

# DEPARTMENT OF MATHEMATICS

Annual Report 09

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$$z_1 = z_0 + \epsilon$$
$$(3+2i) \times (4-5i) = 3 \times 4 - 3 \times 5i + 4 \times 2i - 2 \times 5$$
$$(z_0)^2 = 0$$

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THE LONDON SCHOOL  
OF ECONOMICS AND  
POLITICAL SCIENCE

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# Introduction

This annual report of the LSE Mathematics Department describes the teaching and research activities of the Department during 2009. It has been another busy year for us, with a number of interesting developments on the teaching and research fronts. After a period of rapid expansion the Department has continued to grow, with new academic appointments and greater student numbers, particularly on our new MSc programme in Financial Mathematics, which saw its first cohort of students graduate in 2009.

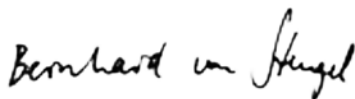
We are delighted to have welcomed two new members of academic staff in 2009: **Albina Danilova** joined us as a lecturer, adding to our expertise in financial mathematics, and **Konrad Swanepoel**, whose research speciality is in combinatorial discrete geometry, also started as a lecturer. In making these appointments we have continued to increase the multinational composition of our academic body and to strengthen our expertise in a range of areas. In addition, **Rebecca Batey** has joined our great administrative team. Rebecca will look after our MSc students. Finally, in 2009 we said goodbye to **Amol Sasane**, who left the department at the end of the year to join the Royal Institute of Technology in Stockholm. Amol has been a valued member of the Department since he joined in 2004 and he will be greatly missed.

Our MSc in Applicable Mathematics continues to thrive, with an intake of 31 students this year. More information on the programme can be found on page 5. Our new MSc programme in Financial Mathematics has proved extremely popular and it has expanded rapidly in only its second year, welcoming 27 new students in 2009.

The BSc Mathematics and Economics programme continues to attract a large number of talented applicants from all over the world, and our graduates proceed on to successful careers or to further study in a range of areas. The department recently took the decision to expand its undergraduate provision and we are very pleased to announce a new BSc in Mathematics with Economics, with a greater emphasis on mathematics, which will welcome new first-year students in 2010.

In 2009 we were joined by a number of new research students in the department. Details of our current research students and their activities may be found on page 5.

The LSE is a unique institution in that its focus is primarily on the social sciences. The Mathematics Department's research mission is to conduct outstanding research in mathematics within this context. Descriptions of our research interests may be found in this report, as well as information about publications, guest lectures, and our other research-related activities.



**Bernhard von Stengel**  
Head of Department



# New members of staff

## Albina Danilova

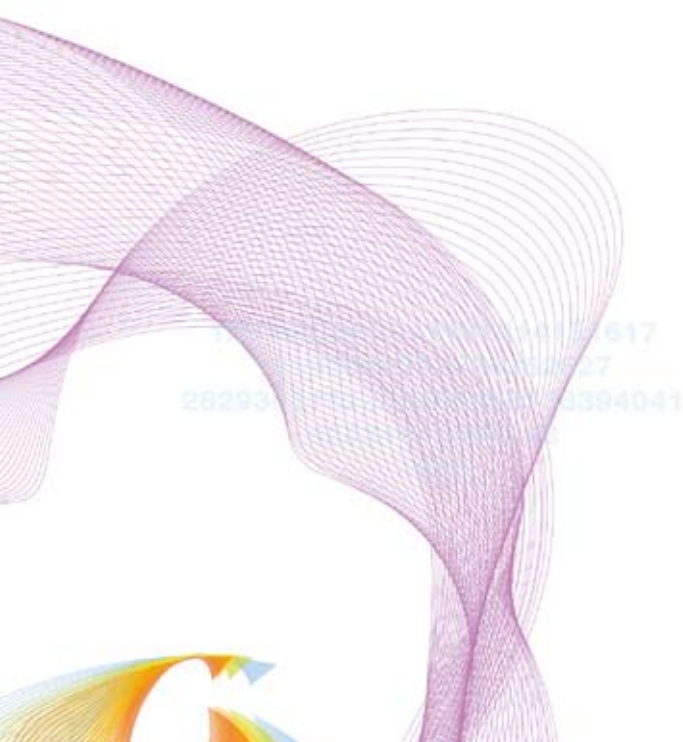


Albina Danilova joined us in July 2009. A former student of Moscow State University, she received her MSc in Mathematical Modelling and Scientific Computing from the University of Oxford in 2000 and completed her PhD degree in Operations Research and Financial Engineering in 2005 at Princeton University. Prior to joining LSE she took up a post-Doctoral fellowship position at University of Oxford and Carnegie Mellon University (Pittsburgh). Her current research interests include filtering, enlargement of filtrations and stochastic control and optimisation; derivatives pricing and hedging in incomplete markets and/or under asymmetric information, utility maximisation and equilibrium.

## Konrad Swanepoel



Konrad Swanepoel joined us in September 2009. He received his BSc and BSc (Hons) in Mathematics in 1992, his MSc in 1993 and his PhD in 1997, all at the University of Pretoria. He held the positions of Lecturer, Senior Lecturer and Associate Professor from 1994 to 2001 at the University of Pretoria, after which he was an Associate Professor at the University of South Africa until 2007. Before joining LSE he held a temporary position at the Chemnitz University of Technology. His main research topics are in combinatorial and discrete geometry including the geometry of finite-dimensional normed spaces and geometric shortest networks such as Steiner Minimal Trees, but he is also interested in axiomatic geometry, finite geometries and extremal combinatorics.



# Departmental staff

## Professors

S Alpern, AB (Princeton), PhD (New York)

M H G Anthony, BSc (Glasgow), PhD (London),  
MA (Institute of Education, London)

N L Biggs, MA (Cantab), DSc (London)

G Brightwell, MA, PhD (Cantab)

O Gossner, Agrégation, PhD (Université Paris 6), Habil (Paris)

J van den Heuvel, MSc (Eindhoven), PhD (Twente)

B von Stengel, Dipl (Aachen), MSc (Austin, Texas), PhD (Passau),  
Habil (Munich)

M Zervos, MSc (NTUA, Athens), MSc, PhD (Imperial, London)

## Readers

M Luczak, MA, DPhil. (Oxford)

A Ostaszewski, BSc, PhD (London)

## Lecturers

T Batu, BSc (Bilkent, Ankara), PhD (Cornell, Ithaca)

A Danilova, BSc (Moscow), MSc (Oxford), PhD (Princeton)

P Gapeev, MSc, PhD (Moscow), Habil (Berlin)

A Lokka, Cand Scient, Dr Scient (Oslo)

A Sasane, BTech (Bombay), PhD (Groningen)

R J Simon, BA, PhD (Bielefeld)

J Skokan, MSc (Czech Tech, Prague), MSc, PhD (Emory, Atlanta)

K Swanepoel, BSc, MSc, PhD (Pretoria)

## Course Tutors

J M Ward, BSc (Birmingham), PhD (London), DIC, BA (London)

M Harvey, BSc (Emory, Atlanta), MSc, PhD (Columbia, New York)

## Visiting Professor

N H Bingham, BA (Oxford), PhD, ScD (Cantab)

## Administration

J Everid

S Jolly, BA, MSc (LSE)

D Scott, BA, MSc (LSE)

R Batey, BSocSc (Manchester)



# Degree programmes

## BSc in Mathematics and Economics

In addition to teaching courses for many of the undergraduate students in other departments of LSE, the Mathematics Department is responsible for its own undergraduate degree: the BSc in Mathematics and Economics. This is a joint degree in mathematics and in economics, carefully structured to ensure the mathematical topics fit well with the economics options. This degree programme is very popular; the number of applications is more than twelve times the target of about 80 first year students the department is now aiming for.

The quality of the incoming students is reflected in the results they obtain at the end of their degree. There were 43 finalists in the degree graduating in the Summer of 2009. Of these, 30 per cent graduated with a First Class Honours Degree and 33 per cent with an Upper Second.

After graduation, our students head off in a wide variety of directions. Many are interested in careers in consultancy and finance, and most have no problem finding positions in top establishments. It is clear that financial companies in particular appreciate the mix of rigorous mathematical study with subjects in which students are exposed to economics and other applications that is the hallmark of our BSc degree.

A significant number of our students are continuing their studies in graduate degree programmes. Popular subject areas include fairly pure mathematics, and economics, and of course our own Masters degrees in Applicable Mathematics and in Financial Mathematics.

## MSc in Applicable Mathematics

The MSc in Applicable Mathematics is an innovative programme, drawing together traditional and modern mathematical techniques related to a social science environment. Students are offered a range of mathematics options, and also the opportunity to take one or two social science modules (from Economics, Finance, Government, Operational Research, or Statistics), where they can see applications of some of the mathematics they are learning. The skills and knowledge gained are then used to prepare an in-depth mathematical project for their dissertation. The MSc opens up a wide range of potential careers to its graduates: in finance, business, government, and industry. Career destinations have been diverse and vary from the big financial institutions to consultancy firms and government departments. The MSc also provides a solid base for further studies at research level and a number of graduates are pursuing further degrees in areas such as mathematics, computer science, economics, and finance.

The programme is intended to have broad appeal to pure and applied mathematicians who wish to make themselves more 'marketable' by adding some social science aspects to their knowledge and skills base, to students with a science or engineering background who want to add more advanced general

mathematical skills to their expertise, and to social scientists with strong quantitative backgrounds who wish to add to and improve their understanding of the mathematics behind much of social science. It is one of the first degree courses anywhere to combine discrete and algorithmic methods with social science and game theoretic ideas. These create a package that can be applied to understanding and solving a wide variety of problems.

The first five years of the degree have seen remarkable academic successes from the students on the programme. Graduates have shown no problems pursuing a successful career. Additionally, for a large percentage of students the degree has been a stepping stone for entry in high-level further degrees. The topics of research degrees we find those graduates in includes pure mathematics, financial mathematics, economics, law, and many others.

We look forward to attracting students of similar outstanding academic calibre in future years. The department has also been happy to welcome students from the MSc as part of our growing group of research students and we hope this relationship between the degrees will continue to flourish.

## MSc in Financial Mathematics

The MSc in Financial Mathematics is an intensive and academically demanding programme that is based in the Department of Mathematics, and is taught in collaboration with the Department of Finance and the Department of Statistics. The programme draws on LSE's strengths in finance, mathematics and related areas. It aims to develop students' understanding of the foundations of financial mathematics, and to equip them with knowledge of a range of mathematical and computational techniques that are required for a variety of quantitative positions in the financial sector.

The Financial Mathematics MSc is now in its second year and it has again attracted large numbers of applications, with over 600 received for a target of 20 places. The first cohort of students graduated in July 2009 with remarkable levels of academic attainment.

## MPhil/PhD in Mathematics

Supervision for MPhil and PhD research is available in pure mathematics in the areas of discrete mathematics (including combinatorics and graph theory), theory of computation and algorithms, game theory (including search theory), financial mathematics, probability theory and in the applications of mathematics in areas such as telecommunications, finance and economics. We currently have a thriving and active group of 20 research students. You can find out more about their projects on page 20.

# Courses taught

During the academic year 2008-09 the department was responsible for teaching the following courses (the number of students who were examined in each course is also given):

Mathematical Methods **619**

Introduction to Abstract Mathematics **174**

Quantitative Methods (Mathematics) **254**

Basic Quantitative Methods **19**

Further Mathematical Methods (Calculus) **239**

Further Mathematical Methods (Linear Algebra) **242**

Real Analysis **103**

Further Quantitative Methods (Mathematics) **27**

Optimisation Theory **69**

Differential Equations **41**

Discrete Mathematics **23**

Game Theory **30**

Game Theory I **55**

Chaos in Dynamical Systems **7**

Optimisation In Function Spaces **9**

Mathematics of Finance and Valuation **26**

Probability for Finance and Economics **6**

Theory of Algorithms **4**

Algebra and its Applications **13**

Game Theory I **28**

Algorithms and Computation **11**

Discrete Mathematics and Complexity **7**

Continuous-Time Optimisation **5**

Information, Communication and Cryptography **30**

Probability and Measure **7**

Functional Analysis and its Applications **10**

Games of Incomplete Information **9**

Stochastic Analysis **38**

The Mathematics of the Black and Scholes Theory **21**

The Foundations of Interest Rate, Foreign Exchange, and Credit Risk Theory **11**

Computational Methods in Finance **2**

Strategic Analysis of Options **15**

Search Games **33**

Dissertation in Mathematics **30**

## Number of students taking taught degrees based in the Mathematics Department, academic year 2009-10

	1st Year	2nd Year	3rd Year
BSc Mathematics and Economics	107	82	66
MSc Applicable Mathematics	31	N/A	N/A
MSc Financial Mathematics	27	N/A	N/A

A large proportion of our undergraduate teaching is provided for students taking degrees run by other departments. Of the 1,400 first-year undergraduates in the School in 2009-10, approximately 870 are taking at least one module in mathematics. We are helped in the delivery of our teaching by a talented and dedicated team of class teachers. Every year, class teachers in mathematics are eligible for School teaching prizes. We are pleased to say that, this year, the prizes were awarded to David Ferguson, Ioannis Kouletsis and Julian Merschen. These are awarded annually by LSE's Teaching and Learning Committee based on a number of factors, including the termly surveys of students' opinions of class teaching.

# Research disciplines and current research interests

## Game Theory

Game theory is the formal study of conflict and cooperation. Game theoretic concepts apply whenever the actions of several agents are interdependent. These agents may be individuals, groups, firms, or any combination of these. The concepts of game theory provide a language to formulate, structure, analyse and understand strategic scenarios.



**Steve Alpern** works on mathematical ecology (mate selection games, predator search problems, caching behaviour), search games, accumulation games, copying games.



**Olivier Gossner** works in game theory, theoretical economics, and statistics. More specifically, games with incomplete information, entropy and codification, and repeated games.



**Robert Simon** works on stochastic games and dynamic systems, games of incomplete information, ergodic theory and topology, matroids and other shellable simplicial complexes.



**Bernhard von Stengel** works on mathematical and computational questions of game theory, in particular on geometric methods related to two-player games and equilibrium computation.

## Discrete Mathematics and Algorithms

The LSE Mathematics Department has a number of academic staff working in various topics in Discrete Mathematics, especially algorithmic aspects. The interface between Theoretical Computer Science and Discrete Mathematics has been highlighted by recent EPSRC Reviews of both disciplines as being one of increasing importance, and LSE is well placed to be at the forefront of future developments.



**Martin Anthony** works in mathematical aspects of machine learning, particularly probabilistic modelling of learning and discrete mathematical problems in the theory of learning, data mining and artificial neural networks; Boolean function classes and their representations.



**Tugkan Batu** works in algorithms and theory of computation. In particular, he is interested in randomised computation, (sublinear) algorithms on massive data sets, property testing, and computational statistics.



**Norman Biggs** is a leading figure in algebraic graph theory. Recently he has written papers on the Tutte polynomial, and on strongly regular graphs. He also continues his research in the history of mathematics.



**Graham Brightwell** works on combinatorics in general, especially finite partially ordered sets, probabilistic methods, and algorithmic aspects.



**Jan van den Heuvel** works in discrete mathematics; in particular in graph theory, matroid theory, applications and algorithmic aspects of graph theory, mathematical aspects of frequency assignment problems, and mathematical aspects of networks.



**Malwina Luczak** works in probability theory, combinatorics, phase transitions, applications to queueing and telecommunications.



**Jozef Skokan** works on various topics in combinatorics and graph theory. In particular, he is interested in extremal set theory, quasi-random structures, probabilistic combinatorics, discrete geometry, graph theory, combinatorial games and topics in theoretical computer science.



**Konrad Swanepoel**: works in combinatorial and discrete geometry including the geometry of finite-dimensional normed spaces and geometric shortest networks such as Steiner Minimal Trees, but he is also interested in axiomatic geometry, finite geometries and extremal combinatorics.

## Financial Mathematics and Control Theory

The area of financial mathematics is concerned with the development and the analysis of models that can be of use to the valuation of investments in financial assets. Since the pioneering days of Black and Scholes, the area has attracted increasingly interest, reflecting the growth in the business of financial institutions. The part of financial mathematics that is concerned with the valuation of investment decision strategies overlaps with the theory of control and optimisation, which is a traditional branch of mathematics with a wide and far-reaching range of applications. Developments in both areas involve advanced theory from several areas of mathematics, including probability and stochastic processes, analysis, and partial differential equations.



**Nick Bingham** works in probability and stochastics, including applications to financial mathematics, and in analysis and statistics. At present he is working on topological variation, prediction theory for stationary time series and the application of Lévy processes to mathematical finance.



**Albina Danilova** works in filtering, enlargement of filtrations and stochastic control and optimisation; derivatives pricing and hedging in incomplete markets and/or under asymmetric information, utility maximisation and equilibrium.



**Pavel Gapeev** works in stochastic analysis and its applications in financial mathematics. He studies optimal stopping problems arising in mathematical statistics and finance. He is particularly interested in optimal stochastic control, interest rate models, and credit risk theory.



**Arne Lokka** works in stochastic analysis, Malliavin calculus for pure jump processes, filtering, optimal stopping problems, valuation of investment decisions, derivative pricing and hedging in incomplete markets.



**Adam Ostaszewski** works in applicable mathematics (mathematical finance, with a particular interest in real options and accounting theory, including corporate disclosure policy; bargaining theory) and pure mathematics (set-theoretic topology, and analytic and regular variation).



**Amol Sasane** works in applicable analysis, mainly in the intersection of operator theory, complex analysis and mathematical control theory.



**Mihail Zervos** works in a number of research areas, including stochastic analysis, stochastic control and optimisation, optimal stopping problems, valuation of investment decisions and investments in real options, options of American type, derivative pricing in incomplete markets, and weather derivatives.



# Publications

## Steve Alpern

(with R Fokkink, R Lindelauf and G Olsder)  
A numerical approach to the 'Princess and Monster' game on an interval  
*Annals, Int. Soc. Dynamic Games* 10 (2009), 149-157

(with A Morton and K Papadaki)  
Optimizing Randomized Patrols  
*OR Working Paper* LSEOR 09.116 ISSN 2041-4668 (Online)

(with S Gal)  
Analysis and design of selection committees: a game theoretic secretary problem  
*International Journal of Game Theory* 38 (2009), 3, pp. 377-394

(with V Baston and S Gal)  
Searching symmetric networks with Utilitarian-Postman paths  
*Networks*, 53 (2009) 4, pp. 392 – 402

(with I Katrantzi)  
Equilibria of two-sided matching games with common preferences  
*European Journal of Operational Research* 196, 3 (2009), pp. 1214-1222

(with S Gal and E Solan)  
A Sequential Selection Game with Vetoes  
*Games and Economic Behavior* (in press) doi:10.1016/j.geb.2009.05.006

(with R Fokkink)  
How to hide information for later use on networks.  
*Proceedings, Game Theory for Networks (GameNets)*, (2009), pp. 453 – 457

## Martin Anthony

(with M Subasi, E Subasi and P L Hammer)  
A new imputation method for incomplete binary data  
*RUTCOR Research Report* RRR 15-2009

On constructing threshold networks for pattern classification  
In *Constructive Neural Network Algorithms* (eds. Leonardo Franco, David Elizondo, Jose Jerez), Springer Studies in Computational Intelligence, 258, (2009) Springer

(with M Subasi, E Subasi and P L Hammer)  
Using a similarity measure for credible classification  
*Discrete Applied Mathematics* 157 (2009), (5, 6), 1104-1112

## Tugkan Batu

(with P Berenbrink and C Sohler)  
A Sublinear-Time Approximation Scheme for Bin Packing  
*Theoretical Computer Science* 410 (2009), (47-49), pp 5082-5092

## Norman Biggs

Tutte Polynomials of Bracelets  
*CDAM Research Report* LSE-CDAM 2009-01

Mathematics of Currency and Exchange: Arithmetic at the end of the Thirteenth Century  
*Bulletin of the British Society for the History of Mathematics* 24 (2009) 67-77

Strongly Regular Graphs with No Triangles  
*arXiv e-print arXiv:0911.2160v1*

Families of Parameters for SRNT Graphs  
*arXiv e-print arXiv: 0911.2455v1*

(with J Hutchinson)  
Knowles' Patent Yarn Balance  
*Textile History* 40, (1), (2009), pp. 97-102

## Nick Bingham

Five questions  
*In Probability and Statistics: 5 Questions* (ed. A Hájek and V F Hendricks), Automatic Press/VIP, 2009, 1-11

For papers by N H Bingham and A J Ostaszewski, see the entry for Adam Ostaszewski on page 11

## Graham Brightwell

(with N Georgiou)  
Continuum limits for classical sequential growth models  
*Random Structures and Algorithms*, (in print) doi:10.1002/rsa.20278



(with B Bollobás and R Morris)  
Shadows of Ordered Graphs  
*arXiv e-print arXiv:0906.3724v1*

(with K Panagiotou and A Steger)  
Extremal Subgraphs of Random Graphs: an Extended Version  
*arXiv e-print arXiv:0908.3778v1*

(with V Patel)  
Average relational distance in linear extensions of posets  
*Discrete Mathematics* (in print) doi:10.1016/j.disc.2009.10.016

(with M Luczak)  
Order-invariant Measures on Fixed Causal Sets  
*arXiv eprint arXiv:0901.0242v1*

(with M Luczak)  
Order-invariant Measures on Causal Sets  
*arXiv eprint arXiv:0901.0240v1*

(with J Henson and S Surya)  
A result in 2d causal set theory: the emergence of spacetime  
*J. Phys.: Conf. Ser.* (2009) 174 012049 (6pp)

## Albina Danilova

(with M Monoyios and A Ng)  
Optimal investment with inside information and parameter uncertainty  
*arXiv eprint arXiv:0911.3117*

Stock Market Insider Trading in Continuous Time with Imperfect Dynamic Information  
Accepted to appear in *Stochastics: An Intl Journal of Probability and Stochastic Processes*

## Pavel Gapeev

(with H R Lerche)  
Discounted optimal stopping for diffusions: free-boundary versus martingale approach  
*CDAM Research Report LSE-CDAM-2009-03*

(with D Belomestny)  
An iterative procedure for solving integral equations related to optimal stopping problems  
*SFB 649 Discussion Papers SFB649DP2006-043*,  
Sonderforschungsbereich 649, Humboldt University, Berlin, Germany

(with M Jeanblanc)  
Pricing of contingent claims in a two-dimensional model with random dividends.  
*International Journal of Theoretical and Applied Finance* 12 (2009), 8, pp. 1091-1104

## Olivier Gossner

(with J Hörner)  
When is the individually rational payoff in a repeated game equal to the minmax payoff  
*Journal of Economic Theory* (in press) doi:10.1016/j.jet.2009.07.002

Ability and knowledge  
*Games and Economic Behavior* (in press), doi:10.1016/j.geb.2009.10.011

(with E Kalai and R Weber)  
Information independence and common knowledge  
*Econometrica* 77 (2009), pp. 1317–1328

(with R Laraki and T Tomala)  
Informationally optimal correlation  
*Mathematical Programming Series B*, 116 (2009), Numbers 1-2

(with T Tomola)  
Repeated Games  
in *Encyclopedia of Complexity and Systems Science* (Ed. R. Meyers), Springer New York

## Jan van den Heuvel

(with D Bauer, H J Broersma, N Kahl and E Schmeichel)  
Degree sequences and the existence of k-factors  
Submitted. A preprint is available via *arXiv eprint arXiv:0912.2916*

(with D Bauer, H J Broersma, N Kahl and E Schmeichel)  
Toughness and vertex degrees  
Submitted. A preprint is available via *arXiv eprint arXiv:0912.2919*

(with L Cereceda and M Johnson)  
Mixing 3-colourings in bipartite graphs  
*European Journal of Combinatorics* 30, 7 (2009) 1593-1606

(with S Thomassé)  
Cyclic orderings and cyclic arboricity of matroids  
Submitted. A preprint is available via *arXiv eprint arXiv:0912.2929*

## Malwina Luczak

(with S Janson)  
A new approach to the Giant Component Problem  
*Random structures & algorithms* 34 (2009) (2), pp. 197-216

(with G Brightwell)  
Order-invariant Measures on Fixed Causal Sets  
*arXiv eprint arXiv:0901.0242v1*

(with G Brightwell)  
Order-invariant Measures on Causal Sets  
*arXiv eprint arXiv:0901.0240v1*

## Adam Ostaszewski

(with N H Bingham)  
Very slowly varying functions – II  
*Colloquium Mathematicum* 116 (2009), pp. 105-117

(with N H Bingham)  
Beyond Lebesgue and Baire: generic regular variation  
*Colloquium Mathematicum* 116 (2009), pp. 119-138

(with N H Bingham)  
The index theorem of topological regular variation and its applications  
*Journal of Math. Anal. Appl.* 358 (2009), pp. 238-248

(with N H Bingham)  
Infinite combinatorics and the foundations of regular variation  
*Journal of Math. Anal. Appl.* 360 (2009), pp. 518-529

(with N H Bingham)  
New automatic properties: subadditivity, convexity, uniformity  
*Aequationes Mathematicae* 78 (2009), pp. 257-270

(with N H Bingham)  
Infinite combinatorics in function spaces: category methods  
*Publications de l'Institut Mathématique, Nouvelle Série* 86 (100), (2009), pp. 55-73

## Amol Sasane

(with K Mikkola)  
Bass and Topological Stable Ranks of Complex and Real Algebras of Measures, Functions and Sequences  
*Complex Analysis and Operator Theory* (in print) doi:10.1007/s11785-009-0009-1

(with R Rupp)  
Reducibility in  $AR(K)$ ,  $CR(K)$  and  $A(K)$   
*Canadian Journal of Mathematics* (in print) DOI: 10.4153/CJM-2010-025-9

The Hermite Property of a Causal Wiener Algebra Used in Control Theory  
*Complex Analysis and Operator Theory* (in print) doi 10.1007/s11785-008-0078-6

(with R Mortini)  
Ideals of denominators in the disk-algebra  
*Bull. London Math. Soc.* 41 (2009) pp. 669-675

(with R Rupp)  
On the density of stabilizable plants in the class of unstabilizable plants: The real symmetric disk algebra case  
*Journal of the Franklin Institute* 346, 8 (2009), pp. 784-793

(with R Rupp)  
Ideal structure and stable rank of  $Ce+I_2(I)$  with the Hadamard product  
*Complex Analysis and Operator Theory* (in print) doi 10.1007/s11785-008-0078-6

(with A Brudnyi)  
Sufficient conditions for the projective freeness of Banach algebras  
*Journal of Functional Analysis* 257, 12 (2009), pp. 4003-4014

Algebras of Holomorphic Functions and Control Theory  
Dover Publications, 2009, ISBN 0486474658

## Robert Simon

(with M Gobbino)  
How many times can a function be iterated?  
*arXiv eprint arXiv: 0901.3230v1*

## Jozef Skokan

(with M Marcinişzyn, R Spöhel and A Steger)  
Asymmetric Ramsey properties of random graphs involving cliques  
*Random Structures and Algorithms* 34 (4), (2009), pp. 419-453

(with P E Haxell, T Luczak, Y Peng, V Rödl and A Rucinski)  
The Ramsey Number for 3-Uniform Tight Hypergraph Cycles  
*Combinatorics, Probability, Computing*, 18 (1-2), (2009), pp. 165-203

(with F Benevides)  
The 3-colored Ramsey number of even cycles  
*J. Combin. Th., Series B*, 99 (4), (2009), pp. 690-708

## Bernhard von Stengel

Follower payoffs in symmetric duopoly games  
Note, *Games and Economic Behavior* (in press) doi:10.1016/j.geb.2009.10.012

(with J Sobel)  
In memoriam: David Gale (1921-2008)  
Editorial, *Games and Economic Behavior* 66 (2), (2009), pp. 581-581

(with S Zamir)  
Leadership games with convex strategy sets  
*Games and Economic Behavior* (in press) doi:10.1016/j.geb.2009.11.008

## Konrad Swanepoel

(with M G Volz, M Brazil and D A Thomas)

Designing optimal flow networks

*Proceedings of the World Congress on Engineering, Vol II, (2009),*  
pp. 1235-1240

(with H Martini and P O de Wet)

Absorbing angles, Steiner minimal trees and antipodality

*Journal of Optimization Theory and Applications* 143 (2009), 149-157

Simultaneous packing and covering in sequence spaces

*Discrete & Computational Geometry* 42 (2009), pp. 335-340

(with B Csikós, G Kiss and P O de Wet)

Large antipodal families

*Periodica Mathematica Hungarica* 58 (2009), pp. 129-138

Unit distances and diameters in Euclidean spaces

*Discrete & Computational Geometry* 41 (2009), pp. 1-27

(with L M Pretorius)

The Sylvester-Gallai theorem, colourings and algebra

*Discrete Mathematics* 309 (2009), pp. 385-399

Triangle-free minimum distance graphs in the plane

*Geombinatorics* 19 (2009), 28-30

## Mihail Zervos

(with T C Johnson)

The explicit solution to a sequential switching problem with non-smooth data

Accepted to appear in *Stochastics: An Intl Journal of Probability and Stochastic Processes*



# Staff research activities

**Steve Alpern** is currently the Principal Investigator of a Collaborative Research Grant from NATO on Search Games on Networks. The team consists of groups from the UK, Netherlands and Israel. In May Steve, along with Robbert Fokkink gave a talk on 'How to Hide Information for Later Use on Networks' at GameNets 2009, International Conference on Game Theory for Networks at Boğaziçi University, Istanbul in Turkey. While in Turkey he also spoke on 'Analysis and Design of Selection Committees: A Game Theoretic Secretary Problem' at Koç University. In addition, Steve gave a talk with David Ramsey on Mathematical Methods in Biology at the University of Bristol.

Steve was responsible for organising the department's Annual International Workshop in Search Games. There were participants from five countries and talks covering both spatial search problems and search in the economists' sense of 'stopping times'. Steve spoke on 'Ariadne's thread suffices to exit a maze quickly' at the event.

Steve currently supervises one research student, Tom Lidbetter, who is working on various problems in game theory.

**Martin Anthony** was LSE co-ordinator for the PASCAL2 Network of Excellence project, a network of European researchers working on formal approaches to machine learning. As part of this, he hosted a visit by Dr Joel Ratsaby in July/August, during which they continued their work on 'sample width' in learning. Martin was an invited speaker at the Workshop on Boolean Functions at Rutgers University in January, where he presented a talk on threshold decision lists. 2009 saw the completion of the Centre for Distance Education research project (with Mark Baltovic, James Ward and Jan van den Heuvel) into the design of 'virtual tutors', and this was the subject of an invited presentation (given by Dr James Ward) at a distance learning conference at the University of London in February.

Martin is currently supervising two research students, Ben Veal and Raju Chinthalapati.

**Tugkan Batu** was invited to speak at the DIMACS Workshop on Property Testing at Rutgers University in March, and in April he attended the British Colloquium for Theoretical Computer Science at the University of Warwick, chairing one of the sessions. In May he gave a research seminar at the School of Informatics at the University of Edinburgh, entitled 'Testing Properties of Distributions'.

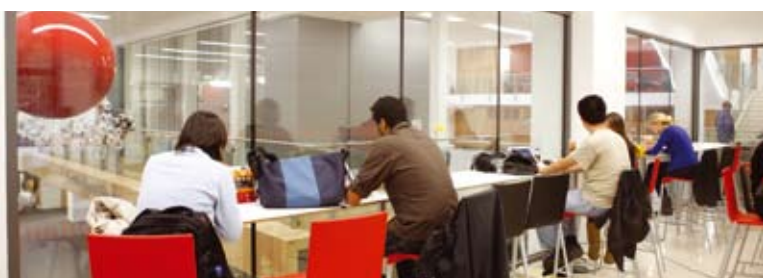
Tugkan was on sabbatical leave during the Michaelmas Term. He was a Visiting Faculty Member at Sabanci University in Istanbul and gave several research seminars during this time. He was also invited to give a tutorial talk entitled 'An Introduction to Approximation Algorithms' as part of the Istanbul Discrete Mathematics Seminar Series.

**Norman Biggs** continues his research in algebraic graph theory. He has extended his earlier results on the chromatic polynomials of bracelets to the Tutte polynomial, and has also written about strongly regular graphs with no triangles. In January he talked at the Manchester Centre for Doctoral Students, and in March he gave a seminar at Royal Holloway on 'Curious curves and graph colouring'. In November he gave one of the main presentations at the IMA conference on the History of Mathematics, entitled 'Applicable Mathematics in the Eighteenth Century: an example from the textile trade'.

**Nick Bingham** has pursued three main lines of work this year. The first, with Adam Ostaszewski, is on their new theory of topological regular variation; they are writing a book to synthesise their numerous recent papers. The second, with Ruediger Kiesel of Essen and John Fry of UEL, is on multivariate elliptic processes and applications in mathematical finance. The third, with Akihiko Inoue of Hiroshima and Yukio Kasahara of Hokkaido, is on prediction theory for stationary time series.

During 2009 Nick gave two seminars on 'Stationary time series and long memory', the first at the University of Manchester in March and the second at the University of Liverpool in May. He also spoke on 'Multivariate elliptic processes' at EURANDOM in Eindhoven in July and on 'Mathematics and the Credit Crunch' at a meeting of the Royal Statistical Society at the University of Leeds.

**Graham Brightwell** gave a number of talks during 2009 on 'Random Partial Orders and Random Linear Extensions': the first as part of the Combinatorial Theory Seminar at the University of Oxford in March, the second at the Pure Mathematics Seminar at Queen Mary, and then at the 14th International Conference on Random Structures and Algorithms in Poznan, Poland in August, and at Georgia Tech in Atlanta, USA in November. In November Graham also visited Dartmouth College where he gave a talk



entitled 'Linear Extension Diameter' and in December he attended a workshop on Causal Sets at DIAS, Dublin, and gave a talk on 'The structure of csg models'.

One of Graham's research students, Viresh Patel, who he supervised jointly with Jan van den Heuvel, was successfully examined for his PhD in 2009. Graham currently supervises Marianne Fairthorne, jointly with Malwina Luczak.

**Albina Danilova** gave three talks in 2009. The first was at the AMS Special Session on Financial Mathematics II in January, where she spoke on 'Stock Market Insider Trading in Continuous Time with Imperfect Dynamic Information'. The second and third were entitled 'Mathematical Models for Insider Trading I and II' and both were given at the Stochastic Analysis Seminar in Princeton, where she was a research visitor in March.

**Pavel Gapeev** was a programme speaker at the Istanbul Workshop on Mathematical Finance in May and at the Symposium on Optimal Stopping with Applications in Åbo/Turku, Finland in June. He was a session speaker at the 33rd Conference on Stochastic Processes and their Applications held at the University of Technology in Berlin in July. In addition, he also gave invited seminar presentations at the Swiss Federal Institutes of Technology in Zurich and Lausanne in March and April, at the Henri Poincaré Institute in Paris and the University of Evry-Val-d'Essonne in November.

Pavel also made research visits to University of Freiburg im Breisgau to collaborate with Hans Rudolf Lerche in April and August, to Stockholm School of Economics to collaborate with Tomas Björk in June, and to the University of Evry-Val-d'Essonne to collaborate with Monique Jeanblanc in November.

Pavel currently jointly supervises Neofytos Rodosthenous with Mihail Zervos.

**Olivier Gossner** has developed his research in Game Theory. His work during this period focused on the theory of repeated games, and on notions of correlation or independence between player's types. He has given invited lectures at several international conferences in 2009, including plenary talks at the Stony Brook festival in Game Theory, the Games 09 Workshop in Udine, Italy, and the Lisbon Conference in Game Theory. He also spoke at the Second Transatlantic Theory Workshop at the Kellogg School of Management and the SAET Conference in Ischia, Italy. In addition, Olivier spoke at a number of seminars in 2009, including the Paris Game Theory Seminar, the Creta Workshop at Warwick University, the IHPST Cognitive Sciences Seminar in Paris, and the Economic Theory Seminar at Princeton University.

Olivier serves on the editorial board of *Mathematics of Operations Research and Theory and Decision*.

**Jan van den Heuvel** gave several presentations during the year. As well as departmental seminars at several UK institutions, he was invited speaker at the Open University Winter Combinatorics Meeting, the Polyhedra and Combinatorial Optimisation Workshop in Paris, and the Midsummer Combinatorial Workshop in Prague.

Jan is a member of the British Combinatorial Committee, the main body in the UK working for the support of combinatorial and discrete mathematics. He is also on the editorial board of the *Journal of Graph Theory* and is guest editor of *Discrete Mathematics* for volumes of that journal dedicated to the British Combinatorics Conference.

One of Jan's research students, Viresh Patel, who he supervised jointly with Graham Brightwell, was successfully examined for his PhD in 2009. Jan currently supervises three research students: David Ferguson, Alexey Pokrovskiy (both jointly with Jozef Skokan) and Somkiat Trakultraipruk.

**Arne Lokka** worked on Malliavin calculus for jump processes and criteria for existence of a smooth density of functionals of jump processes. He gave a talk on this topic at the 25th Nordic-British Congress of Mathematicians in Oslo in June, entitled 'Malliavin calculus and Levy processes'.

**Malwina Luczak** was an invited speaker at a number of conferences in 2009. In April she spoke at an AMS special session on Concentration Inequalities in San Francisco and in May she gave an invited lecture at the Centre de Rencontres Mathematiques in Luminy, France. During the year she was also invited to speak twice at workshops organised by the Banff International Research Station (BIRS) and in July she gave a talk at the 15th APS INFORMS Conference at Cornell. In August she contributed a talk to the 14th International Random Structures and Algorithms Conference at Poznan in Poland and in addition, she spoke at a meeting on New Random Geometries at the University of Bath in September and gave a lecture at the workshop on Causal Sets at DIAS in Dublin in December.

Malwina also contributed to a number of seminar series and visited several colleagues throughout the year. In March she gave seminars at the Oxford University Combinatorics Seminar, the University of Zurich Probability Seminar, and the Mittag-Leffler Institute, where she was a Visitor on their Programme on Discrete Probability. She also spoke twice at the University of Zurich, where she was a guest of Andrew Barbour and she made two visits to the University of California, Berkeley as a guest of Alistair Sinclair. In April, she spoke at the Chalmers University of Technology Probability Seminar and in September, she was Visiting Professor at the Centre Emile Borel, Institut Henri Poincare in Paris on their Statistical Physics, Combinatorics and Probability Programme.

Malwina is currently a reviewer for the *Annals of Applied Probability*; *Combinatorics, Probability and Computing*; *Random Structures and Algorithms*; and *ESAIM Probabilites et Statistiques*. She supervises three research students: Steffen Issleib, Derek Wan, and Marianne Fairthorne (jointly with Graham Brightwell).

**Adam Ostaszewski** continued his collaboration on topological regular variation with Nick Bingham and they have now begun work on a Cambridge Tract in Mathematics, which aims to offer a broad overview of the subject. As part of this they hosted Dona Strauss in order to collaborate on the allied areas in which she works and she provided a talk at the Department's CDAM Seminar. Adam also continued his work on corporate disclosure policy with Miles Gietzmann and they made a number of interesting developments in this area.

During the year Adam gave several talks. In February he spoke at the Free University in Amsterdam on 'Topological Dynamics and Topological Regular Variation.' He also spoke twice at the University of Oxford's Analytic Topology in Mathematics and Computer Science Seminar, the first talk was entitled 'Measure-Category Duality: a bi-topological view' and the second was entitled 'Automatic continuity via analytic thinning.' In December Adam attended the Gdansk Technical University Probability Seminar in Poland and spoke on 'Shift-compactness and Topological Regular Variation.'

Adam is currently supervising one PhD student, Zibo Xu, jointly with Robert Simon.

**Amol Sasane** gave a talk on 'Projective freeness of an algebra of measures used in control theory' at the Operator Theory and its Applications Workshop held at the International Centre for Mathematical Sciences in Edinburgh. He also gave a similar talk at the Seventh International ISAAC (International Society for Analysis, its Applications and Computation) Congress held at Imperial College London.

In December 2009 Amol left the Department to take up the position of Senior Lecturer at the Division of Optimisation and Systems Theory of the Mathematics Department at the Royal Institute of Technology (KTH), Stockholm, Sweden.

**Robert Simon** spoke on 'Games of Incomplete Information and the Borsuk-Ulam Theorem' at the Mathematical Society, University of Goettingen, Germany in June, where he also spent time collaborating with Thomas Schick on a paper soon to be submitted to the London Mathematical Society. Also in June, Robert visited Dresden to work with Katerina Heimann and Jan Rudel of the Technical University of Dresden on a computer confirmation of a counter-example to approximate equilibria in quitting games. In December he gave a talk on 'The Banach-Tarski Paradox and Bayesian Games' at Queen Mary University. Robert also worked on aspects of Bayesian games with Benjamin Weiss of Hebrew University of Jerusalem, Israel.

He currently jointly supervises one research student, Zibo Xu, with Adam Ostaszewski.



**Jozef Skokan** was on sabbatical leave during the Michaelmas term and during this time he was a Fellow at the Institute for Pure and Applied Mathematics (IPAM), UCLA for its Fall 2009 Program on Combinatorics: Methods and Applications in Mathematics and Computer Science. In May he spoke at the University of Oxford's Combinatorial Theory Seminar on 'Multicolour Ramsey numbers for cycles' and during his time at the IPAM he spoke at the UCLA/IPAM Combinatorics Seminar on 'Ramsey-goodness... and otherwise'. During the year, Jozef collaborated with colleagues in Budapest, London, Memphis, Santiago and Sao Paulo.

He is currently jointly supervising David Ferguson and Alexey Pokrovskiy, both with Jan van den Heuvel.

**Konrad Swanepoel** gave a number of talks at conferences and seminars during 2009. In January he gave a talk entitled 'Outer linear measure of connected sets via Steiner trees' at the Joint Mathematics Meetings in Washington DC and in February he spoke on 'Geometric methods in Combinatorics' at the Optimisation and Computer Science Tewkesbury Seminar at the University of Melbourne. In February he gave a talk at the 5th Workshop on Kombinatorik, Graphentheorie und Algorithmen in Chemnitz, Germany on 'Unit distance pairs and diameter pairs in a set of  $n$  points in Euclidean spaces', and he spoke at the Conference on Convex and Discrete Geometry at the Vienna University of Technology on 'Maximal pairwise touching families of translates of a convex body' in July. In August he visited the Department of Applied Mathematics, at Charles University in Prague where he gave a talk on 'Maximal equilateral sets'.

**Bernhard von Stengel** is Vice President for Communications of the Game Theory Society, is co-editor of the International Journal of Game Theory, and serves on the editorial board of Games and Economic Behavior and Mathematics of Operations Research.

In 2009, Bernhard gave a number of invited talks at conferences and seminars. At the Game Theory and Computer Science Day in Paris in February, he gave a presentation on 'Geometric views of linear complementarity algorithms and their complexity'. He talked on 'Strategic characterisation of the index of an equilibrium', joint work with his former PhD student Arndt von Schemde, at the Bellairs Workshop on Algorithmic Game Theory, Barbados, in March, at the Workshop on New Topics on Game Theory, in Seville, Spain, in April, and at the CRETA Marie Curie Workshop, Warwick, also in April. Bernhard presented research on 'Manifolds, Abstract Sperner and PPAD', at the Conference in Honour of Jack Edmonds on Pretty Structures, Existential Polytime and Polyhedral Combinatorics in Paris in April, at the BRICKS Workshop in Amsterdam in June, and as an invited plenary talk at the International Conference on Game Theory in Stony Brook, USA, in July. He talked on 'Constructing and computing equilibria for two-player games' as an invited plenary speaker at the Spanish-Italian-

Netherlands Meeting on Game Theory in Amsterdam in July and at the ERI-CES Seminar in Valencia, Spain, in September.

In 2009 Bernhard supervised five research students: Wan Huang, Anne Balthasar, Julian Merschen, Marta Maria Casetti and Ahmed Abu-Khazneh. Anne Balthasar was successfully examined for her PhD in December.

**Mihail Zervos** was invited to give a number of seminars in 2009, including at the University of California, Berkeley, where he was a research visitor at the Department of Industrial Engineering and Operations Research. He was also a research visitor at the Laboratoire d'Analyse et de Mathématiques Appliquées, University of Marne-la-Vallée, Paris in April and while there he spoke on 'Stochastic control problems with application to the goodwill problem' at their seminar series. In addition he gave talks at the ICEF Research Seminar in Moscow and the Department of Mathematics at the University of Liverpool.

Mihail also gave a number of conference presentations in 2009. In March he spoke at the Risk and Stochastics Day at the London School of Economics and Political Science and in May he attended the Fourth General Conference on Advanced Mathematical Methods in Finance in Ålesund, Norway. In June he attended the Symposium on Optimal Stopping with Applications in Åbo/Turku, Finland and in November he spoke at the Southern Africa Mathematical Sciences Association (SAMSA) Conference in Dar es Salaam, Tanzania. Finally, as part of his work on the project, A Topological Approach to Cultural Dynamics (ATACD) he spoke at the Changing Cultures: Cultures of Change, ATACD Conference at the University of Barcelona in December. During this time he was also a research visitor at Departament de Física Fonamental, University of Barcelona.

Mihail is currently supervising Fares Al-Azemi, Polly Lon, Hessah Al-Motairi, Ovidiu Precup, Dimitris Melas, Pucheng Shi (jointly with Albina Danilova) and Neofytos Rodosthenous (jointly with Pavel Gapeev).

# Special events organised by members of the department

## One-Day Colloquium in Combinatorics, 21 May 2009

It has become a tradition for the LSE Mathematics Department to host a One-day Colloquium in Combinatorics each May. The event is timed to follow a similar event on the previous day at Queen Mary. This year's event took place on 21 May 2009 and attracted around 90 participants from all over the UK, around a third of whom were PhD students.

There were six talks at LSE. Peter Keevash (Queen Mary) explained some of his impressive recent work on a class of processes for generating graphs without a given subgraph, improving the lower bounds on some Ramsey and Turan numbers. Stefanie Gerke (Royal Holloway) gave an entertaining account of her work on thresholds for connectivity in random intersection graphs, with applications to the problem of distributing secure keys in networks. Angelika Steger (ETH Zurich) spoke about her mathematical analysis of a recent model for bursts of neuron firing in the brain, explaining how the rigorous analysis explained some (but not all) of the curious behaviour observed in computer simulations. Leslie Goldberg (Liverpool) spoke about recent work on the complexity of evaluating partition functions: she was able to describe exactly what types of weighted substructures of a large structure are computationally easy to count. Rahul Savani (Warwick), a former student in the Department, explained how two game-theoretic problems related to connectivity in graphs are equivalent, and related to the structure of the graph.

Finally, Jaroslav Nešetřil (Prague) gave the annual Norman Biggs lecture: he spoke about graph-theoretic problems stemming from approaching the subject from the point of view of category theory, and described some of the extraordinarily rich structure of the class of directed graphs with the homomorphism relations.

We would like to acknowledge the support of the London Mathematical Society (LMS) and the British Combinatorial Committee (BCC) in organising this event.

## Eighth International Workshop in Search Games and Rendezvous

The 8th International Workshop in Search Games and Rendezvous was held at LSE this August, with twenty participants from various countries. The topic of rendezvous search, the original focus of these Workshops, was featured in a new result from Richard Weber (Director of Statslab, Cambridge) stating that the simple so called 'Anderson-Weber' strategies found to be optimal for rendezvous on three locations, are not optimal for four locations. It had been widely believed that these strategies were optimal for any number of locations. John Howard (OR Group, LSE) gave a talk proposing some new team optimisation problems which could be thought of as abstractions of the rendezvous problem. These problems feature information delay and how to deal with it. (Subsequent to the Workshop, Richard Weber has made some progress on these problems.) Anatole Beck (Wisconsin, USA) detailed his progress, with Vic Baston (Southampton), on rendezvous problems on the infinite line.

The afternoon session featured talks on search games. David Ramsey (Limerick, Ireland) spoke on his model of mutual mate search in the context of multiple features of heterogeneity. Robbert Fokkink (Delft, Netherlands) spoke on his new results on so called 'high-low' search games, where the Searcher obtains directional feedback based on his guesses about the location of the Hider. Alec Morton (OR Group, LSE) spoke on his work with Katerina Papadaki and Steve Alpern on network games where a Patroller attempts to foil an Attack on a node by optimising his randomised patrols.

Several participants stayed at the School for several days of informal discussions, which have subsequently led to new problems and solutions.



# Research grant news

## Malwina Luczak

### STICERD New Researcher Award, LSE

In the 2008-09 academic year Malwina was awarded a New Researcher Award of £20,000 by the Suntory and Toyota International Centres for Economics and Related Disciplines (STICERD) and she has continued to use this to support a variety of research collaborations, and attendance at talks and conferences. She also employed one of the department's former MSc in Applicable Mathematics graduates and a current PhD student as research assistants using money from this grant.

Malwina was also awarded a grant of \$160,000 Singapore Dollars to setup a Programme on Probability and Discrete Mathematics in Mathematical Biology at the National University of Singapore. She is co-chair of the Organising Committee along with A D Barbour.

## Martin Anthony

### PASCAL2

Martin Anthony is a member of an EU-funded Network of Excellence project, PASCAL2. This runs March 2008 to March 2013, is co-ordinated by University of Southampton, and involves 51 partner sites and a 6M ECU total budget.

## Pavel Gapeev

### ESF Short Visit Grant

Pavel was awarded a Short Visit Grant (€1650) from the European Science Foundation (ESF) through the Scientific Programme for Advanced Mathematical Methods for Finance (AMaMeF). This grant was used for his research visit and collaboration with Robert Dalang (Lausanne) and Martin Schweizer (Zurich). He has also secured a grant for a one-month research visit to the Fields Institute for Research in Mathematical Sciences at Toronto within the framework of the announced Thematic Programme on Quantitative Finance: Foundations and Applications.

## Bernhard von Stengel

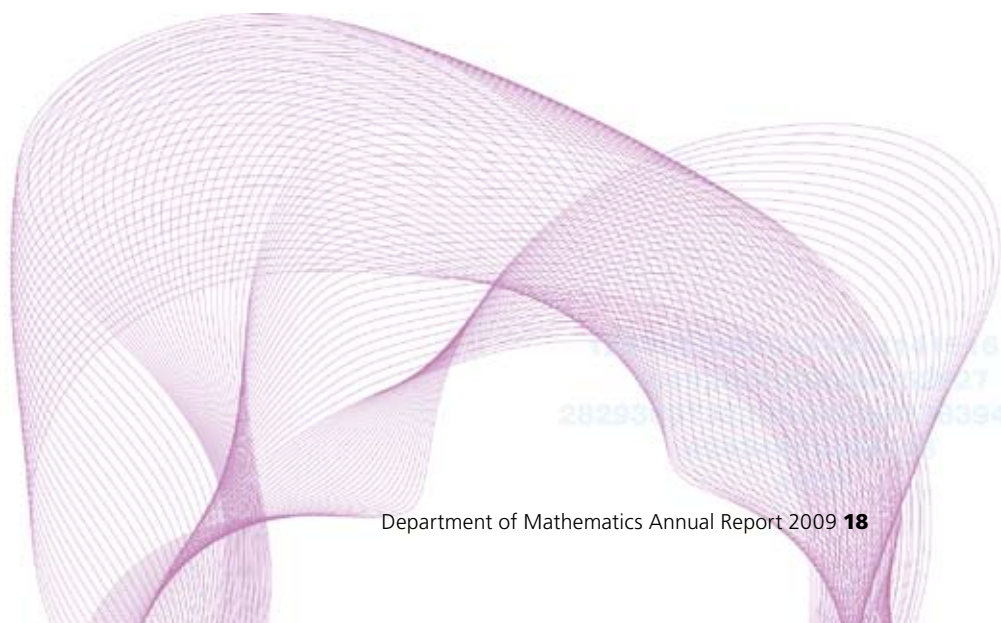
### EPSRC Mathematics Case Project Grant

This grant, for a project entitled 'Algorithmic Theory for Games on Graphs', was awarded to Bernhard von Stengel by EPSRC in collaboration with the Heilbronn Institute for Mathematical Research in Bristol, a part of Government Communications Headquarters. Awarded in 2007 as one of only 15 made by the EPSRC, it continues to support Julian Merschen, who works as a research student under Bernhard's supervision in the area of algorithmic game theory.

## Mihail Zervos

### EU Sixth Framework Programme Grant

Mihail Zervos is the team leader for LSE as one of 20 partner institutions involved in an EU 6th Framework Grant project entitled 'A Topological Approach To Cultural Dynamics (ATACD)'. In December ATACD held its conference on Changing Cultures: Cultures of Change in Barcelona at which Michalis gave a talk entitled 'On the modelling of financial time series'.



# Mathematics at LSE: a brief history

**Norman Biggs is currently working on a brief history of Mathematics at LSE. Beginning at the founding of the School this history is divided into four sections, covering the periods 1895-1966, 1967-88, 1989-2000 and 2001-present, below you can find the first instalment:**

## **I: 1895-1965**

LSE was founded in 1895. Mathematics was not one of the foundation subjects, but from the very first Statistics was regarded as an important tool for the social scientist, and A L Bowley gave regular lectures on the subject. In 1901 his book *Elements of Statistics* was published. It went through several editions with only minor changes, but in his preface to the 1920 edition Bowley indicated a major change of emphasis. 'In the first edition an effort was made to obtain the principal results without the use of the calculus; but as the subject has developed during the past twenty years, it has become necessary to abandon this attempt.' In fact, Bowley's concessions to mathematics were rather limited: he described the normal distribution in terms of an integral, and introduced a small amount of differential calculus. However, from this time forward it is clear that statistics at LSE was taught in a more rigorous way. The appointment of mathematically-trained statisticians such as Roy Allen (1928) and Maurice Kendall (1949) was an important factor.

It is worth mentioning that one of the first benefactors of LSE was Bertrand Russell, already becoming famous for his work in logic and the philosophy of mathematics. Indeed, he is reported to have given a course of lectures at the School in 1896, but sadly they were on German Social Democracy.

A more important impetus came, in due course, from economics. By the beginning of the twentieth century the leading economists, such as Alfred Marshall, were accustomed to using mathematics in their work. In a letter to Bowley, Marshall formulated his famous *Six Principles* of how to use mathematics in economics. '(1) Use mathematics as a shorthand language, rather than as an engine of enquiry. (2) Keep them till you have done. (3) Translate into English. (4) Then illustrate by examples that are important in real life. (5) Burn the mathematics. (6) If you can't succeed in (4), burn (3). This I do often.'

It must be remembered that, to the founders of LSE, 'Economics' was a vague term, covering a broad range of mainly historical enquiries. The prevailing attitude is well-illustrated in a letter from the director (Hewins) to Sidney Webb, written in 1898. 'You may be gratified to know... that in Germany you and Mrs Webb are held in the highest estimation of all English writers on economics. Marshall is nowhere.' Thus it is no surprise to find little evidence of mathematics being required by LSE economists until the 1920s. John Hicks, the future Nobel Laureate, came to LSE as a temporary lecturer in Economics in 1926/27. He had done one year of mathematics at Oxford before switching to PPE, and

found that it was 'sufficient to cope with what anyone (then) used in economics'. But changes were afoot. In 1931 Roy Allen began to lecture on mathematical analysis to LSE students of economics, and his book was published in 1938. He gave a logical development of the subject in the 'modern' style, although he referred to Hardy's *Pure Mathematics* for the foundations of the real number system. In addition, he covered a wide range of economic applications, based on the work of Marshall, Edgeworth, Hicks, F P Ramsey, and others.

In the next twenty years the face of economics changed significantly, and when Allen came to revise his book in 1956 he adopted a different approach. His new book was entitled *Mathematical Economics*, and its theme was the exposition of economics in mathematical way. He incorporated the mathematics as it was needed, and so we find matrices and vectors discussed as in a prelude to the theory of games and linear programming.

These developments produced a climate of opinion in LSE (or at least part of it) sympathetic to the application of mathematics in the social sciences, and the *Robbins Report* on the expansion of higher education in the UK provided the opportunity for action. The minutes of the Academic Board held on 26 May 1965 contain the following paragraph.

'Over the past few years there has been a great increase in the use of mathematics related to the School's subjects and there are more students coming up with advanced level mathematics combined with arts and social science subjects who want to continue the study of mathematics at the School. It is felt that the School should have a group of pure mathematicians to support and expand the work which is already being done by applied mathematicians in social sciences. There is a growing national need for persons qualified in mathematics with reference to the social sciences. The more traditional form of the mathematics degree which contains a large element of applied physics is not as directly relevant to such occupations as operational research, statistics and econometrics. The new degree which is being proposed would remedy this deficiency, and would enable a mathematical specialist to study his subject in relation to social science disciplines rather than those of the physical sciences.'

This is the first in a short series of articles that will trace the story of mathematics at LSE up to the present day. In the next one I shall describe how LSE set about implementing the kind of mathematics degree suggested in the Academic Board Minute. Anyone who has useful archival material (or even anecdotes) is asked to contact the author.

**Norman Biggs**

# Research students



**Fares Al-Azemi** (Fares is working with Mihail Zervos in Financial Mathematics).

Fares has continued his work on stochastic optimal control and he completed a paper on 'An Investment Model With Impulse Stochastic Control'.



**Hessah Al-Motairi** (Hessah is supervised by Mihail Zervos and is working in the area of Financial Mathematics).

Hessah gave a talk at the Fourth General Conference on Advanced Mathematical Methods in Finance in Ålesund, Norway in May, entitled 'Irreversible capacity expansion with proportional and fixed costs'.



**Anne Balthasar** (Anne was funded by EPSRC and the LSE Research Studentship Scheme, and worked with Bernhard von Stengel on Geometry and Equilibria in Bimatrix Games).

Equilibrium tracing in strategic-form games  
*Economic Theory*, 41, (2010), 1, pp. 39-54

Formality of the Constructible Derived Category for Spheres:  
A Combinatorial and a Geometric Approach  
*Mediterranean Journal of Mathematics*, 6, (2009), 4, pp 403-430

In February Anne spoke on 'Computation of the Index of a Component of Nash equilibria for Bimatrix Games' at the Department's Lunchtime Seminar and in April she gave a talk entitled 'Computation of the Index of a Component of Nash Equilibria' at the 25th British Colloquium for Theoretical Computer Science. Anne was successfully examined for her PhD in December 2009, more detailed information can be found on page 21.



**Marta Casetti** (Marta is supervised by Bernard von Stengel and is working in the area of Game Theory).

Marta gave a talk entitled 'On a lemma by Scarf and fractional kernels' at our Lunchtime Seminar in November.



**Raju Chinthalapati** (Raju is supervised Martin Anthony in the field of Computational Learning).

Raju spoke on 'Volatility Forecast in Financial Time-Series Using Evolutionary Computing Techniques'. at the 23rd European Conference on Operations Research in Bonn in June and also at the Department's Lunchtime Seminar.

In October Raju joined the university of Greenwich as a senior lecturer in Finance.



**Marianne Fairthorne** (Marianne is working with Graham Brightwell and Malwina Luczak in the area of Combinatorics).

During 2009 Marianne continued to work on variants of the supermarket model and collaborated on a paper with Graham Brightwell, Gérard Cohen, Emanuela Fachini, János Körner, Gábor Simonyi and Ágnes Tóth, entitled 'Permutation capacities of

families of oriented infinite paths', which is due to appear in *SIAM Journal on Discrete Mathematics*.



**David Ferguson** (David is funded by the EPSRC and the LSE's Research Studentship Scheme. He is supervised jointly by Jan van den Heuvel and Jozef Skokan and works in Combinatorics).

David gave a number of talks in 2009, including a talk entitled '1-2-3 Conjecture', at the Department's Lunchtime Seminar and two talks on 'Ramsey numbers of Cycles', the first at UCL's Discrete Geometry and Combinatorics Seminar and the second at the British Combinatorial Conference in St Andrews. He also spoke on 'Graph Distance Numbers' at HOMONOLO '09, Nova Louka in the Czech Republic. In addition to his research David successfully completed the Associate Level of the LSE Postgraduate Certificate in Higher Education in 2009.



**Wan Huang** (Wan is supervised by Bernhard von Stengel, and is working on equilibria in extensive games).

Wan spent 2009 finalising her PhD thesis, which she plans to submit early in 2010.



**Steffen Isleib** (Steffen is supervised by Malwina Luczak and he is working in the area of probability).

During 2009 Steffen worked on the Ising model with external field on the complete graph and he collaborated with a PhD student at Oxford University on solving trial and error two-player bargaining games.



**Polly Lon** (Polly is working with Mihail Zervos in the area of Financial Mathematics).

In 2009 Polly submitted a paper entitled 'The Stochastic goodwill problem: a monotone follower model with discretionary stopping', and she spoke on this at the London Graduate School in Mathematical Finance PhD Day in March.



**Dimitris Melas** (Dimitris is a part-time student and is currently working with Mihail Zervos in the area of Financial Mathematics).

In 2009 Dimitris worked on optimal consumption and investment decisions with habit formation and hyperbolic discounting.



**Julian Merschen** (Julian is funded by an EPSRC Mathematics Case Project Studentship and is supervised by Professor Bernhard von Stengel. He works in the area of Algorithmic Game Theory).

During 2009 Julian spoke at the University of Warwick's Algorithms and Complexity Seminar on 'Computing an Optimal Strategy for One-Player Simple Stochastic Games Using Interior-Point Methods', at BCTCS 2009 on 'Solving Simple Stochastic Games with Interior Point Methods', and finally at the Department's Lunchtime Seminar on 'n-Person Games, Scarf's Lemma and its Complexity'.



**Viresh Patel** (Viresh's research area was in Graph Theory. He was jointly supervised by Graham Brightwell and Jan van den Heuvel, and was funded by the EPSRC).

(with Graham Brightwell)

Average relational distance in linear extensions of posets  
Published online in *Discrete Mathematics* doi:10.1016/j.disc.2009.10.016

Viresh was successfully examined for his PhD in December 2009, more detailed information can be found below.



**Ovidiu Precup** (Ovidiu is part-time, having joined us from King's, and is supervised by Mihail Zervos in the area of Financial Mathematics).

Ovidiu gave a talk entitled 'A Commodity Storage Valuation Model' at the Department's Lunchtime Seminar in February.



**Ben Veal** (Ben is a part-time student and is working with Martin Anthony in the field of Computational Learning).

During 2009 Ben worked with Zacharias Voulgaris, a PhD student at Birkbeck College, University of London, on combining discernibility with binary similarity measures for feature selection.



**Derek Wan** (Derek is funded by the EPSRC and the LSE Research Studentship Scheme, he works with Malwina Luczak in probability).

Derek has been working on the supermarket model with memory, and showing that it mixes rapidly using arguments established for the original supermarket model.



**Zibo Xu** (Zibo is currently funded by LSE's Research Studentship Scheme. He is jointly supervised by Robert Simon and Adam Ostaszewski and he is working in the field of Stochastic Game Theory).

In 2009 Zibo gave a talk entitled 'Stochastic Ramsey's theorem in two colours', at the Department's Lunchtime seminar.

#### In 2009 four new Research Students joined the Department:



**Ahmad Abu-Kahzneh** (Ahmad is supervised by Bernard von Stengel and he is working in the area of Game Theory).

Ahmad gave a talk entitled 'Primality is in P: The AKS Algorithm' at our Lunchtime Seminar in November.



**Alexey Pokrovskiy** (Alexey is jointly supervised by Jozef Skokan and Jan van den Heuvel and he works in Graph Theory. He is funded by the LSE's Research Studentship Scheme).

Alexey gave a talk entitled 'On the growth of graph powers' at our Lunchtime Seminar in November.



**Neofytos Rodosthenous** (Neofytos is jointly supervised by Michalis Zervos and Pavel Gapeev and he is working in the area of Financial Mathematics).



**Pucheng Shi** (Pucheng is jointly supervised by Michalis Zervos and Albina Danilova and he works in Financial Mathematics. Pucheng is the Department's first recipient of the School's new PhD Scholarships).



**Somkiat Trakultraipruk** (Somkiat is supervised by Jan van den Heuvel and he is working in the area of Combinatorics).

Somkiat gave a talk entitled 'Connectedness of Strong k-colour Graphs' at our Lunchtime Seminar in October.

### PhD Awards

Our congratulations go to Viresh Patel and Anne Balthasar, both of whom were successfully examined for their PhDs in 2009.

**Viresh Patel** was awarded his PhD in June 2009. His thesis was entitled 'Partitions of Combinatorial Structures'. During his doctoral study, Viresh was jointly supervised by Jan van den Heuvel and Graham Brightwell, and funded by the EPSRC and by an LSE Research Studentship. In his thesis, Viresh explores extremal, structural, and algorithmic problems involving the partitioning of combinatorial structures. Structures considered include graphs, hypergraphs and posets. After completing his thesis, Viresh took up a post as Research Associate in the School of Engineering and Computing Sciences at Durham University.

**Anne Balthasar** was successfully examined for her PhD in December 2009. Her thesis, entitled 'Geometry and equilibria in bimatrix games', is on the use of geometric concepts to answer questions on two-player games that had been open. The central concept about games is that of an equilibrium, and her main result is to show when such an equilibrium can become the unique solution when viewed as part of a larger game. One of the three chapters of Anne's thesis has already been published as an article in the journal *Economic Theory*, and two other chapters are in preparation as journal submissions.

Anne is currently employed as a quantitative associate at Barclays Capital, working in Quantitative Analytics.



## The London Taught Course Centre for PhD students in the mathematical sciences.

The LTCC is an ESRC funded consortium of universities in the London region currently comprising: UCL, Queen Mary, Imperial College (Statistics), King's College, LSE, City, Kent and Brunel. It offers a programme of one day a week advanced courses in mathematics and statistics for PhD research students in the region, and short intensive courses open to students from elsewhere in the UK and Europe. It aims to provide mathematical sciences research students with broad mathematical knowledge covering at least one of three areas: pure mathematics, applied mathematics, and statistics. The LTCC also aims to offer doctoral students opportunities to acquire a working knowledge of classical results and recent developments in their own broad research fields but outside the specialised domains of their individual research projects. All our first year research students are taking a range of courses including, Graph Theory, Measure-theoretic Probability and Biomathematics. In 2008-09 the Department provided two LTCC courses, Graph Theory, lectured by Graham Brightwell and Jan van den Heuvel and Cryptography and Mathematics, lectured by Norman Biggs.

## London Graduate School in Mathematical Finance

LSE Mathematics continues to be a part of the consortium of the mathematical finance groups of Birkbeck College, Imperial College, King's College and the London School of Economics and Political Science that makes up the London Graduate School in Mathematical Finance. LGSMF provides a programme of advanced courses in mathematical finance for first year PhD students. A number of our PhD students attended LGSMF courses during 2009. Mihail Zervos lectures the course on Optimal Investment and Incomplete Markets, offered by the LGSMF.

## Student prize winners 2009

### Cyril Offord Prize

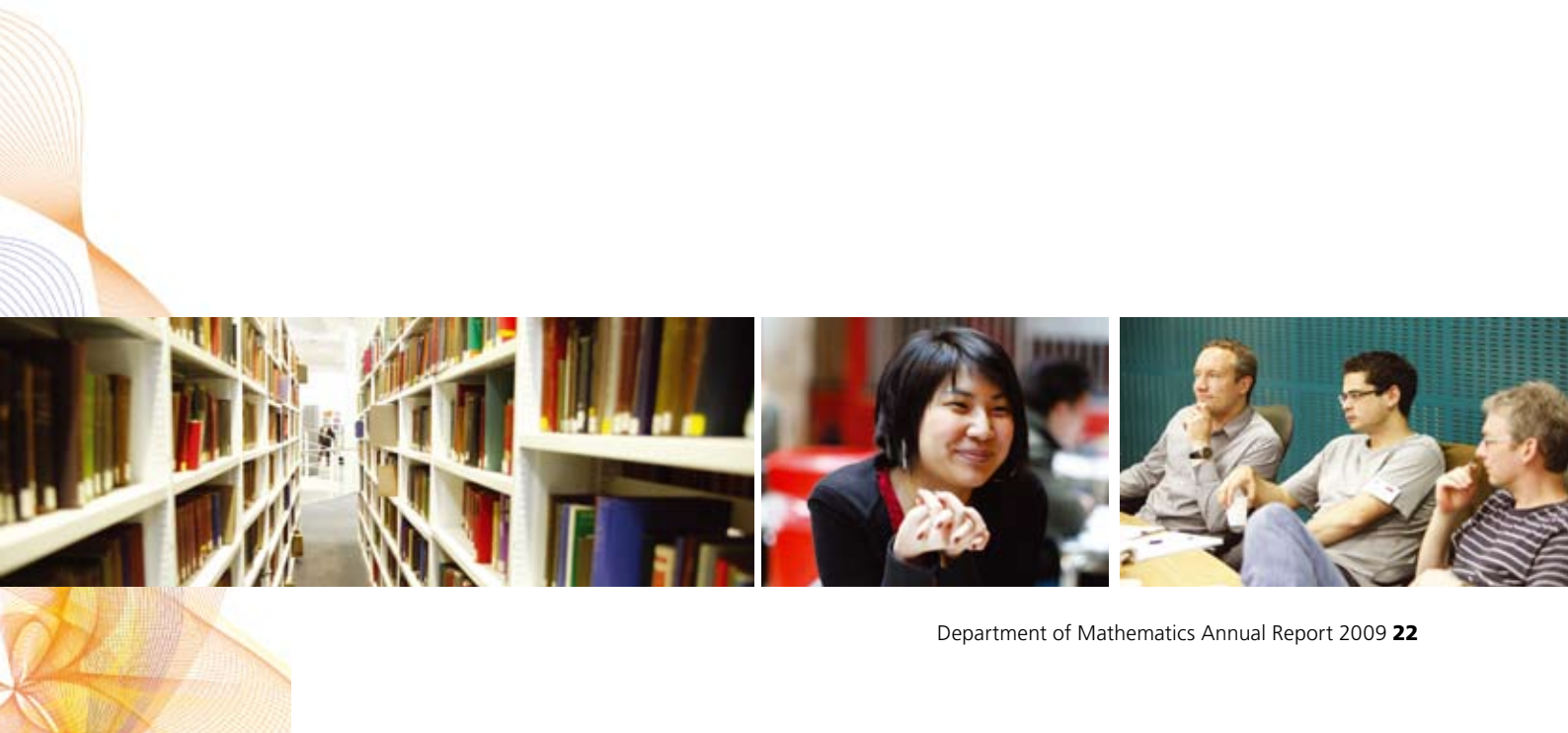
The Cyril Offord Prize for outstanding performance in undergraduate mathematics was awarded to Stephen Almond for his outstanding achievements on the BSc Business Mathematics and Statistics.

### Haya Freedman Prize



Tom Bates and Preeyesh Bhadresha were joint recipients of the Haya Freedman Prize. This prize is awarded in memory of Dr Freedman, and is given annually for 'Best Dissertation' produced by a student on the MSc in Applicable Mathematics.

**Congratulations to all our prize winners.**



**Department of Mathematics**

The London School of Economics  
and Political Science

Houghton Street

London WC2A 2AE

Email: [admin@maths.lse.ac.uk](mailto:admin@maths.lse.ac.uk)

Telephone: 020 7955 7732/7494

Fax: 020 7955 6877

**[www2.lse.ac.uk/math](http://www2.lse.ac.uk/math)**



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