot solve these steps analytically, as opposed to basic 1D systems and Edwin is generalising the beyond-all-orders analysis to systems with non-smooth nonlinearities.

Stochastic active flows - Jeremy Worsfold

Supervisors: Tim Rogers, Paul Milewski

Mathematical models of fluids have been used very successfully to explain the behaviour of a wide range of systems beyond the liquid flows that inspired their initial development. For example, they have been used to describe the formation of traffic jams and the collective behaviour of large animal groups. However, these models typically take a purely macroscopic approach to explain these phenomena. This class of PDE-based models does not capture the effects of noise-induced fluctuations arising from finite size effects in 'fluids' composed of discrete moving agents. Jeremy's research seeks to explicitly link microscopic simulation-based models of interacting agents with macroscopic fluid models, enabling an analysis of the effects of noise induced by finite size effects.

The role of precursors of active regions in space weather forecasting: reliably predicting CMEs and SEPs before their occurrence with the help of machine learning - Tina Zhou

Supervisors: Chris Budd, Apala Majumdar, Silvia Gazzola and Tom Fincham Haines

The Met Office produces real-time operational space weather forecasts: severe space weather has appeared on the UK National Risk Register since 2011. Space weather can have major impacts on UK and international critical infrastructure (e.g. the electricity grid, satellites, aviation, Global Navigation Satellite System (GNSS) positioning, navigation and timing, radio communications) and on human health. The Met Office is constantly striving to produce improved space weather forecasts to meet their customers' needs, but this can be very challenging. The difficulty of solar weather forecasting is due to the uncertainty of solar movement and speed of arrival of an observed event (a few minutes or up to a few days before arrival on Earth). The focus of this project is to develop improved solar weather modelling forecasts based on the analysis of solar and near-Earth space observation data. New data from the spacecraft Parker will be available for research and there is no doubt that Parker can introduce many new results. Part of the approach will use machine learning to train proper models for better forecasting results. Additionally there is the possibility of combining methodologies in applicable probability, statistics theories and methods (for example time series analysis, Markov process and Bayesian simulations) and maths modelling methods in areas of numerical PDEs or stochastic PDEs. Most of those aspects are new and based on several recent technology break-troughs. The output of this project is to establish new methods in tracking space weather forecasts and seek new conclusions from observations by those new technologies.

The effects of climate variation on cocoa farming in Ghana - Oluwatosin Babasola

Supervisor: Chris Budd

Cocoa farming in Ghana is affected by a number of different factors including climate variation. These lead to uncertainties in planning for the future, both in the short term (seeding and harvesting) and in the long term (allocation of land use). The planning process can be helped by the construction of appropriate mathematical models and linking these to data on climate variation. Tosin's project involves constructing such models and comparing them with data on cocoa production and local climate variation. The initial work will look at delay differential models for crop production linked to sun and rainfall prediction.

Monte Carlo Methods for Particle Systems and the Neutron Transport Equation - Tom Davis

Supervisors: Alex Cox and Andreas Kyprianou

The flux of neutrons in a nuclear reactor has traditionally been modelled and understood using deterministic numerical methods. Recent probabilistic treatments have justified the use of stochastic processes to model neutron flux; Monte Carlo methods can then be used to simulate these processes. However, different Monte Carlo estimators suffer from various pitfalls: some techniques have a high per-iteration cost and are very difficult to parallelise, while other estimators have lower cost per individual simulation but an unacceptably high variance. Tom's research project will investigate ways in which the neutron particle system may be simulated, using Monte Carlo algorithms which are both efficient and amenable to parallelisation. He also hopes to establish convergence, and other theoretical properties, of the resulting algorithms.

Hybrid methods for modelling the cell-division cycle - Josh C. Kynaston

Supervisor: Kit Yates

Biological systems exhibit a tremendously wide variety of behaviours at many different spatial scales. While in theory, the behaviour of a system at any scale can be viewed as emergent from the behaviour of its smallest components, deriving these scale relationships is analytically intractable except in only very carefully constructed examples. Numerical methods based purely on a system's microscopic behaviour can quickly become cost-prohibitive as the number of atomic components of a system increases. To achieve computational feasibility, different modelling regimes are used at different scales, though at the cost of information loss when using coarser representations. Josh's work is concerned with hybrid methods, which combine multiple regimes to balance the advantages and disadvantages of each. In particular, he aims to construct a hybrid method based on a model of the cell-division cycle as a reaction-diffusion system, building upon previous hybrid methods such as the pseudo-compartment method.

Statistical applied mathematics for air quality prediction - Laura Oporto

Supervisors: Paul Milewski, Theresa Smith and Gerhard Schagerl

Laura's project involves determining the impact of traffic on local air quality and distinguishing the different sources of pollution. Her project is in collaboration with AVL. Local air quality management can be complex due to the different emission sources such as transport, buildings, industry and more. Also weather conditions, local topography and emissions from distant places may influence pollutant transport and amplify pollution in certain locations. Her project has three main parts: a deterministic approach, where she's looking at a fluid and chemical modelling to predict pollutant concentrations; a statistical model to analyse data from pollution and traffic monitors; and methods combining these two to calibrate parameters, improve the accuracy of the model, and extend prediction horizons.

Prediction of Biological Meta-Data using DNA Sequences - Jordan Taylor

Supervisors: Sandipan Roy, Matt Nunes and Lauren Cowley

A human base-paired DNA sequence is approximately 3 million letters in length and consists of the letters "G", "A", "T", and "C". With the multitude of different combinations, it is of interest to find whether, given a subset of much smaller sub-sequences, one can infer that an individual caught some bacteria from a particular country or any other associated meta-data. The bacteria of interest initially include Shiga Toxigenic Escherichia coli and Salmonella. Though machine learning methods have shown recently to provide state-of-theart results in many domain areas in high dimensional space, many of the methods are seen as "black boxes" with little interpretability. Jordan is investigating explainable machine learning and statistical methods in context of both prediction and ranking of the significance of the sub-sequences.

Antagonistic coevolution in multi-species interactions - Jason Wood

Supervisors: Ben Ashby and Nick Priest

Jason's initial aim is to create models for the coevolutionary dynamics of hosts and parasites are changed by the addition of a hyperparasite. These are two subsets of host-parasite-hyperparasite systems, which are often found in nature (e.g. viruses which infect bacteria, hyperparasitic fungi) and which can have medical or industrial applications, for instance phage therapy. This work will then be extended to focus on vector-borne diseases.

10.2 Past projects

Application of moving mesh methods for the solution of partial differential equations - Simone Appella

Supervisor(s): Chris Budd, Tristan Pryer

Numerical Weather prediction is an essential component to weather forecasting and climate modelling. It is based on the design of accurate and efficient numerical schemes to simulate the motion of ocean and atmosphere. In such context, explicit numerical methods have to satisfy the CFL condition, which imposes a strict time step restriction, in order to be stable. To overcome this limit, the Met Office is currently adopting the Semi-Implicit, Semi-Lagrangian method (SISL), which permits the use of larger time steps without stability issues. However, many global meteorological phenomena of relevance (storms, tsunami) occur on a scale smaller than 25km, that cannot be efficiently resolved by SISL with an uniform grid. A natural way to fix this is to cluster the mesh points in proximity of small features evolving in time. Such adaptive methods, though, are inefficient to use because are either unstable or require small time steps. This issue can be avoided by coupling them with a SISL method. Simone will investigate the adaptive SISL scheme applied on the Shallow Water system, that models the shallow atmosphere. He will start to examine the accuracy and stability of this method in the 1D case. This will be then extended to 2/3 dimensions based on the optimal transport moving mesh strategy.

Design principles for active solids – Guido Baardink

Supervisor: Anton Souslov

Metamaterials are designed materials whose microscopic geometry is carefully engineered to achieve macroscopic properties not readily found in nature. Guido's research focuses on mechanical metamaterials, modelled as large ball-spring networks, and aims to find general design principles for modifying the geometry and topology of the network to attain a variety of unusual mechanical responses. In particular, he is interested in how introducing active mechanical components (e.g., motors that inject energy) into the network can lead to novel materials for applications in such areas as shock absorption and mechanical actuation.

Inclusion of prevalent cohorts to study the causal impact of Systemic Sclerosis on cancer- Eleanor Barry

Supervisors: Anita McGrogan and Jonathan Bartlett

Systemic sclerosis (SSc), or scleroderma, is a long-term condition that causes thickening and hardening of the skin due to a build-up of collagen. SSc can also affect internal organs such as the kidneys, heart, lungs and gastrointestinal tract. It is believed that there is a possible link between SSc and other serious health conditions, and Barry’s Ph.D. explores the association between SSc and the occurrence of serious outcomes compared to people who do not have SSc. Working with the Department of Pharmacy and Pharmacology, she is focusing on statistical techniques used to minimise errors when estimating effects of SSc on occurrence of cancer.

[Accessibility Percolation and Evolutionary Dynamics in Varying Environments]() - Thomas Bartos

Supervisors: Marcel Ortgiese and Tiffany Taylor

The fitness landscape concept originates in evolutionary biology as a metaphor to describe adaptive pathways taken by populations, where fitness is thought of as a height above a multidimensional genotypic space. Such landscapes can be modelled by representing the genotype space as a finite graph and the fitness function as a random vector associated to the vertices of the graph. Researchers have recently made progress in understanding the statistical properties of the number of so-called ‘accessible paths’ - sequences of adjacent vertices of increasing fitness. Thomas is studying how the accessibility properties of a graph are affected by a time-varying fitness function. The first case is where the fitness values are re-sampled according to a Markov chain; to analyse this he is adapting methods from first-passage percolation and dynamic percolation theory. Other situations to be considered include continuously changing landscapes and pairs of interacting landscapes. The aim is also to use the theoretical results obtained to explain the observed patterns of evolution of flagella in a recent experimental study of particular bacterial strains under varying selective pressures.

Efficient elliptic solvers for higher order DG discretisations on modern architectures and applications in atmospheric modelling - Jack Betteridge

Supervisors: Eike Müller and Ivan Graham

One technique for solving partial differential equations numerically is by using the Discontinuous Galerkin (DG) method. This method has high spatial locality, which improves the parallel scalability and can take greater advantage of modern (many core) high performance computing architectures. A hybrid multigrid approach has already been successfully used for elliptic PDEs arising from subsurface flow. Similar methods can also be applied to atmospheric modelling problems, for instance solving the Navier-Stokes equations in a thin spherical shell. Over the course of the project, Jack looked at the computational and algorithmic aspects of implementing a solver for these atmospheric models and the various different pre-conditioners to speed up the solution.

Control of soil transmitted helmiths - Quinn Boulton

Supervisor: Jane White

Macro-parasites cause a variety of diseases throughout the world, including many neglected tropical diseases. When considering mathematical models of macro-parasitic diseases, the SIS models so often used when modelling the spread of bacterial or viral diseases do not capture some of the crucial ways in which macro-parasitic diseases differ. By considering a combination of ODE models, probabilistic and, hybrid models, Quinn attempted to formulate mathematical models which captured the dynamics of host-parasite relationships and macroparasitic infections and then used these to research how best to optimise the treatment of macro-parasitic infections in both people and animals.

Attribution of large-scale drivers for environmental change - Aoibheann Brady

Supervisors: Ilaria Prosdocimi and Julian Faraway

Several large flood events have hit the UK in recent years, and there is a growing concern among the public opinion and policy makers on whether the current level of protection of cities and infrastructure is appropriate. In particular, there is a concern that climate change and its impacts might result in increased flood risks: climate change projections seem to indicate that flooding risk might increase, but this is not fully validated by the observed river flow data, for which there is no strong evidence of increasing trends. Further, due to the short period of river flow record, the testing methods routinely used to assess whether change can be detected in observed data are typically not very powerful (in a statistical sense) and cannot fully differentiate between possible confounders. Aoibheann developed methods to detect and attribute changes in flooding and other environmental variables. This resulted in methods for the detection of spatially coherent trends in environmental data. The project also investigated methods to make an assessment on the main drivers of higher river flows and flooding at a regional or national scale.

Stochastic analysis, rough paths, and conservation laws - Stefano Bruno

Supervisors: Hendrik Weber and Tony Shardlow

Stefano’s project aimed to further the stochastic analysis of the stochastic PDE known as Dean’s equation. This is an example of a stochastic conservation law, which is significantly challenging because of a square-root term in the noise coefficient, which is non-Lipschitz and requires non-negative arguments. The divergence operator is also applied to the noise, leading to poor regularity and making it difficult for classical solution methods. Stefano looked at recent developments in the theory of stochastic conservation laws, using the kinetic formulation and using ideas from rough-path theory, and applied these ideas to Dean’s equation.

Joint modelling of longitudinal and time-to-event data applied to group sequential trials - Abigail Burdon

Supervisors: Chris Jennison and Lisa Hampson

Clinical trials are composed of four stages, each of which has a different primary aim. This project focused on Phase 3; the drug is already deemed safe, the dosage decided and the focus being efficacy and futility. The development of pharmaceuticals and medicines across all phases relies heavily on statistical methodology and accuracy, with Phase 3 summarised by a single hypothesis test for the difference in size of treatment effects. Patient safety and well-being are central to the design process. Abigail’s project considered group sequential trials, a mechanism introducing interim analyses and allowing for a trial to be stopped early for either efficacy or futility. The aspiration is that overall, less patients receive the less effective drug. For the analysis of clinical trials, a primary endpoint must be specified, this is the measurement of interest that is affected by the drug; for example this project focuses on survival or time-to-event as the primary endpoint. There has also been copious recent research on ”biomarkers” which are underlying processes in the body that may be predictive or informative of the primary endpoint. Working with Novartis, Abigail researched a joint model for the two processes and investigated the gain to be made when biomarkers are included in a group sequential trial due to the increase in information.

On-line drill system parameter estimation and hazardous event detection - Dan Burrows

Supervisors: Kari Heine, Mark Opmeer and Inês Cecilio

Dan’s research, in collaboration with Schlumberger, develops statistical methods for automatic detection of hazardous events in oil and gas drilling operations. Initially, only two particular hazardous events are considered. The first is called washout and it means the appearance of a hole in the drill pipe which may compromise the safety and efficiency of the operation as well as equipment integrity. The second event is called mud loss and it means the loss of drill fluid due to a leakage in the drill system to the surrounding rock formation. As the project progresses, more complex scenarios will be considered, involving multiphase flow, influx of gas from the formation, accumulation of rock cuttings around the drill pipe, wear of the drill bit, plugged bit nozzles, or the degradation of the motor. The initially one dimensional model could also be extended to two or three dimensions for increased accuracy.

Branching systems and spatial fragmentations - Alice Callegaro

Supervisors: Matt Roberts and Marcel Ortgiese

Fragmentation, the breaking up of large structures into smaller pieces, occurs naturally in many situations, from earthquakes to hard drives. The mathematical definition of a fragmentation process involves an object that breaks up at random into smaller pieces, which then break up themselves, and so on; but with the rule that the way in which a piece breaks up must depend only on its size. This condition is a huge simplification which allows rigorous study, but prevents traditional mathematical models from accurately representing the vast array of real-life possibilities. In her Ph.D., Alice focused on spatial fragmentations, in which the speed at which pieces fragment depends on their shape in a non-trivial way.

Modelling regularization, and analysis of Dean-Kawasaki type equations - Federico Cornalba

Supervisors: Johannes Zimmer and Tony Shardlow

Nucleation is a physical process, important in fields as diverse as physics, chemistry and biology. Nucleation is, broadly speaking, the process with which a material undergoes the formation of new thermodynamic phases via self-assembly. The mathematical description of this process is comprised of several different relevant features. In his Ph.D., Federico focused on some aspects of the Dean-Kawasaki stochastic model, arising from the fluctuating hydrodynamics theory. Of this model, Federico he was primarily investigating the underlying mathematical geometry, the transition rates analysis in the context of metastability, sought a description of the nucleation pathways.

Mathematical modelling of formulation composition trade-offs for pesticides - Jenny Delos Reyes

Supervisors: Jane White, Begona Delgado-Charro and Josh Fernandes

Creating validated mathematical models that can inform the process of risk assessment during pesticide product development is an industry-wide aspiration. It is particularly challenging given the wide range of formulations that may be used to produce new pesticides and the complexity of developing products that have good foliar uptake but poor dermal absorption. Working with Syngenta, Jenny is developing and analysing a series of spatially explicit mathematical models for membrane penetration parameterised using existing data sets. The impact of formulation products is explored in relation to their physicochemical properties in an attempt to categorise formulation impact across the two membranes. The models will subsequently be combined and analysed within a novel optimisation framework which should highlight the key parameter groupings responsible for good foliar uptake and poor dermal absorption based on existing data sets.

Generative Models Applied to Inverse Problems - Margaret Duff

Supervisors: Matthias Ehrhardt and Neill Campbell

An inverse problem is the process of calculating from a set of observations, the data, the causal factors that produced them, the model parameters. Inverse problems that are interesting are nearly always ill-posed, meaning that small errors in the data may lead to large errors in the model parameter and there are several possible model parameter values that are consistent with the observations. Addressing this ill-posedness is critical in applications where decision making is based on the recovered model parameter, such as for medical imaging. Medical images remain the gold standard for diagnostics of many conditions. However, analysis of medical images raises fundamental issues with the standard “deep learning” approach of training a multi-layer neural network on hundreds of thousands of images. Such algorithms cannot accurately quantify their uncertainty, nor describe the reasoning that led to a given classification for an image. Generative models provide a promising avenue to solve the aforementioned problems. They implicitly model high-dimensional distributions of data from noisy indirect observations. From this, new samples from the distribution could be generated and estimators calculated. However, in pushing the boundaries of computer science, fundamental mathematics has somewhat been left behind and this threatens the ability to exploit the many applications of these methods. Margaret’s project aims to fill some of these mathematical gaps.

Accelerating Bayesian sampling in uncertainty quantification - Gianluca Detommaso
Supervisor: Rob Scheichl

Gianluca's research brought together techniques from statistics, numerical analysis and applied mathematics to accelerate Bayesian sampling. In particular, he dealt with computationally expensive high-dimensional problems, trying to beat down the cost per iteration and performing algorithms that scale well in high-dimension. Gianluca developed interactions among different research fields, bringing together knowledge and experimenting with new ideas. He also tried out new potential sampling accelerations. His research involved multilevel methods, MCMC algorithms, transport maps and Bayesian inverse problems.

Accelerating Bayesian inference with physics-governed likelihoods using deep learning- Teo Deveney
Supervisors: Tony Shardlow and Eike Müller

Statistical machine learning and neural network methodologies have seen significant development in recent years with the advent of faster computation and the discovery of efficient optimisation algorithms. Methods based on such techniques have provided state-of-the-art 26results in many high dimensional data tasks, such as image and speech recognition, artificial intelligence, and more recently, in applied mathematics problems. This project leveraged developments in machine learning to improve methodologies for stochastic differential equations, with particular attention paid to applications in contaminant dispersal. Teo investigated how deep learning and Bayesian methods can be used to solve a range of problems in this area, such as inferring appropriate PDE and SDE models from contaminant dispersal data, and efficiently approximating solutions to the high dimensional Fokker-Planck equations associate with current models.

Optimising Seismic Imaging via Bilevel Learning: Theory and Algorithms - Shaunagh Downing
Supervisors: Ivan Graham, Euan Spence and Evren Yarman

Shaunagh's project, in collaboration with industrial partner Schlumberger, concerned the numerical analysis of wave propagation problems and applications to marine seismic exploration. As part of the seismic exploration process, acoustic waves are emitted from a source into the earth. These waves are then reflected from the subsurface and measured by sensors. The relationship between the earth's subsurface and the measurements are mathematically modelled by partial differential equations (PDEs). Given the measurements, the properties of the subsurface can be inferred from the numerical solution of these PDEs to obtain a detailed image of the subsurface. This is then used to select and drill exploration and production wells. In seismic exploration, a problem of great practical interest is that of optimal sensor placement and this project explores how, if given prior information about the likely make-up of the subsurface (in the form of a class of generic models), the location of the sensors can be optimised to retrieve sufficient information about the subsurface.

Spatial smoothing in statistical regression models - Emiko Dupont

Supervisor: Nicole Augustin

Spatial regression models are commonly used in applied statistics to model data collected at different spatial locations. Such models use spatial random effects to account for residual spatial correlation in the response variable and result in fitted values that are, to some degree, smoothed across the spatial domain of the data. The main focus of this thesis is a problem known as spatial confounding, which causes covariate effect estimates in spatial models to be unreliable. By investigating the estimation theory in a commonly used spatial model formulation based on thin plate splines, we gain a deeper understanding of the problem and the existing methodology. Using this, we develop a novel and easily implementable method for avoiding spatial confounding in practice. Moreover, we include some initial analysis on spatial confounding in models with non-linear covariate effects; an area that has not yet been explored in the literature. The thesis also contains another project within the field of spatial statistics. Here, spatial modelling techniques are used to develop a method for detecting spatially coherent trends in environmental time series data. Specifically, we model river flow data from gauging stations across Great Britain. Using our methodology, we are able to verify, for the first time, a significant upward trend in flood risk over time and identify the regions with the largest trends.

Faraday wave-droplet dynamics: a hydrodynamic quantum analogue - Matt Durey

Supervisor: Paul Milewski

It has been observed on a microscopic scale that when a small fluid droplet is dropped onto a vertically vibrating fluid surface, it will ‘walk’ across the surface of the bath. The droplet-Faraday pilot wave pair’s behaviour is now reminiscent of quantum physics; there is a particle-wave duality where the fluid droplet can undergo similar processes to a particle in the quantum world. On an unbounded domain, pairs of droplets can interact, deflect or capture each other, depending on various parameters. The quantum single-particle double-slit experiment can be reproduced for fluid droplets, with the interactions between wave field and slits causing a diffraction probability distribution for droplet positions to be produced. This phenomenon was the basis for two lines of research that was explored by Matt: (i) The fluid dynamics of droplet-Faraday pilot wave reflection properties at planar boundaries. (ii) The long time stationary behaviour of models for droplet-Faraday pilot wave dynamics in confined domains.

SDEs for embedded successful genealogies - Dorka Fekete

Supervisor: Andreas Kyprianou

Dorka used the mathematical medium of stochastic differential equations (SDEs) to describe the fitness of certain sub-populations in an asexual high-density stochastic population model known as a continuous-state branching process. In particular, she looked at ways to describe genealogies that propagate prolific traits in surviving populations, where ‘survival’ can be interpreted in different ways. For example, it can mean survival beyond a certain time horizon, but it can also mean survival according to some spatial criteria.

Interacting particle systems on dynamic and scale-free networks - John Fernley

Supervisors: Marcel Ortgiese and Peter Mörters

Similarly to the Contact Process, voting models describe competing spread of two ‘opinions’ on a graph of interacting ‘voters’. Cooper et al. in their 2016 paper ‘discordant voting processes on finite graphs’, explored the expected consensus time for a variety of voting models on extremal graphs. These discordant voting models could be seen as a bridge between the classical voter model and the Graph Fission evolving voter model of Durrett. John was interested in finding a universal description of the model’s lifetime on scale-free heterogeneous networks, in particular with Chung-Lu type edge models. These models can then be made to evolve in time by vertex updating, and his next objective would be to show that this speeds consensus.

Topics in random growth models - Tom Finn

Supervisor: Alexandre Stauffer

Multi-particle diffusion limited aggregation (MDLA) was formulated as a tractable model for dendritic growth. Unfortunately, geometric and dynamic properties of it have evaded a strong mathematical treatment for decades and understanding the behaviour of MDLA remains an open challenge. For example, under certain parameters MDLA may observe some limiting shape at macroscopic scales, but at the mesoscopic and microscopic scales will have complex and fractal-like structure. A competition model called ’first passage percolation in a hostile environment’ (FPPHE) has been successfully coupled with MDLA to show a phase of linear growth exists. Tom’s project investigated these links further and attempted to prove stronger results for FPPHE, such as the existence of a ’co-existence’ phase between the competing growth processes. The project also aimed to understand variants of MDLA better, such as 24a Poissonized version of MDLA, whereby there is initially a Poisson cloud of particles, and each particle performs a random walk until aggregated. In one dimension the critical value for the initial density is 1 for linear growth, but in higher dimensions it is conjectured to be 0, and this project aims to prove this and related results.

Bayesian inference for low-resolution Nuclear Magnetic Resonance in porous media - Michele Firmo

Supervisors: Silvia Gazzola, Tony Shardlow and Edmund Fordham

Nuclear Magnetic Resonance is used to infer properties of porous media, such as rocks, through which oil can be extracted. Michele’s research project aims to surpass the current standard inference methodology by providing uncertainty estimates alongside state estimates in an efficient manner and to develop the technique for shales. Working with Schlumberger, this will be achieved through reformulating the problem in a Bayesian framework and applying tools from numerical linear algebra.

A conditional Gaussian process model for molecular property prediction and chemical discovery - Arron Gosnell

Supervisors: Evangelos Evangelou and Kostas Papachristos

Typically, thousands of potential herbicides will undergo a sequence of screening tests (assay tests) in the lab. Each time ineffective compounds will be discarded and those remaining are assessed against a more complex set of criteria, with the final few undergoing rigorous field trials. Evidently, the data from the early trials will exhibit high uncertainty and subjectivity. In most applications, a herbicide is assessed against a range of criteria. Therefore, a method to combine multiple criteria according to their significance for scoring each herbicide is required. Arron's research involved creating a model to predict the herbicide's performance on each test using information such as dosage, plant species, and the chemical's structure which can be presented as a graph. Modern regression methods such as support vector regression, neural networks, and Gaussian process regression were employed to exploit the relationships between plant species and families of chemicals in order to improve predictive performance.

Asymptotic and Numerical Analysis of Wave Propagation in Thin-Structure Waveguides - Will Graham

Supervisors: Kirill Cherednichenko and David Bird

Optical fibres are widely used in telecommunications systems across the world. Photonic crystal fibres are a relatively new development, as they have the potential to provide all of the same service (but better) and more uses than conventional optical fibres. This is because photonic crystal fibres have microstructure at the same length-scale as the wavelength of the light passed through it, which allows for the light to be controlled in more ways. Will analysed periodic "thin-structure" problems that describe the propagation of light through photonic crystal fibres: understanding the spectrum of these problems and their effective "limit problems" can better inform the design or use of such fibres.

Design utility methods for preferentially-sampled spatial data - Elizabeth Gray

Supervisor: Evangelos Evangelou

Spatial preferential sampling occurs when the choice of sampling locations at which a spatial process of interest is measured is stochastically dependent on the values of this process. Ignoring such a sampling scheme when mapping the spatial process leads to inaccurate predictions, particularly at locations further from the sampling sites. This may be dealt with by jointly modelling the sampling process with the spatial process. Existing methods for this require that the sampling locations be independent of one another. In this thesis we dispense with such an unrealistic requirement and model the sampling process as a whole. This is achieved by defining a whole-design utility function over the space of possible sampling designs to assign a 'usefulness' to each design based on a set of possible experimenter preferences and some (unknown) strength of preference parameters.

Raising the Roof: Extension of the Met Office's Unified Model into the Mesosphere and Lower Thermosphere - Matthew Griffith

Supervisors: Chris Budd, Nick Mitchell, David Jackson, John Thuburn

Forecasting weather in the lower thermosphere (85 – 120 km) is of particular interest due to its impact on spacecraft re-entry and radio communications. To this end, Matthew was extending the current 85 km upper boundary on the Met Office's Unified Model (UM) to a height of around 120 km. Thus, he was raising the roof on current numerical weather prediction and paving the way for the development of a coupled whole atmosphere model. In particular, the work focused on including the correct physical processes in the high atmosphere. This included accurately depicting the reversal of the mesospheric zonal jets, forced by gravity waves (GWs). In order to do this, tuning of the GW forcing schemes was required, which is performed by a comparison with radar and satellite data collected by the Department of Electronic & Electrical Engineering.

Euclidean field theories in 3D: nonlinear wave equations and phase transitions – Trishen Gunaratnam

Supervisor: Hendrik Weber

Reservoir Computing with Dynamical Systems - Allen Hart

Supervisor: Jonathan Dawes

Allen studied how well a particular recurrent neural network architecture called the Echo State Network (ESN) can approximate dynamical systems, predicting their future behaviour as well as inferring their topological features. Allen aimed to use ideas from Takens' Embedding Theorem to prove that an ESN trained on a time series of low dimensional observations of a high dimensional dynamical system can learn the topology of the high dimensional system. Having learned the topology to some level of precision, the ideas from the Universal Approximation Theorem could be deployed to prove that a sufficiently large ESN trained on sufficiently many data can predict the future dynamics of a system arbitrarily well. Numerical experiments will also provide some intuition about how well practical ESNs perform on example dynamical systems like the Lorenz, or Mackey-Glass systems.

Stochastic analysis of the neutron transport equation - Emma Horton

Supervisors: Andreas Kyprianou, Alex Cox and Paul Smith

The neutron transport equation (NTE) is a balance equation that describes the flux of neutrons in inhomogeneous fissile mediums such as nuclear reactors. Working in collaboration with Wood plc, Emma modelled nuclear fission reactions via the probabilistic theory of Markov branching processes in order to both unify existing theory and develop new theoretical and numerical techniques that allowed her to study these processes in full generality. In particular, Emma worked to prove the existence of the leading eigenvalue and its corresponding eigenfunction, allowing her to study the limiting behaviour of the system of particles in different regimes. The methods developed allow for more efficient simulations of these processes, providing a greater depth of understanding of such systems for the purpose of safety and optimal reactor design.

Asymptotics beyond-all-orders in wave-structure interactions - Yyanis Johnson-Llambias

Supervisors: Philippe Trinh and Paul Milewski

Despite significant advances in computational hardware and numerical algorithms, the simulation of fully nonlinear three-dimensional free-surface flows around blunt-bodied objects remains particularly limited. On account of the processing power required, most modern desktop (and in some cases high-performance) computations still require the use of simplifying geometrical assumptions and coarse meshes on the order of a hundred points per spatial dimension. In contrast, numerical simulations of comparable two-dimensional flows can be routinely done with O(1000) grid points in the spatial dimension. There continues to be a need for the analytical theories that can provide explicit asymptotic descriptions of the flow properties, particularly for the use of efficient hybrid numerical-analytical approaches. Recently, there has been success in developing new asymptotic techniques for studying linear wave-structure flows in three-dimensions. These techniques are based on the use of exponential asymptotics applied to low-speed hydrodynamical flows. Yyanis's research develops new analytical and numerical techniques related to the area of complex ray theory and asymptotic analysis, to extend these ideas to nonlinear problems.

Variational structures for dynamical fluctuations, in and out of equilibrium - Marcus Kaiser

Supervisors: Johannes Zimmer and Rob Jack

Marcus studied the geometric properties of interacting particle systems and their hydrodynamic scaling limits described by non-linear partial differential equations, such as drift diffusive systems. He looked at processes that can serve as prototypes for non-equilibrium behaviour, having underlying descriptions as irreversible Markov chains. A better understanding of the geometric behaviour and the links between the microscopic and macroscopic models yields new insights, such as the way processes converge to equilibrium.

Bayesian Analysis of Spatial Log-Gaussian Cox Processes - Nadeen Khaleel

Supervisor: Theresa Smith

Point patterns, specifically spatial and spatio-temporal point patterns, occur frequently in the environment sciences and epidemiology. These phenomena are possible to model using point processes from which it is possible to learn about any spatial relationships that cause the point pattern observed as well as stochastic dependence between points in the pattern. In particular, Cox processes (or "doubly stochastic" processes) are practical models when the point pattern is clustering due to environmental heterogeneity that is stochastic. Nadeen worked on computational methods for a particular type of Cox process, log-Gaussian Cox processes where she explored the development of efficient MCMC techniques for fitting large scale spatio-temporal point patterns and compared the effects of predictors in different regions.

Scale-bridging of fast-slow systems in a thermodynamical setting - Matthias Klar

Supervisors: Johannes Zimmer and Karsten Matthies

Matthias studied systems with multiple time scales, so-called fast-slow systems. One aim was to derive effective large-scale descriptions of such systems, by 'averaging out' the fast scale. Thermodynamic systems are prototypical examples of systems with such a separation of time scales, and the aim of this project was to advance averaging methods for thermodynamic models.

Detection of underwater acoustic events in a large dataset with machine learning - Amélie Klein

Supervisors: Philippe Blondel and Kari Heine

Acoustic remote sensing listens to ambient noise underwater and uses it to recognise the sources of the sounds (e.g. marine life, human activities, weather). Passive sensors acquire data at very high rates (up to a million samples/second) for long periods (up to several years). In this project, Amélie is working on automating the processing and exploration of the large dataset using machine learning techniques and high-performance computing system. The project aims to detect long-term trends, like the increase in shipping or seasonal variations in marine life, and transient events, loud sounds associated to seismic prospection, vocalisations by animals (e.g. whales or dolphins), or small-scale weather observations. The key research questions are in the processing and analysing the vast amounts of continuous data and in deciding the best time scale to look at specific processes.

Stochastic Mathematical Biology in Ecology and Evolution - Yvonne Krumbeck

Supervisors: Tim Rogers, Ben Ashby, George Constable (York University)

In this research we describe population dynamics in ecosystems and evolutionary processes through the lens of stochastic mathematical biology and develop methods to analyse phenomena that emerge from fluctuations and uncertainty. In particular, we model the dynamics of large random ecosystems in terms of randomly distributed interaction parameters and derive solutions for the power spectral density of this stochastic process based on statistical properties of the underlying interaction network. Furthermore, we investigate the evolution of mating types in isogamous species, where the number of compatible mating types for sexual reproduction is not necessarily limited to two. Unlike in a model with neutral mutations, we find that fitness differences damp the growth of the average number of mating types and derive predictions independent of the underlying fitness distribution. This research opens up further questions on how fluctuations in ecosystems affect the evolutionary dynamics of embedded species.

Random walks in changing environments - Andrea Lelli

Supervisor: Alexandre Stauffer

Random walks in random environments have become a classical model for random motion in random media, and this model has been the source of many mathematical investigations over the years. More recently, people started to look at random walks in an environment which changes at the same time that the particle is moving. It is believed that when the environment is 'well behaved' (e.g. uniformly elliptic) and changes quickly enough, the random walk will behave in a way that is similar to a random walk on the underlying (non-changing) graph. This has been quantified, especially in the case of the d-dimensional infinite lattice, by the derivation of a law of large numbers and central limit theorems under some conditions related to the mixing time of the environment. Andrea was interested in understanding the effect of a slowly changing environment on the behaviour of simple random walks, e.g. the impact of the environment on the recurrence/transience property of the random walk and the mixing time of the random walk inside a finite, but changing graph.

Distributed optimisation of LTE systems - Amy Middleton

Supervisors: Antal Járai, Jon Dawes and Keith Briggs

Amy's project looked more fundamentally at the mathematics of self-optimising networks; in particular setting up and analysing precise dynamical models in order to gain information about fundamental limits of what can be achieved when system optimisation has to be performed with incomplete information. Working in collaboration with BT, Amy's project developed ways in which existing theory in diverse fields such as information theory, discretetime dynamical systems, stochastic processes, optimisation, and others could be brought together to solve complex mathematical problems.

Dynamics and interactions of infections on networks - Sam Moore

Supervisors: Tim Rogers and Peter Mörters

Recent work in the physics literature has explored the 'two-species contact process' as a model of staged infections. The work has a biological interpretation in terms of host-parasite invasions, for example, when a growing colony of bacteria is under threat from a developing bacteriophage infection. Past studies have focused mainly on simulations on Z2. Sam was interested in exploring the possibility of obtaining mathematically rigorous results for models of this type but evolving on random graphs. He further made use of existing branching methods as a novel approach to the problem.

Stochastic Optimal Control for problems arising in data science - Marco Murtinu

Supervisors: Alex Cox and Kari Heine

Stochastic optimal control is a sub field of control theory that deals with the existence of uncertainty either in observations or in the noise that drives the system. Its aim is to design the path of the controlled variables that performs the desired task with minimum cost. Marco is studying problems where there is a data collection process, and a decision based on this information such as when to stop, or what information to collect. These problems are related to sequential detection problems and to uncertain stochastic control problems, where the law of the stochastic process driving the system is not known. Marco plans to investigate how these problems are related and to explore possible applications in data science, where it is fundamental to understand when, during a sampling procedure, enough samples have been collected to make a decision.

Market microstructure, flash crashes and market manipulation - Kevin Olding

Supervisor: Alex Cox

The aim of market microstructure modelling is to construct models which capture the ecosphere of participants in financial markets involved in high-frequency trading, such as informed investors, market makers and uninformed or 'noise' traders. Such models should be internally consistent, in that all market participants act optimally to solve stochastic optimisation problems, but may also contain features which provide opportunities for a single large trader to manipulate the market. Automatic or algorithmic trades may also inadvertently converge on strategies which have a similar impact. Whilst generating short term profits, such a trader or algorithm could cause instability in the market, leading to a loss of liquidity or a 'mini-flash crash'. Kevin is looking to construct simple models which reflect accurately the ways in which liquidity is provided to, and prices are set in, financial markets and to understand the circumstances that might lead short term trading algorithms to disrupt ordinary market conditions.

Uncertainty quantification in radiative transport - Matt Parkinson

Supervisors: Ivan Graham, Rob Scheichl and Paul Smith

Working in collaboration with Wood plc., Matt's Ph.D. developed computation of uncertainty in flux and fundamental eigenvalue of a simplified 1D monoenergetic neutron transport problem with cross sections modelled by lognormal fields using KL sampling and Monte Carlo method. The methods started with situations where the transport equation could be solved analytically and went on to consider numerical solutions by discrete ordinates and then by analogue MC simulation. He analysed how the MC error and KL truncation affected the results and associated numerical experiments and applied MLMC methods to the problem while assessing the possibility of applying multilevel techniques to the analogue MC solver for the simplified neutron transport problem.

Optimal decision making in drug development - Robbie Peck

Supervisors: Chris Jennison and Alun Bedding

This project, in collaboration with Roche, concerned the optimisation of the drug development process at a program level. This involved considering multiple phases of treatment refinement and dose selection together. While individual phases of drug development had been studied in depth, there was relatively little work that looked at two or more phases jointly. Robbie's project used numerical computations and simulations to model different designs which involved computational challenges including (i) trial designs which used a form of gain function, or 'net present value', in order to optimise decision making throughout phases, (ii) use of Seamless Phase II/III designs that used data from Phase II in the final analysis, possibly through use of a combination test, and (iii) the realistic incorporation of beliefs about drug safety and tolerability into the program level decision making process.

The Helmholtz equation in heterogeneous and random media: analysis and numerics - Owen Pembery

Supervisors: Euan Spence and Ivan Graham

Wave propagation problems arise in applications such as seismic imaging, radar and ultrasound scanning. The Helmholtz equation is the simplest model of acoustic wave propagation - solutions of the Helmholtz equation correspond to acoustic waves with a single frequency. Researchers have been studying the Helmholtz equation, and developing numerical methods to solve it, for many years. However, most of the research effort until now has been concerned with sound waves propagating through a homogeneous medium where the speed of sound is constant. Owen studied the Helmholtz equation where the medium is heterogeneous or random. He developed numerical methods for uncertainty quantification for it and proved rigorous mathematical results about solutions. These results allowed him to study the convergence behaviour of these numerical methods, and suggested new numerical methods.

Geometric Markov Chain Monte Carlo - Tom Pennington

Supervisors: Karim Anaya-Izquierdo and Rob Scheichl

Uncertainty Quantification (UQ) concerns both propagation of uncertainty through a physical model, known as the forward problem, and the inverse problem of inferring uncertain model parameters from noisy measurements. Markov Chain Monte Carlo (MCMC) methods 30are the most widely used tools for computing expectations in UQ and large statistical models in general. Conventional approaches to MCMC are often inefficient and must compute many samples for a high accuracy. Geometric ideas can be used to improve the methods' statistical performance; two prominent algorithms in this line of thinking are Riemann Manifold Hamiltonian Monte Carlo

(RMHMC) and Riemann Manifold Metropolis Adjusted Langevin Algorithm (RMMALA). Tom is interested in extending these ideas to exploit more general ideas from differential geometry, with a focus on developing methods that are suited to problems from UQ.

Optimising First in Human trials - Lizzi Pitt

Supervisors: Chris Jennison and Chris Harbron

Lizzi's project involved developing the statistical methodology used to design and make decisions in Phase I/First in Human clinical trials and is in collaboration with Roche. This is the first stage of testing a potential new treatment in humans, after extensive laboratory testing. The primary aim is to establish the associated safety and tolerability in order to define the range of doses to be tested in phase II. Clinical trials are expensive and time consuming, thus research into optimising this process aims to reduce the number of people required, the duration and the cost. Lizzi looked to develop existing model-based Bayesian dose finding methodology such as the Continual Reassessment Method with this in mind. She investigated properties of trial designs through simulation to ensure a design is both statistically robust and fit for practical use, thus appealing to clinicians. Traditionally, at this stage there is no evaluation of whether or not the treatment works. Lizzi's research therefore incorporated analysing an early signal of efficacy into the trial design. Furthermore, the majority of existing research in this area focuses on oncology, thus Lizzi's centred on a different therapeutic area.

Development and validation of a mathematical model for surge in radial compressors - Kate Powers

Supervisors: Chris Budd, Chris Brace, Colin Copeland and Paul Milewski

Turbochargers are used in internal combustion engines in order to get a better power output for smaller engines and to get better fuel efficiency. Turbochargers work by compressing air. In order to get the most out of a turbocharger the air before and after the compressor needs a high pressure ratio for a relatively low massflow. If the massflow is too low, the air flow can reverse direction and cause surge. Surge is a difficult phenomenon to model because it exhibits chaotic behaviour. Kate worked jointly with the Mechanical Engineering department with the aim of finding a model that could (i) give a better prediction of the onset of surge and (ii) describe what happens to the air flow during surge. This involved analysis of experimental data as well as a combination of theory from compressible fluid dynamics, rotating flows, dynamical systems and bifurcations.

Automatic scoring of X-rays in Psoriatic Arthritis - Adwaye Rambojun

Supervisors: Neill Campbell, Tony Shardlow, Gavin Shaddick and Will Tillett

Patients with Psoriasis Arthritis are graded according to the extent of damage by scoring X-rays. In collaboration with the Bath Royal National Hospital of Rheumatic Diseases, Adwaye worked on automating this scoring process by exploring machine learning techniques from the computer vision community. He worked towards building a statistical model of a healthy hand to be compared to a diseased hand enabling the scoring process to be automated. This will enable scoring to be performed on a large scale basis that will ultimately increase the understanding of how the disease progresses within patients.

Stochastic control problems for multidimensional martingales - Ben Robinson

Supervisor: Alex Cox

Ben studied various stochastic optimisation problems and the connections between them. Recent work on optimal stopping problems has investigated imposing a constraint on the expected value of the stopping time in these problems to obtain so-called constrained optimal stopping problems. Ben built on this work, making use of a connection to stochastic optimal control problems. This approach required developing an understanding of the modern theory of stochastic optimal control, including the theory of weak solutions to partial differential equations in the viscosity sense. Certain problems of this type can be represented in terms of Monge-Ampère equations, a highly non-linear class of PDEs, which arise in the classical Monge-Kantorovich optimal transport problem. Ben was interested in this problem, as well as the variation, martingale optimal transport, in which additional constraints are imposed. Methods of martingale optimal transport have also been used in the Skorokhod embedding problem, a classical problem in probability theory. Each of these classes of problems has a financial motivation. Ben was particularly interested in how these problems are related.

Discrete Time One-Dimensional Models for Faraday Pilot Waves - Eileen Russell

Supervisors: Paul Milewski and Tim Rogers

For a suitably vibrating bath of fluid, a small droplet of the same fluid will "walk" across the surface due to the propulsive interactions with the waves generated by the previous droplet-bath impacts. As the bath vertically vibrates at a sufficiently large (yet sub-critical) amplitude, the droplet will bounce periodically. The bouncing droplet does not make contact with the bath, it is instead propelled back into the air due to the cushioning effect of the lubrication layer of air trapped between the bath and droplet visible only on a microscopic scale. As the amplitude increases, the droplet will destabilise and receive a "kick" in the horizontal direction resulting in the drop walking along the surface. Increasing the forcing vibration will increase the Faraday wave's decay time yielding a longer path "memory" from previous drop impacts. In an infinite domain, the walking droplet will continue in a straight line at a constant speed. If we confine the droplet to a coral, a wavelike statistical pattern emerges from the complex trajectory. Eileen will derive and analyse this pattern using a combination of fluid mechanics and stochastics.

Fast iterative regularisation methods - Malena Sabate Landman

Supervisor: Silvia Gazzola

Malena's project was based on the study of fast iterative regularisation methods, with a particular focus on Krylov subspace methods and novel ways for determining regularisation operators and regularisation parameters. These tools are widely used in solving inverse problems, which are challenging as they can be large scale and severely ill-posed. As an example, Malena explored different imaging applications, such as tomography or deblurring and denoising of images.

Scaling Limits for Random Walks on Random Conductances - Carlo Scali

Supervisors: Daniel Kious, Hendrik Weber

Random walks on random conductances form a well-established class of motions in random environment, that has already been investigated in depth. In the case where the conductances are bounded away from zero and infinity, it is well-known that the re-scaled walk converges to a Brownian motion. Out of this regime, this model showcases “trapping phenomena”, that is, a slow down in the walk due to the presence of small areas in the environment that behave atypically. In this case, the usual invariance principle does not hold anymore. Although this mechanism is now well identified, it is challenging to obtain, in the trapped regimes, functional scaling limits and other fine results (e.g. aging, quenched convergence). Carlo’s project explores trapping phenomena for random walks in random environments and on random graphs. In particular, Carlo will investigate the relationship between the Bouchaud Trap Model and random walks on random conductances in the trapped regimes.

Conditioned Stable Lévy Processes - Tsogzolmaa Saizmaa

Supervisor: Andreas Kyprianou

Tsoogii’s project looked at ways to characterise the notion of path conditioning of a d-dimensional isotropic stable Lévy process. In an attempt to understand their behaviour, she also considered their time-reversed paths. In her analysis, she used both a classical potential theory approach and recently developed methods around the theory of self- similar Markov processes. In doing so, she had the opportunity to consider the role of certain harmonic/excessive functions which have not been previously studied.

Competing growth processes with applications to networks - Anna Senkevich

Supervisors: Peter Mörters and Cécile Mailler

Anna studied a stochastic model for evolution of a structured population of particles equipped with fitness values. Each particle reproduces independently, with rate given by its fitness, and its offspring either inherits the fitness with some probability, or gets a new fitness value drawn from some probability distribution, independent of everything else. The particles of the same fitness are referred to as families. This is a stochastic version of Kingman’s model for population undergoing selection and mutation. However this framework also covers a dynamic random graph model, preferential attachment tree with fitness of Bianconi and Barabási, which is suitable for describing growth characteristics of real-life networks, such as social networks. There are two growth scenarios of the system: growth driven by bulk behaviour and growth driven by extremal behaviour (condensation case). Furthermore, there are two types of condensation: non-extensive, when no individual family makes an asymptotically positive contribution to the population, and macroscopic, when proportion of individuals in the largest family is asymptotically positive. Behaviour of the system is largely determined by properties of the chosen probability distribution. In this project, Anna focused on asymptotic behaviour of maximal families for bounded fitness distributions with a faster decay at the maximal fitness value. She established which of the above scenarios prevailed by drawing links with extreme value theory.

A nonlinear inverse source problem for Poisson's equation with point source and insulating boundary condition - Shaerdan Shataer

Supervisor: Chris Budd

Imaging is a fast growing area driven by its importance in real life application as well as its mathematical challenge. In the field of brain research, imaging brain activity serves as part of the ambition to understand some fundamental questions about cognition and perception. Mathematically, the problem could be perceived as two levels of the inverse problem: first to solve the source intensity image from the scalp measurement, second to infer the cause of source activity from source intensity image solved from the first part. Shaerdan worked to locate the active sources of brainwaves, given measurements of EEG on the surface of the scalp.

Developing hybrid frameworks for modelling reaction-diffusion systems - Cameron Smith

Supervisor: Kit Yates

Spatial hybrid models are emerging methods used to simulate biological, chemical and physical phenomena on multiple scale levels. These methods take different models of the same system and at varying spatial resolutions, and employ them concurrently in different regions of the spatial domain. The main purpose of such hybrid models is to utilise the efficiency of coarser methods, whilst maintaining accuracy by using the finer methods where necessary. Cameron developed various spatial hybrid models for biological processes in order to gain insight into how the underlying systems behave. Focusing initially on reaction-diffusion systems, which can be used to model many biological systems, from cell migration to the intracellular calcium dynamics, he incorporated biological realism into such methods.

Estimating the Frequency of Extreme Events in the Presence of Non-Systematic Records - Tom Smith

Supervisors: Ilaria Prosdocimi, Thomas Kjeldsen and Sean Longfield

Extreme flood events can be devastating, so having good estimates of how often floods of a given size might occur at a specified location is of clear importance. However, the systematically-collected river flow time series from which these estimates may be derived are short, being typically just 40-50 years long in the UK. Consequently, the flood frequency estimates have large uncertainties. The systematic record may be extended by utilising non-systematic records such as newspaper reports, photographs, and flood marks carved 27into buildings. Working with the Environment Agency, Tom is developing methodology to allow these non-systematic records to be routinely used in flood frequency analyses, with a particular focus on the importance of accounting for the many sources of uncertainty that such an analysis involves. He is also investigating the utility of non-systematic records in 'regional' flood frequency analysis, wherein river flow series from hydrologically similar catchments are combined in order to reduce uncertainty. The methodology developed during this research will be applicable to other natural hazards.

Statistical modelling for quantitative risk analysis - Sebastian Stolze

Supervisors: Finn Lindgren, Evangelos Evangelou and David Worthington

Sebastian studied extensions and innovative uses of Bayesian Networks (BNs) as a tool for Quantitative Risk Analysis (QRA). QRA is especially relevant for the oil and gas industry, where analysis is usually carried out probabilistically in order to assess likelihood and impact of safety issues. A common framework to represent results from such analyses are Event Trees (ETs) which lack many properties for dynamic risk assessment. Working in collaboration with DNV GL, the focus of this project was to study how ETs can be cast into BNs in a practical way using information measures that allow for simplifications of BNs. Furthermore, particular time-continuous extensions for BN modelling were considered that allow examination of time-to-event variables in more detail.

Branching processes with selection - Zsófia Talyigás

Supervisors: Sarah Penington and Matt Roberts

Branching random walks are well-studied models in probability theory. In particular, the Nparticle branching random walk (N-BRW), a branching random walk with selection, was first studied in the physics literature as a stochastic model for front propagation. In the N-BRW, at each time step, N particles have locations on the real line. Each of the N particles has two offspring, which have a random displacement from the location of their parent according to some fixed jump distribution. Then among the 2N offspring particles, only the N rightmost particles survive to form the next generation. The main purpose of Zsófia's project was to explore the long-term behaviour of this process with different jump distributions. There has been substantial recent progress in this area, but many interesting questions remain, including the behaviour of the system when the jump distribution has stretched exponential tails.

Combining information from multiple sources: global modelling of air pollution - Matt Thomas

Supervisors: Gavin Shaddick and Melina Freitag

In order to assess the burden of disease which may be attributable to air pollution, accurate estimates of exposure are required globally. There is a need for comprehensive integration of information from remote sensing, atmospheric models and surface monitoring to facilitate estimation of concentrations in areas throughout the world. Data assimilation is a method of combining model forecast data with observational data in order to more accurately understand the state of a system. Methods vary greatly in complexity and Matt explored different methods from both a statistical and numerical analysis standpoint. Elements of a suitable method included flexibility, modularity, the ability to incorporate multiple levels of uncertainty and techniques that allowed relationships between surface monitoring, remote sensing and atmospheric models that vary spatially and allow information to be ‘borrowed’ where monitoring data may be sparse. Throughout the project, the efficacy of different methods in this setting was examined by applying them to data from the Global Burden of Disease project. Of particular interest was their scaleability with regards to use with high-dimensional data.

Indoor propagation of radio frequency small cells: modelling the strength of electromagnetic waves - Hayley Wragg

Supervisors: Chris Budd, Robert Watson and Keith Briggs

Recent developments in high frequency antennas for wireless communication could enable users to have stronger connections. However, these high frequencies within new technologies do not travel through objects as well as the lower frequencies do. In the past, propagation models for indoor wireless communications have not been needed and when used often rely on measurements that are specific to one environment. Hayley developed a mathematical model from Maxwell’s equations to predict the strength of propagation that can be used to optimise the source location. The model accounted for variation in the environment and is therefore relevant outside of one specific location, unlike most of the current models.

Realistic constraints, model selection, and detectability of modular network structures - Lizhi Zhang

Supervisor: Tiago Peixoto, Matt Nunes

The large-scale structure of real-world network systems cannot be directly obtained by inspection, and require instead robust methods of description and extraction. One common approach is to identify modules or ”communities” via the statistical inference of generative models. Despite significant recent work in this direction, most existing methods rely on simplistic assumptions that disregard dynamical aspects of the network generation, and do not contain domain-specific information about the most likely mixing patterns. Lizhi developed general tools applicable when the network grows over time (e.g. a citation network, or the world-wide-web), or when it contains heterogeneous assortative/disassortative mixing patterns (e.g. social networks).

11. Potential supervisors and co-supervisors

There are already a large number of academics associated with SAMBa from across campus. However, new supervisors can be identified and Ph.D. projects developed with them. A brief description of the research interests of the SAMBa supervisor pool is given below.

11.1 Potential supervisors from Mathematical Sciences

Ben Adams

Ben's research is focused on mathematical modelling of epidemiological dynamics and evolutionary processes in host-pathogen systems. He is particularly interested in how spatial and demographic structures influence the spread of infectious diseases, and the processes of immune selection that drive antigenic evolution.

Karim Anaya-Izquierdo

Karim's research lies at the interface between Statistics and Geometry. He is interested in applying geometric ideas to develop new statistical models and methods. This includes, Spatial Statistics, Sensitivity Analysis, Survival and Multivariate Analysis and Distribution Theory. His research can be applied to survival data, pharmacoepidemiology, clinical trials, disease surveillance and Parasitology.

Ruth Bowness

Ruth's research interests lie in developing mathematical models to solve real clinical problems. The main part of her work involves using differential equations and individual-based models to describe infectious disease spread within the human body, and to simulate and compare treatment strategies using pharmacological models. Particular applications are on tuberculosis (TB), as well as other clinically important bacterial/viral infections such as infections found in the urinary tract, SARS-CoV-2, and antimicrobial resistant infections.

Chris Budd

Chris is interested in the theory, application and computation of nonlinear problems with special interest in problems which arise in industry. An example of this is the development of accurate adaptive mesh numerical methods for solving partial differential equations, with particular application to meteorological problems.

Tatiana Bubba

Tatiana's work focusses on computational inverse problems, in particular tomographic imaging. These problems are generally ill-posed, even more so when the data available are scarce or limited. In this case, strategies from sparse regularisation and variational optimisation, especially based on multi resolution system such as wavelets and shearlets, have been very successful in the last 15 years, providing competitive solutions to these very challenging problems. Tatiana's research revolves around combining such variational regularisation (or model-based) techniques with data-driven approaches, coming from machine and deep learning fields, in order to develop new paradigms of data-driven inversion.

Thomas Burnett

Tom's research interest is in medical statistics, with a particular focus on the design and analysis of adaptive clinical trials. While his work is primarily methodological in nature, he collaborates closely with the pharmaceutical industry to ensure the methods are well matched with practice. Such methods have broader potential application as experimental designs, for example in the wider context of personalised healthcare.

Kirill Cherednichenko

Kirill undertakes rigorous analysis of problems in mechanics and electromagnetism, looking at homogeneous systems, particularly partial differential equations and integral functionals and their application to the mechanics of composite materials. He studies a range of other media, including heterogeneous ones, looking at their physical properties.

Federico Cornalba

Federico's research sits at the intersection between stochastic analysis, numerical analysis, and PDE theory. Primarily, he is interested in describing large-scale interacting particle systems (these are ubiquitous in a whole range of applications in physics, social/opinion dynamics, and more) by using equivalent continuous models (often in the form of stochastic equations). These continuous models are, in general, more tractable than the particle models they stem from, especially when it comes to computational costs and specific interpretability features. He deploys methods from stochastic analysis, numerical analysis, and PDE theory to study relevant aspects of these continuous models. He is also interested in Machine Learning tools: so far, he has researched Deep Reinforcement Learning methods for asset-trading applications.

Alex Cox

Alex is interested in questions arising in Probability and their applications in Mathematical Finance, particularly questions which relate to robustness and model-independence when considering the pricing and hedging of financial derivative contracts. His research uses tools such as optimal control, optimal stopping, optimal Skorokhod embedding, optimal martingale transport, Brownian motion, and related Markov processes.

Jonathan Dawes

Jon's research is in applied dynamical systems. He uses a variety of techniques including bifurcation theory and multiple-scale asymptotics to understand the dynamics of physical and biological systems. This includes problems with symmetry, especially reaction-diffusion type systems where patterns form spontaneously and problems in mathematical epidemiology and population dynamics.

Manuel del Pino
Manuel's work deals with the analysis of singularity formation in non-linear partial differential equations. Of central interest is the construction of families of solutions with blow-up patterns in evolution problems in geometry, fluid dynamics and chemotaxis. A closely connected topic in his research is the analysis of singular limits in variational problems with loss of compactness.

Sergey Dolgov
Sergey's research is in numerical linear algebra and scientific computing, with the primary focus on fast numerical solution of problems in high dimensions. Examples include partial differential equations with many coordinates in statistical and quantum mechanics (such as the Fokker-Planck and Schroedinger equations), as well as uncertainty quantification and statistical inverse problems. The central approach is based on approximation of multivariate functions using the separation of variables, which turns into low rank matrix and tensor decompositions on discrete level. However, Sergey is also looking for synergies of the tensor decompositions and other techniques, such as Monte Carlo methods and parallel algorithms for linear algebra.

Matthias Ehrhardt
Matthias is interested in both theory and applications of inverse problems and optimization. Modern inverse imaging problems, e.g. computed tomography (CT), require the solution of large-scale and non-smooth optimization problems. He studies randomized optimization algorithms with proven convergence guarantees which are efficient enough to handle such demanding problems. These algorithms are also very important in modern machine learning problems such as deep learning.

Evangelos Evangelou
Evangelos's research interests are in the area of geostatistics, the collection and analysis of spatial data. He works on developing complex spatial models and methods for fitting these models to data and in spatial network design and spatial data collection. He develops design criteria and algorithms that can be used for general spatial models with applications in environmental data, analysis of human diseases, and agricultural studies.

Jonathan Evans
Jonathan works in the areas of asymptotic analysis, and industrial and applied mathematical modelling. This includes studying complex fluids with memory (which are used in the polymer, food, petroleum and minerals industries), high order nonlinear evolutionary PDEs, free boundary problems for semiconductor fabrication, concrete carbonation and pricing American Options.

Julian Faraway
Julian is interested in the analysis of functional and shape data with particular application to the modelling of human motion. He works at the interface between the theory and application of statistics ranging over astronomy, athletics, concrete, cosmetics, fungicides, fuel filters, marketing of cars, obesity and schizophrenia.

Veronique Fischer

Veronique's research is in analysis on manifolds with application to PDEs. Her work has focused on problems in harmonic analysis on Lie groups, and related questions in micro-local and functional analysis.

James Foster

James is interested in stochastic numerics, differential equations and their application to machine learning. His mathematics research has mainly focused on developing numerical approximations for stochastic differential equations (SDEs), which have subsequently been applied to prominent SDEs within data science, such as Langevin dynamics and Neural SDEs. Alongside his SDE research, James has worked on differential equation models and algorithms in machine learning, especially focusing on problems involving time series. These projects build upon ideas from an area known as "rough path theory" and have been in collaboration with several members of the DataSıg team (https://datasig.web.ox.ac.uk/).

Silvia Gazzola

Silvia is interested in the numerical solution of inverse problems, with particular focus on image processing, such as the restoration of astronomical images, or the reconstruction of tomographic images. Since such problems are typically large-scale and ill-posed, the design of effective algorithms for their solution is a challenging task, and it often requires advanced numerical linear algebra tools, such as Krylov subspace methods. Silvia is also interested in optimisation algorithms that enforce sparsity into the solution, with applications to signal processing problems within the framework of compressive sensing.

Kari Heine

Kari is interested in Monte Carlo methods, especially in the development of efficient sequential Monte Carlo methods for high dimensional filtering problems, keeping in mind the parallelism of the algorithms, which plays an important role with modern computing architectures. The analysis often involves the theory of Markov processes and martingales. He is also interested in the development of computational methods for applications in population genetics, e.g. Bayesian inference on ancestral recombination graphs.

Antal Járai

Antal develops mathematical models of statistical physics, critical phenomena, self-organized criticality, and mean-field behaviour. This specifically includes percolation, the Abelian sandpile model, the Drossel-Schwabl forest-fire model, random walks, self-avoiding walks, uniform spanning trees, and Lace expansions.

Chris Jennison

Chris pursues research into the design and analysis of clinical trials, working on sequential methods, and adaptive clinical trial designs. He also has interests in the statistical image analysis, spatial statistics and the computational methods used to fit complex models to large data sets.

Application areas range from medical and biological data to remote sensing and modelling the atmosphere.

Daniel Kious

Daniel's research is focused on the behaviour of random walks in random media, interacting particle systems, and percolation. In particular, he is interested in peculiar physical phenomena arising in their behaviour, such as the localisation or phase transitions of reinforced random walks, or the trapping mechanisms of random walks in random environments. He is also working on models of reinforcement learning, related to Game Theory.

Yury Korolev

Yury uses functional analysis to better understand numerical algorithms used in machine learning, inverse problems, and mathematical imaging. He studies neural networks as functions in certain function spaces where they achieve efficient approximation rates (that is, rates that do not depend on the dimension of the input space). He also develops data-driven regularisation methods for ill-posed inverse problems and applies them in imaging (primarily, light microscopy) in collaboration with other departments. Yury is also interested in nonlinear eigenvalue problems (that is, eigenvalue problems for non-linear and even set-valued operators such as the subdifferential of a convex function) and their applications in data science.

Lisa Maria Kreusser

Lisa's research is at the interface of partial differential equations, data analysis and mathematical formulations for machine learning. She is interested in combining modelling, analysis, partial differential equations, applied dynamical systems and numerical analysis to nonlinear problems with applications in biology, climate modelling, engineering and industry. Among her more current projects, Lisa is developing mathematical foundations for data-driven applications by building novel connections between mathematical modelling, analysis, numerical simulations and data analysis.

Cécile Mailler

Cécile is interested in discrete probability (and combinatorics) and its application to theoretical computer science. She works on branching processes, including Pólya's urns, the preferential attachment tree, or mutation/selection population processes. She also works on random trees (including Galton-Watson, Catalan or phylogenetic trees) and their application to the algorithmic satisfiability problem (SAT).

Avi Majorcas

Broadly Avi's research tends to lie at the intersection of stochastic analysis and partial differential equations (PDE). This might mean studying certain stochastic PDE with connections to deterministic phenomena or studying properties of deterministic PDE via associated finite dimensional stochastic dynamics; think of the Feynman-Kac relationship between Brownian motion and the heat equation. Currently, Avi is concretely interested in three main areas: regularisation by noise phenomena – whether stochastic dynamics enjoy improved properties over their deterministic counterparts; stochastic quantisation of physical field theories and applications of stochastic analysis to game theory and macroeconomics. In addition, Avi has interests that are adjacent to the above, or at times combine some of them.

Karsten Matthies

Karsten's main research interest is the analysis of partial differential equations and dynamical systems. Typical questions are on the interaction of multiple scales, coherent structures and the rigorous derivation of effective macroscopic models. The questions are often motivated by applications outside mathematics. The aim of Karsten's research is to develop new methods combining ideas e.g. from partial differential equations, functional analysis (semigroups), calculus of variations, the geometric theory of differential equations and probability theory.

Eike Müller

Eike is interested in numerical techniques for simulating systems at all length scales, from high resolution atmospheric models to subatomic particles. He works on the development of fast numerical algorithms and their implementation in efficient and parallel computer code such as fast solvers for PDEs. This has applications in numerical weather- and climate-forecast models.

Monica Musso

Monica's research focuses on the theoretical analysis of non-linear elliptic and parabolic equations, with particular attention to problems with solutions that exhibit concentration phenomena, which may occur when some parameter tends to a limit value or when time approaches some special value. She is also interested in bringing ideas from Differential Geometry into the analysis of important classes of PDEs, and reciprocally in applying tools in non-linear PDEs to problems of intrinsic geometric nature.

Matt Nunes

Matt is interested in the applications of multiscale methods and wavelets to various areas of statistics, such as the analysis of non-uniformly sampled data and images. He is more broadly interested in time series analysis, data with complex dependence structures and network data. He has applied his research in areas such as epidemiology, finance and climatology.

Mark Opmeer

Mark's research interests are in applied analysis. More specifically, he is interested in functional analysis, complex analysis, partial differential equations and numerical analysis. Applications include control theory and model reduction.

Marcel Ortgiese

Marcel's interest is in probability theory, in particular in stochastic systems that involve a spatial or network component. These include population models arising in evolutionary biology modelled by stochastic partial differential equations, processes in random environment and evolving random graphs.

Christoforos Panagiotis

Christoforos is interested in mathematical models arising from statistical physics both in the classical setting of the hypercubic lattice and more generally on groups. This specifically includes percolation, the Ising model, the Potts model, the Blume-Capel model, self-avoiding walk, and Abelian sandpile percolation.

Sarah Penington

Sarah's research is in probability theory, mostly on stochastic processes related to population genetics. Often this involves studying spatial branching processes with interactions between nearby particles. She also uses probabilistic techniques to study solutions of partial differential equations.

Mathew Penrose

Mathew carries out research in probability theory. He is particularly interested in stochastic geometry and random graphs, the interplay between these two topics, and his work is often informed by applications such as statistical data analysis and network modelling. He also works on percolation and interacting particle systems, particularly in the continuum, and in geometrical extreme value theory.

Tristan Pryer

Tristan's research centres around questions in numerical analysis and PDE theory. The applications are focused in two main areas, each with industrial links. 1) Natural disasters and their prediction - working with the natural disaster monitoring centre in Brazil, CEMADEN. For example on landslide prediction, integrating techniques to solve inverse problems, engineering, particulate flow and numerical methods for PDEs. 2) Proton therapy treatment planning - in collaboration with clinicians in the NHS, proton transport through tissue is modelled with the ultimate goal of construction of in vivo proton treatment verification. This involves Monte-Carlo techniques, inverse problems, proton physics and numerical methods for PDEs.

Matt Roberts

Matt's research is in probability, concentrating mainly on systems with an underlying branching structure. This includes traditional mathematical models such as branching Brownian motion and Galton-Watson trees. He is also interested in ways of using branching models to study objects such as computer algorithms, mutation rates in evolutionary biology, and mixing times for Markov chains.

Tim Rogers

Tim is interested in understanding and predicting the behaviour of complicated random events and processes, in particular when there is network or spatial structure involved. Most of his work is connected to the idea of emergence: how large scale order can be created out of the random interactions of individual particles or organisms. The problems come from a wide range of sources including ecology, biochemistry, random matrix theory, social dynamics, and stochastic processes.

Christian Rohrbeck

Christian's research focuses on advancing and combining methodology from several statistical areas, such as Bayesian clustering, extreme value theory, nonparametric regression and spatial statistics. He is also interested in developing new statistical theory and software. His work has been used to model and analyse environmental and financial data, for instance, extreme river flow and property insurance claims.

Sandipan Roy

Sandipan's core research is at the intersection of statistics, machine learning and optimisation methods. His research is focused on modelling data with complex high dimensional network structure, providing methodology for estimating the corresponding structure. He uses tools from nonparametric statistics, graphical models and high dimensional inference. The emphasis is placed on developing new theoretical techniques and computational tools for network problems and applying the corresponding methodology in many fields, including biomedical and social science research, where network modelling and analysis plays an important role.

Matthew Schrecker

Much of Matthew's research to date has focused on the compressible Euler equations. The Euler equations have a rich mathematical structure underpinning one of the most basic physical processes in the universe: the flow of gases. Over the past 250 years, the equations have inspired developments in mathematical analysis, functional and harmonic analysis, dynamical systems and geometric analysis. The Euler equations are also relevant in understanding phenomena in the physical world ranging from the flow out of an exhaust pipe to the motion of galaxies and collapse of stars. In all of these physical processes, the formation of shock waves is a ubiquitous phenomenon (as seen physically, for example, in a sonic boom coming from a Concorde aircraft) that causes a drastic loss of regularity in solutions of the system. The presence of shocks has led to the need to study weak solutions of the Euler equations, as classical (differentiable) solutions will generically blow up in finite time, and so my research has focused on both of these aspects: the existence of weak solutions and the properties and behaviour of smooth solutions on approach to singularity formation. More recently, Matthew has also been working on the problem of the gravitational collapse of stars, a different type of singularity formation in which the physical variables of the system (particularly the density of a star) blow up in finite time as matter falls in towards the centre of the star. Such a phenomenon is also modelled with the Euler equations, but now with a gravitational field as well.

Hartmut Schwetlick

Hartmut's research interests are in analysis, partial differential equations, and applied mathematics, including modelling of biological systems and numerics. He investigates applied mathematical methods arising in the study of dynamical systems for biological or life science problems, and the parameter estimation process to help search and validate different model assumptions in gene regulatory networks, as well as models for bacteria-phage infection.

Tony Shardlow

Tony works on stochastic PDEs and their applications, Langevin equations and numerical methods for strong and weak approximation. These have applications in data modelling and climate science.

Simon Shaw

Simon's interests lie in Bayesian approaches to statistics, in particular Bayes linear methods, the analysis of collections of (second-order) exchangeable sequences, graphical models and uses of conditional independence. He is also concerned with areas of operational research, in particular the development and analysis of nonparametric predictive inference (NPI)-based strategies for age replacement of components.

Pranav Singh

Pranav's research is in the design and analysis of numerical schemes for time dependent problems in quantum mechanics. He is interested in understanding and exploiting properties of relevant Lie algebras and developing methods that are fast but still preserve underlying symmetries and physical quantities. Pranav is particularly interested in problems that arise in design and control of quantum technologies such as NMR, quantum computing and laser control of reactions.

Jey Sivaloganathan

Jey's work spans areas of mathematics including the calculus of variations, analysis, differential equations, topology, geometry, and nonlinear elasticity. Many of the problems are connected with the variational theory of nonlinear elasticity. Topics studied include vector symmetrisation arguments for nonlinear elasticity, nonlinear elasticity and fracture, and multi-dimensional calculus of variations.

Theresa Smith

Theresa's research is in the areas of spatial-temporal models and computation for Bayesian methods. She is interested in point processes, small area estimation, and issues related to combining multiple data sources in a joint analysis. Her work has applications in epidemiology and public health.

Euan Spence

Euan's research lies at the interface between analysis and numerical analysis of partial differential equations. He is interested in problems involving the scattering of acoustic and electromagnetic waves.

Phil Trinh

Phil's research is motivated by a range of physical applications in the applied sciences, with particular emphasis on fluid mechanics and classical hydrodynamics. His primary expertise concerns problems that involve a breakdown of traditional methods in asymptotic analysis and perturbation theory. Such problems often involve the study of nonlinear differential equations and require the development of specialized techniques known as exponential asymptotics.

Jennifer Tweedy

Jennifer’s research involves modelling real life physiological and pathological conditions to understand physiology in health and disease, as well as the effect of potential or actual treatments. Most of her current research is in the mechanics of the eye, including the flow of the aqueous and vitreous humours that fill the chambers of the eye and the flow of fluid in and around the blood vessels at the back of the eye. Her research involves modelling, simplifying and idealising, and solving problems using a variety of techniques, both analytical and numerical.

Ben Walker

Ben's research focuses on problems of mechanics and growth that arise in biology, and the application of mathematical techniques to analyse, simplify, and understand models of biological systems. He often makes use of asymptotic techniques applied to fluid and solid mechanics, along with the classical methods and approaches of mathematical biology through the study of phenomenological models. His research has included the study of swimming on the microscale, modelling the interaction between growing tumours and their environments, and exploring reaction-diffusion equations on growing domains.

Miles Wheeler

Miles is interested in non-linear partial differential equations, especially those coming from fluid mechanics. He studies the bifurcation, continuation, and properties of special solutions such as solitary waves and fronts, with an emphasis on “large-amplitude” phenomena that cannot be understood using perturbative techniques.

Jane White

Jane is interested in mathematical modelling of problems arising from the healthcare sciences with a focus on control and monitoring. She uses a range of ideas from control theory, including optimal and feedback control, to study control of infectious diseases both at the outbreak stage and when infections are endemic in populations. She has worked on infections including HIV, HPV and Chlamydia and is currently interested in scarlet fever. Her other area of research develops and analyses mathematical models to explore how drugs are absorbed and/or monitored through the skin. The skin is an important route for drug delivery and monitoring but the highly heterogeneous barrier is poorly understood and so mathematical models, typically involving both PDE and ODE systems, are useful to explain experimental outcomes and can contribute to the development of new hypotheses.

Kit Yates

Kit’s research interests lie largely in the mathematical modelling and analysis of biological systems. His mathematical interests are focused on systems in which stochasticity plays an important role, such as stochastic focusing, stochastic resonance and multistability, in which the behaviour of the stochastic model can differ significantly from the behaviour of the naive deterministic model. Applications are in a wide range of biological areas including cell migration, collective migration, sleeping sickness, and nematode dynamics.

Luca Zanetti
Luca's research sits at the intersection of machine learning, discrete probability, and theoretical computer science. He is particularly interested in designing algorithms for network analysis that are simple, fast in practice, and that can be rigorously analysed. His tool of choice is spectral graph theory, which is the study of graphs through linear-algebraic means. He is also interested in random walks and other stochastic processes on graphs.

Haiyan Zheng
Haiyan is interested in the design and analysis of clinical trials, particularly in the field of precision medicine. Her research is directed towards added efficiency of trials. This includes (1) leveraging historical data, (2) permitting mid-course adaptations, (3) simultaneous evaluation of multiple treatments, multiple subgroups, or both, under one overarching protocol, (4) enrichment strategies, etc. Haiyan's work has wider applications going beyond clinical trials. For instance, a few Bayesian methods developed to deal with a prior-data conflict can be applied broadly to augment studies or experiments suffering from data sparsity with external information.

11.2 Potential co-supervisors across campus

Department of Architecture and Civil Engineering

Kemi Adeyeye
Kemi's research focuses on finding collaborative, sustainable solutions to water and energy resource issues, addressing sustainability, resource use efficiency, and resilience of the built environment.

Chris Blenkinsopp
Chris's research interests are predominantly in the field of coastal science and engineering. In particular Chris is interested in the dynamic equilibrium of natural beaches, wave breaking and wave transformation in the nearshore, sediment transport in the surf and swash zone, extreme wave and water level prediction, the response of sandy coastlines to sea-level rise, storm erosion and recovery of beaches and wave energy converters.

Kevin Briggs
Kevin's research examines the influence of extreme weather events, climate change and vegetation on near surface groundwater movement and its impact on transport infrastructure. This includes assessing the stability of geotechnical structures such as retaining walls, road and rail embankments and cuttings.

David Coley
David's work includes the prediction of future extreme weather and the performance of strange architectures in buildings, for example beams arranged according to random walks.

Tim Ibell

Tim's research focuses on the appropriate design, analysis and construction techniques associated with concrete structures. An area requiring significant work to enhance the UK's sustainability credentials is loading on structures. Structural engineers over-specify loadings, routinely, adding greatly to building costs. Appropriate risk-based mathematical modelling of loading in, on and around buildings is required.

Thomas Kjeldsen

Thomas's research focuses mainly on the use of mathematical and statistical modelling of environmental and hydrological systems, with emphasis on predicting extreme hydrological events such as floods and droughts. He has worked on developing the UK industry standard methods for flood frequency analysis and aims to understand the effect of environmental change (climate change, urbanisation, land management) on water resource systems. He also conducts risk and uncertainty analysis of extreme events.

Nick McCullen

Nick has a background in Physics, specialising in nonlinear dynamics and coupled oscillators and looking at everything from synchronisation of chaotic signals to modelling diffusion of innovation via social networks. His research includes numerical and experimental work on coupled nonlinear electronic oscillators, with applications from neuroscience to models of electricity micro-grids. He is also interested in modelling urban systems (cities, buildings, transport) using complex systems models, including networks and dynamical systems, and particularly how interactions between the various components, such as buildings, technology, the environment, and people, result in the systematic functioning and energy consumption.

Jun Zang

Jun's research concerns the hydrodynamic loadings on urban, coastal and offshore structures and the impact of extreme events on such structures. Her research group develops and uses advanced CFD tools in modelling urban flooding, coastal flooding, fluid structure interactions, performance and survivability analysis of marine renewable energy devices (including all wave, tidal and offshore wind energy) and violent wave impact on coastal and offshore structures.

Department of Life Sciences

Volkan Cevik

Volkan's research focuses on molecular characterisation of interactions between plants and their pathogens. His research interests include mechanistic understanding of processes such as how pathogens manipulate the host plant to cause disease and in turn how plants perceive microbial pathogenicity proteins to activate defence. He uses multiple omics data and network approaches to predict regulatory genes, proteins and pathways determining the outcome of such interactions.

Lauren Cowley

Lauren's research interests centre around public health and infectious diseases. She uses whole genome sequencing data to investigate bacterial pathogens emergence, spread and maintenance in the world and uses machine learning to improve global epidemiological surveillance of pathogens. She works closely with Public Health England and has access to multiple data sources from them surrounding the sequencing and epidemiology of food-borne pathogens.

Begoña Delgado-Charro

Begoña has a background in biopharmaceutics (drug delivery and pharmacokinetics). Her research has focused on transdermal and topical drug delivery by passive and iontophoretic means, on developing optimised methods to treat nail diseases such as onychomycosis and psoriasis, on non-invasive sampling for drug monitoring and pharmacokinetics, and on developing models to predict chemicals accumulation into the skin and skin absorption from dermatological products.

Ed Feil

Ed's research interests lie in understanding the processes underpinning the evolution and spread of bacterial pathogens of man and animals using whole genome sequence data.

Richard Guy

Richard's research is focused on transport of chemicals (both good and bad) into and through skin. Mathematical modelling is used to derive predictive algorithms with which to estimate the kinetics of (trans)dermal diffusion, the rate and extent at which target or potentially deleterious chemical concentrations are achieved in the skin, and the efficiency of electrically-assisted, percutaneous analyte extraction (e.g., glucose) for non-invasive monitoring.

Daniel Henk

Daniel is interested in understanding how eukaryotic genomes, particularly fungal genomes, respond to simple and complex systems of interactions. Fungi are incredibly diverse, and species often occupy heterogeneous niches that can appear contradictory depending on other conditions (e.g. detrimental or helpful to hosts depending on nutrient availability). The central research seeks to use environmental, genomic and phenotypic data to develop and test models that explain the dispersal, trophic role, and ultimately the limits of fungal genomic flexibility over physiological, ecological and evolutionary time frames.

Robert Kelsh

Robert is interested in fundamental questions in developmental biology, particularly in the related fields of stem cell biology and regenerative medicine. He studies the gene regulatory networks underlying processes such as maintenance of multipotency, specification of cell fate, and the control of differentiation, which are defective in many congenital diseases. He is also interested in guided cell migration and the cell biology and genetics of pigment pattern formation.

Jody Mason

Jody's research focuses on how proteins interact with each other. A major aim of the group is to be able to devise rules to predict which proteins are likely to interact with each other (and how stable these interactions will be) from those which do not. He uses computational algorithms and a wealth of experimental data to assist in this goal. In particular new algorithms to increase the accuracy of predictions and enable the design of inhibitors of proteins implicated in disease need to be developed, as well as the design of protein-protein interactions to apply in synthetic biology-based approaches.

Anita McGrogan

Anita's research is in disease epidemiology and medication safety and uses UK primary care data from the Clinical Practice Research Datalink. Recent work in medication safety in pregnancy includes evaluating medications used for diabetes and for epilepsy to determine current utilisation and safety in terms of maternal and foetal outcomes. Research in disease epidemiology includes evaluating risk factors for diseases and determining whether there are associations between patient comorbidities and serious outcomes. This work uses statistical modelling for the analysis of the data and models are further developed to accommodate limitations with study methods.

Neil McHugh

Neil heads a clinical programme of work in chronic inflammatory rheumatic disease. His group undertakes epidemiological studies utilising large health-related data bases that study disease incidence prevalence and burden, drug utilisation, safety and comparative effectiveness as well as lab-based studies of biomarkers for disease outcome.

Prasad Nishtala

Prasad's research expertise is in the area of pharmacoepidemiology. This employs the methods of epidemiology to study outcomes of drug treatments in specific populations in real-world settings. His work is related to analysing big healthcare data to understand medicines safety. He is interested in using machine learning to predict adverse drug reactions. In his current research, he has used propensity score matching, marginal structural models and algorithms to understand drug-related adverse events.

Nick Priest

Nick's research focuses on combining demographic studies of fruit flies with a range of mathematical approaches to understand links between nutrition, gut microbe growth, immunity and ageing. Most of the work involves understanding how ecological processes generate heterogeneity and reveal individual quality.

Christopher Pudney

Chris is interested in translating fundamental science into new biotechnology solutions that are applicable in healthcare, manufacturing and drug development. Innovations in data quantitation and modelling are the key to successfully translating bench science. For example, by implementing machine learning to detect pathogens based on spectral fingerprints. Chris is developing a new technology for monitoring the use of synthetic drugs, which are typically used by the most vulnerable in society and have devastating medical consequences. The drugs are hard to detect and there is no solution for checking drug strength or telling if a patient in critical condition has taken one of these drugs. Spectroscopic tools can be 51applied to detect these drugs but for this to be successful in the field a quantitative solution is needed to disambiguate the data in real-time.

Department of Chemical Engineering

Tom Arnot

Tom's research falls into two main areas: sustainable water and waste water treatment, and novel drug delivery systems/responsive wound dressings. On the water treatment side he works on renewable energy via anaerobic digestion, membrane bioreactors for water recovery from domestic waste streams, and algal photo-bioreactors for nutrient capture. Modelling challenges involve multi-parameter estimation in complex algebraic, ODE, and PDE equation systems. The work on responsive wound dressings involves the development of nanoemulsions to act as mimics of cell membranes, and hence carry bacteriophage to a wound site and prevent infection. These provide interesting fluid flow, transport, and multi-species interaction problems to model.

John Chew

John has particular interest in the process and computational modelling of the flow behaviour of multi-phase systems where external forces are important, arising from mechanical action and chemical/phase changes. Typical examples of multi-phase flow include, fracking and enhanced crude oil recovery operations (gas-liquid-solid), polymeric materials used as thickening agents in pharmaceutical applications, foods, creams, gels (liquid-solid) and mixing process in chemical reactors (gas-liquid).

Mirella di Lorenzo

Mirella's research aims to micro machine biofuel cell technology and promote the practical use of micro biofuel cells as a potential power source for a number of biomedical accessories, including cardiac pacemakers, neurostimulators, hearing and vision devices, drug pumps, glucose sensors, bladder-control valves, and as a biosensor for waste waters. Her research fuses together biotechnology, fuel cell techniques, fabrication of enzymatic nanostructured electrodes, microfluidics, and micromachining techniques.

Tina Düren

Tina uses molecular simulation (e.g. Monte Carlo, molecular dynamics and ab initio methods) to design innovative porous materials with properties tailored for specific adsorption applications including for example carbon capture, energy storage or drug delivery. In her research she not only studies the applications in detail but also looks at how these porous materials form across different length scales.

Emma Emanuelsson Patterson

Emma works on the development of bioprocesses for fine chemical and pharma molecule synthesis. This includes the development of novel process intensification reactors (e.g. spinning mesh disc reactor), the use of solar energy for chemical synthesis and wastewater treatment, and developing new chemo- and bio- catalysts for pharma and fine chemical reactions.

Carmelo Herdes Moreno

Carmelo's research is framed in the general area of statistical thermodynamics and molecular simulation (i.e. Monte Carlo and molecular dynamics) of materials and complex fluids (e.g. asphaltenes, polymers, surfactants), adsorption and interfacial phenomena (activated carbons, nanotubes, colloids) from the atomistic to the coarse-grained level.

Jan Hofman

Jan is interested in research on heat recovery of sewer systems. Warm water enters the sewer system at all homes and heat recovery from it is an option to reduce the use of primary energy sources and CO2 emissions. Heat content in sewers can be predicted by stochastic behavioural simulations that feed into a hydraulic and heat balance model for a sewer network. The modelling can be used to find the best location for heat recovery in the sewer network.

Matthew Lennox

Matthew's research focuses on exploring the behaviour of molecules in confined spaces using molecular simulation techniques (e.g. Monte Carlo simulations, ab initio and quantum chemical calculations, molecular dynamics). His interests include adsorption-based separations (gas and/or liquid) in nanoporous, microporous and polymeric materials, sensing of toxic or harmful compounds in humid or aqueous environments, and design of effective composite materials for separations and sensing applications.

Tim Mays

Tim has interests in mathematical and statistical modelling, computer simulation and analysis of absorption and mass transfer processes in porous engineering materials for gas storage and separation applications. A major topic is hydrogen storage in low-carbon fuel-cell vehicles. Methodologies include integral and partial differential equations, Monte Carlo simulations (in various ensembles including the grand canonical) and non-linear regression analysis.

Benedek Plosz

Benedek's research interests include assessing the fate of trace organic chemicals in urban water systems (pharma, drug biomarkers),computational fluid dynamics of bioengineered water systems, and biogeochemical used-water resource recovery.

Nuno Reis

Nuno is interested in modelling of fundamental physical, chemical and biological processes that underpin the robust development and performance of novel disruptive biological and biomedical technologies. For example, using CFD modelling to understand mixing, mass and heat transfer, particles suspension, or bubbly flow in two-phase or multiphase unsteady oscillatory flow reactors and in microfluidic (miniaturised) devices. He also explores antibodyantigen binding, mass transfer and matrix effects in novel microfluidic biosensors through numerical modelling and uses mathematical algorithms for stratifying patients' outcome based on a biomarkers fingerprinting from human samples - a statistical approach that could speed up adoption of novel microfluidic tests for rapid diagnosis of e.g. sepsis, viral and bacterial infections, acute renal and cardiac injuries.

Jannis Wenk
Jannis has a broad range of water related research interests, both applied and fundamental. These include water quality assessment, novel water and wastewater treatment methods and the fate and behaviour of chemical contaminants and water borne pathogens during water treatment and in the aquatic environment. He is an expert in environmental photochemistry, the behaviour of aquatic natural organic matter and oxidative water treatment processes (e.g. ozone, chlorine, UV), and strongly interested in industrial collaborations.

Department of Chemistry

Barbara Kasprzyk-Hordern
Barbara's principal research interests fall into the three interrelated research areas of environmental, analytical and water sciences. Her group works in the area of water quality and novel technologies used to decrease contamination of water. Their interests focus on water fingerprinting to inform the state of the environment and public health using large datasets (especially in the context of urbanisation).

Frank Marken
Frank's research is in both the fundamental and applied aspects of electrochemistry and in particular on energy conversion, materials properties, and analysis at electrodes. Work focuses on dynamic phenomena in nano-spaces/pores driven by applied potentials.

Benjamin Morgan
Benjamin uses computer simulations to understand the properties of solid-state materials. His main focus is understanding the behaviour of solid electrolytes - crystalline materials that allow ion transport, which are important for solid-state batteries and fuel cells. His interests include how complex many body processes can be described by simple mathematical and conceptual models, and how these depend on different material chemistries and structures.

Dan Pantos
Dan's main interest lies in supramolecular chemistry, trying to understand how and why molecules interact with each other, and the rules that govern self-assembly in nature. He is also interested in a challenging synthesis or a seemingly indecipherable spectrum. Dan believes that by answering these questions we will be able to produce organic materials with new properties that will ultimately lead to applications that will change everyday life.

Steve Parker

Steve's research interest is in developing and applying atom level simulation techniques to two broad classes of materials research: (i) Energy Materials and (ii) Environmental Materials. In both cases he is interested how surfaces and interfaces affect the transport of ions, molecules or heat, and thus, for example, develop more efficient thermoelectric devices or identify better materials for pollutant remediation.

Department of Computer Science

Neill Campbell

Neill's main area of research involves learning models of shape (2D and 3D) and appearance from images. In particular, he is interested in performing this in an automatic or interactive fashion that allows these technologies to be put to use in a variety of applications without requiring users to have computer vision or graphics expertise. He also works on generative machine learning models, in particular Gaussian processes and Bayesian nonparametric methods, in a variety of applications.

James Davenport

James's main research interest is computer algebra, especially symbolic integration, simplification and equation solving. One specific application has been using computer algebra to generate numerical code. He has side-interests in efficient parallelism, electronic mathematical publishing and "mathematics on the (semantic) Web", robot motion planning and cryptography, especially cracking US public-key cryptosystems.

Tom Fincham Haines

Tom applies machine learning (ML) to a wide selection of problems, particularly those involving computer visions and graphics. He has strong interests in graphical models, Bayesian non-parametric models, directional statistics and active learning, and working on projects involving tools to help artists, ML for education, online/realtime ML, causality, and scaling non-parametric methods to big data.

Eamonn O'Neill

Eamonn's research has the overarching goal of developing an applied science of human-computer interaction (HCI). This involves developing a sound theoretical footing for HCI and deriving design principles for the development of human-computer systems that are theoretically well-founded, empirically tested and operationalised for people's use.

Julian Padget

Julian's main research focus is the use of formal approaches to validation and verification with computational logic-based models. Application domains include legal reasoning, checking and monitoring security policies, investigating interactions between policies and their automatic revision (inductive logic programming), gaming, virtual and mixed environments and agent-based modelling.

Özgür Şimşek

Özgür's research is on artificial intelligence and machine learning, with emphasis on reinforcement learning. She is particularly interested in open-ended learning in complex, dynamic, uncertain environments. Areas of interest include: 1) Statistical properties of natural environments that enable fast, effective learning, 2) Autonomous construction of hierarchies of reusable skills, 3) Intrinsic motivation and curiosity.

Department of Economics

Alistair Hunt

Alistair is an environmental economist whose research is principally concerned with the economic impacts of climate change and responses to those impacts. These responses particularly relate to adaptation and the decision support rules that can handle the uncertainties associated with future climate change impacts. Alistair is also interested in economic valuation of non-market impacts of pollution and environmental degradation, particularly the impacts of air pollution on human health.

Ron Lavi

Ron's research is in algorithmic game theory and internet economics, which is a relatively new research discipline that has evolved since the beginning of the 2000s. It employs mathematical tools (e.g., graph theory, probability theory, combinatorics) to study various topics on the border of economics, game theory and computer science. Examples include the design and analysis of auctions (which are the main source of revenue for Internet companies like Google and Facebook), social networks, crowdsourcing websites, cryptocurrency systems, etc. This active research community holds an annual conference and to obtain a better feel to the type of research being offered. Students can take a look at the list of papers presented there: https://ec22.sigecom.org/program/accepted-papers/

Department of Electronic and Electrical Engineering

Pedram Asef

Pedram Asef is a Lecturer in Electrical Engineering at the Department of Electronic and Electrical Engineering, University of Bath. He is interested in Rotating and Linear Electrical Machines, Transportation Electrification (e.g Electric Drives and controls), Connected Vehicles and Systems, Applied Machine Learning and Optimisation Methods to related applications, and Intelligent Energy Systems (e.g. Renewable Energy Systems).

Adrian Evans

Adrian's research interests are in image processing and analysis. This work includes the development of fundamental techniques for mathematical morphology and colour image processing and application areas such as remote sensing, video coding and biometrics.

Furong Li

Furong's research is concerned with developing fundamentally new economic concepts and theories in the field of electrical systems. She combines market economics with technical analyses to encourage timely investment in energy generation and transmission and promote efficiencies in energy consumption.

Cathryn Mitchell

Cathryn's research interests include the effects of atmospheric scintillation and multipath propagation on GPS navigation signals, tomography (medical and geophysical), and the influence of the sun upon the magnetosphere and ionosphere. She is interested in radio propagation, signal processing and the inversion of multi-directional signals to reveal interesting information about the natural world.

Manuchehr Soleimani

Manuchehr works in tomographic imaging. The work involves the hardware, software and sensor development of new and emerging tomographic imaging techniques and the image analysis of conventional imaging techniques such as X-Ray CT. Particular interests are in electrical and electromagnetic imaging, nonlinear inverse problems, volumetric image reconstruction in X-ray CT, and multi-modality imaging.

Corwin Wright

Corwin's work focuses on the dynamics of the atmosphere of the Earth and other planets, using primarily observational techniques such as satellites and weather balloons. He has particularly strong interests in the terrestrial stratosphere and mesosphere, where a major recent topic of research has been the generation and propagation of small-scale gravity waves.

Department for Health

Dario Cazzola

Dario's research is focused on human movement analysis and biomechanics of injury in sporting and everyday life activities. His research approach is based on in vivo analyses, musculoskeletal modelling, and computer simulation with a specific application to injury prevention and ergonomics. Dario's interests also include bioenergetic of human locomotion and sports biomechanics (e.g. race walking and rugby).

Fiona Gillison

Fiona's research is in the area of obesity prevention, with a particular focus on interventions to bring about behaviour change. She is interested in the application of psychological theories to practice, and taking a systematic approach to design and evaluations to explore the mechanisms by which behaviour change may be brought about. She is also interested in policy initiatives to promote healthy lifestyles and reduce obesity.

Emma Solomon-Moore

Emma’s research is focused on physical activity, sedentary behaviour and public health. Her interests include examining the differences in physical activity and sedentary behaviours among different sub-groups, developing new interventions, and working with external organisations to evaluate community-level organisations.

Keith Stokes

Keith investigates injury risk in sport, with a particular focus on rugby union. The work is carried out in elite and community men’s rugby as well as youth rugby. These epidemiological data are being used to inform the development and evaluation of injury prevention strategies. Although all injuries are of interest, concussion is a key focus.

School of Management

Güneş Erdoğan

Güneş’s research is in exact and heuristic algorithms for integer and mixed-integer optimisation problems and their applications to healthcare and logistics problems. His expertise with exact optimisation methods includes branch-and-cut-and-price and cutting plane algorithms, especially for vehicle routing problems. In terms of heuristic optimisation methods, he has utilized variants of local search, tabu search, and large neighbourhood search in his papers and he has a working knowledge of genetic algorithms and neural networks. The areas of application for his research extend to the optimisation of ambulance location, vehicle routing, and airline crew scheduling.

Elvan Gokalp

Elvan’s research aims to utilize Operational Research techniques to assist organizations from various sectors such as healthcare and pharmaceuticals. Specifically, she has mainly applied stochastic programming, queuing theory, stochastic dynamic programming and reinforcement learning techniques to the relevant decision-making problems under uncertainty. For example, her recent research combined the application of robust optimization and queuing theory for capacity planning in healthcare centers. Another application was scheduling of surgeries with the help of reinforcement learning.

Adam Joinson

Adam’s research seeks to address fundamental questions around privacy, security, trust and communication using computational social science. For instance, recent work has used mathematical models to understand how rapport and trust can be measured in communication exchanges, and how patterns of influence emerge in large online communities. He is co-lead for the Centre for Research and Evidence on Security Threats, and directs work in CREST on connecting digital footprints and patterns of behaviour to social and demographic variables.

Christos Vasilakis

Christos has an academic background in operational research, computer science and health services research. His research focuses on developing and putting in place modelling methods and practical tools for assisting those delivering and managing health and care services. Christos is also interested in the evaluation of the likely impact of healthcare interventions and policy initiatives using mathematical modelling and computer simulation. He directs CHI-2 (Centre for Healthcare Innovation and Improvement), a multidisciplinary research centre with significant working collaborations and links with local, regional and national health and social care organisations.

Department of Mechanical Engineering

Chris Bowen

Chris's research areas include functional materials and composites, which include ferroelectrics and shape memory alloys. Ferroelectric materials have a polarisation that changes with stress or temperature and can therefore convert mechanical motion or temperature fluctuations into an electrical signal. This research is aimed at developing novel sensors or energy harvesting systems capable of converting ambient vibrations or heat into useful electrical energy. Ferroelectrics and shape memory alloys can also be used to provide a shape change, so are being examined for actuation or morphing structures.

Chris Brace

Chris's research is in the area of automotive powertrain systems. He has a particular focus on the intensive measurement, analysis and control of multi-cylinder engine systems running under dynamic operating conditions. Problems that would benefit from greater mathematical insight include investigation of non-linear effects such as in-cylinder turbulence on combustion stability; the dynamic and thermal effects of friction in clutches on subjective vehicle performance; unsteady flow in compressors leading to the surge phenomenon. These problems have important applications in seeking to reduce the emissions of $CO2$ from mass market passenger cars.

Richard Burke

Richard's research focuses on understanding, modelling and optimising powertrain systems operating under transient conditions. Powertrains consist of many components (engines, transmissions, catalysts, electric motors, batteries) that can each be seen as non-linear, dynamic and time dependent sub-systems. At the same time, most of the large fuel consumption gains have already been achieved, and improvements tend to happen in small steps. This requires high precision modelling and testing methods to be able to demonstrate these benefits. The following research topics would therefore benefit from more mathematical and statistical insights: Frequency domain analysis and time series modelling of powertrains, statistical techniques to integrate a form of process control in powertrain testing facilities (such as multivariate statistics), methods for analysing diverse and random on-road data.

Richard Butler

Richard's research interests are focused on analysing the production and performance of composite aerospace structures. His research is on manufacturing process modelling, multi-scale modelling and damage tolerant design of laminates, with applications in civil aircraft wings. He develops novel analytical methods for predicting the strength of composite laminates with defects or following damage, and studies the optimum placement of fibres to maximise strength and improve manufacturability. He is also working with mathematicians to develop new uncertainty quantification methods for use in aerospace manufacturing.

Andrew Cookson

Andrew's research applies computational modelling to a range of problems in cardiovascular biomechanics and medicine, from optimising medical imaging of blood flow to understanding the progression of heart disease. He also has research interests in fundamental aspects of fluid mechanics, including chaotic advection in laminar flows, and flow in helical pipes.

Hamideh Khanbareh

Hamideh is a materials scientist interested in smart materials, which are engineered with respect to their chemical composition as well as the structure at the micro-scale, for the next generation of sensors and energy harvesters. Her main focus is synthesis of biocompatible lead-free materials, porous structures, as well as large-area flexible devices. Synthesis, characterisation and modelling the behaviour of the newly developed materials are among her core activities.

Andrew Plummer

Andrew's interests are in modelling, dynamic analysis and computer control of mechanical systems. His research projects mostly fall in the field of motion and force control, including inverse-model based control of electrohydraulic servosystems, control of parallel kinematic mechanisms, and hybrid hydraulic/piezoelectric actuation. Applications include flight control systems for aircraft, active suspensions for road vehicles, and power take off systems for wave energy converters.

Rosti Readioff

Rosti's research is focused on developing and utilising a combination of cutting-edge experimental (e.g., non-contact optical methods) and computational (applied mathematics) methods to provide engineering solutions for advancing orthopaedic and dental treatments. The engineering techniques can include multi-scale experimental and computational approaches to study structural mechanics and material properties of natural and engineered tissues (biomaterials) and tribological analysis of human joints (e.g., knee joints). The outcome of such techniques can assist in developing new materials for implants and streamlining restorative procedures in orthopaedic and dental practices.

Andrew Rees

Andrew's research is primarily on the modelling of flow, heat transfer and convection in porous media with a particular emphasis on instability. Recent work includes the modelling of (i) heat transfer processes in highly heterogeneous media, and (ii) the flow of yield-stress fluids through porous media. Techniques such as network modelling, asymptotic theory and numerical simulations are used to these ends.

Andrew Rhead
Andrew's research focuses on the impact and damage tolerance of aerospace composite structures. He is particularly interested in the detection and modelling of mechanisms of failure and Non-Destructive evaluation (NDE) of impact damage.

Carl Sangan
Carl's research focuses on improving the efficiency of gas turbines for power generation and aerospace engines, with a particular interest in modelling the fluid mechanics and heat transfer inside rotating systems. Through theoretical and experimental studies he employs the approach that investigations into the underpinning fundamental science are key to understanding the complex rotating disc systems found within these turbomachines. The insight from this research informs the design of future engines and influences the design methods employed by engine designers.

Hui Tang
Hui's research is focused on modelling of flow and heat transfer in aero engines. The aim of her research is to develop physically-based 1-D models that can be used by engine manufacturers in the preliminary design phase. She is also working on developing Bayesian models to solve inverse heat transfer problems from experimental data analysis.

Department of Physics

Philippe Blondel
Philippe's research is about acoustics and its uses in marine environments, from ambient noise (anthropogenic and natural), and mitigating its impacts on animal life, to active imaging of animals and seabed habitats (from coral reefs to submarine landslides). For this, he designs new instruments and innovative approaches to signal and image processing. Experimental work in water tanks is used to pave the way for deployments at sea, in real conditions. Research projects regularly span the bridge between disciplines, involving mathematics, engineering, biology and oceanography.

Dick James
Dick's research focus is to develop and use computational methods for the analysis of patterns and processes in populations of social animals. His particular interest is in the use of network theory to unravel the social structure of group-living animals such as fish, ungulates and mammals, and the dynamics of the passage of goods through colonies of social insects.

Peter Mosley
Peter's research interests are in nonlinear optics and quantum optics, particularly generating and studying light at the single-photon level. His work is focused on how properties of nonlinear materials influence the characteristics of photon pairs, and how dispersion can be engineered to

improve quality of single photons. He is also interested in quantum walks of photons (the quantum analogue of a random walk) through ordered and disordered networks.

Dmitry Skryabin

Dmitry is working in the areas of computational and theoretical nonlinear optics and condensed matter physics, where he studies experimentally relevant and fundamentally challenging problems of light propagation and trapping in micro and nanoscale waveguides and resonators. He uses a range of Hamiltonian and dissipative nonlinear partial differential equations to describe a variety of effects and devices that include extreme broadening of optical spectra, soliton and shock wave propagation, nonlinear dynamics of the optical clocks and exotic states of light, such as, e.g., photonic topological insulators.

Anton Souslov

Anton's research involves modelling the mechanics of soft materials and designing new states of matter. More specific interests include emergent flow and patterns in so-called active fluids, which are composed of self-propelled particles; topological states in which integer invariants characterise phases of soft matter; and the physics of long polymer molecules that are prevalent in biological materials. In addition to modelling naturally occurring materials, Anton is interested in designing exotic material properties via structures called mechanical metamaterials.

David Tsang

Dave works on a broad range of problems in theoretical astrophysics and mathematical physics, such as the physics of neutron stars, black holes, gravitational waves, accretion discs and exoplanetary systems. He is also interested in problems related to (non-Hamiltonian) action principle methods for discrete and continuum systems, and applying geometric methods to develop new analytic and numerical techniques for exploring problems where nonconservative interactions can be important. This includes variational integrators and non-conservative action principles that can be potentially applicable across a wide range of physics, engineering, and applied mathematics.

Stijn Wuyts

Stijn's research explores evolutionary paths of galaxies from the early universe to the present day. To this end he uses multi-dimensional snapshots of galaxy lives, resolved spatially and spectrally. He combines these observational resources gathered with the world's most powerful telescopes with sophisticated modelling of the galaxy stellar populations and dynamics.

Hendrik Van Eerten

Hendrik's astrophysics research focusses on relativistic jets of gas generated by massive black holes and stellar explosions. As part of this work, he uses large-scale computer simulations of fluid dynamics to model the evolution of jets and to compute synthetic observations of how the emission from such jets would appear to distant observers. These are then combined with multi-wavelength data from a range of telescopes and satellites observing cosmic explosions, using statistics to probe the parameter space of jet dynamics and emission parameters in order to constrain the physics behind the jets.

Carolin Villforth

Carolin's research interest is in the field of extragalactic astronomy. Particularly, she studies the growth of supermassive black holes and how supermassive black holes influence the galaxies they reside in. Such studies involve working with large datasets and accounting for a range of selection effects.

Department of Psychology

Julie Barnett

Julie is a social psychologist and interested in how data gets constructed and used in policy. She is working with BANES Local Authority and CCG on projects where joining administrative data sets is done to inform policy decisions. She is also working on projects considering the potential of social media data to inform risk communication.