Isaac Newton Institute
for Mathematical Sciences

Annual Report
2022-2023

UNIVERSITY OF
CAMBRIDGE

Isaac Newton Institute for Mathematical Sciences

The Isaac Newton Institute is an international hub for supporting mathematical sciences research of the highest quality and impact. It aims to attract the world's leading researchers, in all areas of mathematics and its applications, who interact through a variety of long and short thematic programmes as well as associated workshops. Based in Cambridge, and benefiting from a bespoke building and other world leading facilities of this great University, INI is nevertheless an independent forum serving the whole of UK mathematical sciences. INI's environment, and supporting mechanisms, enable its programmes to have a translational effect on their respective research areas.

All INI scientific programmes are carefully designed to allow for novel ideas to be created, nurtured and exchanged. Programme topics cover all areas of mathematics, with increasing focus on emerging intra and interdisciplinary fields, where engagement is with other scientists, social scientists, economists, policy makers etc. The Institute also helps to develop the next generation of mathematical scientists by encouraging participation of young researchers, by widening access, and by addressing the gender gap in mathematics.
The INI has broadened its role in the community in recent years, and informs policy makers and funders about the relevance, value and timeliness of emerging mathematics. Through the Newton Gateway to Mathematics it carries out stand-alone knowledge exchange events, and activities within programmes, aimed at end users of mathematical ideas in commerce, industry, government, and other sciences. Further, it assists universities in achieving their own goals; showcases UK research in the mathematical sciences; and engages with non-mathematicians through public lectures, exhibitions, and other activities for schools and the general public.

Newton Gateway to Mathematics

The Newton Gateway to Mathematics acts as a vehicle for knowledge exchange between the mathematical sciences and potential users of mathematics, including industry, government, business and other academic disciplines, both in the UK and internationally. It does this by facilitating interactions and activities such as programmes of work, research and training events, as well as bespoke projects. The Newton Gateway aims to widen access to mathematics generally, to shorten pathways to impacts for academic research, and to support education and training in areas where mathematical skills are needed.

Director's Foreword

It is hard to believe that only a year ago, the pandemic still had a major impact on INI activities as travel for many of our international visitors remained much restricted. It was not clear to what extent online facilities would replace in-person encounters post-pandemic. But now, just a year later, the Institute has returned to business as usual, only much more so. Our record numbers of visitors for this past year and high numbers of applications for long-term programmes shows the community's hunger for workshops and long-term thematic programmes.

By any measure, this has been a busy year for INI, with activities stretching our capacities. Due to the Additional Grant that the three UK national maths centres received from the EPSRC, we were able to run three instead of our normal two programmes in parallel – two in our much-loved INI building as usual, and one at the nearby Møller Institute, which is part of Churchill College. But while the coffee might be of higher quality and participants have enjoyed working on the terrace at the Møller in the summer sun, it is agreed there is no substitute for the open plan architecture of INI with all its blackboards that invite mathematical discourse and collaboration.

The following report contains detailed descriptions of our 2022-23 programmes. These are important records for us. But for over two years, our Communications Team has collaborated with Plus Magazine to bring the content of our programmes to a broader audience. We have asked journalists Rachel Thomas and Marianne Freiberger to summarise for this annual report their take on the year. I hope that you enjoy their account.

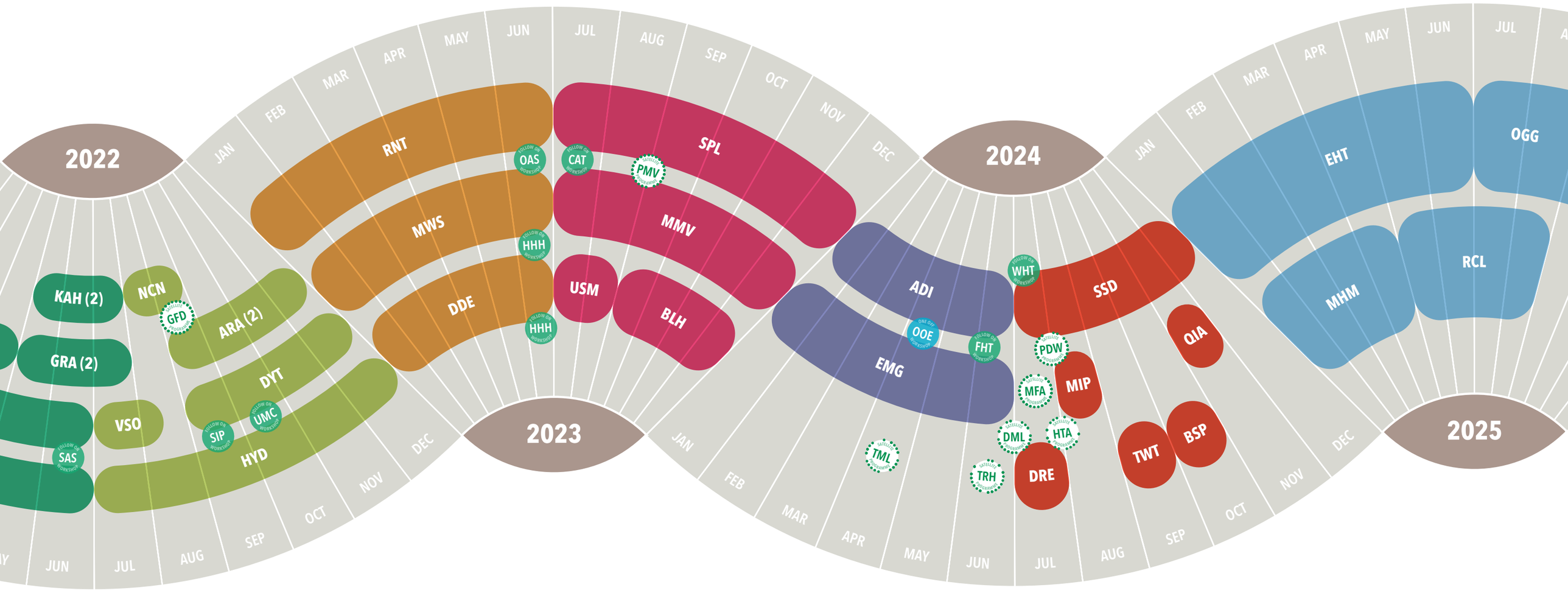
We are determined to ensure that the benefits of INI activities are felt throughout the country. Our new, and popular, *Network Support* scheme is exemplary in this regard. The INI Network grants are considered good value by our Scientific Steering Committee, to whom I am very grateful for taking on the extra burden of evaluating the many applications. Another INI innovation which helps the geographic reach of the Institute is the recent appearance of satellite programmes. In August last year, the first of these programmes under the banner of *"INI@..."* took place in Reading. Scientists from the Met Office met with experts from all over the world for a four-week intensive programme. We hope that future satellite programmes too will shine a spotlight on expert research groups wherever they are in the UK. In August 2023 *"INI@..."* visits Aberystwyth, and for the year 2024, six further satellite programmes are planned.

It was a particular personal pleasure that we could host this year's *Abel in Cambridge* symposium. This is a series of annual celebratory gatherings in conjunction with the Abel Prize Committee's final selection meeting. Our speakers included last year's laureate Dennis Sullivan. Another highlight in our busy calendar was the oversubscribed Newton Gateway event *Communicating mathematics for the public*. This event brought together communicators from a broad spectrum spanning academia, government and the media and included presentations by Hannah Fry, David Spiegelhalter and Tom Whipple to name only a few. With more than 200 participants, this summer's satellite follow-on workshop of the 2018 programme *Homotopy harnessing higher structures* in honour of Mike Hopkins was one of the most attended INI events and included the announcement of the resolution of the 40-year old Telescope Conjecture. This conjecture in stable homotopy theory first stated by Ravenel was actually disproved, and some of our staff were amazed that proving someone was wrong constituted progress in maths. In the meantime, another follow-on workshop was dedicated to the memory of Vaughan Jones, who gave the very first lecture at our first workshop in 1992 and had been a frequent visitor ever since.

This past year has seen quite a few changes in our senior management team. As many of you will be aware, INI's Deputy Director of over ten years, Christie Marr, has been seconded to the Academy for the Mathematical Sciences. I am very pleased we were able to appoint Milla Kibble to take over the Deputy Director's role in the summer. One of Milla's first actions has been to revise and recreate our EDI action plan which we intend to implement in the coming years. After Jane Leeks' departure last summer, Clare Merritt, who will be known to many of you, took over the role in December to lead the Newton Gateway as manager into its second decade. We also welcomed Catherine Hurley as our new Business and Operations Manager. She has now taken over from our wonderful Samantha Skehel, who will put her tremendous experience, skills and good judgement to excellent use developing our special projects of which building a new modern, raked lecture theatre is just one of many.

Ulrike Tillmann

Programme schematic



KAH K-theory, algebraic cycles and motivic homotopy theory

GRA Groups, representations and applications: new perspectives

SAS International conference on computability, complexity and randomness

GFD Geophysical fluid dynamics; from mathematical theory to operational prediction

NCN New Connections in Number Theory and Physics

ARA Applicable resurgent asymptotics: towards a universal theory

VSO Verified software

DYT Frontiers in dynamo theory: from the Earth to the stars

HYD Dispersive hydrodynamics: mathematics, simulation and experiments, with applications in nonlinear waves

SIP Mathematics of sea ice in the twenty-first century

UMC Microbial communities: current approaches and open challenges

RNT Rich and Nonlinear Tomography - a multidisciplinary approach

MWS Mathematical theory and applications of multiple wave scattering

DDE The mathematical and statistical foundation of future data-driven engineering

OAS Operator algebras: subfactors and their applications

HHH A panorama of homotopy theory / Homotopy: fruit of the fertile furrow

SPL New statistical physics in living matter: non equilibrium states under adaptive control

CAT Complex analysis: techniques, applications and computations - perspectives in 2023

PMV GeomPack geometry and packing in material structure and biology

MMV Mathematics of movement: an interdisciplinary approach to mutual challenges in animal ecology and cell biology

USM Uncertainty quantification and stochastic modelling of materials

BLH Black holes: bridges between number theory and holographic quantum information

ADI Anti-diffusive dynamics: from sub-cellular to astrophysical scales

EMG New equivariant methods in algebraic and differential geometry

TML Heavy tails in machine learning

TRH Topology, representation theory and higher structures

OOE Structure and Randomness - a celebration of the mathematics of Timothy Gowers

FHT The intersection of UQ, AI and Digital Twins

WHT The applications, generalisation and implementation of the Wiener-Hopf Method

SSD Stochastic systems for anomalous diffusion

MFA The mathematics of multiphase flows with applications

DRE Discretization and recovery in high-dimensional spaces

DML Diffusions in machine learning: foundations, generative models and non-convex optimisation

HTA Hypergraphs: Theory and Applications

MIP Modelling and inference for pandemic preparedness

PDW Emergent phenomena in nonlinear dispersive waves

TWT Twistor theory

QIA Quantum information, quantum groups and operator algebras

BSP Big Specification

EHT Equivariant homotopy theory in context

MHM Modern History of Mathematics

RCL Representing, calibrating and leveraging prediction uncertainty from statistics to machine learning

OGG Operators, Graphs, Groups

"The participation of 115 junior and senior researchers and the research surveyed across 44 weekly seminars demonstrated the field's broad reach and scope."

Dispersive hydrodynamics: mathematics, simulation and experiments, with applications in nonlinear waves

July - December 2022

Dispersive hydrodynamics has emerged as a unified mathematical framework for the description of multiscale nonlinear wave phenomena in dispersive media, encompassing both dynamic and stochastic aspects of wave propagation. Recent theoretical and experimental developments have opened up new areas for research, with intriguing open issues in both theory and applications. These include the understanding of fundamental regularisation mechanisms of hydrodynamic singularities via the generation of dispersive shock waves and related phenomena. The "Dispersive hydrodynamics" *programme brought together mathematicians, physicists, and engineers specialising in the analysis of dispersive systems, experiments and numerical simulations with the aim to increase the visibility of this burgeoning field and inspire new collaborations.*

A characteristic feature of dispersive hydrodynamics is the dispersive shock wave (DSW), a rank-ordered, expanding, rapidly oscillating wave form that results from the dispersive regularisation of a hydrodynamic singularity. Mathematical challenges in the field abound, including the development of a general analytical framework for DSWs that is akin to conservation law theory for classical shocks, modulation theory and inverse scattering theory for multidimensional dispersive hydrodynamics, the solution of initial value problems for integrable equations with random data, boundary value problems for integrable and non-integrable equations, and the quantitative modelling of physical problems.

The *Dispersive hydrodynamics* programme focused on four major themes: modulation theory and DSWs, analysis of dispersive hydrodynamic problems, integrable turbulence and soliton gases, and physical applications for example from geophysics, nonlinear optics, superfluids and fluid dynamics. The participation of 115 junior and senior researchers and the research surveyed across 44 weekly seminars demonstrated the field's broad reach and scope, including synergies with concurrent INI programmes such as *Applicable Resurgent Asymptotics*.

Four workshops held at the Institute served to kick off each of the four programme themes and averaged more than 70 additional registered, in-person participants each. The programme also held a satellite workshop at Loughborough University, two *Open for Business* events, a visitor programme at OxPDE, University of Oxford, and a joint INI-RIMS seminar with the Research Institute for Mathematical Sciences, Kyoto University.

Long-term junior participants established a weekly, early-career-only seminar that facilitated robust discussion. The *Women in Dispersive Equations* event showcased a range of research in the area by female mathematicians and culminated in a panel discussion on issues of diversity and equity.

The programme provided a huge boost to research efforts, new collaborations, and mentoring of junior researchers in the field of dispersive hydrodynamics. Approximately 70% of participants[1] initiated new collaborations, began research in new directions, and learned of new applications of dispersive hydrodynamics because of their participation in the programme. Research achievements included the solution of generalised Riemann problems, new classes of breathers and rogue wave solutions, a variety of applications and many striking experiments. There were recurring discussions of soliton/breather gases and their numerical synthesis, multidimensional modulation theory, experimental observations, connections to the field of generalised hydrodynamics from theoretical physics and N-soliton solutions with $N \to \infty$ identified with soliton condensates. The generated body of work motivated a successful application for a 2024, one-month INI satellite programme in Newcastle and a proposal to establish a Journal of Nonlinear Waves.

[1] Based on 48 programme survey respondents out of 115 in-person participants (42%).

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Mr G Roberti

78 : 21 : 1
GENDER BALANCE:
(M : F : UNKNOWN, %)

30 : 70
GEOGRAPHIC DISTRIBUTION
(UK : NON-UK, %)

70 : 26 : 4
ECR STATUS
(ECR : NOT ECR : UNKNOWN, %)

New connections in number theory and physics

August – September 2022

ORGANISERS:
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Michael Green *(University of Cambridge)*
Axel Kleinschmidt *(Max-Planck-Institut für Gravitationphysik)*
Daniel Persson *(Chalmers University of Technology)*
Katrin Wendland *(Albert-Ludwigs-Universität Freiburg)*

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KIRK DV FELLOWSHIP
Professor A Taormina

SIMONS FELLOWSHIP
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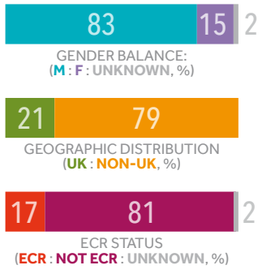
Professor J Funke
Mr M Patnaik
Professor S Sahi
Professor K Wendland
Professor D Zagier



During the 20th century, interactions between geometers and theoretical physicists were revolutionary in both areas, leading to such unexpected developments as mirror symmetry and the impact of topological field theory on invariants of 4-manifolds. Another momentum is now developing around new connections between number theory and physics, mainly but not exclusively through the theory of automorphic forms. We have reached a time when contacts between number theorists and physicists have the potential for another revolution.

The purpose of this interdisciplinary programme was to initiate novel scientific interactions between various fields of mathematics and theoretical physics, with particular emphasis on connections between number theory (modular forms, automorphic forms, mock modular forms) and string theory. Cross-disciplinary collaboration has great benefit to both areas. Recent work has revealed, on the one hand, a profound significance of automorphic forms and automorphic representations for string scattering amplitudes and, on the other hand, an unexpected appearance of mock theta functions in answering key questions pertaining to quantum properties of black holes.

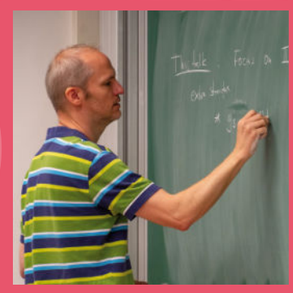
There has also been a surge of interest in analysing the integrands of string theory amplitudes. In the case of genus one string amplitudes, these integrands are doubly periodic functions on the torus and have been dubbed "modular graph functions." Mathematically, this gives rise to a new class of modular objects which exhibit interesting special values. A full understanding of these relations is an open problem and was one of the topics discussed at the programme.

The *New connections in number theory and physics* programme was kick-started with a workshop designed to introduce the key topics and facilitate interactions and collaborations. The workshop featured a series of cross-disciplinary introductory lectures, which provided seeds for discussions that could be further cultivated during the remainder of the programme. The main themes included automorphic forms, representation theory, the Langlands program, string scattering amplitudes and non-perturbative string theory.

During each non-workshop week, there were one or two formal daytime seminars, leaving time for informal discussions and collaborations. In addition, we organized a very successful informal evening seminar series at the Møller Institute, which was well-attended. Another highlight of the programme was a recurring discussion session on *QFT for mathematicians*. Here the aim was to facilitate interactions between physicists and mathematicians, using the framework of quantum field theory as a unifying canvas.

A number of new collaborations were initiated and others were continued during the programme. We view this programme as part of a series of events over the course of several years. It was preceded by an online scientific workshop in 2021 hosted by the Newton Institute, and we plan to have recurring follow-up events in the coming years. To build collaborations across scientific boundaries requires sustained opportunities for interactions. This programme enabled us to build a strong foundation for new interactions between mathematics and physics.

"This programme enabled us to build a strong foundation for new interactions between mathematics and physics."






"The programme created ample space for reflection on the talks, pitching questions and ideas to colleagues, and finding a common vocabulary among participants from different disciplines."





Geophysical fluid dynamics; from mathematical theory to operational prediction

August – September 2022

A better understanding of the climate system is of great societal relevance, due to the need for reliable environmental forecasts and the looming climate crisis. Our ability to understand and forecast weather and climate processes rests on five pillars: on physics to find the relevant equations, on mathematics to guarantee well-posedness and to explore them qualitatively, on numerics to implement these equations and study them quantitatively, on data assimilation to infer parameters and initial conditions, and on statistics to assess predictions against observations.

INI Isaac Newton Institute for Mathematical Sciences @ UNIVERSITY OF READING

The inaugural INI Satellite Programme, held at the University of Reading, brought together a well-balanced mix of researchers with backgrounds ranging from pure mathematics, statistics, data science, to weather and climate science (working both in academia and for operational forecasting centres). The programme aimed to address questions relating to geophysical fluid dynamics and forecasting, such as qualitative and statistical behaviour of geophysical models, response to deterministic and stochastic perturbations, sources of predictability at different spatial and temporal scales, forecast verification, and data assimilation.

Problems were discussed from both mathematical and statistical perspectives, as well as applied and operational perspectives, at the same time. This created a vibrant, interdisciplinary atmosphere in which ideas from various areas were floated and discussed, with early career researchers adding an extra level of enthusiasm and sobriety. The month-long programme was flanked by two workshops. The first, *Mathematics of geophysical fluid dynamic models of intermediate complexity: qualitative and statistical behaviour*, focused more on the analysis of geophysical fluid dynamics, while the second, *Forecast Verification and Data Assimilation in intermediate and large scale models of geophysical fluid dynamics, with applications to medium range and seasonal forecasting*, was more applied in character.

Workshop and programme participation strongly overlapped, showing that both were well integrated. Early feedback from participants emphasised successful efforts by speakers to pitch their presentations for an interdisciplinary audience, yet at the same time placing jumping--off points for more in-depth discussions and collaborations. The programme strongly benefited from Reading being an internationally recognised hub for research in weather and climate, owing to the University's Centre for Mathematics of Planet Earth, the Department of Meteorology, and close connections to ECMWF, the UK MetOffice, NCAS, and NCEO.

The programme fostered new collaborations and a sense of community around the topic of geophysical fluids dynamics and mathematics of planet earth more generally. The programme created ample space for reflection on the talks, pitching questions and ideas to colleagues, and finding a common vocabulary among participants from different disciplines (which is a necessary investment for successful interdisciplinary collaborations). Particularly popular with attendees was the fruitful exchange during the guided discussion sessions in the first workshop. Early career researchers and students greatly benefitted from the longer time frame and interdisciplinarity of the programme, as these allowed to explore further research themes and expand scientific networks.

ORGANISERS:
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Tobias Kuna *(University of Reading; University of L'Aquila)*
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72	27	1

GENDER BALANCE:
(**M** : **F** : **UNKNOWN**, %)

40	60

GEOGRAPHIC DISTRIBUTION
(**UK** : **NON-UK**, %)

23	57	20

ECR STATUS
(**ECR** : **NOT ECR** : **UNKNOWN**, %)

Applicable resurgent asymptotics: towards a universal theory

September – December 2022

ORGANISERS:
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(Akita University)
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(University of Edinburgh)
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Mr N Tamarin
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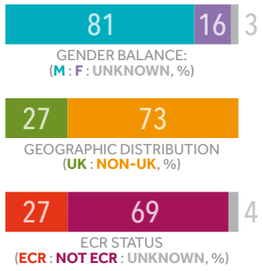

Asymptotic analysis has been a vital technique within mathematics for over a century, but recent breakthroughs have led to radical changes in the mathematical understanding of these methods. By exploiting the idea of "resurgence", researchers have been able to extend asymptotic analysis beyond the boundaries of the traditional asymptotic analysis of Poincaré. Independent parallel developments were being pursued in both mathematics and theoretical physics, being applied to resolve open questions in areas ranging from fluid dynamics to non-perturbative quantum field theories. The main purpose of this programme was to bring together these perspectives from applied mathematics and theoretical physics to build a shared universal theory of resurgent asymptotics.

Following the outbreak of COVID-19, the *Applicable resurgent asymptotics* programme was split into two parts. The latter four-month in-person programme in 2022 followed on from a four-month online programme that took place from March to June 2021. The online portion of the programme, including a Spring School of comprehensive introductory lectures aimed at graduate students and early-career researchers, laid a solid foundation that allowed participants to begin strongly when the in-person component of the programme began.

The focal points of the in-person part of the programme were three workshops, attracting participants internationally, including many early-career researchers, and allowing for a mix of presentations and discussions. In addition to the workshops, there were two weekly seminars and numerous smaller events aimed at generating discussion and academic connections between participants, including several events with a focus on early-career researchers. The final summary workshop provided an outline of the state of asymptotic analysis within both theoretical physics and applied mathematics, and will play an important role in focusing research efforts and shaping the direction of future progress in resurgent asymptotics and its applications.

One important objective of the programme was to merge the two largely-independent research streams in resurgent asymptotics that had developed in recent years. In this capacity, the programme was a great success, with many new collaborative links formed between physicists and mathematicians. Bringing together researchers from such diverse academic backgrounds led to both entirely new ideas and genuine progress on existing open problems. This programme led to mathematical advances including the development of q-Borel techniques, the application of transasymptotic analysis to PDEs, and the development of asymptotic methods that can incorporate numerical or experimental data. Additionally, programme participants made significant advances in theoretical physics, notably the analysis of the types of branes being expressed in the transseries of matrix models, interpolation between different regimes in parameter space of observables, and transseries approaches to integrable field theories.

In summary, the major goals of the programme were to establish connections between the asymptotic perspectives from two different fields (applied mathematics and theoretical physics), to use these connections to produce important results for both fields, and to shape the future direction of research in resurgent asymptotics. These goals were accomplished by participants in the programme, and give many reasons to be optimistic about both the immediate and long-term future of the field.

"Bringing together researchers from such diverse academic backgrounds led to both entirely new ideas and genuine progress on existing open problems."

"The intriguing question of why the geomagnetic field reverses its polarity on long time scales has been a subject of intense group discussions."

Frontiers in dynamo theory: from the Earth to the stars

September-December 2022

Dynamo theory is concerned with how magnetic fields are generated in the planets and the stars, a challenging problem for mathematicians over the last century. The aim of this programme was to bring together researchers in geophysics and planetary physics with those from astrophysics and applied mathematics to review recent progress. We explored how developments which have been successful in one community could be used to initiate new research in other fields to improve our understanding of the fundamental processes of magnetic field generation.

Dynamo theory was the subject of the first programme at the newly formed Isaac Newton Institute in July 1992 when the foundations of the subject were being developed. Since that time, computational models have improved dramatically, as has the observational data from satellites and orbiting telescopes. At the current programme, sophisticated models of the geodynamo were presented, with detailed comparison with the data from satellites and magnetic observatories being possible. The intriguing question of why the geomagnetic field reverses its polarity on long time scales has been a subject of intense group discussions.

Planetary and stellar magnetism is studied by scientists and applied mathematicians in a wide range of different academic departments. Even though planets and stars are very different, there are many common aspects of the dynamics of their deep interiors. It is therefore possible to use advances in one field to make progress in another, which was a major aim of this programme.

The first workshop was focused on the recent data on both magnetic fields and flow patterns coming from space missions and orbiting telescopes, and how this has affected our understanding of dynamo processes and the development of the mathematical models describing them. The second workshop was a satellite meeting in the University of Leeds, and addressed the more theoretical, experimental and computational aspects of the fluid dynamics behind magnetic field generation. Highlights of the final workshop included a discussion of the newly discovered Rossby waves inside the Sun, and of a class of magnetic waves known as MC waves in the Earth's core, which promise a deeper understanding of conditions inside the Sun and the Earth and hence exciting new developments in dynamo theory.

A highlight of the programme was the Kirk Distinguished lecture from Cathy Constable (Scripps, UCSD) who reviewed the long-term behaviour of the geomagnetic field, highlighting recent advances in our knowledge of the Earth's field over the past 50,000 years. Another highlight was the Rothschild Distinguished lecture from Steve Tobias (University of Leeds) who showed how new mathematical techniques could be used to derive simplified dynamo models from time series of observational magnetic data, and how direct statistical simulation models provide an alternative way forward to direct numerical simulation.

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Christopher Jones
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Dr P Käpylä

78 : 21 : 1
GENDER BALANCE:
(M : F : UNKNOWN, %)

34 : 66
GEOGRAPHIC DISTRIBUTION
(UK : NON-UK, %)

22 : 73 : 5
ECR STATUS
(ECR : NOT ECR : UNKNOWN, %)

The mathematical and statistical foundation of future data-driven engineering

January – June 2023

ORGANISERS:
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Sebastian Reich
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Aretha Teckentrup
(University of Edinburgh)
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Dr C Dent
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Ms A Istratuca
Dr J Latz
Dr L Magri
Dr P Moireau
Mr D Murari
Mr C Osborne
Dr J Roden

77 | 21 | 2
GENDER BALANCE:
(**M** : **F** : **UNKNOWN**, %)

60 | 40
GEOGRAPHIC DISTRIBUTION
(**UK** : **NON-UK**, %)

41 | 46 | 13
ECR STATUS
(**ECR** : **NOT ECR** : **UNKNOWN**, %)

Contemporary science and engineering are being transformed at an unprecedented rate due to our ability to measure and produce data as never before; this is driven by the development of sensing technologies, large-scale scientific experiments, and the rapid growth of the web-based economy. Similar advances in the availability of computer-based simulation approaches to science and engineering, as with data from measurement technologies, give rise to the so-called Data Sciences and its mathematical underpinnings. Engineering stands to benefit from this data revolution in particular, but realising this vision requires concerted efforts across the engineering and mathematical sciences, which has been the driving force behind this 6-month programme.

Data-driven engineering is rapidly evolving in a highly interdisciplinary and diverse community, and faces numerous practical and theoretical challenges. The tremendous acceleration of technological advances and the explosion of available data make the need for transferable computational tools and their theoretical foundations more urgent than ever. The goal of this INI programme was to make an important contribution to addressing these challenges in the context of specific technical applications and to bring together experts in the fields of applied mathematics, statistics, and engineering.

The series of programme workshops kicked off with a tutorial workshop at INI to set the scene and facilitate communication among the various research communities present, and also included workshops on *Modelling, Analysis, and Inference for Digital Twins* (held at the Alan Turing Institute, London), *Computational Challenges and Emerging Tools* (at INI), and *Mathematical Foundations* (held at ICMS, Edinburgh). To create the desired long-lasting interactions between applied mathematicians, statisticians, and engineers, the programme included the following deep-dive study periods in addition to the workshops: *Mathematics and Statistics for Low Carbon Energy Systems, From Physics-Based to Data-Driven Evaluation of Structures, Optimal Control and Inference, Data-Driven Optimization, Data-Driven (Modelling and Control for) Fluid Mechanics*, and *Generative Models for Inverse Problems*. Each deep-dive period lasted between one and two weeks and provided an introduction to a particular research topic through explanatory lectures and informal discussions.

Other programme highlights included the Kirk Lecture by Claudia Schillings *(FU Berlin)*, the Rothschild Lecture by Robert Scheichl *(Heidelberg)*, and the *Open for Business* event on *Digital Twins for Engineering Applications – The Emerging Science and Technology* organised by the Newton Gateway to Mathematics. Other regular programme activities included weekly seminars, tutorials and discussions, Gin Fridays (in the colder months) and homemade sangria (in the warmer months).

"Data-driven engineering is rapidly evolving in a highly interdisciplinary and diverse community."

Mathematical theory and applications of multiple wave scattering

January – June 2023

Multiple wave scattering is a vibrant and expanding research area for both theoretical and applied researchers interested in controlling and predicting waves in complex media. Contemporary mathematical challenges are extensive, ranging from design of metamaterials to numerical difficulties associated with massive scattering simulations. The programme was an interdisciplinary joining of forces with the goal of elucidating the fundamental mathematical aspects of multiple wave scattering in a variety of contexts, aiming for a deep understanding of the commonalities.

"... a versatile numerical toolbox was developed during the programme and spread amongst the participants."

The *Multiple wave scattering* programme was hosted in the Møller Institute at the beautiful Churchill College campus. The open-plan space contributed to the close collaborative atmosphere of the programme, which was crucial to its success. We held "coffee breaks" every morning, with at least one informal presentation per week during the breaks (usually from an early career participant), complemented by a seminar series on Thursday afternoons at INI. The formal events kicked off with a *Winter School*, featuring a series of introductory lectures, group research activities and a hackathon. Four week-long research workshops were held, focussing on specific mathematical, physical or applied topics, and involving research talks and poster sessions. A one-day *Open for Business* event built links with practitioners in material characterisation and design. A cross-programme event at INI showcased the work of early-career researchers through 3-minute presentations, followed by a barbecue at the Møller Institute on a glorious sunny afternoon.

The residential long-term character of the programme underpinned a genuine all-community approach to identify the key issues shared among the different branches of wave science that demand new mathematical techniques and computational methods. It accelerated research by introducing methods and results known in one application area to other application areas where corresponding questions were still open. For example, a versatile numerical toolbox was developed during the programme and spread amongst the participants. Moreover, recent ideas in acoustics were found to be transferable to water waves, so as to shortcut the route to efficient renewable ocean energy devices.

Over 100 programme participants were involved, including mathematicians, engineers and physicists, from the UK, Europe, North America, Asia, Africa, Australasia… and Cambridge. We are grateful for support from: INI for participants with families and for DAC fellowships to participants from developing countries; London Mathematical Society for participants from underrepresented groups; Simons Foundation for 19 key participants; UK Acoustics Network for early career researchers; UK Metamaterials Network for the final workshop; US Army and Office of Naval Research (Global) for early/mid career participants from Asia–Pacific regions; and Clare Hall and Churchill College for visiting fellowships. We had two female Distinguished Visiting Fellows (Kirk and Rothschild) and a Heilbronn Distinguished Visiting Fellow.

Two of our early career researchers ran a mini-symposium at the British Applied Mathematics Colloquium in Bristol, with talks from programme participants, and we had a strong presence at other major meetings, such as Phononics in Manchester. Our international participants travelled to give invited seminars across the UK. The programme was also featured in Plus Magazine, and research from the programme will appear in a Special Feature of the Proceedings of the Royal Society A.

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GENDER BALANCE:
(**M** : **F** : UNKNOWN, %)

GEOGRAPHIC DISTRIBUTION
(**UK** : **NON-UK**, %)

ECR STATUS
(**ECR** : **NOT ECR** : UNKNOWN, %)

Rich and nonlinear tomography – a multidisciplinary approach

January – June 2023

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63 : 35 : 2
GENDER BALANCE:
(M : F : UNKNOWN, %)

37 : 63
GEOGRAPHIC DISTRIBUTION
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41 : 46 : 13
ECR STATUS
(ECR : NOT ECR : UNKNOWN, %)

Tomographic imaging provides the ability to image properties in the interior of an object from measurements taken on its surface or in the far field. It is vital for example in medicine, manufacturing, geophysics, advanced materials and security. Sensor technology is increasingly extending not only in the number of detector elements and the speed of acquisition but also by adding capability to resolve frequency, energy, polarisation state, transient response, resulting not only in higher data rates but also in richer data. The highly coupled and often non-linear nature of the underlying inverse problem means that new mathematical and computational methods are needed.

Our *Rich and nonlinear tomography* programme was both ambitious and timely. We aimed to bring together not just those specialising in the mathematical disciplines of analysis and geometry; numerical analysis; optimisation; and Bayesian statistics, but we also aimed to include specialists in the measurement science engineering and applications.

In the first week of the programme, we saw a specialist in radar imaging, sitting with one in neutron tomography making a dictionary to translate the terminology they used for the mathematical objects involved in their reconstruction problems. This early sign of success was sustained throughout the programme. We not only facilitated collaborations between mathematicians and scientists/engineers, but also between seemingly different areas through common mathematics.

In our first workshop we took a risk of combining the fields of Radar, Astronomy and Geophysics. These are well-developed areas of applied inverse problems that rarely communicate. This paid off as lasting new collaborations were formed, and new mathematical problems formulated.

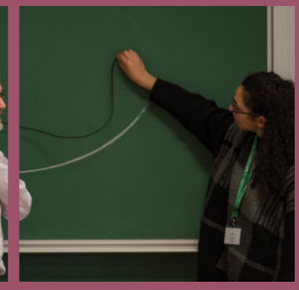
Our *Open for Business* event was novel and unique. We wanted to encourage interaction between engineers who work on radar imaging, including military applications, with those working on inverse problems. Radar scientists are constrained by both commercial and security considerations, and are used to convening at NATO meetings. We did not want to restrict the international, open and collaborative nature of the INI, so we ran a joint NATO Newton Gateway meeting at the ICMS. A key aspect of a successful interdisciplinary meeting between two communities is that the right people come to an unfamiliar meeting, and this worked very well. Indeed, industry radar experts enthusiastically shared and helped mathematically formulate key current challenges.

The programme as a whole was characterised by visitors working on a full range of problems spanning our anticipated mathematical and application challenges. Participants were very positive about the experience, and there was a feeling that Rich Tomography was more than a buzzword but a widely unifying theme that now has momentum and depth.

"... there was a feeling that Rich Tomography was more than a buzzword but a widely unifying theme that now has momentum and depth."






Over the past two years, **plus.maths.org** *editors* Marianne Freiberger *and* Rachel Thomas *have shared a unique interaction with the Isaac Newton Institute. Bringing with them extensive experience in communicating mathematical concepts to non-expert audiences, they have so far provided coverage of 26 INI programmes, events and activities. Through conversations with more than 100 researchers, this has resulted in 112 articles, 16 podcasts, and two videos. In this article, they describe their 2022–2023 highlights from an ever-stimulating partnership.*

Fruitful collaborations – a year of fascinating conversations

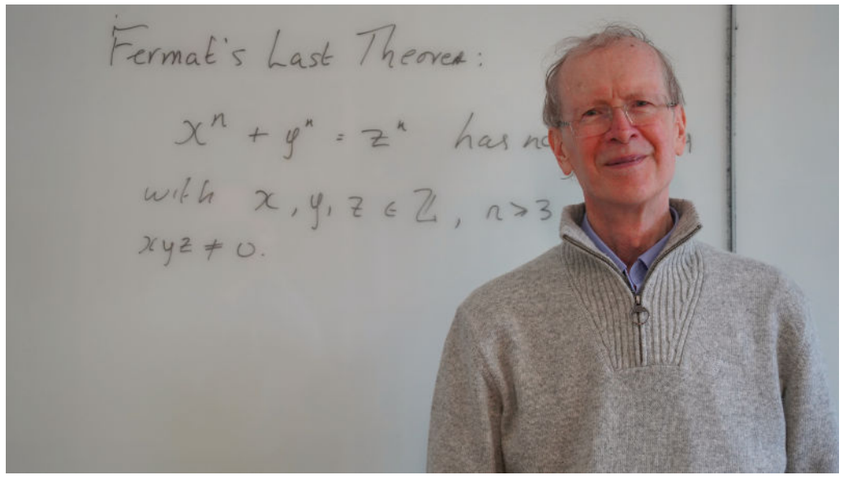
Words: Marianne Freiberger and Rachel Thomas

As mathematics communicators, working with the Isaac Newton Institute (INI) and Newton Gateway is a joy. Since our collaboration began in early 2021, it has opened a door on the breadth of mathematical science and highlighted its applications for people who may not otherwise engage with current research – be they students and teachers, policymakers and press, people working in industry or researchers in other fields, or indeed anyone curious about what happens at the cutting edge of mathematical research.

We aim to give a flavour of the research covered by INI programmes and workshops, woven together with short introductory articles explaining basic concepts that come into play. There clearly is an appetite for such topics – the articles and podcasts are some of the most viewed material on plus.maths.org.

A very old problem turns 30

There were many highlights over the past year. In May 2023 we had the rare opportunity to interview Andrew Wiles, a mathematician whose work demonstrates the impact INI had even in its infancy. He announced his proof of Fermat's Last Theorem during the programme *L-functions and arithmetic* in June 1993, one year after INI first opened its doors.



To mark the 30th anniversary of this announcement we visited Wiles in Oxford together with INI Communications Manager Dan Aspel, to re-trace the mathematical, as well as the personal, journey towards the proof and explore its legacy. Wiles gave an engaging and thoughtful interview that formed the basis of a collection of material published on plus.maths.org that has been very popular with our audience.

Cambridge mathematician Tom Körner, who witnessed Wiles' announcement in 1993 gave us a first-hand report on the events. "Rumours started to get around," Körner told us, about the days leading up to the lecture in question. "I do not know if people knew or just speculated, so I asked one of Andrew's students whether I would regret missing the lecture, and he said yes. The atmosphere was electric."

Wiles himself remembers the announcement with a little more trepidation. "On the one hand I was very excited to present [the result], but on the other there is always a tension the first time [you share the work]," he told us. "You have been thinking about this [for a long time], a lot of it on your own, so you [hope that you] haven't done anything stupid." As it happened, the original proof did contain a gap, but Wiles and mathematician Richard Taylor (who had been Wiles' former PhD student at Princeton) managed to fix this within a year. The overall approach to the proof turned out to be sound.

Connections down the years

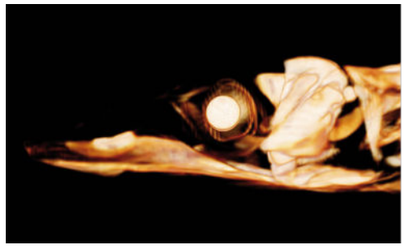
Thirty years on, major results are still being announced at INI, often building on previous research programmes. An example we particularly enjoyed came in June 2023, when four early career mathematicians, Robert Burklund, Jeremy Hahn, Ishan Levy, and Tomer Schlank, announced they had resolved a long-standing conjecture in the field of homotopy theory.

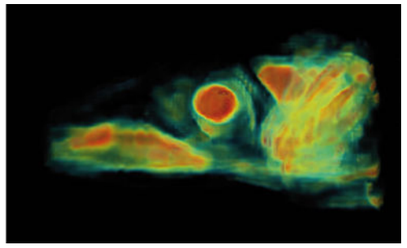
Loosely speaking, the Telescope Conjecture suggested a method for exploring the existence of higher-dimensional holes in higher-dimensional topological spheres. It was part of a whole series of conjectures posed by Douglas Ravenel in 1984. While all of these other conjectures have been shown to be true, Burkland, Hahn, Levy and Schlank worked together to finally disprove the Telescope Conjecture.

The four mathematicians announced their result at the University of Oxford at the conference *A panorama of homotopy theory*, part of a two week INI programme which followed up on the 2018 programme *Homotopy: Harnessing Higher Structures.* "It was a special moment for all of us," Hahn said. "Ravenel was there, and Mike Hopkins, who had proved most of Ravenel's conjectures along with his collaborators, apart from the Telescope Conjecture. So in the room there was the whole history of people who had interacted with these conjectures. We really appreciated the conference which brought all these people together. It seemed like the perfect time to explain our work."

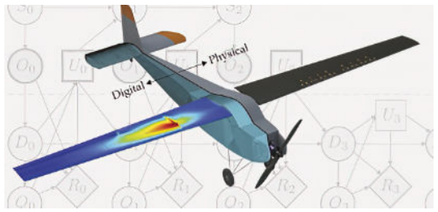
Connections between fields

It's not just connections over the years that INI nurtures, it also encourages connections between fields. For the first six months of 2023 two other research programmes ran in parallel with the *Data Driven Engineering (DDE)* programme at INI.





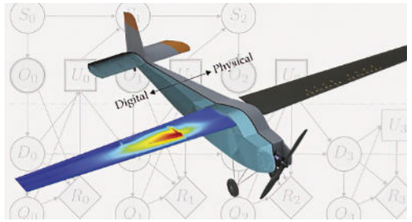
Simultaneously, mathematicians and statisticians came together with the engineers, physicists and clinicians using tomographic data for the programme, *Rich and Nonlinear Tomography – a multidisciplinary approach (RNT)*. Tomography is the area of mathematics that revolutionised medicine by enabling clinicians to see inside a person's body without surgery. Tomography is also used for many other non-medical purposes – from electron tomography of viruses and microchips to muon tomography of volcanoes. The field of rich tomography promises an even better view – more complex measurements offer the opportunity to reconstruct far more detailed structures of the interior of objects.



When we worked with some of the organisers of the RNT programme to explore this area, the connections with the concurrent programmes became obvious. Content we had developed to explain mathematical ideas behind multiple waves scattering crossed over into our collection exploring rich tomography. Bill Lionheart, one of the organisers of RNT, explained why it was so fortunate to have these three research programmes running in parallel at INI. "As many of our inverse problems involve electromagnetic or acoustic waves, the interaction of waves with complicated media is of great importance," says Lionheart. "Our colleagues in MWS specialise in modelling the interactions of waves with matter and numerical solutions of the wave equation. The DDE programme [covers] a probabilistic approach to inverse and [related] problems. RNT has had a fertile interaction with its sister programmes, with participants attending each other's seminars and workshops."

Ongoing collaborations

The importance of ongoing collaborations can be found in a completely different area – and one that has important applications in our lives. In February 2023 a two-week "deep dive" workshop on the Mathematics and statistics for low carbon energy systems ran as part of *The mathematical and statistical foundation of future data-driven engineering (DDE)* research programme. This gave us the opportunity to talk to one of the organisers, Chris Dent, about a topic that is of great interest to many of us: decarbonising the energy network.

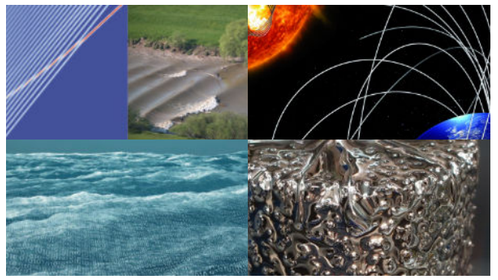


The deep dive workshop continued a series of events that have allowed Dent and his colleagues to build up this area of mathematics. It all started with the INI programme, *Stochastic processes in communication sciences*, held in 2010, which included an energy systems week. "That was the first big gathering of people working on the maths of energy in the UK, which identified common areas of potential mathematical interest," says Dent. There have been many events over time since then, both at INI and elsewhere.

As such, the deep dive workshop, and the longer research programme it was a part of, demonstrate that this type of scientific meeting powers mathematical progress. "Bringing people together for these sorts of discussion is the infrastructure of the mathematical sciences," says Dent. "The deep dive [workshop] is a catalyst for various conversations, drawing people from mathematics, computer science and [other areas] into energy innovation. They all have much to contribute."

Open for Business

Fertile interactions can also ensue between academia and the users of mathematics – in industry, business, the public sector and other scientific disciplines. This is where the Newton Gateway to Mathematics comes in. Celebrating its tenth anniversary this year, the Newton Gateway develops and runs activities such as workshops and meetings that bring people and organisations together. The aim is to share knowledge and stimulate further research and collaboration. A good example are the Gateway's *Open for Business* (OfB) events, which run in conjunction with research programmes held at INI.



An example was the programme *Frontiers in dynamo theory: From the Earth to the stars (DYT)*. The programme itself taught us, much to our surprise, that the processes which generate the magnetic field of the Earth still aren't fully understood. The field of magnetohydrodynamics has been developed to address this problem. Apart from explaining why compass needles always point North, it can also help us understand the magnetic fields of other planets and stars.

But although this highly theoretical field is largely counted as part of fundamental science, it is also of interest to practical applications. The OfB event associated with DYT explored one of them: liquid metal batteries. If these become a commercial reality, they will provide cheaper and cleaner alternatives to traditional batteries and allow us to bridge the intermittent nature of wind and solar energies.

"I have never heard anyone in batteries talk about magnetohydrodynamics," Donald Sadoway, the inventor of liquid metal batteries, said about the OfB. "Listening to all these presentations opened my eyes to features that had been overlooked, and I have taken this under advisement." The podcast episode featuring Sadoway, part of our collection covering the DYT programme, is one of our most popular episodes yet.

The programme *Dispersive hydrodynamics: mathematics, simulation and experiments, with applications in nonlinear waves (HYD)* gave us a great opportunity to cover the basic mathematics of waves in a series of articles. The associated OfB event *From dispersive hydrodynamics to forecasting, machine learning and back* then allowed us to cover its role in forecasting all manner of phenomena, from rogue waves to extreme weather events. We were particularly pleased to talk to participant Tim Palmer, a renowned climate scientist whose work you can appreciate every day when you look at your weather app. Palmer pioneered the technique of ensemble forecasting, which is used to work out the percentage chance of rain. We featured this interview in a podcast.

As the name of the OfB event suggests, artificial intelligence (in the shape of machine learning) may have an important role in improving our forecasts. This new line of research was a major focus of the event.

The mathematics of information

Another field that stands to benefit from AI, but also highlights its potential dangers, is the medical sector. Here, too, the Newton Gateway helped deliver some fascinating insights. In July 2022 the *Medical Image Understanding and Analysis conference (MIUA)* took place at the Centre for Mathematical Sciences, organised by the Newton Gateway together with the National Heart and Lung Institute and the Cambridge Mathematics of Information in Healthcare Hub (CMIH).

With the staggering number of medical images that result from a variety of scans each year, automated image recognition tools could be of real use – but should medical diagnoses be left to machines? Fiona Gilbert, a professor of radiology at the University of Cambridge, talked at MIUA about the NHS breast cancer screening programme, which results in 2.2 million mammograms a year. She presented various approaches to having AI work alongside humans to ease this workload, and explored a range of studies suggesting that such an arrangement could indeed be safe and effective.

Links between practitioners and theorists are vital when it comes to safely developing the applications of AI. As Gilbert put it in her talk, "We radiologists need you, mathematicians and computer scientists, to help us to really deliver healthcare."

The CMIH is closely associated with the Cantab Capital Institute for the Mathematics of Information (CCIMI), which has also benefited from a collaboration with the Newton Gateway. The Connecting with industry event in November 2022 was an opportunity to hear from industry experts as well as CCIMI researchers at all stages of their career. "The CCIMI is a PhD driven programme, we want to generate the new leaders of the field," said Randolf Altmeyer, CCIMI researcher and Deputy Director of the PhD programme. These graduate students were presenting their first research in the field alongside leading researchers from the CCIMI and industry. "The aim of the day is to get to know the exciting maths problems people face in industry, and for industry to see some of the new mathematics."

Communicating mathematics for the public

New mathematics is what excites us at plus.maths.org, and we are driven to communicate it to wider audiences for many reasons. One is that this research is often a profound and beautiful example of human creativity. But another is that it is changing our lives, so it is vital to equip people with the tools to understand it.

For this reason the *Communicating Mathematics for the Public* event, organised by the Newton Gateway in January 2023, was particularly close to our hearts. Alongside renowned scientists working on fields that affect us all, such as David Spiegelhalter (statistics), Emily Shuckburgh (climate science), and Hannah Fry (the mathematics of cities), it included people who, like us, work behind the scenes getting those important concepts across. We heard fascinating presentations from people working for the Office for National Statistics, the Office for Statistics Regulation, and former members of SPI-M-O, the group of epidemic modellers which advised SAGE during the COVID-19 pandemic.

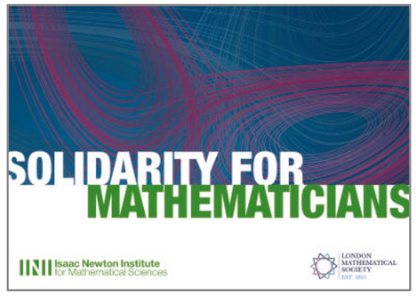
We had never before seen such an inspiring mix of people come together, so it was surprising and encouraging to hear the same messages come through over and over again. To communicate complex mathematics you need to put yourself into the shoes of your audiences, stay away from jargon, be clear about uncertainties, and earn your audience's trust. Aim to inform, rather than convince, and simplify your language, not the science. The event inspired us to produce a practical guide to writing about anything for anyone, based on our experience as mathematics communicators and the writing workshops we have taught over the years.

It's been another exciting year working with INI and the Newton Gateway, taking us from pure mathematics to important questions regarding energy, climate science, and artificial intelligence. We have learnt about a huge variety of thought-provoking topics. Getting to grips with the complex mathematics involved can be a challenge, but the opportunity to work with researchers at the cutting edge of mathematical science is ample reward. We wholeheartedly agree with Emily Cook, a PhD student who took part in the graduate modelling camp organised by the Newton Gateway in July 2023: "It was fun! It was so much fun!"

Other key updates

INI-LMS Solidarity for Mathematicians programme

Established in March 2022, the *INI-LMS Solidarity for Mathematicians* (SLM) programme aims to provide refuge to researchers in the mathematical sciences who have had to leave their country of residence; it covers both refugees of war, and political refugees. So far in 2023, SLM has had 12 new applications, with five of those being successful, and two currently due to be reviewed by the Committee. In most cases, applicants must wait several months to receive their visas, and seven successful applicants from 2022 have been able to travel to the UK and start on the SLM programme during the period of this report. We have invited participants to attend several events and have offered them support arranging talks at other institutions. For both of these initiatives, INI has covered participants' travel and accommodation costs. The Solidarity programme has been entirely funded through generous philanthropic donations.



INI-Simons Postdoctoral Fellowships

INI and the Simons Foundation continue to offer and support the INI-Simons Postdoctoral Fellowships, appointing two new fellows in 2022, and bringing the total number of recipients since the scheme was launched in 2021 to seven. Patrick Sprenger and Nicolas Boulle each spent six months at INI, as participants in the *Dispersive Hydrodynamics: Mathematics, Simulation, and Experiments, with Applications in Nonlinear Waves* and *The Mathematical and Statistical Foundation of Future Data-Driven Engineering* programmes respectively. A further six months was then spent by each alongside research teams: in Nicolas' case in the Faculty of Mathematics at the University of Cambridge, and in Patrick's at the University of Northumbria. INI continues to gather regular updates from INI-Simons post-docs as their careers progress beyond participation in the scheme, with data gathered on: research visits, conference participation, seminars given, accolades awarded, and papers published. Recent successes by fellows have included: finalist positions for the IMA Lighthill-Thwaites Prize, and, as part of a research team, the awarding of $11.3m in funding for collaborative and international research into the scientific use of AI.

Network Support for the Mathematical Sciences

This past year has seen the introduction of the *Network Support for the Mathematical Sciences* scheme. Recognising that the UK mathematical community is supported by myriad official and unofficial networks (some of which have existed only virtually), the aim of the initiative is to help grow and support these groups. *Network Support* provides small funding packages of between £5,000 to £25,000 so that successful applicants can continue and intensify their work, and so that new networks can be formed. Both national and international networks are eligible to apply, and costs covered can include international travel by UK residents as well as travel by non-UK researchers to the UK. We are pleased to share that during this first year of availability, 27 separate groups have been successfully funded by the scheme, chiefly involving researchers from across the UK and including centres such as: Aberdeen, Liverpool, Cardiff and Norwich. Equally varied are the research areas of these groups, spanning modelling of ocean wave energy, spectral theory, data assimilation problems, representation theory, resources for diversity in mathematics, and more.

Talks Elsewhere

Talks Elsewhere is an initiative which encourages and supports long-term programme participants to deliver seminars and lectures at other universities and institutions across the UK. Non-UK-based speakers are eligible to claim expenses involved for any speaking engagement at another UK institution. During this period, 72 separate talks were delivered by speakers from the eight programmes covered within this report. The two most active programmes were *The Mathematical theory and applications of multiple wave scattering* with 26 talks elsewhere, and *Dispersive hydrodynamics: mathematics, simulation and experiments, with applications in nonlinear waves* with 24.

Abel Committee Symposium

The 11th annual Abel Committee Symposium was a one-day, INI-hosted event that featured talks by four leading mathematicians: Fields medalist James Maynard, EMS and Henri Poincaré prize winner Sylvia Serfaty, Shanti Swarup Bhatnagar prize winner Parimala Raman (Kirk Distinguished Visiting Fellow for the 2022 *K-theory, algebraic cycles and motivic homotopy theory* programme), and 2022 Abel laureate Dennis Sullivan. Held on 12 January 2023, the symposium provided an opportunity to share research, and enjoy talks on topics including number theory, geometry, and analysis. A reception at the residence of the Norwegian ambassador was kindly hosted by the Norwegian Academy.

On 22 March it was announced that Professor Luis Caffarelli was the committee's choice, being recognised for his seminal contributions to regularity theory for nonlinear partial differential equations including free-boundary problems and the Monge–Ampère equation.

Social media, podcasts and video interviews

This past year has seen a significant increase in followers and engagement on all of our social media platforms. This is in large part due to the success of our newly created interview series with both the Rothschild and Kirk Distinguished Visiting Fellows. These interviews, undertaken to help promote and celebrate each fellow's keynote talk, have provided a unique opportunity to showcase the research being conducted at the Institute. As detailed by INI's partners at Plus Magazine (see *Fruitful Collaborations*, pages 22-29), in June 2023 the Communications team had the opportunity to record both a filmed interview and an audio podcast with Sir Andrew Wiles (Oxford). The interview, which celebrated the 30th anniversary of Wiles' announcement of the proof of Fermat's Last Theorem, has received more than 40,000 views and led to several hundred new YouTube subscribers within its first few days of release. The Institute's *Living Proof* podcast series has continued to grow, with 14 new episodes released during this report's period, adding more than 1,860 downloads to the "lifetime" total on its current hosting platform of 3,083. Topics covered within the past year include: the disproof of Ravenel's "Telescope Conjecture", how to make data "accessible" in the public sphere, communicating maths to a broadsheet newspaper audience, and the experiences of Ukrainian mathematicians who have been helped to settle in the UK by the INI-LMS Solidarity for Mathematicians scheme. To expand our reach and connect with a broader audience, we have newly established and cultivated a dynamic LinkedIn presence. This business page serves as a hub for disseminating information about job openings, upcoming programmes, and engaging workshops held at the institute or satellite venues. Despite being in its early stage, this initiative has already fostered a thriving community, evidenced by a steady growth in followers, likes, and meaningful interactions.

IMA Induction Course for New Lecturers

INI has continued to host the "IMA New Lecturers Induction course", which in this period took the form of a two-day event from 14-15 September 2022. The course has been designed by the mathematics community to ideally suit anyone who is new to or has limited experience teaching mathematics or statistics within UK higher education. More than 40 new lecturers attended the event. Those sharing their experience and learning across the two days included INI Director Ulrike Tillmann, event organiser Michael Grove (Birmingham), and eight other experienced teachers of mathematics.

Knowledge Exchange Hub for Mathematical Sciences

Following recommendations from the 2018 Bond Review *The Era of Mathematics*, INI took on responsibility for setting up and supporting the Knowledge Exchange Hub for Mathematical Sciences (KE Hub). Its activities began in July 2022, with the aims of:

- scaling up KE activity in the UK;
- connecting researchers, practitioners and end-users;
- supporting existing KE activity in the community; and
- coordinating support for mathematical science KE projects from beginning to end.

In April 2023, Professor Chris Breward (Oxford) took up his position as Scientific Director, and alongside KE Manager, Rachael Harris, set up the Executive Team which includes representatives from Newton Gateway, ICMS, and the KTN. In addition, eight Super Champions, (seven academics with significant and diverse KE Experience and one expert Knowledge Exchange Professional) have joined the Executive Team. In addition, Mathematical Science departments from across the UK were invited to nominate a KE Champion to join the KE Champions' Congress and lead their department's engagement with the KE Hub. To date, KE Champions from 41 departments representing 37 Institutions have joined and have benefitted from regular meetings to share opportunities and good practice, and participate in training. Alongside this, Knowledge Exchange professionals working with Mathematical Sciences departments have been encouraged to join the KE Professionals Forum. So far, 32 KE Professionals have joined, and a mentoring scheme has been launched for both the KE Professionals and the KE Champions.

The KE Hub has welcomed representatives from outside academia to join its Business, Industry, and Government (B.I.G) Partnership; with 48 organisations having already joined. The B.I.G partners will have the opportunity to participate in key KE Hub activities with universities, such as triaging workshops for industry challenges. As part of its remit to support existing KE activity in the UK, the KE Hub has also provided funding opportunities at European Study Group with Industry (ESGI) 171, including: a subsidy to facilitate small and medium-sized businesses (SMEs) presenting a challenge, and a presentation fund to allow researchers to travel to partner organisations to present their findings and to discuss follow on activities. The KE Hub has also provided underpinning funds and administrative support for V-KEMS to further develop the Virtual Study Group activity in the UK.

Academy for the Mathematical Sciences

Over the past year, INI has incubated the Academy for the Mathematical Sciences (AcadMathSci) during its "Proto-Academy" setup phase. The purpose of the Academy is to serve as a unified and persuasive voice for the whole of the mathematical sciences, and to benefit and enrich our world through the power of mathematics.

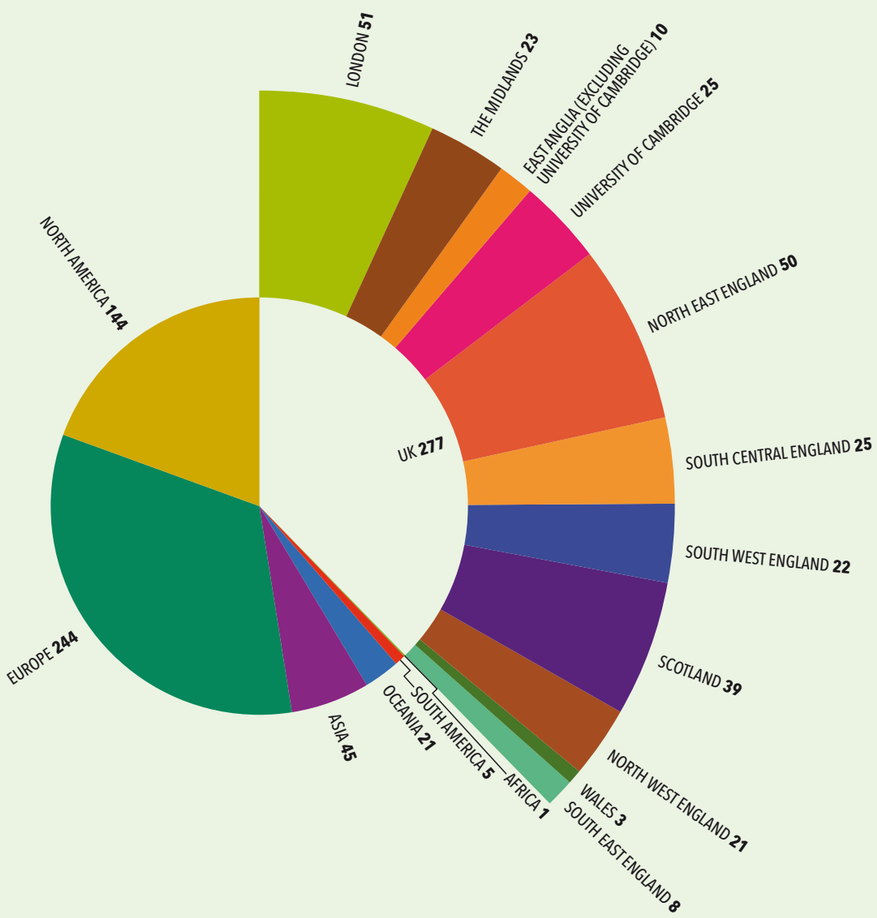
Working closely with the Council for the Mathematical Sciences (CMS), the first step was selecting an Executive Committee, Chaired by Nigel Campbell, and Executive Director. The appointed Committee comprises fourteen field leaders from across academia, education and industry, including past Presidents of all the CMS learned societies. Funded through INI's "Additional Grant from the EPSRC", Dr Christie Marr was seconded from her role as INI's Deputy Director to be Executive Director of AcadMathSci during this setup phase. The Executive Committee's work, across 11 work streams, has been supported by a further 70+ Advisory Board members.

In April 2023 AcadMathSci launched a cross-community consultation, publishing a progress update document and organising five online events kindly hosted by ICMS. These events attracted participation from more than 200 individuals, representing diverse backgrounds in academia, industry, and education.

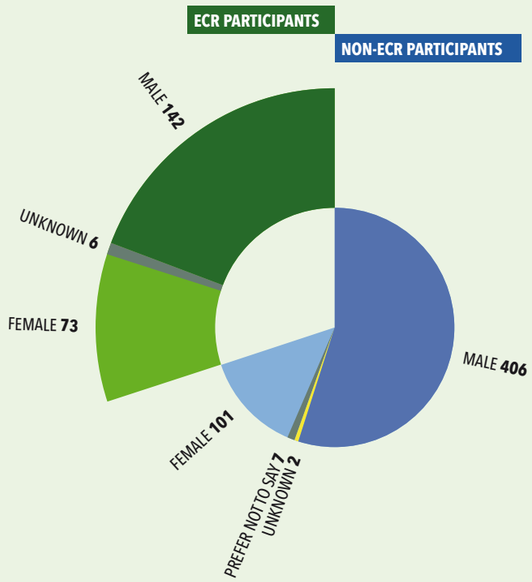
Ahead of the launch of the full Academy, a Policy Unit will be established in Autumn 2023 to showcase AcadMathSci's convening power in engaging with decision-makers. Feedback from the consultation has helped prioritise areas that will be of greatest value. The Executive Committee is committed to putting in place strong governance and effective mechanisms for supporting and nurturing talent wherever it arises, and that the institution is financially sustainable in the long term. A Board of Trustees is currently being appointed, and an application is being made to the Charity Commission for charitable (CIO) status. For more updates visit www.acadmathsci.org.uk, or follow AcadMathSci on LinkedIn.

Back row (L to R): Simon Yun-Farmbrough; Tom Coates; Rachael Harris; Sophie Carr; Lynne McClure OBE; Dame Jil Matheson; Chris Breward; John Greenlees;
Front row (L to R): Nigel Campbell; Christie Marr; Ruth Kaufman OBE; Sir Bernard Silverman FRS; Christine Currie; Rachel Bearon.

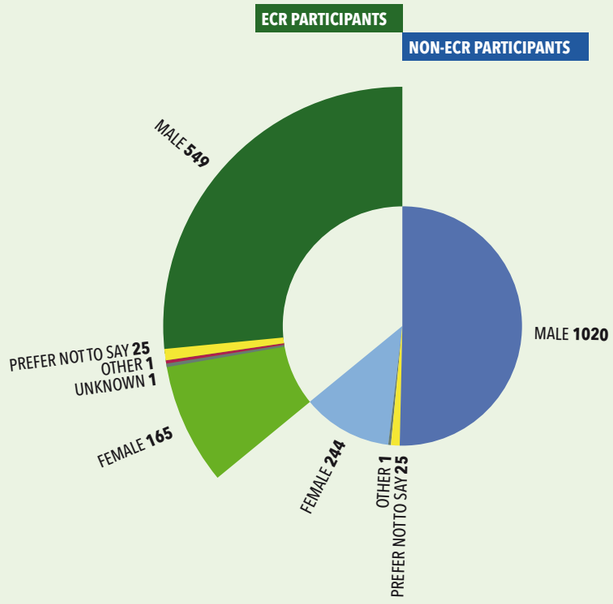
Worldwide geographic spread of programme participants



Gender and ECR* Status



PROGRAMME PARTICIPANTS

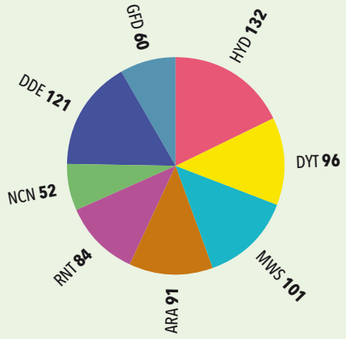


*ECR: early career researcher

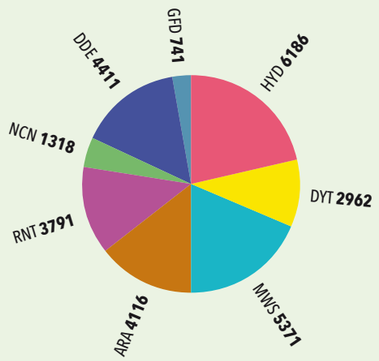
WORKSHOP PARTICIPANTS

Programme and workshop participant numbers

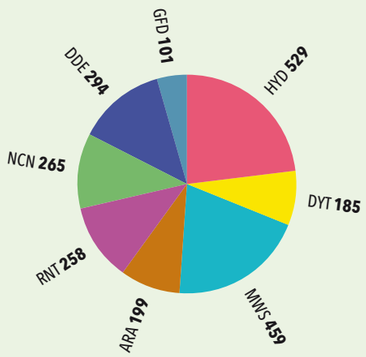
737
PROGRAMME PARTICIPANTS



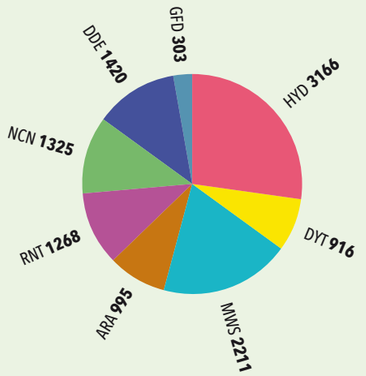
28896
PROGRAMME PARTICIPANT DAYS



2290
WORKSHOP PARTICIPANTS



11604
WORKSHOP PARTICIPANT DAYS



Finances

Accounts for August 2022 to July 2023

For the Isaac Newton Institute and Newton Gateway to Mathematics

Income	*Notes*	2021-2022 £000	**2022-2023 £000**
Research Grants and Contracts	*1*	3,250	**5,004**
Contribution from the University of Cambridge	*2*	499	**650**
Donations	*3*	33	**466**
Additional workshop income		53	**71**
Additional income	*4*	281	**480**
Endowment and investment income		582	**659**
Total income		4,698	**7,330**
Expenditure			
Staff costs		1,357	**1,866**
Travel and subsistence	*5*	2,011	**3,388**
Other operating expenses	*6*	472	**688**
Overheads paid to the University	*7*	830	**844**
Total expenditure		4,670	**6,786**
Surplus / (deficit)		28	**544**

Notes to the Accounts

Note 1 - Research Contracts and Grants (EPSRC, Simons Foundation & Heilbronn Institute for Mathematical Research)

Salaries	1,358
Participant costs (travel and subsistence)	2,875
Estates and indirect income	771
Total	**5,004**

Note 2 - Contribution from the University of Cambridge

The University's financial contribution towards the Institute's running costs. In addition, the University provides the main and Gatehouse building, and pays for all services and rates.

Note 3 - Donations

London Mathematical Society	30
Building Extension	33
Donations, other	403
Total	**466**

Note 4 - Additional income

Merchandise sales	6
HEIF (Newton Gateway)	52
Newton Gateway events income	320
Programme Sponsorship	27
Mathematical Community Support	73
Miscellaneous Income	2
Total	**480**

Note 5 - Travel and Subsistence

Programme & workshop	3,353
Staff travel & subsistence	35
Total	**3,388**

Note 6 - Other operating expenses

Computing	114
Institute running costs	127
Catering	31
Furniture	7
Professional & brought in services	409
Total	**688**

Note 7 - Overheads paid to the University

Includes Estates and Indirect costs on grants and overheads on Trust Funds.

Governance: Advisory Council

Management Committee

The Management Committee is responsible for overall control of the budget of the Institute and for its financial planning. The Director is responsible to the Management Committee, which provides essential advice and support in relation to fund-raising activities, employment of the staff of the Institute, appointment of the organisers of programmes and general oversight of Institute activities. Its aim is to facilitate to the fullest possible extent the smooth and effective running of the Institute's programmes and all related activities. Membership of the Management Committee at 31 July 2023 was as follows:

Name	Institution	End of Service
Dr Ewan Kirk (Chair)	General Board	31-Dec-25
Professor Kerem Akartunali	University of Strathclyde	31-Dec-25
Dr Katie Blaney	EPSRC	
Professor Colm-Cille Caulfield	Head, DAMTP, University of Cambridge	
Dr Nira Chamberlain	SNC-Lavalin	31-Dec-24
Professor Mark Chaplain	St Andrews	31-Dec-24
Professor Darren Crowdy	Imperial College London	31-Dec-25
Dr Milla Kibble (Secretary)	Deputy Director, Isaac Newton Institute	
Professor Niall MacKay	Chair of Correspondents, York	
Professor James Norris	Head, DPMMS, University of Cambridge	
Professor Nigel Peake	Head, School of Physical Sciences	
Professor Marian Scott	University of Glasgow	31-Dec-23
Professor Ulrike Tillmann	Director, Isaac Newton Institute	
Professor Helen Wilson	Chair of the Scientific Steering Committee	31-Dec-26

Scientific Steering Committee

The Scientific Steering Committee (SSC) meets twice each year to consider proposals for programmes (of 4-week, 4-month or 6-month duration) to run two or three years later. Successful proposals are usually developed in a discussion between the proposers and the SSC conducted through the Director, and may well be considered at more than one SSC meeting before selection is recommended. Complete details of the Institute's regular call for proposals, including guidelines for submission, can be found on the Institute's website at **www.newton.ac.uk/science/proposals**. Membership of the Scientific Steering Committee at 31 July 2023 was as follows:

Name	Institution	End of Service
Professor Helen Wilson (Chair)	University College London	31-Dec-26
Professor Nick Barton	Institute of Science and Technology Austria	31-Dec-25
Professor Mark Girolami	University of Cambridge	31-Dec-26
Professor Ken Brown	University of Glasgow	31-Dec-23
Professor Susanne Ditlevsen	Københavns Universitet	31-Dec-24
Professor Robin Henderson	University of Newcastle	31-Dec-23
Professor Noah Linden	University of Bristol	31-Dec-26
Professor Sara Lombardo	Loughborough University	31-Dec-24
Professor Mary Rees	University of Liverpool	31-Dec-23
Professor Laure Sainte-Raymond	IHES	31-Dec-26
Professor Ulrike Tillmann	Director, Isaac Newton Institute	
Professor Minhyong Kim	Scientific Director, ICMS	

Cumulative Financial Grants and Donations above £10,000

Elena Ambrosiadou • Michael Astor • Apple Computers Ltd. • Applied Probability Trust • Autonomy Systems Ltd. • Iain Bratchie • Bank of England • Benfield Greig • BNP Paribas • British Aerospace • British Gas • Howard & Veronika Covington • William Craig • Cambridge Philosophical Society • Clay Mathematics Institute • CNRS • Credit Suisse • Daiwa Anglo—Japanese Foundation • DERA • Deutsche Forschungsgemeinschaft • Emmanuel College • European Molecular Biology Organisation • European Science Foundation • European Union • Dill Faulkes Foundation • Garfield Weston Foundation • GLC Charitable Trust (Lawrence Staden) • Gonville and Caius College • David Harding Foundation • Henderson Global Investors • Hewlett—Packard • Clive Humby & Edwina Dunn • Institute of Physics • Jesus College • John Templeton Foundation • Dr EM Kirk & Dr PJ Turner • Leverhulme Trust • London Mathematical Society • Hamish Maxwell • Steve Mobbs • Magnox Electric • Medical Research Council • Met Office • Microsoft Corporation/ Microsoft Research • National Science Foundation • NATO • Nomura Corporation • Nuffield Foundation • Office of Naval Research • Old Mutual plc • Paul Zucherman Trust • PF Charitable Trust • Prudential Corporation plc • NM Rothschild and Sons • Research Councils UK (SERC/ EPSRC/ PPARC/ STFC/ NERC/ BBSRC/ ERSC) • Rolls Royce • Rosenbaum Foundation • Royal Commission for the Exhibition of 1851 • Schlumberger • Simons Foundation • St John's College • Sun Microsystems Inc. • Thriplow Trust • Trinity College • Trinity College (Isaac Newton Trust) • TSUNAMI • Unilever • University of Cambridge • David & Elizabeth Wallace • Wellcome Trust • Winton Philanthropies • XTX Markets • Anonymous Donation

How to Donate

You may donate to the Isaac Newton Institute online by credit or debit card through the University of Cambridge's secure site. US tax payers may donate to Cambridge in America, a 501(c)(3) tax-exempt organisation, and qualify for an income tax deduction. Please state when making your gift that you would like your donation to support the Isaac Newton Institute for Mathematical Sciences. The University has charitable status and so donations made to it or its constituent parts, including the Institute, may attract tax relief. For UK tax payers this is available under Gift Aid.

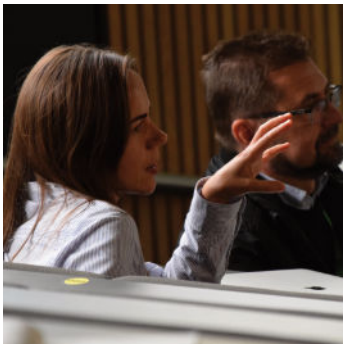
All donors will be acknowledged formally in the Institute's Annual Report (unless anonymity is preferred). The Institute offers recognition in various ways, including naming opportunities. If you would like to discuss these or other aspects of supporting our work, please do not hesitate to contact the Director (+44 (0)1223 335980 /director@newton.ac.uk) or Meaghan Annear at Cambridge University Development and Alumni Relations (+44 (0)1223 332288 / meaghan.annear@admin.cam.ac.uk).

UNIVERSITY OF CAMBRIDGE







Natural Environment Research Council

Biotechnology and Biological Sciences Research Council

Science and Technology Facilities Council

Economic and Social Research Council

Engineering and Physical Sciences Research Council

SIMONS FOUNDATION

LONDON MATHEMATICAL SOCIETY
EST. 1865