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# New Director for IMS: Louis Passes the Baton to Chi Tat >>>

Professor Louis Chen, the Institute's founding Director, will step down at the end of 2012 after heading the Institute for 12½ years. Professor Chi Tat Chong of the Department of Mathematics at the National University of Singapore (NUS) will take over as the new IMS Director starting January 2013.

After the handover, Professor Louis Chen will take his long-overdue sabbatical leave from NUS before resuming full-time duties at the Department of Mathematics and the Department of Statistics and Applied Probability. "I have been director for longer than I expected. Twelve and a half years is a long time. The Institute needs new ideas and fresh energy. I am glad that I will finally relinquish my directorship," said Professor Chen. "I am looking forward to spending more time on research and on hobbies that I had not had time to pursue previously."

As the founding Director of IMS, Professor Chen put in huge efforts to plan and develop the Institute. He built up, basically from scratch, the operational and organizational infrastructure of the Institute. He was heavily involved in the design of the IMS premises — consisting of an auditorium built anew and two other renovated colonial houses where the visitors' offices, a lounge, the general office, a seminar room and a meeting-room-cum-library are located. He also had to overcome the challenges of recruiting, training and retaining suitable supporting staff for the Institute. All his hard work had but one goal in mind — to ensure that the scientific programs and activities held at IMS are of the


Louis CHEN: IMS Director from 2000 to 2012

highest quality and bring the most benefits to the scientific community in Singapore and beyond. An interview article (as part of the tenth anniversary celebrations of IMS in 2010) in which he gave a personal account of his involvement in the key developments of IMS during its formative first decade of operations is available at *http://www2.ims.nus.edu.sg/tenthanniversary/book4.php*.

"In the past 12½ years, the Management Board and the Scientific Advisory Board (SAB) have given a lot of support to the Institute. The guidance and advice of the SAB has been crucial in ensuring a steady flow of good programs," Professor Chen said appreciatively. "My deputy directors have also given me a lot of support and helped me in running

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Chi Tat CHONG: Incoming IMS Director

the Institute and in ensuring success of its programs. My colleagues in NUS and friends outside NUS, both locally and overseas, have also contributed to the success of the programs through their organizational work and active participation. As a director I was demanding on my support staff. I have heard many praises from the IMS visitors for their friendliness, efficiency and professionalism in rendering services and help."

Commenting on Professor Chen's legacy, Professor Chi Tat Chong said: "IMS began its activities in 2001. The Institute has made tremendous progress during this period, and is now firmly established as a major mathematical institute in the Asia Pacific. Professor Louis Chen as its founding Director was instrumental in turning vision into reality within a decade. Through the programs organized, IMS has become a center where senior and young scientists from around the world, not just mathematicians, often visit to conduct research. The benefits this has brought to NUS faculty, and Singapore scientists as well as students in general, are widely acknowledged."

The incoming IMS Director Chi Tat Chong is University Professor at NUS. Professor Chong's main research interests lie in mathematical logic, and especially computability theory. He has held key administrative appointments at NUS, notably as Vice Chancellor, Deputy President and Provost (1996–2004); he has also served as Vice Dean in Faculty of Science (1985–1996), Head of Department of Information Systems and Computer Science (1993–1996) and Head of Department of Mathematics (2006–2012). He has served as an editor of Journal of Symbolic Logic and a member of the Executive Committee of the Council of Association for Symbolic Logic. He has been the Chairman of the Management Board of IMS since 2001 and the Chairman of the Management Board of Asia Research Institute since 2005. He is currently also a member of the Board of Trustees of UniSim and the Board of Management of Temasek Life Sciences Laboratory. He was awarded the Public Administration Medal (Gold) by the Singapore Government in 2002.

Long before his appointment as the Institute's new Director, Professor Chong has been closely associated with the Institute. Besides his chairmanship at the Institute's Management Board, he participated in numerous IMS programs and activities as an organizer, invited speaker or panel discussant. During the past few years, Professor Chong, together with Professors Theodore A. Slaman and W. Hugh Woodin of the University of California at Berkeley, played a key role in conceiving and initiating the Institute's three-year program "Asian Initiatives for Infinity (2010–2013)" — consisting of graduate summer schools on mathematical logic with emphasis on Infinity — funded by the John Templeton Foundation.

Professor Chong outlined his vision for the path ahead for IMS: "Looking forward, IMS has to maintain its current position among the world's leading mathematical institutes and strengthen its existing programs. Several countries in East and North Asia have begun to invest heavily in their mathematical institutes, seeing the development of science and mathematics as a key strategy for economic growth. This presents both a challenge and an opportunity to the IMS, and one of the priorities in the coming years is to see how IMS could work together with its counterparts in the Asia Pacific region in the area of mathematical sciences."

Denny Leung and Wing-Keung To
*National University of Singapore*

# Multiscale Modeling, Simulation, Analysis and Applications >>>

Weizhu BAO

*[Editor's note: From November 2011 to January 2012, the Institute hosted a program on "Multiscale Modeling, Simulation, Analysis and Applications". Weizhu Bao, Co-chair of the Organizing Committee, contributed this invited article to* Imprints *as a follow-up to the IMS program.]*

Many problems in science and engineering have widely varying scales in time and space. As technology advances, the spatial scales used in modeling these problems range from nanometers to millimeters or even kilometers, while the temporal scales adopted range from nanoseconds to seconds or even years. The scientific understanding of problems involving the interaction between different temporal and/or spatial scales is very challenging and has become increasingly important in the face of modern applications such as quantum many-body problems based on first principles in physics, chemical reactions and molecular dynamics in chemistry and biology, defects and microstructures in mechanics and materials, complex fluids and/or turbulence in fluid mechanics and meteorology, massive data and image processing and mining in computer and social sciences, etc.

Traditional approaches to modeling focus on one scale. If the interest is in the macroscale behavior of a system, one models the effect of the smaller scales by some constitutive relations. If the interest is in the detailed microscopic mechanism of a process, one assumes that there is nothing interesting happening at the larger scales. By considering simultaneously models at different scales, one hopes to develop an approach that shares the efficiency of the macroscopic models and the accuracy of the microscopic models. A typical example is the quantum-mechanics-molecular-mechanics (QM-MM) approach in chemistry which is a procedure for modeling chemical reactions involving large molecules, by combining quantum mechanics models in the reaction region and classical models elsewhere. Compared with the traditional approach of focusing on one scale, multiscale and/or multi-physics modeling could be said to be a more natural way of constructing mathematical and computational models by looking at a problem simultaneously from several different scales and different levels of details. This has led to a paradigm shift for mathematical modeling towards a *multiscale modeling and simulation* approach. Such a systematic multiscale approach promises to not only provide means to tackle some very complicated and difficult scientific and engineering problems which we could not imagine solving previously, but also accelerate the close interaction between mathematicians and applied scientists.

The new paradigm of *multiscale modeling and simulation* represents an important scientific and mathematical challenge. It calls for greater participation of mathematicians and computational scientists to address some fundamental questions related to emerging multiscale applications. They need to work together with applied scientists from the modeling to computational stages, in order to design efficient and accurate multiscale computational methods, and to provide multiscale analysis for justifying different models. Over the last several decades, different multiscale computational methods, such as heterogeneous multiscale methods (HMM), multiscale finite element methods (MFEM), quasi-continuum or atomic-continuum methods, asymptotic preserving schemes and hybrid methods, have been proposed. At the same time, different multiscale analysis techniques, such as matched asymptotics, averaging, homogenization and renormalization group methods, have been developed and applied successfully for justifying multiscale models and methods.

With recent advances in the mathematical understanding of multiscale modeling and the advent of multiscale computational methods, multiscale modeling and simulation

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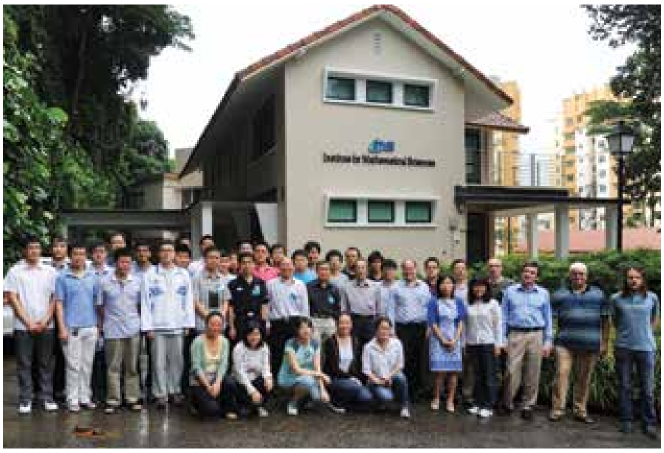
has become a key approach to investigate complicated and advanced scientific and engineering problems in applied sciences and to support future technology development in academia, industry as well as government. With the rapid development in multiscale modeling, methods, analysis and applications, a journal titled "Multiscale Modeling and Simulation: a SIAM Interdisciplinary Journal"[3] was launched by the Society of Industrial and Applied Mathematics (SIAM) in 2003; several great books[1,2] have been published by leading experts in the field; a number of research centers[5] have been established in various places and numerous international conferences[6] have been organized to promote research in the area.

Based on such developments, we designed our IMS program[7] around multiscale modeling, simulation, analysis and applications with emphasis on multiscale problems arising in mechanics and materials, quantum physics and chemistry, and complex fluids. Our aim was to use the program to bring applied and computational mathematicians, theoretical physicists, computational materials scientists and other computational scientists together to review, develop and promote interdisciplinary researches on multiscale problems that often arise in science and engineering. To do so, we arranged three series of tutorial lectures, each followed by a research workshop, a one-month winter school for graduate students and junior researchers from Singapore and overseas, and invited colleagues to spend time conducting research with us outside these main activities. A central theme was to accelerate the interaction of mathematicians and applied scientists by stimulating lively debate on important research issues related to multiscale modeling and simulation, and to promote highly interdisciplinary research with emerging applications.

The first series of tutorial lectures and the first workshop focused on challenges and modeling of multiscale problems in mechanics and materials, the second one centered on multiscale modeling and simulation for defects and their dynamics, and the third one wrapped up with mathematical theory and computational methods for multiscale problems. During each workshop, we scheduled one afternoon activity to be held at Department of Mathematics, National



A multiscaled assembly

University of Singapore (NUS), and invited all faculty members and graduate students from the Department to attend. This provided opportunities for overseas visitors to enjoy the excellent research infrastructure at the Department and interact closely with local mathematicians during their visits to IMS, NUS and Singapore. The student participants were also encouraged to give talks on their own research during the program; in particular, the 1st SIAM Student Chapter at NUS Symposium on Applied and Computational Mathematics was embedded into the program and a group of NUS graduate students organized this very successful event. In the part of the program outside the tutorial and workshop fortnights, collaborative and productive research has been carried out between local scientists and international visitors. In fact, the friendly and relaxed environment at IMS was extremely conductive to research for the participants.

Weizhu Bao
*National University of Singapore*

[1]W. E, *Principles of Multiscale Modeling*, Cambridge University Press, 2011.
[2]G. A. Pavliotis and A. M. Stuart, *Multiscale Methods: Averaging and Homogenization*, Springer, 2008.
[3]http://www.siam.org/journals/mms.php
[4]http://en.wikipedia.org/wiki/Multiscale_modeling
[5]http://www.cds.caltech.edu/cimms/
[6]http://www.mrs.org.sg/mmm2012/
[7]http://www2.ims.nus.edu.sg/Programs/011multi/index.php

## People in the News >>>

**Hans Rudolf Künsch — New President of the Institute of Mathematical Statistics**

Professor Hans Rudolf Künsch of Eidgenössische Technische Hochschule (ETH) Zürich has become President of the Institute of Mathematical Statistics. He assumed the presidency during the 8th World Congress in Probability and Statistics (9–14 July 2012) held in Istanbul. Professor Künsch was Co-chair of the Organizing Committee and an invited speaker of the IMS program Data-driven and Physically-based Models for Characterization of Processes in Hydrology, Hydraulics, Oceanography and Climate (6–28 January 2008).

**Sun-Yung Alice Chang, Jianqing Fan and Ker-Chau Li — Newly Elected Academicians of Academia Sinica**

The Institute offers its congratulations to Professors Sun-Yung Alice Chang (Princeton University), Jianqing Fan (Princeton University) and Ker-Chau Li (Academia Sinica and University of California at Los Angeles) on their election as Academicians of Academia Sinica in 2012.

Professor Chang gave a series of tutorial lectures at the IMS program Geometric Partial Differential Equations (3 May–26 June 2004). Professor Fan is a serving member of the IMS Scientific Advisory Board; he was also a member of the Organizing Committee of the IMS program Meeting the Challenges of High Dimension: Statistical Methodology, Theory and Applications (13 August–26 October 2012) and an invited speaker of several IMS activities. Professor Li gave invited talks at the IMS events Workshop on High-dimensional Data Analysis (27–29 February 2008) and Workshop on Computational Systems Biology Approaches to Analysis of Genome Complexity and Regulatory Gene Networks (20–25 November 2008); he was also a panelist of a panel discussion in the 7th World Congress in Probability and Statistics (14–19 July 2008) held in Singapore.

**Personnel movement at IMS**

Claire Tan, senior executive, left the Institute on 31 October 2012. Claire had been with the Institute since 2004. She was the Institute's program coordinator, providing administrative support to program organizers in their planning and organizing of IMS programs and activities. The Institute takes the opportunity to thank Claire for her excellent service during the past eight years and wish her success in her future career endeavors.

## Programs & Activities >>>

### Past Programs & Activities in Brief

### Financial Time Series Analysis: High-dimensionality, Non-stationarity and the Financial Crisis (1 – 22 June 2012)

Website: http://www2.ims.nus.edu.sg/Programs/012hidim/index.php

**Co-chairs:**
Ying Chen, *National University of Singapore*
Piotr Fryzlewicz, *London School of Economics*
Qiwei Yao, *London School of Economics*

The objectives of the program were (i) to bring together world-leading researchers in the field of financial time series, with a view to learning about the state of the art through workshop presentations, as well as to continuing existing and kick-starting new research projects; and (ii) to expose graduate students to the state of the art in the field and provide them with the opportunity to interact with experts through active participation in the special lectures, poster presentations and informal discussions.

Financial time series is an extremely hot topic both academically and commercially, and it is only becoming more exciting and important as the world's financial markets are being reshaped both by technological changes and by after-effects of the financial crisis. This brought to the fore such statistical issues as high-dimensionality and non-stationarity, which made up the core themes of the program. The program was successful in inviting the world leaders in the field. A special feature of the program was that speakers and poster presenters had been encouraged to use data covering the period of the recent financial crisis to discuss the impact of the crisis on their proposed models, methods and theories.

The program consisted of two workshops with a total of 27 invited talks, and a week of special lecture series which included graduate student poster presentations. The special lecture series were conducted by leaders in the field: Jin-Chuan Duan (NUS), Eric Ghysels (University of North Carolina), Wolfgang Härdle (Humboldt-Universität zu Berlin), Sam Wong (CASH Dynamic Opportunities Investment Limited), and Yazhen Wang (University of Wisconsin-Madison). The poster session provided a platform for graduate students, who are working in the area of financial time series, to communicate and discuss their work with world-leading experts. A total of 92 participants attended the program.

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High-dimensional financial modelers

Analyzers of high finance

Richard Davis: Modeling with sparse vectors

Ying CHEN (first from left), Wolfgang Härdle (third from left) and Sam WONG (fourth from left) in discussion with participants

## Random Matrix Theory and its Applications II (18 June – 15 August 2012)

Website: http://www2.ims.nus.edu.sg/Programs/012random/index.php

**Chair:**
Ying-Chang Liang, *Institute for Infocomm Research*

Random matrix theory (RMT) has emerged as an extremely powerful tool for a variety of applications, especially in statistical signal processing, wireless communications, finance, statistics and bioinformatics. The objective of the two-month program was to provide the mathematicians and engineers a unique platform to discuss interesting fundamental problems, results and explore possible solutions related to RMT and its applications in wireless communications and statistics. The program had brought together experts active in all these fields to share their respective discoveries and thoughts on random matrix theory.

The program consisted of two workshops with a total of 31 invited talks, tutorial lectures conducted by Estelle Basor (American Institute of Mathematics), Pavel Bleher (Indiana University — Purdue University Indianapolis), Yang Chen (Imperial College London) and Merouane Debbah (SUPELEC), and several ad-hoc seminars. It attracted a number of local participants, from NUS (Department Mathematics, and Department of Statistics & Applied Probability, Temasek Laboratories, The Logistics Institute - Asia Pacific, Graduate School of Integrative sciences and Engineering), NTU, SMU, A*STAR — Institute for Infocomm Research, and DSO National Laboratories. There were a total of 85 participants. Out of these 85 participants, 23 were graduate students. At least 9 research collaborations/ papers were initiated during the program.

Random matrix theorists making waves in wireless communication

Ying-Chang LIANG: Of large scale MIMO and cognitive radio

Craig A. Tracy: Asymmetric simple exclusion process

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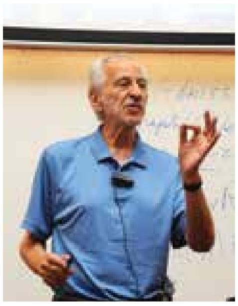
Random statistical exchange? (From left) Peter Bühlmann from the program on Meeting the Challenges of High Dimension, Qiman SHAO and Jianqing FAN

## Asian Initiative for Infinity (AII) Graduate Summer School (20 June – 17 July 2012)

*... Jointly funded by the John Templeton Foundation*

Website: http://www2.ims.nus.edu.sg/Programs/012aiiss/index.php

The objective of the AII Graduate Summer School was to bridge the gap between a general graduate education in mathematical logic and the specific preparation necessary to do research on problems of current interest in the subject. This was the third and the last summer school supported by the John Templeton Foundation. The Summer School consisted of a set of four intensive short courses conducted by Ilijas Farah (York University), Ronald Jensen (Humboldt-Universität zu Berlin), Gerald E. Sacks (Harvard University) and Stevo Todorcevic (University of Toronto). A total of 60 participants attended the summer school.



Gerald E. Sacks: E-recursion

Contemplating infinity

A set of cardinality four (From left to right: Yue YANG, Qi FENG, Ronald Jensen, Chi-tat CHONG)

## Meeting the Challenges of High Dimension: Statistical Methodology, Theory and Applications (13 August – 26 October 2012)

Website: http://www2.ims.nus.edu.sg/Programs/012statheory/index.php

**Co-chairs:**
Peter Hall, *University of Melbourne*
Xuming He, *University of Michigan*
Yingcun Xia, *National University of Singapore*

The topic of high dimensional data analysis has many aspects, motivated by many applications, sometimes relying heavily on dimension reduction and variable selection, and sometimes co-habiting happily with more conventional multivariate methods. The objective of the program was to bring the distinguished statisticians together to discuss new development in the research of the area, including methodology, theory and their applications, and exchange their ideas. The program featured two workshops, tutorial lectures and a public lecture; in addition, there were also two seminars jointly organized with the Department of Statistics and Applied Probability, NUS.

The program's first workshop (13 – 24 August 2012) consisted of 26 invited talks and addressed various aspects of high dimensional data analysis. They lie at the frontiers along which statistical methodology, the applications that motivate it, the questions that it answers, and the theory that underpins it, are advancing today. The program's second workshop (1 – 12 October 2012) consisted of 18 invited talks and continued to address challenges of high dimensional data analysis with more focuses on the methods and applications where sparsity is present. The tutorial lectures of the program were delivered by Geoff McLachlan (University of Queensland) — on modelling high dimensional data via finite mixture distributions and Peter Hall (University of Melbourne) — on methodology and theory for functional data analysis.

The program was successful in bringing together the existing work, raising new research problems and research directions. More importantly, the program benefited the local researchers especially the junior statisticians in Singapore. Around 40 people from Singapore attended the workshops and joint seminars, and a number of research collaborations were undertaken between the local scholars and overseas participants. Many participants also expressed interest in organizing or participating in follow-on or similar programs at IMS. The program attracted a total of 126 participants.

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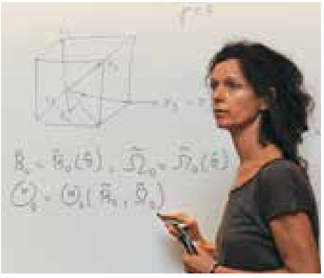
Seeking clarity on dimension reduction: Liping ZHU (left) and participants

Peter Hall: Functional data analysis



Sara van de Geer: Looking at DAGs (directed acyclic graphs)

Statisticians of high dimension in conclave with random matrix theorists

## Joint Workshop of IMS and IMI on Mathematics for Industry: Biological and Climatic Prospects (3 – 7 September 2012)

*... Jointly organized with Institute of Mathematics for Industry, Kyushu University*

Website: http://www2.ims.nus.edu.sg/Programs/012wind/index.php

**Organizing Committee:**

Robert S. Anderssen, *CSIRO*
Kenji Kajiwara, *Kyushu University*
Tomoyuki Shirai, *Kyushu University*
Kim Chuan Toh, *National University of Singapore*
Masato Wakayama, *Kyushu University*

The objectives of this workshop were (i) to help create/enhance the awareness on the applicability and importance of mathematical sciences in industry, and also (ii) to foster closer interactions among industrial researchers/practitioners and mathematical scientists to solve contemporary industrial problems.

The level of the talks in the workshop was excellent. The speakers have provided various interesting and impactful examples on how mathematics is applied and created to solve problems arising from industries. Such examples include the analysis of jamming of traffic in social and biological systems, planning of medical therapy and operation by using optimal control, mathematical analysis for computer graphics in animation industry, weather forecast in Singapore and Japan, the mathematical modelling of maple's sap flow, simulation of heart and tsunami by using supercomputer "Kei" (meaning 10 Peta in Japanese). The speakers also provided new directions on research collaboration with the industries.

The workshop consisted of 21 talks and attracted 40 participants. The academic disciplines of the speakers and participants of the workshop were diverse, including PDEs, optimization, integrable systems, number theory, representation theory, topology, probability, differential geometry, wavelets, statistics, bioinformatics, parallel computing, and visualization.

Mathematicians looking to develop new technologies

Sharing thoughts on topology applied to proteins (From left: Masato Wakayama and Yasuaki Hiraoka)

Peter Deuflhard: Mathematics in virtual medicine

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**Public Lecture:**

IMS Director Louis CHEN and Terry Speed: appreciation between friends

Terry Speed: Introducing the new frontier of epigenetics

Professor Terry Speed of Walter and Eliza Hall Institute of Medical Research, Australia and University of California at Berkeley, USA, gave a public lecture titled "Epigenetics: a new frontier" at NUS on 16 October 2012. In the lecture, Professor Speed first gave a brief introduction of epigenetics, indicating its role in cellular specificity, its control of the spatial and temporal expression of genes, and its association with disease states. He described some principal mechanisms through which epigenetic control occurs, such as DNA methylation and histone modification. He also outlined the data becoming available, summarized some of the progress made so far, and gave a glimpse of the mathematical and biostatistical challenges in the study of epigenetics. The lecture was delivered in an interactive style to an enthusiastic audience of 53 people.

## Current Program

### Optimization: Computation, Theory and Modeling (1 November – 23 December 2012)

Website: http://www2.ims.nus.edu.sg/Programs/012opti/index.php

**Co-chairs:**

Defeng Sun, *National University of Singapore*
Kim Chuan Toh, *National University of Singapore*

This program will provide a platform for exchanging ideas in solving large scale conic optimization problems including semi-definite programming (SDP) and symmetric cone programming (SCP), report on the latest exciting developments in complementarity and beyond and discuss on another closely related theme — optimization under uncertainty. Additionally, exciting applications of optimization models involving uncertainty from engineering, data mining, financial economics, supply chain management, etc. are highly anticipated in this program.

#### Activities

- Workshop I — Large Scale Conic Optimization: 19 – 23 November 2012
- Workshop II — Optimization Under Uncertainty: 10 – 14 December 2012
- Workshop III — Complementarity and Its Extensions: 17 – 21 December 2012

## Next Program

### Algorithmic Game Theory and Computational Social Choice (7 January – 8 March 2013)

Website: http://www2.ims.nus.edu.sg/Programs/013game/index.php

**Co-chairs**

Ning Chen, *Nanyang Technological University*
Edith Elkind, *Nanyang Technological University*

The objective of the program is to bring together experts on algorithmic aspects of economics and group decision making in order to foster interdisciplinary collaboration in two burgeoning research areas, namely, algorithmic game theory and computational social choice. The two areas are closely related to each other, and share strong mathematical foundations. The program serves as a meeting point for researchers from different areas that study incentives and collective action, such as mathematics, game theory, theoretical computer science, artificial intelligence, economics, social choice, and operation research, and will expose the participants (and especially junior researchers) to a wide variety of tools, techniques, and modeling perspectives.

#### Activities

- Research Collaborations: 7 January – 8 March 2013
- Mini-workshop on Mechanism Design: 10 – 11 January 2013
- Winter School and Workshop on Algorithmic Game Theory: 14 – 18 January 2013

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- Winter School and Workshop on Computational Social Choice: 21 – 25 January 2013
- 2-Part Tutorial by Clemens Puppe, Karlsruhe Institute of Technology, Germany: 12 February 2013

## Programs & Activities in the Pipeline

### Workshop on Topological Aspects of Quantum Field Theories (14 – 18 January 2013)

Website: http://www2.ims.nus.edu.sg/Programs/013wquantum/index.php

**Organizing Committee:**
Ralph Cohen, *Stanford University*
Fei Han, *National University of Singapore*
Stephan Stolz, *University of Notre Dame*
Peter Teichner, *Max-Planck Institute for Mathematics at Bonn and University of California at Berkeley*

This workshop will be focusing on, but not limited to, the topics on (i) K theory, elliptic cohomology and various field theories; and (ii) string topology. The objective of the workshop is to bring together researchers working on these areas to communicate ideas and dig out the connections as well as stimulate possible research collaboration. The workshop will also provide graduate students, both local and overseas, with the opportunity to learn new progresses of the relevant fields as well as communicate with working mathematicians.



#### Activities

In this workshop, there will be four-to-five lectures each day, including four 3-lecture minicourses.

### Modular Representation Theory of Finite and p-adic Groups (1 – 26 April 2013)

Website: http://www2.ims.nus.edu.sg/Programs/013mod/index.php

**Co-chairs**
Wee Teck Gan, *National University of Singapore*
Kai Meng Tan, *National University of Singapore*

This month-long program is devoted to the representation theory over a field of nonzero characteristic of finite and p-adic groups, as well as related algebras, especially those arising naturally in Lie theory. The two main topics of the program are (i) Modular Representation Theory of Finite Groups and Related Algebras; and (ii) Modular Representation Theory in the Langlands Programme. The goal of the program is to survey these recent developments and to provide impetus for further insights and progress. In addition, it aims to bring together researchers in these two areas to foster interaction, collaboration and the exchange of ideas.

#### Activities

There will be 6 tutorials (instructional lecture series of 3 or 4 talks each) during the program on the following topics:

- Six tutorials (instructional lecture series of three or four talks each): Weeks 1 – 3
- Research conference: Weeks 3 – 4

### Nonlinear Expectations, Stochastic Calculus under Knightian Uncertainty, and Related Topics (3 June – 12 July 2013)

*…Jointly organized with Centre for Quantitative Finance, NUS*

Website: http://www2.ims.nus.edu.sg/Programs/013wnlinear/index.php

**Chair**
Shige Peng, *Shandong University*

This program will be focusing on, but not limited to, the two areas (i) nonlinear expectations, backward stochastic differential equations and path-dependent PDE; and (ii) nonlinear expectations, risk measures and robust controls. The program is intended for leading researchers working in these areas to exchange ideas and hopefully to inspire new mathematical concepts and results. It is also intended to bring young researchers and investment banking practitioners in the related quantitative areas to the frontier of these two fascinating areas.

#### Activities

- Workshop on Knightian Uncertainty and Backward Stochastic Differential Equations: 10 – 14 June 2013
- Institute of Mathematical Statistics Workshop on Finance — Probability and Statistics: 19 – 21 June 2013
- Workshop on Knightian Uncertainty and Risk Measures: 1 – 5 July 2013

### Complex Geometry (22 July – 9 August 2013)

### Mathematical Horizons for Quantum Physics 2 (12 August – 11 October 2013)

*…Jointly organized with Centre for Quantum Technologies, NUS*

### Inverse Moment Problems: the Crossroads of Analysis, Algebra, Discrete Geometry and Combinatorics (11 November 2013 – 25 January 2014)

### School and Workshop on Classification and Regression Trees (10 – 26 March 2014)

## Mathematical Conversations

# John Ball: Nonlinear Elasticity, Microstructures and Mathematics >>>


Sir John Ball

Interview of John M. Ball by Y.K. Leong

Sir John Ball has made important contributions to the calculus of variations, nonlinear partial differential equations, infinite-dimensional dynamical systems and their applications to nonlinear elasticity and solid mechanics.

He is known for his work on the mathematics of microstructure arising from phase transformations in solids, and has used models in nonlinear elasticity to predict microstructure morphology. In a ground-breaking paper written with R.D. James in 1987, he proposed a new nonlinear theory of martensitic transformation which enables one to understand martensitic microstructures in terms of energy minimization. His latest research interest is in the theory of liquid crystals.

His undergraduate education was at the University of Cambridge and he obtained a D.Phil. in mechanical engineering from the University of Sussex. He then went to Heriot-Watt University in Edinburgh, initially with an SRC (Science Research Council) postdoctoral fellowship held partly at the Lefschetz Center for Dynamical Systems at Brown University. After a distinguished career at Heriot-Watt (where he retains an Honorary Professorship), he moved to the University of Oxford as Sedleian Professor of Natural Philosophy and Fellow of The Queen's College. He is currently Director of the Oxford Centre for Nonlinear PDE. He also serves as Chair of the Scientific Steering Committee of the Isaac Newton Institute at Cambridge University.

His past and present editorial services have been rendered over a wide range of international journals and monograph series in pure and applied mathematics, in particular in analysis, the calculus of variations, continuum mechanics, mathematical modeling, numerical analysis and partial differential equations. He is currently the Chief Editor (with R.D. James) of the *Archive for Rational Mechanics and Analysis*.

His energy and passion for serving science extends outwards to the international community. Since 1986, he has served repeatedly as a delegate to the General Assembly of the International Mathematical Union (IMU); this culminated in his election as President of IMU from 2003 – 2006. Among his international scientific services are those to the following organizations: International Mathematical Union (IMU, President 2003 – 2006), IMU Committee on Electronic Information and Communication, International Council for Science (Executive Board), Conseil Scientifique du CNRS, Conseil Scientifique d'Electricité de France, Weizmann Institute, Israel (Board of Governors and Scientific and Academic Advisory Committee), École Polytechnique, Palaiseau (Conseil de Recherche et de l'Enseignement), International Centre for Mathematical Sciences in Edinburgh (Programme Committee) and Mentoring African Research in Mathematics Project (MARM) (Trustee). He was a member of the first Abel Prize Committee in 2002 and of the Fields Medal Committee in 1998, chairing it in 2006.

He has received numerous awards and honors for his mathematical and scientific contributions, notably the Whittaker Prize, Junior Whitehead Prize, Keith Prize, Naylor Prize, Theodore von Karman Prize, David Crighton Medal, the Royal Medal of the Royal Society of Edinburgh, and the John von Neumann Lecture of SIAM. He is a Fellow of the Royal Societies of Edinburgh and of London. He received several honorary doctorates and was elected to the membership of the following scientific bodies: Norwegian Academy of Science and Letters, Academia Europaea, Academie des Sciences and Istituto Lombardo. He was knighted in 2006 'for services to Science'.

He has been actively involved in the organization of

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scientific meetings and conferences in Europe and the United States. He has held visiting positions and given invited lectures around the world, in the United States, Europe, Asia, Africa and South America. He was at the National University of Singapore to give an invited public lecture on "*Mathematics in the public eye — The story of Perelman and the Poincaré Conjecture*" on 22 July 2009 during the Institute's program *Mathematical theory and numerical methods for computational materials simulation and design* (1 July – 31 August 2009). By then, the events leading to the award of the Fields Medal to Grigori Perelman at the International Congress of Mathematicians 2006 in Madrid, and the subsequent media sensation caused by his refusal to accept the award, were already well known to the public. So when the former President of IMU, who was at the centre of the action, gave a fascinating first-hand account of an unusual mathematical drama that had never before captured so much attention of people around the world, it was a treat for a packed audience. On 27 July 2009, Y.K. Leong interviewed him on behalf of *Imprints* and the following is an edited and enhanced account of yet another treat — a rarely seen mathematical view of the world of microstructures of materials and a moving expression of optimism in the unifying power of mathematics.



***Imprints:*** You obtained your first degree in mathematics at Cambridge University but your doctorate was in mechanical engineering from the School of Applied Sciences of the University of Sussex. Was there any specific reason for choosing Sussex?

***John Ball:*** Yes. I didn't get very good exam results at Cambridge, and though my original thought was to do algebra at Oxford I could only get a one-year grant there. A former school teacher of mine had in the meantime moved to Sussex and was working in the School of Applied Sciences, which was actually not part of the mathematics department, and which offered a grant for three years. So I decided to go there instead.

***I:*** I think that at that time Sussex University was one of the 'new wave' universities in Britain.

***B:*** That's right. It was quite a trendy place! I was lucky that at the same time in the mathematics department, David Edmunds, who eventually took over as my supervisor, was running a programme on differential equations. They were two separate departments. I was officially in Applied Sciences which was mainly engineering. My D.Phil. was in mechanical engineering, but I've never been able to exploit this. [*Laughs*]

***I:*** The topic of your doctoral thesis was on topological methods in nonlinear analysis [of beams]. Did your doctoral research work come in useful for your future research in applied mathematics?

***B:*** Yes, it did. In my thesis, I learnt about partial differential equations and also dynamical systems applied to continuum mechanics. That's how I got interested in mathematics applied to mechanics.

***I:*** Could you briefly tell us how the calculus of variations crops up in the mathematics of the microstructure of alloys and substances?

***B:*** If one writes down a model for elastic crystals based on nonlinear elasticity, then one can show that in some situations the infimum of the energy for deformations satisfying suitable boundary conditions is not attained, so that minimizing sequences for the energy develop in the limit infinitely fine microstructures. In various alloys one indeed sees extremely fine microstructures – this is an example of a situation where the mathematical model does not have a solution in the normal sense, but nevertheless predicts physical phenomena.

***I:*** Do you need to prove the existence of solutions in these models?

***B:*** From a technical point of view, there is in general no minimizer described in the usual way as a function with derivatives, so that you can't prove existence of one, but there are generalized kinds of minimizers that exist described by Young measures.

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***I:*** But physically speaking, the solution must exist, isn't that right?

***B:*** Whether there is a solution depends on the model. Of course one doesn't observe infinitely fine microstructures in nature, but you can modify the model by incorporating interfacial energy so as to understand the length-scales of the very fine microstructures actually observed, and for some of these models a minimizer does exist.

***I:*** Can I come back to Sussex University? I think that around that time Sussex had a lot of very good research work in materials science, discovering new materials and all that.

***B:*** Well, I was not aware of this at the time. My work on materials came much later, and then I came across names of people working on materials who were at Sussex when I was there, but I did not interact with them personally.

***I:*** In the modeling of microstructure of materials, can quantum mechanics be applied directly to provide the model?

***B:*** It certainly can be and is applied. Of course, it depends on what you want to predict. If you want to predict the phase diagram, there is a whole range of different models, for example density functional theory, that come from quantum mechanics. In some sense, if you know the phase diagram, you can then try to understand what is happening at the mesoscopic level, but it is not practical to use quantum mechanics for this purpose, either theoretically or computationally.

***I:*** You mentioned that there are many models for the study of microstructures. Shouldn't there be just one model?

***B:*** Imagine modeling the gas in this room. You know you can do this at different levels of detail. You can try and understand each molecule in detail, using quantum mechanics for example, or study the gas in terms of the motions of all the molecules. Or you can use a model based on the kinetic theory of gases; and then there are all sorts of models that describe the gas at the continuum level. I think that one of the great themes of modern science and modern applied mathematics is to understand how all these different models can be reconciled, and how each can be obtained as an appropriate limit of a more detailed model.

***I:*** Do you formulate a model first and then test it experimentally or do you look at the data first and then formulate a model to fit the data?

***B:*** That's an interesting question. As a mathematician the first thing that may happen is that you get interested in some problem, through reading, talking to somebody or listening to some lecture. Usually you get interested in it because there's something in your own background which you think might give you a chance of saying something about this problem. Then there is the question of interacting with people in that area. Maybe your first idea for a model will have some sense, but more likely it won't. So you have to continue changing your model to try to fit reality better. I think that the direct interaction between theoreticians and experimentalists is always very interesting for both parties.

***I:*** Do you personally interact with the experimentalists?

***B:*** Yes. For example I once had an interesting collaboration with an electron microscopist Nick Schryvers which began with him asking about some images of microstructure he had taken. He explained what he thought were the processes the microstructure had resulted from, but it seemed to me that what we were seeing was not consistent with theory. Looking more carefully we saw that some interfaces we had thought were flat were in fact slightly curved, which was better for the theory, and thus the interaction went on to and fro. In the end, I think we both learnt things, which neither of us would have done on our own. One of the most difficult things is to try to break down language barriers. Researchers in different subjects can mean different things when they say they understand something. For example, physicists may say they understand something if they understand the physical processes involved, while mathematicians will only say they understand something if they can, in some sense, predict quantitatively, or qualitatively, consequences of some well-defined mathematical model.



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***I:*** How do you manage to break down this language barrier?

***B:*** You have got to have an interest in the science, first of all. Then you need both confidence and humility — confidence that you can contribute something, that you understand something that the more experimental people don't understand, and humility because you are not an expert in the experiments and can easily have misconceptions. For example, I never did an undergraduate degree in materials science or physics, so that in interacting with materials scientists my knowledge has always been confined to some small pieces of it. You have to be always checking what you think by listening to people who have different backgrounds.

***I:*** Serendipity has sometimes played an important role in research in the physical sciences. Much of your research is done at the interface between physics and mathematics. Has serendipity played any role in your research?

***B:*** Yes. For example, the reason I got involved in materials science was that Dick James was visiting me in Edinburgh and he asked some questions about what the minimizing sequence for a material would look like if the minimum energy was not attained. I drew a picture of a half-space with a constant gradient on one side and a layered structure on the other, and he said, "That reminds me of something." The next day he came back and said, "You know what that picture is of? It's an austenite/martensite interface." That's a basic kind of interface in martensitic transformations. He had the background to notice the similarity. It was luck in some sense that he asked me this question and that I responded in the way I did. I could have drawn many pictures other than the one I happened to draw.

***I:*** That was something significant which was an insight into interface theory.

***B:*** Well, I won't make big claims about the theory of martensitic transformation based on nonlinear elasticity, but it has certainly given some new insights both theoretically and experimentally. In fact the model Dick James and I developed for austenite/martensite interfaces was not new in the sense that it recovered classical formulae of the successful crystallographic theory of martensite, but it placed that theory in a more general context, which proves useful.

***I:*** Your recent research interest is in liquid crystals. Could you tell us something about liquid crystals?

***B:*** Well, I'm not at all an expert on liquid crystals. The mathematical structure is very similar to elasticity theory, but from the physical point of view it is rather different. Everybody is familiar with liquid crystals from watch displays, televisions and so on. The mathematical model and physical theory preferred by the majority of physicists nowadays is the so called Landau-de Gennes theory, but mathematicians had not really studied this very much. Starting two or three years ago, I started to work on this theory. It came about because a research student Apala Majumdar in Bristol explained to me what she was doing, and I just got into it, and eventually she became a postdoc working with me in Oxford.

***I:*** Are liquid crystals a little bit of liquid and a little bit of solid?

***B:*** Liquid crystals flow like liquids. They retain some orientational order of their molecules. In the special case of nematic liquid crystals, the molecules can be idealized as rods. They are typically quite ordered, more or less pointing in some direction but not perfectly, a bit like matches in a matchbox.

***I:*** Has modeling of microstructure led to the discovery of important new materials?

***B:*** My collaborator Dick James has done some very interesting things connected with materials that have very low hysteresis. The mathematical understanding of the elasticity theory of microstructure leads you to what you need to do to construct such materials. Together with other collaborators, it has been possible to construct such materials but whether they will turn out to be important for technology and applications remains to be seen.

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***I:*** Are some of these discoveries patented?

***B:*** Yes, but not by me.

***I:*** The non-specialist usually associates the theory of elasticity or elastostatics with civil engineering (involving construction of bridges and buildings). Could you give us some idea how elastostatics can be relevant at the molecular level?

***B:*** Yes. It is quite surprising at how small a length-scale elasticity can be a good model. It seems to be applicable in situations where, for example, there are layers whose width is just a few inter-atomic distances. If one thinks of a cube of side-length 10 atoms, then there are already a thousand atoms in this cube. So maybe it is not so surprising that a continuum model still works at this kind of length-scale.

***I:*** I remember that I had a short course on the theory of elasticity as an undergraduate, but somehow or other the theory of elasticity seems to have a lower profile than, say, fluid dynamics. Is it still true now?

***B:*** Yes. It is certainly true. In Oxford I have tried to change that a bit without much success; I think that it is part of the tradition of the country. One thing I would like to see in universities is that continuum mechanics is taught, first of all, as a unified subject; starting with kinematics and the balance laws, and only then specialized to different materials such as solids and fluids

***I:*** Are there any central problems in elastostatics?

***B:*** Almost all the fundamental questions of the subject are poorly understood. As an example, for no realistic model of materials is it currently possible to prove the existence of smooth equilibrium solutions for general boundary conditions, although in some cases we know that there is a minimizer of the energy. The situation is much worse, I think, than for fluid dynamics.

***I:*** In that sense, the problems there are harder than those in fluid dynamics?

***B:*** I wouldn't like to say that they are harder than fluid dynamics because, for example, there are also models of non-linear fluids that give rise to very challenging problems. I think that there is a different flavor of mathematics involved — maybe more algebra and a bit more geometry. Solid mechanics is a kind of melting pot of all sorts of different branches of mathematics, and has been since the time of Cauchy and other founders of the subject.

***I:*** Have you been able to attract more mathematically minded students to look at problems in elasticity?

***B:*** Well, I have had a number of very talented students and postdocs. Still it is not so easy to attract good students to modeling and analysis applied to materials because one needs strong mathematicians who have a good background in analysis, geometry and other areas and at the same time they need to have a genuine interest in science. It's partly the result of how they are taught at university. In Oxford, students tend to get polarized much too early in their career as being pure or applied mathematicians. But both the ancient and modern views of mathematics are not like that. There is no clear distinction between pure and applied mathematics. There is a danger that when undergraduates learn the subject they go one way or the other too early and they adopt values that are different. I'm a strong believer in the value of proving theorems and their importance for understanding Nature. I think that students in the way they are taught may think that they should work, say, in geometry or algebra, as sort of compartmentalized subjects in some sense deeper or less contaminated by the real world. I think this is a misunderstanding of how mathematics has developed over the centuries. This is certainly a barrier to attracting very good students.

***I:*** Does the British tradition still maintain keeping fluid dynamics and applied mathematics within the mathematics department?

***B:*** Yes, that is true. I think a lot of what is termed applied mathematics in Britain is internationally regarded more as theoretical physics. There are unified departments of pure and applied mathematics in some universities in Britain but probably not enough of them.

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***I:*** In the US, fluid dynamics is usually taught in the physics or engineering departments.

***B:*** Yes, but also in the engineering departments in the US you find people who are very sophisticated mathematically and that is not usually the case in Britain.

***I:*** You were President of the International Mathematical Union (IMU) from 2002–2006. If I'm not wrong, most of the past presidents of IMU were "pure mathematicians". It appears that the International Congress of Mathematicians (ICM) 2006 at Madrid was some sort of watershed for probability theory. It also seems to be a paradox that mathematics is diversifying and being compartmentalized into more and more areas and yet at the same time is achieving a deeper and wider unity. What is your view about the way mathematics could develop in the future?

***B:*** Well, there are altogether six questions in one. [*Laughs*] Some of the past presidents, for example, Jacques-Louis Lions, were certainly applied mathematicians. I don't like making the division. Probably you are right that the majority of the presidents have been on the pure side. Yes, probability theory somehow clearly had not been represented enough in the Fields Medals. That was to some extent rectified in Madrid, but that is also a reflection of how important that subject is becoming in recent years.

***I:*** Was there some kind of resistance to accepting probability for the Fields Medal?

***B:*** There might have been some in the past, I suppose. Each Fields Medal Committee has a different dynamic, I think. I can't remember off the top of my head how often probabilists have been on the Fields Medal Committee, but there was certainly one in 2006. One of the guidelines of the Fields Medal Committee is to represent a diversity of fields. This was not always satisfied in the past. I think it is a very good principle.

Yes, I think mathematics is diversifying. It is now in a period where there is increasing interaction between fundamental mathematics and applications. I think we went through in part of the 20th century a period where this artificial division between pure and applied mathematics was accentuated, and that is essentially disappearing. I think mathematicians can contribute something to science which other scientific disciplines cannot do, and most mathematics departments now have some interest in applications.

New mathematics often, if not usually, has its genesis in applications. For example Fourier theory came from trying to understand heat conduction. Mathematicians look at such ideas in a more general way and develop them according to their intrinsic structure, so that later they may become applicable to different areas, as in the case of Fourier analysis. The main feature that distinguishes how mathematicians do mathematics as opposed to how other scientists do mathematics is that we are more interested in this fundamental structure and the natural development of the subject according to this structure.

Well, I don't think anybody should try to predict how mathematics will develop in the future, but it is a general remark that as scientific subjects become more understood, they become more mathematical. You see now that the biosciences and medicine are becoming more understood, so that they become more quantitative and more mathematical. Of course, it took a long time for this to happen. It will be a long time before you go to a doctor and explain your symptoms, and he or she turns on their computer, which solves some equations and helps the doctor arrive at some conclusion. This will happen in the distant future though, I am sure.

***I:*** Do you think that there will be somebody who could understand a lot of fields — some kind of universalist?

***B:*** Well, there are one or two remarkable mathematicians who come close to this ideal; for example, in the younger generation, Terry Tao is one who has tremendous breadth. I think it is possible to have talented people who cover, not all of mathematics, but quite a large part of mathematics. But that requires a lot of intellect.

# Paul Embrechts: Mathematics, Insurance, Finance >>>

Paul Embrechts

Interview of Paul Embrechts by Y.K. Leong

Paul Embrechts has made important and extensive contributions to insurance risk theory, quantitative risk management, mathematical finance and the modelling of rare events.

Embrechts had his undergraduate education at the University of Antwerp in Belgium and obtained his doctorate from the Catholic University of Leuven in 1979. Subsequently, he taught at Imperial College, University of London from 1983 to 1985, immediately after which he moved back to continental Europe where he established a long and distinguished career, first at University of Limburg, Diepenbeek (1985–1989) and then at ETH (Eidgenössische Technische Hochschule or Swiss Federal Institute of Technology) in Zurich where he is full professor of mathematics since 1989. He is the current Director of RiskLab-ETH, which was founded in 1994 as a virtual research cooperation and which he helped reorganize in 1999.

His scientific papers, both single-authored and co-authored, number more than 160 and have made important contributions to actuarial risk theory and risk theory in finance and to mathematical modelling in insurance and finance, in particular, modelling extremal events, econometric modelling, modelling dependence beyond linear correlation and modelling uncertainty in insurance and finance. He has co-authored a number of books and monographs, the most influential being *Modelling Extremal Events for Insurance and Finance* (co-authored with C. Klüppelberg and T. Mikosch).

He is a strong and active advocate of dialogue and interaction between academia and the finance, insurance and energy industries. In addition to serving on the editorial boards of a number of leading journals on finance, insurance and statistics, he has given consultative services to major financial institutions, insurance companies in industry and to international regulatory authorities in Europe and the United States.

Since 1987 he has been actively involved in numerous professional committees of scientific organizations such as Bernoulli Society, Institute of Mathematical Statistics, Foundation for Agency Management Excellence (FAME), Bachelier Finance Society and of universities and research centers in Europe. He has also been active in the organization of major conferences and scientific meetings throughout the world. He has held visiting positions in prominent universities and has been invited to give keynote lectures in many important scientific meetings and special lectures such as the Johann Bernoulli Lecture, Nomura Lecture, Hermann Otto Hirschfeld Lectures, Kuwait Lecture, Humboldt Distinguished Lecture Series, Radon Lecture and Patrick Poon Lecture. He has received honors from many professional bodies such as Institute of Mathematical Statistics, Institute of Actuaries, The Faculty of Actuaries, Belgian Institute of Actuaries and honorary doctorates from Heriot-Watt University, Catholic University of Louvain and University of Waterloo.

Embrechts is a member of the International Advisory Panel to the Risk Management Institute which was established in National University of Singapore (NUS) in 2006 with the support of the Monetary Authority of Singapore. He has close scientific associations and collaboration with the faculty of NUS. He was the Chair of the Organizing Committee of the program "Financial Mathematics" (2 November –23 December 2009), jointly organized by the Institute for Mathematical Sciences and the Risk Management Institute,



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NUS. On behalf of *Imprints*, Y.K. Leong interviewed him on 18 November 2009. The following is an edited and enhanced transcript of the interview in which he gives us a glimpse of the interplay between the abstract in mathematics and the reality manifested in insurance and finance. His ebullience and optimism in the power of the human intellect coupled with unwavering ethical principles in resolving real-life issues and improving the human condition is clearly felt in the interview.

***Imprints:*** What was the topic of your PhD research? Who was your PhD supervisor?

***Paul Embrechts:*** The topic of my PhD research was subexponential distribution functions; it's applied probability and essentially modelling of extremal events in insurance. My supervisor was Professor Jef Teugels from the Catholic University of Leuven. He's very well-known here in Singapore. He's the President of the International Statistical Institute (ISI) [(2009–2011)].



***I:*** Did your PhD research have anything to do with your future work?

***E:*** Oh, yes. From the start of my research — concentrating on the modelling of rare and influential events — "catastrophic risks" — was very much present in my work. So it led to applications to various fields including finance and insurance. In that sense it had a very strong influence on my later career.

***I:*** You taught at Imperial College, London from 1983 to 1985 and then returned to Belgium. Did you ever consider going from London to the US where both the academic and financial attractions must have been irresistible at that time?

***E:*** When I finished my PhD in '79, with my family I immediately went for a postdoctoral to London to work with Nick Bingham at Westfield College. In those days, Westfield College was part of the University of London and I was doing more mathematical research but still on extremal events. There I got an offer by the end of that year to go to the United States, to go to the University of Colorado at Fort Collins, then a world leading place in extreme value theory. For family reasons I did not accept; we had already two children at that time. Concerning the attraction of finance, indeed the United States had a lot to offer. You must, however, realize that my field of research together with specific applications was much more related to insurance. When it comes to insurance then Europe, especially the Continent, has much more to offer. The reason is that in the United States, and to some extent also in the UK, examinations and teaching are very much in the hands of the actuarial societies, the Society of Actuaries and the Casualty Actuarial Society in the US, or in the UK, the Institute and Faculty of Actuaries. On the Continent — Belgium, the Netherlands, Germany, Switzerland, etc, teaching is typically done at departments of mathematics, by their professors. As a consequence, we do more methodological mathematical research. We are also less dependent on the local actuarial societies, though we work together closely. So from the academic point of view, if you are interested in doing research in finance and insurance — for finance, yes, the USA in those days; for insurance, with a much stronger emphasis on mathematics, you came to Europe though, of course, several excellent centers exist outside of Europe. I remember, at Imperial College in those early days, I even started with some colleagues from other UK universities (Heriot-Watt, Edinburgh, Imperial College, City) meetings of lecturers in actuarial science. We brought together people with a common interest in the teaching of actuarial mathematics; we were very few in those pioneering days! Moreover, the stochastic modelling of extremes was also very strong in Europe, leading to an optimal combination for me.

***I:*** But nowadays you are more interested in finance than in actuarial science.

***E:*** Well, I'm still professor of mathematics, and as you know, ETH Zurich has a very strong department of mathematics. As professor of mathematics I'm responsible for teaching and research in actuarial mathematics. When I came to Zurich in '89, it was immediately clear to me that combined teaching and research in actuarial mathematics and mathematical finance would be very important going forward, like in industry, combining asset and liability management. So I started building up a research group both actuarial and

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finance centred, including the foundation of RiskLab in '94. Why '94? Because of the new capital adequacy rules for banks, the so-called Basel I and Basel II guidelines, the financial industry became increasingly interested in teaming up with academia. We started in the beginning with the three main Swiss banks, later expanded through Swiss Re, a reinsurance company. The key structure was a "triangle", the key concept "precompetitive research". The former refers to collaboration between academia, the financial industry and the regulators; the latter stresses that we wanted to do interdisciplinary research, the results of which would be available to all. In academia it is easy to say "We have to do interdisciplinary research"; it's much more difficult to actually do it. Modern academic establishment with all its indices and rankings is not really valuing that very highly. Publications in pillar-thinking top journals are asked for. Anyhow, in October 1994 we started RiskLab with the three players — academia, the financial institutions and the regulators. We roped them together and asked: "Ok, what do you think are important topics to do research on?" As a consequence we jointly came up with a number of topics which were of interest to the three groups. We at ETH looked for excellent students; industry collaborated and also financed the research. The combination worked. Many key ideas and results came out of RiskLab. If you look at the various professors at ETH, I am the one who concentrates most on insurance but, of course, now I also do a lot of research in the direction of finance applications. At heart however I remain an insurance mathematician.

***I:*** So in that sense actuarial mathematics actually precedes mathematical finance.

***E:*** Yes, by far. Many famous mathematicians worked on actuarial problems, including such names as [Carl Friederich] Gauss, Nicolaus Bernoulli, [Bruno] de Finetti, [Harald] Cramér, [William] Feller, [Ulf] Grenander. Becoming an actuary has always been a preferred profession for mathematicians. This was especially noticeable in Scandinavia and much related to problems in life insurance and pension funds. Later mathematicians became also sought after in non-life and reinsurance, and only more recently the banking industry entered the job stage. If, for instance, you look at the early editions of the *Journal of the Italian Actuarial Society*, you find fundamental probability papers by such mathematicians as [Francesco Paolo] Cantelli, [Andrey Nikolaevich] Kolmogorov, [Paul] Lévy. By the way, did you know that it was a Swedish actuary, Olof Thorin, who first proved that the lognormal distribution is infinitely divisible? This was published in the *Scandinavian Actuarial Journal*. Actuarial issues are of high relevance to society and we mathematicians have to get involved. I have told several presidents of ETH, "Switzerland has three important problems to solve in the future: social-insurance, social-insurance and social-insurance.", by social-insurance I mean life, health and pension insurance. No doubt the same holds true for Singapore.

***I:*** I believe that Albert Einstein was reputed to have said that compound interest is the greatest invention of man. I wonder if that is true.

***E:*** It is, indeed, generally accepted that in an interview he said something along those lines; we are, however, not absolutely sure. You know, Albert Einstein was a student at ETH just like John von Neumann.

***I:*** Maybe he said in a joking manner.

***E:*** Possibly, however the compound interest concept is a very important "financial force", just ask all those in serious debt.

***I:*** The instruments of modern finance are abstract objects. Which three of these would you consider to be the most fundamental or most important?

***E:*** I would say that the instruments of modern finance are real objects which are partly described by abstract theory. Let me try to give an answer to your question. The notion of (semi-)martingale and the link to the economic concept of no-arbitrage must come first. Through this link, mathematicians also make the notion of "there exists no free lunch" methodologically precise. Second, I would put the axiomatization of risk measures and the related mathematical description of such concepts as risk aggregation and diversification. Some of my more statistical research is related to the latter. As third I would add the various mathematical and statistical techniques

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for understanding and analysing model uncertainty. Especially concerning this third class of "instruments", here mathematics can, and should play an important role in clearly drawing the line for what can and, more importantly, cannot be achieved concerning pricing, hedging and risk management of complex financial and insurance products.

***I:*** Is risk management a response to the challenges and issues of the stock markets of the 1960s and 1970s? Could you briefly tell us the objectives of risk management?

***E:*** Whatever definition one takes, since the onset of mankind, risk has always been around. And consequently also the various ways in which society wanted to manage these risks. I will refrain from discussing risk from a historical perspective and concentrate on the 1960–70 period. On the more economic front, there were three important events: First, the various oil shocks in the '70s making energy a highly risky business; secondly, there was the end to the Bretton-Woods agreement of fixed exchange rates, and finally the surge in information technology (IT). The first two changes implied an increase in economic and financial risk, and hence triggered off the demand for products to hedge against these risks, the third, IT, made it all possible. I also would like to mention at this point the increased complexity of demands and products in the world of insurance, and this due to demographic and societal changes, the increased penetration of insurance in the overall population and the onset of discussions related to the environment.

As for your second question, risk management is, from a general point of view, a field that devises tools and techniques for channelling and transferring risks from those who do not want it to those who are willing (and hopefully are capable) to take it; for the latter, think, for instance, of an insurance company. This transfer should be done in a transparent and efficient way, embedded in a well-functioning political and regulatory environment. The field of risk management is (or, better, should be) holistic in nature. By this I mean that only in the rarest of cases should risk be seen as a singular issue devoid of any external influence. It is a highly interdisciplinary field.

***I:*** The methods are very mathematical, not empirical or anything like that, isn't it?

***E:*** That is not really true; it very much depends on the kind of risk management duty you are performing, and also to whom you are talking. Of course, if you are pricing and hedging a very specific complex derivative, like electricity swing options or interest rate swaps, then the underlying mathematics is non-trivial. In any case, also in this case you need data to verify the model chosen and calibrate that model to data, hence empirical analysis is very important. If, however, you perform your risk management duties as the Chief Risk Officer of a bank or insurance company, then technical issues are much less in the forefront; the more holistic, global economic and societal aspects enter more prominently. The underlying technical issues remain in the background. Reality will always find itself between these "extremes". Ideally one would have a well-balanced combination of both. It would be a mistake to swing too far away from the more mathematical, quantitative thinking, as much as it would be a mistake to forget about the so-called softer, qualitative side of risk management. And further, a crucial aspect of good risk management is clear, objective and open communication, also this to all types of audience: including the general public, politicians, the media, employees, etc. Especially at that level, mathematicians do not always score highly; we ought to train our students better concerning communication.

***I:*** Are the products first formulated by mathematicians rather than by bankers?

***E:*** Of course, mathematicians, or better, financial engineers, keep on inventing interesting constructions — you could call them products. For me such a construction is called a product if you sold more than one, say. I could give you examples of such "products" which were mathematically interesting, but did not find a market, or indeed were never intended to find one. I would say that the most interesting innovations and important products invariably come from industry, and not from a mathematician's mind. These products are often developed as an answer to specific demands from clients. Unfortunately, some parts of the banking industry more recently have been producing products which not only society did not really need, but more importantly turned out to be highly toxic for the worldwide economic system. It is exactly there that international regulation should step

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in. But likewise, mathematicians working in industry have to draw clear ethical lines not to be crossed when it comes to such product lines.

***I:*** You once mentioned that applied finance and mathematical finance have diverged. Are their current differences essentially methodological or conceptual?

***E:*** It's a remark that I made a while ago, well before the crisis. There is indeed less real contact between the two. And this may be a consequence of their perceived success. On the one hand, the financial industry felt that modern finance, not just mathematical finance, has tamed the credit markets, securitization being the magical word. And whereas these institutions still employ scores of scientists and engineers, including mathematicians, it was felt that the more methodological, mathematical research became less important. On the other hand, mathematical finance, as a subfield of mathematics, has reached a level of maturity as a field of research where progress can be made without worrying too much about reality out there. In a way one can compare this situation with mathematical physics where a lot of research can be carried out without worrying too much about experiments. On its own, this may not be too critical, as long as a sufficient number of intellectual bridges exist between the two worlds so as to keep on feeding academia with new, challenging and practically relevant research problems, and vice versa, academia can step in when it observes a violation concerning the underlying conditions needed so that some of its earlier research results can be applied. At RiskLab it is exactly this kind of bridge we try to maintain.

***I:*** Do they talk to each other?

***E:*** Several of us really try. The workshop here is a nice example where RMI (Risk Management Institute), IMS, industry and the Monetary Authority of Singapore exchange ideas. It is a nice example of the triangular dialogue I mentioned earlier.

***I:*** Is it possible for a mathematical finance specialist to write papers without bothering about what happens outside?

***E:*** From the point of view of scientific research, absolutely. I could give you several examples. Many brilliant students enter the field attracted by the beauty of (some) of the underlying mathematics. Numerous scientific developments in stochastics would never have taken place were it not for the initial questions asked by (applied) finance. In that sense, the issue is not too different from similar discussions around pure and applied mathematics, a distinction I personally do not like when it is pushed too far. At the end of the day, it often is a question of personality.

***I:*** It seems that financial collapse could be caused by a panic response of investors which is more irrational than rational. Is there any attempt to incorporate some kind of human parameters into financial and investment models? In particular, have psychological methods or concepts been incorporated?

***E:*** It is clear that, not just in the current crisis, people realize that there is irrationality in the market and that psychology and human behaviour play an important role. Some mathematical models are looking into that. One important branch of research is "model uncertainty". Let me be very clear on this: the mathematical finance research community is very well aware of the relevance of behavioural factors. Interesting recent research, also communicated at our conference at IMS, tries to capture these factors in precise mathematical language. That this is not easy, already [Isaac] Newton knew. After he lost about 2.72 million US$ (in today's money) speculating on South Sea Company stock, he said "I can compute the motions of heavenly bodies, but not the madness of people". In economics a whole field has been building up around behavioural finance. As mentioned before, I very much hope that both fields will meet up eventually. I expect that, within the next 5 to 10 years, there will be first practical models taking behavioural aspects seriously into account. The moving away from the efficient market hypothesis to the so-called adaptive (or alternative) market hypotheses is more a chance for mathematics than a threat. The same cannot be said for some fields of economics. For instance, mathematicians from day one in the '80s already looked at traders not as a homogeneous group but there are informed traders and there are noise traders. The resulting models very much depend on the balance or unbalance between the two.

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***I:*** Apparently a 38-year cycle has been observed for the history of fluctuations. Do you believe there are definite cyclic patterns underlying financial and economic fluctuations?

***E:*** The old wisdom, what goes up must come down, comes to mind. More seriously, I find it difficult to believe too strongly in theories of cycles. Also, cycles based on Fibonacci numbers are popular. Similar statements have been made about bubbles and financial crises; here it is about 7 years it seems. In the latter case it tells us more about how quickly people forget and how little we learn from past errors made. If you look in detail at what the exact claims are (like the 38-year cycle), how many years of data do you have? How can you statistically prove such a claim? Of course, statistical data mining, current availability of data and advances in related statistical research, coupled with modern computer technology, no doubt will lead to interesting findings. A possible example concerns the field of chartists or technical analysts.



***I:*** Has the recent subprime financial crisis eroded confidence in mathematical finance? Has anything been done to restore this confidence?

***E:*** If you read the media reports, or consider discussions with friends and colleagues inside and outside the university, there is indeed a feeling of that sort. First superficial media reports were keen to headline "How mathematics blew up Wall Street". Whereas such a title may be good for Hollywood, reality is far more complex. No doubt the ever growing complexity of financial products coming out of the financial engineering factories of investment banks grew increasingly distant from the underlying real economy, whatever the proponents of such product lines say. A particularly illuminating example is the so-called Abacus 2700-AC1 synthetic CDO product, of which one of the investment bankers involved with its construction is quoted to have said: "What if we created a thing, which has no purpose, which is absolutely conceptual and highly theoretical and which nobody knows how to price?". Here the classical rule should apply: "If you don't understand it, don't buy it, don't sell it!" Mathematicians will have to communicate better, both bank-internally as well as to the outside world, clearly stating where the limitations of our understanding of such products lie. We have to take our societal responsibility as academics seriously; this will gradually restore confidence.

***I:*** Now the public is more aware that part of the blame is on rogue traders and rogue bankers rather than mathematics.

***E:*** That is correct! Initial Hollywood fever has made way for a more realistic view on what went wrong. We should also not forget about the role politics played.

***I:*** I think some of those people in the frontline don't really know what their products are.

***E:*** Indeed, with some of the more complicated products, as briefly mentioned above, this is true.

***I:*** Have methods of risk management been applied to evolutionary biology, in particular, about how epidemics spread?

***E:*** I would say that it is more the other way around. I know of several applications of the spread of epidemics, say, to the modelling of credit markets. An example is the use of the Pólya-Eggenberger model. And just as an aside, George Pólya was a professor of mathematics at ETH (1914–1940); I still have his couch in RiskLab! Andrew Haldane, from the Bank of England is a great proponent of the use of ideas from evolutionary biology to finance. It is somewhat amusing that "the other Haldane", John Burdon Sanderson Haldane (1892-1964), was a pioneer of bringing quantitative modelling into biology and genetics. To take your question a bit more broadly: by now, quantitative risk management, as described in our 2005 book [*Quantitative Risk Management: Concepts, Techniques, Tools* (with A. J. McNeil and R. Frey)], is widely applied to such fields as environmental research, engineering and the medical field. Talking to scientists from those other fields, I always find it fascinating to try to understand the specificities of their risk management questions and techniques.

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***I:*** You also have research interest in actuarial mathematics. Is it mainly confined to questions in insurance?

***E:*** As I already mentioned before, in a way, insurance mathematics and its applications are my prime area of research. In actuarial applications, extremes often play a crucial role. Think for instance of catastrophe insurance or longevity modelling. Of course, insurance, by definition, interacts with many aspects of society, and as such is by nature multidisciplinary. A more recent phenomenon is the era of bank-assurance and alternative risk transfer. This concerns insurance risk transfer via financial markets. It is fair to say that, whereas the initial hype of industrial bank-assurance institutions is over, interesting cross-products between banking and insurance will always be there. Very often such products are born out of a societal need, like in the case of catastrophic events such as earthquakes and storms. The key word here is catastrophe bonds; these are bonds for which the coupon payment depends on the (non-) occurrence of a specific catastrophic event. I am convinced that worldwide we will see a U-turn from insurance holdings back to their main business, namely insurance. Many of my current students are increasingly in demand from insurance regulators and consultancy companies for the insurance industry; a trigger for this is the growing importance of the changing regulatory landscape. Often via these students interesting research questions come back to us.

***I:*** I notice that in the recent crisis, one of the organizations that collapsed was an insurance company (AIG). With all their calculations, could they have avoided the collapse?

***E:*** It is important to note that the company that created the problems was AIG-FP, where the final two letters stand for "Financial Products", a typical example for my remarks above. Without being able to enter into full detail, AIG-FP was involved with insuring complex credit instruments. It became very big on the so-called Credit Default Swap market. Like the banks with which it had all these deals, their modelling was far too rosy when it came to joint default modelling. I cannot believe that AIG-FB internally, many actuaries were involved. Together with Catherine Donnelly, I have written a paper on the topic: "The devil is in the tails: actuarial mathematics and the subprime mortgage crisis", it will appear in the *Astin Bulletin*, a leading actuarial journal. A copy can also be found on my webpage. The paper contains the full story from an actuarial point of view. The question, under which internal conditions they could have avoided the collapse is for me difficult to answer; no doubt, like so many of the other big players in the crisis, they were blinded by a perceived free-lunch on many of these instruments. The free-lunch turned into a very expensive lunch as soon as the market turned. And this turn came (a) very fast, and (b) with a massive size. All this has happened before with complex derivative positions, especially when one gambles with very high volumes, so-called high leverage. Brought back to its mathematical basics: non-linearity caused havoc!

***I:*** You once mentioned something about the importance of managing large data and that this is a very important aspect. Can you say something more about this?

***E:*** Statistics is a major scientific discipline that teaches us how to efficiently process, manage and analyse data. I am just back from a meeting with the National Science Foundation in Washington on the future of statistical science where we discussed "the next important areas of statistical research and applications". I was invited to present applications in finance and insurance. There is absolutely no doubt that the future belongs to the analysis of large, complex data structures. This may involve so-called "$n$ small – $p$ large" data structures and the related notion of sparsity, or data coming from large complex networks. The former relates to risk management questions involving thousands of factors, only a small proportion of which may be relevant. The latter (networks) relates to problems encountered in the subprime crisis like systemic risk. A key field is machine learning. Whichever problem area you prefer to study, the scientific developments within these fields are gigantic. It is no coincidence that some of the leading academic researchers in these fields were lured into joining hedge funds which are interested in detecting structure in massive financial data sets. In a sense, quantitative risk management will have to keep pace. The only way I can see this to happen is that we train our future generations of mathematicians, actuaries and risk managers so that they also learn about

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## Publications >>>

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these new developments. This is a crucial task for all of us involved and, believe me, not a very easy one. Let me end with two statements I give my students on the way: (1) I tell them to be humble in the face of real applications. Here I typically quote from Shakespeare's Hamlet: "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy". And (2) in all circumstances I ask them to behave ethically, especially in the face of temptation, which surely will come.

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