

### Institution: King's College London

## Unit of Assessment: 10 Mathematical Sciences

#### 1. Unit context and structure, research and impact strategy

#### Structure

UoA10 consists of the **Department of Mathematics**, founded in 1830 and now one of five departments in the **Faculty of Natural, Mathematical and Engineering Sciences** (NMES), along with Chemistry, Engineering, Informatics and Physics. On the census date, the Department had 48 academic staff, 9 research associates, 2 teaching staff and 74 postgraduate research students. The Department holds an Athena Swan Bronze Award.

Research in the Department of Mathematics is organised into seven research groups: **Analysis**, **Disordered Systems**, **Financial Mathematics**, **Geometry**, **Number Theory**, **Statistics** and **Theoretical Physics**. Each group conducts internationally-leading research, has thriving links with institutions worldwide, and benefits from and contributes to the active London mathematical community.

Clearly defined research groups provide a strong disciplinary research environment, which enables early-career researchers to collaborate with those with closely related interests. Furthermore, with this structure, early-career researchers can be effectively mentored and supported.



At the same time, we encourage collaborations between the groups; many researchers are associated with more than one research group. There are rich interconnections between the groups (see diagram) and we additionally have a **Probability** (PR) Research Centre, which promotes intra-disciplinary research in the mathematical sciences, and the Institute for **Mathematical and Molecular Biomedicine** (IMMB) which promotes research collaborations with medical researchers.

An increased focus on probability, statistics and data science led to the creation of a **Statistics** Group in 2016 and the expansion of the **Financial Mathematics** Group and the **Disordered Systems** Group. The only group which is smaller than in REF2014, **Analysis**, was

restored to size by an appointment immediately after the census date.

The Department is led by a Senior Management Team (SMT), consisting of the Head of Department (**Gilmour**), Deputy Head of Department – Research (**Gromov**), Deputy Head of Department – Education (**Rietsch**) and Department Manager. The Department's Research Committee develops ideas for research funding and strategies to further enhance our research environment. It comprises representatives of staff at all career stages, including post-doctoral researchers and PGR students. We also run a research staff forum, chaired by the PDRA Coordinator (**Donnelly**), which shares best practice and makes suggestions for improving the environment for research staff, and a PGR student-staff committee, chaired by the PGR Tutor (**Newton**). Longer term strategic plans are developed by the Strategy Group, which consists of the



SMT and a representative of each research group (plus, from September 2020, the Chair of the EDI Committee and the Enterprise and Engagement Lead).

We run PhD programmes in Pure Mathematics, Applied Mathematics and Statistics. Along with Imperial and UCL, we are one of the partners in the Centre for Doctoral Training (CDT), the **London School of Geometry and Number Theory** (LSGNT, EPSRC grants EP/L015234/1, £4.7M 2014-22, and EP/S021590/1, £6.0M 2019-28) and we co-lead the CDT on **Cross-disciplinary Approaches to Non-Equilibrium Systems** (CANES, EPSRC grant EP/L015854/1, £3.9M 2014-24).

#### **Strategy Overview**

Our goal is to deliver world-class research in pure and applied mathematics and statistics, which is innovative in the mathematical sciences and informs and impacts a wide range of researchers and research users.

To achieve this, we hire outstanding mathematical scientists to pursue innovative ideas in a diverse and inclusive environment that rewards excellence. Our chosen areas of research build on our existing strengths and address national and international needs, e.g. in healthcare and artificial intelligence, as well as strengthening the mathematical base.

We will continue to expand the Department with significant growth consolidating our areas of research strength and expanding into new areas in line with national needs and future directions of the discipline. **Probability**, **Statistics** and **Financial Mathematics** will receive significant investment, with the research strategy being developed in parallel with our education strategy in a financially sustainable way. This will enrich our intra-disciplinary mathematics, advance our inter-disciplinary work and expand the impact of our research. Meanwhile, expansion in **Pure Mathematics** and **Theoretical Physics** will be partly leveraged by increased research funding, especially through fellowships. We will continue to promote collaborations with other groups in London in order to take advantage of the critical mass of outstanding research.

As detailed in our successful Athena Swan application, we will continue to actively improve the diversity of the Department through better-informed hiring practices and fostering positive changes in culture which are championed by our leadership team.

#### **Evidence of Success**

We have surpassed the research plans described for REF2014 as follows:

- *"a department large enough to fully exploit the research strengths of its members."* 
  - We have continued to expand the Department, from 42 to 48 academic staff, with a further 3 (Dogra and Lester in Number Theory, Krause in Analysis) recruited during the review period and in post by October 2020.
- "continue the process of consolidation and branching out into new areas"
  - The **Number Theory** Group consolidated its leading role in automorphic forms and the Langlands Programme in hiring **Newton**.
  - **Analysis** expanded its research directions to random analytic functions with a new appointment (**Buckley**).
  - In Theoretical Physics, with the hiring of Herzog and Anninos, the group acquired expertise in new fields such as applied holography and fundamental properties of quantum gravity on de-Sitter cosmology.
  - The **Financial Mathematics** Group has continued to work closely and fruitfully with industry, leading to substantial work including that described in three of our impact case studies. To meet the increasing focus on data science and machine learning in the financial sector, it has also expanded its interests beyond stochastic analysis with the appointments of **Horvath** and **Donnelly**.



- In order to meet the increasing need for mathematical research to address global healthcare challenges, the **Disordered Systems** Group has expanded its work in mathematical biology through the IMMB, which was founded in 2014 and brings together our researchers with those from the Randall Centre for Cell and Molecular Biophysics.
- "equip each group with sufficient staff, research assistants and PhD students"
  - Research grants and Heilbronn fellowships have equipped the Geometry and Number Theory groups with 15 early-career researchers on fixed term contracts during the assessment period, and the PhD programme has been boosted by 13 LSGNT students.
  - CANES has brought in 26 PhD students to the **Disordered Systems** Group and 3 to the **Statistics** Group since 2014, jointly supervised on collaborative projects.
  - Via a series of ERC grants (awarded £2,952k), the STFC consolidated grant (£2,830k) and fellowships (£816k), the **Theoretical Physics** group sustains a large cohort of PDRAs (13 in the period under review) who collaborate with multiple members of staff and PhD students.
  - We invested in **Financial Mathematics** by increasing its staff from 7 to 9 members.
  - The **Analysis** group received targeted PGR funding in 2019 to recruit 2 new PhD students.
- *"develop the links that exist between groups"* 
  - We founded the Probability Research Centre with members from the Analysis, Disordered Systems, Financial Mathematics, Number Theory and Statistics Groups.
  - King's is a founding member of the LSGNT, which has enhanced the links between the **Geometry** and **Number Theory** Groups through the coordination of training activities, as well as supervision of research projects on interface topics such as the geometry of Shimura varieties.
  - The new Statistics Group links with Financial Mathematics, e.g. Pitt and Pennanen have collaborated on methods to forecast donations for charities on Facebook using time series models.
  - The links between the Analysis and Number Theory Groups have been strengthened by collaborations (e.g. between Buckley and Wigman on quantum chaos).
  - Researchers whose interests straddle more than one group are now formally recognised as members of both (Di Matteo in Financial Mathematics and Disordered Systems; Doyon in Theoretical Physics and Disordered Systems).
- "hiring in the area of statistical inference or computational statistics"
  - We exceeded this objective by establishing a new, world-class Statistics Group, with the appointment of two professors, Gilmour and Pitt, in 2016, followed by three lecturers (Mylona 2016, Pigoli 2017, Rubio 2018). We also created a new PhD Statistics programme in 2018.
- *"extending scientific links across campuses"* 
  - The IMMB enables researchers from Mathematics to spend part of their time on Guy's Campus, embedded in the Healthcare faculties. This has encouraged deep collaborations, leading to new interdisciplinary research and impact, e.g. research on Bayesian modelling of lifetime data by **Coolen** was implemented and led to the impact described in ICS4.
  - The CANES CDT brought together researchers from diverse parts of the university, both within NMES and beyond. For example, **Annibale** has established a productive collaboration with researchers from Chemistry in the area of kinetic network models and coarse-graining, with three papers in highly rated journals, including the paper which was the Editor's Pick for 2019's Journal of Chemical Physics.



- The Stats@Kings initiative brings together statisticians from Mathematics, the Healthcare faculties and King's Business School which, for example, identified common research interests in survival analysis (**Rubio**) with the King's Clinical Trials Unit.
- King's is a founding partner in the Francis Crick Institute, which was established in 2016, and members of the **Disordered Systems** Group (**Annibale**, **Coolen**, **Sollich**, **Kuehn**) have since partnered with experimental biologists, bringing cutting-edge mathematical methods to bear on world-leading biological research.

The growth in academic (42 to 48) and research (5 to 9) staff and research students (60 to 74), the new **IMMB**, **Statistics** group and **Probability** Research Centre have given us the capacity to directly address and achieve the objectives set in REF2014.

# **Future Objectives**

We aim to continue improving our contributions across our areas of research. Building on our success in intra- and inter-disciplinary mathematics, we aim to accelerate such collaborations to deliver King's Vision 2029. Specific objectives over the next five years are:

- To further ensure the vitality and sustainability of the Department by hiring outstanding mathematical scientists in key strategic growth areas. We aim to expand our expertise in Probability, Statistics and Mathematical Aspects of Data Science in order to position our Department as a leader in this field. We will hire staff, by starting a **Probability** Group and growing **Statistics**. We will also expand our postgraduate taught provision in this area to improve the pipeline of potential PGR students and early-career researchers.
- 2. To increase our research income by winning large grants, which will help to support the next stages of the research pipeline. We will take a more systematic approach to identifying candidates for fellowships and supporting their applications. The King's Fellows scheme aims at attracting external applicants and schemes such as NMES20 provide structured support for internal applicants. Increased success will enable further expansion, especially in pure mathematics and theoretical physics.
- 3. To improve the diversity of our academic and research staff, by ensuring our recruitment follows best practice in actively seeking out applicants from under-represented groups, e.g. by advertising on spaces aimed at women in mathematics. We will also encourage and support staff to write grant applications in order to increase the number of early-career and diverse research staff in the Department.
- 4. To make our Group structure more agile. While the Group structure provides a supportive environment for researchers, there has always been collaboration across groups and specific areas of interest that do not neatly fit in to any single group. We will further encourage research in targeted areas by formalising Interest Groups within the department. We will create the Centre in Mathematical Aspects of Data Science, including machine learning, quantum information theory, geometrical and topological data analysis and graph theoretic design of experiments and data analysis. This will work closely with a proposed King's Centre in Artificial Intelligence, currently being developed by a working group with **Gilmour** representing NMES.
- 5. We will continue to support collaborations across King's by fully participating in the IMMB, the Centre for Non-Equilibrium Science (CNES), the London Centre for Urban Science and Policy (see REF5a) and other cross-Faculty initiatives. Closer collaboration with researchers in Healthcare faculties and King's Business School will be promoted by the development of the new Stats@Kings initiative. This will leverage the strength of biostatisticians and econometricians at King's to open new research and pathways to impact.
- 6. We will prioritise the creation of named fixed-term lectureships, with a strong research focus. This will attract outstanding international postdoctoral researchers to King's in areas complementing those of permanent staff and, by giving them a reduced teaching load and research support, will accelerate their research careers. This in turn will contribute to the research environment by ensuring a steady stream of new talent.



 To develop a formal visitor programme. Once pandemic-related travel restrictions are lifted, we will exploit our central London location to expand the number of medium-term visitors (1-4 weeks). This will further our EDI commitments to give early-career researchers more opportunities to interact with leading researchers from diverse backgrounds.

# **Enabling impact**

Our strategy for non-academic impact is to ensure that pathways to impact are a central part of research plans in those areas in which our research is motivated by, and needed for, societal and business problems requiring a mathematical approach, while exploring new avenues for those areas of mathematics where research is entirely curiosity driven. Our approach to enabling and delivering impact has been transformed since REF2014, with stronger communication of the importance of impact in hiring, promotions and workload allocation.

Strategic initiatives taken to enable, deliver and substantiate impact include:

- The establishment of a **Statistics** Group in 2016 and the expansion of the **Financial Mathematics** Group, with the hiring of researchers whose work has the potential for impact and who detail pathways to impact in their research programmes. For example, **Horvath** (appointed 2018) carried out research at King's which had immediate impact in the financial sector leading to ICS3. This arose through extensive networking, including organising monthly seminars for quantitative analysts in the City of London and having meetings with decision-makers in banks to identify the most pressing problems in machine learning.
- The formation of IMMB in 2014 embeds mathematicians with healthcare researchers, leading to close collaborations in research areas with considerable potential for impact on healthcare practice. For example, research by **Coolen** in collaboration with a wide team of healthcare researchers produced the research which led to ICS4.
- The explicit recognition of the time needed to develop impact in our workload allocation model. This ensures that those developing impact still have the time to carry out the excellent research that underpins it. For example, this allowed **Di Matteo** to reduce her teaching load at a crucial time for producing the impact described in ICS2.
- The creation of the role of Impact Champion (**Pennanen**) in the Department, to promote and oversee the documentation of impact. NMES has a new post of Impact Manager, whose expertise supports the gathering of evidence to demonstrate impact. This structured approach enabled us to provide much stronger evidence of impact in ICS1 than would have been possible using just the researcher's knowledge.
- Leveraging institutional initiatives. The EPSRC Impact Acceleration Account (IAA) described in REF5a is managed by NMES. To date, two projects in Mathematics have been funded, including one for **Gilmour**'s work on multi-objective optimal design of experiments, which was crucial in leveraging over £800k of additional research funding through an EPSRC grant.
- The appointment of visiting research fellows with links to industry where impact is likely. For example, we appointed Dr Gueorgui Mihaylov, a Senior Data Scientist at GSK (previously a Senior Statistician at Royal Mail) now involved in discussing research of mutual interest with the **Geometry** and **Statistics** Groups.

The Department's impact case studies stem from research in Financial Mathematics and Statistics, with direct beneficiaries in areas of finance and medicine that impact on large sectors of the population. These only capture part of our approach to enabling impact, which evolved significantly during the assessment period, and is illustrated by the breadth of its engagement with business, industry, healthcare providers, government, charitable organisations and the public. The following, and many more, examples of this are described in Section 4:

• Industrial collaborations include the implementation of **Gilmour**'s research on multiobjective optimal design of experiments in the Genstat and Design-Expert software packages, and that of **MyIona** on displaying the results from the analysis of data from



factorial experiments in at least 5 different products at Janssen Pharmaceutical Companies of Johnson & Johnson.

- Collaborations with government include research with potential impact on our national security through its involvement with the London office of the Heilbronn Institute for Mathematical Research (HIMR); in addition to our hosting a Visiting Senior Research Fellow and a regular cycle of early career Heilbronn Fellows, two staff members in pure mathematics regularly act as consultants at HIMR-London.
- Work with other parts of the state sector include Vivo's unique research on the complexity in legal provision (funded by a UKRI Future Leaders Fellowship), which bears promise of impact on simplifying aspects of the UK legal system. Pigoli's work on estimating growth curves for larvae was developed with the Natural History Museum for forensic entomology investigations.
- **Pitt** and **Pennanen** have developed methods for forecasting charities' income in collaboration with, and now being implemented by, Breast Cancer UK and explored by other UK charities
- The Department also makes rich contributions through public engagement and the arts. Examples include **Drukker**'s pottery, which is inspired by his research in string theory and supersymmetric field theories and has been exhibited worldwide, and **Salamon**'s public lecture on "The Mathematical Skyline" at Gresham College in 2017.

Plans to support the continued vitality and sustainability of the unit's impact include the following:

- A further expansion of the **Statistics** Group, with excellent research with potential for impact being one of the key criteria in hiring new staff.
- The continued rebalancing of the **Financial Mathematics** Group towards machine learning, applied probability and statistics will ensure the continued relevance of the group's research to the financial sector, where these are likely to remain the areas in demand.
- We will further enhance our collaborations with HIMR in order to support the security of the nation and to increase the impact of our research in pure mathematics. This will further our status as an internationally-leading centre of excellence in geometry and number theory. Initially, the department is seeking to appoint a HIMR-sponsored permanent member of staff.
- The successful programme of internships for PhD students on the CANES CDT will continue and expand to be made available to all research students in mathematics. This will provide a route to explore new research collaborations, while strengthening our students' entrepreneurial skills.
- From September 2020, the role of Impact Champion has been expanded to that of Enterprise and Engagement Lead in Mathematics (**Di Matteo**), working closely with the new Vice-Dean for Enterprise and Engagement in NMES.
- We will host an annual series of events for our alumni to forge and maintain close links to graduates working in sectors which can benefit from our research.

# Supporting inter-disciplinary research

The Department supports the university's strategy of extending scientific links across its campuses, both by supporting inter-disciplinary research centres and by facilitating collaborations between groups or individual researchers. The administrative overhead of leading these centres is recognised in our workload allocation model.

The IMMB has fostered a growth in collaborative research projects, with 16 outputs authored jointly by researchers in Mathematics and in Healthcare (10 in the last REF period) and has attracted £2.5M of research funding to Mathematics, e.g. from BBSRC, MRC and ERC. We now aim to broaden the institute to include a wider range of mathematicians, especially statisticians, as well as researchers from other NMES disciplines, particularly Physics and Informatics.

The Centre for Non-Equilibrium Science (CNES) is led by the **Disordered Systems** Group, along with colleagues from Physics and Chemistry, and bringing in researchers from Geography, Pharmaceutical Sciences and the Healthcare faculties. It runs inter-disciplinary seminars and



conferences, as well as the CANES CDT. The CDT has trained 9 students to PhD level, with 29 currently registered, with projects at least partly in Mathematics. All students are jointly supervised by researchers in different fields and members of CNES have over 400 inter-disciplinary publications since 2015.

The Crick gives mathematicians opportunities to work with experimental biologists on cutting-edge collaborative research projects. **Sollich** has established a productive collaboration with Dr James Briscoe at the Crick on the mathematical modelling of pattern formation in developmental biology. **Kuehn** co-supervises a PhD student at the Crick, and in 2019 spent part of a sabbatical in the laboratory of Dr Vassilis Pachnis (Development and Homeostasis of the Nervous System).

Mathematics benefits from myriad other informal collaborations with colleagues in Informatics, Physics, King's Business School and the healthcare faculties. Some have been initiated with support from King's Together, which is described in REF5a. For example, **Pitt** led a project with researchers in Psychosis Studies on using multivariate copulas for measures of psychosis.

## **Open research**

King's Research Portal, KCL-Pure, is our institutional repository used by all staff, providing access to the full text of research publications and other outputs. Where relevant, computer programs linked to the outputs are uploaded onto KCL-Pure or arXiv. King's Library also supports an open data repository, where researchers can upload programs and full results. The Department sponsors the diamond open access journal SciPost.

## **Research integrity**

Enhancements to processes for research integrity are described in REF5a. A Research Integrity Champion has been appointed within NMES, playing a high-level advocacy role. Additionally, a Research Integrity Advisor (**Pigoli**) is embedded in the Department, providing a visible point of contact and advice for researchers.

Internal refereeing of grant proposals and the culture of open access publications help to ensure research integrity. Projects involving the analysis of human data, e.g. medical studies, are cleared by the local research ethics committee, usually led by our collaborators.

# 2. People

#### Staffing strategy and staff development

**Overview.** Our research strategy drives the hiring, retention and promotion of outstanding researchers, together with policies and procedures that motivate and enable them to fulfil their potential. The Department adopts a targeted recruitment strategy. It provides comprehensive support mechanisms that promote equality and diversity and address the needs of early-career staff and postdoctoral researchers. We also offer a suite of incentives to foster innovative research and impact development.

**Management.** In 2019 the Department established a new management structure, with two Deputy Heads of Department, providing better transparency and support in all management processes. Together with the Head of Department and Department Manager, they form the SMT, which meets regularly to steer departmental activities, including research. The Strategy Group meets quarterly to devise longer-term plans for the Department, including recruitment strategy. We have also updated job descriptions for all leadership roles emphasising the EDI objectives of the Department and have reformatted the role of all departmental committees promoting the role of EDI in the overall structure.

**Recruitment.** Recruitment follows best EDI practice, as advised by our Human Resources (HR) People Partner. New posts are designated to research groups, with the aim of either strategically targeting new domains or strengthening existing fields, while still maintaining the flexibility to respond to promising recruitment opportunities. An example of such strategic recruitment was the



creation of the entire **Statistics** Group, formed since 2016 by creating 6 additional posts (one advertised but vacant on the census date). Replacements are sought in either a broad area of mathematics or more targeted, depending on what is needed to best achieve the direction set by the Strategy Group. Our recruitment strategy to achieve further growth, including attracting fellowship holders and targeting recruitment in new areas, such as Probability, are described in Section 1, along with measures of our success over the review period.

Eight staff in post on the previous census date have left, to destinations including Oxford (Schafer-Nameki) and IIS-Bangalore (Kakde), and one passed away (Safarov). Our effective recruitment strategy helped us to attract 15 new appointees, including outstanding researchers from around the world (e.g. 6 from Europe and 2 from USA). On several occasions, we have made two appointments when a single post was advertised, e.g. to the initial Chair in Statistics. We have been successful in attracting Royal Society University Research Fellowship holders (e.g. **Anninos**). A further 6 permanent and 2 fixed-term staff were hired and left within the reporting period (e.g. Mijatovic).

All but one Category A staff (49 members) are on permanent contracts. The large number of early career staff, about 20, is balanced by a large number of experienced professors, about 30, who take on the bulk of tasks needed to manage research activity and provide mentoring to younger colleagues.

**Career development support.** We have several ongoing programmes facilitating career development for staff at all stages.

Every staff member participates in an annual performance development review (PDR) with their Head of Group or another senior member of the Department. This process provides an opportunity to reflect on successes and difficulties, with an emphasis on research performance and career development planning. It also allows the HoD to systematically recognise successes and difficulties and make appropriate adjustments, including to workload, to ensure that adequate time is available for research and related activity, including grant applications, impact development and dissemination of results.

The department has a Promotions Committee, which identifies and considers candidates for promotion and ensures cases are supported. 16 of the staff returned were promoted internally in the review period. To help address the gender imbalance in our Department, female staff identified as being candidates for promotion are now offered additional mentoring. The 4 female members of staff who were eligible for promotion have all been promoted during the review period (3 are still in their probationary period).

Additionally, King's has a comprehensive programme of professional development training, using both internal and external providers, both online and through taught courses. The Department has gone further than King's guidance to make Diversity Matters (unconscious bias) training compulsory for all academic staff (with over 85% completion rate among academic staff). There is a plethora of other training activities suitable for and tailored to researchers at different career stages, e.g. new academics often find useful sessions on applying for research grants, while senior researchers can take advantage of courses on academic leadership. NMES runs a network of Fellows, providing a supportive environment for inter-disciplinary networking.

All academic staff have access to departmental research funds. £120k helped support seminar activities during the reporting period and over £120k was used by staff without recourse to other funding to support travel and other research expenses. Incentive schemes and support mechanisms for securing external funding are described in the subsection below on facilitation.

**Sabbatical leave.** Staff at all career stages, full-time or part-time, can apply for sabbatical leave: for one term after three years, or for a full year after six. Applications are assessed on the strength of the proposed activities, and the potential benefits to the individual's research career and potential impact produced. Staff are encouraged to be ambitious and to use sabbaticals to explore new research fields or challenges and develop ideas for grant proposals and new collaborations, including with industry. For example, **Di Matteo**'s 2016-17 sabbatical was vital to start new research activities and pursue collaborations with industry partners and resulted in two successful EPSRC applications as Co-I. Sabbaticals for a full academic year were taken by 21 staff members



(18 of them fully paid by King's), and a further 7 lasting a semester were taken. In total 32 staff members took paid study leave with 30 weeks average duration over the reporting period.

**New academic staff.** New staff are welcomed with a thorough induction, which introduces them to the Department and its research groups. Lecturers are appointed with an initial probationary period, usually three years. Each staff member on probation has a mentor who gives advice and support according to their needs and helps to build their skills and research profile to promote a smooth transition to being confirmed in post. Heads of Groups and the Head of Department set clear expectations and targets for the probationary period and provide guidance in rare cases when some expectations cannot be met; they also assist in preparing the final probation report.

All new academic staff have reduced teaching and administration loads, initially 50%, and are encouraged to apply for research funding at an appropriate level, e.g. EPSRC New Investigator Awards. They are supported throughout the application process both by senior colleagues, who advise on improvements to drafts and internally referee the full proposal, and by the research support team, including the department's Research Officer.

New staff receive start-up funds to cover travel expenses, visits to and from collaborators and basic research equipment. **Theoretical Physics** immediately enrol new staff into their STFC consolidated grant, allowing extended travel support and money for RAs and PhD students. New staff in all groups are usually invited to organise the relevant seminar programme. This helps build relationships with other members of the group and allows their research areas to be embedded into the group's culture.

Various training activities cater to new staff, such as the Learning and Teaching Practice programme (this, or an equivalent, is a requirement for passing probation) and programmes to develop grant writing skills. Identifying and developing impact is a core consideration in the probation and PDR processes. This enables early-career researchers to exploit the expertise of more experienced colleagues to realistically identify work which has the best chance of leading to impact and subsequently develop those pathways to impact.

As part of our Athena Swan commitment, new academic staff are appointed a "buddy" to help welcome them to King's, navigate university systems and processes and foster initial relationships in the Department.

**Research staff.** A stream of Research Fellows (RFs) and Postdoctoral Researchers (PDRAs) contribute to the vibrancy of the Department's research environment. The unit hosted over 40 early career researchers on fixed-term contracts during the assessment period, with a mean of 17.1 per year. These were mainly in **Theoretical Physics**, **Number Theory** and **Disordered Systems**, with smaller numbers in other groups and several whose research interests straddled groups. Most were funded by research grants held by permanent staff, while three held HIMR Fellowships, two held Marie Curie grants and one held a KC Wong Fellowship.

The probation period for research staff is usually six months. Both the probation and PDR procedures for research staff are different from those for academics and tailored to their needs. We have a post-doctoral research staff forum, with an academic lead contact, where research staff can raise any issues relating to their career, working environment, working relationships and anything else affecting their performance. This is also a forum to review our adherence to the Concordat to Support the Career Development of Researchers, of which King's is a signatory. King's commitments include: 10 days pro rata per year to engage with professional development; increased emphasis on planning for careers within and beyond academia; and to encourage researchers to develop their research identity and broader leadership skills.

The Faculty Research Staff Committee serves as a forum to exchange ideas and best practice between research staff across departments and to ensure they are supported at both Faculty and departmental level. Two post-doctoral representatives belong to the corresponding Faculty forum and the Department's Research Committee. One of the initiatives resulting from this forum is a Department-run programme tailored to PDRAs for fellowship and grant applications. For example, the 2019 workshop led to **Imtak Jeon** being awarded a 5-year Junior Research Group Leader Fellowship (£500k) in APCTP, Korea.



Research staff typically work closely with PIs on the grants providing their funding but are also encouraged to interact with other researchers in their group and more broadly, for example by contributing to the organisation of seminars, colloquia and international journal clubs (for example the London Integrability Journal Club). We also promote the development of their own research programmes; some, especially the Research Fellows, are already more independent. Most fixed-term research staff who left during the assessment period now hold permanent academic or research positions in the UK and at least eight other countries, at universities including Copenhagen, Durham, Haifa and Stony Brook. The remainder are split between further postdoctoral positions at institutions including Harvard and SISSA, Trieste, and employment in industry, primarily in the finance sector.

**Research and Impact recognition and facilitation.** The Department runs several incentives, with budgets of £54k in 2019. Staff who secure substantial research grants are rewarded by additional payments to their individual research support accounts. We also reward staff who make unsuccessful applications for large research grants and those who internally referee successful grant applications. In addition, we award annual prizes for the best research paper each year: one for early career researchers, one for applied mathematics (including statistics) and one for pure mathematics. The incentive scheme also rewards impact development activity with payments to research accounts.

#### **Research Students**

The high-quality PhD training provided by our Department is an essential aspect of our research environment, as well as our mission. 86 PhD degrees were awarded in the review period. Besides authoring over 170 papers published during this period, our PhD students contribute to the vitality of research groups, e.g. through participation in seminars and group meetings and the organisation of junior seminars and study groups. They also contribute to the next generation of leading researchers in academia and industry, in the UK and internationally: the vast majority of PhD recipients have gone on to jobs in research including permanent academic positions in Vienna and Delhi, postdoctoral positions at Edinburgh, ENS-Paris, EPF-Lausanne, Max-Planck and Tel-Aviv, and research positions in industry with Amazon, Aviva, General Motors, G-Research, nChain AG and Tesco. Others are engaged in entrepreneurship (founding Yewno and Valetta Ventures), finance (including Barclays and Citibank), education (King's Mathematics School), the civil service (UK government) and the arts (Fidelio Orchestra founder and music director).

There are 74 students on the PhD programmes in Pure and Applied Mathematics and Statistics, an increase of almost 25% since the REF2014 census date. All but 1 of our academics (the most recent appointment) served as supervisors over the reporting period. Most PhD students are fully funded by a variety of studentships administered by the Department. External sources of funding include EPSRC-funded Centres for Doctoral Training (CANES, LSGNT), EPSRC and STFC DTPs, and individual grants from the Royal Society and ERC. Other sources include King's-sponsored studentships providing leverage for CDTs, NMES Faculty Studentships and the King's – China Scholarship Council Programme (in total we had 10 such positions over the last two years).

**PGR recruitment.** Our approach to recruitment of PGR students is largely driven by attention to research areas and the importance of equality and diversity.

Along with Imperial and UCL, we are one of the partners in the LSGNT, which attracts outstanding students in **Geometry** and **Number Theory**. We have assigned studentships to early-career researchers in pure mathematics so that they are able to start building their own research teams. On the applied mathematics programme, we co-lead CANES (**Sollich** was PI and Director until 2017, **Annibale** has been Co-Director since 2017), which has attracted a strong cohort of students at the interface of **Disordered Systems**, physics and other fields. We also attract many outstanding students in **Theoretical Physics**. Where recruitment is more challenging, we attract a small number of excellent students in **Financial Mathematics** by allocating studentship funding early in the year to early-career researchers in that group. The PhD **Statistics** programme started in 2018 and already has 6 students, the first of whom completed successfully in 2020.

We actively advertise PhD positions online, including through creating and promoting engaging marketing videos, and via our wide network of contacts in other universities worldwide. As a result, last year we attracted 192 candidates and appointed 23. In addition, last year there were 239



applicants to LSGNT. From 2021 our Department will host an open day for potential PhD students with talks and Q&A sessions by potential supervisors and current students.

In the last two years, the department has recruited 10 female and 35 male PhD students, while LSGNT has recruited 11 female and 15 male students. LSGNT is a supporter of the LMS Good Practice Scheme for women in mathematics, as is the Department of Mathematics. All research students are interviewed by at least two academic staff and our diversity and inclusion rules require at least one interviewer to be of the same gender as the candidate.

The Department seeks to improve the pipeline of research students by delivering researchenhanced education at all levels. During the review period, papers have been published based on 4 MSc projects and an MSci final year project. The Department has supported 4 King's Undergraduate Research Fellowships (described in REF5a).

**Training and support mechanisms.** Supervision of research projects is coupled with a range of training activities to develop students' transferrable skills and breadth of knowledge.

The Department is a founding member of the London Taught Course Centre (LTCC), comprising 12 universities, and our staff currently teach 3 lecture courses (out of 28). The collaboration with other universities in and around London enables us to offer research students high-level courses across a range of topics in Applied Mathematics, Pure Mathematics and Statistics. Students in **Financial Mathematics** benefit from the courses of the London Graduate School in Mathematical Finance. In addition, King's is a part of London-wide PhD theoretical physics training network, LonTI, and the Polygon lectures are coordinated via the King's based and supported Triangle Seminars. **Gromov** also organises PhD-level summer schools with industry partners.

Students in the LSGNT similarly benefit from the partners' combined resources. The first year of the four-year programme includes a computing course and mini-projects along with courses in geometry and number theory. Students are assigned supervisors at one of the three institutions at the end of their first year, but continue training activities such as seminars, academic and industrial placements, and mock interview days.

The CANES CDT similarly included a year of courses in mathematics and physics to prepare students for their programme of research, with an ongoing series of lectures and seminars throughout their programme. In addition, our Department was one of the main beneficiaries of two EU Marie-Curie Initial Training Networks (GATIS and NETADIS), which provide a wide range of career and professional development training opportunities and a variety of PhD targeted scientific events.

Research students may also take advantage of lectures offered by our range of MSc programmes in Mathematics, Complex Systems Modelling, Financial Mathematics and Theoretical Physics as well as courses in other departments in London.

Additional training in computing is organised by MathSoc and King's Women in STEM in collaboration with our academics, covering LaTeX, Mathematica and Python. We organise 6 journal clubs at PhD level, where students gain basic presentation skills. The Department also provides a minimum of £3000 travel funds to each PhD student through research training support grants.

Elsewhere, the King's Researcher Development Unit offers considerable training in transferable skills (with over 300 courses), and personal, professional and career development opportunities.

The Department has a PGR Student-Staff Committee, with one student representative from each research group, the PGR Coordinator, the PGR Tutor and the Programme Directors, where students can advocate for and discuss training and support needs.

**Progress monitoring.** Research students are initially registered for MPhil degrees, with the upgrade to PhD usually taking place after about 15 months, by which time they are expected to have started producing research results. In addition to regular meetings with their supervisor, the number of which is recorded, students must submit reports after three months and every six months thereafter. Each student is allocated a second supervisor, who provides further support related to their studies, professional development, pastoral or other matters.



### Equality, diversity and inclusivity

The Department promotes equality of opportunity in all areas of work and ensures that all members and prospective members of staff and students are treated solely on merit, ability and potential. We promote a positive working, learning and social environment free from prejudice, harassment or bullying. King's is slightly below the national LMS benchmarks for gender diversity in staff and PGR students. Our Athena Swan action plan describes how we will rectify this in several ways. Recruitment and other panels are chosen to reflect diversity in gender and other protected characteristics, experience, expertise and cultural background. Participation in schemes such as the BMEntor scheme, the Parents' and Carers' Fund, the Women's Network and the Springboard Women's Development Programme are encouraged. We have a higher proportion of female UG and PGT students than the benchmarks and we are now trying to take advantage of this to attract more diverse PhD applicants by better promoting research to our students at earlier stages of their careers and by guaranteeing interviews to all our MSc students who apply for PhD.

Circumstances which have affected a staff member's ability to spend time on research forms part of the criteria used in deciding when to grant study leave. Flexible working hours are approved for staff with circumstances such as caring responsibilities, with teaching and other timetabled commitments scheduled to suit their needs. Seminars and meetings are normally scheduled during the core hours of 10.00 - 16.00 to support staff with other commitments, though some cross-London seminars are scheduled later in the working day to minimise travel time. The programme for these seminars is fixed well in advance to allow people to make any necessary arrangements. Remote working on one or more days per week is common and staff are free to work remotely whenever they have no timetabled commitments. Staff can also request a specific research day each week to be clear of commitments.

We currently have no fixed-term academic staff, but the 2 during the assessment period were short-term replacements for permanent staff members with research fellowships. Fixed-term staff are treated exactly like permanent staff in terms of probation, appraisal, access to training and career development. If a suitable permanent post becomes available, they are always made aware of it and encouraged to apply.

Conference attendance and other research travel, e.g. for international collaborations, for staff and research students with caring responsibilities are facilitated through (separate) Faculty funds, which cover the extra costs associated with, for example, childcare.

All staff are supported in making applications for research funding according to their individual circumstances. The Department Research Committee monitors equality and diversity of grant applications and successes, conferences, sabbaticals and training. The Senior Management Team have an explicit aim to ensure that research-related leadership roles reflect our commitment to diversity.

As part of our commitment to equality and diversity and to internationalisation, researchers coming from outside the UK academic system are given additional support to prepare research grant applications, both from colleagues in the Department and the Faculty research support team.

Staff returning from long-term leave, such as parental leave, are given reductions in workloads on their return, as explicitly recognised in the workload allocation model. Staff with other exceptional circumstances are treated similarly.

Supporting the wellbeing of staff and students is essential for maintaining an environment in which all researchers can flourish. This enables line managers or colleagues to identify any potential issues early. Where issues do arise, King's has several support services, including a dedicated People Partner in HR, whom staff can approach with any relevant problems, and the independent Employee Assistance Programme.

In selecting outputs for this REF submission, the gender balance of authors of selected outputs was compared with the balance of the Department at each stage and no discrepancy was found.



#### 3. Income, infrastructure and facilities

#### Research income

Research income has grown to a consistently higher level in this reporting period compared with the previous period. The left-hand figure below shows the total amount awarded for all grants which include mathematics, spread equally over the period for which the grant was running. The right-hand figure shows total annual income to the Department of Mathematics, which for the reporting period increased to over £11.5m. Both figures exclude CDT and other funding for PhD students. The average annual income increased by 80% from £909k in 2008-13 to £1,650k in 2013-20.





The Department's main research income is generated by individual grants (ERC £2,952k, EPSRC £3,131k, MRC £1,200k) and group grants (STFC £2,830k). Major grants (>£500k) starting during the reporting period are shown in the following table.

Maths Investigator	Awarded to Maths	Funder	Active	Maths Investigator	Awarded to Maths	Funder	Active
Gromov	£1,614,675	ERC	2020-25	Murthy	£1,336,889	ERC	2016-21
TP group	£1,141,628	STFC	2014-18	Vivo	£883,842	MRC	2019-23
TP group	£855,591	STFC	2020-23	TP group	£832,748	STFC	2017-21
Wigman	£792,417	EU EC	2014-20	Diamond	£589,195	EPSRC	2014-19

A further 16 grants of between £100k and £500k were awarded during the review period, from diverse funding sources (EPSRC, GCHQ, MRC, RS, SFARI). Major grants awarded before the reporting period but generating income during the reporting period are shown in the following table.

Maths Investigator	Awarded to Maths	Funder	Active	Maths Investigator	Awarded to Maths	Funder	Active
Martelli	£1,002,478	ERC	2013-18	TP group	£995,349	STFC	2011-15
Panov	£753,957	RS	2010-18	Sollich	£580,237	EU EC	2012-16
Gromov	£514,569	EU EC	2013-16				

Further grants awarded, but not started during the reporting period, include those awarded to **Fyodorov** (EPSRC £824,648), **Gilmour** (EPSRC £814,578), **Rietsch** (EPSRC £573,795), **Dogra** (RS £546,998) and **Buckley** (EPSRC £272,948).

Support from non-academic partners for research grants involving Mathematics totalled £50k cash contribution and £667k in-kind contributions.



The effectiveness of our use of grant funding to produce high quality research can be illustrated by the fact that grant support was acknowledged in over 75% of the 50 outputs most highly rated in our internal review process. The use of grant funding to produce research with high impact can be illustrated by the four research grants awarded to **Coolen** referenced in ICS4.

Strategies for generating research income include providing extensive support for those applying at both departmental and faculty level, as well as the incentive schemes described in Section 2. We have an internal peer review process, mentoring of early-career researchers by a member of their research group and grant writing workshops. Hiring considers the candidate's track record in, and potential for, obtaining grant funding.

### Infrastructure and facilities

Physical infrastructure. All academic staff and PGR students are accommodated on two floors of the Strand Building, with some research staff in the neighbouring King's Building. We are continually optimising the way this space is used to ensure that there is sufficient space for growth. The Department's 14% expansion in academic staff was facilitated by the university's acquisition of Bush House (pictured), which provided new high-specification meeting and discussion spaces and freed space in the Strand Building, enabling us to continue equipping almost all academic staff with single-occupancy offices. In addition to its central London location incorporating iconic buildings such as Bush House and a wing of Somerset House, the appeal of the Strand Campus is enhanced by a modernisation of the entire site, including the renovation of the Strand Building.

Additionally, the IMMB has dedicated space at Guy's Campus, along with the healthcare faculties. Mathematics' main collection of hard copy books and journals is in the



Maughan Library, a short walk from the Strand Building; extensive e-resources are also coordinated there. Academic and research staff in Mathematics are supported by a team of 9 professional services staff, in addition to further support from NMES. During the review period we have moved to having dedicated departmental support, including a Department Manager and a Research Support Officer, who coordinates the administrative aspects of research grants, from pre-application through the lifetime of the award. PGR matters are supported by the Senior Programmes Manager and from 2021 we will have a dedicated programmes officer for PGR students.

**IT infrastructure and support.** King's purchases licences and support for the key research packages: Matlab, Mathematica, Maple, Stata, SPSS, Nvivo, CoCalc, Endnote, Overleaf, R, Python and many more. All personal computers have 4-year replacement cycles. In addition to our high-performance computing (HPC) infrastructure, powerful desktop workstations are provided when necessary. There are over 350 laboratory workstations in NMES in addition to those centrally provided. The computing needs of the Department are supported by the 12-strong NMES Computing Support Team in addition to the central King's IT Department.

King's has built a new College-wide eResearch function to provide a highly flexible research computing infrastructure supporting all computational workloads, as described in REF5a. Researchers in Mathematics make extensive use of the HPC facility, Rosalind, e.g. **Doyon** supervised a PhD student who used Rosalind for intensive computations, contributing to two papers on non-equilibrium quantum spin systems.

Meanwhile, NMES makes an annual investment of approximately £30k in infrastructure maintenance and renewal in support of the above technologies. Between 2017-18 and 2019-20



£100k was invested in NMES storage and backup infrastructure for research use.

Mathematics invested £30k into a Bloomberg Trading Room, with instant access to real-time financial data, extensive use of which has been made by **Di Matteo** and her PGR students, most of whose research outputs use these data.

**Shared infrastructure.** The unit exploits its central London location to share research infrastructure with other HEIs in London, especially for PGR training. This collaboration is especially successful with the LTCC and LSGNT. The LTCC brings together research students from several HEIs in and around London for advanced training, mostly at the London Mathematical Society in Russell Square. LSGNT students are based at UCL during their first year but receive training and work with researchers at all three universities. London HEIs also run joint seminar programmes as described in Section 4.

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

The Department enjoys and encourages rich collaborations within academia, with users and with broader society, through both formal and informal networks. Researchers take on numerous leadership roles to support the research base, help to shape the research agenda and ensure that mathematical sciences benefit the economy and society.

#### Academic collaborations

We support new and ongoing academic collaborations, both UK and international, through several mechanisms. Among the formal arrangements are the following:

- Several College fellowship programmes facilitate collaborations: for example, a FAPESP-King's fellowship resulted in a roadmap paper of **Drukker** with 20 other international coauthors; a KC Wong Fellowship enabled a post-doctoral researcher from China to spend a year at King's, leading to a joint paper with **Riedle**.
- King's and Technische Universität Dresden established the first official Transcampus programme in Europe, described in REF5a. This initiative provides **Riedle** and **Shargorodsky** with 20% appointments at TU Dresden, through which they collaborate with mathematicians at Dresden and present short courses to its PhD students.
- The Department is one of the centres of the London Mathematical Finance Group, a consortium of researchers from 7 universities providing a seminar series and a programme of advanced courses in mathematical finance.
- The Department plays a leading role in more than 10 cross-university seminar series, including the Paris-London Analysis Seminars and the Triangle Seminars in theoretical physics, by contributing to travel and providing venues. Since April 2020, we have been hosting 7 regular international online seminar series, e.g. the London Integrability Journal Club, which has over 50 participants and over 200 YouTube subscribers.
- **Horvath** contributes to the sustainability of the discipline as co-organiser of the research project on Synthetic Data Generation for Finance and Economics and the research programme on Machine Learning in Finance at the Alan Turing Institute.

In addition, individual staff members play leading roles in the organisation of national and international networks on various scales. Examples include:

- With **Berndt** as UK coordinator, King's was part of an 11-nation research network in geometry and number theory sponsored by the Japan Society for the Promotion of Science (2014-19). The network supported research visits between the UK and Japan, including T. Sano's visit to **Burns**, which resulted in 3 preprints.
- **Annibale** has been a coordinator since 2018 of the Mathematics in Life Sciences network, which is supported by the LMS and organises three themed meetings each year at UK universities.
- **Kassaei** initiated a collaboration between those with expertise in arithmetic geometry and p-adic dynamical systems, securing a grant for an international team (from UK, Chile, USA and Canada) to work together at the Banff International Research Station in 2019.



Smaller collaborations are promoted by generous support for national and international travel, keeping desks or office space available for visitors and encouraging sabbatical applications to initiate or deepen collaborations. In total over the REF period we had over 150 visitors. Researchers whose work with departmentally supported visitors resulted in multiple papers include **Kuehn** (7 papers), **Newton** (4) and **Pushnitski** (4).

Notable international collaborations resulting in high-profile publications include **Newton's** work with Scholze (Bonn), Taylor (Stanford) and 7 other authors, resulting in their landmark paper on potential automorphy, and **Murthy**'s work with Vafa (Harvard) and others on F-theory, spinning black holes and multi-string branches.

#### Interdisciplinary research and collaborations

The Department's promotion of interdisciplinary research (see Section 1) has fostered wideranging collaboration with academics in other fields, including:

- **Murthy**'s international collaborations with physicists on black holes and modular forms, establishing new links between string theory and number theory;
- **Neri**'s collaboration with an experimental group in electronics, testing predictions for the thermodynamics of systems at small scales;
- **Pigoli**'s work with quantitative geneticists at Washington State on covariance estimation (with travel support from King's), and with geographers at King's on spatial statistics (through CNES).

#### Engagement with users and beneficiaries

The Department's approach to enabling impact greatly broadened its engagement with users during the assessment period (as described in Section 1). Specific initiatives include:

- The Department collaborates with GCHQ in the interest of national priorities of security through its involvement with HIMR-London. During the assessment period, two staff members regularly acted as consultants at HIMR-London, one of them also on secondment for one year (2015-16) and subsequently on an advisory group for GCHQ. The Department also hosts a Visiting Senior Research Fellow and a cycle of early career Heilbronn Fellows (3 during the period) who devote half their time to research at HIMR-London.
- **Annibale** has engaged with a clinician in a collaborative project moving towards the release of a diagnostic software for triage in GP practices. This has attracted private funding from the health information technology company ClickSymptoms Ltd.
- **Di Matteo** supervises an ongoing PhD project in collaboration with Amazon on a confidential programme.
- **Vivo** pursues unique research in the Complexity in Legal Provision a collaboration with legal experts with the promise of impact on simplifying aspects of the legal system.

#### Wider contributions to the economy and society

Examples of the Department's wider activities and impact not covered in case studies include:

- **Forde**'s asymptotic results have been used by option trading desks at investment banks including NatWest, RBS and BAML.
- **Gilmour**'s work on multi-objective optimal design of experiments is being implemented in the Genstat and Design-Expert software packages.
- **Mylona**'s work on displaying the results from the analysis of data from factorial experiments is being implemented by multiple teams on at least 5 different products at Janssen Pharmaceutical Companies of Johnson & Johnson and further collaborations in the multi-objective optimal design of experiments are ongoing.
- **Armstrong** has presented his work on the ineffectiveness of expected shortfall, the industry standard tool for risk measurement, at industry conferences QuantSummit and Risk Minds. He is also a member of the Pensions Policy Institute modelling advisory group.



- **Pennanen** and **Pitt** have collaborated with Breast Cancer UK to develop improved forecasts of the charitable donations they have received. These are being used by Breast Cancer UK and are now being taken up by other UK charities.
- **Pigoli** closely collaborated with a forensic entomologist from the Natural History Museum, London, who acts as a consultant for criminal investigations in the UK. They work together to improve the tools available to forensic entomologists for estimating the post-mortem intervals based on evidence at a potential crime scene.

### Public engagement

Members of the Department have engaged with the wider public in various ways, including:

- **Drukker** creates ceramic sculptures inspired by his current research (see picture). He exhibited this work in several shows, including the Royal Academy Summer Exhibition and on Instagram, where he has over 50,000 followers. This and public talks on creativity in science led to media appearances including London Live television, Jewish Chronicle and Londonist.
- Several public lectures were given by staff members, including Salamon, whose 2017 Gresham College lecture on `The Mathematical Skyline' has attracted 1400 YouTube views.
- Staff members frequently give lectures at secondary schools, including the King's Mathematics School (Newton, Rietsch), and Vivo led his PhD students on a visit to the Harris Academy, to discuss 'disordered systems' and 'collective behaviour' in high



'disordered systems' and 'collective behaviour' in biology, finance and materials science.

• The Department runs an annual Teachers' Conference, at which researchers explain their work to inspire and inform secondary school teachers of mathematics. Recent speakers included **Doyon** and **Mylona** in 2019, and Alice Rogers (emeritus) and Simon Singh in 2018.

#### Wider influence and contributions

Indicators of wider influence, contributions to and recognition by the research base include:

- Editorships of journals, including:
  - **Di Matteo** was Editor-in-Chief of the Journal of Network Theory in Finance from 2017-20.
  - **Salamon** was co-editor-in-chief of the EMS Surveys in Mathematical Sciences from 2014-2018.
  - Lambert has been Editor of Physics Letters B since 2015.
- Service on editorial boards for at least 33 journals, including:
  - **Di Matteo**: European Physical Journal B, Journal Advances in Mathematical Physics, Physica A: Statistical Mechanics and its Applications
  - **Diamond**, **Rietsch**: LMS editorial board
  - o **Doyon**: Journal of Statistical Mechanics: Theory and Experiment
  - Drukker: Journal of Physics A
  - **Gilmour**: Statistics & Computing
  - Herzog: Journal of High Energy Physics
  - **Pennanen**: Set-valued and Variational Analysis
  - Pushnitski: Journal of Spectral Theory
  - Salamon: Annali Matematica Pura Applicata



- Our academics regularly receive personal fellowships and personal grants, for example:
  - *Royal Society*: Herzog (Wolfson fellowship £150k), Anninos (URF £466k), Lekili (£302k), Dokchitser (£450k), Doyon (£54k).
  - ERC: Gromov (Consolidator £1,615k), Murthy (Consolidator £1,337k), Wigman (Starting £792k).
  - *UKRI*: **Vivo** (Future Leaders Fellowship £884k).
- Prizes
  - **Gilmour** won the 2017 Lloyd S. Nelson award of the American Society for Quality for the paper in Journal of Quality Technology having the greatest immediate impact to practitioners.
  - **Horvath** won the risk.net rising star award in 2019.
  - Neri was recognised as an outstanding APS Referee.
  - RA **Galante**, was awarded a Bronze medal in the Mathematics section at the 2020 STEM for Britain poster competition in Parliament.
- Membership of national and international committees, including:
  - **Di Matteo** serves (since 2019) as one of the three members of the Board of Directors of Centro Fermi, the national research centre for physics in Italy.
  - **Doyon** was a member of the Theoretical and Mathematical Physics Group Committee of the Institute of Physics (2013-2017).
  - **Gromov** is a member of the Pomeranchuk Prize Committee (from January 2020).
  - Lambert and Shargorodsky are members of sub-panel 10, Mathematical Sciences in Research Excellence Framework 2021 (REF2021); Diamond was a member in REF2014.
  - **Lambert** was a member of the 2018 STFC review panel to report on the status of the UK Theoretical Particle Physics programme.
  - **Pushnitski** serves on the LMS Programme Committee, and **Shargorodsky** served on the LMS Prizes Committee (2018-2020).
- Refereeing publications and proposals; serving on grants committees:
  - In addition to regularly reviewing proposals for EPSRC and ERC, staff members assessed proposals for other UK research councils, such as MRC, NERC and STFC, foundations including the Royal Society and Leverhulme Trust, and funding agencies in at least 11 other countries.
  - Members of staff served on at least 6 EPSRC Prioritisation Panels and 2 Fellowship Panels during the assessment period; 6 are full members of the EPSRC Peer Review College and 3 are associate members.
  - Salamon served on the panel for the award of Marie Curie Fellowships.
  - Members of the Department regularly reviewed for many journals in the mathematical sciences, including Acta Mathematica, Annals of Mathematics, Annals of Statistics, Biometrika, Communications in Pure and Applied Mathematics, Duke Mathematical Journal, Inventiones Mathematicae, Journal of the American Mathematical Society, Journal of the American Statistical Association, Journal of the Royal Statistical Society Series B, Mathematical Finance and Physical Review Letters.
- Cooperation and collaborative arrangements for PGR training:
  - The LSGNT and CANES CDTs and the LTCC have been described in earlier sections.
  - The Transcampus programme with TU-Dresden and the London Mathematical Finance Group include PGR training components described above under Academic Collaborations.
  - The Department was part of the International Training Network (GATIS), which involved 11 academic institutions and 5 private sector partners and NETADIS with 9 academic and 4 private sector partners.



- Invited keynotes and lectures, including:
  - Anninos was a CERN Winter School Lecturer (2018, over 2000 YouTube views).
  - Buckley was invited speaker at "Stochastic Processes and their Applications", July 2017, Moscow, Russia.
  - **Gromov** was one of 18 invited speakers at a conference in LPT ENS, Paris, 2015, attended by 4 physics Nobel Prize winners and 2 recipients of the Fields Medal.
  - **Pigoli** gave a discussion paper to the Royal Statistical Society.
  - **Pitt** was keynote speaker at the 1<sup>st</sup> International Conference on Econometrics and Statistics 2017 in Hong Kong.
  - **Rietsch** gave the plenary lecture at the LMS general meeting (June 2018).
  - Rietsch was an invited speaker at the Annual Meeting of the Simons Collaboration on Homological Mirror Symmetry in NYC (8 speakers preceded by public lecture of Kontsevich).
- Organisation of conferences and workshops, including:
  - **Lambert** won the UK wide bid to start the STFC Virtual Theory Centre.
  - Major conferences at King's, such as Integrability in Gauge and String Theory (IGST) 2015 – Gromov and Drukker in collaboration with Imperial College (180 participants).
  - More focused workshops at King's, including Random Waves in London organised by Wigman in 2016 (40 participants).
  - Major events elsewhere, such as an ICM satellite conference organised by Diamond in Rio de Janeiro, 2018 (over 60 participants).

## **Covid statement**

One researcher was put on furlough for 4 months in 2020 at full salary, due to the impact of the Covid pandemic on his ability to work. The Department provided 10 new laptops and 40 iPads to members of staff and PGR students to enable them to continue working and collaborating remotely. Additional cloud-hosted Windows and Linux personal virtual machines were made available.