Institution: University of Leeds
Unit of Assessment: B10, Mathematical Sciences
1. Unit context and structure, research and impact strategy

1.1 Introduction

The Unit comprises members of the School of Mathematics in the Faculty of Engineering and Physical Sciences (**FEPS**). The School is one of the largest in the UK, with over 100 academic and academic-related staff, over 200 MSc students and PGRs and over 1000 undergraduate students. It was ranked in the top 10 for research quality in REF2014. Its main aim is to carry out world-leading research in the mathematical sciences. It combines a core mathematical focus with a strong interdisciplinary ethos. With its strength in breadth, it empowers staff and students to fulfil their research and impact potential across the mathematical sciences by providing a creative and supportive research environment with clear career trajectories.

With the appointment of **Langfeld** as permanent Head of School, the University committed to sustained strategic leadership, aiming to advance the Unit to the top 20 Mathematics units worldwide. Leadership is overseen by the **Management Team** and facilitated by three Heads of Department: **Speight** (Pure Mathematics), **D Read** (Applied Mathematics), **Houwing-Duistermaat** (Statistics; **Aykroyd** from 2021), the Director of Research and Innovation **Gambino**, the Knowledge Exchange Director **Ward,** the Impact Coordinator **Bokhove** and the REF coordinator **Marsh**, as well as a **Strategy Board** with ECR, postdoc and PGR representation. The Unit is well-embedded in the University governance structure: The Pro-Dean for Research and Innovation, **Harlen**, oversees strategic alignment with Faculty goals, **Barber** is co-head of the Faculty graduate school, **Sturman** is Faculty Pro-Dean for International, and **Langfeld** discusses research priorities in regular all-Heads meetings at Faculty level. In 2020, eight Schools, including Mathematics, joined to form the **Faculty of Engineering and Physical Sciences**. This extends opportunities for collaborative research, in particular with the Schools in Engineering, and offers excellent new pathways to impact.

1.2 Research and impact strategy

The Unit's success is built on a strong community of excellent staff. A research group approach ensures a strong combination of critical mass with a spectrum of research fields and enables expansion into new areas when opportunities arise (see 2.1.1), attracting staff through strong activity and an attractive working environment.

The Unit's research and impact strategy is to focus on key interacting areas across the mathematical sciences. Staff are organised into closely integrated research groups (see 1.2.2) including world-leading groups in Astrophysical and Geophysical Fluid Dynamics (**FluidDyn**) and **Logic**.

The departments and research groups, under **Langfeld**'s lead, provide organisational structure and balance across the Mathematical Sciences and facilitate management of the large Unit, providing coordination and support. A **Research Expectations** policy sets out what is expected from staff.

1.2.1 Achievement of REF2014 research and impact strategy, and evolution

Key **research** principles, formulated in REF2014, were to

K1 Reinforce research group cohesion;
K2 Build strengths in interdisciplinary research beyond Unit boundaries;

K3 Expand in research areas with capacity for long-term interactions with industry;
K4 Further invest in excellent Early Career Researchers and provide strong support for their ambitions to become field-leaders.

Key **impact** principles, formulated in REF2014, were to

I1 Enhance the organisational structures that further impact and secure external third-party input into impact policy;
I2 Strengthen the engagement with support structures that facilitate impact.

The Unit has:

- increased the number of permanent staff satisfying the Category A submitted criteria from 65 (58.9 FTE) in August 2013 to 75 (69.74 FTE) in July 2020, increasing the number of female staff from 3 to 10 (**K1**);
- appointed 18 Lecturers and 7 University Academic Fellows (UAFs) (**K1, K2**, **K3, K4**);
- been awarded 29 fellowships, value totalling more than £7.3m (**K1, K2**, **K3, K4**);
- funded a strong programme of international visitors and conferences, supported by an annual internal budget of £70K and external funds (**K2, I2**);
- led 5 EU-funded Innovative Training Networks (ITNs) (**I2**, **K2, K3**);
- co-led the EPSRC CDT **Fluid Dynamics** (2014, renewed 2019), and supported 4 other CDTs (**I2**, **K4**);
- successfully organised the 162nd **European Study Group with Industry** involving 120+ Mathematicians from 10 countries (and 22+ UK Universities) working, for one week in 2020, on 8 problems sponsored by 7 industrial partners [text removed for publication] (**I2, K2, K3**). This went ahead online, despite the lockdown, at a time when other ESGIs were postponed.
- carried out a £4.5m refurbishment, designed to facilitate collaboration (**K2, I1**);

Further to K2: The **Research Visitors' Centre** (RVC) is central to the Unit's collaboration and dissemination strategy, funding a strong programme of international visitors and conferences (see 3.5.2, 4.1.2), with an annual budget of £70k, supporting grant applications (see 3.2, 4.1.4) and recruitment (see 1.2.1, 2.1.1). The Unit has an extensive programme of regular internal, external and interdisciplinary seminars. To increase the time staff have for research, the Unit recruits Tutorial Assistants and Teaching Fellows and is redesigning assessment practices.

Further to K4: The Unit engages strongly with the **University Academic Fellowship** (UAF) scheme, part of the University's **Great Minds** programme (see REF5a, People). These attractive positions include a five-year development programme, reduced teaching and strong mentoring, leading to Associate Professor status. We have made good appointments: [text removed for publication], **Faber** in algebra; **Brooke-Taylor** in set theory, **Fitzgerald** in industrial mathematics, **Liu** in applied statistics, **Mann** in human and animal behaviour and **Pegler** in fluid dynamics. [Text removed for publication] **Faber** has obtained an EU Marie Skłodowska-Curie Individual Fellowship (2018-2020), and **Brooke-Taylor** transferred an EPSRC Early Career Fellowship to Leeds (2016-2018). **Fitzgerald** has an EPSRC Early Career Fellowship, 2018-2023, and **Mann** has a UKRI Future Leaders Fellowship. **Fitzgerald** and **Mann** were promoted to Associate Professor in 2020, and **Liu** is an Alan Turing Institute (ATI) Research Fellow.

Further to K4: The Unit aims for a thriving postdoctoral community, and appointed 60 postdoctoral research fellows/assistants during the REF period; on the census date it employed 24. The Academic Development Fellowship (ADF) scheme has given postdoctoral researchers the opportunity to extend their position while gaining teaching experience; onward destinations reflect its success (see 2.3.3).

Further to K2, K4 and I2: PGRs are an important part of the Unit. We introduced scholarships to boost numbers and applicant strength. In 2018/2019 and 2019/2020, the Unit spent approximately £700K on PGR support (including Centres for Doctoral Training (CDTs)). This involved funding

contributions for approximately 60 PGRs. The Unit co-leads (via **Tobias)** an EPSRC CDT in **Fluid Dynamics** (2014, renewed 2019). [text removed for publication]. The Unit is a partner in the EPSRC CDT SOFI, **Soft Matter and Functional Interfaces** (2014, renewed 2019 as SOFI2 [text removed for publication]; **D Read** is a deputy director. The Unit contributes to the Leeds EPSRC CDTs **Molecules to Product** (2019-), to a NERC DTP **Spheres** (2014-2018; renewed as **Panorama** (2019-)) and to the ESRC **Centre for Data Analytics and Society** CDT (2017-) based in the **Leeds Institute for Data Analytics** (**LIDA**; see REF5a, Objective 3).

Further to I1: The Unit created a role of **Director of Impact** (**Bokhove**) who leads a team developing impact (together with the External Advisory Board (see 3.3)).

Further to K2, K3 and I2: The Unit encourages **interdisciplinary research**, facilitated by joint seminars (see 3.5.1), CDTs, organization of interdisciplinary conferences (see 4.1.2), visitor funding and engagement with interdisciplinary institutes in the University and beyond. This includes the **Bragg Centre for Materials Research**, the **Leeds Institute of Data Analytics** and the **Leeds Institute for Fluid Dynamics** (see 3.1.1, 3.5.1).

Further to K2: New research connections, involving collaboration, PGR cosupervision and grants, have developed with the School of Earth and Environment, involving 10 Unit staff**.** Connections have also developed with the Schools of Business, Chemistry [Colour Chemistry, Chemical Physics], Computing, Geography, Mechanical Engineering and Medicine and Health, and the Astbury Centre.

1.2.2 Research Groups

We list all Unit submitted staff (except where otherwise indicated); those who are Category A submitted are highlighted in bold throughout the document. An asterisk indicates staff who started during the REF period.

Algebra, Geometry and Integrable Systems (AlgGeomIntSys)

Baur*, **Brooke-Taylor***, **Caudrelier***, **Chalykh**, **Faber***, **Faria Martins***, **Fordy**, **Gambino**, **Halcrow***, **Harland**, **Kokarev***, **MacPherson**, **Mantova***, **Marsh**, **Martin**, **Mikhailov**, **Nijhoff**, **A Parker, Pressland, Ruijsenaars**, **Speight**, **Tange***,**T Ward***, **Wood** (Former staff: [text removed for publication] Crawley-Boevey).

Algebra research lies mainly in representation theory, topological quantum field theory, quantum computing, and connections to logic. The latter have been reinforced by the inclusion of logicians **Brooke-Taylor**, **Gambino**, **MacPherson** and **Mantova** (**K1**). **Baur** is a Royal Society Wolfson Fellow.

Key geometry activity lies in geometric variational problems, such as harmonic maps and morphisms, with applications to nuclear and condensed matter physics; also discrete and computational geometry.

Integrable systems research lies in several strongly overlapping and interacting areas: Hamiltonian and Lagrangian dynamics, discrete integrable systems, symmetry analysis, solitons, differential and difference algebra, enumerative topology, cluster and Poisson geometry and connections with representation theory, quantum integrable systems and many-body systems, and special function theory.

Analysis

Dareiotis*, **Kisil**, **Partington**, **Sharp***, **Strohmaier***, **Young** (Former staff: Daws, C Read).

Key areas are geometric analysis, analysis on manifolds, spectral theory, complex analysis and operator theory, with connections to scattering theory, quantum field theory on curved spacetimes, and control theory. The sad loss of C Read and departure of [text removed for publication] meant there was an opportunity for reinventing the group. The Unit pivoted from its REF2014 plans to develop in quantum groups, and instead made appointments (see 2.1.1) bringing the group closer to Geometry (**K1**).

*Astrophysical and Geophysical Fluid Dynamics (**FluidDyn**)*

Barker*, **Beaume***, **Bokhove**, **Falle**, **Griffiths**, **Hollerbach**, **Hughes**, **Jones**, **Kersalé**, **Komissarov**, **D Parker (submitted to UOA7)**, **Pegler***, **Tobias**

Research covers many topics motivated by astrophysical and geophysical fluid dynamical phenomena. There is a strong interdisciplinary component, often through PGR cosupervision, with the Schools of Earth and Environment, and Physics, as well as external bodies [text removed for publication] (**K2, I2**).

The appointment of **Pegler** in geophysical fluid dynamics jointly to **IndMath** (see 2.1.1) increased interaction between these groups as planned in REF2014 (albeit in a different research direction). In 2018 the group played a key role in the establishment of the Leeds Institute for Fluid Dynamics (**K2, K3, I1**) (see 3.1.1) and obtained an ERC Advanced Grant (**Tobias**). The group has won STFC grants totalling £2.3m in the REF period. **Tobias** is one of 10 investigators on a Simons Foundation Targeted Grant worth $4m. [text removed for publication]

*Complex Materials and Industrial Mathematics (**IndMath**)*

Bokhove, **Evans**, **Fitzgerald***, **Harlen**, **Kelmanson**, **Lesnic**, **Pegler***, **D Read**

Overall, research is concerned with the development of theoretical and numerical techniques for solving continuum and molecular-level processes, with industrial applications. This includes the modelling of materials, non-Newtonian flow and rheology as well as floods, ships and marine structures (**I2**).

The group has a strong focus on interdisciplinarity and academic and industrial collaboration (**I1**), with joint projects with physics, food science, engineering, geology and the biological sciences (**K2**). [text removed for publication]. Following our REF2014 strategy we have integrated the group more closely with **FluidDyn** (**I1**), appointing **Pegler** (UAF) (**K4**) to both groups.

*Leeds Applied Nonlinear Dynamics (**NonlinearDyn**)*

Beaume*, **Mobilia**, **Niesen**, **Rucklidge**, **Sturman**, **J Ward**

Research is highly interdisciplinary, with key interests in pattern formation in fluid dynamics and other nonlinear systems, soft matter quasicrystals, ergodic theory and mixing, numerical methods for nonlinear PDEs, network science, agent-based models and complex systems. Staff across the Unit are associate members. [Text removed for publication].

Logic

Isolde Adler (submitted to UOA 11), Brooke-Taylor*, **Gambino**, **MacPherson**, **Mantova***, **Rathjen**, **Shafer*** (Former staff: Halupczok*).
This long-established group is one of the largest worldwide, with a breadth of expertise that is almost unique, covering set theory, computability theory, reverse mathematics, proof theory, categorical logic, and model theory, interacting strongly with many other areas, including joint work with computer science, philosophy and social science (**K2**).

Mathematical Biology and Medicine (MathBioMed)

Azaele, **Bogachev**, **Gusnanto**, **Kent**, **Lopez-Garcia***, **Lythe**, **Mann***, **Mardia**, **Mobilia**, **Molina-Paris**
The main areas covered are mathematical immunology and epidemiology, viral infection, statistical bioinformatics, population dynamics, evolutionary modelling and theoretical ecology. There are strong links with **AppStat**. [Text removed for publication].

Modern Applied Statistics (AppStat)

Aivaliotis, **Aykroyd**, **Barber**, **Cutillo***, **Gusnanto**, **Houwing-Duistermaat***, **Liu***, **Mann***, **Taylor**

We have reorganized the Statistics groups along pure and applied lines, with a large overlap. This facilitates engagement with LIDA and the Alan Turing Institute (**K2, I1**). **AppStat** develops statistical and AI methods for many areas of application. A strong interdisciplinary and collaborative ethos includes areas such as palaeobiology, criminology, international development and social decision-making (**K2, K3, I2**). [Text removed for publication].

Probability and Financial Mathematics (ProbFin)

Aivaliotis, Bogachev, **Dareiotis***, **de Angelis***, **Grigorova***, **Issoglio***, **Ji***, **Palczewski**, **Veretennikov**

Research focuses on the study and modelling of systems and processes featuring uncertainty and complexity. The group collaborates with academia and industry in areas including engineering, power system management, investment management, predictive analytics and software development (**K2, K3, I2**). The Unit invested substantially in new appointments (see 2.1.1) in stochastic analysis and control, which intersect strongly with financial mathematics, thus expanding in this area as planned in REF2014 (**I1**).

Statistical Methodology and Probability (StatProb)

Aldridge*, **Barber**, **Bogachev**, **Houwing-Duistermaat***, **Kent**, **Mardia**, **Taylor**, **Voss**

Research includes themes across statistics and applications of probability including: group testing, sparse inference, randomised algorithms, probabilistic combinatorics, information theory, shape and directional statistics, spatial statistics, robustness, dimension reduction, applications to astrodynamics, uncertainty quantification and chain event graphs. The group is highly interdisciplinary [text removed for publication].

1.3 Future Strategy

[text removed for publication]

1.4 Open Research Environment

University policy for papers is that the Author Accepted Manuscript is uploaded to the White Rose Repository within 90 days of acceptance. Authors are encouraged to submit this to the main office who will do this, encouraging high compliance levels. Over the REF period, the number of full text deposits increased from 149 to 1601, with 175,855 downloads.

The Unit has access to UKRI funds, topped up by the University, which can be used for gold open access. The Unit itself has funded gold open access when needed, for articles not covered by UKRI or charity block grants.

The Unit follows University policy on data, including data management and deposit, and satisfies funders' requirements.

1.5 Research Integrity

The Unit follows University policy on research integrity (see REF5a, Objective 5) and complies with the Concordat to Support Research Integrity. Training programmes and tailored support are available through Organisational Development and Professional Learning (OD&PL), including online PGR training. Where researchers deal with potentially sensitive data, they take appropriate advanced training.

A Unit colloquium and workshops on ethics in mathematics were given by Maurice Chiodo (Cambridge) in 2019. **Mann** gave an invited presentation at the World Conference on Research Integrity, Amsterdam, 2017. **Cutillo** co-organised an online Royal Statistical Society local group afternoon meeting on **Research reproducibility and good practice in statistical software** in 2020.

2. People

2.1 STAFF

2.1.1 Staff Recruitment

Appointments are overseen by the Management Committee, with Faculty approval. The Unit develops a strong coherent breadth across the Mathematical Sciences, ensuring a critical mass in each research group. It aims to appoint strong mathematicians with the skills for excellent research and impact, teaching and administration, with a strong focus on equality and inclusion, while ensuring long-term sustainability and following the principles above. The Unit aims for a range of experience in each research group and actively encourages applications for postdoctoral fellowships.

New appointments (Category A submitted)

In **AlgGeomIntSys**, appointments of **Faber** (UAF, 2017) and **Baur** (Professor, 2018), create a critical mass in cluster algebras, while **Faber**, **Faria Martins** (Lecturer, 2016) and **Tange** (Lecturer, 2014) expand interactions with algebraic geometry, geometric topology and mathematical physics. Expertise in spectral geometry is expanded by **Kokarev** (Lecturer, 2016), bringing the group closer to Analysis (**K1**). **Caudrelier** (Lecturer 2016) expands work on integrable PDEs. The appointments of **Baur**, **Faber, Faria Martins** and **Mantova** (see Logic) bring out geometric aspects of algebra and integrable systems (**K1**), and **T Ward** expands into ergodic theory (linking to **NonlinearDyn**). **Halcrow** is an Academic Development Fellow (see 2.3.3).

In Analysis, appointments of **Strohmaier** (Professor, 2017) and **Sharp** (Lecturer, 2018) bring the group closer to Geometry (**K1**).

In **FluidDyn, Barker** (Lecturer, 2016) expands the group into the vibrant area of extrasolar planetary systems, and **Beaume** (Lecturer, 2016, jointly to **NonlinearDyn**) and **Pegler** (UAF, 2016, jointly to **IndMath**), increase interaction with other groups (**K1**). The Unit appointed **Fitzgerald** (UAF, 2016, crystal defects) to **IndMath**,

Appointments to **Logic** were: **Brooke-Taylor** (UAF, 2016, expansion into set theory); **Mantova** (Career Development Research Fellow 2016, promoted to Lecturer, maintain model theory and expand towards number theory); **Shafer** (Lecturer, 2017, maintain computability theory and link to proof theory via reverse mathematics).

In MathBioMed, appointments were **Mann** (UAF, 2015, behaviour and ecology) and **Lopez-Garcia** (Lecturer, 2016, cell biology and immunology) (**K1**), building strong interdisciplinary interests.

In **ProbFin**, the Unit expanded substantially in stochastic analysis and control, appointing **Issoglio** (Lecturer, 2014), **De Angelis** (Lecturer, 2015), **Grigorova** and **Ji** (Lecturers, 2018), and **Dareiotis** (Lecturer, 2019, jointly to **Analysis**).

In **AppStat/StatProb, Houwing-Duistermaat** was appointed as a new chair in Data Analytics and Statistics in 2015, working on omics data, electronic patient records and interdisciplinary collaborations. This helped combine biological modelling and statistics and build on existing links with clinicians, as planned in REF2014. **Houwing-Duistermaat** led appointments of **Aldridge** (Lecturer, 2018, information theory), **Cutillo** (Lecturer, 2018, networks (**K1**)) and **Liu** (UAF, 2019, machine learning). This, together with the appointment of **Mann** (UAF, 2015, biological data analysis, jointly to **MathBioMed**), allowed a significant expansion into data analytics and engagement with LIDA and the Alan Turing Institute (see 3.1.2) (**K2**, **I1**).

Since 2014, the Unit included impact in academic job criteria and, from 2016, asked applicants for their impact strategy.

Out of 27 appointments (Category A submitted, permanent), 4 were Professors, 6 were UAFs and 17 were Lecturers (supporting **K4**). Of these, [text removed for publication] Professors, [text removed for publication] UAFs and [text removed for publication] Lecturers were female. On the census date, 95% of Category A eligible Unit staff were on open-ended contracts. All Category A eligible staff were submitted.

The RVC facilitates short- and long-term research visits to the Unit, which assists strong recruitment. For example, **Baur** was a Visiting Professor 2016-2018 before appointment as Professor in 2018.

2.1.2 Integration of New Staff

New staff have a thorough induction and typically a two-year probation (five years for UAFs) with a mentor and probation advisor. Newly-appointed Lecturers have reduced teaching loads for two years (five years for UAFs) to facilitate research development. The **New Lecturers' Club** and **Postdoc Forum** facilitate integration. Early career staff are supported to run workshops, with RVC funding available (see 4.1.2). New staff are often integrated through OD&PL training and roles such as seminar organization, enabling them to build research links.

2.1.3 Staff Development and Review

The **Staff Review and Development Scheme** (SRDS) involves an annual meeting with an academic reviewer, considering research and impact objectives and career aspirations in the context of the Unit's strategy. An **Annual Academic Meeting** (AAM), sometimes combined with SRDS, focuses on communication, impact, workload and strategy. Additional mentoring is provided when needed.

Rucklidge, Head of School 2013-2018, benefited from the University's **Leadership Excellence Programme**. This helped him implement a successful series of improvements, including introduction of Academic Development Fellowships, impact postdoctoral fellowships, Teaching Assistants, and PGR scholarships.

2.1.4 Staff reward/promotion

Promotion opportunities are discussed at SRDS and AAM meetings, and there is a Faculty Promotions Advisor. The Head of School, together with the appropriate Head of Department, identifies staff with strong cases for reward, recognition or promotion, following the University's Equality and Inclusion Framework, and supports them to apply; staff can also initiate promotion applications. Below Grade 10, the line manager applies in the case of reward.

2.1.5 Workload / Study Leave

Each academic staff member with research responsibility is allocated 450 hours per year (out of 1650 hours, pro rata) for research, plus time for commitments such as externally-funded projects, fellowships, supervising PGRs and large grant applications. Staff are encouraged to apply for study leave, and teaching is sometimes concentrated in one semester to facilitate research or impact. The workload model is adjusted to allow for external circumstances when needed.

2.1.6 Postdoctoral research assistants and fellows

The Unit follows the Concordat to Support the Career Development of Researchers (2008 and 2019), supporting postdoctoral researchers to undertake at least 10 development days a year. Each researcher has a probation advisor, separate research mentor, and access to a vibrant seminar and research meeting programme (see 3.5.1, 4.1.2) and wide training opportunities.

Early career staff receive support to submit grant or fellowship proposals, including application surgeries. Where possible, postdocs become co-investigators on grants or PGR co-supervisors.

Out of 8 postdoctoral researchers leaving in 2018/2019, 2 went on to permanent academic positions, 4 to further postdoctoral positions,1 to teaching, and 1 to industry.

Research Fellow Subramanian (2015–19, working with **Rucklidge**) won a L'Oreal–UNESCO Women in Science Fellowship 2017–18, was shortlisted for a **Woman of the Future** award 2018, and won an Oxford Hooke Fellowship in 2019.

2.1.7 Exchanges between academia and external bodies

Industrial secondments are encouraged, and are facilitated by the Unit's strong industrial connections and the Research and Innovation Committee.

Bokhove and **Kelmanson** cosupervised PGRs [text removed for publication] on an EU ITN EID project **SurfsUp: freak waves and breaking-wave impact on offshore structures** (see 4.2.1) [text removed for publication]. [text removed for publication] won the University of Leeds 2017 **Postgraduate of the Year** award.

[text removed for publication]

2.1.8 Reward for impact; Enabling impact

The workload model facilitates impact. [text removed for publication]. Administration and teaching duties were reduced for one year for staff who submitted REF2014 impact cases.

The Director of Impact, impact discussion sessions and the Public Engagement Champion (Houston) help staff develop impact. Support can be provided through Unit funding for activities or for an impact fellowship (with five such positions of total duration 22 months funded since the scheme began in 2015), or feedback. [text removed for publication].

EPSRC **Impact Acceleration Accounts** facilitate impact (e.g. see 2.1.7, 4.2.1, 4.2.3), and totalled £123,049 over the REF period. Seminars included speakers from industry, or with industrial connections [text removed for publication].

2.2 RESEARCH STUDENTS

2.2.1 Overview

As of July 2020, there were approximately 124 PGRs with lead supervisor or at least 50% supervised in the Unit, funded by diverse sources. Each Unit-registered PGR is guaranteed at least £3000 for research expenses over the course of the PhD (with special arrangements for CDTs). The Leeds Doctoral College provides cross-discipline community and training opportunities. PGR admission and progression is overseen by a Director of Postgraduate Research Studies (DPGRS) and two deputies (covering the three departments). They meet PGR representatives at least once a year. Unit PGRs usually sit on a faculty PGR committee.

2.2.2 Recruitment

The Unit aims to recruit strong PGRs. The standard requirement is a First Class MMath or BSc Mathematics Degree, or MSc Distinction. Projects are advertised on open days, Unit webpages, at a Cambridge recruitment event and via international links. Selected candidates are interviewed and a DPGRS or deputy approves offers.

The Unit held a two-week LMS Summer School in 2019, introducing undergraduates to PhDs. An annual **bursary scheme** typically supports 10-12 undergraduates to work on a 10-week summer research project, alongside EPSRC and LMS schemes.

2.2.3 Funding

We estimate that Unit contributions to PGR funding were approximately £700K in 2018/2019 and 2019/2020.

Table 1: Main funding sources, 2019/2020 starters (Unit-registered or at least 50% Unit supervision)

Funder	Number of PGRs
EPSRC	7
NERC	1
STFC	2
CDTs	5
EU	1
Royal Society	1
University/Unit	2
Other countries/self-funded	11
TOTAL	**30**

The Unit coordinated 5 EU Innovative Training Networks in the REF period.

Six-month stipends are provided for PGRs on three-year University-funded scholarships, bringing total support to 3.5 years.

In July 2020, there were 48 international PGRs, mostly supported by their governments, University or Unit scholarships. There were 7 PGRs funded by EPSRC CASE studentships, 2 funded by NIF

scholarships and 1 by an NERC DTP CASE studentship, and 35 PGRs with a Unit supervisor (possibly not lead) and an external co-supervisor, from areas such as Atmospheric Science, Computer Science, Medical Imaging and Transport Studies.

2.2.4 Monitoring and support

Each PGR has a lead supervisor and a co-supervisor or advisor (usually a co-supervisor since April 2017). Students typically meet supervisors weekly. All new supervisors attend a training course.

The DPGRS and deputies monitor progress through interview reports after 6 months and the end of each year and meet students midway through each year (from 2018). An induction course covers milestones, data, support, personal and professional development. After 10-11 months, PGRs undergo a formal transfer process to full PhD status, involving at least two independent assessors. Progress, including formal monthly supervision meetings, and plans, are recorded on the University GRAD system, viewable by the student, supervisors, transfer panel, DPGRS and deputies, and a Faculty team.

The Leeds Doctoral College brings together support services, including the Faculty graduate school, training, the Library, Disability Services, the Language Centre, IT, and the Students' Union. It runs research showcases and talks on mental health, wellbeing and careers. PGRs can get study extensions or suspensions if needed.

In July 2020, 91% of PGRs starting in 2011-2012, 2012-2013 or 2013-2014 had obtained a PhD, 1% were registered, and 8% had withdrawn.

2.2.5 Skills development/careers

Each PGR agrees a training plan with their supervisory team covering the mathematics needed for their project, broadening knowledge and more general skills.

PGRs take advanced taught courses (with 50 hours assessed), mostly specialist postgraduate courses through the MAGIC consortium, via videoconferencing facilities in the RVC. The Unit itself delivered on average 6 advanced courses each year (including non-MAGIC courses). PGRs can attend MSc courses, study groups and reading groups (see 3.5.1). The Unit organised 14 summer/winter schools for PGRs/ECRs in the REF period in Leeds and elsewhere.

PGRs are expected to attend the main seminars of their research group (see 3.5.1) and to give several seminars during their PhD. Several PGR seminar series across the School provide opportunities for contribution and feedback (recently increased in response to a PRES survey). During the 2020 lockdown, some seminars increased invitations to Unit and nearby PGRs to increase opportunities and community.

Additional training is provided by the OD&PL, including presentations, writing, time management, careers, data analysis, HPC, teaching and public engagement.

2.2.6 PGR-led conferences in Leeds

British Postgraduate Model Theory Conference, 3 days, 2014, 2017, 2020, 30-40 participants;
New Connections and Directions in Representation Theory and Related Topics, 3 days, 2019, 35 participants;
Research Students' Conference in Statistics and Probability, 4 days, 2015, 108 participants;
Young Functional Analysts Workshop, 3 days, 2019, 26 participants.

2.2.7 Recognition

[text removed for publication]
Winner, 2018, Emerging Space Leaders Award, sponsored by the International Astronautical Congress in 2018.
Selected to present research work at the UK Parliament event **STEM for Britain** in 2018.

[text removed for publication]
University PGR of the year, 2017.

[text removed for publication]
Vernon Harrison Prize (in 2015 and 2018 respectively) of the British Society of Rheology for the best UK PhD thesis in rheology during the previous year.

2020 **UK Fluids Network thesis competition joint winner.**

2.3 EQUALITY AND INCLUSION

The Unit's diversity is valued highly, and it is committed to equality, inclusion and creating an environment in which everyone can reach their full potential. This is guided by the University's **Equality and Inclusion Framework** and a Unit **Equality and Inclusion Forum** (with PGR representation**)**, meeting every 12 weeks and chaired by **Faria Martins**.

The **Faculty Equality and Inclusion committee** meets termly to identify issues and shape policies. The Faculty of Mathematics and Applied Physical Sciences (replaced by the new faculty in 2019) was awarded an **Athena SWAN** Bronze Award in 2019. The Unit is an LMS Good Practice supporter.

2.3.1 Recruitment

Staff and PGR recruitment is guided by the Equality and Inclusion Framework which includes monitoring and review of recruitment data and other activities supporting Equality and Inclusion. Since 2017, all candidates for positions at Lectureship/UAF level and above are invited to submit an Equality and Diversity statement, tested at interview. Over the REF period, for permanent positions at Lecturer/UAF and above, the number of female staff increased from 3 out of 65 to 10 out of 75. Since circa 2017, all Unit-funded PGR scholarships have been open to non-UK candidates. Projects advertised on the University website state that applications are welcome from all suitably-qualified candidates, while encouraging UK BME applications in particular, since this group is currently under-represented.

2.3.2 Flexibility and leave

Study leave decisions (2.1.5) consider historical and current workload, past periods of absence, number of simultaneous requests, and academic plans. Absences of more than a week in term-time can be agreed with the Head of Department. In addition to the University policy, a flexible working procedure was introduced for permanent staff in 2014, allowing colleagues to reduce their working hours for a period of time and then to revert back later if they wish, to support work-life balance or approach to retirement. In the REF period, 9 staff have changed their hours.

2.3.3 Career pathways

Part-time/Fixed-term staff are encouraged and supported to take opportunities to develop (e.g. 2.1.6), and the OD&PL provides support for PDRAs for grant applications and Advance HE fellowship applications. Part-time contracts are used in a flexible and supportive approach to caring-related commitments and retirement.

[text removed for publication]

Over the REF period, 10 postdoctoral researchers were awarded **Academic Development Fellowships** (ADFs), where, typically, three-year positions were extended to four years, and the Fellow taught the same course in their second, third and fourth years. The fellow gained teaching experience and an extended position to develop research, independence and impact. [text removed for publication].

Other Examples

[text removed for publication]

2.3.4 Conference attendance facilitation

For research meetings and visits, staff can use incentive accounts (see 3.2) or apply to their Head of Department (with typical annual Unit budget of £40k) or the RVC. Funding opportunities are highlighted. Matched funding is offered for the LMS Caring Supplementary Grant. A Faculty scheme offers support for those with family or caring responsibilities. The significant Unit funding of research meetings in Leeds facilitates participation.

2.3.5 Equality and Diversity Considerations in support

A surgery (usually quarterly) helps grant application preparation. All staff have access to Departmental and RVC funds (see 4.1). Since early career staff tend to be more diverse, part of our strategy is to support them in various ways, e.g. PGR investment (see 2.2.3), fellowship extensions, partial support of Leverhulme Early Career Fellowships, ADFs (see 2.3.3).

2.3.6 Support for staff and PGRs returning from leave, or with caring responsibilities

Central (and Faculty) HR provide a wealth of resources and guidance for staff returning from leave, or with caring responsibilities etc., which are followed by the Unit. The Unit, with support from University services, provides bespoke support or funds as needed. [text removed for publication]. The flexible working guidelines (2.3.2) support return. For PGRs study can be extended or suspended as needed, with closer monitoring and University service involvement where required. The Unit funds a Daphne Jackson Fellow [text removed for publication].

2.3.7 Support for staff with protected characteristics for research productivity

Support is provided as needed. Access requirements were prioritized in the recent refurbishment (including a self-opening door, a new lift). Adjustments are made as required [text removed for publication].

2.3.8 Supporting the wellbeing of staff and PGRs

Staff and PGRs are encouraged to approach the Unit Administrator for advice, with referral onto support via HR, Counselling, Occupational Health, and PGR and staff networks (see also 2.2.4). **Social events**, such as walks, seminar coffee, and the Maths Society (open to all staff and PGRs) promote community. Following University policy, a **Community Code of Conduct** was introduced in 2019. A committee, with PGR representation, monitors Health and Safety. A Unit prayer space has been allocated.

2.3.9 Equality and diversity in REF submission

The submission was prepared in accordance with the University's Equality and Inclusion Framework and REF2021 Code of Practice. In particular, this statement was reviewed by the Unit Equality and Inclusion Forum, which also made recommendations on the use of secondary criteria for output decisions and was represented at the final selection meeting. In response to monitoring

diversity in impact case studies the Unit plans further steps to encourage diverse staff take-up of impact opportunities. Distribution data will inform future strategy via the Forum.

2.3.10 Other

We estimate that, at the census date, 37% of PGRs are female (The latest LMS UK Benchmark data for PGR graduates, 2014/2015, states 27.8%). We are strongly international (58 home students, 18 other EU students, 48 non-Home/EU students). The Head of School writes individually to female finalists with high grades, encouraging them to consider a PhD.

Baur featured in the exhibition **Women of Mathematics throughout Europe,** which toured Europe in 2016-2019. **Evans** and **Issoglio** co-organized a visit of the exhibition to Leeds, including a talk by **Baur**, in 2017.

Baur: In the movie **An Insight: Women in Science**, produced by Handwerk and Willems, **Baur** was interviewed about her career and efforts towards achieving gender equality. This was shown at the DMV Jahrestagung (German national mathematics conference) in 2019.

Baur, Faber: Co-organised a workshop **Women in Noncommutative Algebra and Representation Theory** (WINART2) in Leeds in 2019. [text removed for publication] **Baur** and **A Parker** coordinated groups.

Cutillo and **Houwing-Duistermaat**: Organizers of the COSTNET event **Women in Networks** in Leeds, 3 days in 2019. All female participants were fully-funded.

Subramanian, PDRA and ADF (see 2.3.3), was short-listed for a **Women of the Future** award in 2018.

3. Income, infrastructure and facilities

3.1 Strategy

The Unit has a people-first strategy: to do great research, excellent researchers and collaborations are needed. This leads to a focus on fellowships and collaborative grants. The Unit prioritizes impact via industrial funding, collaboration and consultancies. In addition, we invest in multidisciplinary collaborative research centres: large scale infrastructure in key areas where Unit research is world leading. Our aim is to make these into strong national centres with international recognition**,** increasing our reach and visibility:

3.1.1 Leeds Institute for Fluid Dynamics

The Unit played a key role in the establishment of this interdisciplinary institute in 2018, which has over 200 members from 12 Schools across the University, and is funded by the University and STEM Faculties. Fluid dynamics is covered from fundamental physics to real-world application, including experimental, analytical and computational approaches at all scales of flow. **Tobias** is the director, **Bokhove** is Industry Group leader and **Sturman** is International Lead, with 18 Unit (Category A submitted) staff members in total. There is a centre manager (0.2 FTE) and administrative support (0.5 FTE). The LIFD facilitates research, collaboration and impact through strategic partnerships, PGR training, seminars, and facilities coordination. It offers Junior Fellowships (for ECRs) and Senior Fellowships to visiting researchers, funding expenses for 1-6 months. An **Early Career Forum** with lead [text removed for publication] (Unit research fellow) organises seminars, advice surgeries and social events, facilitating research and networking.

The LIFD acts as a focal point for interdisciplinary research and grant applications, facilitating coordination between Schools, such as a recent Royal Society URF application involving the Unit and the School of Earth and Environment.

LIFD seminars contributed to ideas in the preparation for Tobias' Simons Foundation grant application (see 3.2) [text removed for publication].

Future plans include seeking memoranda of understanding with key collaborating international partners, strong public engagement, [text removed for publication] and the provision of a centralised facility for fluids experiments that will significantly benefit the Unit.

3.1.2 Leeds Institute for Data Analytics

As an academic board member**, Houwing-Duistermaat** spearheads Unit engagement with the **Leeds Institute for Data Analytics**, created via £4M of University investment and £12M of external funding. LIDA channels membership and activities with the Alan Turing Institute, facilitates grant applications, and provides safe rooms for research with personal data, NHS DSPT/ISO27001 IT infrastructure for research with identifiable and pseudonymised personal data, and a multidisciplinary research environment for 156 people. **Aivaliotis**, **Liu**, **Mann**, **Palczewski** and **Ward** are also involved in LIDA projects. The Unit match-funded a cohort of PGRs to work on LIDA-related projects, locating the students in LIDA. **Aivaliotis**, **Mann**, **Houwing-Duistermaat** and **Ward** were all awarded ATI Fellowships (2018-2021, **Mann** 2018-2020). **Houwing-Duistermaat** is PI on an ATI flagship project funding **Liu** as Research Fellow.

3.2 Grants

Grant applications are typically instigated by academic staff and researchers, supported by the **Research and Innovation Committee** (RIC), who identify funding opportunities. This encourages novelty and diversity.

Applications above £100k are peer reviewed internally by a subject expert and someone in the wider field; smaller applications are handled informally. Surgeries provide feedback on applications. ECR Fellowship applications are subject to Faculty selection and supported by mock interviews, feedback, a Unit mentor and a mentor in Research and Innovation Services. This approach has been successful: see 4.1.4 for fellowships, and Table 2.

Table 2: Success rates for all grants

Financial Year	Success Rate by Number	Success Rate by External Value
2013/2014	37.00%	22.70%
2014/2015	33.30%	18.00%
2015/2016	46.20%	18.40%
2016/2017	42.40%	19.10%
2017/2018	53.80%	30.00%
2018/2019	50.90%	25.60%

Grant applications are encouraged via staff review and incentive accounts (£1,850 credited in total in 2018 and £5,800 in 2019). The Unit contributes to incentive accounts of staff running CASE studentships, those applying for some grants and those reviewing grant applications. Incentive accounts can be used for travel, equipment, visitors, etc. Despite the lockdown, the value of applications made in 2019/2020 was £23.8M, 92% of plan.

Financial aspects of a proposal are handled by the Faculty finance office. The University's proactive European Office contributes to the Unit's stream of EU grant successes through advice, workshops, peer review, and dissemination of EU experience.

Typically, the Unit match-funds a grant's inward visitor programme and funds a PGR for large grants, fellowships and Research Council New Investigator Grants.

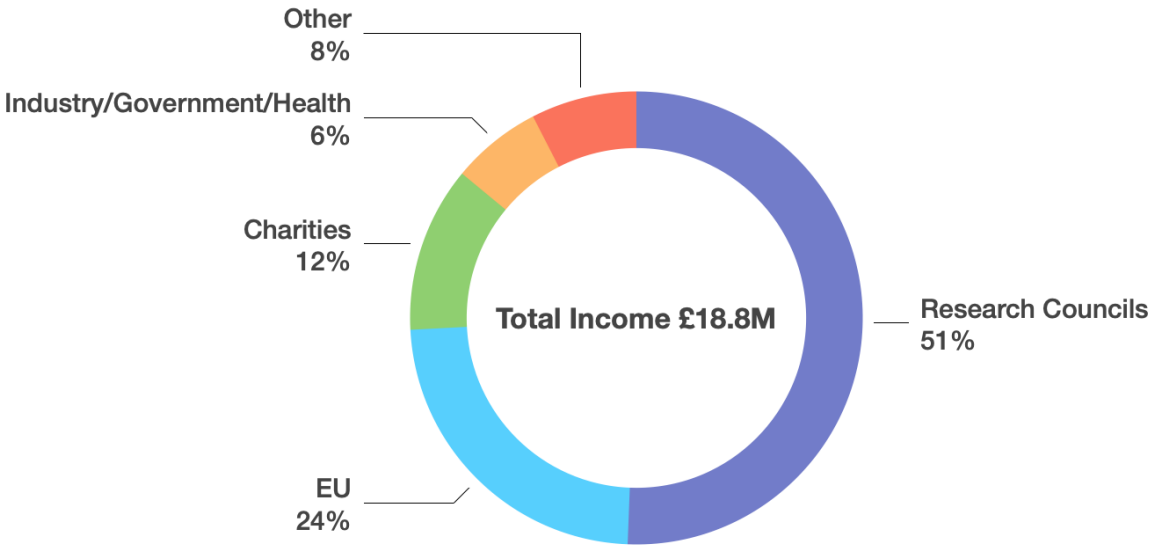


Figure 1: Grant Income in REF Period

Table 3: Selected significant grants starting in the REF period (see 4.1.4 for Fellowships)

Funder	Principal Investigator	Research Groups	Grant	Funder Id	Years	Awarded Value
European Union	**Tobias**	FluidDyn	ERC Advanced	786780	2018-2023	£1,924,922
	Molina-Paris	MathBioMed	ITN	764698	2018-2022	£773,746
	Houwing-Duistermaat	AppStat StatProb	ITN	721815	2017-2021	£486,115
	Bokhove	FluidDyn IndMath	ITN	859983	2020-2023	£472,949
	Bokhove	FluidDyn IndMath	ITN	607596	2014-2018	£429,424
	D Read	IndMath	ITN	607937	2013-2017	£339,943
STFC	**Hollerbach**	FluidDyn	Research	ST/S000275/1	2019-2022	£672,904
	Hughes	FluidDyn	Research	ST/N000765/1	2016-2020	£1,024,741
	Jones	FluidDyn	Research	ST/S00047X/1	2019-2022	£402,460
	Barker	FluidDyn	New Applicant	ST/R00059X/1	2018-2020	£238,465
John Templeton Foundation	**Rathjen**	Logic	Grant	60842	2017-2020	£582,415

Funder	Principal Investigator	Research Groups	Grant	Funder Id	Years	Awarded Value
EPSRC	**Voss**	StatProb	Standard Research	EP/M008363/1	2015-2018	£423,966
	Speight	AGIS	Standard Research	EP/P024688/1	2017-2021	£291,436
	Parker	AGIS	Standard Research	EP/L001152/1	2014-2018	£277,321

[text removed for publication]

These grants relate to high quality research and impact. E.g. **Tobias** is producing high quality work as part of his ERC Advanced Grant, including **Topological Gaseous Plasmon Polariton in Realistic Plasma** in **Physical Review Letters** (Output UOA10-1071), which has received a lot of attention and is the basis for an experimental attempt to detect topological waves at the large Plasma Device at UCLA. [text removed for publication] **Tobias** is one of 10 investigators on an international **Simons Foundation Targeted Grant**, 2019, worth $4m in total.

3.3 Impact

To support impact, the Unit created a role of **Director of Impact** (**Bokhove**) in 2014. **Bokhove** coordinates impact strategy together with the Mathematics Impact Team created in 2019, the Head of School, Heads of Department and the Director of Research and Impact. He supports staff developing impact and coordinates impact discussion sessions. Impact is included in appointment processes (see 2.1.1) and staff appraisals. Staff are encouraged to take consultancies (and many do: see 4.2.2). A Public Engagement Champion, Houston, facilitates outreach impact. The Unit engages with the University impact strategy: **Kelmanson** is a member of the University Impact Advisory Group.

The Mathematics Impact Team played a dedicated hands-on role in developing the structure and content of the impact case studies together with the authors. This strong support and impact culture, together with strong links with many external bodies (see 4.2.1) and Unit-funded impact fellowships (see 2.1.8) facilitated the development of the impact cases. [text removed for publication].

The Unit has an **External Advisory Board** (EAB) [text removed for publication]. It is attended by the chair (**J Ward**), the Director of Research and Impact, the Director of Impact and the Head of School. The EAB aims to facilitate impact and employability. The Unit is thus ensuring that its research is informed by feedback from the EAB and the industrial supervisors of its placement students.

We aim to take on at least one CASE PGR every year, and in July 2020 there were 7 CASE students in the Unit. Two members of staff contributed to the Bond Review (see 4.1.3).

3.4 Industrial Funding

Industrial funding is centred around grants, collaboration, consultancy and CASE studentships. The University Nexus innovation hub (see REF5a, Objective 6) facilitates industrial projects and consultancy with help from **J Ward** in the Unit. The Mathematics Impact Team, the External Advisory Board and strong links facilitate industrial engagement, and the European Study Group with Industry (see 1.2.1) is also expected to yield new projects.

During the REF period, the Unit was awarded £1.2m of industry, government and health body grants (REF3a, REF3b); examples below. See 2.2.3 for CASE studentships.

[text removed for publication]

3.5 Infrastructure

3.5.1 Organisational infrastructure

Research groups (see Section 1) and departments provide a strong organisational context for research and impact in the Unit, providing a flexible collaborative structure which facilitates information flow and seminars, grant applications, PGR supervision and training.

The Leeds Institute for Fluid Dynamics and the Leeds Institute for Data Analysis (see 3.1) provide strong organisational contexts for research, facilitating research grants, impact and interdisciplinary collaboration.

Bragg Centre

The Unit is actively involved in the development of the new interdisciplinary University **Bragg Centre for Materials Research**. **Fitzgerald** and **Harlen** are on the management committee, and **Evans**, **D Read** and **Rucklidge** are members. This correlates well with the CDT SOFI2 in Soft Matter. This will provide strong opportunities for research collaboration and dissemination, PGR cosupervision, and will facilitate grant applications.

Seminars

The School has an intensive seminar programme, supported by an annual budget of approximately £25K. During the REF period, there were 9 weekly and 2 fortnightly subject-focused seminars, many with regular external participation. In addition, each department had a regular seminar/colloquium, and a **School Colloquium** met around twice per semester. An interdisciplinary seminar in Mathematical Biology and Medicine met roughly fortnightly. The Unit ran interdisciplinary seminars for the Fluid Dynamics CDT. Members of the Unit participated in regular Leeds Institute for Data Analytics and Leeds Institute for Fluid Dynamics seminars. The LIFD ECR Forum provided an additional research and networking channel. There have also been at least 25 internal regular reading groups/minicourses.

Seminars moved online after the **Covid-19** lockdown began. E.g. the LIFD has partnered with the Journal of Fluid Mechanics and DAMTP at the University of Cambridge to host the '**Webinars in Fluid Mechanics**' series with more than 2000 registered participants worldwide.

[text removed for publication]

3.5.2 Operational and Scholarly infrastructure

Most of the Unit has been recently refurbished to a high standard. The RVC has space for 26 visitors and seminar-room facilities with Access-Grid video-conferencing equipment. During the REF period, there have been over 800 visits, including 6 Visiting Professors and 44 Visiting Research Fellows, each visiting at least one month. The RVC facilitates research meetings (4.1.2) and PGR training (2.2.5, 2.2.6, 4.1.6).

The Unit has an administrative office with four staff (2.86 FTE). One staff member devotes 0.5 FTE to research support, including the RVC. The Faculty graduate school provides additional PGR administrative support.

The University provides IT support and the **ARC** High Performance Computing (HPC) service, currently two 6500 core Intel/Infiniband architecture machines with 2PB scratch storage and 40 GPU accelerators (equivalent in total to up to 644 CPUs), renewed on a four yearly cycle. Support is provided via a dedicated team, and the Research Software Engineering team provide expertise in project management and parallel code development. Additional hardware can be added via external funding and used by other projects when available, for efficient use.

FluidDyn is a significant ARC user. For example, state-of-the-art calculations using ARC on the mechanisms for generating the Sun's magnetic field (appearing in articles in the Journal of Plasma Physics and the Astrophysical Journal in 2015 and 2016) supported **Tobias**'s successful ERC Advanced Grant application (see 3.2) [text removed for publication]. **FluidDyn** also uses STFC **DiRAC** HPC and the EU Prace facilities. [text removed for publication]. STFC funding supports its substantial HPC use. As of July 2020, 16 PGRs were using HPC.

3.6 Equality and Diversity

The Unit's approach is to provide high quality support for grant applications in general, particularly for ECRs, in order to support equality and diversity, including Unit peer review, surgeries, Faculty selection procedures and mentoring. See also 2.3.4.

The LMS 2013 report (most recent data), **Academic Mathematical Sciences Staff in UK Higher Education Institutions** states that in 2011/12, 18% of UK academic mathematics staff were female. Unit guidelines stipulate that seminar programmes and research meetings aim for at least 25% female speakers, and consider all potential speakers, across gender and ethnicity. Since implementation, the proportion of female speakers at Unit seminars and research meetings recorded in a Unit survey has increased from 16.3% in 2014 to 29.7% in 2019, exceeding the target.

3.7 Benefits in kind

The Unit's strong interaction with industry often leads to benefits in kind supporting research.

[text removed for publication].

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

4.1 Research Base

The Unit supports and encourages research collaborations and contributions to the research base in many ways. There are active conference, workshop and seminar programmes, including summer schools. Collaboration and conference participation is funded and supported through the RVC, incentive accounts, departmental research budgets, and a Faculty mobility fund. Unpaid study leave is usually available on application and paid study leave can often be arranged, or teaching concentrated in one semester. The Unit coordinates various networks, with help from the University EU office. The Unit has an international lead, **Ji**. Scopus data indicates that in 2014-2020, 61.8% of the Unit's scholarly outputs involved international co-authors.

4.1.1 Collaborative Research

Staff engage strongly in collaborative research and networks, facilitated by the RVC (via funding, administration, offices).

Examples

Gusnanto: A collaboration with Cecile de Cat (School of Languages, Cultures, and Societies) since 2017 has produced a 2018 publication which won the **Albert Vladman Award** from CUP, and led to being co-investigator on ESRC grant (ES/S010998/1), 2019-2022.

Mantova: A collaboration with C Fuchs (University of Salzburg), and U Zannier (Scuola Normale Superiore, Pisa) proved a conclusive generalisation of a conjecture of Erdős and Rényi on fewnomials which appeared in the **Journal of the American Mathematical Society** (Output UOA10-3386). It has been used by others to solve a tropical geometry problem.

Partington: A collaboration with I Chalendar, Paris-Est (formerly Lyon), France, produced 17 publications in the REF period.

In the UK, the Unit led EPSRC network **Living with Environmental Change (Maths Foresees)**, 2015-2018, PI **Bokhove**, and from 2019 led an LMS Scheme 3 network, Lancashire Yorkshire Model Theory Seminar, PI **Mantova**. In addition, the Unit is a member of 2 EPSRC-funded networks and 4 LMS-funded Scheme 3 Networks.

Internationally, the Unit coordinated the FP7 (EU) project **MIMOmics**, 2012-2017, which had 15 EU partners, and the EU Marie Skłodowska-Curie ITN, **IMforFUTURE**, 2017-2021 which has 10 EU/UK partners. The Unit was a member of an FP7 (EU) IRSES network **INDOEUROPEAN-MATHDS**, 2013-2017 and an FP7-Energy (EU) Network, **CO2Quest**, 2013-2016.

4.1.2 Sustainability of discipline, interdisciplinary research, national priorities and initiatives

The RVC funds and helps administer a full programme of research meetings, with an annual budget of £70K. Staff apply for funds and are usually expected to apply for external funding also, with internal funds as a back-up or extension. The Research and Innovation Committee (with Faculty input) and the Faculty research office monitor national priorities, initiatives and corresponding funding opportunities, highlighting them to staff and encouraging involvement.

Some highlights

Bokhove was lead organizer for three general assemblies and two study groups for the EPSRC Living with Environmental Change network **Maths Forsees** 2015-2018, 50-80 participants each.

Gambino was lead organizer for **Logic Colloquium 2016** (the main international annual Logic event), 7 days with 240 participants.

[text removed for publication]

The Unit organized 3-day **Leeds Annual Statistics Research (LASR)** Workshops in 2015, 2017, 2019 on interfaces between statistics and fields such as medicine, molecular biology, computer science, and bioinformatics.

Mann co-organised the **2nd Workshop on Mathematics for Social Activism** in 2019, co-funded by the Unit, which brought together mathematicians and data analysts from academia, industry, NGOs and government, on the use of mathematics and data to drive social progress.

Conference Organisation

The Unit is active in research meeting organization. Numbers of meetings of length at least two days in the REF period, co-organized by the Unit in Leeds or elsewhere are given below. Two meetings (not included) moved online and one was cancelled due to Covid-19.

Table 4: Research meetings organised in the REF period

Length (days) / Location	2	3	4	5-7	8+	Programme (3 months+)	TOTAL
Leeds	21	28	8	9	1		**67**
UK (not Leeds)	8	4	3	6	2		**23**
Europe (not UK)	2	2	5	14	0	3	**26**
Outside Europe	0	2	0	8	0	1	**11**
TOTAL	**31**	**36**	**16**	**37**	**3**	**4**	**127**

Unit members have organized 14 summer/winter schools (mostly for PGRs/ECRs), and members led 3- to 4-month programmes at the Hausdorff Mathematical Institute, Bonn (**T Ward**), the Erwin-Schrödinger International Institute for Mathematics and Physics, Vienna (**Strohmaier**), and the Kavli Institute for Theoretical Physics, Santa Barbara (**Tobias**), and co-organised a programme at the Institut Henri Poincare, Paris (**Macpherson**).

4.1.3 Leadership and influence

The Unit encourages staff to show leadership through editorial roles, membership of research council committees, advocacy, and other similar activity, recognised in the workload model. Examples of wide involvement and impact are given below.

Journal roles

Unit staff had chief editor roles at 6 journals, and at least 48 board membership, advisor, etc. roles. Three staff were Editorial Advisors for the LMS journals, and **Partington** has been Analysis Advisor for the LMS Student Texts, CUP since 2003. **Kent** is Honorary Officer for Publications, Royal Statistical Society, 2018-2022.

Staff are encouraged to referee academic publications. Staff have reviewed proposals from approximately 50 research councils internationally. In the UK this includes BBSRC, EPSRC, Leverhulme Trust, LMS, Medical Research Council, Royal Society, STFC, and the Wellcome Trust.

Other roles

Baur is on the Scientific Committee for CIRM, Luminy, France. **Nijhoff** is Chair of the Steering committee for the biennial meetings in Symmetries and Integrability of Difference Equations. **Palczewski** is Chair of an International Federation for Information Processing (IFIP) TC-7 Working group 7.7, Stochastic Control and Optimization. **Rathjen** was on the Scientific Committee of the Oberwolfach Mathematical Research Institute, Germany, 2010-2018. **Tobias** is an Executive Committee member of the UK Fluids Network.

6 staff were EPSRC panel members, and staff were on panels for the DFG (German Science Foundation), Finnish Academy of Sciences, Italian Ministry of Research, Newton Fund, Norwegian Research Council and the Royal Society.

Kelmanson, Lesnic: Invited members of the Review Committee that researched and authored **The Era of Mathematics: An Independent Review of Knowledge Exchange in the Mathematical Sciences** (the Bond Review), 2016-2018.

MacPherson: **British Logic Colloquium President** 2014-2016.
Main author of the EPSRC **Logic Community Overview Document 2016.**

Molina-Paris: Member of the **LMS Research Policy Committee** (2016-present).
Member of the EPSRC Mathematical Sciences Strategic Advisory Team (2019-present).

D Read: Council member and Honorary Bulletin Editor, British Society of Rheology, 2016-present.

Speight: LMS Research Meetings committee member, 2013-2017.
LMS Early Career Researchers committee member, 2017-2018.

4.1.4 Recognition

The School has a prize committee which identifies opportunities and encourages applications and nominations when appropriate.

[Text removed for publication]

Crawley-Boevey was awarded an **Alexander von Humboldt Professorship** in 2016.

Mardia was awarded the **Gandhi Medal of Honour** by the NRI Institute (India) and received the **International Indian Statistical Association Lifetime Achievement award**, in 2019. He was awarded the **Wilks Memorial Medal** by the American Statistical Association in August 2013. The **Mardia Prize** was instituted by the Royal Statistical Society in 2016, funding cutting-edge interdisciplinary workshops.

D Read was awarded the **British Society of Rheology Annual Award** in August 2020, in recognition of his major contribution to predicting the rheology of polymer melts. A significant part of this work was carried out during the REF period.

Fellowships starting in the REF period

European Union Fellowships
ERC Advanced Grant
7 Marie Skłodowska-Curie Individual Fellowships

EPSRC Fellowships
3 Doctoral Prize Fellowships
1 Postdoctoral Fellowship
2 Early Career Fellowships

Leverhulme Trust Fellowships
3 Early Career Fellowships
3 Research Fellowships
1 Emeritus Fellowship

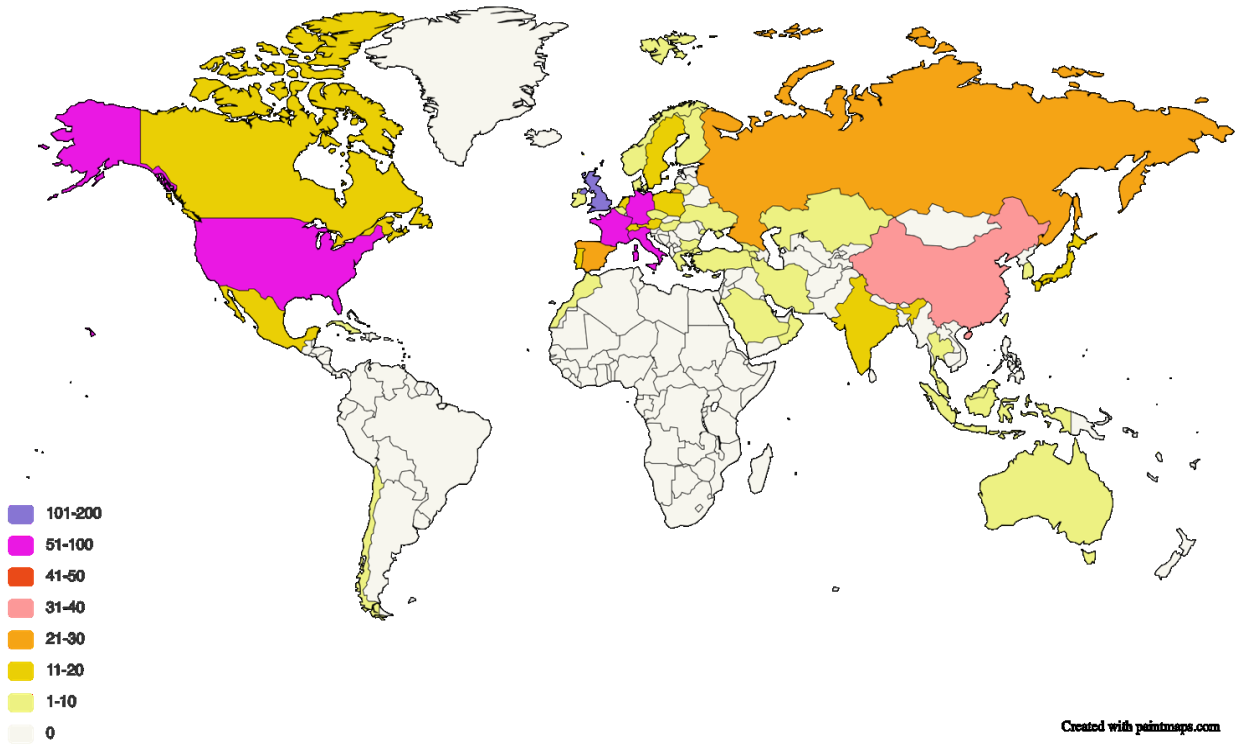
Other Fellowships
Royal Society Wolfson Fellowship
Royal Society Newton Fellowship
L'Oreal-UNESCO for Women in Science Fellowship
Medical Research Council Skills Development Fellowship
UKRI Future Leaders Fellowship
4 Alan Turing Institute Fellowships

[text removed for publication]

4.1.5 Conference Talks

Staff participate actively in research meetings in the UK and internationally. 713 **invited** talks outside Leeds were given by Category A submitted Unit staff at conferences and workshops during the REF period (an additional 15 moving online and 25 postponed due to **Covid-19**).

Table 5: Numbers of invited conference and workshop talks



Examples

Baur and **Faber** both gave series of 4 lectures at the **Isfahan School and Conference** on Representations of Algebras, 2019, Iran.

Gusnanto, Keynote, **Corporate Gathering 2019**: Creating a winning strategy in Industry 4.0, at the Ministry of Industry of the Republic of Indonesia, 300 participants including almost 100 CEOs of medium to major companies in Indonesia.

Jones, Fluid Dynamics of the Earth and Planetary Science Lecturer, 2017, University of Kyoto.

Tobias: Invited talk, **15th European Turbulence Conference**, Delft, The Netherlands, 2015. According to the ETC 2013 website: “Eight outstanding contributors are the central invited speakers”.

4.1.6 PGR Training

The Unit is involved in five CDTs, and the Unit’s substantial seminar and research meeting programmes provide excellent PGR training. In addition, the following PGR training events have taken place in Leeds.

British Logic Colloquium Postgraduate Meeting, 4 days, 2013;
British Postgraduate Model Theory Conferences (3 days each in 2014, 2017 and 2019);
Postgrad combinatorics conference, 3 days, 2016.

4.2 Economy

4.2.1 Industrial Collaborations and Consultancies

The Unit encourages staff to carry out industrial collaborations and consultancies with the aim of creating external relationships with research users to maximise research impact. From Scopus data 2014-2020, 4.8% of the Unit's scholarly outputs involved corporate co-authors.

[text removed for publication]

4.2.2 Industrial enrichment of the research environment

Impact, consultancy and industrial collaborative activity is folded into research activity in the Unit.

[text removed for publication]

4.2.3 Wider impact activity

The Unit is involved in impact activity beyond the impact cases.

[text removed for publication]

4.3 Society

The Unit has a long tradition of strong school engagement. Schools are offered a choice of talks from 15 staff. 47 talks (32 in Yorkshire) were given by Category A submitted Unit staff over the REF period. An annual **Sixth Form conference** provides insight into university-level mathematics, informed by research, aided by PGRs and postdocs. An annual **Mathematics Teachers and Advisers Conference** allows teachers and Unit staff to exchange experiences.

The Unit has a **Public Engagement Champion** (Houston) who is **Education Secretary of the LMS.** Elwes is an **LMS Holgate Session Leader**. In addition to schools, 91 talks were given by Category A submitted Unit staff members to public audiences in the REF period, including 48 in Yorkshire, including the **Leeds Festival of Science**.

[Text removed for publication]. The Unit contributed funding for a three-day international conference in Leeds, **Mathematics Awareness, Training, Resource, & Information Exchange** 2016, co-organised by Elwes and Houston, MathsWorld UK and the Museum of Mathematics, New York. This was attended by Fields Medal Winner Cédric Villani, museum experts and schools.

[text removed for publication]

Lopez-Garcia received an **MRC Public Engagement award**, £1,200, for a day of activities on hospital hygiene at the MRC 2018 Festival at the Thackray Medical Museum.

[text removed for publication]

As part of the 2014 refurbishment, the Unit commissioned an installation from artists at **Superposition** (a Leeds collective collaborating on art, science and making), encouraging a research-based experimental approach. Subsequent discussion between artist and sculptor Dominic Hopkinson at Superposition, and **Rucklidge** and Subramanian (research fellow) about

their quasicrystals research led to Hopkinson being Artist in Residence in the Unit 2017-2018. The sculptures created during this Residence were first widely exhibited at the 2018 Venice Architecture Biennale, which had 275,000 attendees, and at five public events / exhibitions in the UK (2017-2020).

Langfeld is a member of the **Parliamentary and Scientific Committee**, representing the Unit and the Faculty.