Environment (REF5)

Institution: University of Leicester

Unit of assessment: 10 Mathematical Sciences

a. Overview

During the REF period the Unit has averaged 24 permanent research active staff, supplemented by 10 RAs. Staff can be loosely allocated to three groups: Pure Mathematics (PM), Numerical Analysis and Modelling (NAM), and Mathematics of Data and Finance (MDF), with specific and often interlinked research themes of Algebra, Algebraic Topology, Geometry, Mathematical Physics (within PM), Numerical Analysis, Computational Modelling, Model Reduction, Fluid Dynamics, Mathematical Ecology, Physical, Chemical and Biochemical Kinetics, Neuro-mathematics, Adaptive Control (within NAM), Financial and Actuarial Mathematics, Stochastic Modelling, Data Mining, Data Visualization, and Dimensionality Reduction (within MDF). The main strategic focus of the PM group is on excellence in building the foundation of mathematical sciences, while NAM and MDF mainly focus on the development and analysis of mathematical models and techniques underpinning extensive interdisciplinary and industrial collaborations. All groups have a strong track-record in the development of research networks and workshop organisation both in the UK and abroad, and active programmes of PhD supervision.

Staff submitted in this Unit all work in the Department of Mathematics, which is one of seven departments in the College of Science and Engineering, one of four Colleges in the University. The Unit, especially NAM, is strongly integrated with the College's research priority themes and research centres, with the Unit leading in the *Computational Modelling Theme (CMT)*, and the *Mathematical Modelling Centre (MMC)*. In addition, the MDF group has a wider range of collaborations across the University, especially with the College of Medicine, Biological Sciences and Psychology in the area of Data Mining and Visualisation. MDF is also a founding member of the *Institute of Finance*, with departments from the College of Social Sciences.

b. Research Strategy

The main strategic goal of the Unit is to foster the production of high quality mathematical research across a focused set of fundamental topics listed above, and to develop mathematical and computational modelling techniques for application both within and outside Mathematics. We are committed to the development of business and industry links to ensure that our research is used to improve the productivity of the business and industrial sector. We support our research through research grants, commercial contracts, and use of internal resources for specific initiatives (for example, establishing a rolling RA post to support the most promising research directions). *Comparison with previous position.* In comparison with the RAE2008 submission we have **(i)** continued to build on our strengths of fostering interaction and collaboration through both networking and the organisation of conferences and workshops (see section e); **(ii)** significantly increased our PhD student numbers by establishing a vibrant PhD training programme; **(iii)** refocused our output in applied areas (NAM and MDF) towards more rigorous mathematics, while taking maximum benefit from our more interdisciplinary work in response to the impact agenda. As an indicator, the output in SIAM journals from NAM and MDF has risen from around 11% (5/44) to 22% (12/54); **(iv)** created a platform for attracting direct collaboration with industry through industrially funded projects. Three RAs and two PhD students are currently funded by industrial contacts. The Unit has gained around £350K in industrial funding, most very recently, so not appearing in the REF income figures. However this is the culmination of a concerted strategy of industrial engagement implemented over recent years, which is starting to come to fruition.

Future Strategy. The Unit's overarching strategy for the future is to maintain our areas of strength by supporting established staff and to provide support and opportunities for junior staff to build their research portfolio and generate high quality research outputs. We will continue the developments initiated during the REF period and look for new opportunities to support our research, including **(i)** the continued organisation of workshops and conferences involving world leading experts in our research fields; **(ii)** the maintenance and development of international networks, supported by significant travel budgets and funds for staff research visits (see section c); **(iii)** the recruitment, development and recognition of early career researchers, both for fundamental research and for applied research leading to commercial impact; **(iv)** supporting staff

to develop research with economic, cultural and scientific impact. We aim to diversify our funding sources by further development of our interdisciplinary research collaborations and applied research with industry. Our current success with recruiting RAs to work on industrially funded projects (see section d) is creating open-ended contracts for colleagues to work on industrial applications and research as opposed to teaching and research. We aim to generate more such posts in the future. We will also continue to attract staff who have won prestigious research Fellowships (**Schroll** and **Paoli** recruited through this route in REF period).

At group level, the strategic objectives of the PM group are to build further and expand the existing links and applications across other areas of mathematics and the sciences, including biology, dynamics, physics, and visualization. Equally important for the group is to maintain and extend its pioneering developments in key areas of pure maths, for example, at the interfaces of topology and geometry and of category theory and algebra. The group has a strong research record, as evidenced by grants and invitations (see section e), with publications arising from both internal and external collaborations. The interaction of expertise within the group has led to a vibrant research environment and our aim is to further strengthen this activity and develop further applications in other areas. The PM group regularly organises internal working groups on topics which encourage joint projects and a number of collaborations have emerged. For example, a series of seminars on groupoids led **Clark** and **Neumann** to work together on étale groupoids and foliations. Encouraged by the combined submission of MSOR within a single UoA, further new collaborations are starting to develop between PM and the other groups, for example, **Leschke** and **Tyukin** in visualisation, **Paoli** and **Chakrabarty** in topological data analysis, or **Neumann** and **Georgoulis** in the application of de Rham cohomology to finite element methods.

In the traditionally applied mathematics areas of NAM and MDF, the research strategy is focused on the development and analysis of advanced mathematical models and techniques and promoting their wide adoption in sciences, engineering and industry. The development of strategic interdisciplinary collaborations with a wide base of academic researchers and industry is enabling this. For example, within the NAM group, **Georgoulis** leads the College Theme in Computational Modelling (CMT), with the aim of developing a group of numerical analysts who can provide support to other disciplines and external companies in the implementation of state-of-the-art computational methods. Concurrently, we are developing an industrial computational modelling group, which now has an initial RA funded by Weatherford. Another emerging industrial collaboration is between **Tyukin** and Apical for the development of visualisation algorithms. Other examples are described in sections d and e. Within the MDF groups, we have capitalised on the Data Mining expertise of **Gorban** to secure industrial and University funding for an RA to develop commercial and academic data analysis service. Such developments will contribute significantly to the impact of our research and our ability to demonstrate it, which is a key strategic objective of the Unit for the future.

c. People

Staffing Strategy. The departmental Research Committee develops research strategy for the Unit. It is chaired by **Gorban**, who sits on the Departmental Management Group (DMG) which makes decisions about staffing in the department. In developing the staffing strategy, the DMG is guided by the research goals of **(i)** maintaining and enhancing our areas of strength, **(ii)** enhancing our research reputation by attracting established researchers with strong international reputations, **(iii)** identifying areas for strategic development and hiring established world-leading researchers or promising young researchers in these areas.

The Unit has grown in size from 22 staff entered in RAE2008 to 23.6 academic members of staff entered in REF. Guided by the DMG staffing strategy, we have appointed in the PM **Schroll** in algebra, and **Paoli** in algebraic topology and category theory, both at lecturer level. In the MDF group, we have appointed **Levendorskii** to a chair post to lead developments in financial mathematics, and **Utev** (initially as a reader but subsequently promoted to chair) to lead probability and stochastic analysis. Also appointed as lecturers were **Grechuk** in actuarial mathematics, **Wang** to build our expertise in statistics with application in the actuarial industry, and **Chakrabarty** in statistics, with applications in physics. In the NAM group, we have appointed **Cangiani** as a lecturer to strengthen the Numerical Analysis theme and provide focus with **Georgoulis** in finite elements, but in this case with applications in biology, and **Athanasoulis**

(lecturer) at the interface between theoretical and computational partial differential equations. We are pleased that three of the nine new appointees during the REF period were female, as we have a long term commitment to improving the gender balance in the department. We are signatories to the LMS Good Practice Award and have applied for the Athena Swan Bronze Award in November 2013.

In the future, we plan to further strengthen the PM group with the appointment of researchers with very strong international reputations. We will appoint staff who have the ability and leadership skills to build a visionary and internationally recognised research programme in pure mathematics, aimed at significantly enhancing the existing research profile of the PM group. We also plan strategic growth in the NAM group, where we are planning to appoint a junior colleague to support the numerical analysis theme and the CMT in the College. With this our long term goal is to create a centre for scientific computing in the College, whose mission is to develop advanced computational methods and facilitate the uptake of these methods by users in other disciplines and industry.

Staff Development. Research excellence is rewarded through promotion, accelerated increments, and productivity bonuses. Senior colleagues on the DMG advise the Head of Department on potential promotion cases, and professorial colleagues help in the construction of the cases which are forwarded to a University Committee chaired by the Vice Chancellor. In the REF period **Brilliantov**, **Davidchack**, **Petrovskii**, **Snashall** and **Utev** were promoted to chair, **Clark** and **Pirashvili** were promoted to reader, **Georgoulis** was promoted, first to senior lecturer and then to reader, and **Neumann** and **Morozov** were promoted to senior lecturer.

The strong collegiality in the Unit contributes significantly to an environment which supports excellent research. All new staff have an experienced member of staff assigned as a mentor who helps with planning career development, publication strategy, and grant applications. The mentoring and collaboration between senior and junior staff has produced several new collaborations: e.g. **Petrovskii** and **Morozov**, **Gorban** and **Tyukin**, **Levesley** and **Georgoulis**, **Snashall** and **Schroll**. New staff receive a reduced teaching load (at most one course) in the first year so that they can accelerate their research productivity, and start to apply for early career research grants. New staff are also encouraged to help organise or support workshops and conferences organised by the department in order to increase their visibility (e.g. Actuarial workshop for **Wang** and **Grechuk**, ENUMATH 2011 and SIAM regional meeting for **Cangiani**, LMS/EPSRC funded workshops for **Schroll** and **Morozov**). Although most of these events are eventually funded from external sources, the department provides a safety net by underwriting the expense.

In accordance with university policy, staff are eligible for one semester of study leave after six semesters of service. Staff can apply for study leave by submitting an application to the College Study Leave Committee, outlining their research plans and intended outputs. During the REF period, all applications for study leave from members of the Unit were successful (26 staff/semesters in total), resulting in significant research outputs. Whenever possible, teaching load is concentrated in one semester, giving staff more dedicated research time and flexibility for travel in the other semester. In addition to the success of staff in gaining funding for travel and visits from external sources, staff get a £600 travel allowance each year to support them in research visits and conference attendance.

We have a strong commitment to retaining excellent young staff who start on fellowships or as RAs. **Schroll**, a Leverhulme Early Career Fellow, has been appointed to a lectureship. **Paoli** has a Marie Curie International Reintegration Fellowship and has now been recruited as a lecturer. RAs are a key part of the departmental strategy, and the Department has funded one rolling post for the past three years. We use this post to support the Unit's strategic directions and initiatives. The first post holder was in Geometry, after which it extended **Scholl**'s EPSRC grant by 12 months. The post is currently held by an RA, partly funded by the Wellcome Trust, to carry out data mining research with applications to biological and medical sciences.

Following the principles of the Concordat to Support the Career Development of Researchers, we provide many opportunities for career development of our RAs. Most of them are given an opportunity to build up their teaching portfolio by being involved in teaching, development of e-

learning resources, and having access to the University's teaching training. To promote research development and networking, we support RAs in organising, running, and participating in workshops organised by the Unit. Research staff are further supported by Departmental Research Staff Coordinators, the University Research Staff Career Development Advisor and the University Research Policy Committee, through its Research Staff Working Group. RAs are encouraged to attend teaching, research, and career development events organised by the University's Academic Practice Unit. To enable career progression, the department also provides bridging funding where necessary. All RAs who completed their initial projects in the department over the period have gone on to a successful academic career.

Research Student Recruitment. We have significantly increased the number of PhD students completing, from 13 in RAE2008 to 23. By systematically engaging with University-wide initiatives to increase the number of international PhD students, we have recruited strongly from overseas (11 of 23). In addition, we have developed a strong programme of attracting top students from our UG and PGT programmes. We organise regular events where staff inform students about their research and possible PhD projects, our current PhD students share their experience of being a postgraduate student and working on a PhD project. The strongest undergraduate and MSc students have the opportunity to work on open ended BSc, MMath and MSc projects which can become a platform for their PhD studies in the department. Our involvement in the recently funded EPSRC Centre for Doctoral Training (CDT) in Innovative Metal Processing (see section d) will support this strong PhD recruitment in the next period.

Information on training and support mechanisms. The University's Graduate School requires all new PhD students to undertake a series of induction courses and graduate level taught courses. The students attend induction courses jointly with other departments in the College. To facilitate the PhD progress, all PhD students have a probationary period and are transferred to PhD after the first year subject to satisfactory performance. All PhD students have a primary and secondary supervisor. In addition to regular supervision meetings, students are required to attend three taught courses in their first two years of study. These are mainly drawn from courses from the EPSRC-funded Magic Network, two of which Leicester provides. Students are also given the opportunity to develop their teaching and communication skills by receiving training, engaging in small group teaching of UG students and giving frequent internal presentations. The Department allocates £1000 to each student for travel to local and international conferences.

We also have established a programme of activities for our PhD students to develop wider employability skills. The Data Analysis PhD students have been trained in SAS and deliver training to UG and PGT students. We have an annual employability day for students – with speakers from industry. For those students who are interested in academic careers, we organise grant writing sessions. Students are given ample opportunity to develop their research presentation skills. We have an active postgraduate society which, as part of its programme, organises a PhD student seminar series and "seminar surgeries" in Pure and Applied Maths. These surgeries take place before the weekly seminars and consist of students giving other students an informal introduction to the seminar topic of that week. In addition, the MDF group organises a yearly Midlands Postgraduate Workshop, where students from Leicester and Nottingham present the subjects of their research.

Information on progress monitoring. PhD students and supervisors have frequent supervision meetings to discuss the progress of the PhD work and ways to develop the research further. It is University policy that a formal record of these meetings is kept. At the end of the first year, the student is required to submit a report about their work so far on the research topic. The report is assessed by two members of staff (other than the student's supervisor) and an oral examination takes place. Students are required to give a research seminar in the second year of their study to their colleagues and academic staff in their research area. In their final year, students write a plan for submission and writing up. The department supports students in preparing for their final viva by organising a mock examination, which includes a short presentation of the contributions they have made to the subject area of their dissertation.

d. Income, infrastructure and facilities

Income. Research income is derived from a variety of sources. An element of our strategy has

been to diversify our research funding, and in this period we have been funded by EPSRC, NERC, EC FP7, JISC, Wellcome Trust, BGS, Weatherford, ERC, LMS, IMA, the Royal Society, and the Leverhulme Trust. We have sought funding from panels in EPSRC other than Mathematics, including Engineering and Chemistry, and will continue to do so. In total the funding has supported 9 RAs, and 12 PhD students.

Research grant income crucially supports the development and vibrancy of fundamental research in the Unit in four key ways: **(i)** funding activities of early career researchers who bring new ideas and skills to the Unit: EPSRC grants of **Clark** (*Foliations: solenoids, regularity and ends*, £265K), Lazarev (now Lancaster) (*Modular operads and topological field theories,* £278K), and **Schroll**'s recent First Grant (*Geometric representations of cluster categories, Brauer graph algebras and RNA secondary structures*, £100K); **(ii)** bringing researchers who are making the transition from RA to lecturer with a view to them becoming permanent members of the Unit: **Schroll (**Leverhulme Trust Fellowship**,** £64K) and **Paoli** (Marie Curie International Reintegration Grant, €100K); **(iii)** funding development of multidisciplinary research to broaden the base of research users and also increase potential for generation of research income, either on industrial contracts or interdisciplinary bids in funding councils: **Levesley** and **Brilliantov** with BGS and Geology at Leicester (see section e) (£70K) has led to other funding bids, and industrial contracts with Weatherford, **Gorban** and **Levesley** with Schürer in History on a JISC Digging Into Data Challenge grant, *Mining Microdata*, (£97K) is leading to commercial activity in text mining. **Petrovskii** has collaborated with Blackshaw, a zoologist from Plymouth, on a Leverhulme funded project *A Theoretical and experimental approach to understanding insect trapping systems* (£112K). This work has led to a 3-year collaboration agreement with DEFRA and our plan is to retain the RA currently working on this project by securing industrial or government (TSB) funding; **(iv)** the maintenance and extension of international research networks: **Gorban** and **Tyukin** have secured funding as PIs on two Russian grants for a total of ~£100K; **(v)** funding organisation of high level conferences: **Cangiani** and **Georgoulis** securing £60K as co-organisers of the 2014 LMS/EPSRC Durham Symposium.

We have had significant funding to support workshops, which we view as a key route to the development of research collaborations and projects, as well as developing links with industry. In total we have been awarded around £90K to support 20 workshops and conferences. Additionally, we have received funding from the Centre for Numerical Algorithms and Intelligent Software (NAIS) in Edinburgh, Strathclyde, Heriot-Watt. We have received £10K from NAIS for a symposium *Phase Field: Models, Applications, Software*. A further £15K is planned for 2014 linked to the activities of the College CMT. We will continue to apply to a diverse range of funders for such support. To support their research collaborations, many members of the Unit held extended (at least a month) visiting positions funded by the inviting party at top research centres: **Georgoulis** (CNR-IAC Rome, U. of Crete); **Clark** (UIC, Chicago); **Leschke** (Osaka City U.); **Neumann** (CIMAT Guanajuato, IMPA Rio de Janeiro, U. of Nice, U. of Pavia); **Paoli** (CRM, Barcelona), **Snashall** (Tokyo U. of Science); **Utev** (U. of Brussels).

Through the CMT, NAM plans to create a centre for scientific computing, providing both service to other scientists in algorithm development and to industry in providing cutting edge software for industrial problems. To support this initiative **Davidchack** and **Georgoulis** were CIs on the EPSRC grant for HPC Midlands for a total of £1.24M, which has a mission to provide HPC facilities for industrial problems. Similarly, building on the JISC grant mentioned above, and the co-funding of an RA (supervised by **Gorban**) with the College of Medicine and Biological Sciences and Psychology, MDF plans to develop a data analysis function within the University. This will lead to multidisciplinary grant applications.

In recognition of its research success the College has provided significant income to the Unit, including 60% of the salary costs of **Paoli** (matching funds for the Marie Curie), half the salary costs of **Schroll** (matching funds for Leverhulme), and £43.5K of bridging funding for RAs. The College has also supported 9 PhD students in multidisciplinary projects to a sum of around £65K per annum, and a further 2 students are receiving funding from respectively Alstom and Apical with a combined total of around 28K per annum over the next three years. Further funding for PhD students will come from the recently awarded EPSRC CDT in Innovative Metal Processing, with CIs **Cangiani**, **Davidchack**, and **Georgoulis** contributing their expertise in atomistic

simulation and finite element methods.

The College Research Committee is developing an application strategy for *Horizon2020* based around its research themes. **Georgoulis** will lead applications with a significant computational modelling component.

Infrastructure and Facilities: Each member of staff has their own office, with a desk top computer which is replaced on average every 4 years. RAs share offices. Support for IT is provided by the College for more specific needs through the College IT team, and for more generic support from University IT Services. Staff and PhD students working on more computationally intensive research projects are allocated PCs with higher specifications. The Unit has gained access to two sets of specialist equipment through the University's Research Infrastructure Fund (value £110k). The first is the purchase of a CPU/GPU system with two Kepler GH110 units to support the collaboration of NAM with Apical. The second is access to 12 Bloomberg terminals, which are being used for research purposes and to support the commercial activity of the Institute of Finance, supporting the work of members of MDF. The Department is well served by HPC facilities with the University investing in the ALICE supercomputing cluster (£1.5M University plus £300K from BIS) which is used heavily by the NAM group, especially on large-scale computations for interdisciplinary collaborations. Projects with an industrial component have access to HPC Midlands. We are developing links, through **Chakrabarty** and **Georgoulis**, with Physics and Astronomy for developing algorithms for large astronomical calculations, both in modelling and data analysis. This will give us access to the new £2 million DIRAC HPC facility. The University library houses the Mathematics Association collection. In addition to having access to a large number of journals through the University's batched electronic subscriptions, the Unit spends approximately £7K for books, and £20K on journals annually.

Consultancies and professional services: Through the University's Enterprise and Business Development Office, colleagues in the Unit (**Gorban** and **Wang**) have become involved in two Innovation Partnerships and knowledge transfer activities. **Gorban** collaborated with PetScreen in BioCity, Nottingham, to develop a canine lymphoma diagnostic system. This forms part of one of our impact case studies. We plan to form a more formal commercial relationship with Avacta (who bought PetScreen) which will generate income as well as future impact studies. NAM has contracts with Weatherford worth around £250K to support RAs supervised by **Gorban** and **Levesley** to develop mathematical and numerical models for reservoir modelling. BGS paid £40K for support for Lattice Boltzmann modelling and for investigation into robust reservoir modelling software. We plan to develop a more formal relationship with Weatherford and BGS through strategic framework agreements. **Levesley**'s position as visiting research fellow at BGS supports this aspiration. In addition, the Unit is a partner with Engineering and Computer Science in the College's effort to establish such an agreement with Alstom Power. **Tyukin** is supervising an RA funded 50% by Apical through a knowledge transfer scheme for the development of their visualisation software. Apical are also funding a PhD student as part of the collaboration. **Gorban** gained funding from NERC to develop a prototype of data mining software to be used with NERC environmental data sets. MDF plans to use the Institute of Finance as a vehicle for business development in Leicester (initially) and nationally, primarily for SMEs. This will give access to regional development funds and also consultancy from SMEs.

e. Collaboration and contribution to the discipline or research base

Members of the Unit are producing research at the highest international level which has contributed to a wide research base, as well as to public awareness of the importance of mathematics and mathematical modelling. For example, **Gorban** has been recognised by Slemrod as making a fundamental contribution in settling Hilbert's 6th problem. Consequently Gorban was invited with his co-author Karlin (ETH, Zurich) to write a survey of his work in this area in a special issue of the Bulletin of the AMS. The importance of **Gorban**'s work in mathematical biology has been recognised in talks by Gromov at Poincaré Institute. **Brilliantov** collaborated with scientists from Germany to propose a mathematical model of ice plumes formation, which implied the existence of a global ocean of liquid water under the icy surface of Saturn's moon Enceladus. The existence of liquid water and subsequent detection of some organics in the plume made Enceladus the most probable place for the existence of extra-terrestrial life in the Solar system. This initiated a growing interest in the plumes of Enceladus, not only in the scientific community,

but also in the general public: *The New York Times* devoted an article to the discovery of liquid water on Enceladus, while the BBC made a broadcast on the topic.

Collaborations with top researchers within UK and internationally: Examples of research collaboration with top UK researchers: Markowich, Cambridge (**Athanassoulis**); Makridakis, Sussex (**Georgoulis**); Burstall, Bath (**Leschke**); Marsh, Leeds (**Schroll**); Titterington, Glasgow (**Wang**). Non-UK examples of such links include Paul, Ecole Polytechnique (**Athanassoulis**); Brezzi, Pavia (**Cangiani**); Basu and Bhattachrya, Indian Statistical Institute (**Chakrabarty**); Hurder, Chicago (**Clark**); Cvitanovic, GeorgiaTech (**Davidchack**); Melenk, TU Vienna (**Georgoulis**); Gromov, IHES, and Judge, Berkeley (**Gorban**); Pinkall, Berlin (**Leschke**)Beatson, Canterbury (**Levesley**); Stuhler, Gottingen (**Neumann**); Blanc, Haifa, Pronk, Dalhousie, and Lack, Macquarie (**Paoli**); Hastings, UC Davis and Lewis, U. of Alberta (**Petrovskii**); Nijmeijer, TU Eindhoven (**Tyukin**); Peng, Shandong (**Wang**). Members of the Unit have ongoing relations with research groups at prestigious institutions, for example: Bioinformatic Unit of Curie Institute, France (**Gorban**); IMPA, Rio de Janeiro, and UB Barcelona (**Neumann**); RIKEN Brain Science Institute, Japan (**Tyukin**), U. of Zurich, U. of Brussels, National U. of Singapore (**Utev**). Members of PM co-organise the LMS networks *BLOC* and *TTT*, play an active role in the French *SubTile* network (aperiodic geometry), and **Snashall** is on the steering committee of the Anglo-French-German Representation Theory network.

Exemplars and support for interdisciplinary research: The Unit has a very strong track record in interdisciplinary research. While the submissions to REF2014 are mainly in core mathematical journals, we have a significant corpus of work in top journals in other disciplines such as Nature, Physical Review Letters, Psychological Review, RNA, American Naturalist, Journal of Chemical Physics, Chemical Engineering Science, which adds significant innovative mathematics, as well as promotes the increase of uptake of cutting edge mathematics developments in other sciences and engineering. Through the activities of the MMC we have built strong internal relationships with Engineering, Geology and Genetics. **Georgoulis** and **Cangiani** are currently co-supervising with Ludden (Executive Director at BGS) and Barry (Geology) a BGS-funded PhD student researching mantle dynamics. Thanks to his expertise in modelling of solid-liquid interfaces, **Davidchack** has strong collaborative links with the Mechanics of Materials group in Engineering (CI on the €4.8M EC FP7 project MintWeld led by Hong, co-supervisor of PhD projects with Pan). Researchers in PM also increasingly engage in interdisciplinary projects. **Schroll** collaborates on the EPSRC funded project with the RNA biology team at Leicester led by Eperon. This work is supported by an EPSRC DTG PhD student, and one year of university funded RA. **Leschke** collaborates with Chemistry (Hudson) to characterise the properties of metastable phases in aerosols using laser techniques and mathematical modelling, supported by a College PhD studentship.

Collaborations with research users: **Levesley** and **Brilliantov** collaborated on a NERC-funded project to compute the planetary budget of methane hydrate, run by Professor John Rees at BGS (NERC Natural Hazards Team Leader) with Geology colleagues (from Leeds, Leicester and Bristol) providing mathematical modelling expertise, as a result of the strong relationship between Leicester and BGS. The Unit is seeking more formal links with BGS to provide more extensive modelling, computing, and data analysis expertise. **Gorban**'s interaction with Weatherford in Lattice Boltzmann simulation has generated new approaches to modelling of inhomogeneous media, which may lead to further collaboration, but is also a topic of fundamental interest. Our strategy is to open dialogue with industry to give them insight into cutting edge mathematical methods, and to collaborate in the application of these methods for solving industrially relevant problems. **Tyukin**'s collaboration with Apical (see (d)) demonstrates how collaboration can lead to development of infrastructure (specialist computing equipment).

Conferences and Workshops: Examples of leading mathematicians who participated in conferences and workshops at Leicester are Donaldson,Gowers and Lindenstrauss (*BMC 2011*), A. Stuart, Shu (*European Numerical Mathematics and Advanced Applications Conference (ENUMATH) 2011*), Kevrekidis, Slemrod, Budd, McKay (*Algorithms for Approximation*). We view outreach as a crucial part of our activity. Penrose (*BMC 2011*) and N. Higham (*ENUMATH 2011*) have given major public lectures at Leicester during the REF period. Our interdisciplinary mission has brought high level scientists from other disciplines to Leicester: Hansen (Economics, Chicago) and Lipton (Bank of America Merrill Lynch & Imperial College, *Spectral Methods in Finance*),

Esposito (NASA, *The Enigma of Enceladus*), Izhikevitch (Neuroscience, San Diego, *The Mathematics of the Brain*), Gorlov (Engineering, Northeastern, *Free Flow Turbines*), Karma (Physics, Northeastern, *Phase Field: Models, Applications, Software*). In addition to these, PM hosted regional LMS meetings in 2009 and 2013 and NAM organised the SIAM UKIE meeting in 2012. In addition we hosted Mateyasevich, who gave a talk on recent developments in the solution of the Riemann hypothesis.

Leadership: **Levesley** was chair of the Heads of Department of Mathematical Sciences (HoDoMS) from 2009-2011. **Levesley** was a member of the LMS/HoDoMS group who developed the Good Practice Scheme for the promotion of women in UK Mathematics. As a recognised national and international leader in approximation theory he was invited to coordinate the approximation theory submission to the International Review of Mathematics. **Neumann** is a board member for LMS-IMU-AMMSI Mentoring African Research in Mathematics (MARM) scheme responsible for research mentoring partnerships in Subsaharan Africa. From 2007-2011 he was also actively involved as a MARM mentor with universities in Ghana.

Editorial work: **Brilliantov** (Divisional Associate Editor, *Physical Review Letters)*; **Levendorskii** (co-editor of special volume *Int. Journal Theoretical & Applied Finance*); **Levesley** (*LMS Journal of Mathematics and Computation*); **Morozov** (Associate Editor, *Mathematical Modelling of Natural Phenomena*), **Mudrov** (Associate Editor, *Reviews in Mathematical Physics*); **Petrovskii** (Editor in Chief, *Ecological Complexity*); **Utev** (Associate Editor, *International Journal of Stochastic analysis*).

Leadership roles in Research Councils, Learned Societies, etc.: **Levesley** and **Gorban** are members of the EPSRC College; **Neumann** (Board Member, LMS-IMU-AMMSI research initiative, *Mentoring African Research in Mathematics*; Board Member, *Committee for Support of Eastern European Maths*, European Maths Society). **Leschke** is a member of the Standing Committee of European Women in Mathematics. **Snashall** was appointed to the Zeeman Medal Panel for 2014 as a representative of the LMS.

Fellowships: **Cangiani** (2013: Los Alamos), **Gorban** (2008: Courant Inst, 2008: NIH, 2009: IHES, 2010: INI, 2011: Hausdorff Inst); **Neumann** (2011: INI, 2009, 2010, 2012, 2013: TIFR Mumbai); **Paoli** (2011 - 2015: Marie Curie International Reintegration); **Petrovskii** (2010 - 2011: Regional Development Board award); **Pirashvili** (2013: INI); **Schroll** (2008 - 2012: Leverhulme Early Career); **Snashall** (2009: St Etienne, 2012: Clermont-Ferrand).

Scientific advisory board membership (non-Leicester meetings): **Brilliantov** (Scientific Committee**,** Discrete Methods, in Fluid Dynamics 2011); **Neumann** (Scientific organizer of *XVI Spanish Topology Meeting*, Almeria and of 3 workshops at CRM Barcelona); **Snashall** (Scientific organiser of 4th International Conference on Hochschild Cohomology, Buenos Aires).

Prizes and awards: **Wang** (Best Paper Award 2011, *Journal of Nonparametric Statistics*).

Invited keynote lectures & lecture series: **Brilliantov** (keynote address, Int. Conference *"Recent Progress in Physics of Dissipative Particles"*, Kyoto, 2010) ; **Chakrabarty** (Invited lecture series in *Warwick Summer School on Complex Systems*, Warwick Complexity, 2012); **Clark** (Invited lecture series, *SubTile 2013* CIRM); **Georgoulis** (*5th Conference on Numerical Analysis*, Ioannina, 2012); **Gorban** (Euroscience Open Forum ESOF2010, 19th Int. Conf. on *Discrete Simulation of Fluid Dynamics,* Roma); **Leschke** ("Quaternionic holomorphic geometry I-III", lecture series, 2nd OCAMI-KNUGRG Joint Differential Geometry Workshop,"Submanifold Geometry and Lie Group Theory", Osaka); **Neumann** (Invited lecture series on *Algebraic Stacks & Moduli Problems*, IMPA, Rio de Janeiro), 2010 British Mathematics Colloquium, Edinburgh, UK (keynote morning speaker); **Paoli** (Invited lecture series at *Foundational methods in computer science*, Dalhousie); **Petrovskii** (*Models in Population Dynamics and Ecology 2013*, Osnabrueck, Germany, *MBI Workshop: Sustainability and Complex Systems*, Columbus, Ohio, USA, 2013); **Snashall** (*41st symposium on ring theory and representation theory*, Shizuoka, Japan, 2008).