Bulletin#19

Trinity 2021

OXFORD CENTRE FOR INDUSTRIAL & APPLIED MATHEMATICS

University of Oxford Mathematical Institute, Andrew Wiles Building



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cover image: Oxford Collaborations in **Applied Mathematics by Renaud Lambiotte.**





Zhaohe joins us from his PhD at the University of Texas at AU. He is a Marie Curie Fellow working on liquids confined Zhaohe Dai by solid sheets. His bachelor's degree was in Theoretical and Applied Mechanics from University of Science and Technology of China in 2013. Mingchao joins us as a Newton International Fellow, sponsored by the Royal Society. He graduated from Tsinghua University in 2018 with a PhD in Engineering from the Dep. of Engineering Mechanics. His current research is focused on elastic instabilities and their applications in morphing structures and mechanical metamaterials **Ellen** is already here, currently a third year graduate in the EPSRC INFOMM CDT. From 1st September this year she will be working as a post-doc with Chris Breward, Ian Griffiths and Colin Please.





Mingchao Liu **Ellen Luckins**

"Science is not finished until it is communicated."

Sir Mark Wolpert, former medical scientist and Chief Executive of UKRI.

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This term's OCIAM Bulletin says good riddance to languishing in lockdown. We say hello to newcomers and a bittersweet farewell to OCIAM folks who, despite this year's restrictions are moving onwards and upwards. We learn about levitating cylinders from Hilary and John Ockendon and collaborators. We take a closer look at the work of the European Consortium of Maths in Industry (ECMI)

We give details of a few Summer Study Groups with Industry that are planning to run, pending COVID restrictions. Together with details of a new repository called Maths in Industry Reports (MIIR) that makes reports from Study Groups with Industry easier to find.

We congratulate OCIAM early career researchers (ECRs)who have scooped up prizes for communicating their research in the form of a thesis, article, talk or poster this year. Prizes are a positive addition to

your cv, that often offer cash prizes and an opportunity to present your research. So why not have a go? We've listed a number of competitions that you can register for in the coming year. The call for nominations for ICIAM prizes is now open. The deadline is 31st May. Each prize provides international recognition to a mathematician who has demonstrated originality in applied mathematics. There are six prizes each with it's own particular emphasis detailed here.

ICIAM prizes are awarded in connection with the ICIAM Congresses. Prize winners are selected by the ICIAM Prize Committee. The 2023 ICIAM Prizes will be awarded during the Opening Ceremony of the ICIAM 2023 Congress in Tokyo, on August 20, 2023.

OCIAM & Levitation



FIG 1.

THE AUTHORS HILARY OCKENDON & JOHN OCKENDON ARE FOUNDING MEMBERS OF OCIAM. THEY ARE EMERITUS PROFESSORS IN THE MATHEMATICAL INSTITUTE. UNIVERSITY OF OXFORD.

The idea of levitation – i.e. a solid object, with stationary centre of gravity, defying gravity without apparent support – has long been a source of fascination. Electrostatic and magnetic forces were thought to be possible mechanisms until 1842 when Earnshaw proved that the levitated object would always be unstable (unless, say, it was spinning fast enough about a vertical axis). Nowadays Maglev trains are in regular use and the possibility of the magnetic levitation of cars was a problem brought to a Malaysian Study Group recently.

Added impetus came with the silicon revolution, where chip manufacturers had to transport thin sheets around factories without physical contact with solid materials. One way to do this was by putting the sheets on a porous horizontal table through which high speed air jets were fed so that the Bernoulli pressure overcame gravity. Indeed this project formed part of Gregory Kozyreff's postdoctoral work with Pilkington in OCIAM in 2004 [1]. By contrast in DAMTP they were studying the levitation of horizontal sheets using the lubrication pressure exerted by a horizontal viscous film [2].



Soon after this Tom Mullin, who was in Manchester, started experimenting on levitating circular cylinders on a viscous sheet which coated a vertically moving belt (Fig 1). The fact that levitation could be possible was reinforced by the fact that the mathematical model was the same as that for a cylinder rolling down a vertical wall coated with a viscous layer, a problem that has its own literature.

Unfortunately both of these problems proved difficult to analyse mathematically for two reasons. Not only did the angular velocity of the cylinder need to be determined but also the length of the lubrication region in the nip (Fig 2) had to be determined as part of the problem and this region provided most of the force needed to levitate the cylinder. Thus it fell into the category of a cavitation problem

in lubrication theory, a subject that goes back to Reynolds. Indeed one candidate for the extra information needed to complement the pressure condition at the nip ends is Reynolds criterion. OCIAM has contributed to work on this and related problems [3]. Five years later, when Tom was in Oxford, the principle of 'doing the easiest problem first' was invoked and led us to revisit the levitation of a cuboidal block, a configuration that Tom had already looked at experimentally. The block was far easier to analyse than the cylinder because the lubricating film could be assumed to cover exactly one face of the block (Fig 3) but the analysis revealed three

unexpected features.

READ THE FULL SCIENTIFIC PAPER HERE. THE LATEST PAPER FEATURED IN NATURE INCLUDES A FILM THAT SHOWS HOW A SPINNING CYLINDER CAN LEVITATE HERE

1. The dominant levitation force was provided by the shear in the film because the lubrication pressure is almost atmospheric.

2. When the forces are balanced against the weight of the block it was found that there is a precise value of the belt speed that will levitate a stationary block.

3. The block will also levitate at lower belt speeds if a slowly growing 'tongue' of liquid forms beneath the block (Fig 4).

Fortunately these features can all be explained using Reynolds equation between the block and the wall and with a 'free surface' thin film to describe the tongue [4].





Emboldened by this success, Tom, aided by Lucie Domino in the observatory, returned to the cylinder problem despite its theoretical challenges. Fortunately two invaluable young researchers in the form of Mohit Dalwadi and Radu Cimpeanu were willing to get involved. Mo brought his strong asymptotic expertise and leadership skills to the whole project and Radu's involvement enabled the use of vast computational power to help understand the free boundary problem at the end of the nip region. We could thus join the flow in the nip not only to the fluid on the belt but also to the thin film that coats the rotating cylinder. This in turn showed that levitation was now brought about by the asymmetric

lubrication pressure in the nip and that, for light enough cylinders, tongue formation again occurs. Moreover the results agreed really well with the earlier Manchester experiments [5].

The major mathematical payoff has been the identification of the canonical cavitation free boundary problem for the two-dimensional biharmonic equation that describes the flow near the two ends of the nip (it can be thought of as a 'biharmonic Saffman-Taylor problem'). Many conjectures have been made about the well-posedness of this model under various upstream and downstream boundary conditions but in our case, Radu's computation gives compelling evidence for the well-posedness of the free boundary problem.

- A. D. Fitt, G. Kozyreff, and J. R. Ockendon, Inertial levitation, J. Fluid Mech, 508,165(2004).
- 2. E.J.Hinch and J.Lemaitre, The effect of viscosity on the height of disks floating above an air table, J. Fluid Mech, 273, 313 (1994).
- M.Taroni, C.J.W.Breward, P.D.Howell and J.M.Oliver, Boundary conditions for free surface inlet and outlet problems, J.Fluid Mech.708,100(2012).
- T. Mullin, H. Ockendon and J. R. Ockendon, Levitation by thin viscous layers, J.Fluid Mech. 888, A17 (2020).
- 5. Mohit P. Dalwadi, Radu Cimpeanu, Hilary Ockendon, John Ockendon and Tom Mullin, Levitation of a cylinder by a thin viscous film, J.Fluid Mech.917, A28 (2021).

MIR

Mathematics in Industry Reports (MIIR)

is a new website hosted by Cambridge Open Engage for reports produced from numerous study groups with industry. The reports are fully searchable, and cover all industrial sectors as listed right:

Reports are moderated by an international team led by OCIAM's Chris Breward and Hilary Ockendon.



AEROSPACE
AGRICULTURE/FISHERIES
BIOMEDICAL/HEALTHCARE
• CHARITIES
• CHEMICAL
COMMUNICATIONS/NETWORKS
• COMPUTING/ROBOTICS
• CONSTRUCTION
DATA ANALYSIS
• DEFENCE
• ELECTRONIC
ENERGY/UTILITIES
• ENVIRONMENT
• FINANCE
FINANCEFOOD & DRINK
 FINANCE FOOD & DRINK GOVERNMENT
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING MECHANICS
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING MECHANICS PHARMACEUTICALS
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING MECHANICS PHARMACEUTICALS RETAIL
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING MECHANICS PHARMACEUTICALS RETAIL SOCIAL
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING MECHANICS PHARMACEUTICALS RETAIL SOCIAL SPORTS
 FINANCE FOOD & DRINK GOVERNMENT LOGISTICS MANUFACTURING MATERIALS PROCESSING MECHANICS PHARMACEUTICALS PHARMACEUTICALS RETAIL SOCIAL SPORTS TEXTILE/CLOTHING/FOOTWEAR

ECMI

The European Consortium for Mathematics in Industry was founded in 1987. OCIAM is a member of the ECMI network of 112 academic institutions and industrial companies in 26 European countries and Israel.

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ECMI promote and support the use of mathematical modelling, simulation and optimization in industry. The main pillars of their efforts are education, research and outreach.

To educate mathematicians to meet the growing demand for such experts the ECMI overseas 20 masters programmes in Industrial Mathematics, as well as the modelling weeks and summer schools.

To promote research the ECMI provides seed funding to special interests groups (SIGs) that bring together scientists from academia and industry.

You can also set up your own SIG. View current SIGS here.

European Study Groups with

Industry (ESGI) are week-long meetings that focus on current industrial problems; genuine mathematical challenges that often lead to substantial spin-offs in industry. The ECMI supports first-time organisers of ESGI's with seed funding. There's a new Maths in Industry Reports (MIIR) website

(details opposite) that contains the mathematical problems encountered in study groups with industry over the vears.

Other outreach activities include prestiguous prizes, and the bi-annual conference . You can watch from this year's conference Ian Griffiths and Katarina Kaouri's talk on 'Modelling COVID-19 Transmission in indoor spaces" on the ECMI youtube channel. There is also an **ECMI blog** which all EMCI nodes contribute to on topics relevant to industrial and applied mathematics.

ESGI 163

Santiago de Compostela

12 - 16 July 2021

VIRTUAL Registration is free. REGISTER here BY 31ST MAY

ESGI 160

Danish Technical University

16 - 20 Aug 2021 Further details **here** **ESGI 161**

ESGI 156

Alesund, Norway

Further details **here**

7 - 11 June 2021

ISEL, Lisbon, Portugal

Summer 2021 Further details **here**



Professor of Industrial Mathematics Ian Griffiths takes over from Prof. Andreas Muench as Oxford's ECMI coordinator.





European Study Groups with Industry (ESGI) originated in Oxford in 1968, under the name of Oxford Study Groups with Industry, continue to be hosted all around the world.

37th Mathematics **Problems in Industry** Workshop

University of Vermont

14-18 June 2021 contact Taras.Lakoba@uvm.edu

Prizes

ICIAM call for nominations is now open. APPLY

The Anile-ECMI Prize

Is given to a young researcher for an excellent PhD thesis in industrial mathematics successfully submitted at a European university. It was established in honour of Professor Angelo Marcello Anile (1948-2007) of Catania, Italy and consists of a monetary prize of 2500 Euros and an invitation to give a talk at the ECMI conference. Look out for a call on the ECMI website in January each year to apply for the prize.

BMC/BAMC

The British Mathematical Colloquium (BMC) and the British Applied Mathematics Colloquium (BAMC), hosted this year (virtually) by the University of Glasgow, awards prizes for the best early career researcher talks and posters. The call to register for both competitions coincides with the call to attend the Spring conferences.

ICIAM

The ICIAM Prize Committee for 2023 calls for nominations for the six ICIAM Prizes to be awarded in 2023 (the Collatz Prize, the Lagrange Prize, the Maxwell Prize, the Pioneer Prize, the Su Buchin Prize, and the Industry Prize). Each ICIAM Prize has its own special character. For more information, see the Council's **web page**.

IMA Lighthill–Thwaites Prize

This biennial prize was established by the IMA in recognition of the achievement of its first two Presidents – Professors Sir James Lighthill and Sir Bryan Thwaites. The prize is given for a piece of written work and a talk at BAMC that describes an aspect of the candidate's research in applied mathematics. All finalists will be expected to submit an article for publication in the IMA Journal.

STEM FOR BRITAIN

STEM for Britain is an annual poster competition, open to early career researchers (ECR) in Science, Technology, Engineering and Maths. The annual event is run by the House of Commons Parliamentary Scientific Committee. The competition provides an opportunity for ECRs to present their posters and winners receive Gold (£2000), Silver (£1200) or Bronze (£750) Awards. The overall aim is to encourage, support and promote ECR's. The call for applications opens in October each year.

SMITH INSTITUTE TakeAIM

Established in 2011, the Smith Institute's annual TakeAIM competition is an opportunity for university students to showcase their work on the industrial stage. TakeAIM's goal is to highlight the crucial role mathematics plays in solving real-world problems while rewarding the academic exploration of future innovators who undertake pioneering research. Summarise your research in 250 words for the chance to win £1000. Make a note in your diary to apply in November 2021.

SIAM Richard C DiPrima

Established in 1986, this prize is awarded to an ECR who has done outstanding research in applied mathematics and who has completed his/her doctoral dissertation. A cash award of \$2,000 and reasonable travel expenses to the annual meeting will be paid by SIAM. The prize is awarded every even year at the annual meeting of SIAM in July.

GEORGIA BRENNAN STEM for Britain

Georgia Brennan won a silver medal in the Mathematical Sciences category at STEM for Britain 2021 for her poster on 'Mathematically Modelling Clearance in Alzheimer's Disease: A Mathematical Drug Trial for the UK's Protein Pandemic'. She also won poster prizes at the BAMC and Smith Institute's TakeAIM.

Georgias DPhil research is advancing the understanding of the clearance of toxic proteins in Alzheimer's disease by developing, and analysing, the first mathematical network models that include specific modes of clearance.

You can view her poster and abstract here.

MERED

Meredith is a DPhil in OCIAM. She is also now a BMC/BAMC Poster Prize Winner for her entry entitled, 'Predictive models of metabolite concentration for organoid expansion'.

You can view her poster and abstract here.

You can view the work of all the winning entries on the OCIAM website here



MEREDITH ELLIS BMC/BAMC Poster Prize Winner



KRIS KIRADJIEV EPSRC Doctoral Prize

Kristian seems to acquire awards in his sleep. He is a former Gold Medal winner at STEM in 2019, a Graham Hoare Prize winner for a brilliant **Mathematics Today article**, a finalist in the Lighthill-Thwaites Prize 2020, and for his DPhil research - now complete - he was awarded an EPSRC Doctoral Prize postdoctoral fellowship by MPLS division. His research is in the mathematical modelling of flue-gas purification and removal of toxic chemicals from the gas.





HADRIEN OLIVERI IBMTL Presentation

Hadrien Oliveri was awarded best early career researcher presentation at the 6th Oxford International Neuron and Brain Mechanics Workshop in April. His presentation, 'An optic ray theory for nerve durotaxis'. You can watch the full presentation here.

Hadrien is a post-doc in the Oxford Mathematical Brain Modelling group (OxMBM) interested in the morphogenesis of biological systems; more specifically in the dynamic interaction between mechanics, growth and active regulation processes. He is studying the mechanical effects involved in the control of axonal development and pathfinding.



JOE ROBERTS BAMC/BMC Poster Prize Winner

Joe is a DPhil in OCIAM. He is also now a BMC/BAMC Poster Prize Winner for his entry entitled, 'Modelling the Carding of Recycled Carbon Fibre'. You can view his poster and abstract here.



ANA SEIGAL (SIAM) Richard C. DiPrima Prize

Anna Seigal, one of Oxford Mathematics's Hooke Fellows and a Junior Research Fellow at The Queen's College, has been awarded the 2020 Society for Industrial and Applied Mathematics (SIAM) Richard C. DiPrima Prize. The prize recognises an early career researcher in applied mathematics and is based on their doctoral dissertation.

Anna's research interests lie in tensors and multilinear algebra, applied algebraic geometry and algebraic statistics, and their connections to machine learning, numerical analysis, optimization, and computational biology.

She will receive the award at the SIAM Annual Meeting in July in Toronto.



BERNADETTE STOLZ Anile-ECMI Prize

This year's Anile-ECMI Prize was awarded to Bernadette Stolz for her DPhil (PhD). Bernadette developed methods to quantify the unique features of tumour blood vessel networks. She used persistent homology on experimental data from different imaging modalities to validate known treatment effects on the networks and show how the effects of radiation treatments alter the vascular structure.

Bernadette's postdoc affiliated to the Centre for Topological Data Analysis looks at applying persistent homology to quantify the output from mathematical models of angiogenesis.



a Filtration Fix.'

You can view Arkady's paper here.

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You can view the work of all the winning entries on the OCIAM website here

ARKADY WEY Smith Institute Take AIM

Arkady came 2nd in the Smith Institute's "TakeAIM" competition last year for his research into, 'The Contamination Crisis and



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

Events







Data Science Seminars

Richard Samworth 13 May University of Cambridge 3 Jun Ismaël Bailleul Université de Rennes

look out on the **website.**

Talks take place on Fridays at 4pm. There

Networks Seminars

Melanie Weber 11 May Princeton University 8 Jun Mihai Cucuringu University of Oxford

Talks take place on Tuesdays at 2pm will be seminars this term, please keep a Titles and abstracts can be found on the website.

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



Computational Math Seminars

13 May	Karen Willcox
	University of Texas at Austin
20 May	Ragnar Winther
	University of Oslo
27 May	Ulrike Meier Yang
	Lawrence Livermore Laboratory
3 Jun	Ken'ichiro Tanaka
	University of Tokyo
10 Jun	Alan Edelman
	MIT

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



Moving on





MOHIT DALWADI organiser extraordinaire of the IAM seminar and a Hooke Fellow will leave OCIAM over summer to start as an Assistant Professor in the Department of Mathematics at University College London.



LUCIE DOMINO formerly a post-doc in OCIAM is now at the University of Amsterdam for a postdoc. She's working on water wave propagation. And she's still doing experiments!



PIERRE HAAS is now Research Group eader at Max Planck Institutes for the Physics of Complex Systems and of Molecular Cell Biology and Genetics Center for Systems Biology Dresde.

PRIYA SUBRAMANIAN is a Hooke



Fellow in OCIAM. Her next position will be as a Senior Lecturer in the Department of Applied Mathematics, Faculty of Science, University of Auckland. Subject to Covid restrictions and the visa gods Priya will start her new position in September 2021.

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MATT HENNESSEY co-organiser

xtraordinaire of the IAM seminar and a Hooke Fellow will be joining the Department of Engineering Mathematics at Bristol as a lecturer.



ANDREW KRAUSE OCIAM's very own epartmental lecturer is leaving us. He takes up a new post at Durham University in September, as an Assistant Professor in Applied Mathematics.



KRIS KIRADJIEV has moved to Nottingham. He will be a research associate in the plants modelling research group under the supervision of professor Leah Band. He'll be modelling transport of growth hormones in plants with potential applications n the crops industry.



Get in touch with news or ideas for the next Bulletin: kirkham@maths.ox.ac.uk