Institution: King's College London

Unit of Assessment: Mathematics

a. Overview

King's College London (KCL) incorporates 9 academic schools, 4 in Arts and Sciences based mainly around the Strand, and 5 in Health on campuses south of the Thames. The Department of Mathematics forms part of the School of Natural and Mathematical Sciences, and is organized into 6 research groups, 3 broadly speaking in applied mathematics and 3 in pure mathematics.

Each group conducts research that leads the way internationally, and has active links with leading institutions worldwide. Our members of staff have the benefit of being at the heart of the London mathematical community, as well as close to centres of excellence in both the UK and Europe, an advantage that is being exploited to the full.

The **Analysis Group** focuses on partial differential equations, operator theory and spectral theory, though recent emphasis on non-linear aspects of analysis has brought with it applications in areas such as hydrodynamics.

The **Disordered Systems Group** works on new methods from statistical mechanics. It tackles fundamental issues, for example in non-equilibrium systems, and a broad range of applications to complex systems of many interacting units including protein networks and condensed matter.

The **Financial Mathematics Group** studies mathematical risk management and its fundamentals including probability, statistics and optimization. These techniques are applied to fast-moving areas in the financial industry and in financial institutions to improve their risk management practices.

The **Geometry Group** is a newly-formed group with a repertoire of algebraic, differential and symplectic geometry. It includes geometric analysis, though much of its work falls under the heading of correspondences between manifolds and structures that can be defined on them.

The **Number Theory Group** carries out research in algebraic number theory, automorphic forms and (more recently) analytic number theory. Principal interests include Galois representations, the Langlands Programme, p-adic modular forms, Iwasawa theory, and arithmetic random waves.

The **Theoretical Physics Group** is the largest group in the Department. Its goal is to understand nature at its deepest level. In particular, it works on supersymmetry, gauge theories, strings and branes, and conformal field theory.

The balance of clearly-defined groups has proved successful in showcasing research within the Department of Mathematics, and in the hiring of academic staff. Many questions related to funding, teaching and the intake of PhD students are administered by the individual groups, and there is an effective process for integrating their proposals and making decisions within the Department.

b. Research strategy

The Department's driving force is academic excellence in carefully chosen areas of research. Its overall strategy since RAE 2008 has been that of hiring outstanding individuals to promote original thinking, and to both broaden and deepen the scope of individual research groups.

We have continued to reinforce disciplines that were well rooted in 2007, and 5 groups have built on past achievements that had already defined their international profile. Aggressive hiring policy has introduced newer topics that, taken in combination with the traditional work, will ensure that the Department enjoys a dynamic role at the forefront of future research. In particular, it has built up a 6th group, Geometry, a stated aim of the 2008 submission. This has been achieved with the hiring of 3 professors (including one FRS), 1 lecturer and 2 Royal Society URF's, and has enabled KCL to play a crucial role in London-wide expansion of the subject.

Our vision is for a department large enough to fully exploit the research strengths of its members. We will continue the dual process of consolidation and branching out into new areas. In particular, we want to equip each group with sufficient staff, research assistants and PhD students so as to amplify individual contributions. Theoretical Physics is a successful model in this regard, and has 11 permanent staff, including 2 whose salaries are ERC and STFC funded. Analysis, Disordered Systems and Number Theory have established a steady PhD intake, whilst Financial Mathematics and Geometry are building their PhD numbers with new appointees keen to act as supervisors.

Characteristics of the separate groups provide striking opportunities for interaction between their strands of research. Looking to the future, we plan to develop the links that exist between groups. On the forefront of this strategy within pure mathematics, the Department is already strengthening the interface between Geometry and Number Theory, with the hiring of Nick Shepherd-Barron FRS and collaboration on a successful proposal for a London-wide CDT (see section d). Quite apart from this, the research of new members of staff is beginning to relate specific topics in Geometry and Number Theory on the one hand with work in Analysis and Theoretical Physics on the other.

Disordered Systems and Financial Mathematics are groups with a common approach to research and impact; they both have strong interdisciplinary areas of research that generate unpredictable and innovative applications that the Department is keen to develop. There are staff working on the interface of the two groups (on the analysis of systemic risk, and in econophysics), and we are investigating the possibility of hiring in the area of statistical inference or computational statistics. This would provide an extra dimension to the work of both Disordered Systems and Financial Mathematics, which relies increasingly on network and data analysis. It could also provide a focal point for a number of applied statisticians that work in separate departments in KCL.

The Department is also supporting pioneering cross-disciplinary work of the Disordered Systems Group on non-equilibrium systems, which involves members in the Department of Informatics, and in the Schools of Biomedical Sciences and Social Science and Public Policy. Wider KCL strategy is concerned with extending scientific links across its campuses, and the Mathematics Department is keen to a play a future role in this.

The remainder of this section lists research achievements and more specific aspirations by group.

Analysis draws its strength from a well-established reputation as a leading centre for linear analysis. Highlights during the assessment period include:

- Seminal contributions to the theory of non-self-adjoint operators, major work on the asymptotics of eigenvalues and on resonances of quantum graphs.
- Resolution of long-standing problems in the theory of Toeplitz and Schroedinger operators.
- Remarkable results on scattering theory for self-adjoint operators, and the study of isospectral problems in relation to integrable systems.
- Work on spectral generating functions, leading to a study of logarithmic structures in quantum field theory.

Most of the work of the Group remains theoretical in nature, but it is branching out into non-linear theory, an area that is under developed in London overall. There are fewer general techniques available and yet an increasing number of applications relevant to the real world. A rigorous study of water waves has been applied to the modelling of tsunamis, and the Group intends to develop more applications of this type.

Disordered Systems has pursued the areas of mathematical systems biology and quantitative medicine and links with statistics and informatics. The Group has also consolidated its strong profile in condensed matter physics and glasses, and is considering a strategic move towards quantum materials. A characteristic of its research has been the development of methods in statistical mechanics that lead to innovative connections, for example:

- Bayesian inference approaches to the analysis of medical imaging data and protein interaction, and the analysis of general non-parametric inference methods.
- Innovative methods for capturing variability in metabolic networks, and for sampling from graph ensembles.

- Theoretical analysis and new simulation methods for polydisperse soft solids that have together solved a long-standing problem in packing mixtures of spheres.
- Related progress on crumpling of thin sheets and extended objects such as DNA.

Initiatives have led to the development of new models to describe natural and social phenomena, such as systemic risk and catastrophic breakdown in complex systems, with applications to finance and the prediction of power outages. Random matrix theory has become an increasingly important area, studied using extensions of methods for sparse networks. In addition, the Group expects to further strengthen research related to biomedicine.

Financial Mathematics conducts research in all the main sub-disciplines of the subject such as probability, statistics and optimization. This fundamental work is especially important in the financial setting for which evolving models constantly provide new challenges. It has focussed on:

- Convex optimization and financial risk management, and stochastic processes and differential equations with applications to economics and biology.
- Econophysics, complex systems and the science of networks, with links to Disordered Systems.
- The Basel III rules on pricing counterparty credit risk, option pricing and asymptotics for stochastic volatility models.

The Group will maintain close contact with the financial industry in order to keep abreast of latest opportunities. For example, it is carrying out work for the pensions industry in the UK and Finland. Such first-hand knowledge of current trends provides the Group with an edge in selecting the directions of its academic research, such as recent use of techniques from information geometry.

Geometry has taken shape since 2007. Latest appointments are enabling it to carry out research in the parallel fields of algebraic and symplectic geometry, which are linked via Kaehler manifolds and mirror symmetry. This topic fits in well with existing expertise in representation theory, and the study of 3-folds (symplectic, complex and number-theoretic) is a unifying topic for the Group. It has also made original advances in:

- Hyperbolic geometry and pioneering the study of polyhedral Kaehler manifolds.
- The use of twistor techniques to classify complex structures and symplectic manifolds.
- Riemannian transformation groups and special low-dimensional geometry.
- Surfaces with constant mean curvature, and related questions in geometric analysis.

One aim is to channel expertise in both algebraic and differential geometry to develop the links with Number Theory and Theoretical Physics, based on common topics such as arithmetic varieties, theta functions, spectral curves, Sasakian manifolds, and exceptional Lie groups (especially G_2).

Number Theory is making inroads on fundamental questions at the forefront of the subject. While the emphasis is on algebraic number theory, the work is largely motivated by connections between number theoretic objects and analytic ones like automorphic forms, L-functions and nodal lines. To that end, key work during the assessment period has been carried out on:

- The Langlands Programme, developing local correspondences and global reciprocity laws including Artin's Conjecture and Serre's Conjecture.
- The deep arithmetic content of special values of L-functions, including equivariant Tamagawa Number Conjectures and Iwasawa-theoretic Main Conjectures.
- Nodal structures for random models including arithmetic random waves, which appear in diverse physical phenomena including vibrating (Chladni) plates and cosmology.

The Group will continue these fruitful investigations, focussing on emerging topics such as the p-adic Langlands Programme and non-abelian Iwasawa theory, while broadening its scope with the new research directions in analytic number theory.

Theoretical Physics is a group whose goal remains understanding physics at its deepest level. It particularly values originality and the discovery of new directions to provide the building blocks for future research. Over many years, the Group has been responsible for a number of the key discoveries in the subject. Work during the assessment period includes:

- Using the integrability structure present in N=4 Yang-Mills theory to compute some of the first highly non-trivial exact results in any quantum field theory.

- Further understanding of the symmetries of the theory underlying strings and branes.
- Formulating the effective theory of multiple M2-branes, Bagger-Lambert-Gustavson theory.
- The systematic exploration of models of particle physics that can arise within string theory with impact in both LHC particle phenomenology and geometry.
- The discovery of new solutions to supergravity theories that provided new directions of research on the AdS/CFT correspondence.

Six new appointments have brought new expertise in gauge theories, the AdS/CFT conjecture and black holes, and make the Group one of the largest in the UK working on fundamental physics beyond the Standard Model. It intends to continue these investigations, laying cornerstones for research in the long term.

c. People, including:

i. Staffing strategy and staff development

Since 2007, the Department has appointed two thirds as many new staff as it submitted to RAE. Our submission to the REF incorporates 20 of the 31 academics submitted to RAE 2008, along with 22 new permanent staff members (see *Recruitment* below). Of the remaining 11 submitted to RAE 2008, 5 accepted more senior positions at other institutions (4 from Financial Mathematics at UK universities, and 1 from Theoretical Physics in Germany), 3 left academia and 3 retired.

Our current staff list includes 2 Royal Society University Research Fellows, 1 STFC Advanced Fellow and 2 ERC Starting Grantees (one was previously an EPSRC Advanced Fellow, and the other will start in 2014, details in sections d and e).

The Department has acted to enhance or replenish 5 research groups, and has built up a group in Geometry. During the assessment period, the hiring of new members of staff has therefore been carried out group by group, with the goal of appointing in specific fields. This policy will continue, although we also expect to target areas at the interfaces of our existing research bases.

In **Analysis**, Adrian Constantin was appointed in 2011 as Head of Group from the University of Vienna, and Mahir Hadzic arrived in 2013 after completing an instructorship at MIT.

They joined existing members Brian Davies FRS (0.2 FTE), Alexander Pushnitski, Yuri Safarov, Simon Scott, and Eugene Shargorodsky.

The exceptional quality of the Group has been signalled by two recent LMS prizes (see section e), and 5 of its members are professors. Hadzic will support the new non-linear aspects of research introduced by Constantin. The Group expects to expand further in this direction, and is looking to develop more expertise in applied analysis.

In **Disordered Systems**, Eytan Katzav was appointed in 2008 having held a postdoctoral position at the ENS in Paris. Alessia Annibale's position was made permanent after RAE 2008.

Other permanent staff members are Ton Coolen**,** Reimer Kuehn, Isaac Perez Castillo and Peter Sollich (now Head of Group). The Group has hosted two 1-year visiting research fellows, has a BBSRC-funded postdoctoral researcher, and an early career researcher (Matthew Urry).

Coolen directs the College's new Institute for Mathematical and Molecular Biomedicine (IMMB), and this takes up an equal share of his time with the Department. The IMMB is implementing the Group's expansion towards mathematical biology and biomedicine, and its successful development is regarded as a top priority by the Department. The Group expects to hire at least two new academic members in order to free up more resources for biomedicine.

Financial Mathematics has a new set of staff relative to the RAE, reflecting the competitive nature of recruitment in finance, as well as the Department's commitment to this Group, which it had established when the subject was at an early stage academically. Cristin Buescu was appointed in 2008 from Imperial College, and Tiziana Di Matteo in 2009 from the University of Canberra. There were 3 appointments in 2011: Martin Forde from a research fellowship in Dublin City University,

Teemu Pennanen from the University of Jyvaskyla in Finland (he is now Head of Group), and Markus Riedle from Manchester University. Gechun Liang arrived in 2013 from Oxford where he was a postdoctoral fellow, and is an early career researcher.

The Group hosted a 1-year research associate and a 3-year visiting professor during 2008-12. Five fixed-term lecturers contributed to its research from 2007 onwards, one of whom (John Armstrong) joined the Group in 2012 after a successful career in software development and banking.

The Head of Group is its only chair. It plans to appoint another chair to strengthen the leadership team and broaden its subject coverage. It will maintain its broad interdisciplinary expertise but wishes to expand its theoretical expertise, currently concentrated on stochastic analysis.

The establishment of a new **Geometry** group began with the appointment of Jurgen Berndt as Head of Department in 2008, a role that he had previously undertaken at University College Cork. Giuseppe Tinaglia was appointed in 2010 from the University of Warwick, and Simon Salamon in 2011 from the Politecnico di Torino. The Group has 2 Royal Society URF's, namely Dmitri Panov (who arrived in 2010 and previously had an EPSRC fellowship at Imperial College) and YankI Lekili (arriving in 2013 from a JRF in Cambridge). Nick Shepherd-Barron FRS joined the Department in 2013 (also from Cambridge); currently he is Head of Group, and Salamon is Head of Department.

Konstanze Rietsch is the only member who was submitted to RAE, and her expertise in quantum cohomology places her centrally within the new Group. It hosted 3 postdoctoral fellows in 2011-13 from abroad, including Clelia Pech, an early career researcher.

Number Theory has been strengthened by means of the appointment of Mahesh Kakde in 2011 from University College London, and he is an early career researcher. Igor Wigman arrived in 2012 from the University of Cardiff, and was awarded an ERC Starting Grant in 2013.

They joined David Burns, Colin Bushnell, Fred Diamond, all professors, and Payman Kassaei, promoted to reader in 2012. The Group also hosted an EPSRC Postdoctoral Fellow (Shu Sasaki) in 2009-12, and two fixed-term lecturers for periods of at least 1 year.

Kakde's appointment builds on the established expertise of the Group, while Wigman's enables it to develop new directions in analytic number theory. It is looking to further expand in areas such as arithmetic geometry and ergodic number theory that strengthen its links with other groups.

Theoretical Physics has hired 6 new permanent members of staff. Two members retired since 2007, and one person took a chair in Hamburg. Four appointments were made in 2010: Benjamin Doyon (from Durham University), Dario Martelli (as an EPSRC Advanced Fellow from the University of Swansea), Nikolay Gromov (from Hamburg), and Sakura Schafer-Nameki (who had a 5-year position at the University of California at Santa Barbara). Nadav Drukker was appointed in 2011 as STFC Advanced Fellow (from Berlin via Imperial College), and Sameer Murthy arrived in 2013 (from a research position at Nikhef Amsterdam).

The Head of Group is Peter West FRS, and other permanent academics are Neil Lambert, George Papadopoulos, Andreas Recknagel and Gerard Watts. Following 2 promotions, the Group has a total of 4 professors. Lambert returned in 2013 after a 3-year period as staff physicist at CERN.

The appointments since 2008 represent one of the most substantial investments in theoretical physics by any UK university in recent years. In the 2013 STFC consolidated grant round, the Group was awarded two 3-year postdocs and 20% salary for those working in STFC subject areas. The Group's previous STFC grants have allowed 7 additional researchers to work for between 1 and 3 years in the Department during the assessment period.

A major **Planning Round** covering 2014-17 is currently underway in King's College London, and the Mathematics Department's research strategy will be a key factor in dictating its overall policy with regard to student numbers and degree courses, both at undergraduate and postgraduate level. Our first priority will be to strengthen work in the areas of Disordered Systems and Financial Mathematics. In particular, we want the Disordered Systems Group to develop its initiatives in both non-equilibrium systems and mathematical biology, and the Financial Mathematics Group to broaden its research base. We expect to make new appointments to achieve these priorities.

The Department profits from the **Researcher Development Unit** (run by KCL's Graduate School), which hosts the London hub of *Vitae*. It organizes staff and PhD training (see section c ii) and, together with Human Resources, provides guidance to implement the Concordat's principles to support the career development of researchers, and to continually improve the following aspects.

Recruitment. Searches for the new posts extended worldwide to find the best-qualified candidates with those short-listed arriving from Europe, the US and China. Of the 22 new permanent members of staff, 12 were hired directly from foreign institutions, whilst 17 were trained abroad. Overall, our staff body includes 18 different nationalities. New staff have the benefit of induction sessions, and are assigned a mentor (usually head of group) to guide their achievement during a probationary period (between 1 and 3 years). Our submission to REF 2014 includes 4 early career researchers.

Support and training. The Department places great value on independence and innovation in research and on enabling staff, especially those in critical early career stages, to develop research opportunities. Members take advantage of mechanisms that assist them in various ways to apply for external funding, such as budgeting advice and internal review of proposals. The grant portfolio has included 4 EPSRC First Grants during 2010-14, and was recently enhanced by 2 ERC Starting Grants. Major grant holders benefit from significantly reduced teaching and administrative loads, as do newly-appointed lecturers in their first year. Comprehensive training is available from KCL to support staff in all aspects of their academic jobs and to help them combine research capabilities with wider skills. Current members have enrolled on programmes to develop personal organization, leadership and management skills.

Promotion and recognition. Clear advancement procedures and an effective management structure help us to retain staff. The profile and functioning of all 6 research groups has been improved by promotions achieved by their individual members. During the assessment period, 5 staff members were promoted to reader, and another 4 to professor. KCL applies a Performance Development Review process to help staff concentrate on their research strengths, identify career needs and highlight areas where support would be helpful. This also leads on to a process of pay recognition.

Equality and diversity. Since the RAE, 3 permanent appointees (and 2 out of 4 fixed-term lecturers appointed in 2013) have been female; one joins the small group of female theoretical physicists in the UK. Representatives from the Department serve on a committee with contact to KCL's Equalities Unit and a number of staff networks, to maintain awareness of minority issues. We also liaise with various outside organizations to ensure that we follow best practice. For example, the Department belongs to the LMS Good Practice Scheme to support the advancement of women in university mathematics departments, and has received support from a recent LMS workshop to start planning its application for silver Athena SWAN status.

ii. Research students

There are currently 60 PhD students in the Department (of which 7 part-time), and these students are first-supervised by a total of 27 members of staff. The intake of PhD students has risen steadily in recent years from 8 starters in 2008/09 to a total of 21 starting in 2012/13. In the past 5 years, 85% of students successfully submitted their PhD thesis within 4 years.

The balance of pure and applied mathematics guides the selection of PhD students, though a majority has in fact been selected on the applied side. Theoretical Physics has trained 25 PhD students during 2008-13, many funded by an STFC Doctoral Training Grant. Potential supervisors select and interview their applicants and groups have relative autonomy over admissions. Top applicants compete for various types of funded awards within both the Department and KCL.

Current PhD students are funded by EPSRC Doctoral Training Grants, the EU network NETADIS and a BBSRC DTG (for Disordered Systems), the Leverhulme Trust (for Number Theory), STFC studentships and the EU network GATIS (for Theoretical Physics), awards for new and continuing students from KCL, as well as Graduate Teaching Assistantships (GTA's). The latter are awards pioneered by the Department for up to 4 years' study balanced with tutorial responsibilities, and structured GTA training is delivered by the King's Learning Institute. Since 2012, when the GTA scheme took off, 16 PhD places have been funded by GTA's and all groups have profited from the

scheme. In the same period, 5 PhD students have obtained substantial awards (3 of them paying international fees) from KCL's Graduate School.

Various MSc courses run by the Department help to provide effective pre-PhD training. In addition to the MSc in Mathematics and one in Theoretical Physics, there is a large programme in Financial Mathematics and a newer one in Complex Systems Modelling. The latter equips potential research students with the necessary background in statistical mechanics and applications, and a feature of the course is that high-profile visiting lecturers are attracted to teach advanced modules (these have included Leticia Cugliando, director of the Les Houches School, and Matteo Marsili, ICTP).

The Department has a significant investment in the London Taught Course Centre (LTCC). This provides courses designed to broaden PhD students' knowledge, and 5 staff lectured at LTCC in 2012/13. Two will give similar courses at the London Graduate School in Mathematical Finance in 2013/14. Our wide selection of taught MSc courses is also available to PhD students irrespective of thesis topic. KCL's Researcher Development Unit offers considerable training in transferable skills (with over 300 courses), and personal, professional and career development opportunities, as it does for academic staff (see section c i). It employs the Vitae Researcher Development Framework to help identify the needs of PhD students, and to set up tailored training programmes.

The progress of research students is monitored at 3 months after registration and then every 6 months. Student and supervisor fill out respective parts of a form on-line, which is signed off by the Department's director of PhD studies ("PGR Tutor"). This system also enables staff to keep track of student preprints and publications, the production of which is both encouraged and commonplace prior to writing up the thesis. KCL is in the process of gathering such student output in its research information system *Pure*, so that the research can be publicly showcased.

A DLHE survey of 24 recent PhD's to graduate from the Department listed 12 in the university sector, 5 in consultancy and/or finance, and most of the remainder in other teaching or research posts. Informal surveys of PhD students in the writing-up phase revealed that virtually all publish at least one journal paper (more in applied mathematics) as a result of their thesis.

d. Income, infrastructure and facilities

The Department's **Grant Portfolio** increased by roughly 50% from 2007 to 2013. In the academic year 2013/14, external funding will pay 80% of the salaries of 5 members of staff.

Research awards from 1 September 2008 topped £10M (counting payments stretching to 2018). They have included the following Research Council UK funding:

- Engineering and Physical Sciences Research Council: over £1.8M, including
  - Doctoral Training Grants totalling £750K,
  - an Advanced Fellowship (Martelli 2010-13),
  - a Postdoctoral Fellowship (Sasaki 2009-12),
  - First Grants (Doyon 2010-12, Kassaei 2010-12, Riedle 2012-14, Tinaglia 2011-13, and Wigman 2012-14),
  - a Springboard Fellowship (Coolen 2008-10).
- Science and Technology Funding Council: over £3.4M, consisting of
  - two Advanced Fellowships (Drukker 2011-15 and Jan Gutowski 2011-12),
  - Doctoral Training Grants totalling £560K,
  - Rolling Grants (2008-11 and 2011-14) totalling over £2M.

Other sources of major funding were:

- European Commission: over £3.2M, including
  - Marie Curie ITN grants (NETADIS, Sollich 2012-16; GATIS, Gromov 2013-16),
  - an FP7 grant (IMAGINT, Coolen 2010-14),
  - ERC Starting Grants of roughly £1M each (Martelli 2013-17 and Wigman 2014-18).
- Royal Society: approximately £1M, for
  - University Research Fellowships (Lekili and Panov).

- Biotechnology and Biological Sciences Research Council: £446K, including
  - a strategic longer and larger grant (Coolen 2009-13).
- Leverhulme Trust: £217K for
  - Research Project Grants (Diamond and Rietsch).

Smaller grants of note include:

- Prostrate UK: £50K, for the improvement of statistical tools in cancer management.
- ID Business Solutions Ltd and KCL: £60K, for an Industrial CASE studentship (2011-14).

Substantial grants have enabled the Department to hire (both fixed-term and permanent) staff to cover those duties released by recipients. Current grants are also paying for PhD students and/or postdoctoral researchers in Disordered Systems, Number Theory and Theoretical Physics. Since 2011, the Department's budget from KCL has included a figure of approximately £1000 per head to cover seminars, local conferences and visitors. Every new appointee receives a start-up grant of at least £5K. Individual members have also been successful in obtaining separate funds for travel (the most recent one in 2013 being £13K from EPSRC for Tinaglia), and for workshops.

The Department was informed in October and November 2013 that the following were successful:

- Ton Coolen's £1.73M joint application for a Systems Immunology of the Human Life Course MRC/BBSRC flagship consortium grant (MABRA).
- The application to EPSRC for a CDT in Geometry and Number Theory at the Interface, in the area of Core Mathematics. This is led by UCL, with KCL and ICL as partners.

Applications pending in November include an EPSRC First Grant, further EPSRC proposals, and top-up funding from the Royal Society. The Department has also supported 5 Royal Society URF applicants in 2013 to join its research teams.

As regards **Infrastructure and Facilities**, the Department is housed on two floors of the Strand building adjacent to Somerset House, one wing of which is now owned by KCL. A redevelopment of the quad adjacent to the Mathematics Department is in the process of being submitted for planning approval, and will improve the immediate working environment for staff and visitors.

The Department itself provides individual offices for permanent staff, shared offices for postdocs and visitors, and a number of large rooms for PhD students. Its two floors contain seminar rooms, and computing laboratories administered by the School of Natural and Mathematical Sciences (NMS). It also houses an open-plan general office, new in 2010. KCL's Maughan Library is a short walk from the Department and houses mathematics and physics collections of books and journals for both teaching and research, and its staff administer substantial electronic resources.

IT infrastructure and software provision is the responsibility of NMS, and Mathematics has 2 dedicated computational servers with a total of 16 cores and 256GB RAM, in addition to a grid of desktop workstations, and is assisted by an IT team of 3. The Financial Mathematics Group set up a Bloomberg room in 2012 with 12 terminals giving access to live and archival financial data that are bringing significant benefit for research and MSc teaching. In addition, King's plans to invest £350K imminently in a new HPC centre for NMS.

e. Collaboration or contribution to the discipline or research base

The Department takes full advantage of its location in the organization of both seminars and research collaborations. Many staff members have active collaborations with institutions in Paris (ENS, Orsay, Ecole Polytechnique, IHES) and Brussels (ULB), all easily accessible by train. KCL plays key roles in organizing the London-Paris Number Theory Seminar (twice a year), and the Paris-London Analysis Seminar (4 times a year). The first meeting of a London-Brussels Geometry Seminar will take place at ULB on 25 November 2013. The Department also hosts several series of international workshops, which have generated new research collaborations.

Regular home gatherings include the London Analysis Seminar, a joint Geometry Seminar with UCL, the London Geometry and Topology Seminar (based at ICL), the London Mathematical

Finance Seminar, the London Number Theory Seminar and Study Group (the biggest weekly Number Theory gathering in the UK), and the London Triangle (string theory and mathematical physics, also incorporating City University). This activity provides evidence of London's very special status as a centre for mathematical research, and KCL's within it.

Frequent colloquia held at KCL attract participants from around London. Outside speakers have promoted the unity of mathematics and common research grounds. For example, talks by Michael Atiyah and Philip Candelas directly related geometry, number theory and physics, and have helped motivate the strategy to promote interactions between groups (see section b).

Members of the Department of Mathematics are engaged in a number of prestigious international collaborations. For example,

- Neil Lambert works with Jonathan Bagger (Johns Hopkins) on M-theory.
- Dario Martelli works with Juan Maldacena (IAS Princeton) on geometry with torsion.
- Giuseppe Tinaglia has a long-term collaboration (and 3 publications) with William Meeks III (UMass at Amherst) on surfaces with constant mean curvature.
- Igor Wigman has collaborated with Andrew Granville (Montreal), and is currently working with Peter Sarnak (Princeton) on nodal sets of random band-limited functions.

Of 164 outputs submitted for REF 2014, 37 have sole authorship. Of the remaining ones, approximately 90 involve collaboration with one or more institutions outside the United Kingdom, and are co-authored by 110 different members of such institutions.

Examples of **Interdisciplinary Research** and extra-academic collaborations include:

- Reimer Kuehn's research on systemic risk, which was triggered by collaboration at Dresdner Bank. His work has since branched out into other areas, including power grids.
- Teemu Pennanen's consultancy with the State Pension Fund and the Ministry of Social Affairs and Health in Finland, and recent work on a report for the Pensions Policy Institute.
- Nick Shepherd-Barron's work at GCHQ and the Heilbronn Institute.
- Peter Sollich's work on the Cross-Disciplinary Approaches to Non-Equilibrium Systems (CANES) project, which involves departments including Informatics, Geography, Physics, and has recently been formalized with the establishment of a virtual centre in this area.

The Disordered Systems Group coordinates the NETADIS network (Statistical Physics Approaches to Networks Across Disciplines, with 9 EU institutions and 4 private-sector partners), and was part of the PASCAL2 (Pattern Analysis and Statistical Learning) European Network of Excellence (until this ended in 2013). It spearheaded several initiatives at the interface of the mathematical and biomedical sciences, especially the creation of the Institute for Mathematical and Molecular Biomedicine (jointly with KCL's Randall Division) which is devoted to the development of novel mathematical and computational tools for solving problems in biology and medicine.

- Ton Coolen, the IMMB director supported by the Department, works with various multi-disciplinary research consortia in the UK and the EU on advanced statistical and modelling projects in support of immunology and cancer research. He is also leading the establishment of a philanthropically-funded Institute for Quantitative Cancer Research.

The biomedical link will enable members of the Department to participate in future innovative research work at the Francis Crick Institute, of which KCL is a partner.

As evidence of wider commitment, the Department has been working within KCL to set up the King's College London Maths School, due to open in 2014 in Lambeth Walk as part of government plans to improve mathematics education in the state sector. Its head, Dan Abramson, is based at the Strand during 2013/14 to interact closely with us.

The submission concludes with a selection of items highlighting academic leadership.

Conference organization:

- Jurgen Berndt co-organizes the UK-Japan Winter School every year, and it was held at KCL in 2011 and 2013.

- Fred Diamond and Payman Kassaei co-organized an LMS-EPSRC Durham Symposium in 2011 on Galois Representations and Automorphic Forms.
- Nikolay Gromov founded and co-organizes an annual Mathematica summer school.
- Sakura Schafer-Nameki co-founded the String-Maths UK (SMUK) conferences, with an inaugural meeting in 2013 at the University of Surrey, to bring mathematicians and theoretical physicists together on the interface of string theory and mathematics.
- Peter Sollich organizes an annual UK conference on the Statistical Mechanics of Glassy and Disordered Systems.
- Igor Wigman was a co-organizer of the first Finnish-Swedish Number Theory Conference, held in Stockholm in 2010.

Grant holders:

- Adrian Constantin has an ERC Advanced Grant (2011-15) held at the University of Vienna.
- Nadav Drukker is an STFC Advanced Fellow (2011-15).
- Dario Martelli was an EPSRC Advanced Fellow and has an ERC Starting Grant (2013-17).
- Igor Wigman will receive an ERC Starting Grant (2014-18).

Highly cited researchers (Thomson Reuters)**:**

- Adrian Constantin
- Brian Davies

Invited lectures:

- Colin Bushnell gave a mini-course at the Academy of Sciences in Beijing in 2011.
- Adrian Constantin was a plenary speaker at the 6th European Congress of Mathematics.
- Ton Coolen was invited to tour Japan as a visiting speaker in 2012.
- Nadav Drukker (2010), Neil Lambert (2008), Dario Martelli (2010) and Sakura Schafer-Nameki (2009, 2010) have all given plenary talks at the annual Strings conferences.

Journal editorships:

- Adrian Constantin is managing editor of Monatshefte fuer Matematik.
- Brian Davies is the founding and managing editor of the European Mathematical Society's Journal of Spectral Theory.
- Simon Salamon is a founding editor-in-chief of the European Mathematical Society's new Surveys in Mathematical Sciences.
- Peter Sollich is on the editorial board of Journal of Physics A, and is a co-editor of EPL.

Learned societies:

- Brian Davies is a Fellow of the Royal Society, and he was President of the London Mathematical Society in 2007-09.
- Nicholas Shepherd-Barron is a Fellow of the Royal Society.
- Peter West is a Fellow of the Royal Society.

Panel membership:

- David Burns served on committees for the Newton Institute and the ICMS in Edinburgh.
- Colin Bushnell is a regular member of the Leverhulme Prize selection panel.
- Adrian Constantin is on the board of the Schroedinger Institute in Vienna.
- Ton Coolen is on the BBSRC Integrative and Systems Biology Panel to monitor research council investment strategy in this area.
- Fred Diamond is on the panel for REF 2014.
- Simon Salamon was on the panel for VQR 2004-10 (the Italian analogue of REF).
- Peter West was on the panel for RAE 2008, the Dorothy Hodgkin and SC1 Royal Society committees, and was a member of the EPSRC workshop to formulate the Deloitte Report.

Prizes:

- Brian Davies received the London Mathematical Society's Polya Prize in 2011.
- Dario Martelli received the 2010 SIGRAV Prize in Pisa, Italy.
- Alexander Pushnitski was awarded an LMS Whitehead prize in 2011.