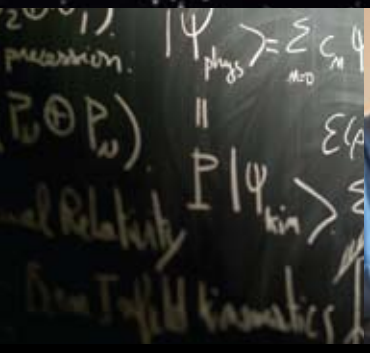
2009 Annual Report



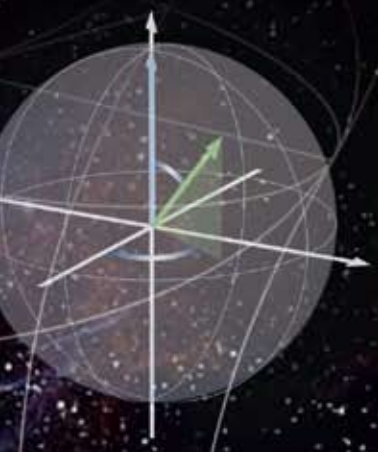
PERIMETER INSTITUTE
FOR THEORETICAL PHYSICS

CONTENTS

This report covers the activities and finances of Perimeter Institute for Theoretical Physics for the period August 1, 2008 to July 31, 2009.

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 determined to collaborate constructively with the surrounding academic community, in particular by creating outstanding educational and research opportunities for graduate students. We are equally determined to create a world-class outreach program which conveys the wonder and mystery of the universe and the importance of future scientific breakthroughs to the general public in Canada and beyond.



MESSAGE FROM THE BOARD CHAIR

WE LIVE IN AMAZING TIMES. To appreciate the extraordinary potential before us, it helps to recall how just over a hundred years ago, after making leaps in our understanding of light and matter, scientists were perplexed by strange phenomena that just didn't seem to fit. The photoelectric effect, for example, didn't agree with Maxwell's wave theory of light. But in 1905, Einstein explained the photoelectric effect, and in doing so gave us the foundation of quantum mechanics, which led to semiconductors, lasers, digital cameras, the Internet—all of our modern communications and computing environment. None of it would have been possible without deep thinkers, driven by curiosity to figure out how the world works at a fundamental level.

This brings me back to the present. Decades of progress have given us an incredibly detailed understanding of matter, energy, time, and the evolution of the universe. And yet, data keeps emerging that is hard to reconcile with this understanding. In these perplexing questions, and the drive to generate answers, there is transformative potential.

It has been nearly ten years since Perimeter started to focus creative minds on some of today's key questions in fundamental physics, using inter-disciplinary and collaborative approaches. To build upon this foundation, Neil Turok was appointed PI's new Director in October 2008. He is an outstanding scientist who held the Chair of Mathematical Physics at the University of Cambridge for over a decade, and a leader whose vision founded the African Institute for Mathematical Sciences (AIMS). Stephen Hawking, a longtime collaborator of Neil's, expressed it best when he said, "the combination of Neil and PI is brilliant and holds great promise for the future."

Over the last year, PI set out an ambitious Five Year Plan, with the full endorsement of the Board. It is aimed at taking PI to the next level of international research and outreach excellence, and an integral part of it is a major facility expansion that will house a critical mass of scientists, including those in training, who will help form a new generation of theoretical physicists. In support of this, and to ensure the Institute's long-term financial sustainability as it grows, a major campaign to build PI's endowment has begun.

History has shown us time and again the power of ideas and the impact of theoretical physics. I believe that PI can make vital contributions that will help shape our future in ways we can only imagine. The best is yet to come.

Mike Lazaridis

MESSAGE FROM THE INSTITUTE DIRECTOR

Perimeter's new Director, Prof. Neil Turok, is a distinguished cosmologist who previously held the Chair of Mathematical Physics at the University of Cambridge, where he was also the Director of the Centre for Theoretical Cosmology. He has made numerous scientific contributions to 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. 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. Steinhardt and Turok also co-authored the popular science book, *Endless Universe: Beyond the Big Bang*.

WELCOME TO OUR ANNUAL REPORT! Since I joined Perimeter Institute just ten months ago, it has been my great privilege and pleasure to work with PI's wonderful team on many aspects of the Institute's development. What attracted me here was the sense that excellent foundations had been laid, and that PI represents an exceptional opportunity not just for Canada, but for the world. Just as strong, principled foundations are essential to the theories we develop, a commitment to excellence in everything PI does—its science, its training, its outreach, its facility, its reporting, its bistro, its public outreach and cultural events, its mentoring and HR systems—will ensure it grows from success to success.

And Perimeter is growing, in every sense. Our new Five Year Plan sets out a series of ambitious goals. We are striving to create the optimal environment for scientific inquiry and discovery, one that challenges and supports researchers to ask, and attempt to answer, some of the deepest questions in science.

Building Perimeter's faculty is a prime objective. We continue to seek and hire exceptional talents, strengthening and complementing Perimeter's twin focus of Quantum Theory and Spacetime. Over this last year, we welcomed Luis Lehner and Robert Spekkens to our faculty. And we will soon be joined by Niayesh Afshordi, Latham Boyle and Pedro Vieira.

Soon after my arrival, we launched Perimeter Scholars International (PSI), designed to bring the most talented students worldwide to PI and provide an exceptional training in theoretical physics through an intense 10-month program. We also appointed 11 of the world's leading physicists to Distinguished Research Chairs at PI, making it their "second research home." We reached out to other institutes to encourage scientific exchanges and collaborations, and initiated a Global Outreach effort to promote the emergence of new centres for training and research in the developing world. Finally, our public Outreach team has continued to scale up its innovative programs to engage more people with the fascination and importance of basic science.

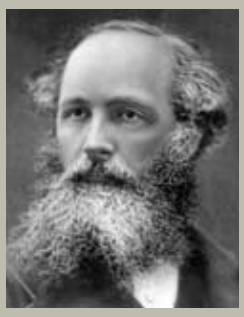
After a detailed planning phase, and with the support of federal, provincial and private partners, construction has just commenced on the Stephen Hawking Centre at Perimeter Institute, which will provide a state-of-the-art space for our expanded research, outreach and training activities.

Perimeter is a place with exceptional spirit—of excitement, intensity, and unconfined intellectual freedom. I am delighted to have joined this bold venture, and am full of optimism for the path ahead.

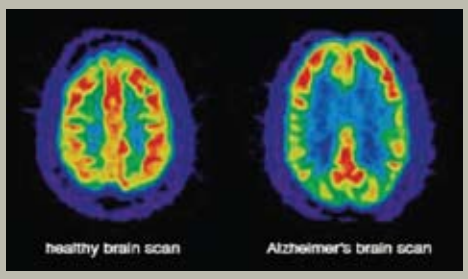
Neil Turok

ONE DISCOVERY CAN CHANGE THE WORLD

Just one major discovery in theoretical physics is literally capable of changing the world, as when Maxwell discovered a unified description of electricity and magnetism, and Marconi applied these ideas to send the first radio signals. Or when Einstein's new ideas about light as tiny particles, or "photons," eventually led to the laser, medical imaging equipment, CD players, and more. Today, quantum theory is leading the way toward tomorrow's computers and communication systems, which may vastly exceed the capabilities of current technologies.



James Clerk Maxwell



Positron Emission Tomography, or PET scanning, is just one of the myriad applications of fundamental physics.

PERIMETER INSTITUTE (PI) WAS FOUNDED IN 1999 as an independent research institute focused on the greatest challenges facing fundamental theoretical physics in the 21st century, namely, discovering a deeper understanding of the quantum laws of physics and the spacetime arena in which they operate. This mission is built on the twin pillars of 20th century physics: quantum theory, describing the behaviour of matter and energy at atomic and subatomic scales, and general relativity, describing gravity, stars, galaxies and the universe itself. Both theories match a huge range of observations to extraordinary accuracy. However, one of the greatest unsolved problems of modern theoretical physics, and a key objective of PI, is to find a consistent framework which unifies the two theories. This question is central to resolving key puzzles about the physical universe, from understanding the dark energy which shapes its cosmological evolution to determining the essential nature of matter and forces on the smallest subatomic scales.

Fundamental physics is a fast-moving field. Over the past decade, observations have transformed our understanding of the universe. Quantum information and computation are new ideas with great technological potential. Powerful concepts like holography, linking quantum theory to gravity in entirely new ways, are bringing dramatic new insights to many areas of physics.

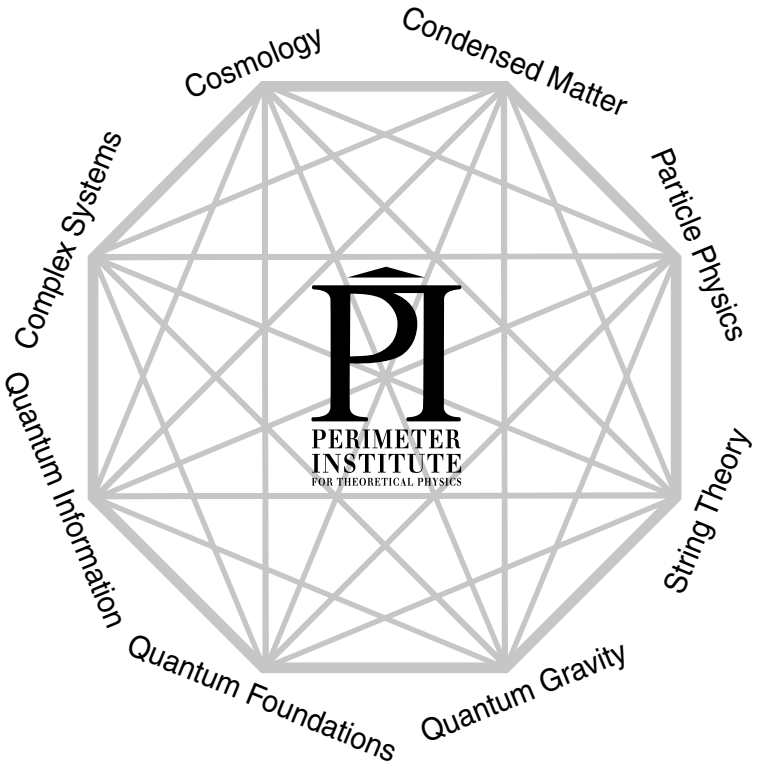
Theoretical physics is one of the lowest-cost, highest-impact scientific disciplines, contributing key concepts to fields from astronomy to neuroscience, pure mathematics to computer science. It is above all a creative field, constantly reinventing itself, discovering deeper insights into nature while broadening its range of application.

THE PI APPROACH

Perimeter promotes healthy debate among competing approaches to foundational areas in theoretical physics, in an environment of maximal research freedom and interaction. There are, for example, research groups pursuing both superstring theory and quantum gravity at PI. This has fostered a highly interdisciplinary research culture, and over 300 visiting scientists from all over the world come to PI each year, furthering the cross-pollination of ideas.

EXPANDING ACROSS THE SPECTRUM

The fundamental unity of theoretical physics is a huge source of research strength. While retaining its twin focus on quantum theory and spacetime, PI is broadening its range of research to incorporate insights from physics on all length scales: from subatomic, to mesoscopic condensed matter systems, to cosmology, and to complex systems, in which many time and length scales are involved. The fields below have been strategically chosen to form a whole greater than the sum of its parts, enabling advances gained in one area to promote progress in others. PI's strategically chosen combination of research directions is unique worldwide; its multidisciplinary approach instills a collaborative atmosphere which maximizes cross-fertilization of ideas and increases the probability of breakthroughs. It is hoped that this long-range vision will enable PI to play a leading role in foundational physics research, and the applications that arise from it, over the long term.



A single research community gaining complementary insights from eight key fields.

PI BY THE NUMBERS

In 2008-09, PI had 94 resident researchers, including 11 Faculty, 10 Associate Faculty, 45 postdoctoral Fellows, and 28 PhD students.

FACULTY

Freddy Cachazo
Laurent Freidel
Jaume Gomis
Daniel Gottesman
Lucien Hardy
Justin Khoury (on leave)
Fotini Markopoulou
Robert Myers
Lee Smolin
Robert Spekkens
Neil Turok

ASSOCIATE FACULTY

(cross-appointed with other institutions)

Alex Buchel
(University of Western Ontario)

Cliff Burgess
(McMaster University)

Richard Cleve
(University of Waterloo)

Adrian Kent
(University of Cambridge)

Raymond Laflamme
(University of Waterloo)

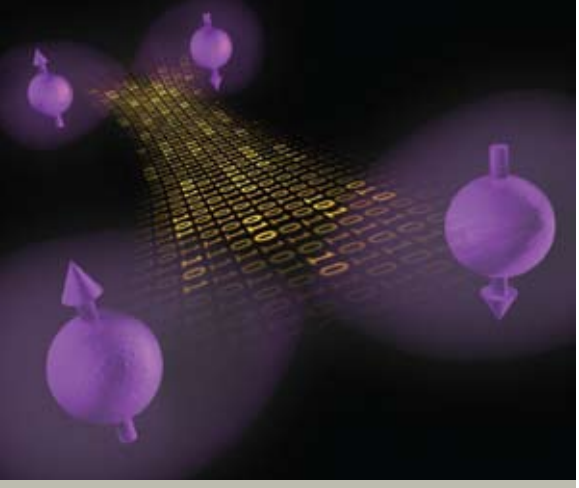
Luis Lehner
(University of Guelph)

Michele Mosca
(University of Waterloo)

Ashwin Nayak
(University of Waterloo)

Maxim Pospelov
(University of Victoria)

Thomas Thiemann
(Max Planck Institute for Gravitational Physics)



QUANTUM INFORMATION

The quantum world is the world of the very small, of atoms and elementary particles—and it is incredibly bizarre. For example, it is possible for a single particle to behave as if it is in more than one place at the same time. Our notion of what is separate and what is not also breaks down in the quantum world: particles could be kilometres apart and still, in some respects, act like a single entity. Although quantum theory poses deep conceptual puzzles, harnessing the properties of the quantum world spawned the transistor, the laser, MRI devices, and many more important 20th century technologies. Many anticipate that we are on the brink of a new quantum revolution, which could reshape the 21st century in equally dramatic ways.

Over the last 15 years, we have come to see that quantum mechanics is much more powerful than the classical laws of physics for manipulating information. It is thought that a quantum computer with 50 quantum bits, or qubits, would be more powerful than today's most powerful supercomputers.

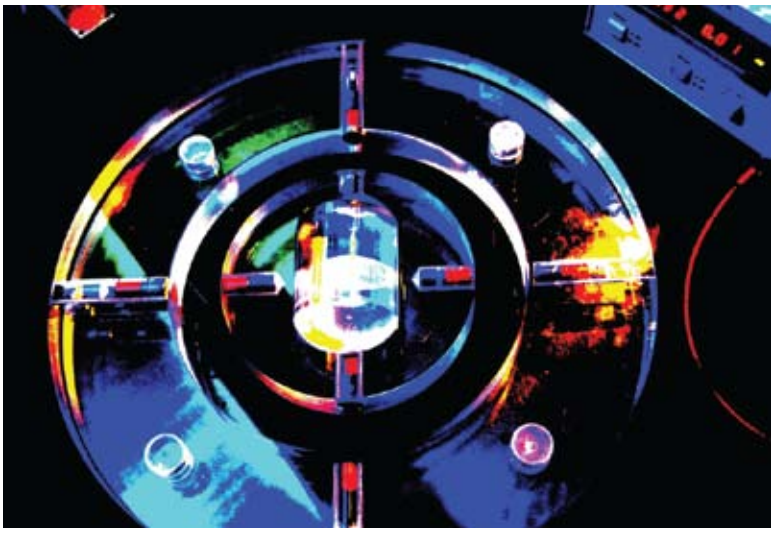
PI researchers focused on Quantum Information are working to understand its properties, to study which information processing tasks are feasible with a quantum computer, and which are infeasible or impossible. It includes research in quantum cryptography—the use of quantum systems to secure information, as well as quantum error correction, which devises techniques to counteract the inevitable errors that arise in quantum computational systems.

WHAT ARE THE LIMITS AND POTENTIAL OF QUANTUM COMPUTERS?

Daniel Gottesman

Daniel Gottesman is working to develop a sound theoretical foundation for quantum computing, which holds promise of computers vastly more powerful than those we know today. He has made important contributions to the theory of quantum error correction, and to quantum fault tolerance, both aimed at developing quantum computers robust enough to become useful as a computational technology. In 2008, he proved that if an error rate under one per thousand gates in the physical components of a quantum computer can be achieved, arbitrarily long quantum computations can be performed reliably—a key result demonstrating that there is no barrier in principle to constructing large quantum computers.

Recently, Gottesman has been studying the application of ideas from computer science to the physics of systems which lack an ordered structure. Glass is an example of such a material: glass is made of the same types of atoms as a quartz crystal, but in glass the atoms are arranged in a complicated, somewhat arbitrary, way rather than the simple regular structure of a crystal. Glass is a solid, however, because the atoms cannot easily rearrange themselves; finding another satisfactory arrangement of the atoms would require moving all of them together in a carefully coordinated way. Extremely difficult computational problems, likely too hard to solve even with a quantum computer, arise naturally in physical systems with similar glassy behavior, and quantum-mechanical glassy systems are harder still. Gottesman is studying just how simple a physical system can be and still be a quantum glass. The results could help us understand the limits of quantum computation and also give us new insight into the physics of glassy systems.

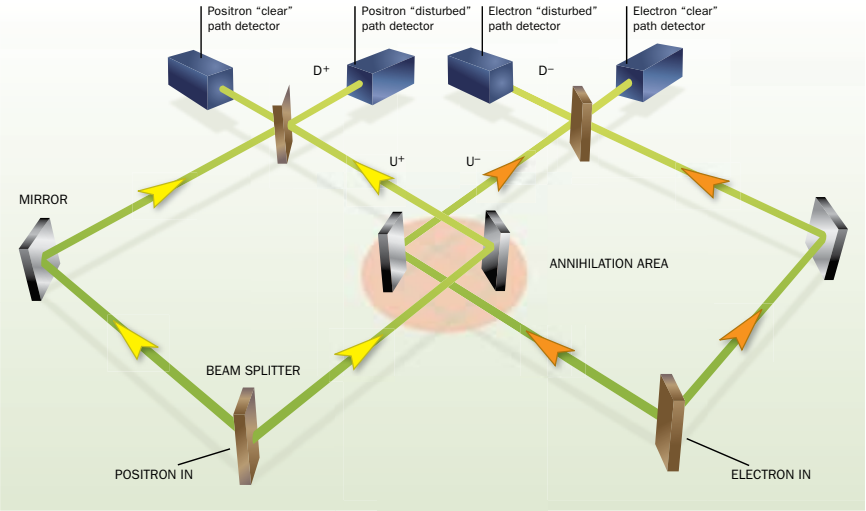


Detail of prototype quantum computer setup.

CAN WE KNOW WHAT HAPPENED IF WE DIDN'T SEE IT?

Lucien Hardy

In 1992, Lucien Hardy proposed a thought experiment that became known as Hardy's Paradox, which gave an elegantly simple proof of non-locality in quantum theory. Although the classical scheme of particle behavior says that when matter and antimatter meet, they should annihilate one another in a burst of energy, Hardy's Paradox (see diagram below) showed it was possible that in some cases when a particle-antiparticle interaction is not observed, they could interact with one another and survive.



The positron and electron go down both arms of each of their interferometers. If they meet in the overlapping arms, they should annihilate each other; strangely, however they are still registered as arriving at the D detectors.

How could this apparent paradox be tested, when the very act of observing systems at the quantum scale (of single atoms and particles) changes them?

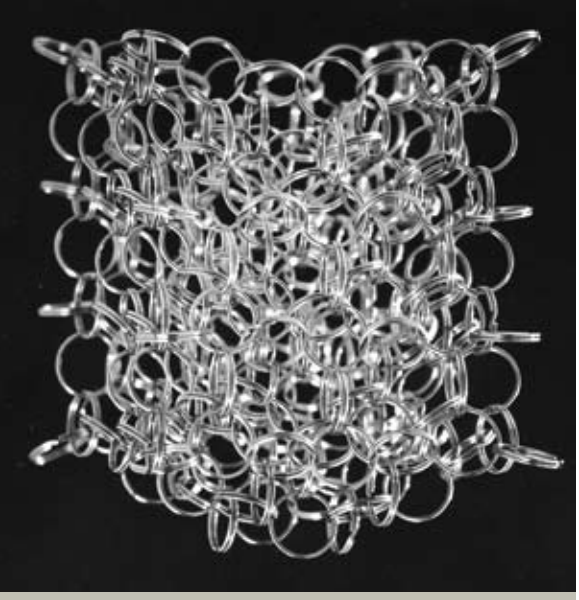
In early 2009, two independent experimental teams at Osaka University and the University of Toronto provided the first experimental confirmation of Hardy's Paradox, using a technique called "joint weak measurement." The experiments, based on Hardy's thought experiment, followed the paths of two entangled photons and used joint weak measurement techniques to achieve the effect of observation without disturbing the system. Both teams measured more photons at some detectors and fewer in others than classical physics would predict—indicating that particles that should have perished had persisted, and confirming Hardy's Paradox. The findings were called a "milestone in quantum mechanics" and were publicized around the world.

QUANTUM FOUNDATIONS

Quantum theory is by far the most detailed and successful scientific description of nature ever achieved. However, by everyday intuition, it is also the strangest, being built on counterintuitive features like "superposition" and "entanglement." For nearly 100 years, the scientific community has been trying to come to grips with what quantum theory really tells us about the physical universe. This profound inquiry into the foundations of quantum theory has been very fruitful, leading to a better conceptual understanding with important implications for future technology.

Perimeter has the largest and most diverse Quantum Foundations group in the world, and research in this area interfaces with quantum information at the more applied end, and quantum gravity at the more fundamental end. Researchers in quantum foundations investigate the conceptual and mathematical structure of quantum theory, covering three broad areas:

- **The investigation of novel quantum effects**
- **Developing a better understanding of the conceptual issues raised by quantum theory itself, as well as major interpretations of the theory**
- **Attempts to construct the theory from more basic principles or axioms**

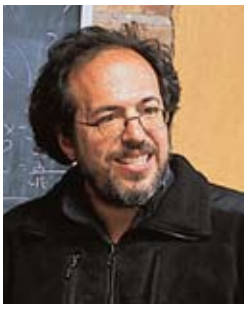


QUANTUM GRAVITY

The two pillars of modern theoretical physics are quantum theory, describing physical phenomena on the smallest scales, and general relativity, Einstein's geometric description of gravity which governs the universe on astronomical distance scales. Quantum gravity investigates one of the greatest intellectual puzzles of all time: reconciling these two very different theories, each of which forces us to think in completely new ways about the universe. History teaches us that unifying seemingly disparate theories is often the key to breakthroughs in our understanding. Such a unification—a quantum theory of gravity—is often called the "Holy Grail" of modern physics, and promises to yield the deepest insights physicists have ever achieved into how our universe actually works.

Quantum gravity research at PI is unique worldwide in terms of the variety of complementary approaches being actively pursued, including loop quantum gravity, spin foam models, "quantum graphity," causal set theory, and superstring theory. This diversity makes PI an attractive destination for young researchers drawn by the ultimate challenge represented by quantum gravity.

CAN WE TEST QUANTUM THEORIES OF GRAVITY?



Lee Smolin

Researchers at Perimeter are working on several approaches that may allow us to use current experiments to test features of a theory of quantum gravity. Faculty member Lee Smolin has pioneered deformed special relativity (DSR), which modifies relativity to take into account quantum gravity effects. With visiting scientist Giovanni Amelino-Camelia, Smolin has recently explored the idea of using results from the Fermi gamma ray space telescope to test the prediction that the speed of light might depend very slightly on energy.

DOES A "SMOOTH" SPACETIME EMERGE FROM DISCRETE MODELS OF QUANTUM GRAVITY?

Laurent Freidel

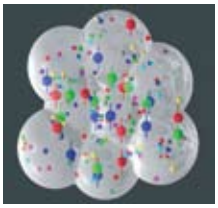
Quantum theories of gravity give us a new picture of the geometry of space at very short distances, which is quantum and discrete—that is, at the smallest scales, space is in some sense "granular." A big question these theories must answer is whether they predict the continuous space in which we feel ourselves to be surrounded. Theorists at PI are studying different approaches to how the continuous space and time of classical physics would emerge from a quantum theory of gravity. Last year faculty member Laurent Freidel and postdoctoral fellow Florian Conrady published a series of papers presenting major results which demonstrate how this happens in a class of theories called "spin foam models." They showed how a class of discrete geometries emerges which satisfies a form of the Einstein equations from general relativity. Meanwhile, faculty member Fotini Markopoulou and her collaborators, including postdoctoral fellow Alioscia Hamma and graduate student Isabeau Prémont-Schwarz, have found two important results that advance our understanding of how spacetime geometry relativity theory may emerge from a quantum theory of gravity. They have constructed models of quantum spacetime in which one can show that at low temperatures the quantum geometry "freezes" and a classical geometry emerges. They did this by modifying a model studied in condensed matter physics, called the quantum Bose-Hubbard model, so that the discrete geometry it is defined on is dynamical. Then, in two papers, they showed how the existence of a maximal speed of light emerges from the kind of models studied in these papers.

Fotini Markopoulou

CAN SUPERSTRING THEORY FIND NEW PHASES OF MATTER?

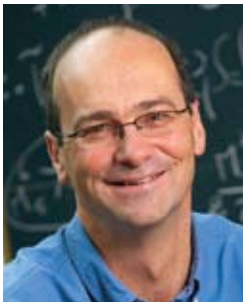
One of the goals of theoretical physicists is to identify the possible states of matter that could have been formed in the Big Bang, as well as the new states of matter that can be created in labs and particle accelerators. PI faculty member Jaume Gomis recently won an Early Researcher Award from the Ministry of Research and Innovation (MRI) of Ontario to support his ongoing research developing new techniques for describing quantum phenomena in particle physics. His work is contributing new theoretical tools which enable physicists to study observables in gauge theories. Ultimately, these tools may allow us to describe precisely how quarks are confined within protons and neutrons, as well as to predict entirely new states of matter, which could be investigated experimentally.

Jaume Gomis



CAN SUPERSTRING THEORISTS STIR UP QUARK SOUP?

The "strong force" is one of the four fundamental forces in nature (along with gravity, the electromagnetic force, and the "weak force"). It couples quarks together to make up the protons and neutrons that form atomic nuclei. This coupling is so strong that nobody is able to pull apart protons or neutrons to observe an individual quark in the lab. Yet at extremely high energies, such as those found in the early universe or produced at particle accelerators, the coupling becomes weaker. Recent experiments smashing together atomic nuclei at nearly the speed of light have discovered a surprising new phase of matter called the "strongly coupled Quark-Gluon Plasma" (sQGP), in which the quarks are neither confined nor free but instead form a strongly interacting liquid. All the more remarkable is that the sQGP seems to exhibit a viscosity orders of magnitude smaller than typical fluids. (Viscosity is a measure of the resistance of a fluid to a deforming stress. It determines key characteristics such as how fluids move and spread—molasses is more viscous than water, for example.) Using new theoretical techniques emerging from superstring theory, faculty members Robert Myers and Alex Buchel are working to achieve better theoretical understanding of this new liquid. In particular, they have been pushing to answer the question: what is the lowest possible viscosity that any physical fluid can achieve?

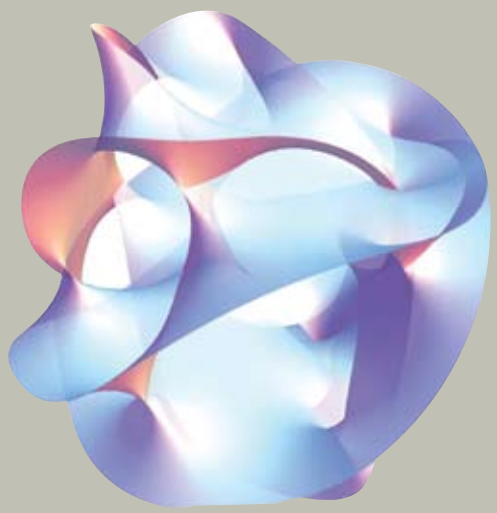


Robert Myers

SUPERSTRING THEORY

Superstring theory is a leading contender to provide a quantum theory of gravity, as well as unifying gravity with the other forces in nature. The starting point is to replace the notion of a fundamental point-like particle with an extended object, the "string." This simple shift leads to a remarkably rich mathematical framework with which theorists hope to describe our physical universe. Superstring theory is a diverse field with strong connections to particle physics, cosmology and mathematics, as well as quantum gravity. It has spawned surprising new insights into quantum gravity, such as "holography," which in turn has drawn remarkable new connections to the study of new phases of matter by nuclear theorists and condensed matter physicists.

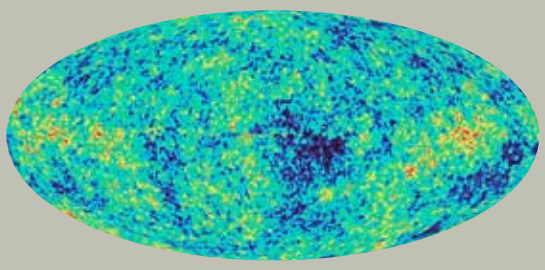
Researchers at PI have made and continue to make contributions across a wide range of topics, including string cosmology, the "landscape," gauge theory amplitudes, gauge/gravity duality, and strings at singularities.



COSMOLOGY

Cosmologists have discovered a great deal about the evolution of the universe over its 14-billion year history and have traced the origins of the universe back to a mere split second after "time zero," when the universe was filled with a primordial "soup" of extremely hot, dense matter and radiation. Despite this tremendous progress, profound mysteries remain, the deepest being: how did the universe actually come into being during this split second, called the Big Bang phase? Recently, cosmology has become one of the most exciting fields of science as new observational technologies have enabled exquisitely accurate and detailed observations to be made. Theory has played a driving role, by defining the key observations needed to test different models of the universe.

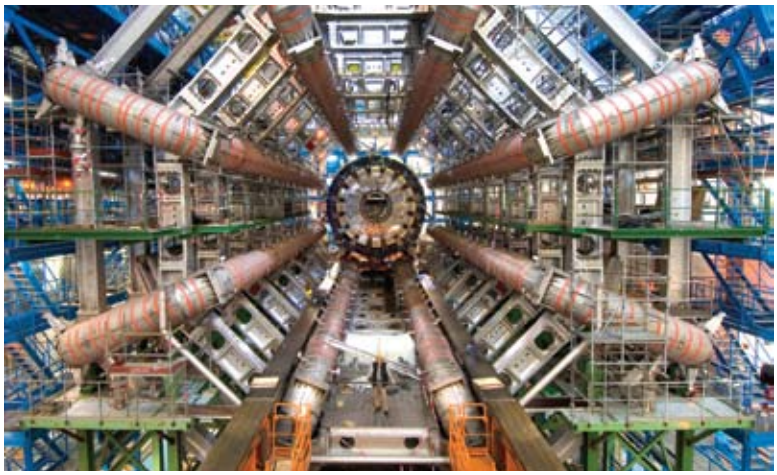
Cosmologists at PI combine recent developments at the interface of astrophysics and fundamental physics to shed light on some of the major puzzles in the field: What is causing the observed cosmic acceleration? What is the nature of dark matter? What can be learned from microwave background and large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



HOW DO WE EXPLAIN THE MATTER-ANTIMATTER ASYMMETRY?

Neil Turok

In 2009, PI Director and faculty member Neil Turok, with Gary Gibbons and Steffen Gielen of the University of Cambridge, and Chris Pope of Texas A&M University, used mathematical symmetry arguments to estimate, for the first time, the size of a fundamental imbalance pervading the subatomic world. This imbalance, called the CP violation, distinguishes matter from antimatter and is essential to understanding why matter predominates over antimatter in the natural world. Turok *et al.* discovered that a uniform distribution, using a natural measure in the space of CKM matrices (which characterize mixing between different sectors of the Standard Model of particle physics), leads to a level of CP violation comparable to the observed value. For the future, this new method may provide a way to evaluate which of the many modifications that have been proposed to the Standard Model of physics are more plausible than others and may help guide future experiments, such as those at the Large Hadron Collider (LHC) at CERN.



ATLAS detector at the Large Hadron Collider (LHC) at CERN.

WHAT IS REALLY HAPPENING AS PARTICLES COLLIDE?

Upcoming experiments at the Large Hadron Collider (LHC) are expected to detect new particles and forces which will bring us closer to answering fundamental questions—such as how elementary particles acquire mass.

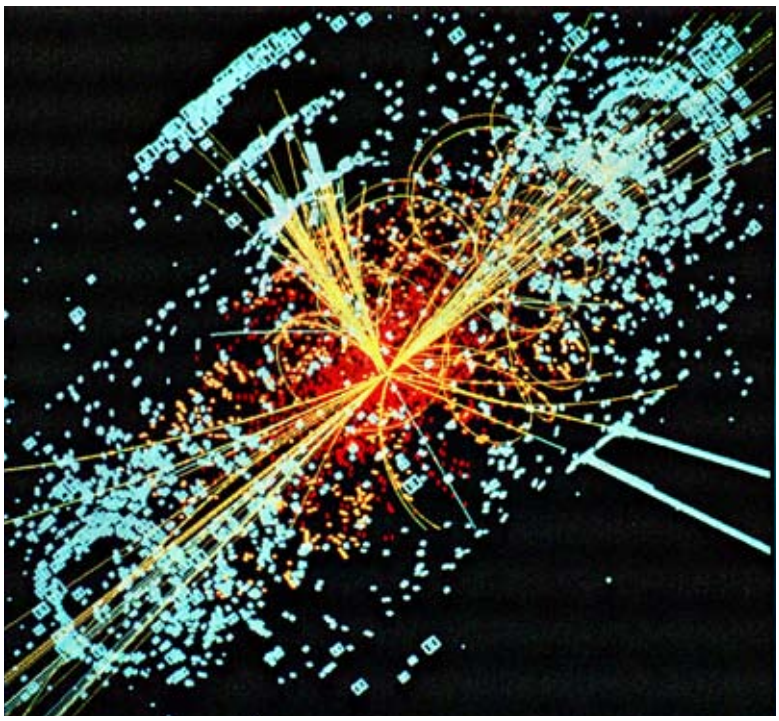
Particle accelerators smash subatomic particles together at near light speeds, causing interactions which can yield entirely new types of particles in a process called scattering. Scattering amplitudes are the calculations giving the theoretical predictions for obtaining various outgoing particles when different incoming particles at various energies collide.

Traditional methods of calculating scattering amplitudes analytically are extremely involved. Faculty member Freddy Cachazo and collaborators

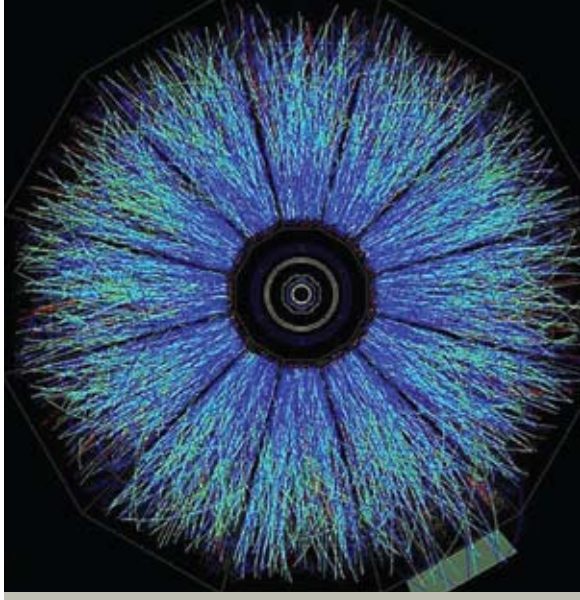
Freddy Cachazo

have drawn together ideas from superstring theory, twistor theory, quantum field theory and complex analysis to develop techniques that greatly simplify these enormously complex calculations. These techniques are becoming increasingly important in high energy physics, and have been implemented as part of BlackHat, software that automatically computes theoretical predictions for certain interactions — and matches experimental data from collider experiments very accurately. In 2009, Cachazo was awarded the Gribov Medal of the European Physical Society for this important work.

Cachazo's work has raised intriguing questions. The simplicity of the analytic expressions comes with a price: the appearance of unphysical interactions which miraculously cancel out in the final answer. The presence of these spurious terms, which would naturally come from a theory where spacetime is not fundamental, hint that there might be a new, "dual" formulation of the same physics. With PI Distinguished Research Chair Nima Arkani-Hamed of the Institute for Advanced Study, and others, Cachazo is pursuing the mystery, which is leading them to try to find a place in physics for complex mathematical spaces called "Grassmannians."



Simulated particle track modelled for the CMS detector on the Large Hadron Collider at CERN. Here a Higgs boson is produced which decays into two jets of hadrons and two electrons. The lines represent the possible paths of particles produced by the proton-proton collision in the detector, while the energy these particles deposit is shown in blue.



PARTICLE PHYSICS

Particle physics aims to understand nature's fundamental constituents and their interactions. At present, experiments have probed down to 10^{-18} metres, the "electroweak scale," and theorists have provided a remarkably successful description of all of the physics thus revealed, known as the Standard Model, that involves 18 elementary particles interacting through the strong, weak and electromagnetic forces. CERN's Large Hadron Collider (LHC) is poised to open a new energy frontier beyond the electroweak scale, and there is enormous anticipation about what it will find: the Higgs, supersymmetry, dark matter particles or perhaps, mini-black holes? PI's research efforts in particle physics have only recently begun, and have focused to date on astroparticle physics, using cosmology as the ultimate high energy experiment. However, leading particle theorists are now coming to PI for extended stays, and it is hoped that PI's future expansion will allow it to become a leading centre for the diverse and exciting phenomenology relevant to upcoming experiments at the LHC at CERN.

RECRUITMENT

PI Distinguished Research Chair Neta Bahcall and incoming faculty member Niayesh Afshordi.

PI BY THE NUMBERS

IN 2008-09...

- Robert Spekkens and Luis Lehner joined PI's faculty
- Pedro Vieira, Latham Boyle, and Niayesh Afshordi were recruited to PI's faculty (to begin next year)
- 11 Distinguished Research Chairs were appointed
- 18 new Postdoctoral Fellows were recruited

"PI allows for a good combination of complete research freedom and contact with senior scientists... PI is probably the best place that I've been so far, both in terms of the research funding and support services, and its visitors and seminar programs."

–Daniel Terno, former PI postdoc, now Senior Lecturer at Macquarie University in Sydney

DIRECTOR APPOINTED

IN OCTOBER 2008, NEIL TUROK TOOK UP HIS APPOINTMENT as PI's second Director, following unanimous endorsements from the Search Committee, the Scientific Advisory Committee and the Board of Directors. Turok previously held the Chair of Mathematical Physics at the University of Cambridge, where he was also the Director of the Centre for Theoretical Cosmology. He has made numerous scientific contributions to theoretical physics and cosmology, focusing on observational tests of fundamental physics. With Paul Steinhardt at Princeton, he has recently 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 also co-authored the popular science book *Endless Universe: Beyond the Big Bang*. Born in South Africa, Turok founded the African Institute for Mathematical Sciences (AIMS), a postgraduate educational centre based in Cape Town that supports the development of mathematics and science across the African continent, for which he was awarded the 2008 TED Prize.

FACULTY RECRUITMENT

In early 2009, Luis Lehner joined Perimeter's faculty in a joint appointment with the University of Guelph. Lehner is a pioneer of modern efforts to extract definite predictions for the behaviour of black holes and other strongly gravitating systems from Einstein's equations. With observational tests using gravitational wave astronomy expected in the near future, Lehner's recruitment positions Perimeter well for the future in this exciting area.

In November 2008, Robert W. Spekkens joined Perimeter as a junior faculty member. He is an emerging leader in the field of quantum

foundations who has also made important contributions to quantum information theory, and he will strengthen PI's efforts in both these interrelated areas. He received his PhD from the University of Toronto in 2001 and held his first postdoctoral position there. He then came to PI for a three-year postdoctoral position from 2003–06, followed by a Royal Society–funded postdoctoral fellowship at the University of Cambridge.

The Institute has recently recruited three additional faculty members, all of whom will arrive in the coming year. Pedro Vieira, a superstring theorist, will join Perimeter from the Max Planck Institute for Gravitational Physics in Potsdam, Germany, where he has been a Junior Scientist since 2008. Also joining Perimeter are two cosmologists: Latham Boyle, currently a Canadian Institute for Theoretical Astrophysics (CITA) Postdoctoral Fellow, and Niayesh Afshordi, who is currently a Distinguished Postdoctoral Fellow at Perimeter and who has been hired with a cross-appointment at the University of Waterloo.

POSTDOCTORAL FELLOWS

Postdoctoral fellows follow independent research programs and are encouraged to be full partners in the research community—organizing conferences and workshops, hosting visitors, and giving talks. Fellowships are for three-year and five-year terms, and PI now hosts the largest community of independent postdoctoral fellows in theoretical physics worldwide. In 2008-09, 18 new postdoctoral fellows were selected from over 400 applicants, joining PI from Oxford, Cambridge, ETH (Zurich), the Kavli Institute for Theoretical Physics (Santa Barbara), and Caltech, among others. PI postdocs have an excellent track record of obtaining permanent positions after they have trained at PI. Within the last year, for example, in the Quantum Gravity group alone, six postdoctoral fellows were offered positions at prestigious institutions, several with resources to begin groups of their own.

DISTINGUISHED RESEARCH CHAIRS PROGRAM

Past experience shows that when complementary insights are brought to bear and critical mass is reached, major advances are possible. With this in mind, in 2008, Perimeter Institute established the Distinguished Research Chairs program to bring world-class researchers to the Institute for extended research visits each year. As PI grows, it plans to reach a steady state of 30 Distinguished Research Chairs, with each appointment lasting for three years. It is hoped that the presence of the Distinguished Research Chairs will spark new scientific collaborations, provide invaluable guidance to the Institute's resident researchers, and inspire our young researchers.

DISTINGUISHED RESEARCH CHAIRS

Yakir Aharonov, Chapman University and Tel Aviv University

Nima Arkani-Hamed, Institute for Advanced Study

Neta Bahcall, Princeton University

Juan Ignacio Cirac, Max Planck Institute

Gia Dvali, New York University and CERN

Stephen Hawking, University of Cambridge

Leo Kadanoff, University of Chicago

Subir Sachdev, Harvard University

Ashoke Sen, Harish-Chandra Research Institute

Leonard Susskind, Stanford University

Xiao-Gang Wen, Massachusetts Institute of Technology

PSI'S 2009-10 FACULTY

John Berlinsky, Director
Niayesh Afshordi, Perimeter Institute & University of Waterloo
Ben Allanach, University of Cambridge
Philip Anderson, Princeton University
Nima Arkani-Hamed, Institute for Advanced Study
Katrin Becker, Texas A&M University
Melanie Becker, Texas A&M University
Carl Bender, Washington University
Freddy Cachazo, Perimeter Institute
Matt Choptuik, University of British Columbia
Susan Coppersmith, University of Wisconsin at Madison
David Cory, Massachusetts Institute of Technology
Kari Dalnoki-Veress, McMaster University
François David, Institute of Theoretical Physics, CEA-Saclay
Jaume Gomis, Perimeter Institute
Daniel Gottesman, Perimeter Institute
Ruth Gregory, Durham University
Leo Kadanoff, University of Chicago
Luis Lehner, Perimeter Institute & University of Guelph
Renate Loll, Utrecht University
Robert Myers, Perimeter Institute
Hiranya Peiris, University of Cambridge
Malcolm Perry, University of Cambridge
Michael Peskin, Stanford Linear Accelerator Center
Frans Pretorius, Princeton University
Sid Redner, Boston University
Anders Sandvik, Boston University
Erik Sorensen, McMaster University
Robert Spekkens, Perimeter Institute
Andrew Tolley, Perimeter Institute
David Tong, University of Cambridge
Neil Turok, Perimeter Institute
Xiao-Gang Wen, Massachusetts Institute of Technology

PERIMETER SCHOLARS INTERNATIONAL

THE LIFEBLOOD OF THEORETICAL PHYSICS IS BRILLIANT YOUNG PEOPLE. In December 2008, the Institute launched Perimeter Scholars International (PSI), a new master's level training course designed to turn talented, highly motivated graduate students into young researchers in an intense 10-month program. PSI is a collaborative effort with partnering Canadian universities, and upon completion of the program, students will receive a master's degree from the University of Waterloo and a Perimeter Scholars Certificate from Perimeter Institute.

Courses will be given by visiting lecturers, as well as dedicated professional tutors, in a syllabus designed to expose students to a wide spectrum of theoretical physics. The emphasis will be on the development of problem-solving skills through group and individual work, with opportunities to delve more deeply into the research areas that excite students the most. John Berlinsky, of McMaster University, has been recruited as the program's Academic Director, while six eminent PSI Patrons will provide oversight and advice on the quality and content of the program. Response to the program has been strong; 220 applications were received, and a first class of 28 students from 17 countries has been selected, with classes commencing in August 2009.

perimeter scholars international™

UNIVERSITY OF Waterloo

COURSES

The Institute's researchers enrich the curriculum offerings of several surrounding universities by offering credit courses in areas of expertise at both the undergraduate and graduate level, and through special topic courses delivered by distinguished visiting scientists. Last year, these courses attracted students from among the eight regional universities, in person and remotely. All courses are recorded and available for viewing over the web on the Perimeter Institute Recorded Seminar Archive.

PHD STUDENTS

There were 28 PhD students in residence over the past year pursuing full-time graduate studies under the supervision of PI faculty members. Students receive their degree from a partnering university where the faculty member has an affiliation. The graduate program at PI offers students excellent opportunities to interact with both resident and visiting physicists from around the world. Eight new PhD students arrived in 2008-09, and there are plans to expand these numbers significantly in the coming years, in tandem with faculty growth. Perimeter's PhD students have successfully obtained continuing postdoctoral positions at institutions including the Kavli Institute for Theoretical Physics at UCSB (USA), the Max Planck Institute (Germany), Kinki University (Japan), and the Institute for Theoretical Physics at Utrecht University (Netherlands), as well as Canadian institutions such as the University of British Columbia, McGill University, the University of Toronto, and others.

UNDERGRADUATE RESEARCH PROJECTS

Perimeter postdoctoral fellows gain mentoring experience while furthering their research programs by developing 2-4 month research projects requiring the assistance of an undergraduate student. Over the summer months, undergraduates recruited from around the world join PI's research community, gaining research skills, learning about specific research areas in depth, and more generally about being a theoretical physicist.

My research related to the cosmological constant problem... I proceeded in small steps, learning one piece at a time, gradually fitting it together into the bigger picture. The most valuable part was having the opportunity to really do physics, as it's done "in the real world." I realized physics is a living tradition, and I was grateful that I had an opportunity to contribute to it.

– PI summer undergraduate researcher Adam Bognat, University of Waterloo

2008-09 COURSES HELD AT PI INCLUDED:

Astrophysics and Cosmology through Problems,
Sept. – Dec. 2008
Instructors: Niayesh Afshordi, Mark Wyman, Perimeter Institute

Quantum Field Theory I,
Sept. – Dec. 2008
Instructor: Volodya Miransky, University of Western Ontario

Selected Topics in Theoretical Physics,
Jan. – Apr. 2009
Instructor: Freddy Cachazo, Perimeter Institute

Introduction to the Bosonic String,
Jan. – Apr. 2009
Instructor: Alex Buchel, Perimeter Institute and University of Western Ontario

Integrability and planar AdS/CFT,
Feb. – Mar. 2009
Instructor: Pedro Vieira, Max Planck Institute for Gravitational Physics

RESEARCH EVENTS

PI BY THE NUMBERS

In 2008-09, PI hosted over 900 researchers at:

- 18 conferences
- 172 seminars
- 27 colloquia

Over 1290 scientific talks have taken place at PI to date. Talks are available on the Perimeter Institute Recorded Seminar Archive (PIRSA) at: http://pirsa.org

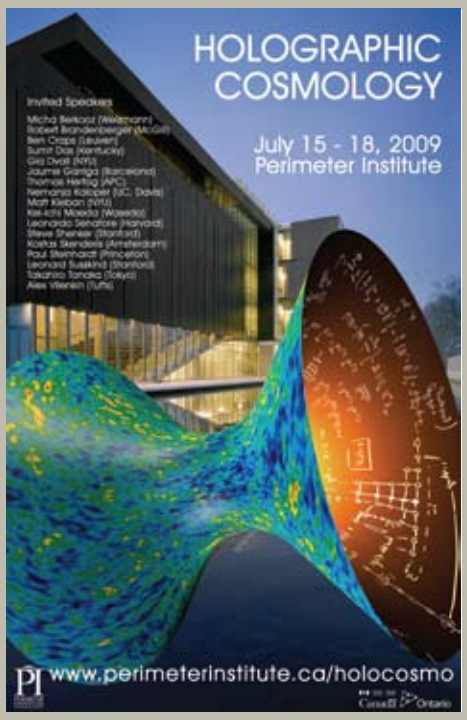
CONFERENCES, WORKSHOPS AND SUMMER SCHOOLS

In addition to resident and visiting scientists contemplating and calculating their ideas in a supportive, but often solitary atmosphere, the Institute recognizes that a lively program of high-level conferences and workshops is essential to maintaining a dynamic research centre. Topics of workshops and conferences are chosen strategically by identifying new areas of exceptional promise where an event is likely to have a significant outcome. PI has become known for its workshops and conferences in cutting edge fields. (For a complete list of all conferences held in 2008-09, see Appendices.)

COLLOQUIA AND SEMINARS

Perimeter hosts eight active weekly seminar series, fostering collaborations and sharing knowledge with leading researchers around the globe. To date, almost 1300 scientific talks have taken place at PI and since 2002 most have been recorded and made freely available via the Perimeter Institute Recorded Seminar Archive (PIRSA). Speakers at the nearly 200 seminars and colloquia over the past year included Sir Michael Berry (University of Bristol), Xiao-Gang Wen (MIT), Raphael Bousso (University of California), Ramesh Narayan (Harvard), Leo Kadanoff (University of Chicago), Abhay Ashtekar (Pennsylvania State University), and many others. PI also participates in the International Loop Quantum Gravity Seminar, which virtually brings together researchers from 15 quantum gravity groups across Europe, North America, and South America each week.

Exploring the Cosmological Frontiers: Perimeter hosted the 7th annual Canadian Summer School for Theoretical Physics, jointly organized with the Asia Pacific Center for Theoretical Physics and the Center for Quantum SpaceTime. Over 50 graduate students from around the world attended courses on Early Universe Cosmology, Dark Matter and Gravitational Wave Astronomy.



BRINGING THE SCIENTIFIC COMMUNITY TOGETHER

Holography is one of the most recent exciting developments in theoretical physics, based on the principle that the description of a volume of space can be thought of as encoded on a boundary to the region—imagine that the entire contents inside a ball are encoded on its surface. It implies that the entire universe may be seen as a two-dimensional information structure "painted" on the cosmological horizon. This four-week workshop was the first to be held on this topic worldwide, and brought together leading researchers working in cosmology, superstring theory and quantum gravity to understand and develop the implications of holography for early universe cosmology.

RESEARCH LINKAGES

Director Neil Turok with University of Waterloo President David Johnston.

Perimeter hosted 310 short-term scientific visitors and 19 long-term visitors in 2008-09.

VISITOR PROGRAM

An active scientific visitor program enables PI researchers to stay abreast of new developments and to spark new interactions. During the past year, Perimeter hosted 329 scientific visitors, 19 of whom chose Perimeter as their research destination during longer-term leaves from their home universities. Just a few visitors of note at Perimeter over the past year included quantum computing pioneer David Cory (MIT), cosmologist Robert Brout (Université Libre de Bruxelles), particle physicist Victor Novikov (ITEP Moscow), and superstring theorist Herman Verlinde (Princeton).

Visiting scientist Kristina Giesel of the Nordic Institute for Theoretical Physics (NORDITA)

AFFILIATES

Affiliates are select faculty members at Canadian universities who are invited for regular informal visits to Perimeter Institute for scientific collaboration and the opportunity to be involved in the Institute's research activities. The goals of the Affiliate program are to foster interaction between PI and Canadian universities, to play a role in strengthening the Canadian physics research community, and to broaden the base of research at PI by fostering interaction with Affiliates working in fields of research related to PI's. In 2008-09, 25 new Affiliate Members were added, and there are now 91 Affiliates drawn from universities across Canada.

NATIONAL LINKAGES

Perimeter Institute aims to serve as a focal point for theoretical physics in Canada. Memoranda of Understanding have been signed with nearly 30 Canadian universities and institutes, and PI cooperates with its academic partners via cross-appointments, adjunct appointments, joint postdoctoral fellowships, graduate training, and numerous joint research events, such as the popular "PI-CITA days" held twice annually.

In addition to our longstanding and synergistic relationship with the nearby Institute for Quantum Computing (IQC) at the University of Waterloo, Perimeter has forged strong ties with the Canadian Institute for Theoretical Astrophysics (CITA), Canada's world-class centre in theoretical astrophysics.

PI also has productive relationships with the Canadian Institute for Advanced Research (CIFAR), the Fields Institute, the Institute for Particle Physics (IPP), the Centre de Recherches Mathématiques (CRM), the Pacific Institute for Mathematical Sciences (PIMS), Mathematics of Information Technology and Complex Systems research networks (MITACS) and the Shared Hierarchical Computing Network (SHARCNET).

Visiting scientist Amihay Hanany (Imperial College) and PI faculty member Laurent Freidel.

UNITING QUANTUM FOUNDATIONS FROM TOP TO BOTTOM

Both Canada and Australia have emerged as hubs of scientific activity in quantum foundations and the closely related areas of quantum information and quantum computing. In 2008, researchers at Perimeter and several Australian universities joined forces to form PIAF, the Perimeter Institute — Australia Foundations Collaboration to promote progress in quantum foundations. PIAF will fund four new postdoctoral training positions, with fellows spending part of their time in Australia and part of their time at PI; a scientific exchange program; and conferences to accelerate research. In September 2008, PIAF held its first major conference, "The Clock and the Quantum: Time and Quantum Foundations," featuring Sir Roger Penrose, Bill Unruh, and Gerard Milburn, and conducted a joint workshop on "Categories, Quanta, Concepts" in June 2009.

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Griffith UNIVERSITY

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

THE UNIVERSITY OF SYDNEY

FAST FACT

- Nearly 1300 PI seminars, talks and colloquia are archived on PIRSA.

PIRSA
PERIMETER INSTITUTE
RECORDED SEMINAR ARCHIVE

- Researchers and students around the world can view scientific events at PI as they happen via PIRSA, the Perimeter Institute Recorded Seminar Archive. With recordings dating from 2002, and a new user interface launched in 2008, PIRSA provides a permanent, free, searchable, and citable online archive of video recorded seminars, conferences, workshops, and courses. Playback is available in Windows and Flash formats, with MP3 audio files and PDFs of slides and supporting materials from talks. PIRSA is becoming a digital focal point for the international scientific community— in the past year, over 33,000 unique visitors from 136 countries accessed PIRSA over 63,000 times.
  See http://pirsa.org

INTERNATIONAL LINKAGES

In early 2009, Perimeter Institute and the Centre for Theoretical Cosmology (CTC) at the University of Cambridge concluded an agreement that will encourage collaborative research, and provide for faculty members and postdoctoral fellows to conduct regular scientific exchange visits up to several months. Additional agreements are in process with the Princeton Center for Theoretical Science, the Institute for the Physics and Mathematics of the Universe (IPMU) in Japan, the Stanford Center for Theoretical Physics and CERN's Theory Division.

To increase contact between theory and experiment, PI is expanding its engagement with national and international experimental and observational centres such as the LHC, SNOLAB, and the Planck satellite; VISTA, VLT, the SKA and other giant observatories; and LIGO, LISA and other gravitational wave detectors. By encouraging PI postdoctoral fellows and other researchers to visit these facilities and collaborate with observers and experimentalists, PI can help to stimulate new experimental and observational tests of fundamental theory.

PERIMETER INSTITUTE
FOR THEORETICAL PHYSICS

AWARDS

Freddy Cachazo accepts the 2009 Gribov Medal of the European Physical Society.

THE INSTITUTE'S RESEARCHERS ARE RECIPIENTS of many awards and honours. Highlights from the last year appear below:

- Faculty member Freddy Cachazo was awarded the Gribov Medal from the European Physical Society (EPS) "for his research with others that led to significant simplifications in the calculation of scattering amplitudes in both gauge theories and gravity ones."
- Associate Faculty members Raymond Laflamme and Cliff Burgess were inducted as Fellows of the Royal Society, the highest scholarly accolade awarded in Canada.
- Faculty member Jaume Gomis received a 2009 Early Researcher Award from the Ministry of Research and Innovation of Ontario.
- Faculty member Lee Smolin was awarded the 2009 Klopsteg Memorial Award from the American Association of Physics Teachers (AAPT) for "extraordinary accomplishments in communicating the excitement of contemporary physics to the general public."
- Work by Robert Spekkens *et al.* was selected for inclusion in the *New Journal of Physics'* "Best of 2008" issue.
- Faculty member Fotini Markopoulou won a prize from the Foundational Questions Institute (FQXi) for her essay "Space does not exist, so time can."
- Chris Fuchs was elected Chair of the American Physical Society's Topical Group on Quantum Information (to begin 2011).
- Postdoctoral fellow Sarah Croke won the 2008 QEP group thesis prize from the Institute of Physics (UK).

OUTREACH

EDUCATIONAL OUTREACH IS A CORE COMPONENT of Perimeter's mission and has been since its inception. Scientific outreach can do much to nurture a culture of innovation from the ground up, by conveying scientific principles in understandable terms, by helping to develop reasoning and problem solving skills, and by demonstrating the links between basic research and innovation. The Institute's unique and award-winning outreach programs are not only having an impact across Canada, they have become an international model for sharing the excitement and importance of basic research, and the power of theoretical physics.

PI's approach is to develop and deploy powerful content that can scale up the number of people reached over time. Activities are tailored for specific audiences involving students, teachers and the general public, and almost all content is made freely available online to share the joys of research and discovery.

FAST FACTS

Since 2000 PI Outreach has...

- Held 60 on-location workshops for over 2000 teachers across Canada and beyond
- Hosted 10 "EinsteinPlus Teacher Workshops" for 400 educators from Canada and 18 other countries
- Distributed over 4200 "Perimeter Explorations" in-class resources (via hard kit and web downloads) featuring video and teacher guide.

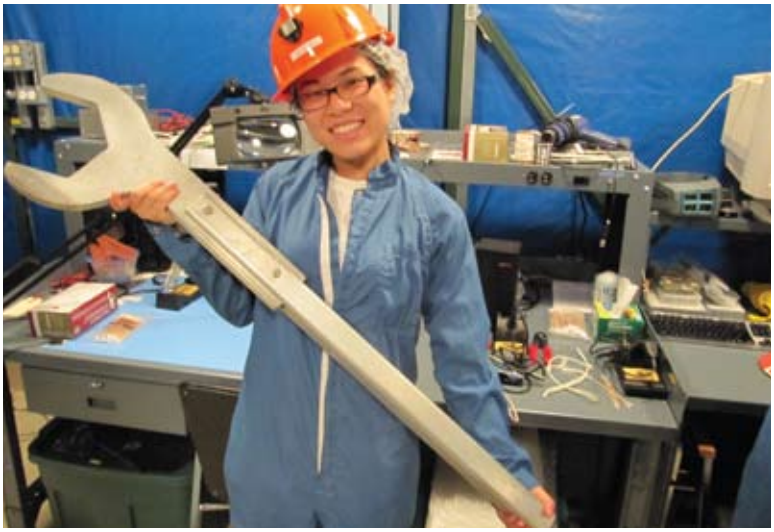
INSPIRING YOUNG PEOPLE

Perimeter Outreach initiatives for students involve the delivery of inspirational content to junior high school grades to get youth excited about physics, and more detailed content on modern physics for senior high school students.

In Physica Phantastica, Outreach staff members provide accessible content in entertaining ways in classrooms and at science fairs across Canada. Presentations such as "The Physics of Innovation" feature images and animations to make abstract ideas come alive, and have helped thousands of students see the connections between fundamental knowledge and technological innovations.

Senior students enjoy presentations involving much richer multimedia content (see "Perimeter Explorations" below) covering topics in modern physics, from the quantum to the cosmos. Students who are actively considering a future career in research can ramp up their interest by attending the International Summer School for Young Physicists (ISSYP). The annual camps attract talented young people from across Canada and around the world, providing advanced lessons on modern physics, mentoring sessions with researchers and an introduction to experimental physics through lab tours at the Institute for Quantum Computing and SNOLAB.

Outside the classroom, PI offers a variety of web content, ranging from a series of one-minute "Alice & Bob in Wonderland" animations that capture the imagination, to "Meet a Scientist" interview clips that share the stories of eminent researchers. Interactive online resources also include the "Power of Ideas" section on how discoveries and unifications in physics have advanced technology. At a more advanced level, the "Virtual ISSYP" contains some of the best content from past summer student camps, and is dramatically scaling up the program's reach across Canada and around the world.



ISSYP students got a taste of cutting-edge experimental physics at the Sudbury Neutrino Observatory (SNOLAB).

PARTNERING WITH TEACHERS

Programming for teachers involves the creation of in-class resources combined with face-to-face training that, over time, is giving rise to a PI Teacher Network across Canada and beyond.

"Perimeter Explorations" are comprehensive in-class modules on topics in modern physics that consist of 30-minute videos, teacher manuals and student worksheets. Distributed at no cost to teachers, the modules convey complex ideas in highly visual and hands-on ways. Putting these toolkits in the hands of teachers reaches many more students than Outreach staff members could on their own. Distribution efforts and polling feedback indicate that "The Mystery of Dark Matter"

"ISSYP was the most intense, valuable and enjoyable learning experience I have ever had. I have gained a deeper understanding of what physics is and, as I begin my physics degree at Oxford University, I feel inspired to delve deeper into these fascinating topics. Combined with the opportunity to meet great people from all over the world with different backgrounds, but united by a passion for physics, this was a truly unforgettable two weeks."

– David Lloyd, St Clement Danes School, Hertfordshire, UK

FAST FACTS

Over 400 students from across Canada and 25 countries around the world are ISSYP alumni. To learn more, go to: www.issyp.ca

"This is my second year at EinsteinPlus—I couldn't get enough! When I came, I had no idea about the cutting edge of physics. This program bridges the gap between the classical physics that's in most of our curriculums with the cutting edge of physics. I was part of a peer network afterwards and did two workshops last February... Being able to share that knowledge with other teachers is great."

– EinsteinPlus teacher Karen Kennedy-Allin, Weyburn Comprehensive School, Weyburn, Saskatchewan

Teachers at EinsteinPlus learning how to construct a scientific model.

and "The Challenge of Quantum Reality" (now in production), are on track to reach over 100,000 students annually—impact that will continue year over year as each module is re-used.

The Institute also provides face-to-face instruction for educators through on-location workshops at teacher conferences across Canada each year. In addition, every summer PI hosts the "EinsteinPlus Teacher Workshop," teaching highly motivated educators how to effectively convey key concepts in modern physics. The growing "PI Teacher Network" is made up of EinsteinPlus alumni who return home to conduct remote workshops for fellow educators. This successful "training the trainer" approach is scaling up the impact of EinsteinPlus to hundreds of teachers annually. In this past year, PI Outreach staff and PI Teacher Network members reached educators in Vancouver, Calgary, Edmonton, Winnipeg, Ottawa, Toronto, Kingston, Waterloo Region, Montreal, and Halifax. The presentations not only inspired and equipped larger numbers of high school science teachers with PI tools and techniques, they also served as a feedback loop for new resources in development.

David Fish, high school teacher and EinsteinPlus presenter.

A hundred Einsteins assembled for the launch of EinsteinFest.

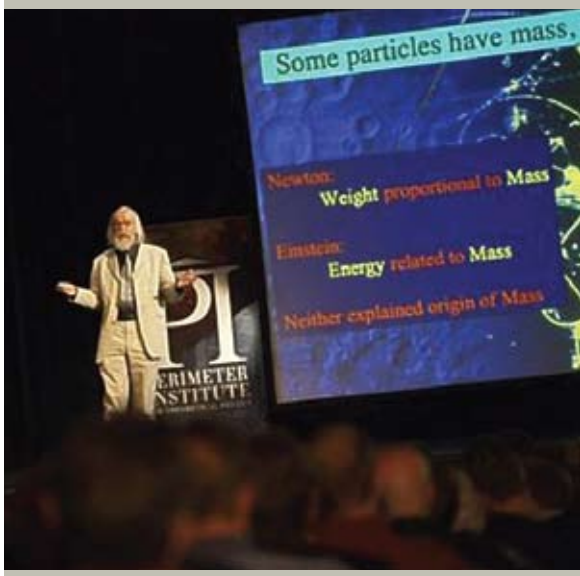
GENERAL PUBLIC PROGRAMMING

Perhaps the best known Outreach activity is the popular "PI Public Lecture Series," which attracts over 600 people to each scientific lecture. The talks are viewed by wider audiences on-demand over Perimeter's website and through a wide range of television and radio playback agreements that have, over time, included partnerships with TVO, Rogers Television, Discovery Channel and CBC Radio. A DVD containing all-time favourite public lectures is being prepared for educational organizations and libraries around the world.

Special events take place from time to time, such as "EinsteinFest" in 2005 that attracted over 28,000 to PI over a span of just three weeks. PI is presently planning its tenth anniversary celebration, to be known as the "Quantum to Cosmos: Ideas for the Future" festival. This public event will provide a wide range of scientific activities for all ages and aims to reach hundreds of thousands on-site, online and on television. The event will also see the Canadian premiere of Perimeter Institute's "The Quantum Tamers: Revealing Our Weird & Wired Future," which is near completion. This stylish television documentary will share the mysteries of quantum physics and the potential of quantum information to reshape our thinking and our technologies.

Perimeter Institute also shares the wider joy of creative inquiry with the surrounding community through "Event Horizons," which presents top quality concerts, art talks and cultural performances in the unique atmosphere of Perimeter Institute.

Yo-Yo Ma and the Silk Road Ensemble performing at Perimeter Institute.



A TRADITION OF ENGAGING TALKS ON SCIENCE

- PI has held over 125 monthly Public Lectures and special talks for capacity live audiences that are rebroadcast on TV and available on PI's website.
- Lecturers in the 2008-09 Public Lecture season included Brian Schmidt (Australian National University), Leonard Mlodinow (Caltech), Brian Greene (Columbia University), Frank Wilczek (MIT), Ben Schumacher (Kenyon College), Rob Cook (Pixar Animation), Roger Penrose (University of Oxford), and Patrick Hayden (McGill University)

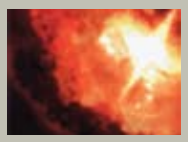
IT'S ALL ONLINE

Most PI Outreach programming is freely available on our website, including ISSYP lectures, Perimeter Explorations, Meet a Scientist, the Power of Ideas, and much more. See it all at: www.perimeterinstitute.ca

Alice & Bob in Wonderland

Are you ready to question reality? Dive into these mind-warping adventures with Alice & Bob as they wonder about our amazing universe.

Black Hole Science Cafés



Step into the exciting world of research in these informal discussions with researchers and members of the Outreach team.

Meet a Scientist Video Interviews

What makes a scientist tick? Find out by watching PI's new series of video interviews with researchers from around the world.

INTERNATIONAL RESOURCE

Although PI Outreach is largely geared toward serving youth, teachers and the general public across Canada, the majority of tools, techniques and presentations are shared via the web with online audiences around the world. The PI Public Lecture series is watched by many online, and the Perimeter Explorations in-class modules can be downloaded from PI's website. The growth of the Internet has opened up vast, cost-effective channels to people and organizations around the globe, which PI continues to explore. In addition, the PI Outreach team coordinates face-to-face activities at select, international gatherings in partnership with leading education organizations. This year, PI Outreach conducted a mini-EinsteinPlus Teacher Camp for European science teachers in Switzerland, in conjunction with CERN, in addition to presentations to the UK Institute of Physics teacher network and the American Association of Physics Teachers.

PI also engages with the media when requested. In June–July 2009, PI Outreach provided three professional development sessions for reporters at the World Federation of Science Journalists (WFSJ) conference in London, UK, which is the largest international gathering of science media in the world. The sessions covered the topics of quantum information, cosmology and philanthropy in science.

Teachers participating in PI's on-location workshop during the CERN High School Teachers Program.

FACILITY

PI'S MAIN FACILITY IS LOCATED AT THE SOUTHERN EDGE OF SILVER LAKE in the heart of Waterloo, Ontario. Researchers can step out PI's door and enjoy contemplative walks through Waterloo Park, or stroll to the restaurants, shops and cafés in Uptown Waterloo. The University of Waterloo and Wilfrid Laurier University are both located within a 10-minute walk.

The Montreal architectural firm of Saucier + Perrotte designed Perimeter's current 65,000 square foot building with extensive input from scientists to create a unique facility that would foster productive research. There are three types of space throughout: quiet offices with an abundance of natural light to encourage contemplation; highly interactive "think" spaces where researchers can spontaneously cluster; and formal areas for traditional activities, including a two-storey library, and lecture rooms and theatre spaces that are wired to record activities for archiving on the Perimeter Institute Recorded Seminar Archive.

STEPHEN HAWKING CENTRE AT PERIMETER INSTITUTE

To accommodate the growth of PI's scientific community and the new PSI research training course, Perimeter has embarked on construction of the Stephen Hawking Centre at Perimeter Institute, a 55,000 square foot addition to the existing facility.

Governor General Award-winning firm Teeple Architects has designed the expansion such that it will nearly double PI's current research space, yet still retain the productive research environment and amenities featured in the original structure. The addition will include over 80 research spaces and an array of informal and formal areas for collaborations, seminars and workshops. When complete, the building will accommodate up to 250 researchers and students, as well as state of the art IT infrastructure able to support visualization and analysis of complex calculations, and remote collaboration with international colleagues to reduce the need for carbon intensive travel. Construction commenced in July 2009 and is expected to be completed in 2011.

FINANCIALS

MANAGEMENT DISCUSSION AND ANALYSIS OF FINANCIAL RESULTS

RESULTS OF OPERATIONS

Despite the strained economy of the past year PI's objective of continued growth was reflected through a 17% increase in research and outreach expenditures from the previous year. New initiatives and programs such as the Distinguished Research Chairs and Perimeter Scholars International, as well as continued success in researcher recruitment, were the main factors contributing to increased expenditures.

Of the total operational expenditures, approximately 80% were disbursed in support of the scientific activities undertaken at PI, with $9.3 million funding various scientific programs and initiatives and a $3.1 million investment in outreach and education through a varied portfolio of programs and products.

Research expenditures comprised a wide array of expenses with the primary contributing expenditure being researcher compensation, accounting for 76% of the cost in this category. The remainder of research expenditures was devoted to supporting programs designed to foster scientific interaction and collaboration such as the visitor, conference and workshop programs.

Research training accounted for $333,000, used primarily to support the development of the Perimeter Scholars International master's training course. The remaining 22% of operational expenditures was devoted to the Indirect Research and Operations of the Institute including facilities, administration, development and information technology. Of the $3.7 million in Indirect Research and Operation expenditures, $1.2 million pertains to administration costs incurred to support the Institute.

Funds to provide for these operational expenditures were derived from two main sources: public grants and private donations. The 2008-09 fiscal year demonstrated the continued support of our generous donors with $40 million in private contributions. Concurrently, multi-year commitments from federal and provincial governments remained in place, providing for funding of research and outreach activities.

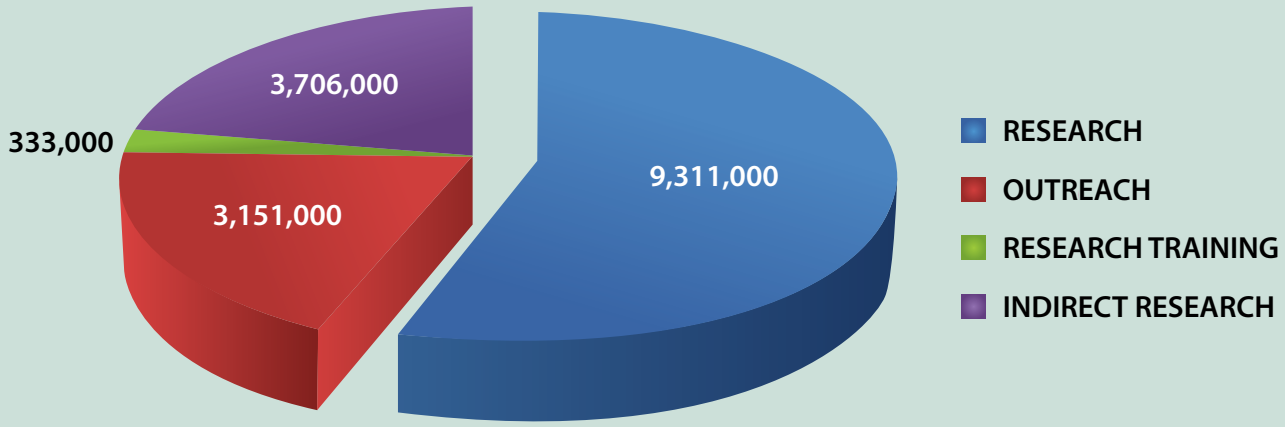
Recognition of public funding in the financial statements is identified as grant revenue and, in accordance with our revenue recognition policy, is recorded in the year the funds are received or receivable. Accordingly, during fiscal 2007-08, two annual payments were received and recorded as revenue in fiscal 2007-08. Disclosure of the revenue recognition policy avoids incorrect interpretations when comparing grant revenue of 2008-09 to that of the prior year.

BALANCE SHEET

As is the case with many other organizations, PI has not been immune to the worldwide financial crisis, resulting in the investment portfolio experiencing a loss of 21.9%. The amount of the loss is in keeping with the losses suffered by North American market indexes over the same period (the Dow Jones Industrial Average and the S&P/TSX, which lost 19.4% and 20.6% respectively). A number of prominent Canadian public not-for-profit

OPERATING EXPENDITURE SUMMARY

FOR THE YEAR ENDED JULY 31, 2009



organizations fared much worse during this period, incurring losses in some cases that were as high as 31%. Despite the worldwide economic downturn, PI withstood the impact and maintained an exceptionally strong balance sheet.

The balance sheet reflects a strong working capital position, and affords PI continuing opportunities to expand and improve operations. While bank indebtedness was incurred during the last quarter of the fiscal year, the utilization of this credit was strategically deployed as a temporary measure while consciously targeting optimization of working capital.

RISKS AND UNCERTAINTIES

Perimeter Institute exists through a cooperative and highly successful public-private partnership that provides for ongoing operations while safeguarding future opportunities. Perimeter Institute continues to be an innovative example of a public-private partnership, uniting government and philanthropists in a common quest to secure the transformative potential of scientific research in Canada.

Following the establishment of the Institute in 2000 with $120 million in personal commitments from Mike Lazaridis ($100 million) and fellow RIM executives ($10 million each), contributions totaling over $57 million followed from public sources involving all levels of government. Illustrating a strong resolve by public funders for Perimeter's success, in 2006 and 2007 the governments of Ontario and Canada renewed and increased their commitment to the Institute by contributing $50 million each for expanded research and outreach operations over the next five years. These were matched by further donations from Mr. Lazaridis of $50 million in 2008, and $20 million in 2009, bringing his total contribution to $170 million.

In 2008-09, the Government of Canada and the Province of Ontario committed $20 million toward the expansion of Perimeter's award-winning facility. A further $20 million in private contributions have been secured.

During fiscal 2009, multi-year commitments from federal and provincial governments remained in place, providing for funding which will continue through to March 2012. While this public funding removes uncertainty by providing for the short term, PI is actively seeking to continue this successful public-private partnership to support the long-term vision of the Institute.

Public partners finance core research operations and outreach activities and, in keeping with individual grant requirements, receive ongoing reports on research productivity and outreach impact, in addition to yearly audited financial statements. Private funds are protected in an endowment designed to maximize growth and minimize risk in order to contribute to the strongest possible long-term financial health of the Institute. Although the endowment is invested in a diversified portfolio and managed by an active investment committee, market values do vary over time.

AUDITORS' REPORT

To the Directors of Perimeter Institute

The accompanying summarized statement of financial position and summarized statement of operations and changes in fund balances are derived from the complete financial statements of Perimeter Institute as at July 31, 2009 and for the year then ended on which we expressed an opinion without reservation in our report dated September 30, 2009. The fair summarization of the complete financial statements is the responsibility of management. Our responsibility, in accordance with the applicable Assurance Guideline of The Canadian Institute of Chartered Accountants, is to report on the summarized financial statements.

In our opinion, the accompanying financial statements fairly summarize, in all material respects, the related complete financial statements in accordance with the criteria described in the Guideline referred to above.

These summarized financial statements do not contain all the disclosures required by Canadian generally accepted accounting principles. Readers are cautioned that these statements may not be appropriate for their purposes. For more information on the entity's financial position, results or operations and cash flows, reference should be made to the related complete financial statements.

Zeifmans LLP

Toronto, Ontario
September 30, 2009

Chartered Accountants
Licensed Public Accountants

Perimeter Institute

(Incorporated Under the Laws of Canada Without Share Capital)

SUMMARIZED STATEMENT OF FINANCIAL POSITION AS AT JULY 31, 2009

Assets

	2009 TOTAL IN $	2008 TOTAL IN $
CURRENT ASSETS:		
Cash and cash equivalents	**4,885,927**	24,641,307
Investments	**207,877,993**	214,638,903
Government grants receivable	**5,072,000**	—
Other current assets	**1,476,919**	310,988
	219,312,839	239,591,198
Other receivable	**57,024**	78,422
Property and equipment	**28,656,950**	28,132,045
TOTAL ASSETS	**$248,026,813**	$267,801,665

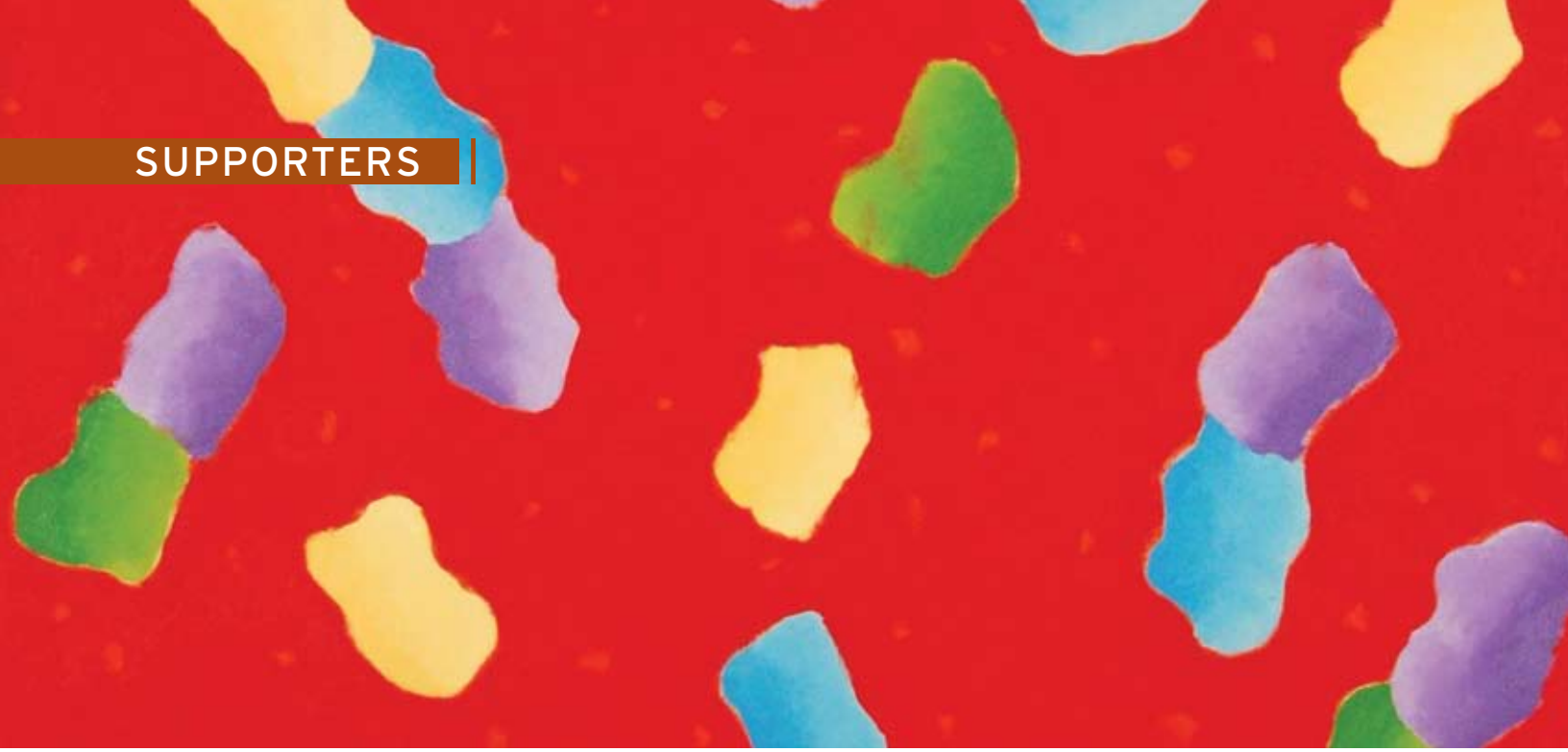
Liabilities and Fund Balances

CURRENT LIABILITIES:		
Bank overdraft	**615,232**	—
Bank indebtedness	**3,275,000**	—
Accounts payable and other current liabilities	**1,959,209**	3,718,005
	5,849,441	3,718,005
Obligation under capital lease	—	9,482
TOTAL LIABILITIES	**5,849,441**	3,727,487
FUND BALANCES:		
Invested in capital assets	**28,069,304**	27,660,028
Externally restricted	**131,019,937**	107,051,771
Internally restricted	**82,903,934**	121,660,474
Unrestricted	**184,197**	7,701,905
TOTAL FUND BALANCES	**242,177,372**	264,074,178
	$248,026,813	$267,801,665

Perimeter Institute

SUMMARIZED STATEMENT OF OPERATIONS AND CHANGES IN FUND BALANCES
FOR THE YEAR ENDED JULY 31, 2009

	2009 TOTAL IN $	2008 TOTAL IN $
REVENUE		
Donations	**40,087,038**	50,005,164
Grants	**5,713,200**	21,290,448
	45,800,238	71,295,612
EXPENDITURES		
Research	**9,643,807**	8,778,288
Outreach	**3,151,042**	2,001,465
Indirect Research and Operations	**3,706,447**	3,354,712
TOTAL OPERATING EXPENDITURES	**$16,501,296**	$14,134,465
Excess of revenue over expenses (expenses over revenue) before investment income and amortization	**29,298,942**	57,161,147
Amortization	**(1,763,308)**	(1,728,000)
Investment loss	**(49,432,440)**	(2,036,427)
Excess of revenue over expenses (expenses over revenue)	**(21,896,806)**	53,396,720
Fund balances, beginning of year	**264,074,178**	210,677,458
FUND BALANCES, END OF YEAR	**$242,177,372**	$264,074,178



SUPPORTERS

Detail of Painting L (B180), Gershon Iskovitz, 1983.

PERIMETER INSTITUTE WISHES TO THANK the following federal, provincial and municipal government representatives for recognizing the need to invest in foundational scientific research and outreach:

Government of Canada
The Right Honourable Stephen Harper, Prime Minister
The Honourable Tony Clement, Minister, Industry Canada
The Honourable Gary Goodyear, Minister of State (Science and Technology), Industry Canada

Government of Ontario
The Honourable Dalton McGuinty, Premier
The Honourable John Milloy, Minister, Research and Innovation and Minister, Training, Colleges and Universities
The Honourable John Wilkinson, Minister, Revenue (former Minister, Research and Innovation)

City of Waterloo
Mayor Brenda Halloran and the Waterloo City Council

PERIMETER INSTITUTE WISHES TO THANK the following individuals and organizations for their generous support over the last year:

Mike Lazaridis, $20 million
Doug Fregin, $20 million
Industry Canada, $13.5 million
The Canada Foundation for Innovation, $10.4 million (commitment for facility expansion)
The Ministry of Research and Innovation, $10.4 million (commitment for facility expansion)

PI also thanks the following past supporters:

Government of Canada

Industry Canada, $50 million (commitment 2007 - 2012)
Natural Sciences and Engineering Research Council, $25 million (2002 - 2006)
Canada Foundation for Innovation, $7.3 million (2002, 2004)
Promoscience, $59,990 (2005), $50,700 (2006)

Government of Ontario

Ministry of Research and Innovation, $50 million (2006), $50,000 (2008)
Ministry of Economic Development and Trade, $15 million (2002), $150,000 (2005)
Ontario Research and Development Challenge Fund, $5.95 million grant shared equally with the Institute for Quantum Computing (2002)
Ontario Innovation Trust, $5.6 million (2002)
Ontario Research Performance Fund, $120,000 (2005)

City of Waterloo

The City of Waterloo, land donation and site development considerations (ongoing)

Private Donors

Over $1,000,000

Mike Lazaridis, $100 million founding donation (2000), $50 million (2008)
Jim Balsillie, $10 million (2000)
Doug Fregin, $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

Harry and Angela Brodie (2006)
Dennis Kavelman (2003)

Up to $5,000

Robin Korthals (2004 - 08)
Bruce North (2001)
Dare Foods (2006)
Canadian Federation of University Women, Kitchener-Waterloo (2005)
Dr. Alex Maznytsya (2005)

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

Funding for EinsteinFest Outreach Programming (2005)

The American Express Philanthropic Program
Mike Lazaridis
The Ontario Cultural Attractions Fund
The Ontario Trillium Foundation
The Kitchener and Waterloo Community Foundation
The Region of Waterloo Arts Fund
Cowan Wright Beauchamp
Fibretech
Zeifman and Company, LLP
Goodman and Carr
Sleeman
Cober Printing
Neil Bresolin
Christopher Duda
Jennifer Scully-Lerner
Goldman Sachs

All figures in Canadian dollars.

GOVERNANCE

PERIMETER INSTITUTE IS AN INDEPENDENT NOT-FOR-PROFIT CORPORATION governed by a volunteer Board of Directors drawn from the private sector and academic community. The Board is the final authority on all matters related to the general structure and development of the Institute.

The Board of Directors is supported in fulfilling its fiduciary responsibilities with respect to financial management of the Institute through two Board committees. The Investment Committee is responsible for overseeing the investment and management of funds received according to a Board-approved investment policy that outlines guidelines, standards and procedures for the prudent investment and management of funds. The Finance and Audit Committee is responsible for overseeing Perimeter Institute's policies, processes and activities in the areas of accounting, and internal controls, risk management, auditing and financial reporting. The Board also forms other committees as required to assist it in discharging its duties.

Reporting to the Board of Directors, the Institute's Director is a pre-eminent scientist responsible for developing and implementing the overall strategic direction of the Institute. The Chief Operating Officer (COO) reports to the Director and is in charge of day-to-day operations. Support of the COO is provided by a team of senior administrative staff.

The Institute's resident scientists play an active role in scientific operational issues via participation on various committees in charge of scientific programs, and report to the Director. The Scientific Advisory Committee (SAC) is an integral oversight body, created to assist the Board of Directors and the Institute Director in ensuring a high standard of scientific excellence.

BOARD OF DIRECTORS

MIKE LAZARIDIS, O.C., Chair, is Founder, President and Co-CEO of Research In Motion Limited (RIM). A visionary, innovator and engineer of extraordinary talent, he is the recipient of many technology and business awards, and the Order of Canada. At RIM, Mr. Lazaridis leads R&D, product strategy and manufacturing for the world-renowned BlackBerry®.

DONALD W. CAMPBELL is the senior strategy advisor at Davis LLP. Prior to joining Davis, he 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 President of Sentinel Associates Limited. He is a past Senior Vice-President of Noranda Inc. and former Director of numerous organizations including Empire Life, The Bank of Nova Scotia, University of Toronto Press and Dominion of Canada General Insurance Company. He is currently a Director of Scotia Investments; a member of the Operating Board of Directors of the Centre for International Governance Innovation; an Honorary Director of The Bank of Nova Scotia; and a Director Emeritus of Research in Motion.

COSIMO FIORENZA, Vice Chair, is the Vice-President and General Counsel of the Infinite Potential Group. In addition, he is a director of, and very involved in, a number of public and private non-profit and charitable institutions. Mr. Fiorenza is a member of the Law Society of Upper Canada, the Canadian Bar Association and the Canadian Tax Foundation.

PETER GODSOE has been a Director of Rogers Communications Inc. since October 2003 and Lead Director since March 2006. He has served as Chairman (1995), Chief Executive Officer (1993), President and Chief Operating Officer (1992) and Vice Chairman (1982) of The Bank of Nova Scotia. Mr. Godsoe holds a B.Sc. (Mathematics and Physics) from the University of Toronto and an M.B.A. from Harvard Business School.

JOHN REID is a Senior Partner with KPMG responsible for managing the Ontario Region. He mainly focuses on mergers and acquisitions, high technology and health care. Mr. Reid 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 is Professor Emeritus in Electric Engineering at the University of Waterloo. Among other honours, he was Secretary and Coordinator of the G10 group of leading Canadian research universities, President of the Canadian Association for Graduate Studies, Chairman of the Ontario Council on Graduate Studies, and former Dean of Graduate Studies at the University of Waterloo.

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

SCIENTIFIC ADVISORY COMMITTEE (SAC)

The SAC, comprised of eminent international scientists, offers independent scrutiny and advice, helping to ensure PI's activities meet high standards of scientific excellence. Members serve three-year terms and participate in an annual meeting held at the Institute to thoroughly review PI's scientific, educational and outreach programs, after which the Chair writes a report to the Board of Directors and the Institute Director.

GERARD MILBURN, Chair, University of Queensland (joined 2009). 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 their potential for a general audience.

ABHAY ASHTEKAR, Pennsylvania State University (joined 2008). Professor Ashtekar is 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. He has written a number of descriptions of loop quantum gravity that are accessible to non-physicists.

SIR MICHAEL BERRY, University of Bristol (joined 2009) Professor Berry is a mathematical physicist at the University of Bristol. He is known for discovery of the Berry phase, a phenomenon observed in quantum mechanics and optics. He specializes in semiclassical physics (asymptotic physics, quantum chaos), applied to wave phenomena in quantum mechanics and other areas such as optics. He was elected a fellow of the Royal Society of London in 1982 and knighted in 1996. He has won numerous awards, including the Wolf Prize in 1998 and London Mathematical Society's Polya Prize in 2005.

GERARD 'T HOOFT, Utrecht University (joined 2008)
Professor 't Hooft's research focuses on gauge theories in elementary particle physics, quantum gravity and black holes, and fundamental aspects of quantum physics. In addition to the Ben Franklin Medal, Professor 't Hooft's contributions to science have been recognized with many awards, including the 1999 Nobel Prize in Physics, with the citation "for elucidating the quantum structure of electroweak interactions in physics."

IGOR R. KLEBANOV, Princeton University (joined 2007)
Professor Klebanov's research has touched on many aspects of theoretical physics and is presently centered on relations between superstring theory and quantum field theory. He is currently 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.

MICHAEL PESKIN, Stanford Linear Accelerator Center (joined 2008)
Professor Peskin's research interests include all aspects of theoretical elementary particle physics, but particularly the nature of new elementary particles and forces that will be discovered at the coming generation of proton and electron colliders. He was a Junior Fellow at the Harvard Society of Fellows from 1977-80 and was elected to the American Academy of Arts and Sciences in 2000. He is co-author of a popular textbook on quantum field theory.

JOHN PRESKILL, California Institute of Technology (joined 2009)
Professor Preskill is John MacArthur Professor of Theoretical Physics at the California Institute of Technology and Director of the Institute for Quantum Information, also at Caltech. His work focuses on mathematical issues related to quantum computation and quantum information theory. In addition to his numerous awards, he was elected a fellow of the American Physical Society in 1991 and named the Morris Loeb Lecturer at Harvard University in 2006.

DAVID SPERGEL, Princeton University (joined 2009)
Professor Spergel is Charles Young Professor of Astronomy at Princeton, as well as the Chair of the Department of Astrophysical Sciences. He is known for his work on the Wilkinson Microwave Anisotropy Probe mission. Professor Spergel is a MacArthur Fellow as well as a member of the US National Academy of Sciences. He is currently the chair of the Astrophysics Subcommittee of the NASA Advisory Council.

FOUNDING EXECUTIVE DIRECTOR

Howard Burton [1999-2007]
Perimeter Institute recognizes the outstanding contribution of Founding Executive Director, Dr. Howard Burton, who played such a critical role in establishing and guiding the Institute during its first eight years.

EMERITUS SCIENTIFIC ADVISORY COMMITTEE

Ian Affleck [2001-2004]
University of British Columbia

Artur Ekert [2001-2008]
University of Cambridge

James Hartle [2001-2003]
University of California - Santa Barbara

Chris Isham [2001-2005]
Imperial College

Cecilia Jarlskog [2001-2006]
CERN, Lund Institute

Sir Anthony Leggett [2004-2008]
University of Illinois (2003 Nobel Laureate)

Sir Roger Penrose [2001-2007]
University of Oxford

Joseph Polchinski [2001-2004]
University of California - Santa Barbara

Jorge Pullin [2003-2007]
Louisiana State University

Paul Steinhardt [2003-2007]
Princeton University

Scott Tremaine [2001-2006]
Princeton University

Neil Turok [2008]
University of Cambridge

Frank Wilczek [2003-2007]
Massachusetts Institute of Technology
(2004 Nobel Laureate)

LOOKING AHEAD: FUTURE PRIORITIES AND OBJECTIVES

IN 2008-09 THE INSTITUTE UNDERTOOK A LONG-TERM PLANNING EXERCISE in order to articulate a set of strategic and operational objectives for the future. The resulting objectives are aimed at conceptualizing and then realizing the best research environment for fundamental theoretical physics in the world in a well-planned and integrated manner. The objectives articulated in PI's new Five Year Plan are as follows:

- **Achieve major research breakthroughs** – by continuing to focus on advancing fundamental research across PI's research areas, encouraging complementary and multidisciplinary approaches, and instilling a collaborative atmosphere which maximizes cross-fertilization of ideas and increases the probability of breakthroughs.
- **Become the research home of a critical mass of the world's leading theoretical physicists** – by continuing top level recruitment initiatives, offering collaboration and interaction opportunities second to none, and fostering cooperative links throughout the Canadian and international research community.
- **Generate a flow-through of the most promising talent** – by furthering our commitment to recruiting the most promising postdoctoral researchers, facilitating researcher engagements with experimental and observational centres, attracting and training brilliant young graduate students through the PSI program and recruiting the best for further PhD training, and providing research training opportunities to promising undergraduate students.
- **Provide a second "research home" for many of the world's outstanding theorists** – by continuing to recruit top scientists to the Distinguished Research Chairs program, by attracting Visiting Researchers, and through agreements that encourage joint activities between researchers at PI and leading centres throughout the world.
- **Support the growth of a network of theoretical physics centres around the world** – via partnership and collaboration opportunities that can help accelerate the creation of centres of excellence in math and physics.
- **Increase PI's role as Canada's focal point for foundational physics research** – by continuing to develop national and international relationships, maximizing technologies allowing remote participation, and fostering research interaction opportunities between faculty members and affiliates across the country.
- **Host timely, focused conferences, workshops, seminars and courses** – by focusing on workshops that do not happen anywhere else with top scientists discussing the hottest topics and sharing their research results, as well as through an active seminar program and carefully selected advanced graduate courses for credit at surrounding universities.
- **Engage in high impact outreach** – by communicating the importance of basic research and the power of theoretical physics to general audiences, developing brilliant young Canadians for the field by supporting a network of educators across the country with professional development and resources, and by guiding the very best scientifically-minded students toward a career in theoretical physics. PI will also serve as an international resource for outreach expertise to emerging centres of excellence in the developing world, and will provide resources online and through selective presentations at major international educational gatherings.
- **Create the ultimate environment and infrastructure to support excellence in theoretical physics research** – by continuing construction of the Stephen Hawking Centre at Perimeter Institute, an expanded facility with the productive research areas and technologies necessary to maximize the possibilities of scientific breakthroughs.

APPENDICES

POSTDOCTORAL FELLOWS, 2008-09

Niayesh Afshordi, PhD Princeton University (2004)

Michele Arzano, PhD University of North Carolina at Chapel Hill (2006)

Brian Batell, PhD University of Minnesota (2008)

Dario Benedetti, PhD Utrecht University (2007)

Sundance Bilson-Thompson, PhD University of Adelaide (2002)

Robin Blume-Kohout, PhD University of California, Berkeley (2005)

Evgeny Buchbinder, PhD University of Pennsylvania (2003)

Samuel Colin, PhD Vrije Universiteit Brussel (2005)

Florian Conrady, PhD Humboldt University of Berlin (2005)

Sarah Croke, PhD University of Strathclyde, Glasgow (2007)

Claudia de Rham, PhD University of Cambridge (2005)

Eleonora Dell'Aquila (on leave), PhD University of Cambridge (2005)

Steve Flammia, PhD University of New Mexico (2007)

Ghazal Geshnizjani, PhD Brown University (2005)

John Giblin, PhD Yale University (2008)

Philip Goyal, PhD University of Cambridge (2005)

Razvan Gurau, PhD Université de Paris (2007)

Alioscia Hamma, PhD Università degli Studi di Napoli Federico II (2005)

Joe Henson, PhD Queen Mary - University of London (2003)

Sabine Hossenfelder, PhD Goethe University (2003)

Zhengfeng Ji, PhD Tsinghua University (2007)

Tim Koslowski, PhD Julius-Maximilians-Universität Würzburg (2007)

Xiao Liu, PhD Stanford University (2006)

Nicolas Menicucci, PhD Princeton University (2008)

Akimasa Miyake, PhD University of Tokyo (2004)

Leonardo Modesto, PhD University of Torino (2004)

Takuya Okuda, PhD California Institute of Technology (2005)

Yutaka Ookouchi, PhD Tokyo Institute of Technology (2005)

Federico Piazza, PhD University of Milan (2002)

Piero G. Luca Porta Mana, PhD KTH Royal Institute of Technology (2007)

David Rideout, PhD Syracuse University (2001)

James Ryan, PhD University of Cambridge (2007)

Amit Sever, PhD The Hebrew University of Jerusalem (2005)

Parampreet Singh, PhD University of Pune (2004)

Aninda Sinha, PhD University of Cambridge (2004)

Constantinos Skordis, PhD University of California (2002)

Rolando Somma (on leave), PhD Balseiro Institute and Los Alamos National Laboratory (2005)

Simone Speziale, PhD University of Rome (2005)

Ward Struyve, PhD Ghent University (2004)

Andrew Tolley, PhD University of Cambridge (2003)

Michael Trott, PhD University of Toronto (2005)

Samuel Vazquez, PhD University of California, Santa Barbara (2007)

Jonathan Walgate, PhD Oxford University (2005)

Mark Wyman, PhD Cornell University (2006)

Tom Zlosnik, PhD University of Oxford (2008)

SCIENTIFIC VISITORS, 2008-09

Please note that researchers who made multiple visits are only listed once.

Bobby Acharya, Abdus Salam International Centre for Theoretical Physics
Allan Adams, Massachusetts Institute of Technology (MIT)
Miguel Aguado, Max Planck Institute
Iván Agulló, University of Valencia
Maqbool Ahmed, National University of Sciences and Technology
Andreas Albrecht, University of California
Emanuele Alesci, Centre de Physique Théorique - Marseille
Rouzbeh Allahverdi, University of New Mexico
Alex Amblard, University of California, Irvine
Giovanni Amelino-Camelia, Sapienza, Università di Roma
Marcus Appleby, Queen Mary - University of London
Nima Arkani-Hamed, Institute for Advanced Study
Sujay Ashok, The Institute of Mathematical Sciences
Abhay Ashtekar, Pennsylvania State University
Alán Aspuru-Guzik, Harvard University
Benjamin Bahr, Max Planck Institute for Gravitational Physics (Albert Einstein Institute)
Guillermo Ballesteros, Universidad Autónoma de Madrid
Somshubhro Bandyopadhyay, Université de Montréal
Aristide Baratin, Max Planck Institute
Julian Barbour, Independent
Neil Barnaby, Canadian Institute for Theoretical Astrophysics, University of Toronto
Glenn Barnich, Université Libre de Bruxelles
Howard Barnum, Los Alamos National Laboratory
Jonathan Barrett, University of Bristol
Bruce Bassett, University of Cape Town
Thorsten Battefeld, Princeton University
Juliane Behrend, Ulm University
David Berman, Queen Mary - University of London
Aaron Berndsen, Simon Fraser University
Edmund Bertschinger, Massachusetts Institute of Technology (MIT)
Mirko Boezio, Istituto Nazionale di Fisica Nucleare (INFN)
Hector Bombin, Universidad Complutense de Madrid
Raphael Bousso, University of California, Berkeley
Dirk Bouwmeester, University of California
Latham Boyle, Canadian Institute for Theoretical Astrophysics, University of Toronto
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"To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science."

— Albert Einstein





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