Institution: Maxwell Institute for Mathematical Sciences

Unit of Assessment: UoA 10 - Mathematics

1. Unit context and structure, research and impact strategy

1a. Overview

The Maxwell Institute (**MI**) is an internationally leading research centre in the Mathematical Sciences. It builds on a long-standing collaboration which combines the research activities in the mathematical sciences of the School of Mathematics at the University of Edinburgh (UoE) and the School of Mathematical and Computer Sciences at Heriot-Watt University (HWU), forming an international hub whose research spans the full spectrum of the discipline and whose influence is global.

Since REF2014, the MI has grown in strength and in depth, using its scale to forge powerful new connections to other disciplines, notably through its participation in the Edinburgh City Region Deal, specifically the £270M investment in the two universities in Data Driven Innovation (DDI); to support a community of early career researchers which includes one of Europe's largest Graduate Schools; and to build a flourishing knowledge exchange community, whose capacity extends across major industries and government agencies.

Bayes Centre, central hub of the Maxwell Institute

This major step up of activity has been made possible by the MI's move to its new location in the Bayes Centre, opened in 2018. This £40M investment in Edinburgh's city centre supports the STEM activity of the City Region Deal in DDI and is the base of the Maxwell Institute Graduate School, currently training 200 PhD students. This spectacular space also hosts the International Centre for Mathematical Sciences (**ICMS**), one of the UK's two flagship centres for workshops, established in 1990 as a joint venture of both institutions and managed by the MI.
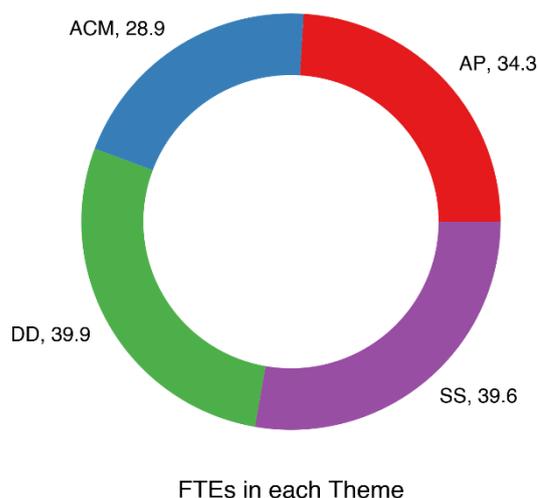
The MI's research capacity has expanded considerably in volume, with the recruitment of 70 new faculty since 2014 and a 55% increase in FTEs submitted for REF, and in scope, most strikingly through a step-change in our statistics and data-science activities. The quality of our work over the REF period is widely recognised and evidenced for example by:

- a research income of £39.1M, up by 77% from REF2014,
- the award of 19 major fellowships to our staff, with value up by 127%,
- the award of 2 EPSRC Centres for Doctoral Training (CDTs) representing an overall investment of more than £11M in PhD training,
- attracting almost £2.5M investment from industry, business and agency partners, for collaborations in research, development and innovation,
- the award of more than 30 prizes and honorary fellowships to our staff.

1b. Context and structure

The MI was founded in 2005 to establish Edinburgh as an internationally leading centre for the mathematical sciences, building on the complementary strengths of its constituent departments and on a history of close collaboration. Research activities have been steadily integrated since, leading to joint submissions to RAE2008 and REF2014 and to major successes in attracting infrastructure funding. This integration has culminated in the last three years with the creation of the Maxwell Institute Graduate School, the acquisition of a MI home at the Bayes Centre, and the adoption of a new organisational structure, centred on four **Research Themes** that encompass the activity of all our groups. These are:

ACM, 28.9 — AP, 34.3 — DD, 39.9 — SS, 39.6

FTEs in each Theme

- **Analysis & Probability** (**AP**, 34.3 FTEs),

- **Applied & Computational Mathematics** (**ACM**, 28.9 FTEs),

- **Data & Decisions** (**DD** – including Optimization & Operational Research, Statistics and Actuarial Science, 39.9 FTEs),

- **Structure & Symmetry** (**SS** – including Algebra, Geometry, Topology and Mathematical Physics, 39.6 FTEs).

Governance. The MI is led by 2 Co-Directors (Cheltsov at UoE and Schroers at HWU) who convene the MI Management Committee featuring the 2 Heads of School (Gordon at UoE and Pelloni at HWU), the 2 Co-Directors of the Graduate School (Dindos at UoE and Saemann at HWU), and the Directors of Impact (Sabanis at UoE and Cairns at HWU). Each Theme is headed jointly by two coordinators, one at each institution. These meet regularly as part of Research Committees whose work inform the strategic decisions taken by the MI Management Committee.

1c. Research strategy

Mission. The MI's mission is to be an internationally leading centre for the mathematical sciences, addressing the challenges of the 21st century. We aim to advance mathematical research and its applications, promote work at interdisciplinary interfaces, and deliver research training of the highest quality. In doing so, we contribute to the impact of mathematics on society and to its increasing visibility as an agent of progress.

Strategy. To deliver our mission, we have adopted a strategy with three broad objectives:

(i)   to vigorously develop fields which directly connect to applications, particularly those driven by the rapid growth in data science;

(ii)   to strengthen our world-leading activities in core mathematical science topics;

(iii)   to invest in early-career staff and graduate students and thoroughly support their development.

Together, these ensure the excellence and sustainability of the MI across the entire mathematical science spectrum. To achieve objectives (i)—(iii) our four priorities have been:

- **to target infrastructure funding** and other large-scale grants, building on our critical mass and our successful Science & Innovation centres (Centre for Analysis & Nonlinear PDEs 2007-2014 and Numerical Algorithms and Intelligent Software 2009-2014),

- **to stimulate applications for fellowships** by staff at all career stages, by offering extensive support throughout the application process, teaching and administrative relief, matching funds when appropriate, and a policy to convert long-term fellowships into

permanent posts,

- **to strengthen our impact** outside academia by building up capacity in fields directly connected to applications, by expanding our links with other disciplines and with business and industry, and by investing in professional services that support these activities,

- **to expand graduate training** in volume and in quality, by investing heavily in studentships and in the Bayes Centre, and by seizing opportunities such as CDTs in mathematics and in cognate areas.

The re-organisation of the MI into four Themes has played an important part in the delivery of our objectives. The Themes serve as centres for research activities, foster collaborations and enhance visibility; their mass and breadth have been crucial in mounting competitive bids for large-scale grants.

Achievements. Our strategy has been rewarded by major successes since 2014:

- Our investment in the **most promising early career researchers** has led to 7 ERC Starting Grants, 7 EPSRC First Grants & New Investigator awards, 1 UKRI Future Leaders Fellowship, 1 Ernest Rutherford Fellowship, and 5 Royal Society University Research & Dorothy Hodgkin Fellowships,

- Our **research leaders** have been awarded 2 ERC Consolidator Grants, 2 EPSRC Established Career Fellowships and 3 Leverhulme Fellowships,

- We have been awarded **two EPSRC CDTs**:

  o the Maxwell Institute Graduate School in Analysis and its Applications (**MIGSAA**, 2014-2022) funded by a £5.0M EPSRC grant and SFC,

  o the CDT in Mathematical Modelling, Analysis and Computing (**MAC-MIGS**, 2019-2028) funded by a £6.1M EPSRC grant, backed by a further £3.6M investment by UoE and HWU and £5.5M pledged by over 35 industry and government-agency partners,

- We have greatly **strengthened areas most closely linked to applications**, expanding by 19 FTEs in Statistics, 12 FTEs in Applied & Computational Mathematics, 6 FTEs in Operational Research and 3 FTEs in Actuarial Science. These include joint appointments with Biomathematics & Statistics Scotland (2), and the HWU Schools of Energy, Geoscience, Infrastructure & Society (1) and of Engineering & Physical Sciences (1). This boost in interdisciplinarity has led to 19 grants worth over £1.8M with Engineering, Geosciences, Physics, Informatics, EPCC and the Medical School,

- We have enhanced our external engagement by founding the **Statistical and OR Consultancy Units**, which interface between industry and our experts in mathematical statistics and operational research, and by reinvigorating the **Scottish Financial Risk Academy**, an industry-academic partnership dedicated to improving the understanding of financial risk, and by appointing three Business Development Executives,

- Our founding partnership in the **Alan Turing Institute** and the massive expansion of the Statistics Theme following an external review in 2013 have boosted our Data Science activities, funding 13 Turing Fellows and enabling our participation in the **City Region Deal in Data Driven Innovation**, from which the universities received £270M funding from the UK and Scottish Governments in 2018,

- Our **investment in the Bayes Centre** (£40M, opened 2018) has provided the MI and ICMS with dedicated space equipped with state-of-the-art facilities, improving the experience of the participants to ICMS workshops and benefitting the entire mathematical science community. This has combined with ICMS securing over £4.5M of EPSRC funding since 2014 and set to receive an additional £1M/year from 2021, doubling its budget,

- Our **large investment in PhD training** (including £4.4M in MI-funded studentships) and the creation of the Maxwell Institute Graduate School (MIGS) have had a transformative

impact: they underpin the award of MIGSAA and MAC-MIGS CDTs and our partnerships in four other PhD training centres (EPSRC CDT in Data Science, 2014-22; NERC Centre in Satellite Data in Environmental Science – Sense 2020-26; NERC DTP Edinburgh Earth & Environment 2014-2022; NERC DTP Edinburgh Earth, Ecology & Environment, 2019-28). One result has been the rapid growth in our PhD student intake, which more than doubled from 22 in 2013-2014 to 50 in 2019-2020 and the current cohort of 200 PhD students.

These achievements are underpinned by strategic developments of each of our four Themes which we now describe.

1d. Research Themes

Analysis & Probability (34.3 FTEs returned; grant income: £8.75M)

The Theme groups around 45 researchers including 35 permanent academic staff, working on the rigorous analysis of partial differential equations (PDEs) and stochastic PDEs, regularity structures, harmonic analysis, geometric measure theory, calculus of variations, optimal transport, stochastic processes, and numerical methods. Our strategy has prioritised interactions between these areas and an expansion of our capacity in targeted areas of applications: data science and machine learning, finance and economics, and communication and energy networks. The award of the **MIGSAA CDT** has been a primary focus driving the development of the Theme, underpinning several of its 13 new appointments since 2014: Azzam, Assiotis, Ball, Breit, Bruned, Cheyvrev, Haji-Ali, Hickman, Majka, Ottobre , Pocovnicu, Scardia and Schulte.

Research highlights in *Analysis* include: classification of rectifiable sets, with impact on free boundary problems to the theory of quasicrystals (Azzam); proving emergence and optimality of defects in materials science (Ball, Scardia); verifying the linear stability of Kerr spacetimes (Blue); development of a theory for Schatten-von Neumann perturbations of Gibbs semigroups (Boulton); development of a new concept ('semiflow selection') for selecting physically relevant solutions to ill-posed PDEs from fluid mechanics (Breit); a groundbreaking duality theory of multilinear factorisation of operators (Carbery); the first ever result of finite-time singularity formation for the two-phase incompressible Euler equations with surface tension (Coutand); the discovery of p-ellipticity and its implications for dimension-free embeddings and PDEs (Dindos); a new regularity theory for boundary problems (Gimperlein); the best progress to date on the Fourier Restriction and Kakeya conjectures and a resolution of Hormander's longstanding conjecture on oscillatory integral operators (Hickman); proving the Chopp conjecture on mean curvature flows (Karakhanyan); major developments in the well-posedness of dispersive (stochastic) PDEs supported by 2 ERC grants (Oh – Starting followed by Consolidator); the proof of integrability of classes of local and nonlocal noncommutative nonlinear PDEs and their realisation as Fredholm Grassmannian flows (Malham); and the construction of a linearisation operator at equilibria of parabolic p-Laplacian problems (Rynne).

In *Probability***,** research highlights include: explicit error bounds for approximation by geometric sums for stochastic systems (Daly); introduction and analysis of a new class of spatial dynamical stochastic models (Foss); major advances in degenerate stochastic parabolic PDEs (Gyongy); investigation of the probabilistic coupling technique as a tool for studying convergence rates of jump processes (Majka); a bound for the stability region of a standard wireless transmission protocol (Shneer); and groundbreaking results in the analysis of stochastic processes with multiple equilibria which was awarded the 2019 Whittaker Prize (Ottobre).

Interdisciplinary and engagement activities have included collaborative projects with Aberdeen Standard Investment attracting £115k funding (Sabanis), projects on asset management (Peters), on energy, transport and communications networks (Foss, Shneer), on lifespan prognostics for electric batteries (Dos Reis), and on automatised trading and execution of complex financial products (Siska). We engage strongly with the Alan Turing Institute (Szpruch had a 90% FTE secondment as Programme Director for its £12M programme in Finance and Economics, and Sabanis is a Fellow). Multidisciplinary collaborations include work on liquid crystals, polycrystals and dislocations (Ball), a collaboration with the National Robotarium (Gimperlein) and a project on

the mathematical modelling of cell therapy resulting in a publication in Nature (Gyongy).

Applied & Computational Mathematics (28.9 FTEs returned; grant income: £15.3M)

The Theme consists of approximately 45 researchers, including 29 permanent academic staff. Its strategy in the REF period has been to drive expansion along two main axes: computational and data-driven methods, and multidisciplinary applications. This builds on an exceptional environment, with our participation in the Alan Turing Institute (5 staff are Turing Fellows), the presence of the Edinburgh Parallel Computing Centre, the data-science hub that is the Bayes Centre, and world-leading research groups in science, engineering, informatics and medicine offering outstanding collaboration opportunities. The award of the **MAC-MIGS CDT** and our participation in **two EPSRC Programme Grants** (Higham, Vanneste) are the most visible rewards for our strategy. To realise it, we have recruited 11 staff, including research leaders Higham (EPSRC/RCUK Established Career Fellow 2015-2020, Royal Society Wolfson Research Merit Award) and Pelloni (FRSE, now Head of School at HWU), and rising stars Teckentrup (SIAG/Uncertainty Quantification Early Career Prize and Leslie Fox 2nd Prize 2017), Schratz (ERC Starting Grant), Varri (UKRI Future Leaders Fellow, joint appointment with Physics), Pearson (EPSRC Postdoctoral Fellow, Leslie Fox 2nd Prize 2015), Cummins (joint appointment with Engineering), Bourne, Ptashnyk, Linkmann and Page (Osborne Reynolds Award 2015).

Research highlights in *Computational Mathematics* include: new network centrality algorithms, based on the theory of zeta functions and matrix polynomials, that avoid the drawbacks associated with backtracking walks (Higham); pioneering work on multilevel Markov chain Monte Carlo methods enabling the calibration of large-scale PDE models (Teckentrup); forefront Langevin-based sampling algorithms that incorporate adaptivity, temperature ladders, memory, and configurational constraints (Leimkuhler); the first iterative solvers for PDE-constrained optimization for fluid flow control, imaging problems, pattern formation and chemotaxis (Pearson); putting convergence of adaptive time-stepping of stochastic PDEs on firm theoretical foundation (Lord); and new Bayesian framework and algorithms for the task of binary classification using a graph formulation of semi-supervised learning (Zygalakis).

In *Applied Mathematics,* research highlights include: the discovery of simple rules for the genetic makeup of growing cell populations (Antal); combining mathematical modelling with experiments to determine the mechanisms of RNA transcription elongation (Goddard); improved understanding of sea turtle navigation (Painter); resolution of a longstanding contradiction between model predictions and data for patterned vegetation (Sherratt); a new mathematical model of the spreading of airborne diseases such as Covid-19 during breathing and clinical procedures (Cummins); mathematical modelling which directed disease management efforts to control the spread of African swine fever and tuberculosis in wildlife populations (White); a new framework for the multiscale analysis of stochastic gene expression (Popovic); mathematical modelling of Tyndall star initiation, which explains the observation of thin discs (Lacey); uncovering an unexpected degree of phase space complexity in collisional stellar systems (Varri); discovery of a planar interface that supports multiple Rayleigh waves (Mackay); the first practical implementation of uniform asymptotic expansions for integrals with coalescing critical points (Olde Daalhuis); development of a new parameterisation of ocean turbulence, now implemented in the NEMO community ocean model (Maddison); a new theory of inertia-gravity-wave scattering that explains observed kinetic energy spectra in the atmosphere and in the ocean (Vanneste); demonstration of the non-universality of large-scale structures in two-dimensional turbulence, shown to arise through either first or second-order phase transitions (Linkmann); discovery of the first exact coherent structure in a viscoelastic channel flow, explaining the dynamical origins of elasto-inertial turbulence (Page); and a new probabilistic framework for Lagrangian uncertainty quantification, rooted in information theory and information geometry (Branicki).

Interdisciplinary and engagement activities in the Theme have transformed our interactions with industry, business and government agencies, culminating with the pledge of more than £5.5M (including £1.3M direct funding) by more than 35 partners for our successful MAC-MIGS CDT bid. Our partners represent a broad array of industries: finance (Aberdeen Standard Investments, Moody's Analytics, Royal Bank of Scotland, Oliver Wyman), computing (IBM, nvidia), technology (MacLaren, Leonardo), chemical and biochemical engineering (Akzo Nobel, Biova, Cresset, Procter & Gamble, uFraction8, Infineum), energy (Mocean, NM group, Ofgem) and more.

Examples of recent engagement projects include work on police deployment (Higham with Police Scotland), wind-turbine management (Leimkuhler with DNV GL) and metal-grain models (Bourne with Tata Steel). In parallel, we have developed collaborations in the life sciences with academic departments (UoE Centre for Medical Informatics, Engineering) and with other partners such as Scottish National Heritage, Institute of Game, NHS Scotland, and Wildlife Research (Spain).

Data & Decisions (39.85 FTEs returned; grant income: £7.5M)

The Theme groups our activities in Optimization & Operational Research, Statistics and Actuarial Science. It has benefitted from a large investment over the REF period resulting in its **expansion from 17 permanent staff in 2014 to 40 in 2020**. This investment was driven by the rapidly increasing importance of statistics and optimization for data science and machine learning, and by opportunities to consolidate our international standing in actuarial mathematics. A core element of the Theme's strategy has been the development of impact through interdisciplinary collaborations. Recruitment has been carried out across all seniority levels, from rising stars to the newly established Thomas Bayes' Chair of Statistics (King, FRSE, FLSW), with: Wood (EPSRC Established Career Research Fellowship), Anjos (Schoeller Senior Fellow), Lindgren (Elected Member of International Statistical Institute), de Carvalho (Young Scientist Prize for The World Academy of Sciences, Elected Member of International Statistical Institute), Cetinkaya-Rundel (Elected Member of International Statistical Institute), Peters (Young Academy of Scotland, Royal Society of Edinburgh), Pereyra (Marie Curie Fellow), Gair (Royal Society URF; President's Medal of the Royal Society of Edinburgh), Elvira (Fulbright Research Fellowship, Marie Curie Fellowship) and Oktem (Rutherford Visiting Fellowship).

Research highlights in *Optimization & Operational Research* include: a novel orbital branching for structured symmetry in unit commitment problems (Anjos); a complete theory of warmstarting interior point methods in the column generation context (Gondzio); new tighter error bounds for monomial convexification in polynomial optimization (Gupte); new penalty alternating direction methods for mixed-integer optimization (Schewe); simplification of inclusion-exclusion on intersections of unions in the context of network systems reliability (Garcia); a new algorithm for optimization of eigenvalues of Hermitian matrix functions (Yildirim); explaining structural properties of Voronoi diagrams in facility location problems with continuous demand (Kalcsics); a variable metric forward–backward algorithm for convex optimization (Repetti); stabilising scenario decomposition algorithm for stochastic unit commitment problems (McKinnon); solving security constrained optimal power flow problems using interior point method (Grothey); parallelizing the dual revised simplex method (Hall); assessing the role of nightly rechargeable grid-scale storage to power generation capacity (Dent); and providing fluid and diffusion approximations of probabilistic matching systems (Buke).

Research highlights in *Statistics* include: novel statistical learning techniques for high-dimensional classification problems applied to oncology (Cannings); efficient, scalable computational techniques applied to problems ranging from malaria control in Africa to energy forecasting in France by EDF and farm analytic tools in the US and Canada (Lindgren, Wood); new statistical models for the evaluation of criminal evidence used for drugs on banknotes and other forensics applications (Wilson, Aitken); development of epidemiological methods recently used to inform disease control policy in New Zealand, Australia and Austria (Gibson, Streftaris); the first precise estimate of the mean persistence time from endemicity to extinction for a population model in more than one dimension (Clancy); and a comprehensive mathematical and computational framework for performing uncertainty quantification in inverse problems applied to imaging sciences (Pereyra).

Research highlights in *Actuarial Mathematics* include the development of new statistical models leading to the discovery of anomalies in national population data (Cairns); and development of a dynamic mathematical model of cascade genetic testing in families with inherited heart disorders (Macdonald).

Interdisciplinary and engagement activities are at the heart of the Theme. These have been boosted over the REF period by a joint appointment with BioStatistics Scotland (Gair followed by Newman), a joint appointment with Engineering (Repetti), the establishment of the Centre for Statistics which unites data-driven researchers from across the MI and associated institutions, the

creation of the Statistical and OR Consultancy Units, and increased activities of the Scottish Financial Risk Academy (SFRA). Our external partners include Google, Oracle Labs, NTT, Cargill, NHS, EDF, National Grid and the UK, Canadian and American Societies of Actuaries.

Structure & Symmetry (39.6 FTEs returned; grant income: £18.7M)

This Theme has 60 researchers, including 40 permanent members of staff. The creation of the Theme deliberately brought mathematical physics, algebra, geometry and topology together to break down boundaries between disciplines, promote new collaborations between existing researchers and attract new members with interests that span disciplines (Ciobanu, R. Davison, Sheridan, Dimofte). We have built on our existing strengths in algebra and in geometry, bringing them together to **lead a £3.4M EPSRC Programme Grant** at the interface between algebra and geometry (with our former colleagues Wemyss and Bridgeland), we have supported new areas in mathematical physics, with novel directions in gravitational physics, holography, and condensed matter physics, and we have grown to establish a strong geometric group theory group. Our vigorous recruitment has attracted world-class researchers: Adamo (Royal Society URF), Barwick (Berwick Prize 2019), Ciobanu, B. Davison (Royal Society URF; ERC starting grant; Whitehead Prize 2020), R. Davison (STFC Ernest Rutherford Fellowship), Dimofte, Hartong (Royal Society URF), Hollands (Anne Bennett Prize 2018, Royal Society Dorothy Hodgkin Fellowship), Martin, Pires, Sheridan (Whitehead Prize 2019, Royal Society URF; ERC starting grant) and Sisto.

Research highlights in *Algebra, Geometry and Topology* include: classification of constructible sheaves and construction of the first complete invariant of smooth varieties over number fields (Barwick); advances in the foundations and applications of stability conditions in algebraic geometry (Bayer); solution of the Calabi problem for smooth Fano three-folds using purely algebraic approach via K-stability (Cheltsov); proof of the positivity conjectures in quantum cluster algebras using cohomological Donaldson-Thomas theory (B. Davison); new constructions of HOMFLY-PT link homology using supersymmetric gauge theories and mirror symmetry (Dimofte); construction of quotients of ordered groupoids with applications to their homotopical and homological algebra (Gilbert); confirmation of a conjecture of Bonnafe-Rouquier that identifies Kazhdan-Lusztig combinatorics in colliding points in the rational Calogero-Moser model (Gordon); proof that $4M$-4 generic intensity measurements of a vector are sufficient to reconstruct the vector up to a global phase factor (Hering); introduction of the quantum geometric Langlands topological field theory and its use to resolve conjectures of Ben-Zvi, Bonahon-Wong and Witten (Jordan); pioneering work on magnitude and magnitude homology, invariants of metric spaces and enriched categories that encode subtle geometric information (Leinster); asymptotics of Bridgeland stability conditions for three-folds and the differential geometry of the walls (Maciocia); construction of the Hitchin connection in positive characteristic (Martens); development of new geometric tools to reveal non-positively curved features of large classes of Artin groups (Martin); investigation of exceptional rigidity-flexibility phenomena in symplectic embeddings of ellipsoids into toric manifolds (Pires); deformation quantisation for symplectic and Poisson structures in derived algebraic geometry (Pridham); definition of coisotropic structures for derived stacks and their relationship to quantum groups (Safronov); proof of homological mirror symmetry for Calabi-Yau and Fano hypersurfaces in projective spaces (Sheridan); computation of primitive ideals in the enveloping algebra of the Witt algebra using techniques from Poisson geometry (Sierra); initiation of the theory of hierarchically hyperbolic spaces which has grown into its own subfield of geometric group theory (Sisto); and development of structure theorems for left nilpotent braces, solving some longstanding and some recent open problems related to adjoint groups of rings, to differential polynomial rings and to Acons (Smoktunowicz) .

In *Mathematical Physics* research highlights include: discovery of a novel description of supergravity as a string theory in its own right (Adamo); construction of explicit BPS monopoles directly from the spectral curve together with its ground-breaking charge 2 implementation (Braden); classification of kinematical Lie algebras and the corresponding spatially isotropic homogeneous spacetimes in all dimensions (Figueroa-O'Farrill); discovery of a theory of non-standard scaling at first order phase transitions with sub-extensive degeneracies (Johnston); construction of a classical Lagrangian for a six-dimensional superconformal field theory which was previously believed to be impossible (Saemann); construction of some of the first non-relativistic gravity and string theories, and development of non-Lorentzian geometries and their applications

to fluid dynamics, soft condensed matter and field theory (Hartong); pioneering the extension of abelianisation techniques to higher rank flat connections on Riemann surfaces and its relation to exact WKB methods (Hollands); classification of all massive infrared phases in the Ising field theory (Konechny); discovery of the first example of an asymptotically flat black hole solution with lens space topology (Lucietti); uncovering key links between set theoretic solutions of the Yang-Baxter equation coming from nil rings and quantum integrability (Doikou, Smoktunowicz); first rigorous construction of moduli spaces of fractional instantons on ALE spaces using framed sheaves on root toric stacks (Szabo); demonstration that the transport of energy in strongly correlated systems is related to the quantum scrambling processes that govern the chaotic properties (R. Davison); discovery of the first infinite family of exactly solvable models of magnetic skyrmions (Schroers); development of two-dimensional conformal field theory tools to compute the quantum entanglement of excited states at finite temperature (Simón); and the first rigorous algebraic construction and analysis of Baxter's Q-operator for an open quantum spin chain (Weston).

Interdisciplinary and engagement activities within the Theme stem from the impact of our research beyond mathematics. For instance, we led work packages in two STFC Consolidated Grants worth over £3.4M with the Higgs Centre for Theoretical Physics; we are developing collaborations with experimental groups at Forschungszentrum Julich in Germany and Keio University in Japan on emerging information storage technology; our prediction of a large negative thermal magnetoresistance due to mixed axial-gravitational anomaly was confirmed experimentally in the Weyl semi-metal NbP; and our work on the interactions of infinite groups with theoretical computer sciences answered a 30 year old open question and opened up a new area of research which has attracted £0.5M investment by EPSRC.

1e. Impact strategy

One of our priorities has been to strengthen our impact outside academia and help address current socio-economic challenges. To this end, we put in place a deliberate strategy that consists of:

   (i)   identifying and nurturing activities with potential economic and/or societal benefits;
   (ii)   developing new structures to engage systematically with industries that translate mathematics into innovations available to a wide public;
   (iii)   providing effective support to staff engaged in impactful research and translation activities.

The success of this strategy is evidenced by a **3-fold increase in the number of businesses and agencies we interact with,** and a **10-fold increase of the average consultancy income per year**. The strategy has created a supportive environment in which every activity which has a potential to create an impact (reaching beyond the REF2021 census date) is encouraged and nurtured from the start. Part of our support for early career researchers has targeted impact: we have more than 20 match-funded industrially sponsored PhD students; co-funded 2 academic-industry partnership postdocs with a £6.4m EU COFUND scheme; established an Impact Time policy, which frees up time for younger members of staff (4 so far) to carry out impactful activities; provided systematic industrial training for our PhD students, including through the organisation of industry-driven sandpits and modelling camps. The rich portfolio of over 35 industry and agency partners contributing to the MAC-MIGS CDT is enabling us to scale up this student engagement.

To ensure that our research reaches beyond the MI, we have invested in **3 Business Development Executives** all of whom are trained mathematical scientists, and **3 consultants in industrial mathematics, statistics and operational research.** Together they support the whole range of our external engagement activities. Additional support is provided by central University services which interact with companies at an institutional level and facilitate industrial collaborations by dealing with contractual and IP issues. Our goal is to work on projects that combine exciting research challenges with benefits for society and the partners with whom we work. We engage with companies at all research levels, from MSc and PhD projects to funded postdoctoral or faculty secondments and consultancy, and at various scales, from one-off projects (e.g. with Edinburgh Airport) to sustained relationships (e.g. with Aberdeen Standard, Adidas, Airbus, Aviva UK Life, AWE, BT, Cargill, Format Solutions, Google, IBM, National Grid, NPIF, Oracle Labs, Prudential). Our strategy has enabled us to seize opportunities such as the EPSRC

Impact Acceleration Account (12 projects for a total of £426K) and to secure a total of almost £2M of industrial funding.

We have focused most of our effort on industries that we identified as offering the best potential for engagement or are best aligned with strengths of the local economy. These are:

- **Finance**: we have reinvigorated the Scottish Financial Risk Academy – under its new Director (Peters), SFRA was approved as a Special Interest Group within Scottish Financial Enterprise, consolidating its position as a crucial link between industry and academia; we nurtured a relationship with Aberdeen Standard Investment which has led to a £1M investment in our activities; and we lead the £12M Alan Turing Institute programme in Finance and Economics with partners HSBC and Accenture. These activities have been supported by investment in staff (Peters), in postdocs (2 funded by Aberdeen Standard), and in 4 PhD students.

- **Energy**: through our Optimization and OR group, we have developed capacity in the energy sphere, particularly around security of supply and preventive maintenance planning for electric grids where we work with EDF and National Grid, advise government and collaborate with Engineering. This work has been supported by the appointments of Anjos, Dent, Schewe and Wilson and has attracted £1.65M of research funding. Work in this area has led to an impact case study submitted for this REF.

- **Pensions and Insurance**: our experts in actuarial mathematics guide the policies of pensions and insurance sector in the UK and worldwide. Crucial discoveries of anomalies in national population and mortality data made by Cairns have influenced procedures used by the Office for National Statistics, Prudential Retirement in the US, UK pension funds, and UK and international actuarial consultancies such as Milliman. The work of the Actuarial Science group (Cairns, Donnelly, Streftaris) has attracted £2.3M of research funding from UK, US and Canadian Societies of Actuaries. In 2018 we were granted status as Center of Actuarial Excellence by the US Society of Actuaries, the first to be granted in Europe. Work in this area has led to two impact case studies submitted for this REF.

- **Software:** new algorithms developed and implemented by MI staff have delivered software used worldwide. The multiple award-winning work of Hall on high performance linear optimization (selected as best papers in Mathematical Programming Computation and in Computational Optimization and Applications) has yielded industrial impact with Cargill, FICO, NTT, Huawei and Google. A current low-cost open-source initiative to develop and maintain the HiGHS software will further increase this impact. The work of Loisel with OpenGoSim has provided high performance simulation techniques for carbon capture and enhanced oil recovery. Our growth in the software space has been stimulated by appointments in computational mathematics (Higham, Teckentrup, Zygalakis, Schratz, Bourne) and optimization (Anjos, Gupte, Kalcsics, Schewe, Yildirim). Work in this area has led to an impact case study submitted for this REF.

- **Data analytics**: our impact in the area has been amplified by our participation in the Alan Turing Institute (with 13 staff awarded Turing fellowships and 3 Turing research fellows joining the MI), the creation of the Centre for Statistics with its team of (2 currently) Statistical Consultants, and the MI's contribution to the Bayes Centre and the Edinburgh City Region Deal on Data Driven Innovation. More than 20 appointments in data-related areas have enabled us to make the most of these initiatives.

We have had impact beyond industrial applications in areas that include epidemic control, wildlife conservation, security and forensics, each of which has led to an impact case study submitted to this exercise. In the last few months up to the REF census date, the COVID-19 emergency has driven new impactful research on the efficacy of wearing face masks (Cummins). This was the only such study in the UK referenced in the UK Government's Scientific Advisory Group on Emergencies (SAGE) report as evidence of mask protection against SARS-CoV-2 and subsequently informed a UK Government statement on the widespread use of face masks. The work has generated almost 500 news articles and over 80 broadcast clips in 18 countries.

1f. Open research

The MI has actively embraced the Open Research agenda, putting in place ambitious goals and rigorous support for Open Access and data sharing. Over the REF period, 95% of the papers authored or co-authored by MI staff have been made available immediately on publication through Open Access journals or repositories. Most papers have been released earlier as preprints on the arXiv, a longstanding open culture amongst our staff which predates the REF open access policy. Data Management has become increasingly important for the MI with the expansion of computational mathematics and data science. We make our codes and data publicly available through University-maintained repositories DataShare and Pure or on GitHub.

1g. Future strategy

The Maxwell Institute is now an internationally leading centre for the mathematical sciences and their applications. Our future strategy builds on this. We believe in the breadth of the mathematical sciences, and will continue to value the range and quality of our research. Through our expertise and size, we will support, influence and lead the mathematical sciences community, both in the UK and internationally. We will grow our impact, adapting to the changing industrial and societal landscape, and using our scale to seize opportunities on short timescales.

Our strategy since REF2014 has delivered a greatly strengthened and expanded staff. As well as developing and enhancing our existing strengths across the discipline, we have already identified areas for future growth, in keeping with our broad, inclusive vision of the mathematical sciences. These include Energy, Data Ethics, Finance, and the interface between technology and mathematics education, with an explicit ambition to become the top UK centre for research in Technology Enhanced Mathematical Sciences Education.
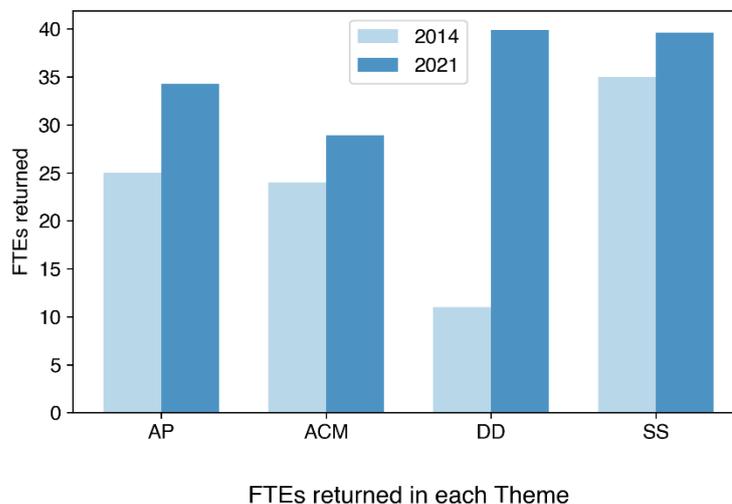
In building MIGS we have created one of the most vibrant and largest Graduate Schools in Europe. This has unlocked the energies of the MI, creating new intellectual collaborations and opening numerous international partnerships. We will always invest in it, to provide high-quality training for all our PhD students at scale, shifting the entire MIGS to the model adopted by the CDTs, whereby students are admitted on Theme-based PhD programmes and select their PhD project after having experienced courses and projects.

The value of the mathematical sciences, both intrinsically and as a key to addressing the world's most pressing challenges, is increasingly recognised and our skills, our contributions and how we communicate them are more important than ever. We look forward to the future with great optimism, for the discipline and for the Maxwell Institute.

2. People

2a. Staffing strategy

The staffing strategy of the MI is to recruit outstanding mathematicians from around the world, based on research achievements, or potential in the case of early career researchers. Our strategy has had three main aims: achieve a mix of exceptional early and mid-career staff, meet the MI's strategic objectives, and improve gender balance. This has been achieved through a combination of targeted recruitment exercises and opportunistic hires. We made the latter possible by establishing dedicated schemes giving us the agility required to recruit exceptional researchers at short notice.

FTEs returned in each Theme

The **staffing level** of the MI has grown markedly in the REF period, **increasing by 55%** from 93.2 FTE in 2014 to 144.65 FTE in 2020. We have appointed **70 new academics** (see section 1e for the new staff in each Theme). In the same period, 22 staff members have retired or migrated elsewhere, several of whom have taken their talents into other areas such as the industrial sector – for example, former staff member Cruise joined a start-up company in Mathematics in Energy Systems (Cambridge). We have strengthened each of our 4 Research Themes, with a particularly large expansion in Data & Decisions by 28 new staff including 7 at Chair level (King, Lindgren, Clancy, Anjos, Wood, Peters, Oktem). The new area of Technology-Enhanced Mathematical Sciences Education has also been introduced with the recruitment of Sangwin for a dedicated Chair and Cetinkaya-Rundel. Our recruitment has been resolutely international, with our new staff representing 24 countries and 4 continents.

Fellowships. The success of our recruitment strategy is indicated by the prestigious research fellowships awarded to our staff. Major fellowships during the REF period include:

- ERC Consolidator (Bayer, Oh),

- ERC Starting (Bayer, B. Davison, Jordan, Oh, Schratz, Shapiro, Sheridan),

- UKRI Future Leader Fellowship (Varri),

- Royal Society University Fellowships (Adamo, B. Davison, Foscolo, Gair, Hartong, Sheridan),

- Royal Society Dorothy Hodgkin Fellowship (Hollands),

- STFC Ernest Rutherford Fellowship (R. Davison),

- EPSRC Fellowships (Higham, Pearson, Wood),

- Marie Curie Fellowships (Elvira, Pereyra),

- Fulbright Fellowship (Elvira),

- Lise Meitner Fellowship (Martin),

- Royal Society of Edinburgh Fellowship (Chumakova).

We have invested heavily in our own fellowship schemes which attract outstanding early-career researchers from all over the world and enable them to pursue independent original work. These

schemes are: *Chancellor's Fellowships* (2 since 2014) which fund 5-year tenure-track posts leading to permanent positions, *Seggie Brown Fellowships* (4 since 2014) which fund 2-year postdoc positions, *Whittaker Fellowships* which currently fund three early-career researchers in 3-year positions, and *Bicentennial Actuarial Fellowships,* funding two 2-year postdoc positions. Our Seggie Brown and Whittaker Fellows typically go on to secure external fellowships (EPSRC, Royal Society of Edinburgh) and permanent academic positions, including at Leeds, Paris VI, McGill, Alfred Renyi Institute, Sheffield and Kent.

Visitors. Many mathematicians from around the world visit Edinburgh to collaborate with MI staff and to engage with our research activity programme and workshops, including those run by ICMS. Notable visitors since 2014 include: Bacceli (Austin), Boyd (Stanford), Dunson (Duke), Ferrari (Buenos Aires), Gunzburger (Florida State), Hillen (Alberta), James (Minnesota), Joshi (Sidney), Krylov (Minnesota), Madden (Ohio State), Mazzeo (Stanford), Murray (Adelaide), Pardon (Princeton), Ramanan (Brown), Sayas (Delaware), Seeger (Wisconsin), Sogge (John Hopkins), Stolyar (Urbana-Champaign), Vaintrob (Oregon), Wang (Hefei), Yang (New York) and Young (UCSD).

The MI also organises high-profile lecture series that attract leading figures to Edinburgh. In the period 2014-20, the *MI Colloquia*, a series of distinguished lectures accompanied by specialist workshops open to the entire UK community, invited notable figures including Del Moral (INRIA Bordeaux) and Zannoni (Bologna). The *MI Lectures* are intended for a broad scientific audience and brought to Edinburgh the likes of Maggioni (Duke) and Hairer (Imperial). The *Whittaker Colloquia* included lectures given by Blake (Alan Turing Institute), Pintz (Alfred Renyi Institute), and Witten (Institute for Advanced Studies, Princeton). These events complement our 10 regular series of weekly seminars and colloquia.

2b. Staff development and support

Early career researchers (ECRs). The balance of ECRs and senior staff achieved by the MI enables us to comprehensively support the development and career progression of our junior academics. All staff have an affiliation with a Theme, and new staff are assigned a research mentor within their Theme – an experienced member of staff who helps them with the transition to their academic position by providing guidance for professional development, completion of probation, and promotion. All new staff are provided with a thorough induction within their institutions, which also offer a selection of training courses aimed at developing their competencies and personal and professional capabilities. Examples include the Research Development Programme and the Research Futures Programme which foster development of key academic attributes of collaboration, interdisciplinarity, innovation and leadership.

ECRs receive a light administrative load and at least a 50% reduction in their teaching load during their first year. They are prioritised as supervisors for the allocation of PhD studentships and are offered comprehensive support for grant applications, with a systematic internal reviewing process. Applications to EPSRC First Grant/New Investigator Awards are supported by matched funding from the MI for PhD studentships and postdoctoral associates. ECRs run an Early Career Research Forum and are actively encouraged to take every opportunity for external professional development, e.g. the EPSRC Early Career Forum (Ottobre, Pereyra) and the Young Academy of the Royal Society of Edinburgh (Peters). All new staff are also encouraged to participate in the Scottish Crucible, a scheme for Scottish Universities to equip ECRs with skills in networking, creative thinking and innovative research.

One of the central aims of the MI is to nurture Research Fellows (35 since 2014) and Postdoctoral Research Assistants (128 since 2014) to enable them to achieve their potential. The number of Research Fellows and PDRAs has been rising fast over the REF period, by 80% from 21 in 2014/15 to 38 in 2018/19, creating a vibrant community that plays a central role in organising seminar programmes and leading numerous working groups. They are supported by individual mentors, they have full access to the diverse development activities organised by the institutions, and they take advantage of our dedicated support for maximising the impact of their research, in academia, industry or society. They also benefit from a systematic policy that gives

them the opportunity to undertake modest teaching activities. By these means we offer a broad platform for the development of research excellence, of teaching experience and of transferable skills. This gives our postdocs the best opportunities for permanent jobs. Members of the MI have gone on to have positions at top-level institutions and industry.

All staff benefit from an annual Performance and Development Review (PDR) conducted by designated senior staff. The PDR reviews performance during the previous year and includes a forward job plan, providing a mechanism to support research activities including external funding, publications, research supervision, and impact. We have introduced numerous financial incentives for our staff to apply for grants. The Schools operate a transparent work allocation model which takes into account investigator time on grants and PhD supervision. All staff have access to travel funds of up to £1.3K/year within their Schools, and teaching and administrative duties are allocated flexibly to enable staff to undertake extended research visits or attend conferences. Sabbatical and study leave is granted on a regular basis (typically 1 in 8 semesters), with further provisions for staff with impact case studies. Additional leaves are granted to staff who secure funding for teaching replacement.

2c. Research students

An ambition of the MI is to attract the best research students from around the world and help them achieve excellence in research, teaching and knowledge exchange. We offer them the highest quality of training and support towards their aspirations and careers. The **establishment of the Maxwell Institute Graduate School (MIGS)** in 2017, backed by institutional funding for further studentships, has enabled us to achieve this, through intensified recruitment efforts, enhanced training, and improved research and pastoral support. Our investment in the Bayes Centre has been central to the success of MIGS, providing a physical hub that hosts all first-year students and much of the research and training activities. Our efforts have had a transformative impact on the graduate school. Numbers have grown **from 118 students in 2014/15 to 194 students in 2019/20;** a total of 179 PhD students who were supervised by MI staff have graduated during the current REF period, marking an increase of 80% over the

PhD student social space at the Bayes Centre

assessment period of REF2014. The **award of two EPSRC Centres for Doctoral Training** (CDTs) – the MI Graduate School in Analysis and its Applications (MIGSAA, 2014-2022) and the MI Graduate School in Mathematical Modelling, Analysis and Computation (MAC-MIGS, 2019-2028) – evidences the external recognition received by our PhD programme.

Funding. We offer a range of PhD scholarships: EPSRC DTA studentships (4/year), STFC DTP scholarships (1/year), James Watt scholarships (3/year), UoE Principal's Career Development Scholarships (3/year) and UoE School of Mathematics Scholarship (c15/year). MI funding is also used to offer partial scholarships and attract external funding, from sources such as the Leverhulme Trust, the Royal Bank of Scotland, Adidas, EFI, and the British Geological Society. The two CDTs, which combine EPSRC funding, MI matching, and investment by industry and agency partners, make a strong contribution to MIGS. MIGSAA will train around 60 students by 2022; MAC-MIGS will train around 75 students by 2028. The MI is a partner of four other PhD training centres (EPSRC CDT in Data Science, 2014-22; NERC Centre in Satellite Data in Environmental Science, 2020-26; NERC DTP Edinburgh Earth & Environment 2014-2022; NERC DTP Edinburgh Earth, Ecology & Environment, 2019-28) which provide further studentship opportunities. Additional PhD students are also supported by research grants (e.g. from the Royal Society and ERC) and by schemes from their country of origin (e.g. China Scholarships, Conacyt and Conicyt).

Recruitment. All studentship applications to MIGS are made through an online system, which advertises individual research projects as well as general availability of staff for PhD supervision. MIGS hosts two recruitment days per year (in December and February) to which the most promising applicants are invited. Other promising PhD applicants are invited for a video interview. MAC-MIGS, and previously MIGSAA, run dedicated recruitment campaigns tailored to the specificities of CDTs. Student excellence and research potential are the primary criteria for funding, with secondary factors including the mapping of research projects to the MI's research strategy, the support of newly appointed staff and staff without PhD students, and improving gender and ethnic diversity of the cohort.

Training and support. All PhD students have two designated research supervisors (for whom training on PhD supervision is mandatory) who interact closely with them. Each student is also assigned a Personal Adviser, a member of staff outwith the student's research theme who offers pastoral support. During the first year of their PhD, all students are co-located at the Bayes Centre, where they undertake a 6-month training period focussed on developing key mathematical and transferable skills, public engagement, collaborative research and cohort building. Students are required to take up to 6 modules which typically comprise an independent reading project plus a selection of broad training courses provided through the Scottish Mathematical Sciences Training Centre (SMSTC), a consortium of Scottish universities in which the MI has played a central role since its inception over a decade ago (Carbery, Duncan and Leinster have each held the post of SMSTC Director). The cohort experience of working in groups and following the same suite of courses allows our students in their first developmental year to thrive in a well-connected environment and avoid working in isolation. Students then mainly focus on their research project and relocate to one of the two campuses to enable closer contact with their primary supervisor. Throughout their studies, students participate frequently in meetings run at the Bayes Centre, such as cohort activities, seminars, Theme meetings and study groups, advanced courses provided by Themes, together with workshops, modelling camps and networking opportunities at the ICMS. All PhD students are allocated a yearly travel allowance to attend schools and conferences outside Edinburgh.

Progress of PhD students is monitored through regular meetings with their supervisors and the MIGS or CDT Directors. All students undergo a formal annual review, and an informed decision on progression is made based on a combination of a seminar delivered to an audience of Theme members, a written report and a viva conducted by a member of staff other than the supervisors. This monitoring provides formal opportunities to discuss academic progress, training needs and intended activities for the following year.

Throughout their PhD, students are required to undertake around 50 hours per academic year of transferable skills training. This includes general skills training courses run by MIGS and the two universities (such as presentation and writing skills, proposal writing activities), and professional development training through MIGS in one of three streams: outreach, teaching, industry. Almost all our students participate in teaching activities, and are offered the opportunity to take Learning Enhancement and Development Skills (LEADS) courses or Edinburgh Teaching Award (EdTA) leading to accreditation by the Higher Education Academy. They lead MI activities such as weekly PhD student colloquia and the Edinburgh SIAM-IMA Student Chapter.

Students enrolled in our CDTs follow a more intensive programme focusing on applications in multidisciplinary contexts as well as experience of industrial collaboration. Industrial and agency partners provide internships, development programmes and research projects which help maximise the impact of students' work, while academic partners, representing 10 leading institutions in the United States and Europe, provide further opportunities for collaborations and research visits. The CDTs are overseen by International Advisory Boards who benchmark student assessments and training against the highest international standards.

Student achievements. The quality of our training of PhD students is evidenced by the prizes and scholarships they have been awarded, such as: Google Europe Fellowship in Optimization Algorithms (Konecny, 2014), LMS Cecil King Travel Scholarship (Crawford, 2018), Scottish Civil Engineering Conference Prize (Stark, 2016), SIAM UKIE Prize (Stocek, 2019), EMS PhD Thesis Prize (Feyzbakhsh), Hystrix Best Paper Prize 2016-17 (Jones), 2019 Canadian Operational Research Society Best Student Paper (Bingane), Sverdrup Award for Young Researchers

(Fuglstad), 2020 MOPTA Competition Fermin Cueto, Gjeroska & Sola Vilalta).

Many students have continued their research career, taking up postdoctoral positions in institutions such as Berkeley (Xie, Fountoulakis), Brown (Shang), Chicago (Matthews), Courant (Xie), Duke (Sachs), Harvard (Nicholson), ETH (Shang), Sorbonne (Estrada), Hausdorff Center for Mathematics (Tolomeo), IST Austria (Gerencser), Ecole des Ponts ParisTech (Tse), Hamburg University (Bunk), Max Planck Institute for Mathematics (Muller), Jacob Blaustein Institute for Desert Research (Bennett), UCLA (White) and Flatiron Institute (Plochocka). Some who graduated since 2014 have already been successful in securing permanent academic positions (Xie in Peking, Moore and Shang in Birmingham, Thomas at Imperial College London, Lau in Emory, Fountoulakis in Waterloo, Worthington in St. Andrews, Castro and Swallow in Glasgow, Hickman in Edinburgh, Tanner in Stirling). Several of our former PhD students during the REF period have moved to the industrial sector, with positions at companies such as Credit Swiss (Ying), Legal & General (Mylonas), FINRA (DeBellis), Aviva (Savva) and Collins Aerospace (Barnes).

2d. Equality and diversity

Equality and diversity are high on the agenda of the MI, with the need to redress gender balance in the mathematical sciences the most obvious issue, though not the only one. Of the 63 appointments over the REF period, 17 are female, including one Head of School (Pelloni). In contrast, only one of the 22 leavers in this period has been female (Beck), giving an overall **increase of female representation among MI staff from 10% in 2014 to 17%**. It is the result of a series of actions driven by our Good Practice committees to remedy female underrepresentation. During staff recruitment, we seek to achieve gender representation in shortlists, interview invitations, and shortlisting and interview panels. Unconscious bias and diversity training has been recommended for all staff and made mandatory for members of appointment panels. The management group at both School and MI level has achieved gender balance, with two female Directors of Research and one female Head of Department in the REF period. We are signatories to the London Mathematical Society Good Practice Scheme for advancing women's careers in mathematics.

Both Schools constituting the MI hold Athena SWAN Bronze awards. Dedicated self-assessment teams have created an awareness among all staff of the need to change behaviour and culture to achieve a more inclusive and equitable workplace. As part of our action plan, we have implemented initiatives which encourage all staff to excel and overcomes barriers for female careers. All seminars and committee meetings are timed within hours that accommodate those with caring responsibilities. Dedicated resources are in place to support staff taking parental leave or career breaks to care for dependants, and to enable flexible return to work by reducing the initial teaching and administrative loads. We monitor our seminar series to ensure gender representation among invited speakers. Each Theme maintains a list of mathematicians from underrepresented minority groups that we consult when inviting for seminars and colloquia, and when recruiting. We have increased the transparency of our promotion process by organising yearly meetings to apprise staff of the process, and by including representatives of the Good Practice committees in our promotion committees. This contributed to the successful promotion of 70% of non-professorial female staff over the REF period.

Beyond these targeted actions, we recognise that flexibility and consultation are key to achieve a truly inclusive environment. We have applied these principles in the choice of outputs for this REF exercise: every submitted researcher had the opportunity of ranking and rating their own papers; the rating was then extensively moderated externally and internally by distinct peer-review groups whose members all had received unconscious-bias training. Our flexible approach has facilitated our adaption to the COVID-19 pandemic, enabling staff to take part in in-person activities at a level adapted to their personal risk tolerance. We will build on lessons learnt from the COVID-19 experiences to implement remote-working practices that accommodate staff with caring responsibilities or disabilities.

By bringing up equality and diversity issues in MI all-staff newsletters and emails, we encourage discussions as we strive to find optimal solutions. We also take extremely seriously the all-round wellbeing of all staff and their feedback on issues that affect it, so that across the MI there is a wide variety of flexible working patterns, and distribution of responsibilities. The results of staff surveys indicate that this focused attention has had a positive impact in creating an environment where everybody is empowered to achieve their aims. For instance, 84% of the respondents of a 2018 survey among MI UoE staff agreed that 'everyone is treated on their merits irrespective of their gender' and 77% of those with caring responsibilities agreed that 'meetings are completed in hours that allow them to attend'. In the 2019 HWU staff survey, 82% of staff in the School feel respected by their line manager (9% higher than the institutional average) and 77% feel they work in an environment where equality, diversity and inclusion are valued (again, 9% higher than the institutional average).

The MI Graduate School plays a full part in promoting cultural change in relation to equality and diversity: we are proud of admitting an increasingly diverse cohort of students. Around 65% of our PhD students in the current REF period have declared White ethnicity, with 10% Chinese and 14% other ethnicities. Through our well-established links with the African Institute for Mathematical Sciences (AIMS), 25% of the "other ethnicities" PhD students we have admitted in this REF period are Black African. MI PhD students founded the Piscopia Initiative, which encourages women and non-binary students to pursue a PhD in mathematics and is now represented in 11 UK universities.

The MI is also involved in two EPSRC Equality, Diversity and Inclusion awards under the "Inclusion Matters" call: *Evidence-Base; Growing the Big Grant Club,* tackling the poor diversity in large-scale funding leadership, and *Disability Inclusive Science Careers*, focused on disability inclusivity at early career stage entry to the science sector. We also contribute to activities promoting diversity through our management of ICMS which, for instance, hosted the exhibit *Women of Mathematics throughout Europe*, portraying 13 women mathematicians as role models for young scientists. MI staff contribute to national and international efforts: Pelloni is a former Chair of the Women in Mathematics Committee of the European Mathematical Society and of the equivalent committee of the London Mathematical Society on which Gordon also served.
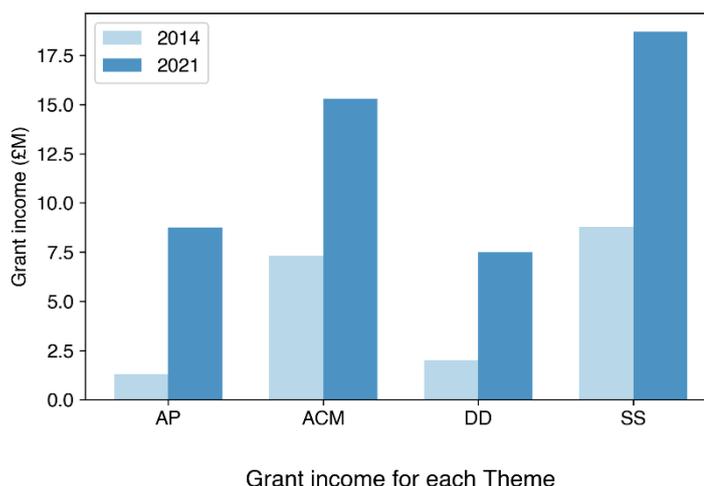
3. Income, infrastructure and facilities

3a. Research income

Grant income to the MI **has increased** steadily, rising **by 128%** from £22M (REF2014) to £50.25M (REF2021, including CDTs). This has been achieved through net increases in income in each of our four themes, with awards to the AP and DD Themes each more than tripling in total value since 2014.

Grant portfolio. Our most significant funders are EPSRC, STFC, ERC, Leverhulme Trust, the Institute & Faculty of Actuaries and the Society of Actuaries (USA). The income generated has been overwhelmingly spent on delivering our research

Grant income for each Theme

strategy through support of staff, postdoctoral associates and postgraduate research students. Major new grant awards to the MI in excess of £1M during the REF2021 period include:

- STFC Consolidated Grant *Particle Theory at the Higgs Centre*, 2014-2018 - £2.05M,

- STFC Consolidated Grant *Particle Theory at the Higgs Centre*, 2017-2021 - £1.47M,

- EPSRC Mathematical Sciences Infrastructure Grant *International Centre for Mathematical Sciences,* 2018-2024 - £3.07M,

- EPSRC Programme Grant *Enhancing Representation Theory, Noncommutative Algebra & Geometry Through Moduli, Stability & Deformations,* 2018-2024 - £3.39M,

- EPSRC Centre for Doctoral Training *Maxwell Institute Graduate School in Analysis & its Applications*, 2014-2022 - £4.54M (with additional £400K funding from the Scottish Funding Council),

- EPSRC Centre for Doctoral Training *Maxwell Institute Graduate School in Mathematical Modelling, Analysis & Computing*, 2019-2028 - £6.11M.

During the REF period, the MI has further participated in two multi-million-pound EPSRC Programme Grants (Higham, Vanneste). In addition to the many fellowships indicated in Section 2, the MI also holds a large portfolio of individual grants supporting specific research projects (157 grants in this REF period).

Strategy. Our strategy for generating grant income has been guided by the MI's four priorities: to target infrastructure funding, stimulate applications to fellowships, strengthen impact, and expand graduate training. We have put in place support and incentive mechanisms aligned with these: we offer incentives (teaching and administrative load reductions) for staff applying for large-scale and impact-related grants and have provided more than £3.1M in matching funding for Programme Grant and CDT bids. We offer incentives for applying for grants in the form of staff travel-budget top-ups. Since 2015, we have extended these to include staff supporting fellowship applications by external candidates. In line with our enhanced support for ECRs, we have invested £380K in matching funds for First Grants and New Investigator Grants; this has contributed to our staff securing over £1.5M of such grants. Grant applications are rigorously reviewed at both the MI and institutional level by review teams to ensure the highest quality of submissions. For grant holders, PI time and postdoc supervision are accounted for in the staff workload model.

A key success of our strategy has been the diversification of our grant portfolio through international sources. Examples include the US National Science Foundation (Foscolo), Swiss Science Foundation (Ciobanu, Sisto), Australian Science Foundation (Ciobanu), German Research Foundation DFG (Schratz, Linkmann), US Office of Naval Research (Branicki), US National Institute of Standards & Technology (Olde Daalhuis), US Army Research Labs (Elvira), Simons Foundation (Sheridan), Institute and Faculty of Actuaries (Cairns, Donnelly), Canadian Institute of Actuaries and (American) Society of Actuaries (Streftaris). The MI has also increased its collaboration with industrial and financial partners. Examples include: £102K in grants from Oracle Labs (Gondzio), £120K from Adidas (Ross), £47K from Unilever (de Carvalho), £23K from Airbus (Garcia Quiles), £112K from Cambridge Cancer Genomics (Canning), £115K in multiple grants from Google (Gondzio, Hall), £0.5M funding from collaborative projects between industry and staff in the AP theme, 12 Impact Acceleration Account projects with matched funding of £132K (with Aberdeen Standard Investments £113K), and a £268K project with the Data Science & Innovation Theme of Train@Ed, a recent Edinburgh fellowship scheme within the Horizon 2020 Marie Sklodowska-Curie COFUND scheme.

3b. Infrastructure and facilities

Estate. MI staff benefit from estate facilities in three locations and from the £2M invested in our buildings over the last 5 years to improve our working environment. At the Riccarton Campus, all staff have offices in the Colin Maclaurin Building, a purpose-built space with 3 large fully equipped mathematics seminar rooms and a large common room. This site also houses the Global Research, Innovation and Discovery centre, a facility supporting enterprise and impact development. At the King's Buildings Campus, staff occupy offices over four floors in the James Clerk Maxwell Building, which includes dedicated Mathematics seminar rooms and a large common room.

Our key estate investment since 2014 has been in the **Bayes Centre**, a new £40M building located in central Edinburgh. The building hosts an array of data-science businesses and services in addition to the MI which occupies the entire 1000 m² top floor. We have invested £1.2M in fitting out this space to create state-of-the-art facilities for our staff, for around 45 first-year graduate students per year, and for the International Centre for Mathematical Sciences (ICMS). The space contains an open-plan office area for 42 PhD students, an 82-seat lecture room, and seminar and teaching rooms, all equipped to high modern standards. It also offers quiet study spaces, group working rooms, staff hot desks and a large communal area supporting social interaction, lunch and coffee breaks. The availability of a dedicated MI space, conveniently accessible from both the Riccarton and King's Buildings campuses and accommodating a wide range of activities – seminars, SMSTC and other advanced courses, ICMS and MI workshops, Alan Turing Institute events, etc. – has transformed interactions between MI staff and created a hub for the mathematical sciences in the UK.

Main lecture theatre at the Bayes Centre

During the COVID-19 crisis, the MI has been at the forefront of the use of technology to support the research life of the mathematical community, and ICMS has provided a national platform for online mathematical seminars and meetings. We will be making increased use of this technological experience to contract the physical space between the three poles of the MI, and the MI and the rest of the world. This will allow us also to increase our long-term sustainability, mitigating the increase in space and resource required by the fast-growing numbers of occupants of the Bayes Centre.

Centres. The presence of **ICMS** is a tremendous asset for the MI environment. We manage ICMS and support it vigorously, by offering staff time, access to facilities and equipment, and direct funding (£50K/year). ICMS plays a vital role for the UK mathematics community, by running workshops of high international standing (96 since 2014), hosting visitors for its research-in-group programme (102 participants since 2014), and organising a broad range of knowledge-exchange and public-engagement activities (e.g. at the Edinburgh International Science Festival, Maths Week Scotland and the New Scientist Live). In the last few years, ICMS has been particularly active in supporting interdisciplinary research and the engagement of the UK mathematics community in UKRI grand challenges. The review of mathematical infrastructure carried out by EPSRC in 2015 provides ample evidence of ICMS's status in the community, with for instance 83% of the respondents to an associated survey rating it as 'the key maths infrastructure in the UK'. We drove the 2018 move of ICMS to the Bayes Centre which has provided it with state-of-the-art facilities and greatly improved the experience of participants to its activities. The success of ICMS has been rewarded by continuous support from EPSRC: since 2014, we have been awarded two major grants worth £4.7M and will receive an additional EPSRC investment of £1M/year from 2021. MI staff benefit from ICMS by attending its workshops and meetings and by interacting with the many leading mathematicians that these attract. ICMS supports the wider mathematical community by administering the SMSTC PG courses, organising externally funded conferences, and managing mathematics journals.

We play a leading part in several other centres of excellence. We have invested staff time in the **Scottish Financial Risk Academy** (0.2 FTE of a senior academic, and 0.3 FTE of an administrative position), and a £1M per annum investment in the **Alan Turing Institute** with 13 ATI fellows and 3 flagship projects in the MI. In 2017 we founded the now 77-strong **Centre for Statistics** to build the data-science capacity needed to address key scientific and societal challenges. The MI was awarded funding to host and staff the national **Actuarial Research Centre** for 5 years, with additional funding from the US Society of Actuaries (SoA) and the

Canadian Institute of Actuaries, and currently we are the only European Institution to hold Center of Actuarial Excellence Status from the SoA.

Support staff. Both the number and scope of research administrative staff have increased over the REF period. Two Research Administrators prepare the financial and other technical details for all our grant applications. Three Business Development Executives support external engagement and control an impact-generation account that helps develop impactful projects. They played a pivotal role in trebling the number of companies we interact with and increasing our consultancy income by a factor of ten over the REF period. Dedicated members of staff help organise small workshops, visits and seminars. Our Information Technology team, handling frontline support, has grown to keep up with increasing researcher numbers; two staff have been appointed in Human Resources to deal with increased recruitment resulting from our grant success.

Equipment and facilities. MI staff and PhD students benefit from the use of video-conferencing facilities throughout all three locations, which are used for MI-specific activities such as broadcasting of seminars, postgraduate training and interactions with external collaborators. All staff have access to high-performance computing systems including the ARCHER and CIRRUS facilities through the Edinburgh Parallel Computing Centre, the ECDF computing cluster Eddie, as well as two dedicated servers at the Riccarton Campus; they further benefit from our £120K investment in an NVIDIA GPU machine. The housing of the MI at the Bayes Centre facilitates interdisciplinary work, as evidenced by the success of our CDTs which receive continued investment from companies. Other resources are available such as those provided through The Data Lab, who offer up scholarships and research funding. The co-location of the MI with ICMS makes it possible to share all profile-raising activities in terms of external impact and industrial engagement, and to engage with our Business Development Executives who are based at the Bayes Centre.

4. Collaboration and contribution to the research base, economy and society

4a. Research collaborations

The internal cohesion of the MI partnership is ensured by a broad array of joint research activities. All lectures and events are jointly scheduled and recorded on a central calendar, with many of the seminars and dedicated colloquia taking place centrally at the Bayes Centre. We encourage co-supervision of all PhD students across the two institutions, irrespective of their primary affiliation (in particular, our CDT students receive joint degrees from both institutions). The co-supervision of research students is central to our cohesion; it has proved particularly effective in integrating new staff members into the MI. Most medium- and large-scale research proposals have investigator teams with representations from both universities, and we coordinate research strategy and outlook at our regular MI management and research committee meetings.

Virtually all MI staff are engaged in international collaborations, which have resulted in hundreds of research visits to and from the MI over the census period. The MI has also played leading roles in several large-scale collaborative projects:

- We lead the EPSRC Programme Grant *Enhancing Representation Theory, Noncommutative Algebra & Geometry through Moduli, Stability & Deformations* with partners in Glasgow and Sheffield,
- We led the Horizon 2020 COST Action *Quantum Structure of Spacetime (QSPACE)* which from 2015-19 administered networking activities across 28 European partner countries,
- We have been the only consistently named partner for 3 iterations of an EPSRC/CNRS/DFG network (*Representation Theory Across the Channel* and then *Anglo-Franco-German Representation Theory*).

We are part of several international networks, such as the *Simons Collaboration on Homological Mirror Symmetry* with partners at Columbia, Harvard, U Penn, Vienna, IHES, Berkeley, Miami, Simons Center, Brandeis and MIT, and the *International Research Network on Quantum Fields & Strings (IRN:QFS)* which gathers 80 research institutes across 24 countries throughout the world. We led several UK subject networks, such as the *GLEN Algebraic Geometry Seminar* and *Algebra*

& Representation Theory in the North (ARTIN), the UK Network on Hyperbolic Equations and Related Topics and the *Scottish Numerical Methods Network*.

The MI is one of the founding partners of the Scottish Mathematical Sciences Training Centre, contributing several graduate courses per semester, and leading one of the 4 streams as well as having had the Directorship for 2 years during the REF census period. We contribute to the Academy for PhD Training in Statistics. We also provide a biennial course and a representation on the Executive Committee of the National Taught Course Centre in Operational Research. Our CDTs are sources of systematic international collaborations: MAC-MIGS is the centre of a network of academic partners at Brown, Duke, Ecole des Ponts, Norwegian University of Science & Technology, Potsdam, Turin, TU Berlin, Vienna UT, Utrecht and TU Denmark, enabling systematic research visits.

4b. External engagement activities

The MI strongly supports knowledge transfer and outreach, with activities and investment in dedicated staff at all its sites. Our key research users include other quantitative disciplines, industry, government and other policy makers, and the general public.

Outreach. We run a broad range of outreach activities, which include annual contributions to Maths Week Scotland and to the Edinburgh International Science Festival, each informed by our research. We organise regular Maths Circles for children aged 5-16 with over 1,000 annual participants, Mathematics Masterclasses for schools, widening participation courses through the Sutton Trust, and events with Native Scientist. Staff have been involved in public outreach talks at venues spanning the globe (Science & Cocktails, Johannesburg; Pint of Science, Glasgow and New York). We offer a Massive Open Online Course (MOOC) on Statistics which attracts around 10,000 viewers annually, and we support the global use of STACK, an online mathematics assessment system, including in Africa in collaboration with charities such as the MasterCard Foundation.

Economy and society. We contribute to the competitiveness of the UK economy through our industrial collaborations (see sections 1d-e), through our graduate training, which includes a strong component of industry-focused activities (such as the regular industry sandpits and modelling camps run by our CDTs MIGSAA and MAC-MIGS), through the Alan Turing Institute (with partners that include NHS England, the UK Government, and HSBC), and through the Scottish Financial Risk Academy and its network of over 200 financial services companies.

The MI also makes wider contributions to society. Gordon serves on the Scottish Government's STEM Implementation Group, representing Universities Scotland. This group oversees the implementation of the Government's STEM strategy across all sectors of education and beyond; it has been responsible for ensuring the central role of STEM in schools and in apprenticeships. We also offer Continuing Professional Development courses in R for users of Statistics, to research staff within our Universities, and to public bodies such as the NHS.

Sustainability of the discipline. The MI is committed to supporting the development of the Mathematical Sciences in the UK and abroad, increasing the recognition of their societal impact, and accelerating their uptake by industry and government. Through our Graduate School and CDTs, we are training PhD students across the full spectrum of mathematics and statistics to produce new generations of outstanding young academics, and leaders in the industrial, financial and other private sectors.

The MI is engaged in initiatives to support Mathematics in Africa and the developing world. We are highly active in the African Institutes for Mathematical Sciences (AIMS): each year MI staff teach intensive courses at AIMS centres in South Africa, Rwanda, Ghana and Senegal, and over 20 AIMS alumni have come to Edinburgh to do their PhDs in MIGS. Through ICMS, we administer the James Clerk Maxwell AIMS Fund, financed by the Scottish Funding Council, which compensates departments for the release of staff for AIMS teaching. The MI has been instrumental in the national conversation on the benefits of mathematics and on making the case for investment

in mathematics research, both as an institute, through individuals, and through ICMS hosting and facilitating the national discussion around these themes.

4c. Contributions to and recognition by the research base

MI staff contribute to setting the research agenda for the mathematical sciences, nationally and internationally, through participation in high-level grant funding committees (EPSRC and Royal Society fellowship panels, European Research Council funding committees, Netherlands Organisation for Scientific Research NWO panels, German Research Foundation DFG panels), by acting as trustees of national and international professional bodies (London Mathematical Society, Institute of Mathematics & its Applications, Edinburgh Mathematical Society, European Mathematical Society, Royal Statistical Society), on scientific advisory boards (Arnold-Regge Centre), and on scientific committees of major international conferences (International Congress of Mathematicians 2014, International Congress of Actuaries 2014, International Colloquium on Group Theoretical Methods in Physics 2018, Category Theory 2019, Abel Symposium 2019, Geometric & Asymptotic Group Theory with Applications 2020, International Liquid Crystal Conference 2020).

The international reputation of our academics gives them opportunities to lead and influence the research base. Exemplars of leadership are provided below to give an indication of the breadth and depth of their contributions.

Awards, fellowships & honours. The most significant prizes and awards received by MI staff since 2014 are:

- Adams Prize (Bayer 2015);
- American Statistical Association Waller Education Award (Cetinkaya-Rundel 2016);
- Anne Bennett Prize (Hollands 2018);
- Berwick Prize (Barwick 2019);
- Bob Altin von Gesau Memorial Prize (Donnelly 2018);
- Breakthrough Prize in Fundamental Physics (Gair 2016);
- Caroline Herschel Prize (Varri 2019).
- Chauvenet Prize (Leinster 2019);
- EURO Excellence in Practice Award (Schewe 2016);
- Harvard Pickard Award (Cetinkaya-Rundel 2019);
- Honorary Degree from the University of Bucharest (Ball 2018);
- Inaugural Early Career Prize of SIAM Uncertainty Quantification (Teckentrup 2018);
- Institute of Mathematics Prize of the Polish Academy of Sciences (Smoktunowicz 2018);
- International Chinese Statistical Association New Researcher Award (Cannings 2019);
- International Society for Bayesian Analysis Lindley Prize (de Carvalho 2020);
- International Society for the Interaction of Mechanics & Mathematics Prize (Ball 2018);
- J Clarence Karcher Award (de Ridder 2017);
- Kamil Duszenko Award (Sisto 2018);
- King Faisal Prize for Science (Ball 2018);
- Leonardo da Vinci Award of the European Academy of Sciences (Ball 2018);
- Mahony-Neuman-Room Prize of the Australian Mathematical Society (Lawson 2018);
- President's Medal of the Royal Society of Edinburgh (Gair 2016);
- Robert I. Mehr Award (Cairns 2016);
- Royal Statistical Society Howard Medal (Aitken 2018);
- Shephard Prize (Higham 2020);
- 3 Whitehead Prizes (Bayer 2016, Sheridan 2019, B. Davison 2020);
- 2 Whittaker Prizes (Bayer 2016, Ottobre 2019);
- Young Scientist Prize of The World Academy of Sciences (de Carvalho 2015);

The most notable fellowships received by MI staff include:

- 2 Fellowships of the Association of European Operational Research Societies (Anjos 2017, Gondzio 2019);
- Fellowship of the Institute of Physics (Mackay 2014);
- Fellowship of the Learned Society of Wales (King 2018);
- 5 Fellowships of the Royal Society of Edinburgh (Leimkuhler 2014, Vanneste 2014, Cairns 2016, King 2018, Pelloni 2020);
- Young Academy of Science Fellowship of the Royal Society of Edinburgh (Peters 2018);
- Senior Fellowship of the Schoeller Research Center for Business & Society (Anjos 2020);
- Simons-CRM Fellowship (Teckentrup 2019).

Other honours bestowed on MI staff during the REF period include invitations as distinguished lecturers such as the EPFL Bernoulli Lecture (Leimkuhler 2016), van Leeuwenhoek Lecture (Sherratt 2018), A R Mitchell Lecture (Higham 2019), and the Mary Cartwright Lecture (Pelloni 2019), and Best Paper Awards in: Journal of Global Optimization (Yildirim 2014); Computational Optimization & Applications (Hall 2015); Joint Statistical Meetings Section on Teaching Statistics in the Health Sciences (Cetinkaya-Rundel 2015); Mathematical Programming Computation (Hall 2018); SIGEST Paper in SIAM Review (Teckentrup 2019).

Plenary & keynote lectures. The plenary and keynote lectures given by MI staff are further evidence of our international recognition. These include invited lectures at:

- Abel Symposium (Malham 2016, Bayer 2017);
- Applied Topology: Methods, Computation and Science (Leinster, 2016);
- Biénale Francaise de Mathématiques Appliquées et Industrielles (Pereyra 2019).
- Biennial Numerical Analysis Conference (Higham 2019);
- ∞-categories and their applications (Barwick 2020);
- Category Theory (Leinster 2018);
- Canada Pension Plan Triennial Seminar (Cairns 2018);
- Clay Research Conference (Sheridan, 2014),
- XXI Colloquio Latino Americano de Algebra (Smoktunowicz 2017);
- Effective Methods in Algebraic Geometry (Hering 2017);
- European Actuarial Journal Conference (Cairns 2014);
- 3rd European Conference on Queueing Theory (Foss 2018);
- EUROPT 2019 (Gondzio 2019);
- GAMM Microstructures Conference (Scardia 2019);
- Groups, Rings and Associated Structures (Smoktunowicz 2019);
- Harmonic Analysis & PDEs (Wright 2018);
- Householder Symposium on Numerical Linear Algebra (Pearson 2017);
- Indo-UK Workshop on Stochastic Differential Equations & Applications (Gyongy 2015);
- Insurance Risk & Finance Research Conference (Cairns 2014);
- Integrable Systems & Quantum Symmetries (Szabo 2017);
- International Conference on Applied Algebraic Topology (Leinster, 2017);
- 15th International Conference on Integral Methods in Science & Engineering (Duncan 2018);
- International Conference on Special Functions (Olde Daalhuis 2017);
- 9th International Conference on Stochastic Analysis & Its Applications (Gyongy 2018);
- XXVIII International Fall Workshop on Geometry and Physics (Figueroa-O'Farrill, 2019);
- International Statistical Ecology Conference (King 2016);
- International Workshop on Stress Test & Risk Management (Peters 2019);
- 4th ISM-ZIB-IMI MODAL Workshop on Mathematical Optimization & Data Analysis (Hall 2019);
- IST Lectures on Algebraic Geometry and Physics (Martens 2018),
- Jubilee Congress for the 100th anniversary of the Polish Mathematical Society (Smoktunowicz 2019);
- Liège Oceanography Colloquium (Vanneste 2014);

- Meeting of the Australian and New Zealand Mathematics Societies (Sheridan, 2014)
- SciCADE 2019 (Schratz 2019);
- SIAM Annual Conference (Higham 2019);
- SIAM UQ18 (Teckentrup 2018);
- Strings & Fields 2019 (Szabo 2019);
- Wave 2015 (Banjai 2015);
- Winter Meeting of the Canadian Mathematical Society (Vanneste 2014);

Research consortia. In addition to the large-scale collaborative projects mentioned in section 4a, MI staff have leadership roles in international and national research consortia including:

- Cairns is PI of the project "Modelling, measurement & management of longevity & morbidity risk" (2016-20) involving City University, Aarhus University and Southampton University, funded by the Institute & Faculty of Actuaries;
- Dent, McKinnon and Grothey are Co-Investigators on the EPSRC funded Centre for Energy Systems Integration (2016-21);
- Garcia, Kalcsics and Gondzio are Co-Investigators on an EPSRC project "IP-MATCH: Integer Programming for Large and Complex Matching Problems" with the University of Glasgow (2017-2020);
- Gibson was Co-Investigator in the consortium "Modelling animal pathogens: Review & adaptation" (2013-16) with University of Copenhagen, Biostatistics Scotland, and the Institute of Occupational Medicine, funded by the European Food Safety Authority;
- Gondzio was a Co-Investigator on the EPSRC project "Computational Design Optimization of Large-Scale Building Structures: Methods, Benchmarking & Applications with University of Sheffield and University of Bath (2016-19).
- Lindgren is a Co-Investigator in the H2020 project "RISE: Real-Time Earthquake Risk Reduction for a Resilient Europe" (2019-2022) involving 24 partners;
- Pereyra is Principal Investigator (PI) of the collaborative project "Bayesian model selection & calibration for computational imaging" (2020-22) with University College London, Ecole Polytechnique Paris, Ecole Normale Supérieure Cachan, and Université de Toulouse;
- Schratz was PI on the Collaborative Research Centre 1173 "Wave phenomena: Analysis & numerics" (2015-19), funded by the German Research Foundation DFG;
- Streftaris is PI of the project "Predictive modelling for medical morbidity risk related to insurance" (2019-22) involving the University of California at Santa Barbara and Southampton University, funded by the US Society of Actuaries;
- Vanneste was the PI on a joint NERC/NSF project "Stimulated Loss of Balance" with the University of California, San Diego (2017-2020);

Conferences, meetings & workshops. Our contributions to the research base include the organisation of conferences, programmes, symposia and workshops. Notable contributions by MI staff include:

- Abel Symposium (Figueroa-O'Farrill, 2019);
- 26th Annual Conference of the International Environmetrics Society (Gibson 2016);
- ESI programme "Higher Structures in String Theory & Quantum Field Theory" (Szabo 2015);
- FIM workshop "Higher-genus invariants from categorical structures" (Sheridan, 2019);
- GGI programme "Emergent Geometries from Strings & Quantum Fields" (Szabo 2020);
- IAS Workshop on "Homological Mirror Symmetry: Methods & Structures" (Sheridan 2016);
- IMA Conference on Inverse Problems (Pereyra 2019);
- International Conference on Mathematical Analysis & its Applications (Ball 2019);
- ISBA World Meeting (Dos Reis 2018);
- IST Lectures on Algebraic Geometry and Physics (Hering, 2019);
- LMS-EPSRC Durham Symposium "Higher Structures in M-Theory" (Saemann 2018);
- MATRIX workshop "Tropical geometry and mirror symmetry" (Sheridan, 2019);
- MITP Workshop on "Geometry, Gravity & Supersymmetry" (Figueroa-O'Farrill 2017);
- MSRI programme "Higher Categories & Categorification" (Barwick 2020);

- Noncommutative and non-associative structures, braces and applications workshop (Smoktunowicz 2018);
- NYU-Oxford Workshop on Mathematical Models of Defects & Patterns (Ball 2016);
- Simons collaboration workshop "Current advances in mirror symmetry" (Sheridan, 2020)
- Simons Center Workshop "Flat Holography" (Simon 2016);
- Workshop "Non-commutative stochastic analysis" (Chevyrev 2019).

We regularly co-organise workshops in leading international research centres including the Isaac Newton Institute (3 since 2014), Oberwolfach (4), Banff (1), Luminy (1), American Institute of Mathematics (1), Hong Kong Institute for Advanced Study (1), and ICMS (more than 40).

Advisory boards. Our staff contribute to the membership of international and national advisory boards, with examples including:

- Chair of Academic Advisory Board for AIMS Ghana 2012-2017 (Schroers);
- Chair of the LIGO Science Group and of the LIGO Collaboration Cosmology Working Group (Gair);
- External Assessor for Italian Research & University Evaluation Agency (ANVUR) (Painter).
- Mathematical Editor of the Digital Library of Mathematical Functions (Olde Daalhuis);
- Member of the academic council of the Financial Conduct Authority (Szpruch);
- Member of the Advisory Board for Centre d'Excellence Africain en Sciences Mathematiques, Benin (Ball);
- Member of the Coordination Board of the EURO Working Group on Locational Analysis (Kalcsics);
- Member of EPSRC Advisory Group Additional Funding in Mathematical Sciences (Gordon);
- Member of the External Advisory Board for EPSRC initiative Bayesian Data Science for Health (Gibson);
- Member of the International Biometrics Society Editorial Advisory Committee (King);
- Member of the Isaac Newton Institute Scientific Steering Committee (Gordon);
- Members of the Newton Gateway Scientific Advisory Panel (Gondzio, Higham, Lord);
- Members of the REF2021 panel (Higham, Pelloni);
- Member of the Scientific Advisory Board for MRC Centre for Global Infectious Disease Analysis (Gibson);
- Member of the Scientific Steering Committee for the Past Earth Network 2015-19 (Lindgren);
- Member of Scottish Government's STEM Strategy Implementation Group (Gordon);
- Review Member for the Lorentz Center (Lord);
- Scientific Programme Committee for ICIAM 2023 (Higham);

Professional bodies. MI staff are members of the main professional bodies: London Mathematical Society, Institute of Mathematics & its Applications, Society for Industrial and Applied Mathematics, Royal Society of Edinburgh, European Mathematical Society, Royal Statistical Society, Institute & Faculty of Actuaries, European Women in Mathematics, Institute of Physics, European Academy of Sciences.

Several staff also play key roles on these and other bodies, including:

- Chair of the Institute for Mathematics and its Applications 2016-19 (Higham);
- Chair of the Institute of Mathematical Statistics Committee to select Administrative Officers (Bochkina);
- Chair of the Section on Statistics & Data Science Education of the American Statistical Association (ASA) (Cetinkaya-Rundel);
- Chair of the Women in Mathematics Committee of the European Mathematical Society (Pelloni);
- Elected Member of the International Committee of the AFIR-ERM Section of the International Actuarial Association 2009-17 (Cairns);

- 3 Elected Members of the International Statistical Institute (de Carvalho, Lindgren, Cetinkaya-Rundel);
- Elected Member of the Royal Statistical Society Council (King);
- 2 Members-at-large of the Council of the London Mathematical Society (Pelloni, Ptashnyk);
- Member of the ASA Data Science Advisory Committee and DataFest Executive Committee (Cetinkaya-Rundel);
- Member of the European Mathematical Society Committee for Developing Countries (Schroers);
- Member of the Executive Committee of the European Mathematical Society (Pelloni);
- Member of the Executive Board of ISBA (Bochkina);
- Member of the Expert Review Committee for the Bond Report (Lord);
- Member of the Implementation Working Group to develop the national agenda and response to the Bond Report for the UK Government (Dent, Peters);
- Member of the International Biometrics Society Council (King);
- Member of the Life Research Committee of the Institute & Faculty of Actuaries (Kleinow);
- 2 Members of the Strategic Advisory Team for the Mathematics Programme of EPSRC (Gordon, Pelloni);
- President of the Edinburgh Mathematical Society (Gibson);
- President of the International Biometrics Society: British & Irish Region (King);
- President of the UK and Ireland Section of SIAM 2015-17 (Higham);
- Vice-President of the London Mathematical Society (Gordon);
- Secretary Chair of the Bayesian Nonparametric Section of the International Society of Bayesian Analysis (ISBA) (Wade);
- Secretary of the Royal Statistical Society Statistics & Law Committee (Wilson).

Prize & fellowship awarding bodies. Several MI staff have served on prize and fellowship committees for some of the most notable awarding bodies, including:

- EPSRC Mathematics Fellowships (Ottobre, Pelloni, Szabo);
- European Academy of Science (Ball);
- Finnish Academy of Sciences (Wright);
- Fudan Prize Committee (Ball);
- London Mathematical Society Prize Committee (Higham, Gordon);
- Newton International Fellowships (Pelloni);
- Okubo Prize Committee (Sherratt);
- STFC Stephen Hawking Fellowships (Schroers);
- Royal Society Fellowships (Ball);
- Royal Society of Edinburgh Fellowship Sectional Committee for Informatics, Mathematics & Statistics (Gordon, King, Pelloni, Vanneste);
- Royal Spanish Mathematical Society Francias Prize Committee (Ball).
- Royal Statistical Society (RSS) Prize Committee (King);

Some staff have assumed the role of Chair or Co-Chair of awarding committees, such as the Agreenskills+ Scientific Committee (Gibson), the Gavin Brown Prize Committee of the Australian Mathematical Society (Smyth), the Institute for Mathematics & its Applications Leslie Fox Prize Committee (Higham) and the RSS Mardia Workshop Prize Committee (Lindgren).

Editorships. MI staff members are prominently involved on editorial boards of high-profile journals, and notably as Editor-in-Chief during the REF census period for Annals of Actuarial Science (Macdonald), ASTIN Bulletin (Cairns), Archive for Rational Mechanics & Analysis (Ball), Journal of the Royal Statistical Society B (Wood), Proceedings of the Royal Society of Edinburgh A (Pelloni), Queueing Systems: Theory & Applications (Foss) and SIAM Review (Higham).

We also serve as editors or associate editors for numerous international journals including:

- Algebras & Representation Theory (Gordon),
- Analysis & PDEs (Wright),
- Annals of Applied Statistics (Lindgren),

- Applied Mathematical Finance (Szpruch),
- Atmospheric Science Letters (Vanneste),
- Biometrics (King),
- Bulletin, Journal, and Transactions of the London Mathematical Society (Bayer, Pridham),
- Calculus of Variations & Partial Differential Equations (Ball),
- European Journal of Applied Mathematics (Leimkuhler),
- European Journal of Operational Research (Gondzio),
- Foundations of Data Science (Leimkuhler),
- Geoscientific Model Development (Maddison),
- Groups, Complexity, Cryptology (Ciobanu),
- IMA Journal on Numerical Analysis (Leimkuhler, Higham),
- Insurance: Mathematics & Economics (Cairns),
- Journal of the American Statistics Association (de Carvalho),
- Journal of Complex Networks (Higham),
- Journal of Nanophotonics (Mackay),
- Journal of Statistical Physics: Theory & Experiment (Weston),
- Journal of Physics A (Szabo),
- Journal of Physics Communications (Doikou),
- Methodology & Computing in Applied Probability (Clancy),
- Nonlinearity (Pelloni),
- Philosophical Transactions of the Royal Society A (Ball),
- Proceedings of the London Mathematical Society (Barwick, Bayer, Gordon, Wright),
- Proceedings of the Royal Society A (Leimkuhler, Olde Daalhuis, Pelloni),
- Proceedings of the Royal Society B (Gibson),
- Pure & Applied Analysis (Ball),
- Selecta Mathematica (Bayer),
- Semigroup Forum (Lawson),
- SIAM Journal on Matrix Analysis and its Applications (Higham),
- SIAM Journal on Scientific Computation (Lord),
- SIAM Review (Pelloni, Teckentrup),
- SIGMA (Szabo),
- Stochastic Partial Differential Equations: Analysis & Computations (Gyongy),
- Stochastic Processes & Their Applications (Foss),
- Theory & Applications of Categories (Leinster).

Several MI staff also contribute editorial and management roles for the Proceedings of the Royal Society of Edinburgh A and the Proceedings of the Edinburgh Mathematical Society, which are both managed through ICMS.