Institution: University of Aberdeen

Unit of Assessment: 10 (Mathematical Sciences)

a. Overview

This submission is based on the **Institute of Pure and Applied Mathematics (IPAM)** at the University of Aberdeen, which consists of 29 academic staff (10 Professors, 6 Readers, and 13 Lecturers/Senior lecturers), of whom 25 are included in this submission (23.1 FTE). Core research in Pure Mathematics is in Algebra (4 members) and Topology (5 members), with other interests in Mathematical Physics (3) and Analysis (3). The Algebra and the Topology groups are strongly linked and form a very active centre in Modular Representation Theory, which enjoys a strong reputation for its innovative research, exemplified by the theory of *p-local finite groups,* created in Aberdeen by **Levi** in a joint work with Broto and Oliver. The Topology group has been traditionally a strong and dynamic group and includes young researchers with a wide range of interests in Homotopy Theory and Geometry. The Algebra group contains leading academics in the subject, Professors **Benson** and Robinson. **Benson** is a very active member of the wider community by maintaining a preprint archive in Representation Theory as well as being an editor of various journals. Robinson is an active member of IPAM, presently on a 3-year secondment until 2015, and hence not eligible for within this submission.

The Applied Mathematics group was established in 2006, with key staff submitted to General Engineering in RAE 2008. The group has since expanded significantly, recently merging to create the Institute for Pure and Applied Mathematics (IPAM). The Applied group specialises in mathematical modelling through the theory of Dynamical Systems and Stochastic Dynamics with broad multidisciplinary applications to science, engineering and medicine. Professor **Grebogi**, who is a prominent researcher in this field, leads the group. Much of the group's activity is now focused on the important area of systems biology, involving close collaboration with biologists and medical researchers. The group has become acknowledged as one of the most prominent UK based centres for Nonlinear and Complex Dynamics. Members of the group have been Principal- and Co-Investigators, responsible for the modelling research in major systems biology, building a successful track record in RCUK and ERC grants, including BBSRC/SysMO £449K (of £898K total grant), BBSRC/SABR £1.4 million (of £2.5 million), and other EPSRC, BBSRC, NERC, MRC and EU FP7 grants of total value £5.9 million, more than £2 million of which is directly secured by staff submitted to this Unit.

b. Research strategy

Structure and leadership. Presently, the main research groups within Pure Mathematics are *Algebra* and *Topology* with smaller groups in *Mathematical Physics* and *Analysis*. The research in all themes has links with Representation Theory, which is a pivotal research area. This approach fosters interaction between the researchers. The Algebra group is therefore strategically important. It includes two distinguished experts in *Modular Representation Theory* (**Benson** and Robinson) and efforts are being made to expand it. **Benson** is well known for his interest in both Representation Theory and in Algebraic Topology. He has authored 10 books and has 125 publications in peer-reviewed journals.

Research in Applied Mathematics is highly interdisciplinary and strategically centred around the Theory of *Dynamical Systems* and *Mathematical Modelling*. This group is led by **Grebogi,** who is renowned for his seminal contributions to the theory of Dynamical Systems and their applications, and is a Thompson-ISI Highly Cited Author with 19,000 citations and ISI h-index 64. **Lai** (10,000 citations and Google Scholar h-index 52) leads the theme on compressive sensing, relativistic quantum chaos (graphene), and population dynamics. **Politi** (7,000 citations, Google Scholar h-index=43) leads the theme on non-equilibrium stochastic dynamics, statistical mechanics and neural networks. **Kurths** (ISI Highly Cited Author with 18,000 citations and ISI h-index 57) leads the theme on time series analysis, complex networks and fractional differential systems.

Strategically, the Applied Mathematics group endeavours to translate new abstract results directly into applications in physics, biology, neuroscience, engineering and medicine. Overall, the group's research can be broadly classified into (i) the development of new mathematical approaches to address technological, biological and physical systems, and (ii) the application of these approaches to develop predictive models. Individuals within Applied Mathematics focus on areas such as discrete mathematics and graph theory, differential and chaotic dynamical systems, Boolean and tropical algebras, and data and time series analysis and hypothesis testing.

The structure described above of a small number of pivotal research areas within IPAM, reflects

a university-wide strategic concept that areas of strength – Representation Theory and Mathematical Modelling in our case – will be given priority in terms of investment.

Current position and strategic achievements: The evidence the group in systems biology has shown since 2008 in attracting funds in various application areas, led the University of Aberdeen to highlight the formation of an internationally leading group in applied mathematics as an objective in its Strategic Plan. Through strategic recruitment, the group in applied mathematics has substantially grown from 3 to 14 members over the REF period. At the same time, collaboration between the groups in pure and applied mathematics has been encouraged and supported in both the teaching and research, efforts that have culminated in the recent launch of IPAM.

The aim for Mathematics at Aberdeen is primarily to sustain, expand and develop the strength of the leading research groups in Representation Theory and Topology, and in Dynamical Systems. Our areas of strength are the key to our academic vitality and sustainability, and our primary goal is to focus on the existing foundations of our activity in which we are successful. At the same time, in order to enhance the productivity of our research environment, we aim to increase the interactions among all the researchers. We will do this by creating bridges between existing research themes by means of suitable additional appointments of new staff with relevant expertise. Generating connections between the Pure and Applied groups is a current priority in the strategic aim of the unit. Examples for the implementation of this strategy to consolidate these groups include the results of existing fruitful collaborations (e.g. Thiel/Robinson), and the recent appointment of **Izhakian** (2013) whose research on Tropical Algebras is related to both Representation Theory and to the Applied Mathematics group, linking to the research interests especially of **Schelter** and **Thiel**.

The future strategic plan is to further develop the current academic excellence of IPAM, to allow it to achieve its' full potential. This lies in the strength and reputation of our senior staff (**Benson**, **Grebogi, Kurths, Lai, Politi,** Robinson), which is able to attract and guide new staff and lead research projects of considerable scientific importance. We aim to take advantage of their international reputation to attract and appoint academic staff with promising research potential to sustain the long-term future and stature of the Institute.

We endeavour to create an all-round research environment by maintaining our approach to recruit to fill in the gaps between groups, and to strengthen existing ones. For example, the recent appointment of **Tikuisis** (2013) strengthens the Analysis group. **Ginelli** and **Politi** were appointed in 2011 to address a gap in non-equilibrium statistical mechanics, which was required for our collaborations with life sciences. This was augmented by the appointments of **Perez-Reche** (2012) and **Henkes** (2013) in Non-equilibrium Stochastic Dynamics. The appointment of **Schelter** in Dynamical Systems, whose innovative approaches to nonlinear data analysis give us another leap forward in our ability to perform data-base mathematical modelling, also strengthen our unit's leadership and international standing in that field. **Politi**'s research in Network Dynamics also connects to, and complements, the Algebraic Topology approach implemented by **Levi** in his involvement within the Blue Brain project in neuroscience (see section e). We also plan to recruit further early career staff to fill in gaps within the Algebra group, with emphasis on Representation Theory.

We will create new research groups as such opportunities and needs arise, taking advantage of our strength and reputation in the core areas. A primary example of the success of this strategy is **Grebogi**'s appointment in 2005, which established the Applied Mathematics group; **Sevastyanov**'s and **Gorbunov**'s appointments in 2005 and 2006 established the group in Mathematical Physics.

Stronger collaboration between the Pure and Applied groups is viewed as offering significant future potential. Thus, an important aspect of our strategic plan has been to consolidate these groups by creating the Institute of Pure and Applied Mathematics (IPAM). The view is that combining the two groups into one physical unit will increase the interaction between their members, and maximise opportunities for both inter-disciplinary research, and the development of further impact. In addition we intend to invest in further appointments of academic staff with interests common to both groups. This process has already begun, and includes (i) successful appointments made to date (for example **Izhakian** described above), and (ii) joint activities in student training highlighted by joint supervision of postgraduate students.

Our international competitiveness in developing predictive dynamical models backed by experimental validation of the models through data analysis is an important aspect of our strategy. We will deepen this in order to expand the scope of our inter- and multi-disciplinary collaborations

through groups in the life sciences and in medicine (such as the BBSRC/SABR project on cell stress and EU/BBSRC/SysMO project on homeostasis), and also linked to other disciplines such as physics (graphene, **Lai, Grebogi**), engineering (EPSRC project on flow of information and energy in networks, **Baptista**) and social sciences (tipping points, **Thiel**). We also engage with commercial enterprises, for example, Ingenza Ltd. (protein synthesis led by **Romano)** and TauRx (a dementia-targeted project led by **Schelter**). The goal is to attract internal and external investments, to secure the standing and unique features of mathematics research at Aberdeen. The commitment to pure and applied mathematics has been complemented an upgrade to physical infrastructure in 2009 for IPAM, with further growth accommodated within a new Science building planned for 2018.

Our vision for Mathematics is to preserve our strength as a leading centre in Representation Theory, Topology, Theory of Dynamical Systems, and Mathematical Modelling. The Applied Mathematics group will fulfil its ambition by actively and sustainably creating and developing research ideas, collaborating with other scientists across the breadth of academic disciplines, professionals, business and other end users.

These developments will lead to continued expansion of our Institute, both in size and quality, by researchers of the highest potential. Our strategic plan positions us to fulfil our ambitions in terms of new knowledge creation, impact, and staff career development, through the continued consolidation of the Pure and Applied groups. It is anticipated that this will facilitate growth in postgraduate student numbers and research fellowships in Mathematics, both internally- and externally-funded. Growth in this area will help maintain and develop a vibrant, flexible and sustainable research environment, with important consequences for the size and quality of our undergraduate student intake.

c. People, including:

i. **Staffing strategy and staff development**

Staffing strategy. In line with the strategic plan, we appointed highly promising young researchers in areas close to existing strengths in Pure and Applied Mathematics. In Pure Mathematics these included **Gramain** (Algebra, 2011), **Hepworth** and **Mclean** (Topology, 2011 and 2013, respectively) and **Tikuisis** (2013), to strengthen the Analysis theme. In Applied Mathematics, **Ginelli** (Networks and Spatial Dynamics, 2012), **Pérez Reche** and **Henkes** (Non-equilibrium Stochastic Dynamics, 2012 and 2013, respectively) and **Schelter** (Nonlinear Time Series Analysis, Data-base Modelling and Statistics, 2012) were appointed. Four of these young staff members are Early Career Researchers. Furthermore, the appointments of **Izhakian** (Pure, 2013) and **Politi** (Applied, 2011) reflect the plan to integrate the Pure and Applied groups.

In addition to internal investments, external resources have been secured to expand the Institute. Aberdeen's successful application to join SUPA (Scottish Universities Physics Alliance) in 2009 resulted in award of funding for three new staff positions in Applied Mathematics (Chair – **Politi**, and 2 Lecturers – **Ginelli** and **Pérez Reche**). We also benefited from two other Scottish Funding Council (SFC) research pooling initiatives, SULSA (Scottish Universities Life Science Alliance) with 3 positions (Chair – **Kurths**, 2 Lecturers – **Romano** and **Ullner**), and NRPe (Northern Research Partnership in Engineering) with two positions (Chair – **Lai**, Senior Lecturer - **Baptista**).

Equality & Diversity. The University has been awarded the bronze *Athena Swan Award* for supportive environment for female researchers. Training on equality and diversity legislation, and the University's E&D policy is compulsory for all staff sitting on selection or promotion panels.

Staff development. Early career researchers have reduced teaching and administration loads to give them time to concentrate on research and to apply for appropriate research funding. In the first year of their appointments, the reduction in teaching is 50% and in the second year it is 25%. In addition, dedicated funds (a minimum of £1K per year) are allocated to ECRs in the first 3 years of their employment to support research activities such as conference attendance and research visits. Senior colleagues are appointed as their mentors. They provide advice and support in the development of collaborative research, explore their training and development needs, and advise on managing a balance between teaching, research and administration. Progress is reviewed annually by the mentors. We operate an annual appraisal scheme for staff in the Unit, including academic staff, research assistants and support staff. With respect to research staff, for example, appraisal addresses both progress and future plans regarding their specific research projects, and their wider career and personal development. Upward feedback is provided to inform departmental

and wider institutional strategy for staff development.

Researchers are supported financially through several institutional funding schemes. The *Principal's Excellence Fund* supports and encourages academic endeavour by academic staff and postgraduate students by means of small grants awarded to projects or initiatives that meet the University's Strategic Plan. Such funds have been utilised to organise an international conference on the Isle of Skye in 2009 on "*Algebraic Topology, Group Theory and Representation Theory*" and to fund a Workshop *on Dementia* (2011) to enable us to lead a large EU competitive proposal on dementia involving a number of partners.

Teaching loads are assigned in a flexible manner, and the Unit has made investment in teaching fellowships to reduce the teaching load of research-active staff, with 11 Teaching Fellows currently employed at IPAM. The University has a flexible policy of Research Leave from which the academic staff has benefitted. Since 2008 our host School, the School of Computing and Natural Sciences, approved a total of close to 3 years of staff leave to allow academics to take advantage of research fellowships. This included **Gorbunov** (6-9 months leaves at the Hausdorff Institute and at the Max-Plank-Institute in Bonn in 2008 and 2012) and **Benson** (6 months at Berkeley MSRI in 2008).

The University has a dedicated Researcher Development Unit (RDU) providing a programme of professional development courses and workshops for researchers in all levels. These range from induction courses for new appointees with emphasis on support for ECRs, to an International Leadership Development Programme. The RDU also manages a Researcher-Led Initiatives fund to support career development. Our Research and Innovation section advises researchers on available funding opportunities and application guidelines, and supports the application process. The University holds an *HR Excellence in Research Award* (2008) from the European Commission, recognising alignment with the Concordat to Support the Career Development of Researchers, and an *Investor in People Award* (IiP), recognising and valuing the contribution of employees in accordance with IiP Standards.

Post-doctoral research fellows (PDRFs), usually funded by research councils, trusts, and commercial enterprises, also have access to the University's generic skills courses. PIs are intensively involved in the development of their research fellows and the monitoring of their progress. Between 2008 and 2012 the Pure Mathematics group hosted 9 PDRFs of whom 7 were subsequently appointed to academic positions elsewhere, giving a strong indication of the effectiveness of our development activities and the environment we provide. Examples are Drs Diaz (Malaga), Mazza (Lancaster) and Glesser (California State University Fullerton). The 7 PDRFs and 14 Postgraduate researchers in Applied Mathematics benefit from monitoring schemes aligned with SUPA (Scottish Universities Physics Alliance) and SULSA (Scottish Universities Life Science Alliance), in addition to the University's provision. After leaving the IPAM several of these post-doctoral staff have secured prestigious research positions in academia, for example Brackley (Edinburgh) and Rodrigues (Max-Planck-Institute for Applied Mathematics, Leipzig), in addition to positions in industry, e.g. Almeida and You (AstraZeneca).

Scholarly activities. IPAM supports a programme of weekly seminars in Algebra, in Topology, and in Dynamical Systems, and monthly IPAM colloquia. Independent study-groups are often organised by the postgraduate students in a variety of subjects related to their research, and are supported by the senior members of staff. Recent examples are study-groups in Lie Theory (2011, run by a former PG student J. Taylor); Symplectic Homology Theory (2013, run by **Hepworth, Kedra** and **McLean**); Nonlinear Dynamics (run by **Thiel**), and the postgraduate and post-doctoral seminar series in Applied Mathematics (run by the postgraduate student J. Karschau).

The Potter Fund supports an annual visit of an influential overseas mathematician to give a high profile lecture. Recent invitees were Gunnar Carlsson (Stanford) and Charles Curtis (Oregon). We also host one annual Edinburgh Mathematical Society Lecture that is normally intended for a general mathematical audience. As a member of North British Differential Equations Lecture Tour, we host prominent Applied Mathematicians (for example, Pego, from Carnegie-Mellon University, 2009). To promote multidisciplinary activities within the College, a regular non-specialised seminar is organised by the School of Natural and Computing Sciences, attended by mathematicians, physicists, computer scientists, engineers and others.

IPAM is also involved in the organisation of international conferences. In 2009 we organised a conference in the Isle of Skye, which highlighted collaborations between the Topology and the Representation Theory communities. In 2007 and 2009 we organised conferences on Dynamical

Systems and on Systems Biology, respectively, which stimulated a broad range of collaborations with external peers (See section e).

Fellowships awarded to members of IPAM in open competition include **Benson** who won the *Simons Professor* fellowship for the Programme on Representation Theory of Finite Groups and Related Topics at MSRI, Berkeley between January and May 2008, and **Tikuisis** who was awarded a research fellowship in 2013 for 2 years from the Natural Sciences and Engineering Research Council of Canada.

Visiting scholars: IPAM, supported by the School's external grant income, encourages invitations to external researchers and collaborators. In Pure Mathematics, examples of research visits have included an Huef (Otago) in 2008, 2011 and 2013; Intermont (Kalamazoo) in 2009; Kaniuth (Paderborn) 2010; Brandenbursky (Vanderbilt) in 2011; and Chermak (Kansas) in 2011 and 2012. Their research interests cover Algebra, Topology, and Analysis.

Researchers in the Applied Mathematics group have hosted close to 80 international scholars since 2008, including a number of repeat visits, and several undergraduate, MSc and research postgraduate students from overseas project partners and collaborators. Notable examples include Lefranc (Lille University, 2009 and 2012), Geddes (Olin, 2010 and 2011), Cerdeira (ICTP, Trieste, 2013), Americo (University of Sao Paulo, 2011 and 2013), Schiff (Penn State, 2006 and 2009), Sauer (George Mason, 2009), and Gluckman (Penn State, Sabbatical, 2013) . Such visits are used to stimulate and progress research collaborations, and to contribute to the vitality of the research environment especially for early career post-doctoral staff and research students.

ii. **Research students**

All applications for a supervised PhD are reviewed and evaluated by the Graduate School and sent to the Postgraduate Coordinators for scientific evaluation and suitability. Applicants are assigned a provisional advisor to suit their academic field of interest. The research students work with a supervisory team, with a designated lead supervisor. Students' progress is monitored within a framework set up by the School. A report on training and progress is completed by the students every 6 months, after which the student is interviewed by the supervisory team which reports upwards to the Graduate School. The student's progression to the next stage in the programme is reviewed annually by the School. Written feedback is given to students and their supervisors. **Levi** (current PG Coordinator) manages this process with support from the Research Office and the Graduate School. The numbers of students, particularly those with external funding, is increasing. This trend benefits from the funding from the Brazilian "*Science without Borders*" programme (3 students, 2013), Nigerian Government (3 students, 2012), and the Chinese Natural Science Foundation (2 students, 2011).

Generic skills and supervision. The recruitment, supervision, generic skills training and progression monitoring of postgraduate students is organised centrally by the College of Physical Sciences Graduate School, supplemented with specialist skills training provided within the Unit. All new postgraduates attend a two-day induction programme covering the basics of postgraduate education in the University. Further training is provided in the form of university-wide core courses in generic skills (e.g. academic writing), which continue throughout the studentship, culminating in half-day workshops on thesis and viva preparation. They also benefit from involvement in training through the University's Public Engagement with Research Unit (PERU), which is augmented by the Principal's Prize for Public Engagement with Research. Students' progress is monitored by a committee of two members of staff nominated for this purpose at the commencement of the programme.

Academic training. Postgraduate students are encouraged to run study groups on topics related to the strengths of IPAM. Senior members of staff support these seminars, as described above. These seminars contribute to the student's interaction with staff and their engagement with research activities in the Institute. Postgraduate students are also expected to attend the regular research seminars, and when appropriate to contribute to them. To broaden our students' mathematical background we utilise networks of comprehensive programmes of postgraduate courses in Mathematics from both SUPA (Scottish Universities Physics Alliance) and from the SMSTC (Scottish Mathematical Sciences Training Centre). Both are delivered by means of advanced video conferencing facilities. The sections in Topology and Geometry and in Mathematical Modelling are co-ordinated by the University of Aberdeen. We also take part in teaching the Algebra and Analysis sections and in the SUPA-wide curriculum. A programme of more advanced internal and external postgraduate courses augments the consortium courses.

Awards. Three of our postgraduate students were awarded the SUPA Postgraduate Studentship Prize (Obrer Rubido, McLeman, Oniga) and the Carnegie Scholar Fellowship (Oniga). In 2012, our students Guseva and Radmaneshfar were invited and paid by Springer-Verlag to publish their doctoral theses.

d. Income, infrastructure and facilities

Infrastructure and facilities: Since 2009 Pure Mathematics has been located in a newly constructed annex, specifically designed to support mathematical research. It has a large open plan, common area for informal discussion, and a lecture room with state of the art equipment, forming a small-scale conference facility. The expansion in size of the Applied Mathematics group led to its relocation to renovated new quarters, which offer convenient working space with excellent facilities for interaction and collaboration, including a large common room and the SUPA advanced video-conferencing facility. IPAM benefits from a library budget of £760K allocated to the School of Computing and Natural Sciences, which is used to obtain access to most journals required by the staff. Electronic access is available through a University wide subscription list. In addition, the university has built a modern library facility with overall cost of £57 million.

IPAM, with RCUK and University funding, has procured and installed a High Performance Computer Cluster, with 554 cores and a capability of 12 Teraflops. It is the most powerful on campus. It is used to support our nonlinear time series analysis and database modelling development. Two high level technicians maintain IPAM's computer cluster and the large network used by the academic staff, PDRFs, students and visitors.

Income. Funding for research activities in IPAM is obtained mainly from UK and European Research Councils, Mathematical Societies, and industry. In the Pure group funding is usually from EPSRC and small grants from LMS, EMS and the Glasgow Math. J. Trust (**Archbold**, **Hepworth**, **Kedra**, **Sevastyanov**). We also secure European funding (**Levi**). In the Applied group, our approach for funding is to collaborate on multi-disciplinary projects particularly with life sciences and engineering, submitting joint applications. Examples are the joint BBSRC/SysMO and BBSRC/SABR projects with the College of Life Sciences & Medicine. The majority of the Unit's income comes from Research Councils, the EU and commercial enterprises, including current grants with BBSRC (totalling £1.76M), EU/ITN Marie Curie (£228K), EPSRC (£260K), Ingenza (£171K) and TauRx (£788K), a reflection of the success of our strategy. These are the contributions to IPAM; the total value of these grants is often significantly greater.

Postgraduate and personal-development teaching is a source of income separate from research grant funding. We developed and teach a popular SUPA postgraduate modelling course, which is an important component of our SUPA involvement. The course attracted more than 80 students in 2013 from across Scotland. We have also developed a Pure and Applied Mathematics MSc programme, recruiting 9 students in its first year (2013). An MSc programme in Systems Biology, funded by BBSRC, is well established, shared between IPAM and the Institute of Medical Sciences (about 10 students per year). All such taught postgraduate courses have been designed as a direct result of the success of our research outcomes.

e. Collaboration or contribution to the discipline or research base

Leadership and contribution to the research base. The Pure Mathematics group includes two influential researchers in Modular Representation theory (**Benson** and Robinson**)** and it is a leading centre for collaborative research in this area and in Homotopy Theory. This role was highlighted in 2009 when the Institute organised a conference at the Isle of Skye on "*Algebraic Topology, Group Theory and Representation Theory*". The event brought together a group of 120 Topologists and Representation Theorists to interact and collaborate, two groups that until very recently had little in common. Among the invitees were key figures such as Michael Aschbacher, Bob Oliver, Raphael Rouquier, and others. The January 2013 volume of Proc. Ed. Math. Soc. is the resulting conference proceedings. Other examples demonstrating this collaborative leadership is the ongoing joint work of Chermak (Kansas), **Levi** and **Libman** on p-local compact groups, and **Libman**'s articles (HHA 2010, J. Algebra 2011) on Linckelmann's gluing problem, introducing geometric methods to a purely algebraic problem centred on Alperin's weight conjecture. Our members of staff are frequently invited to international events on the subject (recent example is **Benson** and **Libman**, Amiens, 2012; **Levi**, Copenhagen, 2013).

To promote collaboration between new colleagues in Aberdeen and Glasgow, **Archbold** organised an Operator Algebra meeting in 2013 and **Tikuisis** is organising a meeting "C^*-algebras in Scotland" in 2013. **Sevastyanov** is the local organiser (Aberdeen) of ARTIN meetings – Algebra

and Representation Theory in the North – since 2008. **Hepworth** was the main organizer of the British Topology Meeting in Aberdeen in 2013. **Kedra** is a member of the Steering Committee of the CAST (Contact and Symplectic Topology) network grant 2010-2015, funded by the European Science Foundation. **Benson** was an organiser of various events and was also an invited speaker at the ICM2010, Hyderabad.

The applied group in IPAM led Aberdeen's team to the International Genetically Engineered Machine competitions (iGEM) at MIT in 2010 and 2011, which is an important event for the synthetic biology community. The team won a gold medal in the first year for overall performance, and a silver medal in the following year. We organised two large conferences at the University of Aberdeen in 2007 and 2009 with over 150 participants in each, one on Dynamical Systems and another on Systems Biology. Distinguished participants included David Rand, James Yorke, Mark Chaplain, Robert MacKay, Floris Takens, Robert Devaney and Sir Michael Berry. **Schelter** has just secured for the University of Aberdeen the hosting of the 2014 Experimental Chaos Conference, an international series going back to 1990. **Thiel**, **Romano**, **Schelter** and **Moura** were also the organisers of three international conferences on Poincare Recurrence, Systems Biology, and Data-based Modelling in Neurobiology. The first conference resulted in the publication of a Springer book (2010) and the second in a special issue of the AIP Chaos (2010).

IPAM took part in the creation of the *Aberdeen-Lanzhou-Tempe Joint Research Centre for Computation and Complexity* at Lanzhou University in 2012 to carry out joint research work on quantum relativistic chaotic dynamics with emphasis on graphene systems, on population biology, and on complex networks.

In 2008, the American Physical Society selected **Grebogi**'s 1990 paper with Ott and Yorke on *Controlling Chaos* (Phys. Rev. Lett. 64, 1196-1199) as a milestone of the last 50 years (http://prl.aps.org/50years/milestones). **Izhakian**'s paper in Israel. J. Math 182 (2011) was awarded the 2012 Editor's choice. **Lai** and Tamas Tel's book (Springer, 2011) on *Transient Chaos* has become a standard reference, as did **Benson**'s book "Representations and Cohomology" (1998).

Politi was awarded the Humboldt Senior Prize in 2012; **Kurths** the Lewis Fry Richardson Medal in 2013 and Dr.h.c. from Lobatschevsky and Chernischevsky State Universities**.** Honorary professorships were awarded, for example, to **Grebogi** (Xi'an Jiaotong Univ., 2011 and Xi'an Univ. of Technology, 2012), **Lai** (Lanzhou University, 2012), and **Kurths** (Humboldt Univ., 2010); **Grebogi** was awarded the Freiburg Institute for Advanced Studies Senior Fellowship, 2011-2013; and **Benson** became an inaugural Fellow of the American Mathematical Society in 2013.

Wider influence. The pioneering work of Broto-**Levi**-Oliver in 2001 on p-local finite groups, initiated by **Levi**, has revealed a deep connection between Modular Representation Theory and Homotopy Theory. This subject attracted a lot of attention in the past decade yielding collaborations between mathematicians in these areas.

Our research in Applied Mathematics frequently influences the developments and research agenda in other disciplines. **Schelter**'s research led to his inclusion in the Advising Committee of the biannual series of International Workshops on Seizure Prediction in Epilepsy. He played a major role in the design and compilation of the largest and most comprehensive database of its type for epilepsy research, through the project EPILEPSIAE.

Wider community. The members of the Institute of Pure and Applied Mathematics take part in community activities such as leadership in societies and editorships. Robinson is a member of the London Mathematical Society Prizes Committee since 2013. He is currently the Director of the *Heilbronn Institute*. **Archbold** was the President of the Edinburgh Mathematical Society (2007-2009), Vice-President (2009-2010) and convenor of the Research Support Fund (2010-2013). While President, he represented the Society on the Council for Mathematical Sciences. He is Chair of the Scottish Mathematical Council (2011-present) and he is a member of REF2014 sub-panel B10. **Gramain**, **Kedra**, **Libman** have served as Trustees of the Edinburgh Mathematical Society (2008 to 2013). **Grebogi** was elected Fellow of the Royal Society of Edinburgh (2012) and **Kurths** of Academia Europaea (2010). **Grebogi** is an External Scientific Director of the Max-Planck-Society.

Benson has been a Chief Editor in the LMS Student Texts, since 2007 and an Editorial Advisor for the LMS in 2011-12. He is also a member of the editorial board of Forum Mathematicum, Transformation Groups, Bulletin of the American Mathematical Society, and other journal. He was an editor in Advances in Mathematics until 2009. Other examples of editorships are **Grebogi** (Theme Associate Editor of the Philosophical Transactions of the Royal Society A and then Board

Member), **Politi** (Associate Editor of both Journal of Physics A and Physical Review E), **Lai** (Co-Editor of European Physics Journal). IPAM members sit in another dozen Editorial Boards.

Exemplar Collaborations. Prof **Levi** is collaborating with the *Blue Brain* team at EPFL (Lausanne, Switzerland). It is one of the most prominent research groups in Neuroscience. A grant was awarded to the team of which £80K was allocated to fund a postgraduate student under **Levi**'s supervision to work on applications of Algebraic Topology to the Blue Brain project

The Applied Mathematics programme involves collaborations across Europe, Asia and the Americas as well as industrial collaborations. Collaborations include the Institute of Mathematics in Manchester on Tropical Algebra, TU Eindhoven on Non-differentiable dynamics, Freiburg Institute for Advanced Studies on data-based modelling, Max-Planck-Institute for the Physics of Complex Systems on non-hyperbolic dynamics, and many other academic collaborations.

Collaboration of **Romano** and **Thiel** with the Groenemeyer Institute for Microtherapy (Germany) gave rise to the development of the novel dynamical systems approach of "twin surrogates" designed to generate new trajectories, and in such a way to determine the underlying dynamical system in passive experiments. The collaboration had a crucial importance in the clinical research conducted by our partners. In addition, the IPAM enjoys collaborations with industrial partners. For example, **Schelter**'s collaboration with Micromed (Italy), whose purpose was the design of a device for seizure prediction in epilepsy patients, and with BrainMarker (The Netherlands) for the development and marketing of dementia diagnosis algorithms. Also **Romano**'s collaboration with Ingenza (UK) gave rise to a novel method to accelerate processes in protein engineering.

Approach to interdisciplinary research. As a strategy, the basic research in dynamical systems at IPAM does not only focus on questions arising from developments in theoretical dynamics itself, but reacts to arising problems in adjacent sciences and fields of application. It is our researchers' mission to explore and take advantage of such activities as part of their mathematical research. For example, the Theory of Complex Dynamical Systems and Systems Biology play a central role in integrating mathematical developments with biological and medical experiments. Indeed, a great deal of our interdisciplinary research is concentrated in these areas. Notable examples are **Romano**'s work on synchronisation of maternal-foetal heartbeats with researchers from Groenemeyer Institute for Microtherapy, and **Thiel** and **Schelter**'s work on early diagnosis of dementia joint with the Institute of Medical Sciences in Aberdeen. The synergistic developments in systems biology research are vigorously promoted and pursued by the members of the Institute, covering a wide range of mathematical approaches. In addition to pure research, we also seek industrial partners who are likely to benefit from our mathematical developments, and by this we inherently take part in multi-disciplinary activities with engineers, both in academia and industry. Examples are abundant: **Schelter**'s involvement in the development of the LTM-Express by Micromed, Italy and TauRx, Scotland; **Romano**'s collaboration with Ingenza on methods in protein engineering; and **Baptista** and **Grebogi**'s patent application, being helped by guidance from the University's legal team, for an advanced underwater wireless communication system.

Public engagement: The unit is involved in various activities intended to introduce mathematics research to the public. IPAM coordinates the *Scottish Mathematical Challenge* competition for schools in the North of Scotland since 1976. The goal is to engage children with mathematics. Last year 472 pupils from 34 schools took part. Public lectures on mathematics and its applications given by members of IPAM include **Benson**'s lectures on mathematics and music: "Mozart, Maths and Mechanics" at the Music Hall in Aberdeen in 2009 (approx. 600 attendees), and "Symmetry in Music" at MSRI - Berkeley, 2013 (approx. 200 attendees). **Thiel**'s lectures include "Dating Poems with Mathematics" (Word Festival 2009 approx 70 attendees), "The War Within Us: How Biologists and Mathematicians Team Up to Fight Diseases" (British Science Festival 2012, approx. 40 attendees), "Mathematics and Crime" (Science Festival 2012, approx. 40 attendees), and "Mathematics of Dating" (Café Scientifique, Aberdeen 2013, approx. 80 attendees). He also gave various lectures at Albyn school (Aberdeen). Evidence of the success of these events is the application of pupils for summer studentship awards (e.g. Nuffield Foundation). We typically have 3 pupils every summer, some of whom have gone on to prestigious HE establishments, e.g. Loughney (Oxford, Physics).