Institution: Royal Holloway, University of London

Unit of Assessment: B10 Mathematical Sciences

a. Overview

The School of Mathematics and Information Security at Royal Holloway comprises two departments: the Department of Mathematics (DoM) and the Information Security Group (ISG). There are strong and flourishing links between the two sister departments within the School, and the line between the two is fluid. However, the majority of DoM staff are being submitted to UoA B10 and the majority of ISG submission falls under UoA B11. The submission to the Mathematics sub-panel is made up of activities from five research groups within the School: three in pure mathematics (Algebra, Combinatorics and Number Theory), a group in Quantum Dynamics, and a group in Statistics. Membership of these groups is as follows:

- Algebra: Barnea, Klopsch, Nucinkis, Wildon;
- Combinatorics: Blackburn, Gerke, Moffatt, Ng;
- Number Theory: Dietmann, Harman, McKee, Widmer;
- Quantum Dynamics: Audenaert, Bolte, Kay, Mota-Furtado, O'Mahony, Schack;
- Statistics: Koloydenko, Sharia, Shcherbakov.

Though each staff member is assigned to one group, many members of staff have interests that cross between groups. Kay, Mota-Furtado and O'Mahony have close research links with Physics (indeed, the quantum dynamics group was submitted under the Physics UoA in 2008; Kay is submitted under UoA B9 in this REF); Blackburn, McKee, Ng and Schack have research links with information security (especially cryptography). Koloydenko has close research links with CS and Biomedical Physics; his research has also involved computational algebraic geometry.

b. Research strategy

Our vision is to build upon the excellent mathematics research carried out at Royal Holloway, strengthening our existing areas of research in algebra, combinatorics, number theory, quantum dynamics and statistics**.** Our strategy is to hire staff of the highest quality, and to provide all staff with a supportive and stimulating environment, and the facilities and funding they need, to develop each group's research programme fully. Our workload model ensures a transparent and equitable distribution of research time. Staff define their individual research programmes; our staffing policies (see below) are designed to provide intellectual stimulation, exposure to new ideas and appropriate support to allow staff to produce research of the highest quality. Our Director of Research, Impact Officer, our Outreach Officer liaise with staff to develop funding opportunities and external links. Compared to RAE 2008, the pure mathematics groups and the statistics group have grown and become stronger; the quantum dynamics group has maintained its size and strength. The staffing aims formulated in RAE 2008 have been achieved and surpassed. All mathematics staff are now research active, with most contributing their outputs to the REF. As planned, the School has made a number of either new or replacement appointments to enhance expertise across all of its research groups, thus reaffirming our commitment to these areas of research.

The School has been very successful in carrying out all the New Research Initiatives proposed in our Maths UoA submission for RAE 2008. We have built on our world-leading reputation for cryptography: in 2012 Royal Holloway was accorded the status of a Centre of Excellence in Cyber Security Research by EPSRC and GCHQ; Royal Holloway's EPSRC-funded Centre for Doctoral Training in Cyber Security was established in 2013; Blackburn is currently Chair of the cryptography working group for EU COST action (IC1104) on Random Network Coding and Designs over GF(q); six members of the UoA B10 submission have published or undertaken consultancy in this area over the current REF period. There has been significant research relating to sensor networks; highlights are outputs by Blackburn and Blackburn/Gerke, an EPSRC CASE studentship on Network Coding (with GCHQ as the industrial partner) and involvement with the EU COST network. Combinatorialists in the School have continued to benefit from their links with both applicable and pure mathematics, as evidenced by the range of outputs, from pure to applicable, produced by the combinatorics group. The School's work in other pure areas of mathematics has continued to develop strongly. Achievements in number theory relative to the 2008 strategic aims include the following: McKee obtained an EPSRC/LMS PhD CASE studentship with industrial sponsorship by the Heilbronn Institute for Mathematical Research, on the topic of Salem numbers, Pisot numbers, graphs and matrices (covering Salem numbers and applications of combinatorics to number theory); Dietmann obtained an EPSRC postdoc grant on Forms in Many Variables (analytic number theory); Galbraith (now Aukland) and McKee published high-quality outputs

applying number theory to cryptography; Galbraith was involved (with Paterson from the ISG) in organising and editing the proceedings of Pairings 2008, an international conference on pairings held at Royal Holloway; Harman has produced many papers in the area of sieve methods in analytic number theory. The remaining research initiatives mentioned under the Maths UoA in RAE 2008 were also very successful, but will be detailed under our UoA B11 submission.
The School has also made excellent progress in achieving the aims for the Quantum Dynamics group that were detailed in the 2008 RA5a for UoA 19 (Physics). In the area of Atomic Theory and Quantum Chaos, Mota-Furtado and O'Mahony have focused on solving the time-dependent Schrödinger equation for atoms or molecules when they are subject to short intense laser fields, a new direction for them. Bolte has published three papers on quantum graphs. In the area of Theoretical Quantum Information Processing, Audenaert has published five papers in quantum statistics, 16 papers on the theory of matrix inequalities and their applications to quantum information theory, and one paper on the additivity problem. Schack has published four papers on quantum Bayesianism. Osborne (now Hannover) published a significant body of work on interacting quantum spin systems and related topics.

Detailed strategic aims:

Algebra: Barnea plans to use commensurators to study the connections between local and global structure of totally disconnected, locally compact groups, and the relationship between their discrete and abstract cohomology. He intends to explore the links between his current interests and geometric group theory, so as to explore geometric interpretations of *p*-deficiency. Nucinkis will continue her study of classifying spaces for families via the cohomology of functor categories, and plans to describe centralisers of elements in Thompson's groups and their generalisations, as well as computing their homology, to give insight into the K-theoretic Farrell-Jones conjecture for these groups. Wildon aims to increase our understanding of the representations of the symmetric group (in all characteristics) with the goal of proving the Foulkes Conjecture and throwing light on Alperin's Weight Conjecture and the decomposition number problem.

Combinatorics: Blackburn plans to continue his work on the combinatorics and algebra of communication theory and cryptography, especially the emerging applications to network coding, and to pursue associated pure questions. Gerke plans to continue her research into random graph theory and algorithms, and to explore applications to information security. Moffatt aims to extend his work on knot invariants and graph polynomials, exploring applications to quantum field theory and to the modelling of blood clotting. Ng aims to work on the borderline between pure combinatorics and its applications, particularly to authentication in vehicular ad hoc networks.

Number theory: Two of the most exciting recent directions in Analytic Number Theory are the connection to questions in Diophantine Geometry and Additive Combinatorics. Dietmann plans to continue with an ongoing project (joint with Jörg Brüdern, Göttingen) on Random Diophantine problems, extend his research on Probabilistic Galois Theory to other interesting Diophantine objects such as counting number fields, and (joint with Christian Elsholtz, now Graz) generalise existing results on Hilbert cubes to more general subset sum problems. McKee plans to continue his research into Salem and Pisot numbers. Widmer will continue a project on using o-minimality for asymptotically counting objects of Diophantine nature such as lattice points and certain algebraic points of bounded height, and investigate the properties of Bogomolov and Northcott for subfields of the algebraic numbers, in particular, a conjecture of Bombieri and Zannier regarding the fields generated by all algebraic numbers of uniformly bounded degree.

Quantum dynamics: Audenaert's research aim is to develop further the two strands of quantum information theory and matrix analysis, and the interaction between them, and to develop new links with other disciplines, such as operator theory and communications engineering. He aims to become one of the world leaders in the field of matrix inequalities, to whom people would be turning if they needed help. Bolte's work will focus on quantum graphs, which are proving to be very useful in many areas of mathematical physics and beyond. A particular focus will be many-particle systems on graphs and Bose-Einstein condensation, as well as gauge-field models on graphs. O'Mahony and Mota-Furtado aim to make a contribution to the theory of atoms or molecules interacting with very short (attosecond) intense laser pulses, an emerging area where recent experimental progress makes it possible to study electron motion in real time. A major aim is to understand how these pulses interact with multi-electron systems in atoms, molecules and in solid state systems. Their research is part of an EU COST funded programme, XLIC, which runs from 2013 to 2017. Schack plans to work on quantum Bayesianism within the emerging area of

quantum foundations, and to study the impact of quantum information science on practical information security.

Statistics: The Statistics group plans to continue both its theoretical work, much of which is motivated by applications, as well as purely applied projects. Koloydenko will continue his work on inference from sequential, spatial, and other structured data, accounting for non-Euclidean geometries. He will be addressing computational efficiency and increasing data sizes, new protocols in statistical and machine learning, and asymptotic theory. He is also committed to his collaboration on biomedical applications such as Diffusion MRI and Computer Aided Diagnosis and Surgical Treatment of Skin Cancer, the latter being funded by NIHR and entering its commercialisation stage. In addition to continuing her work on stochastic approximation, Sharia plans to study Markov processes in the presence of boundaries, a field with applications to Levy processes in physics, biosciences, finance and telecommunications. Shcherbakov plans to study asymptotic behaviour of certain classes of Markov chains and interacting particle systems, and related models of statistical physics, and to continue his work on applications of probability to finance and on statistical inference for spatial-temporal stochastic processes.

c. People, including:

i. Staffing strategy and staff development

Our staff recruitment policy focuses on maintaining a balance of high quality appointments within each of the research groups described above, with a view to developing each group's research programmes and maintaining strong links between them. The two early career staff together with 13 mid career staff and 6 professorial staff provide a balanced staff profile to implement and sustain our research strategy over the next decade.

Staff changes during the assessment period include: the moves to part-time contracts by Harman (number theory) and Klopsch (algebra; now working as a joint appointment in Düsseldorf); the departures of Osborne (quantum dynamics; to Hannover), Galbraith (number theory; to Auckland), Elsholtz (number theory; to Graz), and Godolphin (statistics; retirement); the arrival of Nucinkis and Wildon (algebra; from Southampton and Bristol), Moffatt (combinatorics; from South Alabama), Dietmann and Widmer (number theory; from Bristol and Pisa), Kay (quantum dynamics; from Oxford), Koloydenko and Shcherbakov (statistics; from Nottingham and Durham).

New staff appointments are critical for any research group. Throughout the REF period, our strategy has been to maintain a balance between all the areas listed above, with new appointments in algebra, combinatorics, number theory, quantum dynamics and statistics listed above. Applicants who can strengthen links between research groups, or links with other academic subjects (computer science, information security and physics are areas where we currently have strong ties), or areas of impact outside academia, are favoured.

Individuals are given the freedom to define their own detailed research goals, articulated as part of the annual staff appraisal round; peer feedback is also provided. The School's Director of Research works with the Research and Enterprise Office to make staff aware of new funding opportunities in their areas.

Staff and PhD students are encouraged to interact with each other, to deepen their understanding of their area and to explore new research interests, in several ways:

(i) The School runs three weekly seminars, with mainly external speakers, during term time. The Pure Mathematics Seminar covers algebra, combinatorics and number theory; the Quantum Dynamics Seminar is attended by members of the Department of Physics as well as members of the quantum dynamics group; the ISG Seminar's scope includes mathematical topics of interest to members of the combinatorics and number theory groups in particular. Seminars are well attended, attracting approximately 20 participants. The School funds the provision of refreshments to encourage discussion before and after the seminars.

(ii) The Statistics group organises an annual one-day Applied Statistics and Probability Theory Colloquium, with a similar intended function to the seminar series in (i). The one-day format allows three external academics the opportunity to speak; there are approximately 20 attendees. The group also organises 2-3 ad hoc seminars per year.

(iii) The School organises a 'Hewlett-Packard Day', a one-day meeting with three external speakers (usually from outside academia) each December, and twice-yearly Networking Dinners. These events are attended by representatives from the information security industry, and are particularly useful for those mathematicians who have interests in these areas of application.

(iv) Discussion groups and research-level lecture series are encouraged. Recent examples include

reading groups on topology and combinatorial group theory, hyperbolic geometry, group representations in probability and statistics, representation theory of the symmetric group; and lecture series on *p*-adic integration and arithmetic groups, and lattice-based cryptography.
(v) The School provides a dedicated seminar room that can be booked at short notice, and a common room for more informal discussions. Mathematics staff and PhD students have offices in a single cluster on campus.

A transparent workload model allows an equitable distribution of research time. The workload model rewards PhD supervision and applications for substantial research grants, as well as providing credit for large administrative and teaching tasks. The School attempts to reduce or eliminate administration that needs to take place in the summer period, to maintain the quality of the research time that is available.
The School provides travel and subsistence support for conference participation, at a rate of approximately one international conference per year, to all staff who are not able to fund these expenses via grant budgets. Support for travel to local meetings is also provided.
A standard teaching load is between 2 and 3 undergraduate courses (each of 33 lectures) per year, or equivalent. The School operates the institutional sabbatical policy of one term in nine, with an average of 4 staff taking sabbatical leave in any one year. Royal Holloway provides central funding for sabbatical teaching cover.
The School reduces the load for all new lecturers by the equivalent of approximately one undergraduate course during their first three years. This is usually achieved by freeing them of all administrative duties during the probation period. We have a policy of allocating offices in core space to new staff, in order to facilitate integration into the department. Each junior staff member is assigned an advisor to provide guidance, advice and support throughout probation. Royal Holloway provides a comprehensive staff induction package together with additional research training for less experienced staff (see below).
RAs are fully integrated into the research culture of the School. Each RA's career development needs are coordinated by their primary contact in the department (usually the PI of the grant funding their position). Our RAs are encouraged to provide leadership within existing discussion groups, as well as initiating new ones. They are offered teaching experience through the delivery of appropriate amounts of lecturing and tutorials. Our portfolio of research grants brings significant levels of travel funds. These are used to ensure RAs have the opportunity to present their work at international conferences. RAs are also supported by Royal Holloway's staff induction package. New staff attend an induction day introducing them to the institution's mission and objectives, its values and philosophy, and operational matters. One-day workshops are run at least once a term and supported by an induction handbook and online guidance. The postgraduate-level Certificate in Academic Practice in Teaching and Learning, CAPITAL, is available to all academic staff, and (in particular) is completed by all those new to teaching and in the early stages of their academic career. CAPITAL is accredited by the Higher Education Academy. Royal Holloway's library and Computer Centre offer a wide range of training courses to acquire and update ICT skills to all staff.
The School operates the institution-wide appraisal scheme where all staff are appraised annually. During appraisals work objectives, including research, are set for the following academic year and training and career development needs are identified.
Royal Holloway offers the On Track Researcher Development Programme - an established development programme open to researchers at any stage in their careers. Workshops are led by a mixture of external facilitators and internal experts, and are tailored specifically to science disciplines where appropriate.
Royal Holloway actively endorses the seven principles outlined in the *Concordat to Support the Career Development of Researchers* and has policies and practices at both institutional and departmental level designed to facilitate full implementation of these principles, for example: mandatory training for all members of selection panels including equal opportunities training; equitable treatment for part-time and fixed-term staff; a clear and equitable promotions process. Extensive staff development opportunities are offered including a centrally administered mentoring programme (supplemented by departmental mentoring for early career staff) which is open to all research staff, and a comprehensive annual equality and diversity data monitoring and review exercise. The mentoring scheme is particularly valuable for ECRs and mid-career staff. More experienced staff are asked to volunteer as mentors. The scheme is reviewed on an annual basis.

Royal Holloway has a Women in Science (WiS) Steering Group supported by senior management, which oversees the implementation of the WiS Action Plan 2010 – 2013 focused on ensuring gender balance in a wide range of areas including flexible working, promotions, equal pay, recruitment and selection, childcare, probation, mentoring, communication, networking and profile. Royal Holloway achieved Athena SWAN institutional Bronze status in July 2010. Currently all departments are working towards Athena Departmental Bronze/Silver status. The School is a supporter of the LMS Women in Mathematics Good Practice Scheme.
In October 2011 the Department of Mathematics volunteered to be one of only 8 science departments across the UK to assist the UKRC in piloting a short questionnaire called 'QuickCAT' (Quick Culture Analysis Tool), which provides qualitative and quantitative information on how much staff know about their organisation's policies, practices and outcomes, their views on how fairly these are implemented in practice and the level of their own personal commitment to gender equality. The answers were analysed and led to a set of recommendations on the monitoring of appraisals, mentoring, behaviour and workload that have been implemented by the School.

ii. Research students

Each PhD student has a supervisor and an advisor, to provide advice and support in developing a research programme. There are regular formal meetings, with an annual review (attended by the student, supervisor and advisor) where the student's progress is discussed and monitored. All students are initially registered for the MPhil programme, generally transferring to the PhD programme after one year. In order to transfer, the student must have completed a significant piece of work in their area, given a presentation on their work (either at an internal seminar or at a conference), and shown that they have the ability to complete a PhD.
All PhD students have access to full library facilities (including inter-library loan facilities) together with free printing and photocopying. All full-time students are provided with their own desk, and an up-to-date computer. Part-time students desk-share; they are provided with a computer if needed. All writing-up students are offered access to computer facilities and desk space. All PhD offices are in core office space. The School purchases software licenses for PhD students.
We provide subject-specific training aimed at PhD students, over and above the seminars and research discussion groups outlined above. Sessions on good writing, on LaTeX, and on using research literature are run each year; students also run their own seminar series for practice in giving presentations. Students attend any MSc courses that are useful for their development, and we make extensive use of the London Taught Course Centre. School funds are used for attending specialised courses elsewhere. Money is provided for conference fees and travel expenses for PhD students.
Royal Holloway is a Centre of Doctoral Training (CDT) in Cyber Security, funded by the EPSRC. The CDT has an intake of 10 PhD students per year; the first students arrived in October 2013. Students in the CDT undertake a four-year programme, 25% of which consists of taught courses. Students will also undertake a three-month industrial placement. The CDT is based in the School's core space, and mathematicians are involved in supervising CDT PhD students, and teaching some of the optional courses for the CDT,
Royal Holloway offers a Generic Skills Programme: a full programme of research training and career development workshops based on Vitae's Researcher Development Framework. This comprises a varied mix of workshops delivered by both internal experts and external facilitators, as well as a number of online courses. The institution subscribes to the Epigeum 'Research Skills Master Programme' which offers 18 online courses on diverse topics and is especially valued by students remote from the campus. The Generic Skills Programme has separate discipline strands where appropriate, and is supplemented by provision at Faculty and Department level.
The INSTIL programme enables research students who wish to make a career in HE to develop skills as a university teacher, to share ideas with peers, and to determine what approaches will work in teaching situations. The course is accredited by the Higher Education Academy.
Royal Holloway has an annual allocation of scholarships to support both HEU and OS PGRs. Matched funding is available for PhD students supported by external sponsors. The School provides additional maintenance grants, as well as departmental assistantships. The reputation of our large PhD group, assisted by our scholarship funding and our network of research contacts, ensures that we are able to recruit an excellent cohort of students.

d. Income, infrastructure and facilities

The School's core space is the McCrea Building. As well as office space and centrally bookable

teaching rooms and computer laboratories, the building contains a seminar room that can be booked at short notice and a staff common room that is used for more informal discussions. The building was refurbished in 2012-13. All academic and postdoctoral staff and all full-time PhD students are provided with a high specification desktop or laptop computer under a four-year replacement cycle. Mathematica is available to all under a site licence; MATLAB licences are purchased for those users who require them. The School shares a system support team with the Department of Computer Science, who are able to deal with School-specific support issues. Royal Holloway's Computer Centre provides generic computing support and training.
The library provides access to over 2400 mathematics, computer science and physics journals, including ACM, IEEE Xplore, IoP, JSTOR, ScienceDirect, SpringerLink, and Wiley Online packages together with MathSciNet access; the libraries of the institutions in the University of London and full access to inter-library loan facilities provide additional resources. The library building, adjacent to the McCrea Building, provides study space and access to books and paper journals. Royal Holloway is investing to improve its library space further, with a new £35m library building scheduled for completion in 2015 which will include postgraduate research spaces, environmentally controlled archive spaces and state-of-the-art IT infrastructure.
The School provides funds for travel and conference expenses; academic staff and PhD students have access to funds supporting international conference attendance, over and above travel funded by research grants. We are able to fund approximately one international conference per year for those who do not have access to travel expenses via other sources. We also fund small-scale research projects such as visits of external research collaborators to Royal Holloway.
All staff are expected to submit grant applications. Our Director of Research who chairs the School's Research Committee coordinates this, assisted by our system of peer mentoring. Royal Holloway's Research and Enterprise Office (R&E) notifies academics of calls for research proposals, and provides grant-related support such as calculating Full Economic Costings, assisting with all other financial issues relating to grants, advising on Intellectual Property issues, and negotiating and managing contracts. The Research Strategy Fund (RSF) provides seed funding (GBP 4k-7k) for academics at Royal Holloway to develop research proposals for external funding bodies, to support the preparation of large multi-partner grant applications (such as EU grant applications), and to support research networking events for early career staff. Coordination of non-grant related research is provided by our network of discussion groups and seminar series.

Many mathematicians at Royal Holloway pursue consultancy activities, for HMG and for companies needing advice on information security (cryptography in particular). Much of this activity is carried out in tandem with R&E, who negotiate contract terms and invoice industrial partners; some activity is also carried out in partnership with Codes and Ciphers Ltd, whose Director is a former Professor of Mathematics at Royal Holloway. Networking opportunities such as HP Day and Networking Dinners detailed in REF3a help maintain consultancy links and keep our industry-focused research relevant.

e. Collaboration and contribution to the discipline or research base

The School is an active contributor to the mathematics community in the UK and beyond.
Meetings: Barnea organised the 2008 EPSRC-funded workshop 'The Algebraic Structure of Profinite Groups' at Royal Holloway. Barnea and Klopsch were co-organizers of the LMS- and EPSRC-funded South of England Profinite Group Theory Meetings (2008-12), a triannual series of two-day meetings which attracted many young mathematicians from the UK and from Europe. The series continued in 2013, with an LMS-funded meeting on Cohomology in Profinite Groups organised by Barnea and Nucinkis at Royal Holloway. Nucinkis co-organised the LMS Regional meeting and Workshop on Limit Groups (2009; Southampton) and the 100th LMS/EPSRC Durham Symposium on Geometric and Cohomological Group Theory (2012). Wildon obtained LMS funding for the one-day meeting 'The symmetric group: representations and combinatorics' held at Royal Holloway in 2011; he also organised a GRASP (Group Research Attacks on Speculative Problems) workshop 'Stanley's Positivity Problems and P versus NP', held in Bristol in 2012. Galbraith co-organised Pairings 2008, an interdisciplinary conference involving number theory, algebraic geometry and cryptography, sponsored by Voltage Security, the LMS and Microsoft Research. Blackburn, Gerke and Wildon organised the 24th British Combinatorial Conference, held at Royal Holloway in 2013 and attracting over 150 participants from around the world. Audenaert was co-organiser of the 2011 Summer School 'Modern Statistical Methods in Quantum

Information Processing', Physikzentrum Bad Honnef, Germany. Bolte organised the workshop 'Dynamical Systems on Random Graphs', CIEM, Castro Urdiales, Spain in 2012. Koloydenko and Sharia organised one day Applied Statistics and Probability Theory colloquia on campus in 2012 and 2013. In addition to organisation of meetings, mathematicians in the School have contributed over 50 invited talks at conferences and workshops in over 15 countries over the last REF period.
Networks: Blackburn is a Working Group Chair in the EU COST Network IC1104 'Random Network Coding and Designs over GF(q)' (2012-). Bolte is a member of the EPSRC Network 'Analysis on Graphs and Its Applications' (2012-). He has been jointly awarded an International Joint Project Grant by the Royal Society, and is hosting R. Rueckriemen (DFG postdoctoral fellow; 2012-) and S. Egger (DAAD postdoctoral fellow; 2013). O'Mahony and Mota-Furtado have participated in the EU COST Network CM0702 'Chemistry with ultra short pulses and free electron lasers' (2008-12). Koloydenko is the Royal Holloway Principal Investigator in an NIHR i4i interdisciplinary multi-university research grant for 'Raman spectral imaging for automated Mohs Micrographic surgery of high-risk Basal Cell Carcinoma'.
Other service: Blackburn is a REF Panel Member (2011-2014), a member of the EPSRC Peer Review College, and regular EPSRC panel member for responsive mode grants and special calls. He is an editorial board member for J. Mathematical Cryptology; Cryptography and Communications; Groups, Complexity, Cryptology. He is a Fellow of the IMA and the Institute of Combinatorics and its Applications. Gerke has served as a panel member for the NSF (USA). Audenaert is an editor for Linear and Multilinear Algebra (LAMA). Bolte serves on the Advisory Board of Journal of Physics A: Mathematical and Theoretical. Schack is a Fellow of the IMA.
Visits: Barnea hosted visits to Royal Holloway by J.-C. Schlage-Puchta (Ghent), M. Ershov (University of Virginia), N. Boston (Wisconsin) and A. Jaikin-Zapirain (Madrid). Nucinkis collaborated with D. Kochloukova (Campinas) and C. Martinez-Perez (Zaragoza) under EPSRC funding in 2008. She has also visited Campinas and Brasilia (Brazil), Binghamton (USA), Athens (Greece) and Seoul. Wildon regularly visits R. Padget (Kent), partially funded by an LMS Research in Pairs grant. Blackburn has hosted EPSRC- and Royal Society-funded visits by T. Etzion (Technion) and an EPSRC-funded visit by D. Stinson (Waterloo, Canada). Gerke has hosted visits by P. Balister (Memphis) and has visited A. Frieze (CMU) and A. Coja-Oghlan (Edinburgh, Warwick) funded by her hosts. Widmer has visited Yuri Bilu (Bordeaux), Ulrich Derenthal (Munich), Robert Tichy (Graz), J. Vaaler (U Texas at Austin), G. Wiese (Essen) and W.M. Schmidt (U Colorado at Boulder), and has also visited the IHES, Bures-sur-Yvette, France. Koloydenko has hosted visits by J. Lember (Tartu, Estonia), D. Zhou (Brighton) and K. Kong (Nottingham) funded by NIHR. Funded by the Estonian Science Foundation via his Estonian collaborator (J. Lember), Koloydenko has also been on two long term visits to Tartu. Koloydenko also makes regular short term visits to Nottingham, funded by NIHR. Sharia hosted a visit by B. Polyak (Moscow) funded by the LMS. Audenaert made research visits to Vienna, the Fields Institute (Toronto), Innsbruck, the Alfred Renyi Institute (Budapest), the East China Normal University (Shanghai), Ulm, and the Mittag-Leffler Institute (Stockholm). O'Mahony was an invited Research Professor at the Univ. of Louvain for two periods.
In addition to the research visits listed above, we pursue many other collaborations (over 90 collaborations took place during the REF period). These include: **Algebra:** N. Avni (Harvard), A. Jaikin-Zapirain (Madrid), U. Onn (Beer Sheva, Israel), P. Kropholler and I. Leary (Southampton), C. Voll (Southampton and Bielefeld). **Number Theory:** J. Brüdern and V. Blomer (Göttingen); T. Wooley (Bristol), T. Browning (Bristol), P. Elliott (Boulder, Colorado), C. Elsholtz (Graz), I. Shparlinski (Sydney), S. Galbraith (Auckland), C. Smyth (Edinburgh), J. Vaaler (UT Austin), J. Thunder (Northern Illinois), U. Derenthal (LMU Munich). **Combinatorics**: J. Britnell (Imperial), A. Taraz (TU Munich), A. Steger (ETH), R. Gurau (Perimeter Institute, Canada), S. Huggett (Plymouth), D.M.R. Jackson (Waterloo), M. Loebl (Charles University, Czech Republic), D.Thurston (Columbia), S.Garoufalidis (Georgia Institute of Technology), L. Chen (HP Labs) and Q. Li (Singapore). **Quantum Dynamics**: D. Wenzel (TU Chemnitz), M. Mosonyi (Bristol), F. Verstraete (Vienna), D. Petz (TU Budapest), J. Eisert (Berlin), M. Nussbaum (Cornell), A. Szkola (Max Planck Institute, Leipzig), L. Piraux (Louvain), Y. Popov (Moscow State), C. Fuchs (Perimeter Institute, Canada). **Statistics**: K. Kuljus (Uppsala), I.L.Dryden (Nottingham), I. Notingher (Nottingham); W. Perkins, S. Varma, I. H. Leach and H. Williams (Nottingham University Hospital NHS Trust); S. Singh (Cambridge), M.D.Penrose (Bath).