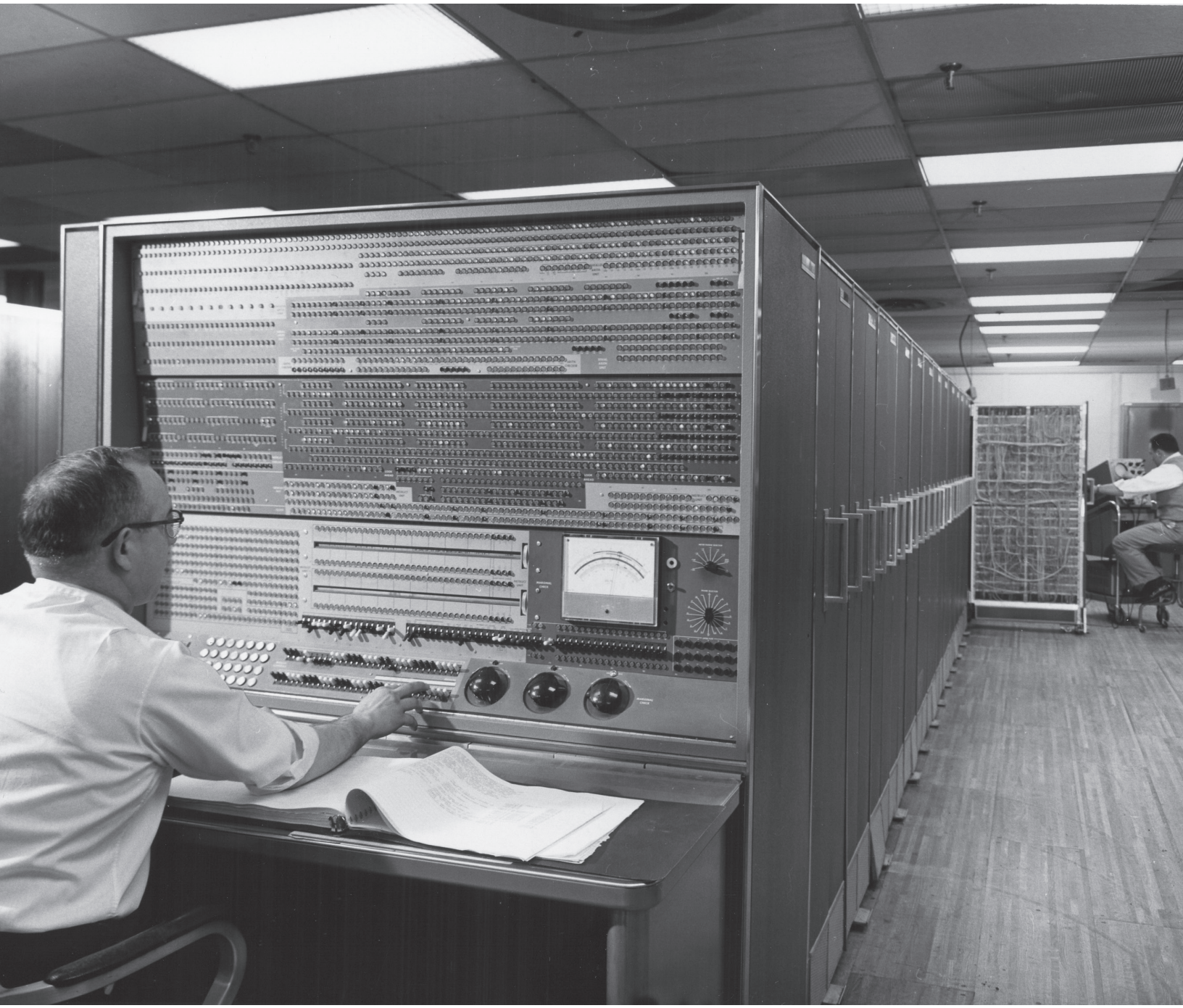
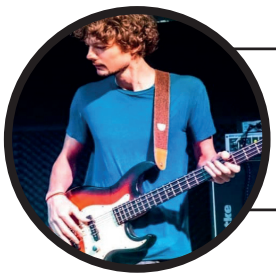
Bulletin17

HT 2020

OXFORD CENTRE FOR INDUSTRIAL & APPLIED MATHEMATICS
University of Oxford
Mathematical Institute, Andrew Wiles Building



Welcome



Sam Palmer

Sam joins OCIAM as a postdoc in the Mathematical Modelling of Thymus Development working with Jon Chapman. Sam is interested in the area where bioinformatics meets mathematical modelling. He is part of SynThy, a research group focusing on thymus regeneration. His background is theoretical physics (string/M theory).

Pierre Haas

After undergraduate studies at Cambridge, Pierre joined DAMTP for his doctoral work. He stayed in DAMTP for a postdoc, and will join the Mathematical Institute and OCIAM as a Hooke Research Fellow in June 2020. Pierre 's research interests range from the biophysics of development in the green alga Volvox to shape-shifting droplets and the stability of microbial communities.

Industrial Mathematics has been at the heart of OCIAM since it's inception thirty years ago.

This issue is devoted to Industrial Mathematics in OCIAM.

We welcome new DPhil students from Cohort 5 of the InFoMM CDT, who each work with an industrial partner on a specific problem.

Our newest academic appointee to OCIAM is the Professor of Industrial Mathematics Ian Griffiths, who was both a student and Post-doc in OCIAM. In this issue he describes some of the recent challenges that his team and his collaborators are working on.

We hope you enjoy it.

Corrections
Bulletin16, p14
Jess Williams not Jess Philips (candidate for the Labour Party Leadership) has started a postdoc here.

New DPhils

DPhil Students from Cohort 5 of the InFoMM CDT, each work with an industrial partner on a specific problem.

Oliver Bond graduated with an MMath degree from the University of Exeter. After a few years working as a fully qualified maths lecturer in Further Education, he successfully enrolled onto the InFoMM programme. He's now carrying out a DPhil research project in partnership with Tokamak Energy, on the thermoelectric magnetohydrodynamics of liquid metal lithium inside the divertor of a tokamak (toroidal plasma confinement device) nuclear fusion reactor.

Joel Dyer is affiliated with the Oxford INET Complexity Economics group, under the supervision of Doyne Farmer and in collaboration with Improbable. His research involves developing agent-based models of opinion dynamics with a focus on prediction. He is also interested in likelihood-free and Bayesian estimation methods.

Meredith Ellis's DPhil project is a collaboration with Cellesce Ltd, a biotech company specialising in organoid culture. Her research focuses on modelling the process for organoid expansion in their bioreactor - in particular the culture media stoichiometry. The model will provide quantitative predictions for the fluid flow profiles and the oxygen and metabolite concentrations throughout the bioreactor, which can then be used to optimise the bioreactor operating parameters to improve uniformity and reproducibility of organoids.

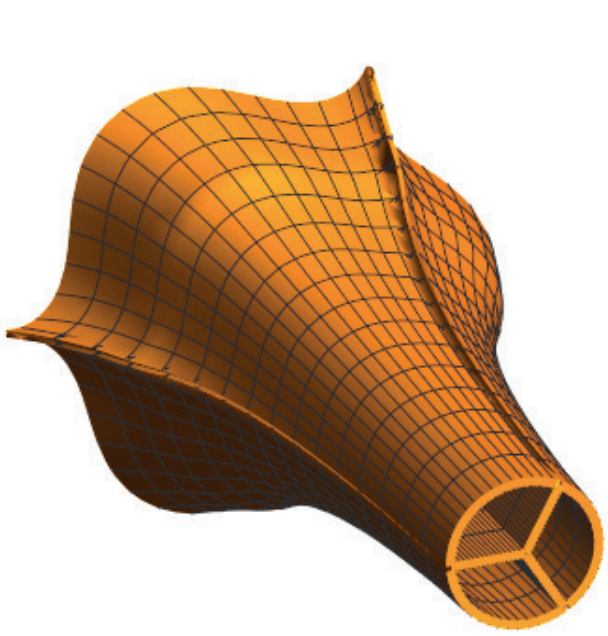
John Fitzgerald is investigating the applicability of temporal network analysis techniques to publication data with the aim of gaining insights into the process of knowledge production in collaboration with Elsevier. The size of the dataset requires the development of new, more efficient methods. We hope to provide policy suggestions to institutions in the Global South as an outcome of our work.

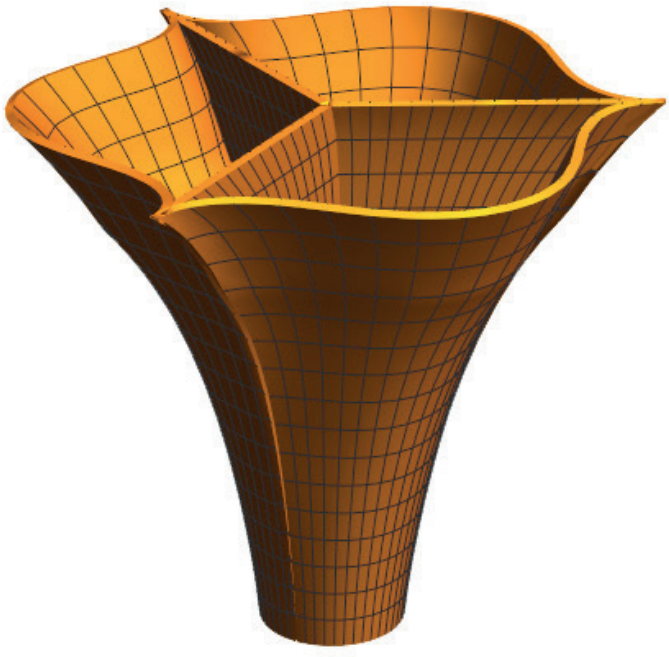
Matthew Shirley's research project is in partnership with Elkem, a major producer of silicon based products. He will be working with Colin Please, Jim Oliver, and Matthew Moore to develop models for the flow of materials and heat transfer in the submerged arc furnaces Elkem uses to produce silicon. The aim of the project is to develop a model to help understand the effect of changes in properties of the raw materials on conditions in the furnace.

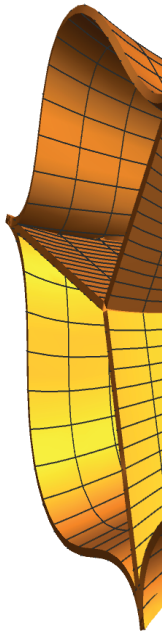
Yu Tian's research lies in the area of networks science and complex systems, including graph modelling, role structure extraction, and further the mechanism when changing the range of nodes in the network. Her industrial partner is Tesco. We are also very keen to combine networks with the knowledge from other areas like information theory.

Arkady Wey's research on modelling filtration is a collaborative project between Oxford and WL Gore & Associates. The project involves the derivation and solution of differential equations that describe changes to the size-dependent densities of particles in the feed solution and pores in the filter material during filtration. The aim is to develop a filtration regime that optimizes important filter properties, such as efficiency and lifetime.

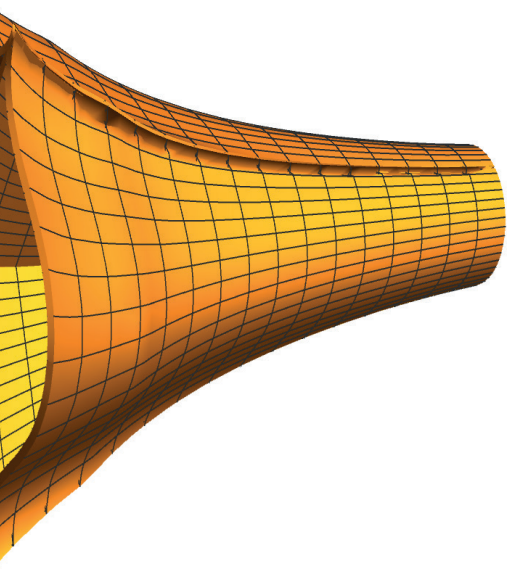
Cheerios, Dyson & Smartphones







Our newest appointee to OCIAM, as Professor of Industrial Mathematics is Ian Griffiths, who was both a student and postdoc in OCIAM. He describes some of the recent challenges that his team and his collaborators have been working on.



Drawing of a microstructured optical fibre with a tri-junction cross-section.

Industrial processes offer a playground of interesting mathematical challenges, which is one of the reasons why OCIAM has had so many success stories. Industrial collaborations have the dual advantage of providing industries with answers, which allow them to overcome a particular technological hurdle, while also providing mathematicians with new challenges, which often involve the development of new mathematical approaches.

Ian Griffiths will be delivering the Oxford Mathematics Public Lecture on 13th February 5-6pm in L1, 'Cheerios, iPhones and Dysons: going backwards in time with fluid mechanics.'

Please email **external-relations@maths.ox.ac.uk** to register.

1. Optical fibres

Project Team

Oxford: Christiana Mavroyiakoumou (MSc Student) and Prof. Peter Howell

Christiana tackled a problem concerning the manufacture of microstructured optical fibres. The air channels in such fibres can be arranged in a multitude of patterns, offering adaptable optical properties. Such fibres are made using an extrusion process whereby liquid glass is pumped through a hole or die, and drawn off. Surface tension causes the cross-section to evolve and so the final product does not necessarily match the profile of the die. We therefore ask, 'what die shape should we use to fabricate a given microstructured optical fibre?'

Christiana derived equations for the evolution of threads of thin viscous liquid, which are joined together to form junctions. Exploiting the slenderness of the tubes that are manufactured allows us to derive a problem that is well posed for negative time, meaning that we can consider the shape of the final product we want and then run time backwards to determine the die shape required to generate a given tube shape.

2. Smartphones

Project Team
Oxford: Dr Doireann O'Kiely (DPhil Student now at Limerick), Prof. Chris Breward, Prof. Peter Howell
Schott AG: Dr Ulrich Lange

Doireann O'Kiely worked with specialist glass company Schott AG on the manufacture of ultra-thin glass sheets for smartphones and tablets. Such sheets are fabricated by stretching a glass block in a heater zone. However, during this process, the edges of the sheet gather in, resulting in 'fat edges' in the final product, which must be wastefully and laboriously cut off before the sheets can be used. Doireann used asymptotic analysis to derive a model that both explained the appearance of these edges and predicted how to optimize the initial block shape to eliminate them. Her theory is now used in Schott's manufacturing process for glass used in smartphones, augmented reality devices and fingerprint sensors.

3. Vacuum cleaners

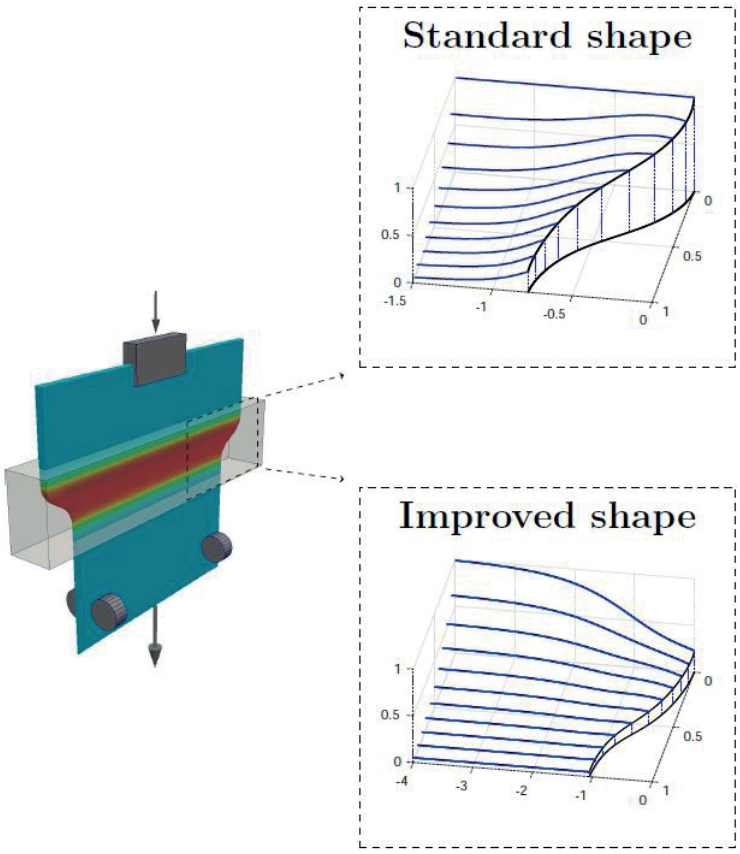
Project Team
Oxford: Galina Printsypar (postdoc) Dr Maria Bruna (Research Fellow now at Cambridge)
Dyson: Dr Gareth Morris, Dr Tom Grimble, Ben Hovell

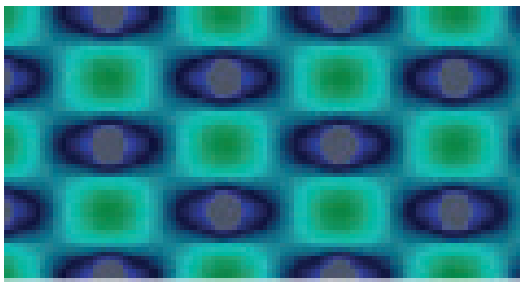
If you've ever replaced the filter in your vacuum cleaner you will have seen that it is composed of a 'non-woven medium' – a fluffy material comprising many fibres laid down in a mat. These fibres trap dust particles as contaminated air passes through, protecting the motor from becoming damaged and clogged by the dust. A key question that Galina addressed along with collaborators at Dyson is to understand how the arrangement of the fibres in the filter affects its ability to remove dust. Galina tackled this question using homogenization theory to derive reduced models that she then solved using finite-element methods. The results of the model now feature in in-house codes in Dyson.

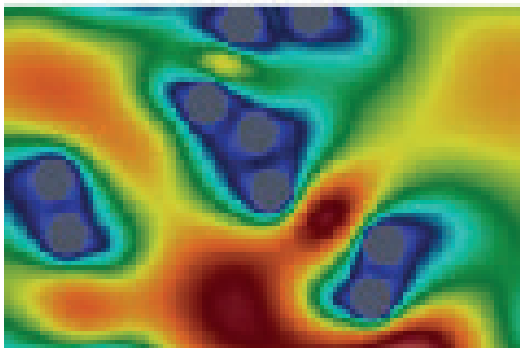
4. Smart Separations

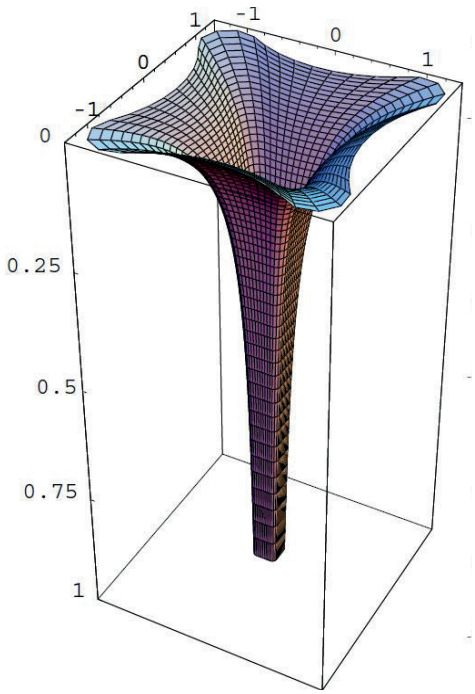
Project Team
Oxford: Tori Pereira (postdoc), Meredith Ellis (DPhil Student), Dr Mohit Dalwadi (Hooke Fellow)
Smart Separations: Dr Hugo Macedo, Dr Enrique Ruiz-Trejo

Smart Separations Ltd are a start-up company who have developed a novel fabrication method for ceramic membranes with micron-sized conical pores. The membranes offer great potential in the field of separation of blood and the removal of dust and pollen from the air. Tori and Meredith are working with Smart Separations to explore and quantify the behaviour and performance of the membrane and its link to the underlying pore structure using mathematical modelling. Their approach involves model reduction based on the slenderness of the pores to obtain a tractable model that enables them to perform comprehensive parameter sweeps to determine optimal operating regimes for a given filtration challenge.

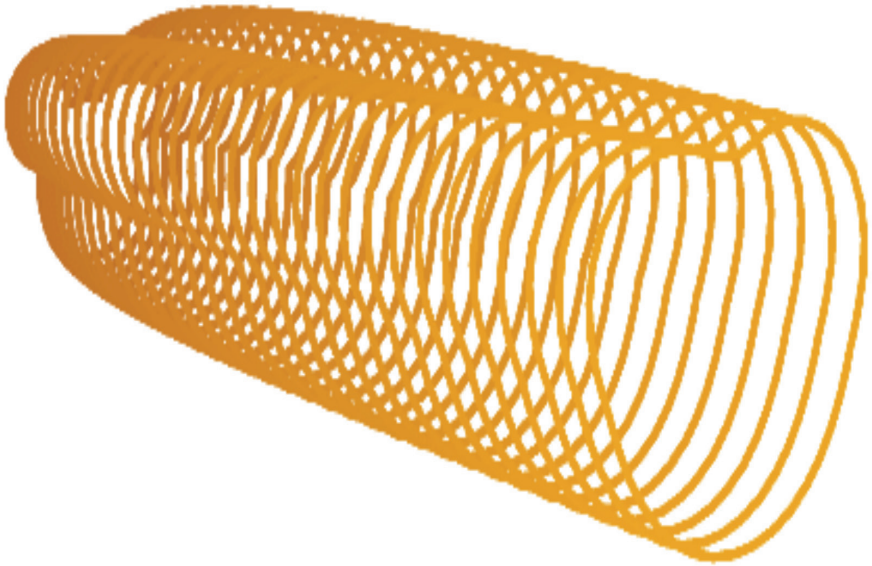








Above. Mathematical model prediction for the evolution of a rectangular glass preform as it is stretched and drawn in a redraw furnace. The resulting sheets have thick edges. In the lower right panel we begin with an optimally shaped glass preform for which the final sheets have uniform thickness. **Right.** Randomly arranged obstracles in a filter (right) lead to channel flows that improve performance compared with periodic arrangements.



Above. Extruding cereal mixture from a Mickey Mouse-shaped die.
Below. A laterite-based arsenic filter in a family home in India.

5. Cheerios

Project Team
Oxford: Michael McPhail (DPhil Student), Prof. Jim Oliver
Nestlé: Dr Ritchie Parker

How do you make a star-shaped Cheerio? Cheerios are manufactured via an extrusion process similar to that used for the manufacture of glass tubes (p5). However, here we gave the added complication that the liquid has a much more complex rheology and undergoes signficant expansion due to bubble nucleation as it is extruded and cools to form the final product.

Michael worked with food and beverage company Nestlé to derive models for the evolution of liquid cereal mixture and the internal bubble evolution as it passes through and out of the die and is drawn off to make the final cereal product. The results of this work can be used to understand how we improve the manufacture process of products, such as Nestlé's Alphabet cereal. The work might also provide guidance into how the operating regime affects the 'mouth feel' of the product.

6. Water purification

Project Team
Oxford: Dr Lucy Auton (postdoc), Dr Sourav Mondal (postdoc), Dr Raka Mondal (postdoc - now Indian Institute of Petroleum & Energy)
IIT Kharagpur: Prof. Sirshendu De

The Ganges–Brahmaputra Delta is a global hotspot for arsenic groundwater contamination. Naturally occurring arsenic concentrates occur in water drawn from deep wells. This has been described as the largest mass poisoning of a population in history. A novel technology has been discovered by Sirshendu De, which uses naturally abundant laterite soil to filter arsenic. This technology has the potential to provide a global breakthrough, supplying clean water to the world.

We have developed a mathematical framework using homogenization theory and asymptotic analysis that distils the complex process into a simple predictive tool. We predict how frequently filters must be replaced, and how the filters may be upscaled to serve, for example, a school or community. Filters now serve more than 5000 people, with 40 community-scale filters being installed in Bangladesh and India. We are now working to develop applications of our ressearch to remove fluoride and the reactive dyes used in the textile industry.

Above. SO_2 Illustration by Zdenek Sasek
Credit:Getty Images/iStockphoto
Right. PM5544: common PAL test pattern

7. Sulphur dioxide

Project Team
Oxford: Kristian Kiradjiev (DPhil Student), Prof. Chris Breward
Gore & Associates: Dr Uwe Beuscher and Dr Vasudevan Venkateshwaran

In the drive to protect the environment, reducing the concentrations of harmful chemicals that are released into the atmosphere has become a priority for industries. One key example is the removal of sulphur dioxide (SO_2) from flue gas.

Most existing methods for the removal of SO_2, such as 'gas scrubbing', require high input power and a specifically suited operation site. Kris works in collaboration with W.L. Gore and Associates on a more desirable and cost-effective method of removal of SO_2: flue gas flows through stacks of parallel open channels and diffuses into their porous surface, where a chemical reaction takes place and converts SO_2 into liquid sulphuric acid. This method requires very low input power, does not need a special operation site, and generates sulphuric acid for free.

However, these filters exhibit one main problem: as liquid sulphuric acid accumulates, it gradually blocks the filter and limits its subsequent efficiency. Kris is developing a multi-scale mathematical model that couples an understanding of how liquid sulphuric acid evolves on the microscale with a device-scale model to predict the global filter properties such as its efficiency over time. The result of our model will inform the future design of Gore's filters to maximize their lifetime.

8. Preventing image burn in LCD devices

Project Team
Oxford: Oliver Whitehead (DPhil Student), Prof. Colin Please
Strathclyde: Prof. Apala Majumdar
Merck: Dr Leo Weegels

You might remember the old CRT monitors that suffered from image burn if you left an image on the screen for too long and which led to the introduction of screensavers. With the replacement of CRT monitors with LCD versions, this problem has been largely eliminated. However, image burn remains an issue for LCD screens that are left on a single image for many hours. While these effects are not permanent like in CRT monitors, they can still remain for minutes and are thus undesirable. Moreover, their origin is currently unclear, but it is thought to be due to the interplay between the liquid crystal orientation under the applied electric field and ion transport within the liquid crystal.

Oliver is working in collaboration with pharmaceutical company Merck to understand the origin of these image-sticking effects by combining the Leslie–Ericksen framework with models for ion transport.

ECMI

European Consortium for Mathematics in Industry

Anile-ECMI Prize for Mathematics in Industry - for DPhil Students

The Anile-ECMI Prize for Mathematics in Industry was established honouring Professor Angelo Marcello Anile (1948-2007) of Catania, Italy. The prize is jointly funded by ECMI and by the Angelo Marcello Anile Association. It consists of a prize of 2500 Euros and an invitation to give a talk at the ECMI conference. The prize is given to a young researcher for an excellent PhD thesis in industrial mathematics successfully submitted at a European university.

Hansjörg Wacker Memorial Prize - for Masters Students

The Hansjörg Wacker Memorial Prize was established in memory of ECMI founding member Hansjörg Wacker (1939-1991), who was Professor of Numerical Mathematics at the Johannes Kepler University, Linz. The prize is jointly funded by ECMI and by a consortium of institutions from Linz which comprise the Industrial Mathematics Institute and the Institute of Computational Mathematics of Johannes Kepler University, and the Johann Radon Institute for Computational and Applied Mathematics of the Austrian Academy of Sciences. It consists of a prize of 1000 Euros and the invitation to attend the ECMI conference presenting his/her project as a contributed talk. The prize is awarded for the best mathematical dissertation at the Masters level on an industrial project, which was submitted at an ECMI institution.

Call for nominations for Prizes to be awarded at the next ECMI conference.

Deadline for applications: 15 April 2020

Award announcement: 22-26 June 2020.

ECMI 2020

21st Conference on Industrial Mathematics, University of Limerick

22 - 26 June 2020

The main areas of application to be covered by the conference include:
Applied Physics
Manufacturing
Biology and Medicine
Cybersecurity
Data Science
Economy, Finance, and Insurance
Energy
Production Systems
Social Challenges
Vehicles and Transportation

The series of ECMI conferences are devoted to enforcing the interaction between academy and industry, leading to innovations in both fields.

DEADLINES
MINISYMPOSIA
Monday 3rd February 2020

CONTRIBUTED TALKS / POSTERS
Friday 13th March 2020

ECMI Member Early Bird - €440.00
ECMI Non Member Early Bird - €520.00
Student Early Bird - €290.00

Details on the ECMI2020 website.

Study Groups

Roses are red,
Violets are blue.
Can Industrial Maths
solve the problem for you?

Knowledge Transfer Network

ESGI 157

Fontys in Tilburg, Netherlands
27 - 31 January 2020

ESGI 158

Centre de Recerca Matemàtica, Barcelona
27 - 31 January 2020

ESGI 159

ECMI 2020 conference, University of Limerick, Ireland
22 - 24 June 2020

ESGI 162

University of Leeds, UK
20 - 24 July 2020

ESGI 161

ISEL, Lisbon, Portugal
6-10 July 2020

ESGI 160

Danish Technical University, Denmark
17 - 21 August 2020

IPSW

10th Industrial Problem Solving Workshop
University of Montreal
17 - 21 August 2020

IPSW

Industrial Problem Solving Workshop
Université d'Orléans
27 - 31 Jan 2020

Study Group with Industry

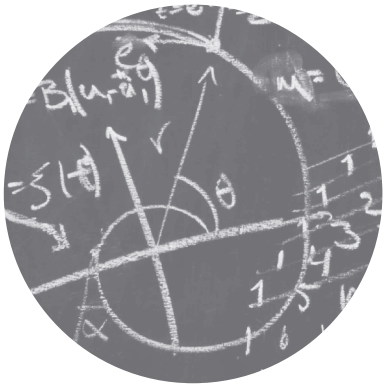
Clean & Sustainable Growth
University of Nottingham & Knowledge Transfer Network
20-22 April 2020

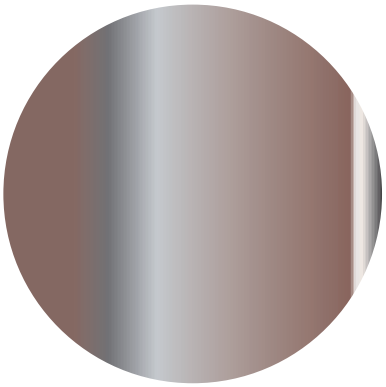
MPI

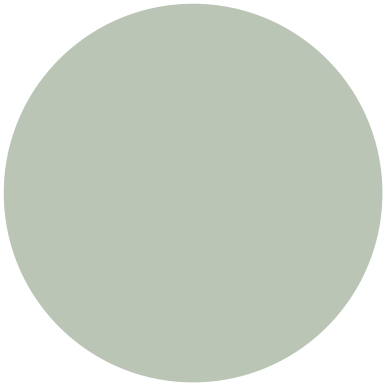
Mathematical Problems in Industry
University of Vermont, USA
15 - 19 June 2020

OCIAM-relevant seminars, talks and colloqiua are listed here.

Events







OCIAM Seminars

30 Jan **Susana Gomes**
University of Warwick

6 Feb **Oliver Jensen**
University of Manchester

13 Feb **Panos Kevrekidis**
University of Massachusetts

20 Feb **Marie Elizabeth Rognes**
Simula Research Laboratory

27 Feb **Peter Howell**
University of Oxford

5 Mar **Valentina Balbi**
University of Limerick

12 Mar **Elizabeth Guazzelli**
MSC CNRS Universite de Paris

Talks take place on Thursdays at 4pm in L3. Titles and abstracts can be found on the **website**.

Computational Finance
Seminars

30 Jan **Samim Ghamami**
Financial Services Forum & NYU

6 Feb **Jean Philippe Bouchard**
CFM & Ecole Polytechnique

13 Feb **Christophe Siebenbrunner**
University of Oxford

20 Feb **Frontier in Quantitative Finance**
Marco Avellaneda

27 Feb **Zihao Zhang**
University of Oxford

5 Mar **Yufei Zhang & Anastasia Borovykh**
Oxford & Centrum Wiskunde

12 Mar **Christina Zou**
University of Oxford

Talks take place on Thursdays at 2pm in L4. Titles and abstracts can be found on the **website.**

Math Bio & Ecology
Seminars

31 Jan **Dr. Shelby Wilson**
University of Maryland

7 Feb **Dr. Tom Thorne**
University of Reading

14 Feb **Dr. Jonathan Wagg**
Roche Pharmaceutical Research

21 Feb **Ann Seigel**
University of Oxford

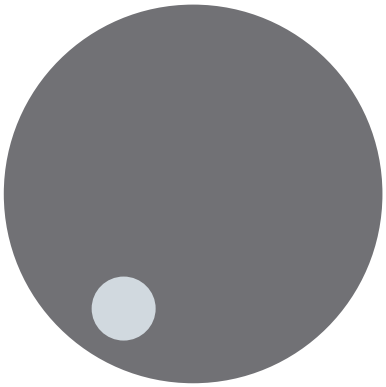
28 Feb **Dr. Rina Ariga**
University of Oxford

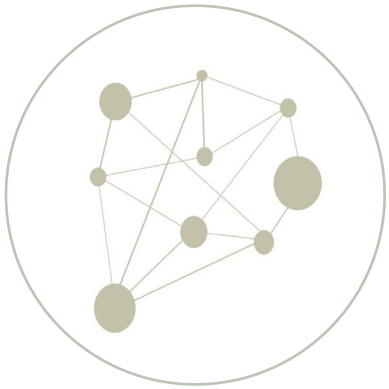
6 Mar **Prof. Adriana Dawes**
Ohio State University

13 Mar **Prof. Aan Garfinkel**
UCLA

Talks take place on Fridays at 2pm in L3 Titles and abstracts can be found on the **website.**

If you would like your event listed please get in touch.





Data Science
Seminars

24 Jan Geovani Grapiglia
Universidade Federal do Paraná

Talks take place on Fridays at 12pm. There will be seminars this term, please keep a look out on the **website.**

Networks
Seminars

28 Jan Justine P Coon
University of Oxford
11 Feb Ivan Kryven
Universitat Utrecht
25 Feb Marya Bazzi
Alan Turing Institute
3 Mar Vincenzo Nicosia
queen Mary University
10 Mar Fernando Rosas
Imperial College
7 Apr Florian Klimm
Imperial college

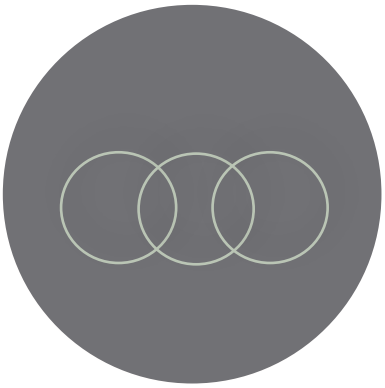
Talks take place on Tuesdays at 12pm in C1 Titles and abstracts can be found on the **website.**

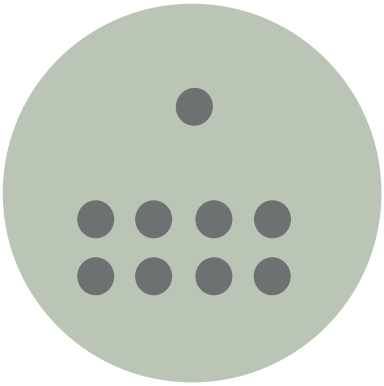
Computational Math & Applications
Seminars

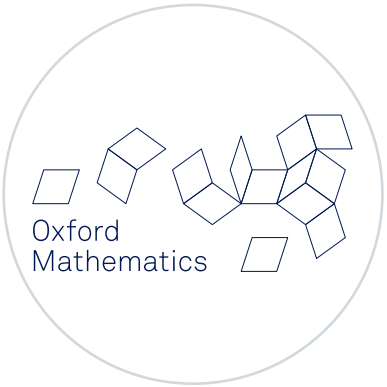
30 Jan Iain Duff
Rutherford Appleton Laboratory
6 Feb Raphael Hauser
University of Oxford
13 Feb John Hauenstein
University of Notre Dame
20 Feb Francesco Tudisco
Gran Sasso Science Institute GSSI
27 Feb Gunnar Martinsson
University of Texas at Austin
5 Mar Catherine Powell
University of Manchester
12 Mar TBC

Talks take place on Thursdays at 2pm in L4. Titles and abstracts can be found on the **website.**

Events







Industrial & Interdisciplinary
Workshops

31 Jan Michael Ostroumov
Value Chain Lab

Fast algorithms for a large-scale multi-agent Travelling Salesman Problem

14 Feb Juan Reveles
Oxford Space Systems

Membrane form finding for foldable RF reflectors on satellites

Talks take place on Fridays at 10am in L3. Abstracts can be found on the **website.**

Special Lectures

Reddick Lecture
Professor Eddie Wilson (Bristol)

Systems Thinking and Problem Solving: Value-based Approaches to Mathematical Innovation

Friday 20 March 4.10pm
Bernard Sunley Lecture Theatre
St Catherine's College.
Details here

Brooke Benjamin Lecture in Fluid Dynamics
Prof Beverly McKeon
McKeon Group Caltech

Friday 28 April 5pm
Mathematical Institute, L3
Followed by a drinks reception
Details here

Oxford Mathematics
Public Lecture

30 Jan Henry Segerman
Oklahoma State

Artistic Mathematics: truth and beauty

This lecture is about mathematical visualization: how to make accurate, effective, and beautiful pictures, models, and experiences of mathematical concepts. What is it that makes a visualization compelling?

Henry will show examples in the medium of 3D printing, as well as his work in virtual reality and spherical video. He will also discuss his experiences in teaching a project-based class on 3D printing for mathematics students.

5.00pm-6.30pm, L1
Please email **external-relations@maths.ox.ac.uk** to register.

The Oxford Mathematics Public Lectures are generously supported by XTX Markets.

Oxford Mathematics
Public Lecture

13 Feb Ian Griffiths
University of Oxford

Cheerios, iPhones and Dysons: going backwards in time with fluid mechanics

How do you make a star-shaped Cheerio? How do they make the glass on your smartphone screen so flat? And how can you make a vacuum filter that removes the most dust before it blocks? All of these are very different challenges that fall under the umbrella of industrial mathematics.

Ian Griffiths is a Professor of Industrial Mathematics and a Royal Society University Research Fellow in the Mathematical Institute at the University of Oxford.

5.00pm-6.30pm, L1
Please email **external-relations@maths.ox.ac.uk** to register.

The Oxford Mathematics Public Lectures are generously supported by XTX Markets.

Oxford Mathematics
Public Lecture

11 Mar Alan Champneys
University of Bristol

Why pedestrian bridges wobble - synchronisation and the wisdom of the crowd

There is a beautiful mathematical theory of how independent agents tend to synchronise their behaviour when weakly coupled. Examples include how audiences spontaneously rhythmically applause and how nearby pendulum clocks tend to move in sync. Another famous example is that of the London Millennium Bridge. On the day it opened, the bridge underwent unwanted lateral vibrations that are widely believed to be due to pedestrians synchronising their footsteps.

In this talk Alan will explain how this theory is in fact naive and there is a simpler mathematical theory that is more consistent with the facts.

5.00pm-6.30pm, L1

Please email **external-relations@maths.ox.ac.uk** to register.

BMC-BAMC
Glasgow

The next joint meeting of the **British Mathematical Colloqium (BMC) and the British Applied Mathematics Colloquium (BAMC)** will be held at the University of Glasgow,

Monday 6th - Thursday 9th April 2020.

Registration is open (see **Registration Page** for details)

The call for BMC-BAMC contributed Talks & Posters is now open. Further details are available **here**
Deadline 31st January

Provisional details of BMC sessions and BAMC mini-symposia are available on the **Programme page.**

cover image by the IBM Group ©