

OCTOBER 2008



PERIMETER INSTITUTE
FOR THEORETICAL PHYSICS



31 Caroline Street North, Waterloo, Ontario



TABLE OF CONTENTS

Overview	2-1
Mission Statement	2-2
The People	3-1
Scientific Leadership	3-1
Faculty	3-2
Associate Faculty	3-4
Postdoctoral Researchers	3-7
Long Term Visitors	3-17
Associate Postdoctoral Researchers	3-19
Graduate Students	3-20
Affiliate Members	3-21
Scientific Advisory Committee	3-24
Board of Directors	3-28
Administration	3-30
The Research	4-1
The Research Areas	4-2
Scientific Activities	4-4
Research Linkages	4-7
PIRSA	4-8
Scientific Publishing	4-9
Research Prizes	4-9
Scientific Outreach Programs	5-1
Inspiring Students	5-2
Partnering with Teachers	5-6
Perimeter Explorations	5-8
Reaching the General Public	5-9
Event Horizons	5-19
Facility	6-1
Thoughts behind the design	6-2
Aspects of the final design	6-3
Original Facility	6-5
History of the Institute	7-1
Key Milestones	7-4
Summary of Financial Support	7-5
Sponsorships	7-8
In the News	8-1
Selected Articles	8-2
NSERC Review	9-1

PI OVERVIEW

As Perimeter Institute begins its eighth year of operations, it is most gratifying to report that we continue to meet our dual goals of scientific research at the highest international levels in tandem with providing educational outreach activities that share the joys of research and discovery with Canadians and beyond.

From an initial complement of 9 scientists in the fall of 2001, we are delighted to be currently staffed with over 90 resident researchers (9 Faculty, 10 Associate Members, 44 Postdoctoral Researchers, 3 Associate Postdoctoral Researchers, 24 Graduate Students, and 10 - 15 Long-Term Visitors annually) in addition to greatly increased numbers of Short-Term Visitors and Affiliates. Our scientific activities, involving six core areas of research, continue to be extremely active, while our related visitor program is exceptionally vigorous, with current expectations of hosting some 300 scientists throughout this academic year.

In addition to providing an international focal point in foundational research, the Institute's interactions with the surrounding academic community continue to intensify and we will further engage with the University of Waterloo, McMaster University, University of Western Ontario, University of Guelph, Canadian Institute for Advanced Research, University of Toronto, Canadian Institute for Theoretical Astrophysics, Fields Institute and other centres to increase research links, improve opportunities for graduate students, and generally help shape the development of the wider area as a natural cluster of theoretical physics activity.

Construction of our permanent facility was completed in 2004 and a wide range of researchers now benefit from the award-winning attributes of our building – as do many students, teachers and members of the general public who connect to modern physics through the Institute's outreach programs. The flagship PI Public Lecture Series continues to grow in popularity with average attendance topping 600 people per event and seen by even larger audiences on television and via the Institute's growing website. The success of our inaugural Young Physicists summer school in August 2003 motivated the development of an expanded international version which now involves up to 100 Canadian and international students each year. We also engage in special workshops for science teachers regionally, provincially and nationally as well as host our own international *Einstein^{Plus}* workshops for physics educators from across Canada and around the world. Our *Physica Phantastica* program, which brings the excitement of physics directly into high school classrooms, continues to develop throughout Canada. Finally, the new *Perimeter Explorations* in-class resources for science teachers was launched in February of 2008 and has already begun to reach hundreds of thousands of students across North America and beyond.

As is clear, there are many reasons to feel profoundly optimistic about Perimeter's future development on all fronts. We remain confident in our mission and plan to continue expanding upon the proven world-class scientific research and educational outreach initiatives.

MISSION STATEMENT

Perimeter Institute for Theoretical Physics is an independent, resident-based research institute devoted to foundational issues in theoretical physics at the highest levels of international excellence. We strive to create a lively and dynamic research atmosphere where many approaches to fundamental questions, both orthodox and unorthodox, are pursued simultaneously and where a balance between formal and phenomenologically-oriented research is established. We are further determined to interact constructively with the surrounding academic community whenever possible, particularly with regards to the inclusion of graduate students, and are equally determined to create a world-class outreach program to disseminate the mysteries and wonder of the physical world to the general public throughout Canada and beyond.

THE PEOPLE

SCIENTIFIC LEADERSHIP

Executive Director

NEIL TUROK [2008]

PhD Imperial College (1994)

Dr. Neil Turok earned his PhD at Imperial College and, in 1994, became a Professor of Physics at Princeton University. Among his many honours, he was awarded the 1992 James Clerk Maxwell medal of the U.K. Institute of Physics.

Dr. Turok has worked in a number of areas of theoretical physics and cosmology, focusing on observational tests of fundamental physics. In the early 1990s, his group showed how the polarization and temperature anisotropies of the cosmic background radiation would be correlated, a prediction which has been confirmed in detail by recent precision measurements. The team also developed a key test for the presence of the cosmological constant, also recently confirmed.

With Stephen Hawking, he later developed the Hawking-Turok instanton solutions describing the birth of inflationary universes.

Most recently, with Paul Steinhardt at Princeton, he has been developing a cyclic model for cosmology, according to which the big bang is explained as a collision between two “brane-worlds” in M-theory. In 2006, Steinhardt and Turok showed how the model naturally allowed the cosmological constant to relax to very small values, consistent with current observations. Steinhardt and Turok co-authored the popular science book “Endless Universe: Beyond the Big Bang.” A full multimedia talk about this subject may be viewed online by clicking on Perimeter Institute Public Lectures and reviewing Dr. Turok’s presentation “What Banged?”.

Born in South Africa, Dr. Turok founded the African Institute for Mathematical Sciences (AIMS). Based in Cape Town, this postgraduate educational centre supports the development of mathematics and science across the African continent. For this work and his many contributions to theoretical physics, Dr. Turok was recently awarded a prestigious TED Prize and a “Most Innovative People” award at the 2008 World Summit on Innovation and Entrepreneurship (WSIE).

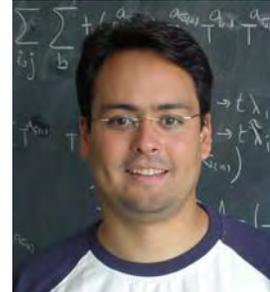
Dr. Turok assumed the position of Executive Director at Perimeter Institute in October 2008.



FACULTY

Perimeter Institute Faculty members demonstrate proven research excellence, leadership and mentoring experience together with prodigious cutting-edge scientific activity.

FREDDY CACHAZO [2005] PhD Harvard (2002)
Superstring Theory



LAURENT FREIDEL [2006] PhD Ecole Normale Supérieure (1994)
Quantum Gravity



JAUME GOMIS [2004] PhD Rutgers (1999)
Superstring Theory



DANIEL GOTTESMAN [2002] PhD Caltech (1997)
Quantum Information



LUCIEN HARDY [2002] PhD Durham (1992)
Quantum Foundations



JUSTIN KHOURY [2006] PhD Princeton (2002)
Superstring Theory / Cosmology



FOTINI MARKOPOULOU [2001] PhD Imperial College (1998)
Quantum Gravity



ROBERT MYERS [2001] PhD Princeton (1986)
Superstring Theory



LEE SMOLIN [2001] PhD Harvard (1979)
Quantum Gravity



ASSOCIATE FACULTY

Associate Members generally have shared appointments at the Institute and a university. As part-time Faculty they also provide a combination of proven research excellence, leadership and mentoring experience.

ALEX BUCHEL [2003] PhD Cornell (1999)
(University of Western Ontario)
Superstring Theory



CLIFF BURGESS [2004] PhD Texas, Austin (1985)
(McMaster University)
Particle Physics



RICHARD CLEVE [2005] PhD Toronto (1989)
(University of Waterloo)
Quantum Information



ADRIAN KENT [2007] PhD Cambridge (1986)
(DAMTP)
Quantum Information



RAYMOND LAFLAMME [2001] PhD Cambridge (1988)
(University of Waterloo)
Quantum Information



MICHELE MOSCA [2001] PhD Oxford (1999)
(University of Waterloo)
Quantum Information



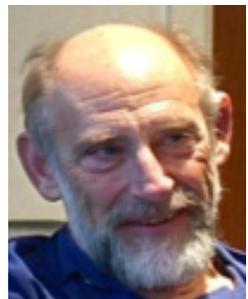
ASHWIN NAYAK [2003] PhD Berkeley (1999)
(University of Waterloo)
Quantum Information



MAXIM POSPELOV [2004] PhD Budker Institute (1994)
(University of Victoria)
Particle Physics



LEONARD SUSSKIND [2007] PhD Cornell (1965)
(Stanford)
Particle Physics



THOMAS THIEMANN [2003] PhD RWTH Aachen (1993)
(Max Planck)
Quantum Gravity



POSTDOCTORAL RESEARCHERS

Perimeter Institute's Postdoctoral members are researchers who have recently received their PhDs and have been invited to Perimeter for a specific term, typically 3-5 years in duration.

NIAYESH AFSHORDI [2007] PhD Princeton (2004)
Distinguished Research Fellow
Cosmology



MICHELE ARZANO [2006] PhD UNC Chapel Hill (2006)
Quantum Gravity



BRIAN BATELL [2008] PhD Minnesota (2008)
Particle Physics



DARIO BENEDETTI [2007] PhD Utrecht University (2007)
Quantum Gravity



SUNDANCE BILSON-THOMPSON [2006] PhD Adelaide (2002)
Quantum Gravity



ROBIN BLUME-KOHOUT [2007] PhD Berkeley (2005)
Quantum Information



EVGENY BUCHBINDER [2006] PhD Pennsylvania (2003)
Superstring Theory



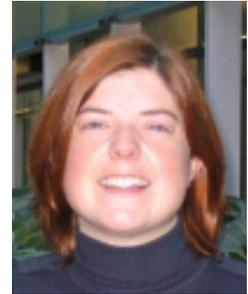
SAMUEL COLIN [2006] PhD Brussels (2005)
Quantum Foundations



FLORIAN CONRADY [2007] PhD Humbolt, Berlin (2005)
Quantum Gravity



SARAH CROKE [2007] PhD Glasgow and Strathclyde (2007)
Quantum Information



CLAUDIA de RHAM [2006] PhD Cambridge (2005)
Cosmology



ELEONORA DELL'AQUILA [2007] PhD Rutgers (2007)
Superstring Theory



STEVE FLAMMIA [2007] PhD New Mexico (2007)
Quantum Information



GHAZAL GESHNIZJANI [2007] PhD Brown (2005)
Cosmology



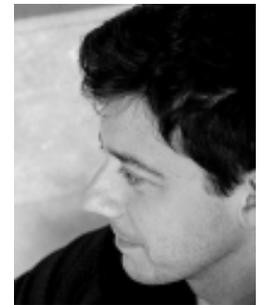
PHILIP GOYAL [2007] PhD Cambridge (2005)
Quantum Foundations



RAZVAN GURAU [2008] PhD Paris (2007)
Quantum Gravity



ALIOSCIA HAMMA [2008] PhD Napoli Federico II (2005)
**Interdisciplinary Quantum Information/Quantum Gravity/
Quantum Foundations**



JOE HENSON [2007] PhD Queen Mary College, London (2003)
Quantum Foundations



SABINE HOSSENFELDER [2006] PhD ITP Frankfurt (2003)
Quantum Gravity



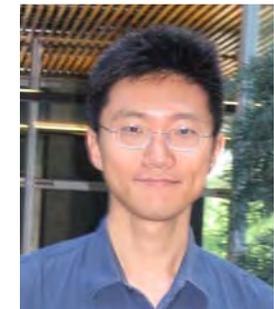
ZHENGFENG JI [2008] PhD Tsinghua (2007)
Quantum Information



TIM KOSLOWSKI [2008] PhD Wurzburg (2007)
Quantum Gravity



XIAO LIU [2006] PhD Stanford (2006)
Superstring Theory



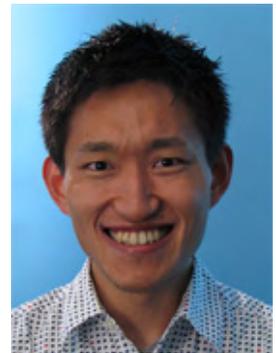
LUCA MANA [2008] PhD Royal Institute of Technology (2007)
Quantum Foundations



NICOLAS MENICUCCI [2008] PhD Princeton (2008)
Quantum Information



AKIMASA MIYAKE [2008] PhD Tokyo (2004)
Quantum Information



LEONARDO MODESTO [2008] PhD Torino (2004)
Quantum Gravity



TAKUYA OKUDA [2008] PhD Caltech (2005)
Superstring Theory



YUTAKA OOKOUCHI [2008] PhD Caltech (2005)
Superstring Theory



FEDERICO PIAZZA [2006] PhD Milan (2002)
Cosmology



DAVID RIDEOUT [2007] PhD Syracuse (2001)
Quantum Foundations



JAMES RYAN [2007] PhD Cambridge (2007)
Quantum Gravity



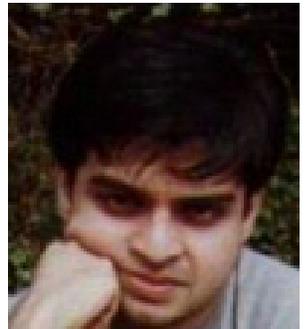
AMIT SEVER [2008] PhD Hebrew University (2005)
Superstring Theory



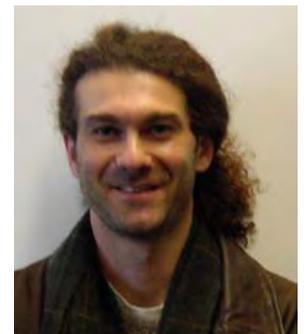
PARAMPREET SINGH [2007] PhD University of Pune (2004)
Interdisciplinary, Quantum Gravity/Cosmology



ANINDA SINHA [2007] PhD Cambridge (2004)
Superstring Theory



CONSTANTINOS SKORDIS [2005] PhD California (2002)
Cosmology



ROLANDO SOMMA [2007] PhD Instituto Balseiro (Argentina)
and Los Alamos National Laboratory (2005)
Quantum Information



SIMONE SPEZIALE [2005] PhD Rome (2005)
Quantum Gravity



WARD STRUYVE [2004] PhD Gent (2004)
Quantum Foundations



ANDREW TOLLEY [2006] PhD Cambridge (2003)
Distinguished Research Fellow
Cosmology



MICHAEL TROTT [2008] PhD Toronto (2005)
Particle Physics



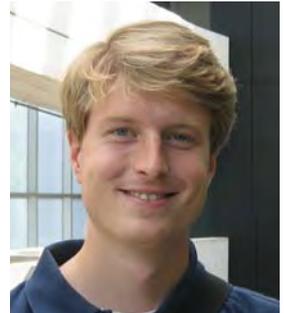
SAMUEL VAZQUEZ [2007] PhD California at Santa Barbara (2007)
Superstring Theory



JONATHAN WALGATE [2006] PhD Oxford (2005)
Quantum Information



MARK WYMAN [2006] PhD Cornell (2006)
Cosmology



TOM ZLOSNIK [2008] PhD Oxford (2008)
Cosmology



LONG TERM VISITORS

Long Term Visitors are researchers of the highest calibre who are visiting professors and retain their position at the home university. They are generally invited for more than a three month term.

CHRIS FUCHS [2007] PhD New Mexico (1996)
Quantum Information



ROBERT McNEES [2007] PhD Texas at Austin (2002)
Superstring Theory, Cosmology, General Relativity



VICTOR NOVIKOV [2008] PhD Federal Centre of Dual
Technologies, Sojuz (1998)
Particle Physics



KRISTIN SCHLEICH [2008] PhD Chicago (1987)
Quantum Gravity



RAFAEL SORKIN [2004-2005, 2006-2011] PhD CalTech (1974)
Quantum Gravity; Quantum Foundations



DON WITT [2008] PhD Wisconsin (1986)
Quantum Gravity



SHORT TERM VISITORS

Information about those researchers invited for periods of up to six weeks through the Visitor Program may be found online at: <http://www.perimeterinstitute.ca>

ASSOCIATE POSTDOCTORAL RESEARCHERS

These researchers have recently received their PhDs and have been invited to Perimeter Institute by PI Faculty or Associate Members.

MOHAMMAD ANSARI [2004] PhD Waterloo (2008)
Quantum Gravity



MATT SAUL LEIFER [2007] PhD Bristol (2003)
Quantum Information



OLIVER WINKLER [2006] PhD AEI (2001)
Quantum Gravity



Graduate Students

This group includes Canadian or International students who are conducting research to obtain their PhDs under the tutorship of a PI Faculty or Associate Faculty member. In some cases, graduate students of Long Term Visitors may also spend a considerable amount of the year at PI.

Paolo Benincasa [2008] Superstring Theory
Joel Brownstein [2005] Quantum Gravity
Oscar Dahlsten [2007] Quantum Information
Jorge Escobedo [2008] Superstring Theory
Cohl Furey [2006] Quantum Gravity/Quantum Foundations
Sean Gryb [2007] Superstring Theory
Yu-Xiang Gu [2008] Superstring Theory
Bruno Hartmann [2003] Quantum Gravity
Doug Hoover [2004] Particle Physics
Shunji Matsuura[2006] Superstring Theory
Filippo Passerini [2006] Cosmology
Alexander Patrushev [2007] Quantum Gravity
Isabeau Premont-Schwarz [2006] Quantum Gravity
Chanda Prescod-Weinstein [2006] Quantum Gravity
Brandon Robinson [2007] Superstring Theory
Amir Jafari Salim [2006] Superstring Theory
Rajabi Sayeh [2008] Superstring Theory
Ajay Singh [2008] Superstring Theory
Cozmin Ududec [2008] Quantum Foundations
Yidun Wan [2005] Quantum Gravity
Matthias Wapler [2005] Superstring Theory
Honbao Zhang [2007] Cosmology
Nathan Chow [2007] – Masters Cosmology
Jonathan Hackett [2006] – Masters Quantum Gravity

UNDERGRADUATE STUDENTS

This group involves students from a University who are under the tutorship of PI researchers.

AFFILIATE MEMBERS

Affiliate membership is granted to select Faculty at surrounding Canadian Universities who have the opportunity to be regularly involved in the Institute's many research activities.

Ian Affleck [2008] University of British Columbia
Leslie Ballentine [2008] Simon Fraser University
A. John Berlinsky [2002] McMaster University
Richard Bond [2002] CITA/University of Toronto
Robert Brandenberger [2008] McGill University
Gilles Brassard [2002] University of Montreal
Bruce A. Campbell [2002] Carleton University
Hilary Carteret [2004] University of Calgary
Jeffrey Chen [2006] University of Waterloo
Andrew Childs [2007] University of Waterloo
Dan Christensen [2004] University of Western Ontario
James M. Cline [2003] McGill University
Alan Coley [2003] Dalhousie University
Claude Crepeau [2004] McGill University
Saurya Das [2003] University of Lethbridge
Rainer Dick [2002] University of Saskatchewan
Joseph Emerson [2008] University of Waterloo
Doreen Fraser [2007] University of Waterloo
Valeri Frolov [2002] University of Alberta
Jack Gegenberg [2003] University of New Brunswick
Patrick Hayden [2005] McGill University
Kentaro Hori [2003] University of Toronto
Peter Hoyer [2003] University of Calgary
Viqar Husain [2002] University of New Brunswick

Affiliate Members continued...

Catherine Kallin [2002] McMaster University
Joanna Karczmarek [2008] University of British Columbia
Gabriel Karl [2006] University of Guelph
Achim Kempf [2004] University of Waterloo
Brian King [2002] McMaster University
Lev Kofman [2002] CITA/University of Toronto
Pavel Kovtun [2007] University of Victoria
David Kribs [2003] University of Guelph
Gabor Kunstatter [2002] University of Winnipeg
Debbie Leung [2004] University of Waterloo
Hoi-Kwong Lo [2003] University of Toronto
Michael Luke [2008] University of Toronto
Norbert Lutkenhaus [2007] University of Waterloo/IQC
Robert Mann [2004] University of Waterloo
Dominic Mayers [2003] Université de Sherbrooke
D. Gerald McKeon [2004] University of Western Ontario
Brian McNamara [2008] University of Waterloo
Volodya Miranskyy [2005] University of Western Ontario
Guy Moore [2003] McGill University
Wayne Myrvold [2003] University of Western Ontario
Garnet Ord [2008] Ryerson University
Maya Paczuski [2008] University of Calgary
Don Page [2002] University of Alberta
Amanda Peet [2004] University of Toronto
Levon Pogosian [2008] Simon Fraser University
Eric Poisson [2004] University of Guelph
Erich Poppitz [2002] University of Toronto
Robert Raussendorf [2008] University of British Columbia
Mark van Raamsdonk [2002] University of British Columbia
Adam Ritz [2007] University of Victoria
Moshe Rozali [2002] University of British Columbia

Affiliate Members continued...

Barry Sanders [2003] University of Calgary

Kristin Schleich [2003] University of British Columbia

Douglas Scott [2008] University of British Columbia

Gordon Semenov [2002] University of British Columbia

Kris Sigurdson [2008] University of British Columbia

John Sipe [2003] University of Toronto

Phillip Stamp [2008] University of British Columbia

Aephraim Steinberg [2002] University of Toronto

Alain Tapp [2002] University of Montreal

James Taylor [2008] University of Waterloo

Bill Unruh [2002] University of British Columbia

Mark Walton [2004] University of Lethbridge

John Watrous [2002] University of Waterloo

Steven Weinstein [2004] University of Waterloo

Donald Witt [2003] University of British Columbia

Resident Affiliate Members:

John Moffat [2004] University of Toronto/University of Waterloo

SCIENTIFIC ADVISORY COMMITTEE

The SAC is an integral oversight body, deliberately created to assist the Board of Directors in ensuring objectivity and a high standard of scientific excellence. The SAC advises the Board on matters of scientific policy, appointments and renewal of the scientific staff, performance reviews of the scientific staff, outreach initiatives and general structural concerns. The SAC meets on an annual basis. It is composed of eminent scientists drawn from the international community.

GERARD MILBURN, Chair, [2007] University of Queensland

Professor Milburn's research interests include quantum optics, quantum measurement and stochastic processes, quantum information and quantum computation. He has published over 200 papers in international journals, with over 6000 citations. He is also the author or co-author of several books, two of which seek to explain quantum phenomena and its potential for a general audience.



ABHAY ASHTEKAR, [2008] Penn State University

Abhay Ashtekar is the Eberly Professor of Physics and the Director of the Institute for Gravitational Physics and Geometry at Pennsylvania State University. As the creator of Ashtekar variables, he is one of the founders of loop quantum gravity and its subfield loop quantum cosmology. Professor Ashtekar completed his undergraduate education in India and then studied under Robert Geroch at the University of Chicago, receiving his PhD in 1974.



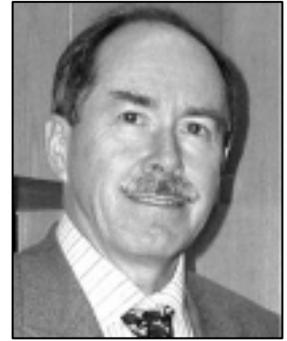
ARTUR EKERT, [2001] University of Cambridge (DAMTP)

Professor Ekert's research extends over most aspects of information processing in quantum mechanical systems. This is a cross-disciplinary field bringing together theoretical and experimental quantum physics, mathematics, logic, computer science and information theory.



GERARD 'T HOOFT, [2008] Utrecht University

Recipient of the 1999 Nobel Prize in physics for work in elucidating the quantum structure of electroweak interactions, Professor 't Hooft is a professor in theoretical physics at Utrecht University. He was awarded the Lorentz Medal in 1986. The 1953 Nobel laureate in physics, Frits Zernike, was his great-uncle.



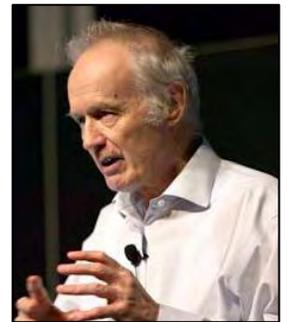
IGOR KLEBANOV, [2007] Princeton University

Igor R. Klebanov's research has touched on many aspects of theoretical physics and is presently centered on relations between string theory and quantum field theory. He is currently a Thomas D. Jones Professor of Mathematical Physics at Princeton University. He has made many highly regarded contributions to the duality between gauge theories and strings.



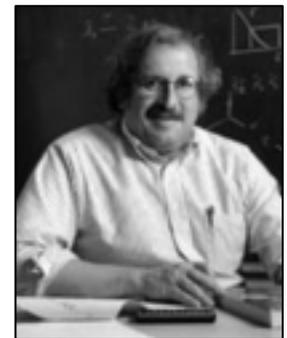
SIR ANTHONY LEGGETT, [2004] University of Illinois

Professor Leggett is the *John D. and Catherine T. MacArthur Professor* and *Center for Advanced Study Professor of Physics* at the University of Illinois. He is renowned for his work in the theory of low-temperature physics and is a 2003 Nobel Prize winner for his work on superfluids. Professor Leggett was knighted by Queen Elizabeth II in 2005.



MICHAEL PESKIN, [2008] Stanford Linear Accelerator Center

Michael Peskin received his B.A. from Harvard in 1973 and his PhD from Cornell University in 1978. After holding postdoctoral appointments at Harvard, Cornell, and Centre d'Études Nucléaires, Scalay, he joined the faculty of the Stanford Linear Accelerator Center in 1982. He is the co-author of *An Introduction to Quantum Field Theory*. Prof. Peskin was elected to the American Academy of Arts and Sciences in 2000.



EMERITUS SCIENTIFIC ADVISORY COMMITTEE

IAN AFFLECK, [2001-2004] University of British Columbia

Professor Affleck's main research interests are in theoretical condensed matter physics, in particular its interface with elementary particle theory. He has received a great number of prizes and honours, most recently, the British Columbia Science Council "New Frontiers in Research" Award.



JAMES HARTLE, [2001-2003] University of California - Santa Barbara

Professor Hartle is concerned with applications of Einstein's theory of space, time and gravity—general relativity—to cosmology. He is a member of the US National Academy of Sciences, a fellow of the American Academy of Arts and Sciences, and past Director of the Institute for Theoretical Physics (ITP) at Santa Barbara.



CHRIS ISHAM, [2001-2005] Imperial College

Professor Isham has made enormous contributions in the fields of quantum gravity and the foundations of quantum mechanics. His other area of interest is topological quantum field theory, especially its relation to the canonical approach to the quantization of gravity.



CECILIA JARLSKOG, [2001-2006] CERN, Lund Institute

Professor Jarlskog is a prominent member of the Theoretical Physics Division of CERN. She is a Member of the Royal Swedish Academy of Sciences and is also past Chair of the Nobel Prize Committee for Physics. One of her many areas of interest is the mathematics of particle physics.



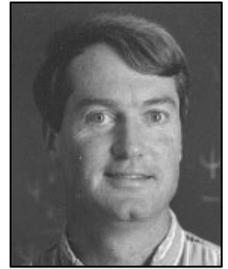
SIR ROGER PENROSE, [2001-2007] Oxford University

Professor Penrose's interests range from geometry, to general relativity theory, to quantum foundations. In 1994 he was knighted by Queen Elizabeth II for his service to science. Among his many awards are the 1988 Wolf Prize, shared with Stephen Hawking, the Royal Society Royal Medal, and the Albert Einstein prize.



JOSEPH POLCHINSKI, [2001-2004] KITP

Professor Polchinski has written an influential two-volume set of books on string theory. One of Professor Polchinski's main contributions in string theory was the discovery of D-branes: topological defects on which strings can end. This has had an enormous impact on the development of string theory.



JORGE PULLIN, [2003-2007] Louisiana State University

Professor Pullin's research interests include gravitational physics, both classical and quantum mechanical. He is currently using general relativity, Einstein's theory of gravity, to predict what will happen when black holes collide. He has received many prestigious awards, the most recent being the Fulbright fellowship.



PAUL STEINHARDT, [2003-2007] Princeton University

Professor Steinhardt is one of the leading theorists responsible for Inflationary theory. He constructed the first workable model of inflation and the theory of how inflation could produce seeds for galaxy formation. Among his awards is the 2002 Paul Dirac Medal of the International Centre for Theoretical Physics.



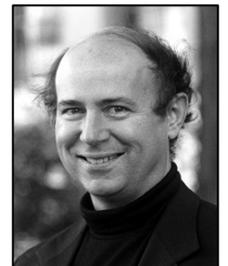
SCOTT TREMAINE, [2001-2006] Princeton University

Professor Tremaine's main research area is the dynamics of astrophysical systems. He is Imasco Fellow of The Canadian Institute for Advanced Research (CIAR), Director of CIAR's Cosmology and Gravity Program, member of the Institute for Advanced Study in Princeton, and Director of the Canadian Institute for Theoretical Astrophysics (CITA).



FRANK WILCZEK, [2003-2007] MIT

Professor Wilczek is 2004 Nobel Prize winner in Physics for the discovery of asymptotic freedom in the theory of the strong interaction. He is also known for the development of quantum chromodynamics, the invention of axions, and the discovery and exploitation of new forms of quantum statistics (anyons). Other awards include the 2002 Lorentz Medal and the 2003 Lilienfeld Prize of the American Physical Society.



BOARD OF DIRECTORS

Perimeter Institute is an independent not-for-profit corporation governed by a volunteer Board of Directors. The Board approves and monitors strategic plans and is the final authority on all matters of substance related to the general structure and development of the Institute.

MIKE LAZARIDIS, Chair, is founder, President and Co-CEO of Research in Motion Limited (RIM). He is the recipient of many technology and business awards, and led the research and development efforts of various technological innovations including the BlackBerry, the first complete wireless email solution.



DONALD W. CAMPBELL is the senior strategy advisor at Davis LLP. Prior to joining Davis, Mr. Campbell was Executive Vice-President of CAE Inc. where he led the company's world-wide government procurement activities. Mr. Campbell joined CAE after a distinguished career with Canada's Department of Foreign Affairs and International Trade, including serving as Canada's Ambassador to Japan.



KEN CORK is Managing Director of Sentinel Associates Limited. He is past Senior Vice-President of Noranda Inc. and a current Director of numerous organizations including Empire Life, The Bank of Nova Scotia, University of Toronto Press and Dominion of Canada General Insurance Company.



COSIMO FIORENZA is a Partner with Bennett Jones LLP, specializing in tax and personal planning services. He also acts as tax counsel for public and private technology companies. In addition to dealing with tax-related litigation, Cosimo focuses on trusts and estate planning for individuals, non-profit corporations and charities.



PETER GODSOE began his career with Scotiabank in 1966. He rose rapidly through various positions and was elected President and Chief Operating Officer in 1992, Chief Executive Officer in 1993, and Chairman in 1995. Mr. Godsoe retired from Scotiabank in March, 2004. He holds a B.Sc. in Mathematics and Physics from the University of Toronto, an M.B.A. from the Harvard Business School, and is a C.A. and a Fellow of the Institute of Chartered Accountants of Ontario. Mr. Godsoe holds honorary degrees from University of King's College (1993), Concordia University (1995), University of Western Ontario (2001) and Dalhousie University (2004). In 2002, he became a member of the Canadian Business Hall of Fame and an Officer of the Order of Canada. Mr. Godsoe remains very active throughout a wide range of corporate boards and non-profit directorships.



JOHN REID is the Chief Operating Officer KPMG Canadian Region. He mainly focuses on mergers and acquisitions, high technology and health care. John is the Chairman of the Grand River Hospital Board of Directors and a member of the Board of Governors of Conestoga College of Applied Arts and Technology.



LYNN WATT: Professor Emeritus, Electrical and Computer Engineering University of Waterloo. Honourary D.Eng, Carleton University, Honourary Member University of Waterloo, Dean of Graduate Studies, Chairman Ontario Council on Graduate Studies, President Canadian Association of Graduate Schools, Executive Vice-Chairman OCGS, member NSERC Committee on Grants and Scholarships, Coordinator Ontario Centres of Excellence, member of a number of Provincial and Federal Committees dealing with Graduate Studies and Research. Coordinator Group of Ten, Policy Analyst, Industry Science and Technology Canada.



DOUGLAS T. WRIGHT, O.C., is President Emeritus and Adjunct Professor of Engineering at the University of Waterloo. His numerous honours include an Officer of the Order of Canada, a Chevalier dans l'Ordre National du Merite de France, and recipient of the Gold Medal of the Canadian Council of Professional Engineers.



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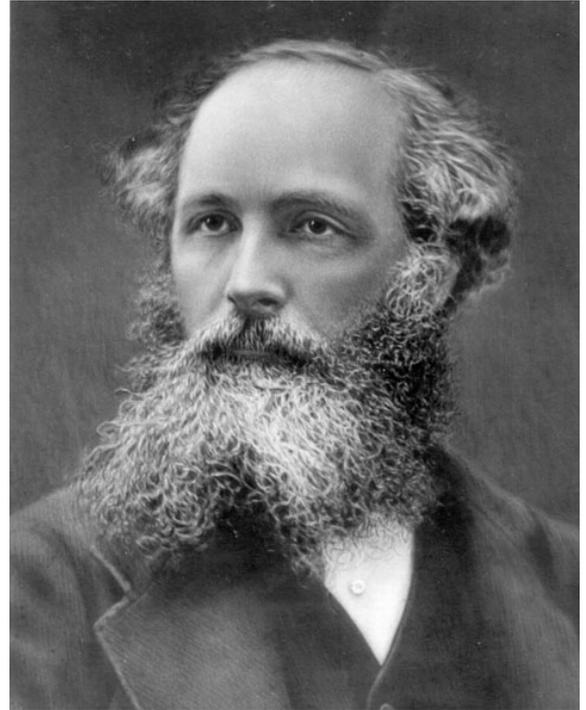
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THE RESEARCH

IMPORTANCE OF THEORETICAL PHYSICS

After Maxwell discovered a unified theory of electricity and magnetism, Marconi applied these ideas to send the first wireless message between continents. The Communications Age was born, changing our lives with radio, TV and now cell phones and wireless internet. That's how understanding drives innovation. Theoretical physics is at the heart of it. Today a diverse group of scientist from around the world have clustered in Waterloo to forge new, mind-bending ideas about the ultimate nature of space, time and matter. Driven by curiosity, their mission is to unlock nature's most profound secrets hidden deep inside the atom and far across the universe.

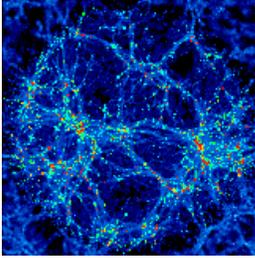


Additional information about the Institute's role and impact within the world of theoretical physics can be viewed in the 2006 NSERC Review section of this booklet.



THE RESEARCH AREAS

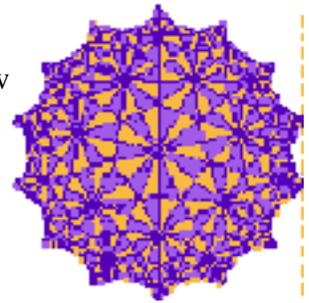
Cosmology



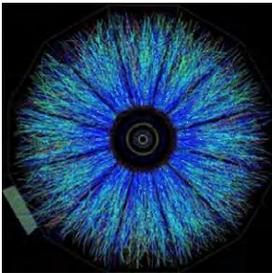
Cosmologists at PI combine recent developments at the interface of astrophysics and fundamental physics to shed light on some of the major puzzles in the field: What is causing the observed cosmic acceleration? What is the nature of the dark matter? What can be learned about theories of fundamental physics from microwave background and large scale structure observations? Is inflation the correct paradigm of early-universe cosmology?

Quantum Foundations

This area of research at PI concerns the conceptual and mathematical underpinnings of quantum theory. Researchers address issues such as how quantum theory should be interpreted, what the deeper principles are which underlie the theory, and how quantum theory might be modified. This often involves the search for, and analysis of, novel quantum effects which illustrate the peculiar properties of the theory. Research in quantum foundations naturally interfaces with research in quantum information and quantum gravity.



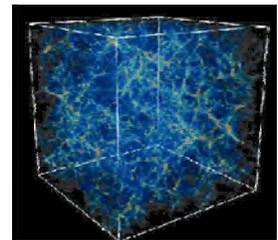
Particle Physics



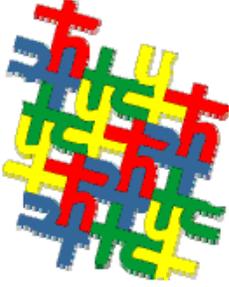
Particle physics is the science which identifies nature's constituents and interactions at the most fundamental level, with an emphasis on comparing theoretical ideas with both terrestrial experiments and astrophysical observations. This mandate gives it a strong overlap with string theory, quantum gravity and cosmology. Particle physicists at PI are currently involved in identifying how cosmological observations and terrestrial accelerator and underground experiments constrain the theoretical possibilities for physics beyond the Standard Model.

Quantum Gravity

Quantum gravity is concerned with unifying Einstein's general theory of relativity with quantum theory into a single theoretical framework. At Perimeter Institute, researchers are actively pursuing a number of approaches to this problem including loop quantum gravity, spin foam models and causal set theory.



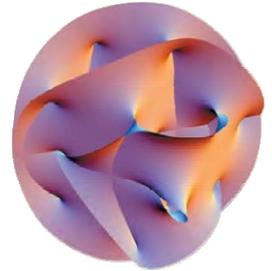
Quantum Information



Quantum mechanics redefines information and its fundamental properties. Researchers at Perimeter Institute work to understand the properties of quantum information and study which information processing tasks are now feasible, and which are infeasible or impossible. This includes research in quantum cryptography which studies the trade-off between information extraction and disturbance, and its applications. It also includes research in quantum error correction which involves the study of methods for protecting information against decoherence.

String Theory

String theory is a broad and varied field with strong connections to quantum gravity, particle physics and cosmology, as well as mathematics. This research group has been working on a wide range of topics in all three connections. Some of the main research topics are: string cosmology, the landscape, gauge theory amplitudes, gauge/gravity duality, black rings, and strings at singularities.

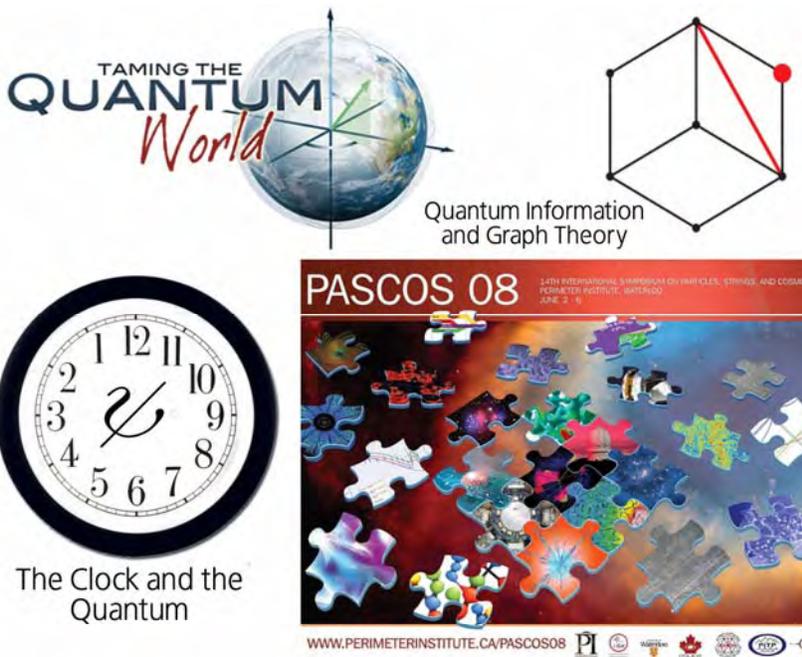


SCIENTIFIC ACTIVITIES

WORKSHOPS, CONFERENCES AND SUMMER SCHOOLS

The Institute recognizes that a lively program of conferences and workshops is essential to maintaining a dynamic scientific atmosphere by regularly exposing our research staff to current ideas in the wider theoretical physics community. The Institute is committed to a combination of internal and external programs; both aligned with and outside of its core research areas, and particularly encourages postdoctoral fellows to initiate innovative workshops and conferences. The Institute is also committed to playing an active role in graduate education through regular summer schools and conferences oriented towards graduate students and advanced undergraduates.

Since 2001, PI has been involved in sponsoring and/or hosting conferences and workshops outside of Waterloo, but since the inception of the permanent research facility in 2004, PI now hosts large numbers of activities on-site – in keeping with our mandate of establishing PI as an international research focal point.



PI continues to build partnerships by co-hosting and/or sponsoring select events. Examples include:

- Workshop on Cosmological Frontiers (jointly organized and sponsored by PI and Laboratoire APC – AstroParticle & Cosmologie)
- The Summer School on Particle Physics, Cosmology and Strings (co-hosted by PI, PITP, APCTP, PIMS)
- PI/CITA Cosmology workshops.

COLLOQUIA AND SEMINARS

PI hosts a vigorous calendar of scientific events each week. Scientists actively attend, present and invite guest speakers. The many talks in the scheduled series regularly attract students and professors from among the regional universities.



Types of Events

In a given week, the following types of events occur:

- Colloquium
 - These talks of general interest to the PI community include both reviews and updates of the fields, and interesting new directions. Approximately one out of four talks is reserved for topics outside of those pursued by PI researchers.
- Seminars
 - The seminars target the six individual research areas more specifically. Most are available to view online via PIRSA.
- Talks
 - Talks are less formal than the seminars and also target specific research areas such as Foundations, QIT and Strings.

SHUTTLE SERVICE

PI is fortunate to be within 100 km of eight research centres and, via our full-time transportation link, is able to increase interaction among researchers and students at all locations.

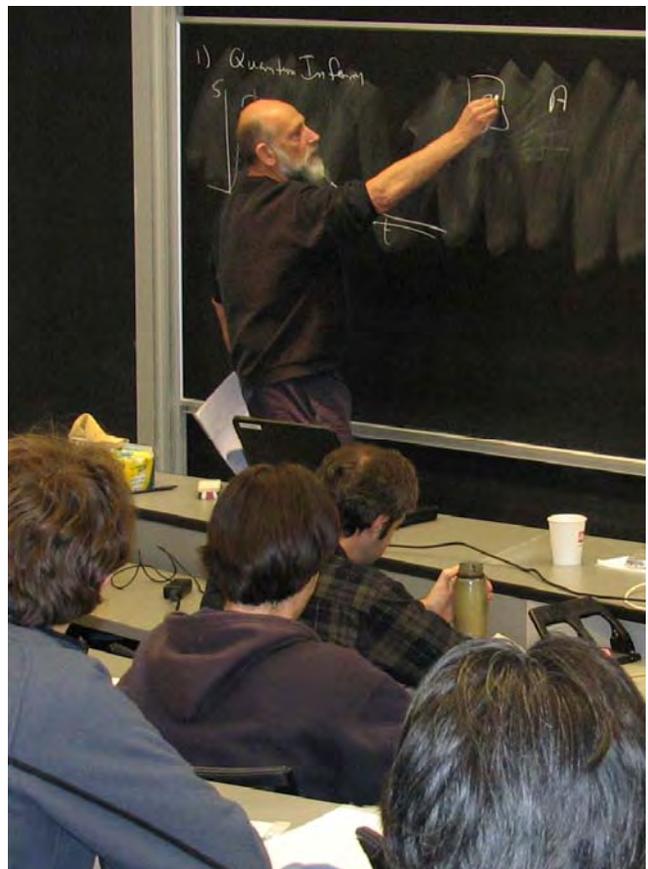


COURSES

The Institute offers a number of planned courses each year, including cross-listed programs with universities and mini-courses given by PI Faculty, Associate Faculty and Long Term Visitors. In addition to providing excellent learning opportunities for young researchers at PI, the courses are made available to all students enrolled in surrounding universities. The popular courses are attended by students from University of Waterloo, University of Western Ontario, McMaster University, University of Guelph, University of Toronto, York University and other centres. The growing number of courses have included:

- Symmetry Principles in Physics – Harvey Brown, Long Term Visitor
- Special Topics: Superstring Theory – Rob Myers, Faculty
- Introduction to Quantum Gravity – Lee Smolin, Faculty
- The Standard Model and Quantum Field Theory – Cliff Burgess, Associate Faculty
- Introduction to Quantum Information from a Foundational Standpoint – Jeffrey Bub, Long Term Visitor
- Advanced Topics in Cosmology – Viatcheslav Mukhanov, Long Term Visitor
- Black Holes & Holography – Leonard Susskind, Associate Faculty
- Interpretation of Quantum Mechanics: Current Status and Future Directions - Raymond Laflamme

Pictured at right is Dr. Leonard Susskind teaching Black Holes & Holography.



RESEARCH LINKAGES

In addition to the joint-conferences and workshops mentioned above, PI has developed productive relationships with a plethora of relevant Canadian scientific organizations and institutions, including the Institute for Quantum Computing (IQC), Canadian Institute for Advanced Research (CIFAR), Canadian Institute for Theoretical Astrophysics (CITA), the Fields Institute, the Institute for Particle Physics (IPP), the Centre de Recherche Mathematique (CRM), the Pacific Institute for Mathematical Sciences (PIMS), Mathematics of Information Technology and Complex Systems research networks (MITACS) and Shared Hierarchical Academic Research Computing Network (SHARCNET). Such interaction encompasses regular mini-workshops (PI-CITA days), extended thematic interaction (PI-Fields theme year in superstring theory), joint postdoctoral fellowships (PI-IPP fellowships), joint sponsorship of summer schools (PIMS, MITACS) and access to high performance computing resources (SHARCNET).

The Institute also has signed Memoranda of Understanding with nearly 30 Canadian universities and institutions to further its goal of serving as a focal point for all relevant members of the Canadian theoretical physics establishment. These include:

University of Alberta
Brandon University
University of British Columbia
Brock University
University of Calgary
Dalhousie University
University of Guelph
Institute for Particle Physics
Laurentian University
University of Lethbridge
McGill University
McMaster University
Mount Allison University
University of Manitoba
University of Montreal

University of New Brunswick
Queen's University
University of Regina
Ryerson University
University of Saskatchewan
Simon Fraser University
University of Toronto
University of Victoria
University of Waterloo
University of Western Ontario
University of Windsor
University of Winnipeg
Wilfrid Laurier University
York University

PIRSA

Research activities at PI are accessible on the Internet to the global scientific community through PIRSA (Perimeter Institute Recorded Seminar Archive). PIRSA is a permanent, free, searchable, and citable archive of recorded seminars, conferences, workshops, and Outreach events. Since 2002 Perimeter Institute has recorded over 1700 seminars and continues to record them at a rate of approximately 10 per week. PIRSA makes these talks permanently available.

On-demand seminars with video and timed presentation materials can be accessed in Windows and Flash formats with MP3 audio files and PDFs of the supporting materials. Viewers come face to face with a split-screen image (please see image below) that enables them to watch the seminar from the perspective of an audience member, with the added advantages of being able to zoom-in, pause, and examine specific slides, equations, or figures more closely.

The screenshot displays the Perimeter Institute Media interface. At the top, the header includes the Perimeter Institute logo and the text "PERIMETER INSTITUTE FOR THEORETICAL PHYSICS". Below the header, there are navigation options: "Polls", "Ask", "Slide Show", "Slide List", and "Max Slide". The main content area is split into two sections. On the left, a video feed shows a speaker, Christopher Fuchs, at a desk. Below the video feed, there is a sidebar with the following information: "13 Quotes from Everett Papers and Why They Unsettle Me", "Presenter(s): Christopher Fuchs", "Date: 09/24/2007", "Time: 11:40 AM EST", and a "Details" button. On the right, a slide show is displayed. The slide show consists of four slides, each with a "PREVIEW SLIDE" and "PLAY FROM SLIDE" button. The first slide shows a diagram of a cube with the quantum state $|\psi\rangle$ written inside. The second slide shows a diagram of a box with a starburst and the text "the 'standard' quantum measurement". The third and fourth slides show handwritten text under the heading "Informational Completeness". The text on the third slide reads: "quantum states $\rho \in \mathcal{L}(\mathcal{H})$ — \mathcal{D} -dimensional vector space. Choose POVM $\{E_i\}$, $i=1, \dots, \mathcal{D}$, with E_i all linearly independent. (Can be done). \mathcal{D} numbers $p(i) = \text{tr}(\rho E_i)$ determine ρ ." The text on the fourth slide reads: "Informational Completeness quantum states $\rho \in \mathcal{L}(\mathcal{H})$ — \mathcal{D} -dimensional vector space. Choose POVM $\{E_i\}$, $i=1, \dots, \mathcal{D}$, with E_i all linearly independent. (Can be done). \mathcal{D} numbers $p(i) = \text{tr}(\rho E_i)$ determine ρ ." At the bottom of the slide show, there is a navigation bar with a play button and the text "Science at your fingertips."

Video feed focuses on the speaker.

Slide show options let you view support material used during the seminar, and zoom in to view details or scroll through to find something specific.

SCIENTIFIC PUBLISHING

Since inception, researchers at PI have published over 880 papers in 50 different journals, receiving over 13,000 citations. Copies of these publications are accessible at:
http://www.perimeterinstitute.ca/en/Scientific/Papers/Publications_Search/

RESEARCH PRIZES

The Institute's researchers are recipients of many awards and honours. A partial listing of selected awards appears below and is followed by some detailed information. Additional awards appear via the curriculum vitae of individual researchers, accessible online via links to individual homepages through the "People" section of PI's website.

Last	First	Role at PI	Title of Award
Laflamme	Raymond	Associate	2008 Royal Society Fellow
Cleve	Richard	Associate	2008 Royal Society Fellow
Laflamme	Raymond	Associate	2008 Premier's Discovery Award
Cleve	Richard	Associate	2008 CAP/CRM Prize in Theoretical and Mathematical Physics
Buchel	Alex	Associate	2007 Early Researcher Award
Thiemann	Thomas	Associate	2007 Vasilis Xanthopoulos Prize (shared with Martin Bojowald (Penn State))
Christensen	Dan	Affiliate	2007-08 Distinguished Research Professorship
Lo	Hoi-Kwong	Long Term Visitor and Affiliate	2007 NSERC Discovery Accelerator Supplement
Bond	Richard	Affiliate	2007 Gerhard Herzberg Canada Gold Medal for Science and Engineering
Boileau	Jean Christian	Graduate Student	2007 John Brodie Memorial Prize
Steinberg	Aephraim	Affiliate	2007 NSERC Steacie Fellowship
Cachazo	Freddy	Faculty	2006 Early Researcher Award
Thiemann	Thomas	Associate	2006 Early Researcher Award
Ansari	Mohammad H.	Graduate Student	2006 John Brodie Memorial Prize
Myers	Rob	Faculty	2006 Royal Society Fellow
Khoury	Justin	Faculty	2006 Foundational Questions in Physics and Cosmology (FQXI) Award
Leifer	Matthew	Postdoc	2006 Foundational Questions in Physics and Cosmology (FQXI) Award
Markopoulou	Fotini	Faculty	2006 Foundational Questions in Physics and Cosmology (FQXI) Award

Last	First	Role at PI	Title of Award
Valentini	Antony	Long Term Visitor	2006 Foundational Questions in Physics and Cosmology (FQXI) Award
Myers	Rob	Faculty	2005 CAP/CRM Prize in Theoretical and Mathematical Physics
Myers	Rob	Faculty	2002 CAP/CRM Award in recognition of exceptional achievements in theoretical and mathematical physics
Poisson	Eric	Affiliate	2005 CAP Herzberg Medal for Outstanding Achievement by a Physicist ages 40 or less
Burgess	Cliff	Associate	2005 Killam Research Fellowship, Canada Council for the Arts
Laflamme	Raymond	Associate	2005 Ivey Foundation Fellow at CIFAR
Laflamme	Raymond	Associate	2005 Medaille Grande Ecole de l'Association des Diplomes de l'Universite Laval
Livine	Etera	Postdoc	2004 Prize of the Thesis, Université d'Aix-Marseille, France
Terno	Danny	Postdoc	2004 Linkage International Award (co-recipient), Australian Research Council
Malecki	Justin	Undergrad	2004 UW Alumni Gold Medal in the Faculty of Science
Gottesman	Daniel	Faculty	2003 List of MIT Technology Review's World's Top Young Innovators
Gottesman	Daniel	Faculty	2003 CIFAR Scholar in Quantum Information Processing program
Markopoulou	Fotini	Faculty	2003 Topical Lecture, American Association for the Advancement of Science
Laflamme	Raymond	Associate	2002 CIFAR Fellow in the Quantum Information Program
Laflamme	Raymond	Associate	2002 Canada Research Chair in Quantum Information
Laflamme	Raymond	Associate	2002 Premier Research Award
Markopoulou	Fotini	Faculty	2002 Young Researchers Competition in Physics, Princeton

Raymond Laflamme
2008 Premier's Discovery Award

Associate Faculty member Dr. Laflamme, a leader in the field of quantum information, received the prestigious Premier's Discovery Award for his contributions to natural sciences and engineering. Raymond Laflamme obtained his PhD in Mathematics from Cambridge University in 1988 under the direction of renowned physicist Stephen Hawking. Following fellowships at the University of British Columbia and Cambridge, Dr. Laflamme worked at the Los Alamos

National Laboratory. In 2001, he returned to Canada to lead the Institute of Quantum Computing at the University of Waterloo and as a founding member at the Perimeter Institute. Dr. Laflamme is also Scientific Director of QuantumWorks, Canada's quantum information research consortium; Director of the Quantum Information Processing program at the Canadian Institute for Advanced Research (CIFAR); and a Canada Research Chair (CRC) in Quantum Information.

Richard Cleve

2008 CAP/CRM Prize in Theoretical and Mathematical Physics

Associate Faculty member Richard Cleve was awarded this prize for his seminal contributions to quantum information science, including the structure of quantum algorithms and the foundations of quantum communication complexity. Richard Cleve received his PhD from the University of Toronto in 1989, specializing in computational complexity and cryptography. He was a postdoctoral fellow at Berkeley's International Computer Science Institute from 1988 to 1990, after which he became a faculty member in the Department of Computer Science at the University of Calgary. In 1994 he became interested in quantum information processing, and since that time he has made several contributions to quantum algorithms and information theory. In particular, he played a major role in the development of quantum communication complexity. Since August 2004, he is a Professor in the School of Computer Science at the University of Waterloo, where he holds the IQC Chair in Quantum Computing.

Alex Buchel

2007 Early Researcher Award

Associate member Alex Buchel was recognized with this award for building on the Theory of Superconductivity with research that will expand the fundamental understanding of the properties of this matter. His research will keep Ontario at the leading edge in the field of theoretical physics and may lead to the development of new and novel materials.

Freddy Cachazo

2006 Early Researcher Award

Faculty member Freddy Cachazo, PhD Harvard, received the award to continue work in string theory on perturbative and non-perturbative methods of taming the strong interactions. Much of researchers' current understanding about nature is based on theories in which a particle, like a photon or a gluon, mediates forces among other particles - such as the electromagnetic force between electrons or the strong interaction between quarks. Although physicists find these theories simple to express, it is usually very difficult to extract useful information from them. Freddy Cachazo and a team of PI researchers will be developing new techniques to help fill the gap between the elegant formulation of theories and the wealth of predictions they should provide.

Thomas Thiemann
2006 Early Researcher Award

Associate member Thomas Thiemann, PhD Aachen, was recognized with the award to support ongoing research at the interface of cosmology and quantum gravity. It allowed him to recruit Oliver Winkler, a former PI postdoctoral researcher with expertise in quantum gravity. The other members of the collaboration were Stefan Hofmann, a former PI postdoctoral researcher in cosmology, and Kristina Giesel, a graduate student of Thiemann's at the Albert-Einstein-Institute in Potsdam, Germany. The aim of this timely project was to investigate possible imprints of quantum gravity on cosmology, which might be detectable with planned satellite missions within the next decade.

Mohammad H. Ansari
2006 John Brodie Memorial Award

The award was established in honour of John Brodie, one of the first postdoctoral researchers at Perimeter institute. During his short career, he published sixteen research papers of considerable breadth, many of which have proven to be quite influential. This award recognizes in others the creativity and independence which John showed in his research.

The annual prize was presented in its inaugural year to Mohammad H. Ansari. Mohammad, currently an Associate Postdoctoral Researcher at PI, was a PhD student in the Dept. of Physics and Astronomy at the University of Waterloo, has been working under the direction of Fotini Markopoulou and Lee Smolin at the time of the award. He was selected as the winner for his significant contributions to the field of quantum gravity using tools from statistical mechanics. In particular, he has observed that, despite a complicated emission spectrum, it is possible to derive sharp spectral lines in the Hawking radiation of black holes. Overall, he has authored or co-authored four papers to date and has demonstrated the technical skill, inventiveness, and independence of spirit which provided fitting tribute to the award's namesake.

Rob Myers
2005 CAP/CRM Prize in Theoretical and Mathematical Physics

The CAP-CRM prize is jointly awarded by the Canadian Association of Physicists and the Centre de Recherches Mathématiques, and is Canada's top honour recognizing outstanding contributions to theoretical physics. The award consists of a medal and a cash prize, and was formally awarded at the Canadian Association of Physics convention in Vancouver in June 2005.

Rob's award is in recognition of his stature as an outstanding theoretical physicist on the world stage, whose many ground-breaking contributions to string theory, including the well-known "Myers" effect, have played and continue to play a pivotal role in the development of string theory. Among his most recent contributions is the discovery that string theory may predict the presence of extremely long 'cosmic strings' of a novel type, which can stretch across the entire visible universe and have consequences for cosmological observations. Such objects, if found, could provide the long-sought smoking gun confirmation of string theory.

The CAP-CRM prize will take its place on Rob's shelf with many other prestigious research awards, such as the CAP's Herzberg medal (1999) and his three prizes in the annual Gravity Research Foundation Prize Essay Competition.

Eric Poisson**2005 CAP Herzberg Medal for Outstanding Achievement by a Physicist ages 40 or less**

Eric Poisson, an affiliate member of Perimeter Institute and a Professor of Physics at the University of Guelph, received the award for his work in the physics of black holes and gravitational waves. As a graduate student with Werner Israel, Eric initiated the study of black hole interiors and the properties of the singularities at their core; however, his main work has focused on the study of black holes and neutron stars as sources of gravitational waves. Eric has been a pioneer in various approaches to calculating the detailed profile of gravitational radiation produced by binary systems.

Cliff Burgess**2005 Killam Research Fellowship**

The Canada Council for the Arts awarded Associate Faculty member Cliff Burgess a Killam Research Fellowship. These distinguished awards are offered on a competitive basis to support researchers in humanities, social sciences, natural sciences, health sciences and engineering. The fellowship is intended to support scholars of exceptional ability engaged in research projects of broad significance and widespread interest.

Daniel Gottesman**2003 list of the world's Top Young Innovators**

Daniel Gottesman was named to the 2003 list of the world's 100 Top Young Innovators by Technology Review, MIT's Magazine of Innovation. The TR100, chosen by the editors of Technology Review and an elite panel of judges, consists of 100 individuals under age 35 whose innovative work in technology has a profound impact on today's world. Daniel was recognized for his work on quantum computation and quantum cryptography. He has contributed to the understanding of quantum error-correcting codes which can be used to protect quantum states against accidental disturbances. His methods are now used worldwide by researchers designing the first rudimentary quantum machines.

Fotini Markopoulou**2003 Young Researchers Competition in Physics**

Dr. Markopoulou, a Faculty member at Perimeter Institute, shared first prize in the Young Researchers competition at the Ultimate Reality Symposium in Princeton, New Jersey. She earned this recognition for her development of a new formulation of quantum cosmology in which quantum theory is applied to a system that contains its own observers, such as the whole universe. She has also explored the role of causality in the quantum theory of gravity and developed methods to study the relationship between the quantum and classical theories of gravity.

SCIENTIFIC OUTREACH PROGRAMS

Educational outreach is an essential component of Perimeter Institute's vision and mission and has been since inception. In establishing Perimeter Institute, the founders were not only motivated to create a research centre of the highest international standing, they were simultaneously determined to strongly affect the prevailing culture by celebrating the importance and impact of scientific inquiry.

There are few other physics institutes in the world with an explicit mandate for both top quality research and top quality outreach programming. Perimeter has set itself the very ambitious goal of being the dominant international brand in physics outreach. The considerable success of the first years of our comprehensive outreach program has proved a welcome endorsement of this vision.

This overview of Perimeter Institute Outreach programs highlights the following areas:

1. Students

International Summer School for Young Physicists
Physica Phantastica

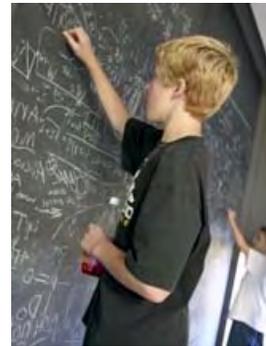
2. Teachers

EinsteinPlus
On-location Workshops
Perimeter Explorations

3. General Public

Public Lecture Series
Open Houses
EinsteinFest
Black Hole Sessions
Website
Researcher Participation
Programs and Partnerships in
Development

4. Event Horizons



INSPIRING STUDENTS

INTERNATIONAL SUMMER SCHOOL FOR YOUNG PHYSICISTS



Each July and August, high school students from Canada and around the world come to Perimeter Institute for intensive two week programs that include lectures on Einstein's ideas and the quantum world, mentorship with PI scientists, and an introduction to the most profound unsolved puzzles of 21st century physics. Sessions are mixed with social and cultural activities to foster long-lasting friendships and help make the ISSYP a life changing experience for budding young physicists. The programs also invite international physics educators to join Canadian teachers in pedagogical workshop activities.

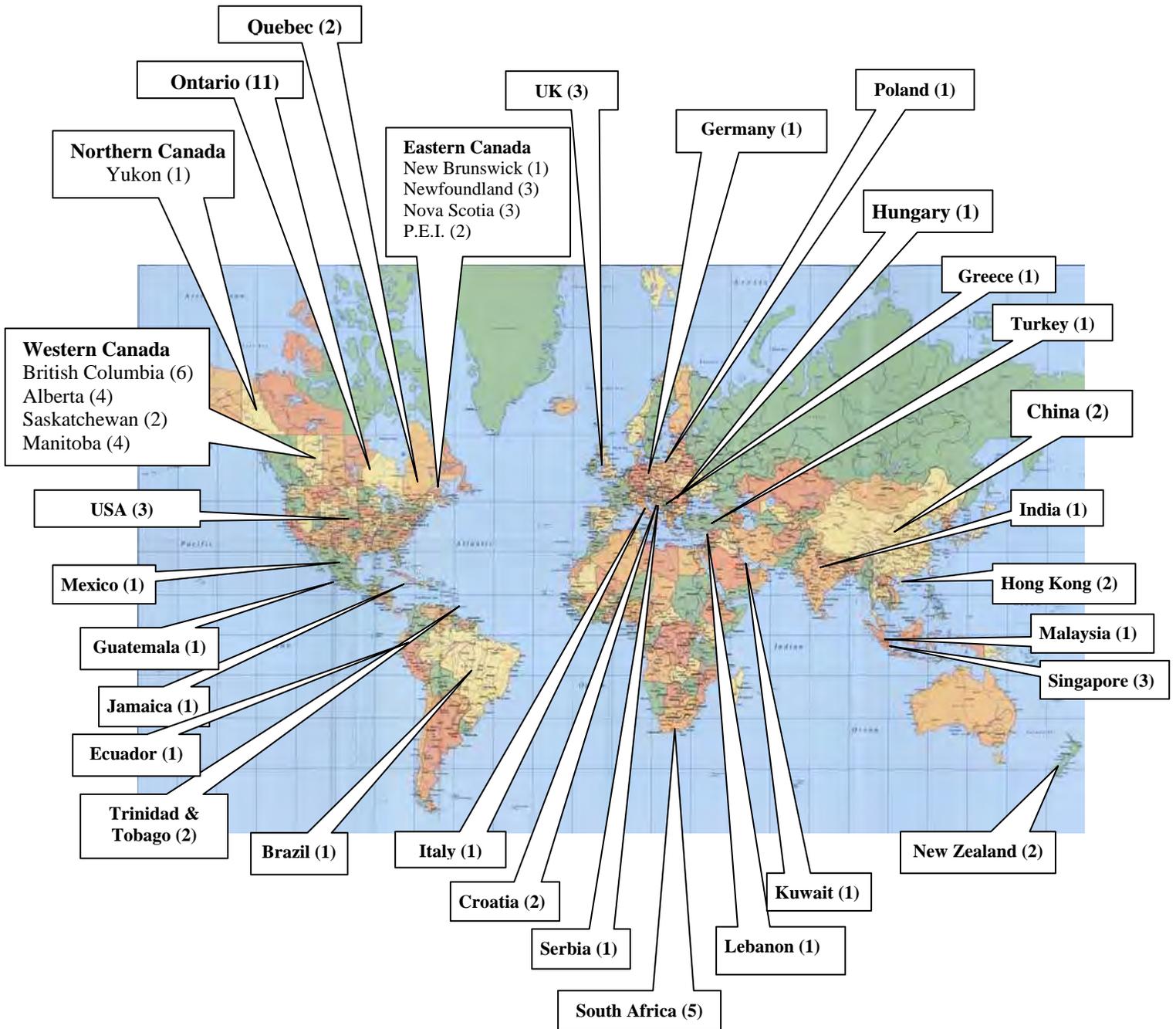
Selections for the program are based on an essay written by the student and a confidential teacher assessment. International students apply to ISSYP, generally, via local government and educational community representatives.

The programs feature:

- Keynote sessions on contemporary physics led by PI researchers
- Mentoring sessions with leading scientists
- Laboratory tours at the University of Waterloo's Institute for Quantum Computing and other facilities in Ontario
- Cultural events including visits to The Stratford Festival and Niagara Falls



ISSYP has wide, global reach. The 2008 program, for example (student numbers depicted below), attracted 79 participants – comprised of students from across Canada and international students from 26 countries. In addition, international teachers arrived in Waterloo to observe the unique workshop activities.



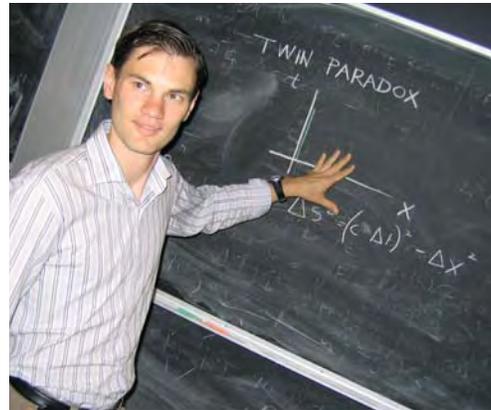
PHYSICA PHANTASTICA LECTURES

Perimeter Institute's Senior Manager of Scientific Outreach provides inspirational science lessons on-location across Canada. All programs share the splendour of our universe and demonstrate how scientific research is the wellspring of existing and future technologies. The interactive Physica Phantastica classroom lectures reach into schools across the country. Presentations are pedagogical in nature and focus on the *process* of science and its enormous impact on technology and society.

Lecture topics to choose from include:

Special Relativity: The Profound Unity of Spacetime

The purpose of this lecture is to demystify special relativity by leading students to a deeper understanding of Einstein's unification of space and time. Simple graphical arguments are introduced that clearly demonstrate how time moves at different relative rates for observers in relative motion. This, in turn, leads to understandable explanations of time dilation and length contraction. In addition, one of Einstein's easily understandable thought experiments is presented to demonstrate to students how he conducted part of his research. The common question of why nothing can travel faster than the speed of light is also addressed.



Quantum Theme

The presentation opens with a dramatic demonstration of the wave nature of matter using an electron diffraction tube. It is emphasized that what students see on the tube's screen has no "commonsense" explanation, with quantum explanations ranging from the electrons behaving as if they are in many places at once to the many-worlds interpretation of our universe. This involves a discussion of the superposition principle — the heart of quantum mechanics, and its exciting present-day application to quantum computers. A simple quantum coin toss analogy leads immediately to one of the most bizarre properties of our universe: quantum entanglement. The presentation concludes with quantum teleportation — a fascinating application of quantum entanglement and a topic that always generates much discussion.

Relativity Theme

Einstein said: "Imagination is more important than knowledge." This presentation gives students an appreciation of Einstein's meaning by taking them through the actual thought experiment that led him to the idea of gravity as a manifestation of warped spacetime geometry. Students discover that science is a highly creative process. Beginning with a discussion of inconsistencies with Newton's force model of gravity, students explore the nature of artificial gravity in a rotating space station to see how special relativity implies that space and time inside the station are "warped". The presentation concludes with a discussion of why a baseball travels on a parabolic trajectory, due to the nature of time in our universe, and an application of these ideas to the Global Positioning System.



Electromagnetism: Rise of the Field Concept

This lecture provides a clear explanation of what the field concept is and *why it is necessary* to describe our universe. Using pictures and analogies, not mathematics, the model of electric and magnetic field lines is introduced, followed by a discussion of electric and magnetic induction. Emphasis is placed on how the specific speed limit of 3×10^8 m/s arises within electromagnetism, leading Maxwell to the profound realization that light is nothing but electromagnetic radiation, and hence the unification of three heretofore separate branches of physics: electricity, magnetism and optics. Students are brought to a deep, intuitive understanding of the nature of light and also learn how the field concept grew to become the dominant model describing *all* physical phenomena.

Quantum Theory: The Mystery of Superposition



The lecture begins by immediately bringing students face to face with the bizarre behaviour of particles, as witnessed in both the single and double slit experiments. The necessity of using wave concepts such as diffraction and interference to describe this strange particle behaviour is made very clear. The de Broglie relation and its deep significance emerge naturally. Emphasis is placed on the fact that Newtonian particle trajectories simply do not exist at this level of nature: quantum theory tells us the probability a particle will go from A to B, but tells us nothing about how the particle "gets" from A to B. It is this superposition phenomenon that is at the heart of quantum theory and responsible for all of its strange features. The lecture concludes with discussion of the new, highly active field of quantum information theory, which promises to deliver exciting new technologies.

National presentations of Physica Phantastica sessions have reached Quebec, Newfoundland, British Columbia, Alberta, and Saskatchewan. Provincial presentations have reached across the province, including underserved areas in Northern Ontario such as Dryden, Fort Frances and Rainy River. Additionally, special presentations have been given to 2nd year University of Waterloo Engineering Students and have been made at Science North in Sudbury.

PARTNERING WITH TEACHERS

In response to overwhelming demand, Perimeter Institute is fulfilling the needs of teachers with a combination of special workshops created specifically for them. These programs combine cutting edge research with pedagogical techniques and provide an opportunity for teachers to meet and interact with top scientists from Perimeter Institute.

Einstein^{Plus}: Teachers' Workshop on Modern Physics

Multiple one-week workshops for select teachers from across the country and around the world are held annually in Perimeter's Waterloo facility. The program focuses on several key concepts in modern physics: the field concept, quantum mechanics and special and general relativity. What are the deeper insights and enduring understandings we want our students to have? How do we lead students in this direction and inspire a love of scientific exploration?

A unique and powerful feature of *Einstein^{Plus}* is the opportunity for teachers to discuss physics and physics education with Perimeter Institute researchers. Due to demand, in recent years the program was expanded to include more sessions and international participants from over 16 countries. Selection for the program is based on the teacher's letter of application and a letter of recommendation from his or her principal. For full program details visit www.einsteinplus.ca.



ON-LOCATION WORKSHOPS

Perimeter Institute's teacher workshops can also be conducted on location across the country. In addition, our Senior Manager of Scientific Outreach travels throughout North America to meet with various associations and promote physics education at conferences and annual meetings. Past workshops include:

- American Association of Physics Teachers (AAPT) 2008 Summer Meeting (Edmonton) – Invited
- CERN High School Teachers Program (France/Switzerland)
- Toronto DSB (Toronto)
- Waterloo Region DSB (Perimeter Institute)
- Ottawa-Carleton DSB (Ottawa)
- Science Department Heads (London)
- Science Teachers' Association of Ontario Annual Conference (Toronto)
- Saskatchewan Science and Mathematics Teachers' Societies "Sciematics 2004" (Saskatoon) - Invited
- Calgary Science Network Special Workshop (Calgary) - Invited
- B.C. Science Teachers' Association "Catalyst 2004" (Richmond)
- Waterloo Region Catholic DSB (Perimeter Institute)
- Science Teachers' Association of Ontario Annual Conference (Toronto)
- Thames Valley DSB (London) - Invited
- Ontario Association of Physics Teachers Annual Conference (University of Western Ontario)



PERIMETER EXPLORATIONS



This new audio-video resource fulfills the number one request from the hundreds of educators who attend the Institute's popular 'Einstein^{Plus} Teachers' Workshop on Modern Physics' – to receive PI's lessons in a turn-key format that teachers can use in-class to:

- Present content related to curricula worldwide that is also at the cutting edge of scientific knowledge,
- Challenge students with deep concepts, abstract ideas and formulas in highly visual ways,
- Engage students with real researchers who demonstrate passion for their work.

Over 100 international teachers and researchers contributed to the first module, which has been classroom tested with over 1000 students. The first module *The Mystery of Dark Matter* has been designed with both the expert and novice teacher in mind. The full kit, which is free to educators, includes:

- 25 minute DVD with indexed chapters to stop/start as needed,
- Teacher Notes with supplementary materials including hands-on demonstrations,
- Student Worksheets, including electronic versions to edit and tailor for individual classes.

REACHING THE GENERAL PUBLIC

Public Lecture Series

Perimeter Institute hosts great thinkers from around the world. Events range from monthly lectures exploring the mysteries of nature to debates probing current issues in science education and science in the media.

Events are explicitly tailored for the general public to help make abstract ideas understandable. Events are regularly sold out with an attendance of over 600 people.



Public lectures are also recorded for high definition television broadcast and made available to stream on demand through Perimeter Institute's website www.perimeterinstitute.ca.



PUBLIC LECTURE SERIES

Event	Date
<i>Before the Big Bang: Is There Evidence For Something and If So, What?</i> Sir Roger Penrose, Oxford University, 691 people	Oct. 1, 2008
<i>Black Holes and a Myth of Icarus</i> Brian Greene, Columbia University, 643 people	Sept. 3, 2008
<i>Time and Einstein in the 21st Century: The coolest stuff in the universe</i> William D. Phillips, National Institute of Standards and Technology, 635 people	June 4, 2008
<i>Science Fiction and Reality</i> Gerard 't Hooft, Utrecht University, 600 people	May 7, 2008
<i>The Curious World of Probabilities</i> Jeffrey Rosenthal, University of Toronto, 579 people	April 2, 2008
<i>What Banged?</i> Neil Turok, Cambridge University, 612 people	Mar. 5, 2008
<i>Rocketeers: How a Visionary Band of Business Leaders, Engineers, and Pilots is Boldly Privatizing Space</i> Michael Belfiore, Science Journalist and Author, 350 people	Feb 6, 2008
<i>Panel discussion on Information and Reality</i> Leonard Susskind, Stanford University Chris Fuchs, LTV, Perimeter Institute Seth Lloyd, MIT Anthony Leggett, University of Illinois Host: Bob McDonald, CBC National Radio "Quirks and Quarks", 605 people	Dec. 5, 2007
<i>The Large Hadron Collider – World's Most Powerful Microscope</i> John Ellis, CERN Robert S. Orr, University of Toronto, 607 people	Nov. 7, 2007
<i>From Einstein's Intuition to Quantum Bits</i> Alain Aspect, Institut d'Optique & Ecole Polytechnique, 617 people	Oct. 3, 2007
<i>Death of the Dinos: Giant Impacts and Biological Crises</i> Jay Melosh, University of Arizona, 608 people	June 6, 2007
<i>What's the Big Idea?</i> Marc Abrahams, Editor of the Journal "Annals of Improbable Research," 598 people	May 2, 2007
<i>Quantum Cryptography: A Tale of Secrets Hidden and Revealed Through the Laws of Physics</i> Daniel Gottesman, Perimeter Institute, 576 people	April 4, 2007
<i>Life, the Universe, and SETI in a Nutshell</i> Jill Tarter, Director, SETI, 644 people	Mar. 7, 2007
<i>Fundamental Physics in 2010</i> Nima Arkani-Hamed, Harvard, 607 people	Feb. 7, 2007
<i>From Here to Eternity: Global Warming in Geologic Time</i> David Archer, University of Chicago, 594 people	Dec. 6, 2006

Event	Date
<i>Time and Motion</i> Harvey Brown, Oxford, 605 people	Nov. 1, 2006
<i>A Madman Dreams of Turing Machines: Limits of Truth and Mind</i> Janna Levin, Cosmologist, Astrophysicist and Author, 603 people	Oct. 4, 2006
<i>Impossible Crystals</i> Paul Steinhardt, Princeton University, 601 people	Sept. 6, 2006
<i>Faster than the Speed of Light – Could the laws of physics change?</i> João Magueijo, Imperial College and Perimeter Institute, 534 people	June 23, 2006
<i>The Quantum and the Cosmos</i> Edward W. Kolb, Particle Astrophysics Center at Fermilab and University of Chicago, 503 people	June 7, 2006
<i>A Night with Nobel Special Presentation: The Origin of Mass and the Feebleness of Gravity</i> Frank Wilczek, MIT	June 6, 2006
<i>The Search for Miss Leavitt</i> George Johnson, Writer, 430 people	May 3, 2006
<i>Programming the Universe</i> Seth Lloyd, Professor, MIT, Special Toronto Lecture, 509 people	Apr. 19, 2006
<i>The Music of Science, The Science of Music</i> Stuart Isacoff, Writer and Musician, 553 people	Apr. 5, 2006
<i>Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions</i> Lisa Randall, Professor of Physics, Harvard University, 607 people	Mar. 1, 2006
<i>Mission to Mars: Still Roving on the Red Planet</i> John Grant, Smithsonian Institute and Jet Propulsion Laboratory, 610 people	Feb. 1, 2006
<i>Theatre of the Mind</i> Jay Ingram, Author, 629 people	Jan. 4, 2006
<i>The Drug Trial: You Be The Judge</i> Miriam Shuchman, Author, 361 people	Dec. 7, 2005
<i>The Big Bang</i> Simon Singh, Author, Journalist and TV Producer, 514 people	Nov. 2, 2005
<i>Was Einstein Right?</i> Clifford Will, University of Washington, St. Louis	Oct. 5, 2005
<i>The Superstring Adventure</i> Rob Myers, Perimeter Institute and University of Waterloo, 578 people	June 24, 2005
Audience Night Audience members were given the opportunity to pitch their ideas and theories to a panel of PI scientists	June 1, 2005
<i>Einstein - Relativity and Beyond</i> , Panel Discussion, 511 people John Stachel, Director, Center for Einstein Studies, Boston University Lee Smolin, Faculty Member, Perimeter Institute John Moffat, Affiliate, Perimeter Institute Moderator: Howard Burton, Executive Director, Perimeter Institute	May 4, 2005
<i>The Quest for Supersymmetry</i> Edward Witten, Institute for Advanced Study, 593 People	Apr. 6, 2005

Event	Date
<i>From Einstein to Quantum Information</i> Anton Zeilinger, University of Vienna, 518 people	Mar. 2, 2005
<i>The Black Hole Wars</i> Leonard Susskind, Stanford University, 512 people	Feb. 2, 2005
<i>The Florentine Heretic? Galileo, the Church, and the Cosmos</i> David C. Lindberg, University of Wisconsin, 601 people	Jan. 5, 2005
<i>Harnessing the Quantum World</i> Raymond Laflamme, Perimeter Institute and IQC, University of Waterloo, 568 people	Dec. 2, 2004
<i>Proofs and Pictures: The Role of Visualization in Mathematical and Scientific Reasoning</i> James Robert Brown, University of Toronto, 565 people	Nov. 3, 2004
<i>Top Minds Lecture Series, Grand Opening Gala</i> , 1260 people Steven Weinberg, University of Texas at Austin Juan Maldacena, Institute for Advanced Study Margaret Geller, Smithsonian Astrophysical Observatory Anthony Leggett, University of Illinois James Hartle, University of California, Santa Barbara Sir Roger Penrose, Oxford University	Oct. 2, 2004
<i>The Stability of the Solar System</i> Scott Tremaine, Princeton University, 535 people	June 2, 2004
<i>A Debate on the Meaning of Quantum Theory</i> , 550 people Wayne Myrvold, University of Western Ontario Lucien Hardy and Antony Valentini, Perimeter Institute	May 5, 2004
<i>The Art of Mathematics</i> Robert and Ellen Kaplan, Harvard University, 410 people	April 7, 2004
<i>Making Light of Mathematics</i> Sir Michael Berry, University of Bristol, 540 people	Mar. 3, 2004
<i>Was there a Big Bang?</i> Robert Brandenberger, Brown University and Perimeter Institute, 474 people	Feb. 4, 2005
<i>Defrauding the Honour System: Physics, Society, and the Bell Labs Scandal</i> Leonard Cassuto, Fordham University, 385 people	Jan. 7, 2004
<i>Limits to Scientific Knowledge</i> John Casti, Technical University of Vienna, The Sante Fe Institute, 430 people	Dec. 3, 2003
<i>Canada's International Scientific Reputation - Panel Discussion</i> , 425 people Tom Brzustowski, President, NSERC David Johnston, President, University of Waterloo Mike Lazaridis, President and Co-CEO, Research In Motion Stephen Strauss, Science Reporter, The Globe & Mail Thomas Thiemann, Researcher, Perimeter Institute Moderator: Howard Burton, Executive Director, Perimeter Institute	Nov. 5, 2003
<i>The Science of Time</i> Dr Fay Dowker, Perimeter Institute and Imperial College, 430 people	Oct. 1, 2003
<i>How Does Science Work?</i> Dr Lee Smolin, Perimeter Institute, 435 people	June 3, 2003

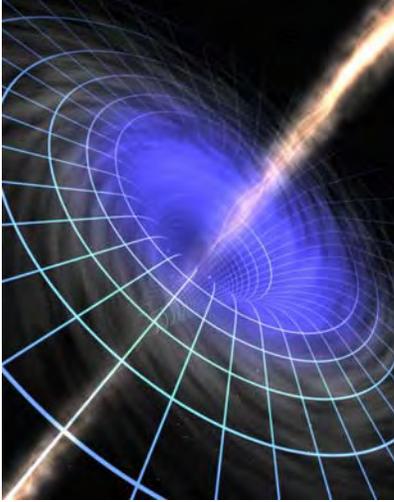
Event	Date
<i>Superstring Theory: Past, Present, and Future</i> Dr John Schwarz, California Institute of Technology, 417 people	May 7, 2003
<i>The Mathematics of Chance</i> Dr Simon Singh, Author / Journalist / TV Producer, 422 people	April 2, 2003
<i>Can Science Journalism be Entertaining and Responsible?</i> Panel discussion, 370 people Peter Calamai, Science Writer, Toronto Star Lynn Haddrall, Editor-in-Chief, Grand River Valley Newspapers Jim Handman, Senior Producer, Quirks and Quarks Rob Myers, Faculty Member, Perimeter Institute Ivan Semeniuk, Producer, Discovery Channel Moderator: Howard Burton, Executive Director, Perimeter Institute	Mar. 5, 2003
<i>Science and Education - Panel Discussion</i> , 310 people Marietta Bloch, President, Science Teacher's Association of Ontario Raymond Laflamme, Director, IQC; Associate Faculty, Perimeter Institute Mike Lazaridis, Co-CEO, Research In Motion Leon Lederman, Founder, Illinois Mathematics and Science Academy Tony Vander Voet, Director, Research Technology and Innovation Branch, MEOI Moderator: Howard Burton, Executive Director, Perimeter Institute	Feb. 5, 2003
<i>Space and Time Close Up</i> Dr Fotini Markopoulou, Perimeter Institute, 304 people	Jan. 8, 2003
<i>Einstein's Biggest Blunder – A Cosmic Mystery Story</i> Dr Lawrence Krauss, Case Western University, 410 people	Dec. 4, 2002
<i>Subversive Rumbblings in the Philosophy of Mathematics</i> Dr Reuben Hersh, University of New Mexico, 274 people	Nov. 3, 2002
<i>Entanglement and Other Mysteries of Physics</i> Dr Amir Aczel, Bentley College, MA, 280 people	Oct. 16, 2002
Open House , 82 people	Oct. 9, 2002

PUBLIC OPEN HOUSES

Over 8000 people visited Perimeter Institute on October 2, 2004 during the Grand Opening Gala and first annual open house. Activities included a self-guided tour through the new research facility with multiple opportunities to stop and chat with researchers. Thousands of children and adults took part in hands-on scientific experiments while others enjoyed stimulating lectures by Perimeter scientists and special guests including Steven Weinberg, Juan Maldacena, Margaret Geller, Sir Roger Penrose, Sir Anthony Leggett and James Hartle.



BLACK HOLE SESSIONS



Powered by coffee and questions, members of the general public have enjoyed informal drop-in sessions at Perimeter Institute where challenging ideas could be presented in a spontaneous atmosphere. Topics ranged from black holes and time travel to the mysteries of our quantum universe. One gathering entitled “Through Einstein’s Eyes” featured the latest video simulations to show what people would see if they traveled at close to the speed of light.

While up to 100 people per event have attended these sessions, the Black Hole Sessions are being reformatted to suit wider audiences via the internet. This exciting development in 2008 will ensure that engaging scientific content reaches all interested people around the world.

Topics included:

- Through Einstein’s Eyes
- M-Theory (the theory formerly known as superstrings)
- Dark Matter and Dark Energy
- Black Holes, Worm Holes, Time Travel and all that
- Gamma Ray Bursts— Cataclysms Extraordinaire!
- Did the Big Bang Really Happen?
- The Mystery of Quantum Entanglement
- 21st Century Applications of the Quantum: Quantum Computing, Quantum Communication, Quantum Cryptography



EINSTEINFEST



EinsteinFest was North America's most comprehensive celebration of the 100th anniversary of Albert Einstein's miracle year of 1905. The three-week event from September 30-October 23, 2005 examined Einstein's prolific contributions and the transformative times in which he lived via a full spectrum of compelling public lectures, engaging debates, inspiring concerts, hands-on exhibits and special educational programming for school groups.

24 days, 38 lectures, 21 concerts and performances

Attendance at EinsteinFest topped 28,000 including visitors from across Canada, the United States, United Kingdom, Europe, Australia, South America and beyond - testimony to the lengths people will go to "think big" in a wide theatre of ideas.

From Wireless to the Wright Brothers, Fashion to Philosophy, Jazz to Judaism, EinsteinFest dug deep into a wide spectrum of human activity sparked by the 1905 era and was met with a resounding, thundering response that was beyond expectations.

In addition to the Festival's popularity, this Canadian contribution to the "World Year of Physics" was also a critical success. Journalists from Germany to China not only marveled at the scope, scale, intensity and diversity of the scientific, educational and cultural programming, but noted that each activity was at the highest international level. There simply was no other event like it in the world.

EinsteinFest
The Man | The Science | The Times | The Legacy
September 30 to October 23 | 2005

Join us for a spectacular celebration of the 100th anniversary of Albert Einstein's *annus mirabilis* - "miracle year" - of 1905 when, at the age of twenty-five, he published several groundbreaking ideas that led physics - and thereby, the world - into the modern era.

EinsteinFest explores our rapidly changing civilization at the turn of the century and sets Einstein's prolific contributions in context with the science, philosophy, politics, art and music of the day. A full spectrum of exhibits, educational activities, compelling lectures and inspiring performances examines the discoveries, brilliant minds, and rich culture of this transformative period in history.

displays&exhibitions
Jazzie Bradley, Curator
Four Perimeter Institutes, look around and listen up! Viewing stations include:

- The *Miracle Year* - the 1905 Einstein papers, demystified
- The rapidly changing world around Einstein in 1905:
 - the birth of wireless communication, flight, jazz and silent film
 - the brilliant minds of Freud, Schoenberg, Picasso, Joplin and Picasso
 - Works of art, listening stations, manuscripts, memorabilia and more.
- In Einstein's Footsteps - cutting-edge research today at Perimeter Institute.

Displays and Exhibitions are free to the public and are located throughout Perimeter Institute's award-winning building. Advance tickets guarantee entrance to the exhibitions at a set hour and are recommended.

familyfun
Perimeter Institute's Director of Scientific Outreach presents:

- Einstein Inside Out!
- Science experiments and more in the *Physica Plantarctica Centre*.
- PLUS**
- Interactive displays, talks, concerts, silent film for the whole family.

Advance tickets guarantee entrance to the Physica Plantarctica Centre at a set hour and are recommended.

performances
Stunning sights and sounds of Einstein's world featuring:

- Concerts
- Silent Film
- Theatre
- Jazz and Blues in the Black Hole Bistro

Tickets are required for all performances and purchasing in advance is strongly recommended. Tickets are not required for Jazz in the Black Hole Bistro. Seating is limited and a cover charge applies.

lectures
Leading experts in their fields explain:

- The Man** - Einstein - His life, religion, politics and celebrity.
- The Science** - The *Black Hole*, Year and the 1995 Papers.
- The Times** - The Birth of Jazz, Silent Movies, Wireless Communication and Flight.
Brilliant minds and revolutionary ideas in psychology, mathematics, literature, music and more.
- The Legacy** - Beyond Einstein - the current frontier of foundational physics.
- PLUS**
- Bistro Banter** - Debates, discussions and Q & A - served with refreshments in the informal setting of the Black Hole Bistro.

Lectures are free to the public. Tickets are required and advance seating is recommended. Tickets are not required for Bistro Banter but seating is limited.
Please note! All lecture ticket holders must take their seats a minimum of 15 minutes prior to the start of lectures. Unoccupied seats will be distributed to the waiting list after this time.

Order tickets online at www.einsteinfest.ca or call (519) 883-4480

WEBSITE

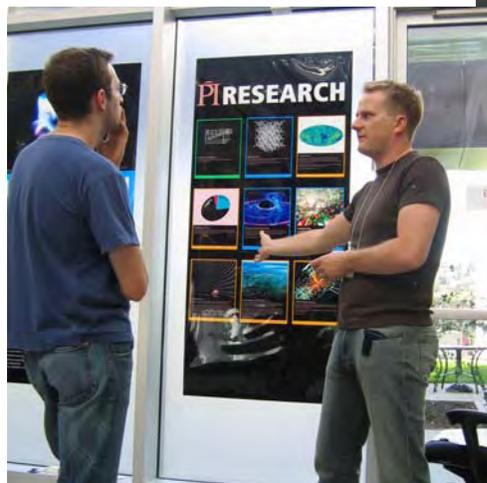
Perimeter Institute offers a growing portfolio of content via its website. Visitors to the site can learn about the Institute's research areas and then seek in depth information via the wide variety of recorded scientific outreach talks. Special pages for teachers also provide information and support for the Perimeter Explorations in-class lessons.



RESEARCHER PARTICIPATION

Outreach programming benefits directly from the wisdom and participation of scientists. The Senior Manager of Scientific Outreach, himself a PhD in quantum information theory, deliberately utilizes research staff to:

- Vet and improve upon new, educational content
- Provide key-note presentations and mentorship sessions within ISSYP and Einstein Plus to the benefit of students and teachers
- Meet with members of the general public via monthly “Black Holes,” festivals and special events



PROGRAMS AND PARTNERSHIPS IN DEVELOPMENT

Perimeter Institute is continuously expanding its Scientific Outreach activities to reach more people in new ways.



For the general public, the Institute's website will expand to include additional, interactive content. The Institute will also continue to provide a growing variety of public lectures and debates online and offer this same content via television.

Co-sponsorships and support for related activities will also continue to grow – including PI relationships with the *Canada-Wide Science Fair* and the *Canadian Chemistry and Physics Olympiad* - while, at the same time, new partnerships will be explored with major school boards and government organizations as well as with UNESCO.

It is our strong belief and fervent hope that the presence of Perimeter Institute and the intellectual excitement that it represents will have a profoundly positive impact on the attitudes and future development of students, teachers and the general public around the world.

*Juan Maldacena speaks on "Black Holes and the Structure of Spacetime,"
October 2, 2004.*

EVENT HORIZONS

Complementing the twin mandates of top quality research and educational outreach is an integral mix of musical programs and cultural events. Perimeter Institute aims to be an attractive and dynamic facility in the broadest possible sense – a stimulating setting for leading-edge scientists to think and an accessible and engaging environment for the community at large.

From Aristotle to Einstein, from Leibnitz to Pascal, history is populated with examples of outstanding intellects who had wide-ranging interests and made fundamental contributions across the complete spectrum of the sciences and humanities. Today, Perimeter Institute shares the joys of creative inquiry with the wider community through Event Horizons, an ambitious agenda of top quality musical and cultural events throughout the arts and sciences.

The sponsored and ticketed talks, performances and exhibitions at Perimeter Institute capitalize on the intimacy of the Mike Lazaridis Theatre of Ideas, the innovative possibilities of the four-storey atrium and the casual atmosphere of the roof-top Black Hole Bistro. We invite the general public to fully engage in the experience, mingle with artists, meet scientists and move forward in stimulating journeys of discovery.

2008-2009 SEASON

<i>Jake Langley</i>	26-Sept-08
<i>Baroque Cabaret</i>	10-Oct-08
<i>Brentano String Quartet</i>	17-Oct-08
<i>The Glenn Buhr Band</i>	24-Oct-08
<i>Lynn Harrell, Jon Kimura Parker</i>	4-Dec-08
<i>Gil Shaham and Friends</i>	4-Feb-09
<i>James Galway, and Christopher O'Riley</i>	10-Mar-09
<i>Valdimir Feltsman</i>	17-Apr-09

PERIMETER **PI** INSTITUTE FOR THEORETICAL PHYSICS

EVENT HORIZONS 08-09
Classical World Artists

Brentano String Quartet
Friday October 17, 2008 at 7:30 pm
Our 2008 Season guests with the incomparable Brentano String Quartet. Described as passionate, uninhibited and spellbinding, the quartet performs throughout the world to critical acclaim, garnering praise that places them at the forefront of a new generation of chamber musicians.

Lynn Harrell, cello and Jon Kimura Parker, piano
Thursday December 4, 2008 at 7:30 pm
Considered to be one of the preeminent cellists of the last century, Lynn Harrell is a consummate soloist, chamber musician, recitalist, conductor and teacher. His work throughout the Americas, Europe and Asia has placed him in the highest echelon of today's performing artists. He will be joined by extraordinary Canadian pianist, Jon Kimura Parker who is internationally acclaimed for his charisma and dazzling technique.

Gil Shaham and Friends
Wednesday February 4, 2009 at 7:30 pm
Straight after throughout the world for social and concert appearances, Gil Shaham is recognized by audiences and critics alike as one of today's most virtuosic and engaging hornists. His dream of bringing together friends and colleagues for chamber music in the inspiration behind an all-brass programme which comes to Perimeter Institute from Carnegie Hall.

James Galway, Rute and Christopher O'Riley, piano
Tuesday March 10, 2009 at 7:30 pm
Sir James Galway is regarded as both the supreme interpreter of the classical flute repertoire and a consummate entertainer whose vast talent crosses all musical boundaries. With over 30 million albums sold and countless appearances with the world's leading orchestras, his virtuosity is equaled only by his tireless vision. Sir James will be joined by pianist Christopher O'Riley whose prodigious gifts and technical mastery have made him one of the most important and versatile pianists performing today.

Valdimir Feltsman, piano
Friday April 17, 2009 at 7:30 pm
An actor of immense energy and insight, Valdimir Feltsman is recognized as one of the most imaginative and interesting musicians of our time. Lauded for his powerhouse technique and interpretive genius, Mr. Feltsman is a regular guest soloist with leading orchestras and soloist on the most prestigious concert series and music festivals worldwide.

perimeterinstitute.ca/eventhorizons
519.883.4480
Full programmes to be announced.
Concerts held in Perimeter Institute's Mike Lazaridis Theatre of Ideas

EVENT HORIZONS 07-08
Classical World Artists

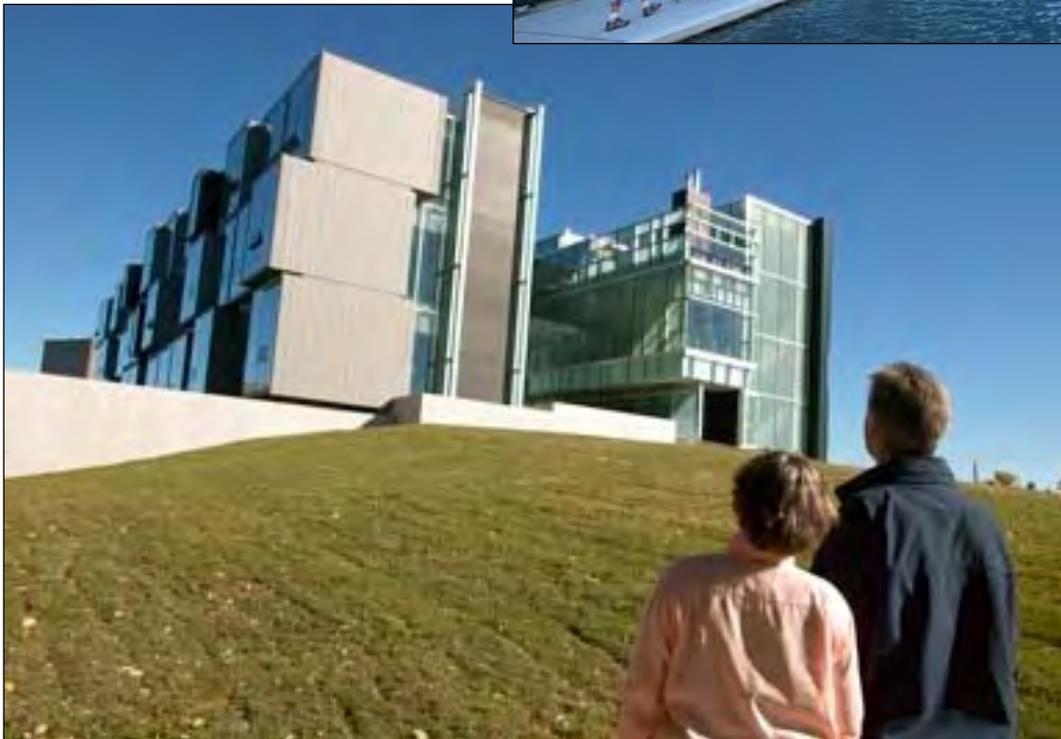
Special Performance
Yo-Yo Ma and Friends
March 4, 2008 at 7:30 pm
Cellist Yo-Yo Ma's many-faceted career is testament to his continual search for new ways to communicate with audiences and stimulate the imagination. Perimeter Institute is honoured to present an evening with one of the world's most celebrated musicians.

Previous Event Horizons Seasons have included performances by such luminaries as Yo-Yo Ma.

FACILITY

The Institute building was custom designed by Montreal's Saucier + Perrotte Architectes, a leading firm that has designed many landmark buildings in Canada and abroad. Perimeter's facility has been recognized with the 2006 Governor General's Medals in Architecture as well as a citation in the 349th annual P/A awards, a 2005 Ontario Association of Architects Award and a 2005 Ordre des Architectes du Québec Award.

For more information and a virtual tour throughout the building, visit www.perimeterinstitute.ca/About/Facilities/Facilities_Overview/.



THOUGHTS BEHIND THE DESIGN

A building dedicated to theoretical physics is, from a strictly practical perspective, quite similar to an ordinary office building – there are no laboratories or heavy machinery and one instead finds only desks, computers, lounges and blackboards. But an Institute is far more than a place to store desks and chairs, and Perimeter’s founders recognized from the outset that in order to establish a Waterloo-based Institute of the highest international standing it would be necessary to create a landmark building, both functionally and aesthetically, to attract and retain the very best researchers the world has to offer.

So when the City of Waterloo offered Perimeter officials a choice of several prime sites to donate to the Institute, the choice was an easy one to make. Despite the quality of all of the sites, only 31 Caroline Street had the unique combination of advantages that we were looking for: located on the south shore of Silver Lake in Waterloo Park where researchers could easily enjoy contemplative walks through the park, within close proximity to both University of Waterloo and Wilfrid Laurier University and still in the heart of Uptown Waterloo – a short stroll from a wide selection of restaurants, shops and cafes.

Equipped with an optimal site, we then set out to create an appropriately spectacular facility that could fully capitalize on the magnificent setting based on the following principles:

1. The building must present a warm and convivial atmosphere, be aesthetically pleasing, and contain an abundance of natural light.
2. There must be a harmonious balance between private and public space throughout – a productive mixture of formal and informal discussion space combined with areas for quiet reflection and calculation.
3. The facility should be capable of running scientific conferences and occasional public events without unduly impinging on the resident research activities.
4. The Institute should be a landmark building for the entire community of Kitchener-Waterloo – to showcase a top quality, international research centre made possible by the vision and the success of its founder.

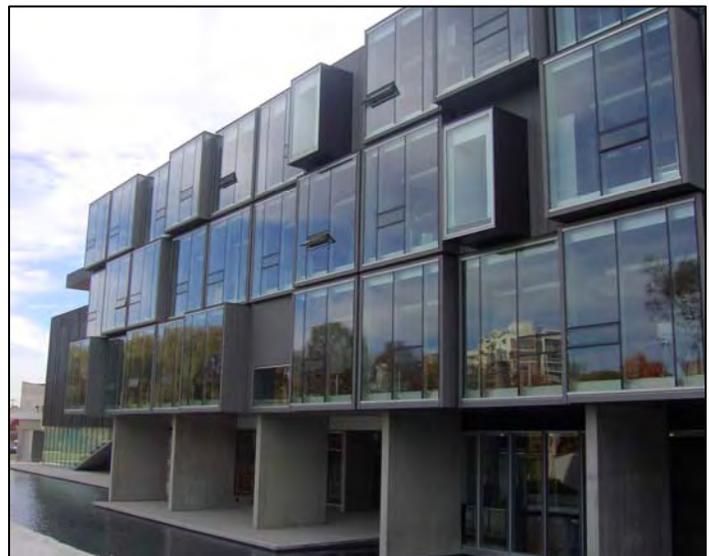
ASPECTS OF THE FINAL DESIGN



Three bridges span the exterior garden connecting the building on the third and fourth levels, with each bridge culminating in an informal meeting area allowing an easy continuance of scientific discussion for researchers returning from a seminar or a meal.

The building has four levels and is approximately 65,000 square feet. There are 44 scientific offices on the north side. These, together with larger offices on the south side, give the Institute a steady-state capacity of 80 researchers in the building at any given time, in addition to administrative staff and 20-30 graduate students. The facility also contains the bi-level George Leibbrandt Library, two seminar rooms (each with a capacity of 50-60 people), the 205 seat Mike Lazaridis Theatre of Ideas and the naturally attractive Black Hole Bistro, complete with a rooftop deck.

The building has uniquely inviting atmosphere throughout with its six wood-burning fireplaces, lounges, informal meeting areas and numerous espresso machines. To enhance the quality of natural light a large exterior courtyard was created in the heart of the facility adjacent to a large atrium with a glass roof. The building is open on the western side to diminish shadows and to allow for the maximum passage of light in the afternoon. A reflecting pool abuts the north side of the building, providing a clear demarcation of the Institute from the park, while offering an added perspective of reflection and tranquility.



OFFICES

Most research space at the Institute provides a peaceful, treetop view of Silver Lake and Waterloo Park, with windows that open to the fresh air. Offices are equipped with floor-to-ceiling blackboards and fully controllable lighting. Printers, coffee makers and other amenities are just steps away.

COLLABORATION AREAS

Comfortable leather couches, cappuccino machines and blackboards around every corner make the research lounges scattered throughout the building ideal for discussion and debate.

SEMINAR ROOMS

The Institute's two seminar rooms – Bob and Alice – accommodate 60 and 50 researchers, respectively. Bob is a traditionally tiered, forward facing space. Alice is a multi-purpose room with maximum flexibility to orient chairs and desks in any configuration – depending on the workshop or other needs.

THEATRE

The 205 seat Mike Lazaridis Theatre of Ideas is the main centre of activity for high-level conferences. It is also home to many of Perimeter's outreach and cultural activities. The theatre contains a number of features ranging from the very latest audio/visual technology to window blinds that can be raised to introduce natural light - depending on the presentation.

LIBRARY

A variety of physics books and periodicals can be found in the George Leibbrandt Library, accessible from the first and second floors. PI scientists can also access the University of Waterloo library system, which extends to the University of Guelph and Wilfrid Laurier University. Electronic access to journals is also provided.

THE BLACK HOLE BISTRO

The fourth floor bistro provides morning coffee, mid-day lunches and evening meals. The Bistro is open to PI residents and their guests. Members of the general public are invited to join researchers and enjoy the atmosphere in conjunction with ticketed outreach events.

HEALTH FACILITIES

The Institute provides an onsite exercise area with a range of fitness equipment, games areas and change rooms.

ORIGINAL FACILITY

The original home of Perimeter Institute, at 35 King St N, is an historic post-office building with clock tower. It is located just steps away from the main facility and offers additional workshop space and collaboration areas. Used for a change of pace, this century-old building features wooden floors throughout, a large second seminar room, and lounge with refreshment area.



HISTORY OF THE INSTITUTE

Perimeter Institute is a basic research centre dedicated to exploring the world around us at its most fundamental level. It began in the summer of 1999 when Mike Lazaridis, founder and Co-CEO of Research In Motion (RIM) – maker of the successful BlackBerry™ – found himself in a position to help foster research and innovation in Canada. In August 1999, he hired a Founding Director, Howard Burton, a PhD graduate from the University of Waterloo, to research how a world-class organization devoted to theoretical physics would take shape in Canada. In the fall of that same year a Board of Directors was also established, consisting of seven individuals from business, finance and academe.

With an organizational framework in place, a thorough study began involving travel to a number of scientific institutions and research environments throughout North America and Europe in order to review a whole host of relevant issues from research breadth to interaction with the surrounding academic community, structural organization and architecture. After several months of travel to locales such as the Institute for Advanced Study (Princeton), Institute for Theoretical Physics (Santa Barbara), Santa Fe Institute, CERN (Geneva), International Centre for Theoretical Physics (Trieste) and others, the following conclusions were made about how Perimeter Institute should be structured:

1. The Institute should be *independent*
2. The Institute should focus on *foundational, non-directed research*
3. The Institute should be *resident-based*
4. The Institute should be a *flat hierarchy of a true community of scholars*
5. The Institute should develop a *strong public presence*

After careful deliberation of these conclusions, it was recognized that all of them involved potential pitfalls if not implemented correctly. The independence of the Institute was regarded as essential in order to exercise maximum flexibility with regards to hiring faculty, accommodating visitors, structuring public outreach activities and other matters. But there was also a universal recognition that it was essential for the future Institute's culture and atmosphere to develop some structured way to substantially involve students and younger researchers in the mainstream of the Institute's activities. Moreover, as befitting its central mission statement of strengthening theoretical physics research throughout Canada, Perimeter was determined to place itself in a cooperative, rather than a competitive, relationship with the surrounding academic community.

With these concerns in mind, it was concluded that the Institute would begin by offering positions for senior faculty. This involved a structure that enabled a greater integration of PI researchers within the surrounding academic community through the potential of cross-appointments at local universities. The resolve to interact with other organizations combined with the Institute's own aggressive recruitment efforts would, in the fullness of time, generate a cluster of top international talent and thereby strengthen the entire region in fundamental physics research. Moreover, and in tandem with other organizations, the Institute would be able to accommodate graduate students from Canadian universities for various periods of time within its own walls, thereby ensuring a lively and dynamic research environment.

While the Institute planned to focus on foundational, non-directed research, it was also noted that particular attention must be paid to realize an appropriate balance between formal and

phenomenological approaches to fundamental issues as befitting a physics, rather than a mathematics, institute. Further, there was an explicit motivation to ensure that the Institute foster a climate that welcomed a diversity of approaches towards foundational issues within a culture of excellence, deliberately encouraging deep, innovative thinkers to boldly push the boundaries of our current understanding of physical law. To this end, the Institute would benefit from a combination of advice generated by a Scientific Advisory Committee (SAC), on-site researchers and external scientific experts to ensure that the scientific mission statement is continually met.

Although Perimeter planned to be resident-based rather than program-driven, it was fully recognized that workshops, conferences, summer schools and the like would represent an excellent opportunity to interact with the international academic community and expose resident researchers to interesting developments in neighbouring fields. As a result, the Institute would set out to run a wide range of scientific programs year round. A new facility, already being contemplated, would feature a 205-seat lecture theatre, seminar rooms and collaboration areas to specifically foster the activities.

The structure of the Institute also required a considerable amount of deliberation. As mentioned, there was a strong motivation to ensure that the Institute function with the flattest possible hierarchy as would be efficacious and consequently develop a culture of a true community of scholars. In recognition of the fact that many of the seminal discoveries in theoretical physics have historically come from young researchers, Perimeter set out to have a youth-oriented focus and consequently give its many postdoctoral researchers as much research freedom and opportunity as possible. Its senior Faculty, meanwhile, would be a blend of younger and more experienced scientists, providing a combination of proven research excellence, leadership and mentoring experience together with prodigious cutting-edge scientific activity. The Scientific Advisory Committee – to be comprised of internationally renowned researchers – would be an integral oversight body, deliberately created to assist the Institute’s leaders and ensure objectivity and a high standard of scientific excellence.

In establishing Perimeter Institute, the founders were not only motivated to create a research centre of the highest international standing, they were simultaneously determined to strongly affect the prevailing culture by celebrating the importance and impact of scientific inquiry. As a result, a comprehensive program of educational outreach activities would be established with a reach extending across Canada and, eventually, the world. Specific programs would be designed to engage students, teachers and members of the general public with targeted content by way of in-class lessons, customized workshops, on-site summer schools, year-round lecture series, special festivals and more.

Complementing the twin mandate of top quality research and educational outreach would be an integral mix of musical programs and cultural events. Perimeter Institute would aim to be an attractive and dynamic facility in the broadest possible sense – a stimulating setting for leading-edge scientists to think as well as an accessible and engaging environment for the community at large.

With the ambitious scope and scale of activities now determined, Perimeter Institute for Theoretical Physics was officially launched on October 23, 2000 with a \$100 million personal commitment from Mike Lazaridis and, later in 2008, this grew by an additional \$50 million in personal philanthropic funding for a total and fully completed donation of \$150 million to PI.

Also in 2000 at the inception of the institute, a separate \$20 million donation was provided by fellow RIM executives Doug Fregin and Jim Balsillie consisting of \$10 million each. The City of Waterloo donated a premier site in Uptown Waterloo at that same time for the Institute's new building. An eminent, international eight member SAC was selected in late 2000 and had its first meeting in Waterloo in the spring of 2001. Research operations began in temporary facilities in October 2001 with a core scientific staff of 9 internationally recognized scientists which expanded to 24 in a little over a year.

Since the fall of 2001, the Institute has run an extremely active scientific seminar series, entertained thousands of international visitors, hosted a wide variety of scientific workshops and conferences, appointed seventy affiliate members from across Canada, and instantiated and developed a full array of educational outreach programs.

The Canada Foundation for Innovation awarded Perimeter Institute a \$5.6 million infrastructure grant for its new facility in January 2002 which was later matched by a corresponding \$5.6 million from the Ontario Innovation Trust. On June 14, 2002, Prime Minister Jean Chrétien came to Waterloo to announce the Government of Canada's direct contribution of \$25 million over five years through NSERC to support Perimeter Institute's unique research mandate. The Government of Ontario pledged a further \$15 million in direct support in their June 2002 budget, in addition to their previous joint award of \$5.95 million to Perimeter and the University of Waterloo's Institute for Quantum Computing through the Ontario Research and Development Challenge Fund. The Institute, to that time, received in excess of \$54 million in public funding commitments, illustrating a strong resolve by government for Perimeter's success. Some five years later, with initial seed monies set to expire, the Ministry of Research and Innovation renewed the Ontario government's commitment to Perimeter Institute with a further \$50 million while, at the same time, providing an additional \$50 million to the Institute for Quantum Computing. More recently in March of 2007, as initial federal monies via NSERC were expiring, the Government of Canada renewed and increased its investment in the order of \$50 million for expanded research and outreach operations for the next five years. This followed a full review by NSERC in September of 2006 which positively reported upon all aspects of the Institute. In 2008, as indicated above, Mike Lazaridis donated an additional \$50 million in personal funding, over and above his initial \$100 million, for a total and completed philanthropic donation of \$150 million to PI.

Through this period, specifically in October of 2004, the Institute moved into its permanent facility, designed by the Montreal-based firm Saucier + Perrotte Architectes. The award-winning research centre was custom designed to facilitate productive research and outreach activities by sustaining resident scientists and hundreds of international visitors each year with a variety of creative blackboard-lined spaces in which to contemplate and calculate exciting new ideas about the ultimate nature of space, time, matter and information.

In May 2007, founding Executive Director Howard Burton left the Institute to pursue other interests. Scientific Direction has been provided since that time by Perimeter senior scientist and founding member, Dr. Rob Myers. A search for a permanent Director to lead the next phase in the Institute's development led to the selection of Dr. Neil Turok, a renowned physicist from Cambridge University, who began work at PI in October 2008 (please see The People – Scientific Leadership for more information).

Through strong leadership and the passionate support of leading philanthropists and the Governments of Ontario and Canada, Perimeter Institute for Theoretical Physics continues to be an innovative and successful example of private-public partnership in science research and education.

KEY MILESTONES

- Incorporation of name, letters patent (Fall 1999)
- Appointment of Board (Fall 1999)
- Investigatory trips (Winter-Spring 2000)
- Founding principles of research structure, aspects of governance, etc (Summer 2000)
- Public announcement of PI's existence (Fall 2000)
- Selection of Scientific Advisory Committee (Fall 2000, Winter 2001)
- Hiring of first 3 Faculty (Winter 2001)
- First meeting of SAC (Spring 2001)
- Begin research operations in temporary facility (Fall 2001)
- First public lecture (Roger Penrose, Fall 2001)
- Awarded CFI/OIT Grant (Winter-Spring 2002)
- Awarded ORDCF Grant (Spring 2002)
- Hosted first conference (MRST 2002)
- Awarded multi-year \$25 million federal operating grant through NSERC (Spring 2002)
- Awarded multi-year \$15 million provincial operating grant (Spring 2002)
- Begin summer school for young physicists (Summer 2002)
- Begin monthly public lecture series (Fall 2002)
- Begin national teacher workshop (Summer 2003)
- Completion of new building (Fall 2004)
- First undergraduate/graduate course taught at PI (UW, Fall 2004)
- EinsteinFest attracts over 28,000 (Fall 2005)
- Government of Ontario announces \$50 m to PI for future operations (Spring 2006) via Ministry of Research and Innovation
- Government of Canada announces \$50 m to PI for future operations (March, 2007) following objective and positive assessment by the Natural Sciences and Engineering Research Council of Canada (NSERC)
- Mike Lazaridis, President & Co-CEO RIM donates an addition \$50 million (Spring 2008)

SUMMARY OF FINANCIAL SUPPORT

PUBLIC MONIES

Government of Canada:

\$50 million Government of Canada announcement (2007)
\$25 million grant through NSERC (2002)
\$5.6 million grant from the Canada Foundation for Innovation (CFI) (2002)
\$1.7 million grant from CFI Infrastructure Operations Fund (CFI-IOF) (2004)
\$59,900 grant from Promoscience for ISSYP program (2005)
\$50,700 grant from Promoscience for EinsteinPlus Program (2006)

Government of Ontario:

\$50 million grant through MRI (2006)
\$15 million grant through MEDT (2002)
\$5.95 million grant from the Ontario Research and Development Challenge Fund (ORDCF), shared equally with the Institute for Quantum Computing (2002)
\$5.6 million grant from the Ontario Innovation Trust (OIT) (2002)
\$150,000 grant through MEDT for outreach programming (2005)
\$120,000 grant from the provincially administered Research Performance Fund (RPF) (2005)
\$20,000 for 2003 Summer Institute (2003)

City of Waterloo:

Additional support of \$212,000 for cost-sharing of some site development expenses (2000)
Premier site in Uptown Waterloo to serve as the location for the Institute's permanent facility (2000 – forward)

PRIVATE MONIES

Over \$1,000,000

Mike Lazaridis, President & Co-CEO Research In Motion: \$100 million (2000) and \$50 million (2008) for total donation of \$150 million
Doug Fregin, Vice President (Operations) Research In Motion: \$10 million (2000)
Jim Balsillie, Chairman & Co-CEO Research In Motion: \$10 million (2000)

Up to \$500,000

E. Kendall Cork (2006)
Don McMurtry (2004)
The Kitchener and Waterloo Community Foundation (2005)

Up to \$50,000

Robin Korthals (2004, 05, 06, 07)
Harry and Angela Brodie (2006)
Dennis Kavelman (2003)

Up to \$5,000

Dare Foods (2006)
Dr. Alex Maznytsya (2005)
Canadian Federation of University Women, Kitchener-Waterloo (2005)
Bruce North (2001)

Donations in memory of George Leibbrandt (since 2001):

Individuals

O. Brian Allen	Elmer & Mary Jo Alyea
Ursula & Hans Baurose	Wenfeng Chen
Wm. H. Clarke	Bill Clausen
Mary Anne & Silvano Dallan	Gerarda Darlington
Bruno Di Stefano and Anna Lawniczak	Fred Gault
Hans Heinig	John Holbrook
Katherine Ingram	Breck Jones
Andreas Kaminski	David & Michelle Kaminski
Ingrid & Werner Kaminski	Susan M. McCormick
Joseph & Lillian Mokanski	Florence E. Newman
Su-Long Nyeo	Reid and Bonny Parkinson
Ron Pope	Louisa Rosa
Luk St. Onge	Donna J. Smith
Mark Staley	Robert Tang and Beverly Cayton-Tang
J. Neville Thompson	Lynn A. K. Watt
George R. Weiss	William & Elizabeth Winegard

Organizations

Diabetogen Biosciences Inc.
DiverseyLever Canada
University of Guelph
University of Guelph Department of Physics
University of Guelph Faculty Association

Organizations continued

University of Guelph Mathematics & Statistics Club
University of Guelph Staff of the Office of the Dean Ontario Veterinary College
Viron Therapeutics Inc.

EinsteinFest Funding (2005)

\$200,000 grant through The American Express Philanthropic Program
\$200,000 donation by Mike Lazaridis
\$54,798 grant through the Ontario Cultural Attractions Fund
\$44,900 grant through The Ontario Trillium Foundation
\$25,000 grant through The Kitchener and Waterloo Community Foundation
\$10,000 grant through the Region of Waterloo Arts Fund

Up to \$5,000

Cowan Wright Beauchamp (2005)
Fibretech (2005)
Zeifman and Company, LLP (2005)
Sleeman (2005)
Cober Printing (2005)
Neil Bresolin (2005)
Christopher Duda (2005)
Jennifer Scully-Lerner (2005)
Goldman Sachs (2005)

All figures in Canadian dollars

SPONSORSHIPS

2008

Science Superheroes

WWSEF 2008, Waterloo-Wellington Science Engineering Fair

TEXAS 2008 Symposium

Science Olympiads

PI/APS GQI Award

International Summer School for Young Physicists Award, Youth Science Foundation Canada

Ontario Association of Physics Teachers Conference 2008

9th International Conference on Quantum Communication, Measurement and Computing

8th Canadian Summer School on Quantum Information

2007

Origins of Dark Energy Conference

Theory CANADA 3, Canadian Association of Physicists

CAM Graduate Student Physics Conference 2007, Montreal

PI/APS GQI Award for Best Student Paper in Theory

Participant Scholarship, Science Communications Program, Banff Centre, Alberta

Ontario Association of Physics Teachers Gr. 11 Physics Contest 2007

IPP/PI National Fellowship in Particle Physics

WWSEF 2007, Waterloo-Wellington Science Engineering Fair

International Summer School for Young Physicists Award, Youth Science Foundation Canada

Ontario Association of Physics Teachers Conference 2008

Quantum Gravity in the Americas III Conference, Penn State

Lifetime Achievement Award, Kitchener Waterloo Arts Awards

Black Holes VI, University of New Brunswick

12th Canadian Conference on General Relativity, University of New Brunswick

From Quantum to Emergent Gravity: Theory and Phenomenology, SISSA

Victor Elias Memorial Conference, University of Western Ontario

Canadian Chemistry and Physics Olympiad, University of Toronto

2006

International Summer School for Young Physicists Award, Youth Science Foundation Canada

PI/APS GQI Award for Best Student Paper in Theory

IPP/PI National Fellowship in Particle Physics

Summer School on Strings, Gravity and Cosmology, UBC

WWSEF 2006, Waterloo-Wellington Science Engineering Fair

Participant Scholarship, Science Communications Program, Banff Centre, Alberta

Canadian Chemistry and Physics Olympiad, University of Toronto

Theory CANADA 2, Canadian Association of Physicists

Quantum Gravity in the Americas III Conference, Penn State

2005

2005 Canadian Mathematical Society Meeting on String Theory and Integrable Systems
Strings 2005 International Conference, Fields Institute
Loops 2005 International Conference, Albert Einstein Institute/Max Planck
ISSYP Award – 2005, Youth Science Foundation of Canada
Great Lakes Geometry Conference, University of Waterloo
Workshop on Random Matrices, University of Waterloo
Workshop on String Gas Cosmology, McGill University Physics Department
2004-2005 Lifetime Achievement Awards, Kitchener-Waterloo Arts Awards
First Robotics Team, Waterloo Collegiate Institute
Theory CANADA 1 Conference, Pacific Institute
WWSEF 2005, Waterloo-Wellington Science Engineering Fair
National Lecture Tour, Canadian Association of Physicists

2004

Summer School on Strings, Gravity and Cosmology, University of British Columbia
Ishamfest, Imperial College
Summer Institute (ISSYP) – 2004, Youth Science Foundation of Canada
Canadian Chemistry & Physics Olympiads, University of Toronto
WWSEF 2004, Waterloo-Wellington Science Engineering Fair
QIP Conference, Institute for Quantum Computing
Graduate Student Support, CITA

2003

ASTI – 2004, African Summer Theory Institute
Physics Olympiad, University of Toronto
MWR13, The 13th Midwest Relativity Meeting, University of Windsor
Frontiers of Mathematical Physics 2003, Pacific Institute for the Mathematical Sciences
Black Holes IV Conference, University of Waterloo
Canadian Mathematical Society Summer 2003, University of Alberta
10th Canadian Conference on General Relativity and Relativistic Astrophysics, University of Guelph
Participation Fee, Youth Science
WWSEF 2003, Waterloo-Wellington Science Engineering Fair

2002

Frontiers of Mathematical Physics 2002, Pacific Institute for the Mathematical Sciences
Program Sponsorship, Institute for Particle Physics

2001

CUPC 2001, Winnipeg
Workshop on Modeling & Scientific Computation, University of New Brunswick
Atlantic Provinces General Relativity & Cosmology Conference, Saint Francis Xavier University
MITACS project - Applied Cryptography, Fields Institute
Frontiers of Mathematical Physics 2001, PIMS
Contemporary Issues in the Foundations of Quantum Theory, University of Western Ontario
Canadian Conference on General Relativity and Relativistic Astrophysics, University of Alberta

IN THE NEWS

INTRODUCTION

Perimeter Institute is frequently called upon to comment on matters regarding Canada's growing role in basic research and issues involving scientific literacy.

Much of the media's fascination with research topics is often explained through the eyes of students, teachers and members of the general public who enjoy highly accessible content through the Institute's outreach programming.



Past stories and features have appeared via:

- Science, Nature, The Economist, The Times of India, Globe and Mail, Maclean's, Toronto Star, Ottawa Citizen as well as Canadian Press and Associated Press wire stories to other North American dailies.
- Discovery Channel, CNN International, Global TV, CTV News, CBC Television's "The National" and "The Nature of Things" as well as CBC National Radio's "Sounds Like Canada" and "Quirks and Quarks" among other broadcasts



SELECTED ARTICLES (next pages)

"Decoding the Universe", Maclean's Magazine, September 8, 2008

"Leaps of Faith", Report on Business Magazine, April 25, 2008

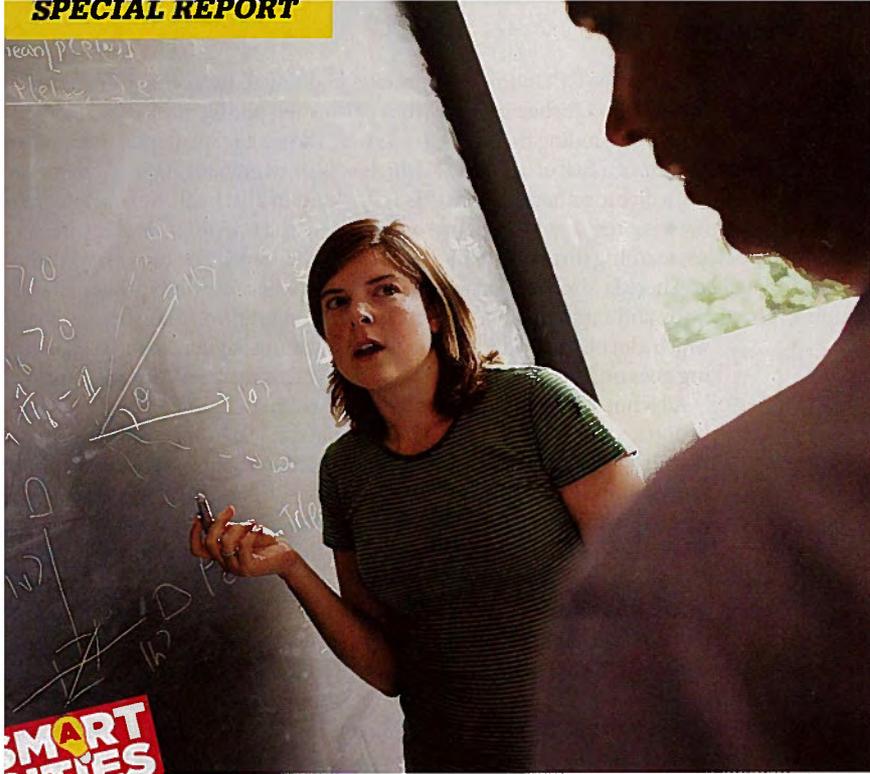
"Raising the Value of Research", Toronto Star, October 2, 2004

"Beyond Newton", Toronto Star, July 15, 2006

"The Science of Space", Canadian Architect, March 2005



*'Quirks and Quarks'
Host Bob McDonald*



SMART CITIES

DECODING THE UNIVERSE

Waterloo is one smart city. The Perimeter is making it smarter.

BY PAUL WELLS • When I visited the Perimeter Institute for Theoretical Physics in Waterloo several weeks ago, it was by most accounts an ordinary day. Physicists and mathematicians from around the world had gathered for an interdisciplinary conference on the origins of the universe, so the Black Hole Bistro was serving a buffet instead of the regular sit-down menu. William Phillips, the 1997 Nobel Prize-winner for Physics, was in town to give a public lecture in a nearby high-school auditorium on super-cold temperatures. Like most Perimeter public lectures, it would play to a packed house of 600 ordinary Kitchener and Waterloo residents.

A Perimeter press lady had loaned me an empty workspace where I could leave my stuff while I wandered around the sleek, slate-black building, interviewing the physics think-

tank's various thinkers. Presently she tracked me down and announced that she had to kick me out of the little office. "Mike's here and he wants to do some work before the announcement."

Mike, of course, is Mike Lazaridis. The founder and co-CEO of Research In Motion, the people who make BlackBerry smart phones. He founded Perimeter in 1999 and fuelled it with \$100 million of his own money a year later.

So it's kind of striking, and oddly charming, that the very hands-on patron of a world-beating institute designed to crack the basic riddles of the cosmos has never asked for a permanent office in the place. It was all the more striking on this particular day, because the "announcement" he was preparing to make was an additional \$50-million donation to Perimeter. Add that to the original \$100 million and a separate \$50-million grant

PERIMETER INSTITUTE researchers use such high-tech tools as chalk, pens and paper

for the University of Waterloo's Institute for Quantum Computing and it's a cool \$200 million that Lazaridis has donated to science in Waterloo.

An outsider would be tempted to point to Lazaridis as the biggest single reason why Kitchener/Waterloo does so well in the Canadian Council on Learning's annual Canadian Learning Index—Kitchener is fourth among major cities, and Waterloo is one of the fastest-rising communities in the country. But Lazaridis is always careful to depict himself more as a product of the region's assets than as someone extraordinary.

"Think about it. We've got two major universities and one of the largest colleges in one city. If you consider the whole region and include Guelph, that's another university. Combine all that with this massive co-op learning program that is bringing this transfusion of new talent to the city every four months. Consider the influence the universities have had on the high schools in the region. Look at performance in math competitions, science competitions, computer science competitions. All of this is coming together as a confluence."

Things were already moving quite quickly at Perimeter, but they are about to move even faster. Less than a decade after its launch, it is beginning an astonishing new burst of growth. Neil Turok, one of Britain's most renowned and controversial physicists, is moving to Waterloo as Perimeter's new executive director. He will enhance Perimeter's reputation as the global headquarters for some of science's greatest debates, even as he forges new links between Waterloo and the best young minds in sub-Saharan Africa. Perimeter is expanding its award-winning efforts to explain science to the general public, and to lure high school and university students into a life in science.

Perimeter's ambition is to decode the secrets of the universe, nothing less, and to turn that knowledge to human benefit. "Longing on a large scale," Don DeLillo once wrote, "is what makes history." The people at Perimeter long to understand the cosmos. Simply by making the effort they are already making history.

It would be hard to know where to begin explaining all of this action if one man were not so clearly at the centre of

it all: Mike Lazaridis. He sat in this borrowed office, silver-haired and ebullient, pecking at a veggie platter. He swore me to secrecy and handed me the latest BlackBerry model, as

IN A KNIFE FIGHT WITH APPLE, RIM'S FOUNDER IS STILL INVESTING

he does with evident pride each time we meet. And he explained why, even as RIM heads into a knife fight with Apple and Google for dominance in the high-end smart phone market, he continues to pour his personal fortune into eggheads and chalkboards.

"Throwing your money around again," I said.

"No," he shot back with a grin. "Investing it."

It is not always clear why "investing" would be the right word. Perimeter is not the research branch of Research In Motion. Its mandate is not to build better little keyboards for PDAs. Its faculty, visiting scholars, postdoctoral researchers and graduate students come here to follow their curiosity, free from mandates or deadlines, into the most esoteric corners of human knowledge. The dawn of time. Other dimensions. The neurotic and fundamentally unpredictable behaviour of atoms and their constituent parts. Riddles so vast it is hard to take their measure or even give them names.

I asked one faculty member, a curly-haired Brit named Lucien Hardy, how he would explain his current research to a colleague. "I'd say I'm working on a sort of quantum foundations-inspired approach to quantum gravity," he replied. "And building a framework for probabilistic theories that can accommodate indefinite causal structure." And what are the tools for this... whatever it is? "Chalk, pen, papers," Hardy said. "I use computers to write papers and send emails. That's it."

But a cover story last year in Britain's *New Scientist* magazine speculated about the possible end result of Hardy's investigations: the revolution after the next great computing revelation, "quantum gravity computers" so advanced they would not deal with space and time in ways most of us could even recognize. Computers that would blur the rules of cause and effect. "If, as Hardy suggests, a quantum gravity computer might be able to see its result without having to run its algorithms, it is essentially no different to having a quantum computer strapped to a time machine," the *New Scientist* article said.

But that magic box is decades off and, in a real sense, none of Hardy's concern. He is simply trying to figure out the rules.

This is what fascinates Lazaridis and has driven him to become the modern world's closest equivalent to the Medici family, the research patrons of medieval Florence. As an undergrad engineering student at Waterloo, Lazaridis grasped, and fell in love with, a lesson that is ignored by generations of students: in science, abstract knowledge never stays

abstract for long.

"Basic research is a long-term investment that has always, always contributed to our success, well-being and financial security," Lazaridis said. "I mean, you look at every single major unification in theoretical physics. (A "unification" is a discovery of intimate relationships between branches of physics where none had been seen before.) Everything from electromagnetism and electricity,

to energy-matter-time, to wave-particle duality. Whether you're talking about wave equations that changed communications, gave us wireless communication; to induction, power generation and transmission lines. All this stuff was the technology that came out of these fundamental understandings of the phys-

ical world around us.

"Look at things like wave-particle duality"—the notion, controversial in the 1890s, that everything sometimes acts like a wave and sometimes like a particle. "Just the study of something as esoteric as that! People thought it was crazy back then! You remember, Einstein to his dying day didn't believe in it, in quantum mechanics. But that fundamental understanding gave us semi-conductors. Integrated circuits. The laser. They are the foundation of the Internet and our information society."

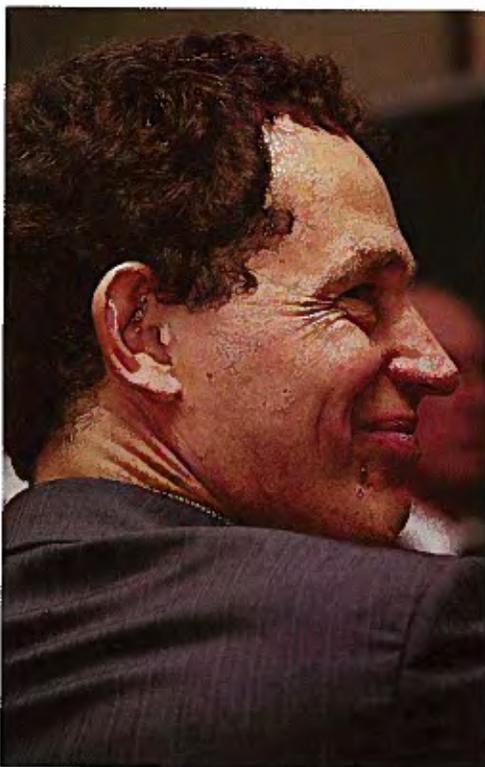
Perimeter's job is not to fiddle at the edges of those 20th-century advances, but to keep asking the same big questions: where did the universe come from? What is matter made of? Do answers to the second question provide keys to answering the first? (The short answer: they sure do.) How can Einstein's theory of relativity be unified with quantum theory?

In 1999 Howard Burton, a bearded, intense Waterloo physics Ph.D., was hoping to escape life as a highly paid market analyst on Wall Street, where awesome math skills come in handy. He sent Lazaridis his resume and wound up getting hired as Perimeter's first executive director. Burton resigned from that post in 2007, days after the Harper government announced stable five-year funding for Perimeter's research program (other costs are paid out of the interest on Lazaridis's endowment). Nobody involved will discuss the reasons for Burton's departure, but all speak highly of his success in building a leading research institute from scratch. "The reputation of PI has grown from being a place that people had barely heard of, six years ago, to being a place that everyone in theoretical physics, certainly, is very aware of," Hardy said.

ITS SCIENTISTS LONG TO UNDERSTAND THE COSMOS, NOTHING LESS

The question after Burton left was who could take Perimeter to dominance the way Burton had built it from zero. A search committee with members of Perimeter's faculty, its board and its blue-chip Scientific Advisory Committee looked around the world. Eventually they settled on Neil Turok, the chair of mathematical physics at Cambridge University, home to Isaac Newton and Stephen Hawking. Turok had not applied for the job. He needed to be wooed. The Perimeter committee, led of course by Lazaridis, wooed hard. Turok starts work as Perimeter's second executive director in September.

Turok brings two extraordinary advantages. His own theories stand to revolutionize the study of the universe's origins. And his most



TUROK is Perimeter's new executive director

cherished pet project, the Perimeter-like African Institute for Mathematical Studies, will become part of a global network of research centres. The hub of that network, he hopes, will be Perimeter.

For 40 years the most widely accepted theory of cosmology has been the so-called inflationary, or "Big Bang" model. In this model the universe was born more or less from nothing 14 billion years ago in an unbelievably violent explosion. Astronomers believe they see evidence of that cataclysm at the dawn of time when they see galaxies continuing to drift apart. The inflationary model is widely taught as fact.

But a decade ago Turok and Princeton's Paul J. Steinhardt became so annoyed by discrepancies in the Big Bang theory they started

casting about for alternatives. In their book, *Endless Universe*, Turok and Steinhardt lay out their critique of the inflationary model and their elegant, strange alternative.

The biggest problem with the inflationary model is that no force anyone has seen could grow the universe from nothing to, well, a universe, in the first fraction of a second after the Big Bang. Theorists had to imagine a new force, "inflationary energy," to explain the stunning expansion at the dawn of time. Inflationary energy would be untold trillions of times more powerful than gravity, but it

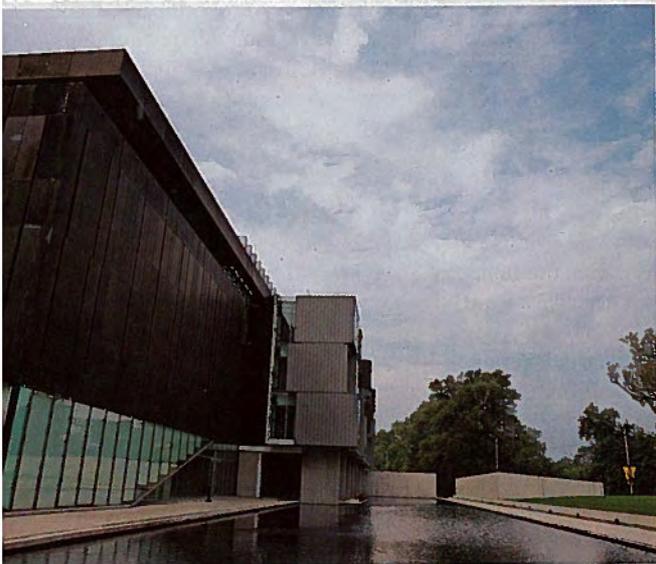
hardt's theories are being discussed seriously where they once met derision.

Turok has no interest in turning Perimeter into a test lab for his pet cosmic theory. "The last thing Perimeter should ever become is a centre for one particular school of thought," he told me by teleconference from Cambridge. Indeed, Perimeter is a meeting ground for leaders in sometimes antagonistic schools of thought. One faculty member, Lee Smolin, wrote a book criticizing a powerful school of physics called string theory. Yet Perimeter is also home to prominent string theorists.

lions for aid into Africa," Turok said.

"One trillion dollars has been spent over the last 40 years. And you ask, what is the long-term outcome of that one trillion dollars? You can't see it. People have been pouring money into Africa with very little positive outcome. I would argue that the single most important thing they have missed is that they view Africa as a huge problem that needs to be reduced. I mean, that's what poverty reduction is. Whereas the people who will fix Africa are the brilliant young minds—African people—who are able to do something about it."

A SETTING FOR GENIUS: Controversial new director Neil Turok encourages young researchers with a disrespect for the conventional



would last only a tiny fraction of a second after the Big Bang. Having unfolded the universe like God's own camping tent, inflationary energy would then obligingly vanish.

Turok and Steinhardt didn't like any of it. Turok writes with disdain that inflationary energy appears "put in by hand," to paper over a theory's flaws rather than improving it. They revived an ancient theory, the "cyclical model," in which the universe expands and contracts like a squeezebox. But what would set each cycle going? They settled on the idea that our entire universe, all of creation, might be a three-dimensional "brane," short for membrane, that coexists with other universes along some other dimension. Two such branes could be close together and never know it. Except when, every few trillion years, they collide. The energy from that collision would drive the expansion that now looks like evidence of the Big Bang, but eventually the two branes would stop drifting apart, start drifting back together, collide and start it all again.

Weird? Deeply. But extra universes are not harder for some theorists to believe than a special force, unimaginably vicious, that appears just long enough to blow out the universe before vanishing. Turok's and Stein-

hardt's theories are being discussed seriously where they once met derision. Turok questioned one of the central tenets of modern physics because he felt his calculations pointed to a better idea. He will be looking for young researchers with a similar disrespect for the conventional. Some will come from Africa.

In 2003 Turok opened the African Institute for Mathematical Studies (AIMS) outside Cape Town. It offers graduate education in physics and mathematics at the highest level, at perhaps one-fifth what it would cost to educate the same students in London or Boston. The goal is to radically enrich the continent's human capital. Turok has said the next Einstein should come from Africa. African nations have invested heavily in a network of AIMS-like educational institutes and a formal African Einstein Initiative.

Physics researchers for a continent that often lacks food, sanitation and just government? Surely that's a hard sell. "It is, and I think the people who do not get the reason for investment include the international development agencies who are pouring bil-

Some of the AIMS students—"highly motivated young people who basically will work their socks off"—will find their way, whether for short visits or eventually as faculty, to Perimeter.

Perimeter staff, in turn, will teach at AIMS. Turok's colleagues, including perhaps Stephen Hawking, will come to view Waterloo as a congenial place to visit when they need to crunch a problem for a few months. Perimeter has begun sending information-rich DVDs to high-school physics classes across Canada and,

soon, abroad. Summer sessions for promising university students will help them appreciate the challenges of a life in science. This fall the Discovery Channel will begin broadcasting the Perimeter public lectures.

The goal is to bring unprecedented resources to bear. The outcome is uncertain. Isn't \$200 million a lot to bet? "You're dead right," Turok said. "This is a bet. There is not a guaranteed outcome. Maybe we'll look back 20 years from now and say, 'Well, Perimeter, it was a brave attempt, but it failed.' And I would say that, in fact, that's what makes it exciting. If it was guaranteed, it would be boring." ■

TUROK HAS SAID THE NEXT EINSTEIN SHOULD COME FROM AFRICA

Raising the value of research

WATERLOO—Even Mike Lazaridis, the BlackBerry entrepreneur, was a little awed by the futuristic new home for his bold dream to transform how Canadians think about science and how the world regards Canada's research prowess.

On a tour last week with a visitor, Lazaridis for the first time saw the building's eye-popping south wall stripped of the protective paper that had hidden the stunning geometric patterns created by reflecting black panels.

"It's really something, isn't it?" he said of the \$25 million headquarters of the Perimeter Institute for Theoretical Physics, which has its gala opening this weekend.

That comment is being echoed by a lot of people who haven't yet seen the new three-storey building, with its rooftop bistro, tubular glass passageways, six wood-burning fireplaces in cozy lounges, soaring atrium over a garden and blackboards on the walls every few metres so that no brilliant idea is lost.

Instead, those people are referring to Lazaridis's vision in creating the institute through his \$100 million donation, plus the impact Perimeter has already had in its three years' existence with a handful of senior researchers working out of funky temporary quarters.

"The whole atmosphere for science changes when someone does something like this," says Chaviva Hosek, chief executive of the Canadian Institute for Advanced Research (CIAR) in Toronto and a policy adviser to Jean Chrétien when he was prime minister. "Mike Lazaridis has broadened people's imagination, both about what's possible and about what's important to do."

Like Perimeter, CIAR concentrates on supporting fundamental science that's geared primarily toward expanding human knowledge without obvious practical applications in sight. That's also the focus of Artur Ekert, a pioneer in quantum physics and member of Perimeter's science advisory board.

"I see a vibrant pioneering atmosphere there with people who are aware that something exciting is being created. It's not an exaggeration to say that Perimeter could be Number 1 or Number 2 in the world," says Ekert, a professor at the University of Cambridge.

That's number 1 or 2 in some of the six challenging aspects of the theoretical physics where Perimeter is concentrating its intellectual firepower: quantum gravity, string theory, quantum information theory, quantum mechanics and, soon, cosmology and elementary particle physics (see Glossary).

Yet, researchers working at Perimeter have already published more than 100 scientific papers that include notable contributions in some of these more rarefied realms of physics (see Achievements). As well, leading physicists from around the world constantly course like an electric current through the institute as invited visitors, energizing both themselves and Perimeter's resident thinkers.

"The existence of Perimeter has enabled interesting work to happen. People are inspired when they come here," says executive-director Howard Burton.

Lazaridis wants that inspiration to go well beyond the realm of theoretical physics.

His dream is for the institute to contribute to fundamental scientific discoveries that eventually transform the world and also convince Canadians and their elected leaders to put a much higher value on such basic research. In pursuit of that goal, the institute runs an extensive outreach program, including public lectures and a summer physics school for Grade 11 students from Canada and abroad.

"I'm interested in the education of our society about the importance of science," Lazaridis says. "There is no shortage of mysteries, unknowns and adventures when it comes to science. And no shortage of value for deciphering those mysteries and exploring those unknowns."

On the value of basic science, Lazaridis speaks with millions of dollars of authority. As the founder of Research In Motion Ltd. here, the University of Waterloo dropout used technology derived from basic science to create the wireless BlackBerry e-mail device.

As a successful entrepreneur,

Mike Lazaridis wants to educate Canadians about the importance of science

So, he's pledged millions on an institute for pure research, writes Peter Calamai



KAZ EHARA/TORONTO STAR

Mike Lazaridis, founder of Research In Motion Ltd., stands outside the new headquarters of the Perimeter Institute for Theoretical Physics in Waterloo. Lazaridis and fellow executives put up \$120 million in their own stock to fund the institute. Some of the endowment money, plus grants from the Ontario and federal governments, paid for the \$25 million building.

Perimeter Institute achievements

Here are a few of the Perimeter Institute's notable contributions over the past three years, and the scientists chiefly responsible:

Black holes, spinning doughnuts: Mathematical modelling of a theoretical version of black holes that could exist in 10 dimensions and resemble spinning doughnuts (David Mateos).

Safer cryptography: Improving encryption by using quantum information theory to create coded "keys" that can be transmitted to other users without risking interception (Daniel Gottesman, Raymond Laflamme and Rob Spekkens).

Was Einstein right? Investigating "doubly special relativity," one possible violation of Einstein's special theory of relativity that could arise from combining quantum theory and general relativity (Laurent Freidel, Florian Girelli, Etera Livine, Lee Smolin, Artem Starodubtsev).

Improved computing: Discovering how to reduce errors efficiently when using a quantum computer to run a series of tests that are themselves unreliable (Mike Mosca).

Death signals: Proposing to use Earth-orbiting satellites to measure the gamma rays sent out by matter being sucked into distant black holes to test fundamental assumptions of

quantum theory (Antony Valentini).

Universal theory: Combining quantum information techniques with quantum gravity produced a way to apply quantum theory to the universe that avoids the drawbacks of earlier approaches (Fotini Markopoulou).

Vanishing information: Invoking the concept of quantum teleportation helped make clearer what happens to the information inside black holes when it evaporates through a kind of radiation first identified by English theoretical physicist Stephen Hawking (Daniel Gottesman).

Very big strings: Proposing that large vibrating strings of energy left over from the early universe could produce gravitational waves capable of being captured at detectors on Earth (Robert Myers).

Cosmological conundrum: Einstein said his "greatest blunder" was proposing the cosmological constant, an arbitrary parameter that changes the rate of expansion of the universe in mathematical equations; finding a way to set a value for the constant recently brought two speculative proposals (Olaf Dreyer, John Moffat).

Perimeter Institute for Theoretical Physics

Lazaridis has been openly critical of what he considers the shameful underinvestment by governments in basic science. He's even attacked the keystone of the federal innovation strate-

'There is no shortage of mysteries, unknowns and adventures when it comes to science'

Mike Lazaridis, Research In Motion

gy: increased commercialization of university research.

Yet, he's done more than criticize. Four years ago, Lazaridis pledged \$100 million in his own RIM stock to endow the Perimeter Institute, with fellow RIM executives Doug Fregin and Jim Balsillie adding \$10 million apiece.

But even a \$120 million endowment wasn't going to generate enough annual income to erect a headquarters and pay

the 130 people who will eventually work here, including 80 scientists, about 25 administrative staff and 30 graduate students. (Currently, the institute has 40 research scientists and 15 graduate students.) So, Lazaridis and Burton turned to the federal and provincial governments for funds.

Inside the federal bureaucracy, finance department officials opposed grants to Perimeter, arguing that it would create a bad precedent if wealthy private donors set national research priorities.

Yet, Lazaridis's dream found support from the heads of federal science agencies, like Tom Brzustowski, president of Science and Engineering Research Canada.

"It was exactly the sort of precedent we should encourage," Brzustowski says. "When you've got a concentration of very

Glossary

Elementary particle physics:

Study of the laws governing the two dozen basic constituents from which all matter is built up, such as quarks, electrons, neutrinos and photons.

Quantum: In physics, the smallest amount of energy that a system can gain or lose; only noticeable on the atomic scale; despite popular misuse, a quantum leap is actually a very small shift from one quantum state to another inside an atom.

Quantum theory, quantum mechanics: The laws that apply primarily on the smallest scale where everything, including light, has the properties of both discrete particles and electromagnetic waves.

Quantum computing: New way of information processing using phenomena unique to quantum mechanics and derived from quantum information theory.

Quantum gravity: Any theory that tries to meld Einstein's general theory of relativity with quantum theory, producing a so-called Theory of Everything where the same physical laws apply from the cosmological scale down to the sub-atomic.

Quantum teleportation: Not yet *Star Trek* transporters, but elementary particles have been instantly moved across distances by taking advantage of a property known as entanglement.

String theory: Cosmological theory assuming the existence of threadlike concentrations of energy hypothesized to exist within space-time; one approach to solving the quantum gravity challenge.

bright people, good things usually emerge. But governments today don't seem to have the patience for that."

Eventually, Ottawa and Queen's Park ponied up \$54 million, with \$11.2 million earmarked for the building. The major federal operating grant, \$25 million over five years, was announced in 2002 by Chrétien when he turned sod for the new building.

The former PM's brother, noted medical researcher Michel Chrétien, is known as a strong proponent of more money for basic research. Dr. Chrétien's name nestles among the list of eminent physicists, local dignitaries and government officials invited here to Perimeter's official ribbon-cutting.

Michel Chrétien won't talk about lobbying his brother on Perimeter's behalf. But he does argue strenuously that major medical advances depend upon a marriage of physics and the bi-

ological sciences, and he ardently praises Lazaridis's own thirst for knowledge and commitment to maximum intellectual freedom for the institute's researchers.

"Mike has concluded that academic freedom is the name of the game for people to know more. And he's created an institute where people have that freedom," Chrétien says.

Not only do Perimeter's scientists have far greater freedom to follow their intellectual curiosity than all but a handful of university professors, they also wield a major say in the running of the Institute, modelled on a "community of scholars."

Perimeter's nine long-term researchers, here on renewable contracts for five to seven years, have to approve any recommendation to the institute's board to hire another one of their ilk.

"We're going very carefully, very slowly in the hiring," says Lee Smolin, a high-profile pioneer in quantum gravity and, at 49, among the oldest researchers at Perimeter.

This deliberate pace is dictated by the special culture that the institute is creating through its hiring choices — researchers who actually practise interdisciplinary co-operation, who represent competing approaches to problems and who are eager to take intellectual risks.

"We're interested in people who are going for the biggest things. We're not interested in me-too science," Smolin says.

Fotini Markopoulou-Kalamara is a living example of how Perimeter's deliberate culture of challenging inquiry helps shape research. When she joined the Institute three years ago, her chief interests were in a field called loop quantum gravity.

But the institute operates an active program for visiting researchers, who stay from a week to more than a year. In particular, Perimeter sought physicists who specialize in the foundations of quantum theory, an area of study largely neglected elsewhere. And the institute's culture encourages discussion in which no line of questioning is off limits, even those challenging basic assumptions.

"Because of that, I'm actually starting to know what that field is all about and have become interested in working on programs that combine our fields," she says.

Experiences like that have probably contributed to Ekert's judgment that the Perimeter Institute has reached critical mass even before this weekend's celebrations.

"I think Perimeter is here to stay. It's going to fly," the physicist says.

'I'd pay my own money to come'

► Teachers From F1

iversity enrolment in the natural sciences generally, and in physics and chemistry in particular. In some countries the proportion of university students in the natural sciences has plunged to half the levels of a decade ago.

At their annual meeting last month, Canada's university deans of science heard that declining enrolments in the natural sciences nationally mean there might not be enough physicists and chemists here to be competitive in emerging hot fields like nanotechnology.

The Perimeter Institute began tackling the problem in 2003 with summer workshops for top high school physics students and the next year added Einstein Plus for the often overlooked physics teachers.

Dave Fish, who's been teaching physics at a Waterloo high school for 15 years, has been with the program since the start.

"If you've been out teaching for 20 years, then when you were in university, quantum physics was a graduate course. Even for younger teachers it could be six years since they were exposed to this stuff," Fish says.

"Our message to the teachers is that you can understand it and the kids can handle it."

That message was hammered home in an intense week-long mix of lectures, resource-sharing, hands-on experiments, question-and-answer sessions, lab visits at the University of Waterloo, group projects and informal idea-swapping at every opportunity.

And because this was happening at a world-class theoretical physics centre, everything was kicked up several notches.

The question-and-answer session, for example, featured a droll and soft-spoken Sir Tony Leggett, who shared the 2003 Nobel Prize in physics for work in low-temperature physics and is a member of Perimeter's scientific advisory committee.

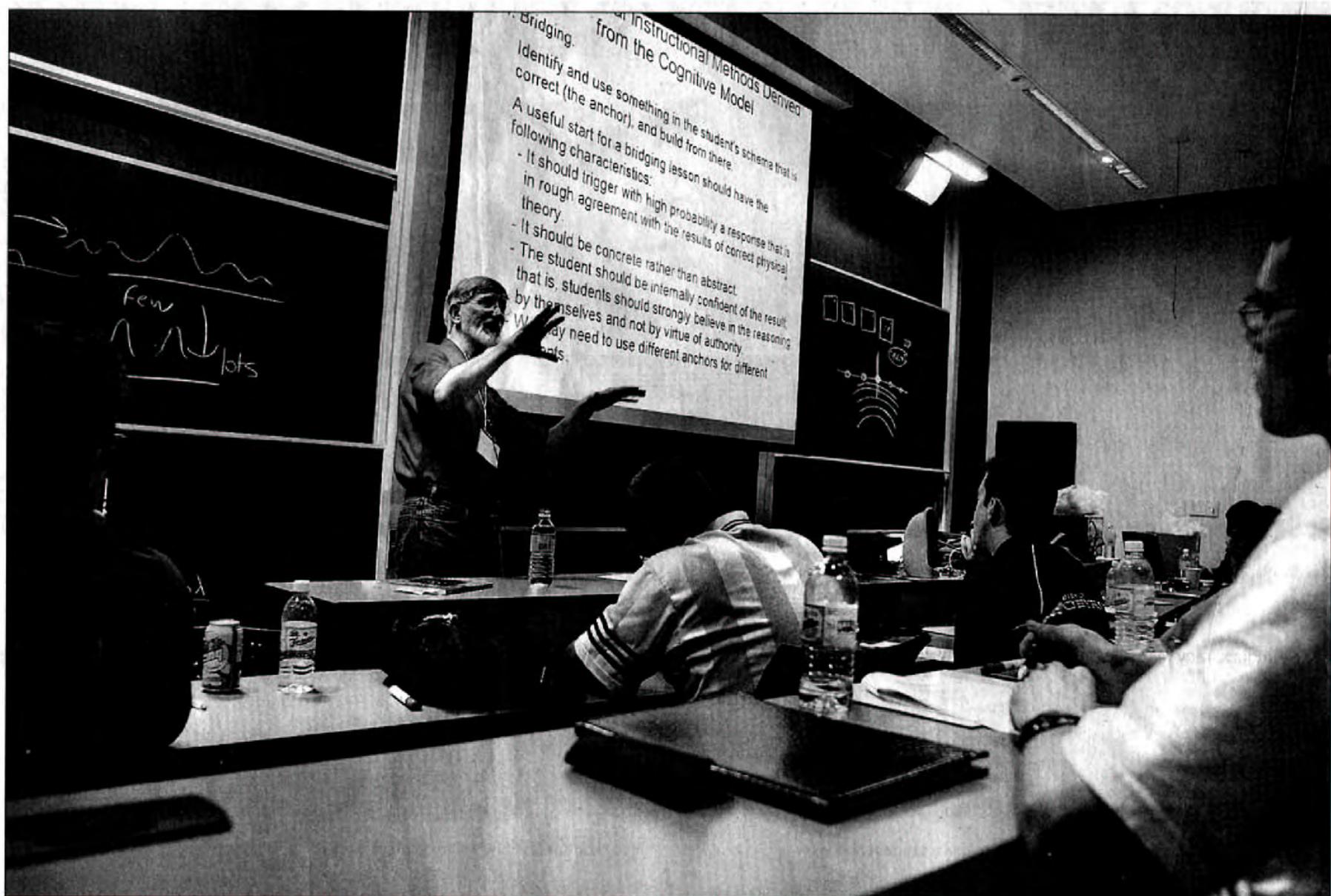
"None of the rules of physics are so sacrosanct that they couldn't be overturned by future experiments," Sir Tony said in response to one teacher. He added with a chuckle: "But don't expect the law of gravity to break down tomorrow morning."

The 68-year-old British physicist, now at the University of Illinois, encouraged the teachers to persevere in teaching the basics of quantum mechanics to high-school students.

"It's a lot simpler than algebra, even though it's much more bizarre," he said.

During the week the student-teachers got lots of exposure to the bizarre side of modern physics, but they also picked up practical ways to pass along these concepts in class.

"You don't have to dumb it down," insisted Roberta Devlin, who teaches physics at Dan-



Veteran Waterloo physics teacher Ed James shows the way to high school instructors at the Perimeter Institute.

STUART NIMMO FOR THE TORONTO STAR

forth Technical School in Toronto.

Devlin took part last year as a student and was back this month as one of several "translators," conspicuous in red Einstein Plus T-shirts. "The people at Perimeter know university physics but they don't know the high school curriculum. We translate for them," she said.

Devlin used approaches learned at the workshop to teach relativity in Grade 12 physics at Danforth this year.

"The students were talking in the corridors telling others how cool it was," she said. "They really like this stuff."

Classes at dozens of high schools across the country this coming school year may be equally excited when their Einstein Plus teachers hand out \$5 packets of coloured LEDs, resistors and batteries. That's what veteran Waterloo physics teacher Ed James gave the student-teachers here to show how something as seemingly arcane as Planck's constant can actually be hands-on.

But not necessarily a slam-dunk. Lab partners Gary Kirchner from Dorval, Que., and Ron Adair from Invermay, Sask., somehow crossed wires and

'Our message to the teachers is that you can understand it and the kids can handle it'

Dave Fish, teacher with Einstein Plus program

produced a puff of acrid smoke. "No matter how many times you run this through your school lab your students will find all the things that can go wrong," Kirchner said philosophically.

On the bench just behind,



STUART NIMMO FOR THE TORONTO STAR

British Nobel winner Sir Tony Leggett provided some inspiration for would-be teachers of quantum physics.

however, Ann Choe of Surrey, B.C., teamed up with Peter Cavallaro, one of the four international participants, to ace the experiment, producing one of the most accurate answers.

Cavallaro said he heard about Einstein Plus through the Australian science teachers association and was intrigued enough to pay his own way from Nango in Queensland state.

"This course should be a model for other countries. It's novel for teachers to have the chance to learn about incorporating quantum physics in the classroom.

"It's not technical problems that are the issue in teaching quantum physics. It's the conceptual side which goes against much of what we've come to understand about the world," Cavallaro said.

The conceptual gap between everyday experience and the bizarre quantum world was constantly driven home in the

workshop. Damian Pope, the Institute's director of scientific outreach, suggested distilling modern physics to four phrases on a T-shirt: wave-particle duality, superposition, genuine randomness and Heisenberg's uncertainty principle.

If those concepts intimidate you, don't fret. They also challenged some teachers, especially those who hadn't majored in physics at university. Particularly perplexing was the uncertainty principle which maintains that it's impossible to know exactly both the position and the velocity of a speck of dust floating across the room, or an electron shooting through a gap.

"But how could the fact that there was something different in my head, just the potential of knowing the position of the electron, cause a physical change?" asked one.

He and others could take some solace from the musings of Hans Westman, a Swedish physicist and post-doctoral researcher at Perimeter, who suggested that

Facts surrounding the Perimeter

What: The Perimeter Institute for Theoretical Physics in Waterloo launched in October 2000 with a \$100 million pledge by Mike Lazaridis, founder of RIM, and \$20 million from two other RIM executives. Now has three dozen faculty.

Goals: Frontier research in areas like cosmology, superstring theory and quantum gravity plus world-class educa-

tional outreach.

Track record: More than 500 peer-reviewed scientific papers, 800-plus visiting researchers, 30 major conferences and workshops and three-week-long EinsteinFest last summer, which attracted 28,000 people.

Public funding: More than \$100 million given or pledged from federal and Ontario governments.

Stump the physics teacher

Here are three of the toughest questions about modern physics participants in last year's Einstein Plus workshop faced in their teaching careers.

■ Where does the mass come from if mass increases as you approach the speed of light?

■ Would Earth be dark if we were travelling away from it at the speed of light? Imagine someone shining a flashlight from Earth as you move away

at the speed of light. What would you see?

■ If the speed of light is universally constant at 300 million metres a second, how can the speed of light be less than that when travelling through materials such as glass?

The answers to these and three other tough questions are buried deep in the Perimeter Institute's website. A shortcut: tinyurl.com/gb7wn

—Peter Calamai

quantum theory may not describe reality at all, but some idealized world.

"I'm not very happy with the state of affairs now. Quantum theory is an extremely successful theory but it's hard to see how it can be a fundamental theory," he told the teachers.

To Dave Fish, this uncertainty and relativity of quantum physics can be seen as yet another manifestation of post-modernism, mirroring the attitudes of Gen-X much better than those of older Canadians.

"It's part of the generation gap,

where kids and their parents have a fundamentally different view of the universe," he mused.

By the end of the week, an exhausted Sarah Torrie was already contemplating giving that different view a higher profile in her Grade 12 class, by starting with modern physics in the fall rather than its usual rushed spot at the term end.

"Many of us came out of the workshop thinking we could make a real change in the way physics is taught across the country," she said. "Perimeter made us feel valued."

Perimeter Institute for Theoretical Physics, Waterloo, Ontario
Saucier + Perrotte architectes

A new academic research facility for physicists establishes a striking iconographic presence in Waterloo.

The Science of Space

by David Theodore

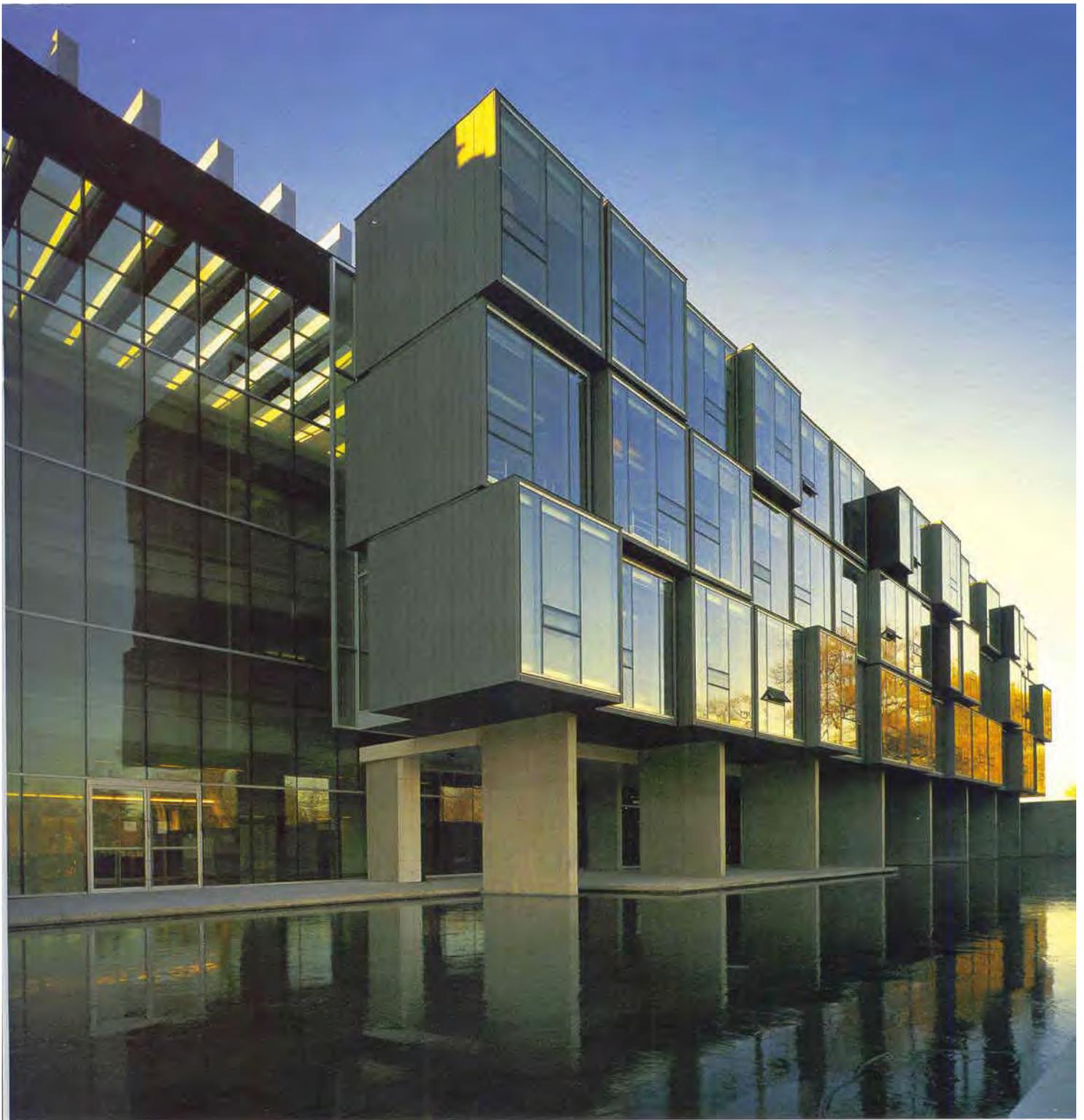


Founded in 2001, the Perimeter Institute for Theoretical Physics is an independent resident-based academic organization devoted to exploring topics like quantum gravity and string theory. This young institution opened a brand new \$24.5-million home in October 2004. Constructed over an old landfill on the edge of uptown Waterloo, Ontario, the black and grey building is a striking 6,000-square-metre concrete and glass warped prism.

Perimeter, along with New College Residence and the CCIT building at the University of Toronto, marks the first work west of the Quebec-Ontario border—and the first major extra-provincial buildings by a Montreal firm of their generation—for Montreal-based Saucier + Perrotte architectes. In J.B. Jackson's seminal 1953 essay

"The Westward-Moving House," the geographer poetically argues that as the frontier moved west, emerging social values and construction techniques fundamentally changed the American home. Moving west in Canada holds similar promise for Perimeter's designers. "You have to build elsewhere to know who you really are," said principal Gilles Saucier. "It's the first time we were able to give ourselves that kind of freedom of expression."

Perimeter is a university building, but one without a campus or a building tradition to harmonize with. The first task, then, was to find appropriate symbols that link architecture to theoretical physics. According to Saucier, our perception of the striking south façade is designed to mimic the experience we might have when confronting

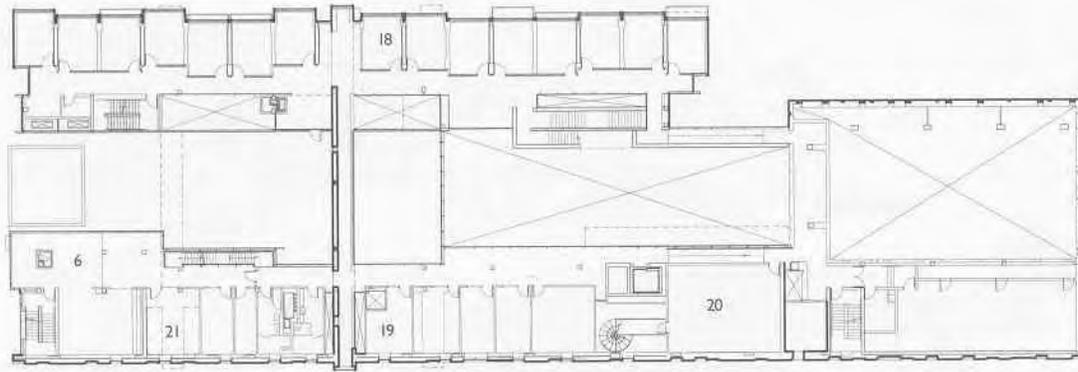


esoteric scientific discourse. Ventilation grilles and window openings framed with mirrors punctuate the surface of black anodized aluminum panels, creating a façade whose image changes with different lighting and weather conditions. At first we might be baffled by the envelope's complexity, but then we can always "make an effort" to understand the design.

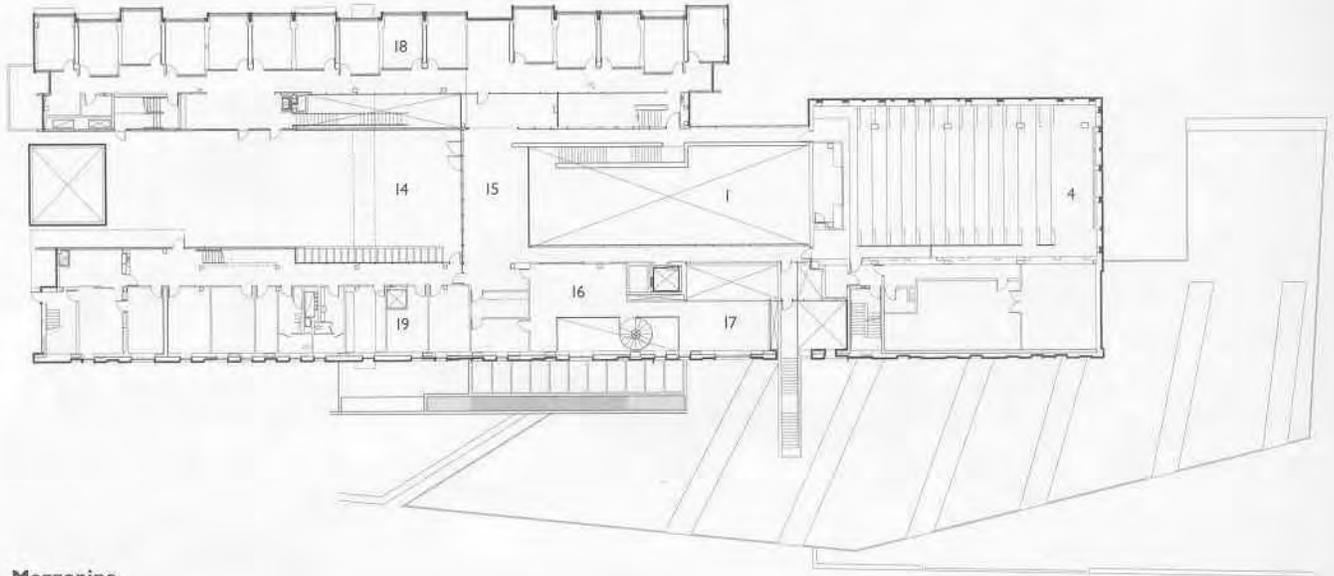
The next task involved creating a setting for Perimeter by manipulating the natural topography. In response to the almost urban location—bounded by a busy highway, a tranquil artificial lake and a parking lot—the design capitalizes on the image of a sculptural object in a park. However, since well-used pedestrian pathways separate the building from Father David Bauer Drive and Silver Lake, the actual

Opposite: mirror-framed windows, ventilation grilles and painted anodized aluminum panels form the dynamic south façade. Above: the north elevation is comprised of 44 stacked cantilevered boxes containing researcher's offices overlooking the reflecting pool.

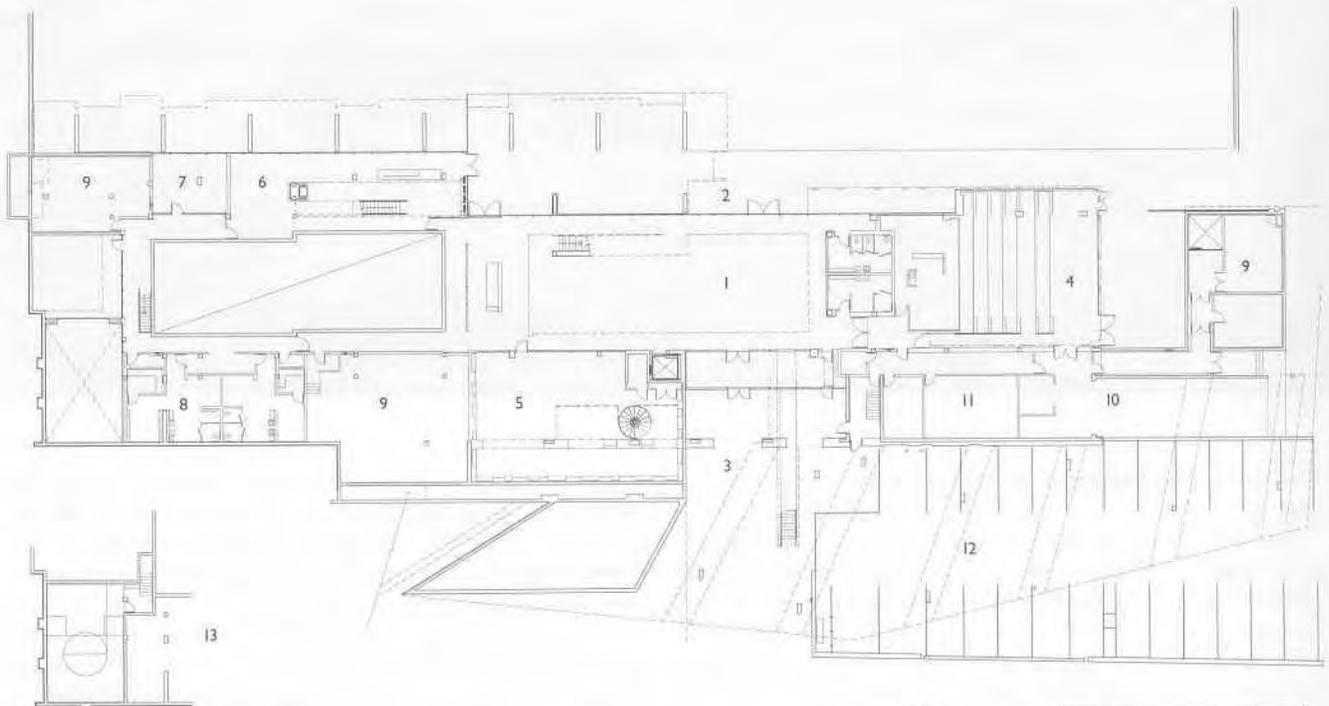
terrain near the building symbolically recreates the broader landscape. A long reflecting pond on the north side thus imitates Silver Lake—and pragmatically acts as a buffer between joggers on the path and thinkers in their offices. Since the water table is high, there is no basement. Instead, a grass-covered concrete berm rises up a full story, creating a base for the building and marking the north entrance.



Second floor



Mezzanine



Ground floor

- | | | | | | |
|--------------------|-------------------|------------------|------------------------------|---------------------------|------------------|
| 1. main hall | 5. library | 9. mechanical | 13. squash (basement) | 17. reading room | 21. meeting room |
| 2. north entrance | 6. lounge | 10. loading dock | 14. garden | 18. researcher's office | |
| 3. south entrance | 7. gym | 11. storage | 15. mezzanine (hall) | 19. administrative office | |
| 4. lecture theatre | 8. changing rooms | 12. parking | 16. mezzanine of the library | 20. seminar room | |





SAUCIER + PERROTTE ARCHITECTES

Echoing its name, Perimeter is indeed a series of perimeters or layers. Conceptually, the designers drew an abstract line in the middle of the site, thickened it into a wall, widened the wall further into an inhabitable zone, and then further still into two private blocks separated by a public zone. The south block houses administration, the north research offices. Glass planes, sometimes transparent, and sometimes serigraphed with abstract patterns, delimit each interior edge of these four-storey blocks. The ground floor gives public access to a 205-seat lecture theatre, a library, and an external courtyard. Overhead, floating concrete staircases animate a full-height atrium. Three bridges allow researchers and staff to travel between the north and south blocks. The bridges extend slightly beyond the façades, opening views out into the surroundings.

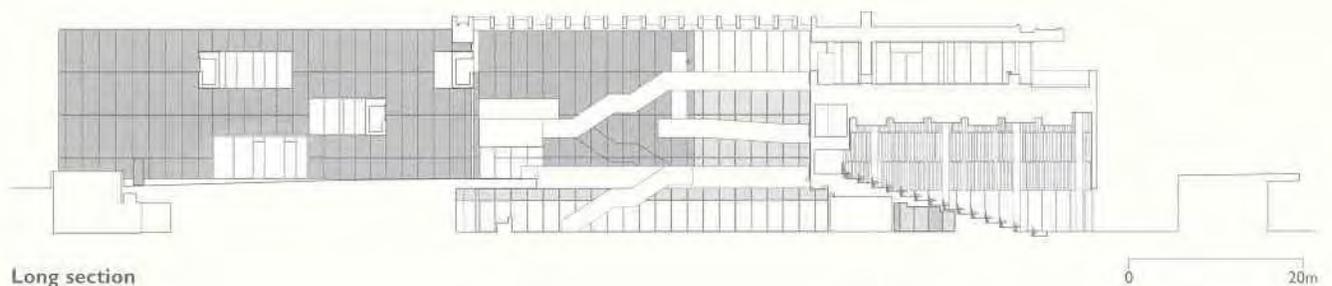
The client asked for various degrees of formality in the types of teaching spaces. The architects responded with a formal lecture hall in the north block, and a stack of seminar rooms in the south. At the points where the bridges re-enter the research wings from the atrium, the designers created more informal areas equipped with chalkboards and sometimes fireplaces. In an effort to make common spaces that encourage researchers to linger and exchange ideas, these lounges are lined with white oak—warm spots of colour in an otherwise cool grey

Above: a view of the north elevation at dusk from across Silver Lake.

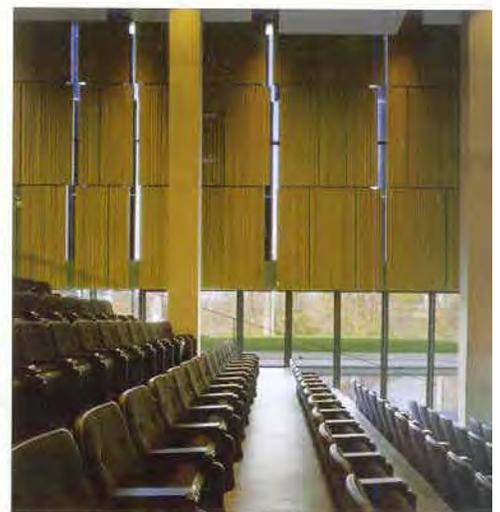
building. For similar reasons, ipê wood envelops the top-floor bistro and roof deck on the north block.

Arguably these design moves have a lot in common with other recent Canadian academic architecture. So is it really fair to suggest that Perimeter might represent a peculiarly Montreal way of conceiving architecture? The speculation arises partly because Perimeter shares a parking lot with that touchstone of contemporary Canadian architecture, the Canadian Clay & Glass gallery, which was completed by Patkau Architects in 1993. The only nod to the gallery, however, is in the alignment of the Institute, which sits at a crisp 90 degrees to its neighbour. Certainly in terms of architectural intentions, they could not be more different. The Clay & Glass gallery vaunts tectonics, the expression of construction, and the articulation of materials; Perimeter blazons “an expression of space” rather than of detail, a modulation of surfaces rather than their assembly. This is not to say that details are unimportant. “You want things built to perfection,” said Saucier, “but to your perfection, not a generic perfection.”

Quintessentially Montreal or not, Saucier + Perrotte’s work is dif-



Long section



difficult to appraise equitably. Their polished compositions are so modishly elegant that detractors readily dismiss the buildings as mere echoes of superficial trends. Perimeter's resident researchers, for example, are housed in 44 stacked, cantilevered boxes facing north over Silver Lake. This north façade recalls many well-known recent projects, such as MVRDV's 1997 Amsterdam housing, or Eric Gauthier's 2003 residence for the Cirque du Soleil in Montreal. For Saucier + Perrotte, however, the boxes find their rationale not in shallow fashion-mongering, but deep within their architectural philosophy: a will to symbolize—however literally—the individuality of the researchers, to use innovations in building technology to refine the expression

of space, and to experiment with ways of controlling climate. The last is especially crucial. "In our climate there are many things that can interfere with our experience of nature," said Saucier. A small innovation can make a big difference. The use of overhead radiant heating, for instance, leaves each office's floor-to-ceiling, glued-glass window (each includes an operable unit) unencumbered by heaters like those needed in the glass bridge they designed for Montreal's Cinémathèque québécoise in 1997.

Nevertheless, despite these obsessions with climate and nature, space and symbol, it remains Saucier + Perrotte's grand control of pictorial effects that gives Perimeter its sense of place. Is there not something undeniably

important about making buildings that convey powerful images? Saucier himself argues well for the idea that clients and users have to take the time to understand and live with the individuality of the design. "You can recognize our signature," said Saucier. "It's that signature that makes it not just a generic building." In other words, is it not precisely because Perimeter is such a recognizable object that it creates the conditions of belonging: an identifiable home for the community of researchers and a landmark for its neighbourhood? 

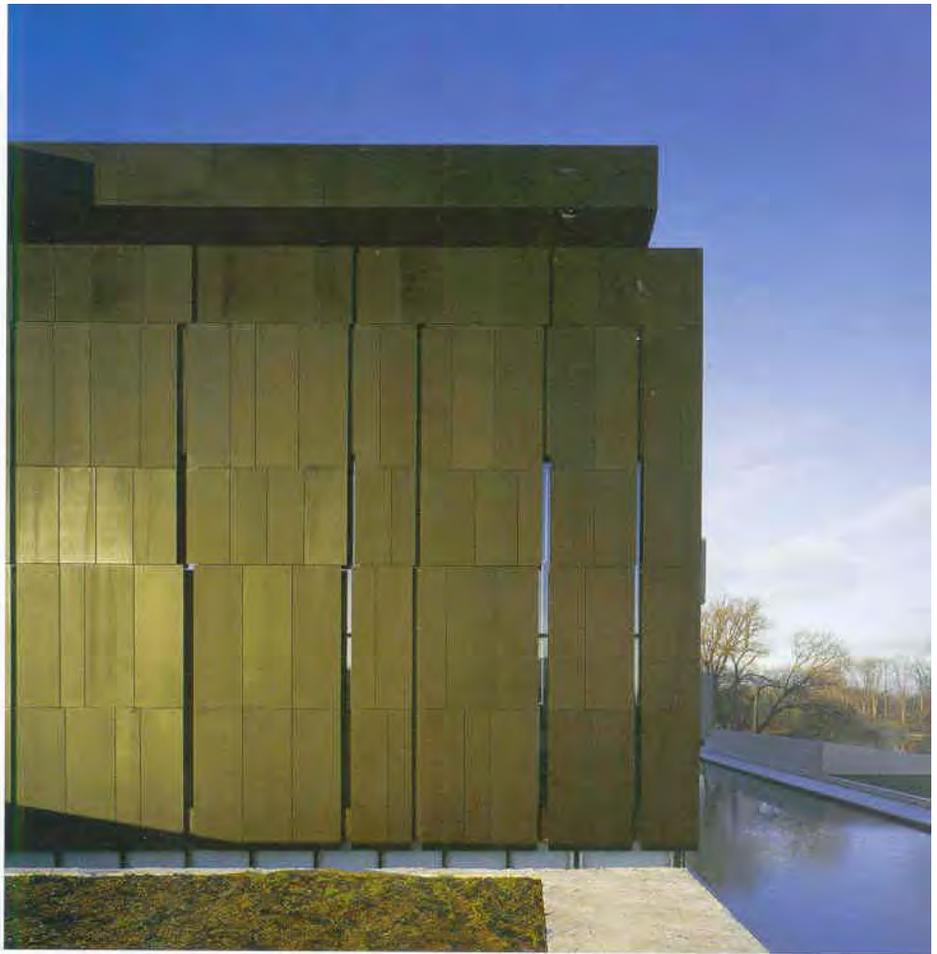
David Theodore is Research Associate and College Lecturer at the McGill University School of Architecture.



Site plan

- 1. Silver Lake
- 2. erupting ground plane
- 3. reflecting pool
- 4. train tracks
- 5. Canadian Clay & Glass Gallery
- 6. Seagram Museum

Opposite, left to right: view of the cavernous skylit main hall; view across the courtyard reveals a massive chunk of slate which serves as an outdoor blackboard; stepped lecture theatre offers controlled views to the reflecting pool. Right: narrow slit windows in the exterior elevation permit slivers of light into the lecture theatre. Below: the courtyard is illuminated by the transparency of the building at night.



Client: Perimeter Institute for Theoretical Physics
Architect Team: Gilles Saucier, André Perrotte, Audrey Archambault, Anna Bendix, Andrew Butler, Trevor Davies, Dominique Dumais, Maxime Gagné, Jean-Louis Léger, Laurence LeBeux, Christine Levine, Eric Majer, Sergio Morales, Quinlan Osborne, Pierre-Alexandre Rhéaume, Guillaume Sasseville, Samantha Schneider, Sudhir Suri
Structural: Blackwell Engineering Limited
Mechanical: Crossey Engineering Ltd.
Electrical: Crossey Engineering Ltd.
Civil: Stantec Consulting Limited
Landscape: Saucier + Perrotte architectes
Contractor: Eastern Construction
Acoustics: Acoustics Engineering Ltd.
Area: 64,000 ft²
Budget: \$24.5 million
Completion: September 2004
Photography: Marc Cramer unless otherwise noted

INFORMATION DRAWN FROM THE 2006 NSERC REVIEW OF PERIMETER INSTITUTE

OVERVIEW

This independent review took place during September of 2006, in accordance with all procedures, at the time an initial NSERC multi-year grant of five years earlier was reaching expiration.

The review process thoroughly examined all aspects of the Institute, including scientific research and educational outreach activity, dating back to inception. The Review Committee also discussed and evaluated future plans – in conjunction with PI's requested commitment of the Government of Canada to continue and increase funding.

The following pages detail the:

- Charge of the Committee
- Main Conclusions
- Select Findings
- Concluding Remarks and Recommendations

CHARGE OF THE COMMITTEE

Review of the Perimeter Institute for Theoretical Physics

Charge of the Committee

June 28, 2006

According to the Grant Agreement between NSERC and the Perimeter Institute for Theoretical Physics (PI), a formal evaluation of the past and planned activities of PI is required by NSERC. Under the aegis of NSERC, the review of PI is to be conducted by an international *ad hoc* Committee. The Committee is asked to carry out a thorough review of the achievements of the Institute since it launched its operations in 2001, and to evaluate its strategic and operational plans for the next five years. The Committee is to summarize its review and findings in a report, which must be submitted to NSERC no later than September 22, 2006. The report should represent the consensus of the entire Committee. NSERC will share the content of this report with Industry Canada, which might use it at its discretion for any appropriate needs or purposes.

The Committee members will be chosen for their expertise. The Committee will include highly regarded scientists from abroad and Canada. NSERC's guidelines with respect to conflicts of interest will be strictly applied. NSERC's Grant Selection Committees (GSCs) that serve disciplines covered by PI will be represented by ex-officio members. These are the Space & Astronomy, Subatomic Physics, and General Physics GSCs (17, 19, and 29, respectively). Moreover, the Major Resources Support GSC will also be represented by an ex-officio member. An NSERC representative will act as an observer during all phases of the Committee's review.

As part of the review, the Committee is asked to perform a thorough analysis of the past, current, and future research and outreach activities of the Institute, its operating and management structure, as well as its current operating budget and articulated financial needs. As part of the assessment, the Committee should address each of the following criteria:

- Quality, pertinence, and impact of the past, current, and planned scientific activities, and significance of the research themes (areas of discipline) to the related communities.
- Merit and excellence of the Institute's researchers and users.
- Extent to which the research activities of the Institute meet the needs and plans of the scientific communities that are related to PI's areas of research.
- Role and impact of the Institute on the advancement of the areas of research and, when applicable, on the dissemination and use of the generated knowledge in these areas.
- Extent and excellence of the contribution to the cutting-edge scientific training of Canadian highly qualified people, and to the attraction and retention of high-caliber researchers.

- Appropriateness and effectiveness of the Institute's management structure and accountabilities. Excellence of the overall governance of the Institute.
 - Quality of strategic and operational plans of the institute for the next five years.
 - Demonstrated need for financial assistance, including the appropriateness of the requested resources, and extent of the commitment and support from universities, other private or public organizations, and users.
 - Effectiveness of the financial and budgetary control mechanisms.
 - Effectiveness of the public-private partnership model used to fund the Institute since its establishment.
 - Outputs and benefits generated by the Institute since its launch. Scientific and technological impact and extent of the return on the investment.
 - Demonstrated scientific and/or technological benefits to Canada. This includes a demonstrated contribution to the positioning of Canada at the forefront of knowledge creation, innovation, and competitiveness.
 - Synergy between existing private and public resources in the proposed areas of research, and depth of scientific and economic linkages between the Institute, the scientific communities in the research areas covered by PI, and institutional partners.
 - Collaboration with complementary Canadian or, if applicable, international institutions.
 - Ease of access to, and actual use of, PI's resources by researchers from related research communities in Canada.
 - Outreach activities to the scientific and academic communities in order to raise the awareness about the Institute, its research areas, its accomplishments, and the opportunities it offers.
 - Outreach activities to the broad public, in particular the youth, to trigger and sustain interest in science.
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**MAIN CONCLUSIONS DRAWN FROM FINAL REPORT
OF NSERC REVIEW OF THE PERIMETER INSTITUTE**

September 26, 2006

- PI has been a great success on a world-wide scientific scale, for Canadian science, and for education and outreach. A number of major research achievements can be attributed directly to the existence of PI. The Institute should be applauded for its success in attracting such high quality researchers.
- PI has outstanding management. It provides strong oversight while retaining the creativity and flexibility needed for a rapidly growing enterprise. PI's plans for the future are excellent and the Institute appears very well prepared to move ahead with its proposed plans for the next five years.
- We strongly support PI's request for government funding to its full extent and for a period of at least 5 years.

SUMMARY OF SELECT FINDINGS
DRAWN FROM FINAL REPORT OF NSERC REVIEW OF THE PERIMETER
INSTITUTE

Research Related

- PI was founded just seven years ago, and since that time has developed an excellent international reputation as a leading center for some of the important areas of foundational physics.
- PI recognized early that the emerging area of quantum information was under appreciated by the general academic community, and was therefore a subject where a newly formed institute could have a large impact. Although it now seems that this was an obvious course of action, we must not forget that many strategies that seem obvious in hindsight actually require great insight to pursue.
- PI's activities in quantum information (QI) have helped place Canada at the forefront of the field internationally (and) a number of major research achievements in QI can be attributed directly to the existence of the Perimeter Institute.
- It is also responsible for bringing Raymond Laflamme to Canada and nurturing the resulting development of the Institute for Quantum Computing (IQC) at the University of Waterloo.
- In the area of quantum information theory it is likely that, in the not too distant future, there will be "real world" applications of the concepts and methods that are now being developed. The strength of PI in this area might provide Canada with technical expertise of significant economic importance.
- The committee notes that, even in abstract fields like string theory, quantum gravity and foundations of quantum theory, there is a significant effort to make contact with experiment and observations. This is very important for any physics organization, but not always realized at those institutes focusing on theory.
- (Regarding Sting Theory) the choice of faculty has been excellent, producing a remarkably balanced research effort, and Perimeter should be applauded for its success in attracting such high quality researchers.
- The Quantum Gravity group is internationally renowned, and often referred to as the pre-eminent group in this field.
- (Regarding Particle Physics) the associates and visitors are of very high caliber (and) it hopes to become a leading centre in this area during the next five years.
- In a small field like Foundations of Quantum Theory (also known as Quantum

Foundations), the PI group has rapidly become a reference, and we expect it to increasingly play this role in the future.

- (Regarding Cosmology) it is particularly fortunate that, with Paul Steinhardt as the Director of its Scientific Advisory Committee, PI has the expertise of one of the world's most eminent cosmologists at its disposal (and) the plans of PI to develop a strong and focused activity in this area are timely and very well justified.

Outreach Related

- It is the committee's assessment that the outreach component of PI is making a highly valued contribution to the public understanding of theoretical physics and participates in the contributions of physics, and science generally to culture.
- In a society and economy increasingly dependent upon the fruits of science, the value of educating Canadians—adults, young people and leaders—about science itself and the credibility and beauty of science and the scientific method cannot be overstated.
- The panel appreciates that PI has applied the resources and expertise required to strongly launch each outreach product and then build and sustain the success of each product.

Management Related

- The Institute is consistently applying the best practices of strategic management in a not-for-profit context.
- The Scientific Advisory Committee, an expert group of distinguished physicists, is an important resource to both Board and management in assuring that strategic plans are well informed and well grounded in the field.
- Given the past success and the depth of the observed best practices, PI is very well prepared to move ahead plans for the next five years.

Budget Related

- Given the nationally and internationally important role played by PI in building Canada's leadership in science and that it is a vital national resource for Canadian researchers and institutions; the panel strongly supports PI's request for government funding to its full extent and for a period of at least 5 years.
- ...it is important that the funding be as stable as possible over a period not less than five years. This will give it the flexibility it needs to grow without compromising on faculty quality.
- During this five year period Ontario and Canada may wish to consider how to

increase their research funding envelopes to accommodate the Institute's needs beyond 2012 as part of the regular research funding process.

Canadian Impact Related

- It is clear that PI has established the nucleus of a world class group with the ability to attract first class researchers from around the world.
- PI (has) had a tremendous and positive impact on the training of highly qualified personnel beyond the local area, bringing together researchers from across Canada and around the world.
- It is clear that the primary economic benefit arising from activities at PI is the training of the best and brightest Canadian minds.
- While some of these will pursue academic careers in physics, the vast majority will apply their analytic and technical skills outside of the physics research environment (and) it seems clear that in the long run this will make Canada more competitive.
- The 21st century is the information age. Access to highly trained people will dictate how competitive a country will be in the long run. Foundational theoretical physics is one of the least resource intensive areas of exploration at the frontiers of knowledge. Thus, it provides an especially cost-effective way to stay at the forefront of one of the most cutting-edge fields of science. In this sense, support for PI is a very efficient use of resources to foster a group of world class researchers in Canada and train Canadians in this information age.
- These payoffs, not only in areas such as quantum information technology but also in gaining a more fundamental understanding of the mechanisms underlying gravity, could be enormous.
- One can already see a number of spin-offs into the local community (primarily through the PI's outreach and cultural programs).

Concluding Remarks and Recommendations

- In a very short period of time, Perimeter Institute has grown from nothing to an important international center for theoretical physics.
 - PI is very visible on the international scene, having hosted some of the key international conferences.
 - It has vibrant educational and outreach programs that have enriched the local community and are also of national and international scope.
 - The public-private partnership model used to fund the Institute since its establishment has proven extremely effective.
 - To be frank, the committee is amazed by the success that PI has had over the last few years.
 - Given the great success of PI and the strong support it receives from the private sector, we recommend that Canada's federal government continues to provide strong financial support to Perimeter Institute and be an active partner of this successful and promising enterprise.
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