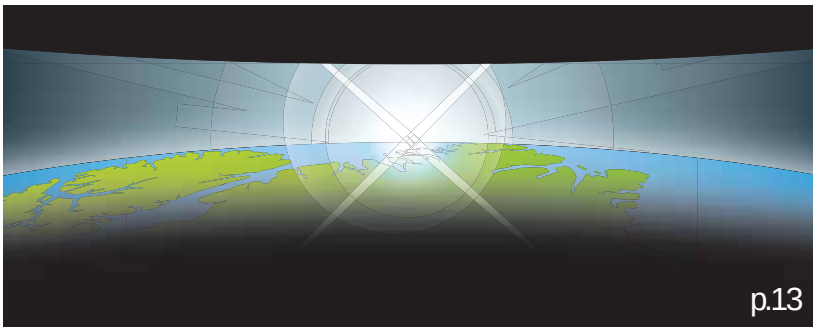
inside the perimeter

summer 2011


p.7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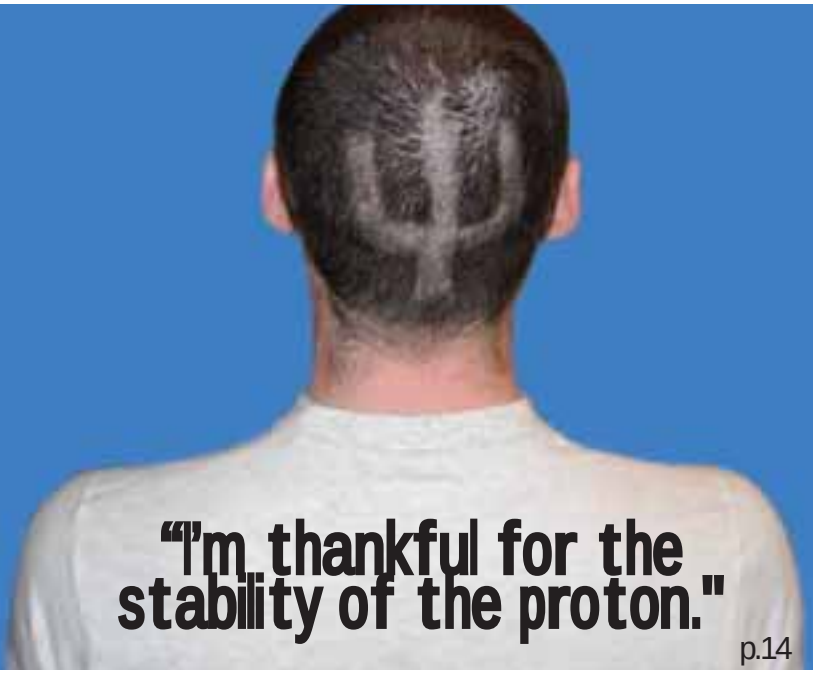

p.14


p.28

p.27


p.3

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

in this issue

▲ Stephen Hawking Centre Grand Opening

The official launch of the new Stephen Hawking Centre at Perimeter Institute will take place over three exciting days, from September 16 to 18, 2011. To celebrate the expansion, the Institute's award-winning outreach team is planning a number of activities.

To learn more, go to www.pitp.ca/grandopening.

Departments

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On June 18, PI celebrated the sucessful completion of the second class of the Perimeter Scholars International (PSI) Masters program. From left to right: Tibra Ali, Denis Dalidovich, Callum Durnford, Robert Spekkens, Lucien Hardy, Ruth Gregory, Jeff Chen, Neil Turok, John Berlinsky, Heather Russell, and Antti Karlsson.

Up, Up and Away

We recently learned the wonderful news that both the federal and provincial governments have decided to renew their investments in Perimeter Institute.

It has been a privilege to work as a part of PI's team, preparing and presenting our application. And let us offer our profound appreciation to the leaders who made these farsighted decisions in challenging economic times. As they renewed their support, so should we renew our commitment to deliver outcomes which will make Canada and Ontario proud.

Our funding renewal is a vote of confidence in Perimeter and our plans for the future. We have been given an extraordinary opportunity: our challenge is to live up to it. How do you actively speed up progress in theoretical physics, probably the most fundamental, successful, and difficult field in all of science?

We need to maintain our energy and enthusiasm and keep adding reinforcements. In that context, there is very good news. I know you'll join me in welcoming to our senior faculty Guifre Vidal, newly arrived from Australia. He has pioneered new methods for solving quantum spin systems and will strengthen and deepen our expertise in quantum information and condensed matter physics.

PI is also being joined by some truly outstanding junior faculty members. Avery Broderick and Itay Yavin, leaders in black hole astrophysics and particle physics respectively, have joined us as Associate Faculty, appointed with the University of Waterloo and McMaster University, respectively (see p. 6). And Bianca Dittrich, an outstanding quantum gravity researcher who currently leads a research group in Canonical and Covariant Dynamics of Quantum Gravity at the Albert Einstein Institute in Potsdam, Germany, will be joining us in the New Year (see p. 7).

Finally, eight senior theorists from around the world have accepted appointments as Distinguished Research Chairs at Perimeter Institute: James Bardeen, Ganapathy Baskaran, James Gates, Gerard 't Hooft, Frans Pretorius, Eva Silverstein, Paul Steinhardt, and Senthil Todadri. They join Perimeter's 19 current DRCs. Collectively they represent an incredible array of scientific expertise. They will, no doubt, continue to invigorate and enliven our research community in unexpected ways during their extended research visits each year.

Building for the future has certainly been this year's theme! As I write, workers are assembling furniture and putting the finishing touches on our own Starship Enterprise, the Stephen Hawking Centre. We'll throw open the hatches September 16 to 18. Plan to beam up with your friends and explore its think spaces, peer through its portholes, ask some big questions, and have loads of mind-bending Outreach fun.

With summer's arrival, we said a fond farewell to our second class of PSI Masters students. Every day they reminded us to keep questioning and to plunge in, no matter how daunting the task. To our second set of PSIons, we have enjoyed seeing you spreading your wings as young scientists. Now we look forward to seeing you fly.

I would like to recognize and thank John Berlinsky for his constant leadership of the PSI program, and our wonderful tutors, Tibra Ali, Denis Dalidovich, and Callum Durnford, for their fantastic work and commitment over the past year. PSI couldn't work without you! I'm delighted that Tibra and Denis will be returning as PSI Fellows, continuing to teach but also with time to do their own research. And let us bid a teary goodbye to Callum who will be returning to the UK.

To those of you arriving, a hearty welcome! To those of you leaving (for now), we'll miss you: come back soon.

Let me wish you all a brilliant summer!

—Neil Turok

neil's notes

Kudos to...

Incoming Faculty member **Davide Gaiotto** has won the European Physical Society's 2011 Gribov Medal for outstanding work by an early career physicist in Theoretical Particle Physics and/or Field Theory "for the uncovering of new facets of the dynamics of four-dimensional supersymmetric gauge theories. In particular, for discovering a large class of four-dimensional superconformal theories and for finding with others important intricate relations between two-dimensional theories of gravity and four-dimensional gauge theories."

Associate Faculty member **Niayesh Afshordi** was awarded the Professor M. K. Vainu Bappu Gold Medal from the Astronomical Society of India for his contributions to our understanding of the dark universe, including the distribution of plasma in galaxy clusters, the phenomenology of dark energy, and the structure of dark matter distribution on small scales.

PI Distinguished Research Chair **Leo Kadanoff** has won the 2011 Isaac Newton Medal of the UK Institute of Physics for "inventing conceptual tools that reveal the deep implications of scale invariance on the behavior of phase transitions and dynamical systems." Professor Kadanoff is also a Lecturer in the PSI Masters program.

Associate Faculty member **Luis Lehner** was awarded a $120,000 Discovery Accelerator Supplement (DAS) from the Natural Sciences and Engineering Research Council of Canada (NSERC). The DAS Program aims to provide substantial resources to outstanding research programs.

PI Distinguished Research Chair **Christopher Isham** has won the 2011 Dirac Medal of the UK Insitute of Physics for "his major contributions to the search for a consistent quantum theory of gravity and to the foundations of quantum mechanics."

Faculty members **Lee Smolin** and **Laurent Freidel**, with colleagues **Giovanni Amelino-Camelia** and **Jerzy Kowalski-Gliknanwon**, won second prize in the 2011 Gravity Research Foundation essay competition for "Relative Locality: A Deepening of the Relativity Principle."

Associate Faculty member **Michele Mosca** was named to Canada's Top 40 Under 40 by *The Globe and Mail*.

Distinguished Research Chair **Sandu Popescu** has won the John Stewart Bell Prize for his "enormous contributions to the field of quantum mechanics." Professor Popescu, of the University of Bristol, is world-renowned for his many contributions to our understanding of nonlocality, entanglement, and the quantum foundations of statistical mechanics.

Erik Verlinde, a leading string theorist from the University of Amsterdam and a member of Perimeter's Scientific Advisory Committee, has won the 2011 NWO-Spinoza Prize, the highest award in Dutch science. The prize carries a cash award of 2.5 million euros.

Associate Faculty member **Adrian Kent** has been awarded a Research Fellowship by the Leverhulme Trust for his project, "Mathematical Characterization of Quantum Reality."

Associate Faculty member **Luis Lehner** has been named a Fellow of the Canadian Institute for Advanced Research (CIFAR) Cosmology and Gravitation program.

Postdoctoral Researcher **Adrienne Erickcek** has been named a Junior Fellow in CIFAR's Cosmology and Gravitation Program.

Former Postdoctoral Researcher **Andrei Starinets** has won the 2011 Maxwell Medal and Prize of the UK Insitute of Physics.

PI Director **Neil Turok** received an honorary doctorate from the University of Ottawa in recognition of his scientific work and leadership in founding the AIMS Next Einstein Initiative.

PhD student **Sean Gryb** received the 2010 John Brodie Memorial Prize for his academic achievements.

Sean Gryb, winner of the 2010 John Brodie Memorial Prize, is congratulated by John Berlinsky, PI's Academic Programs Director. ▶

PI Welcomes Renewed Federal and Provincial Investments

Canada

Ontario

Both the Government of Canada and the Province of Ontario have recently announced renewed support of $50 million each for Perimeter Institute.

The $100 million will support PI's research, training and outreach operations. In addition, the *Expanding the Perimeter* advancement campaign is targeting an additional $100 million in private funds, taking the successful public-private partnership to new levels.

At the PI Public Lecture held in June, PI Director Neil Turok publicly thanked government representatives, saying, "We well appreciate the courage it took to renew Perimeter's funding in these harsh economic times. On behalf of all of us who are privileged to work at Perimeter I make this pledge to you, and to the taxpayers: we shall continue raising the bar and delivering outcomes that make you proud."

From left to right: PI Founder Mike Lazaridis; Hon. Glen Murray, Minister of Research and Innovation; Hon. John Milloy, Minister of Training, Colleges and Universities; and PI Director Neil Turok.

The Hon. Gary Goodyear, Minister of State (Science and Technology).

Two New Associate Faculty Join PI

Welcome to Itay Yavin and Avery Broderick, who are joining PI as Associate Faculty members.

In announcing their appointments, PI's Director Neil Turok said, "We are very pleased to welcome these very talented young scientists to Perimeter. Dr. Broderick is an outstanding astrophysicist who recently produced the first conclusive evidence for the existence of the event horizon of the black hole in the centre of our galaxy, and obtained evidence that it is spinning. Dr. Yavin is a leader in confronting particle physics theories with experimental data, an area brimming with possibility as new data come flooding in from the Large Hadron Collider."

Avery Broderick will join Perimeter as an Associate Faculty member in theoretical astrophysics, starting in September 2011, and will hold a joint appointment with the University of Waterloo. Dr. Broderick completed his PhD at Caltech in 2004, under the supervision of Prof. Roger Blandford. He was a Postdoctoral Fellow at the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics from 2004–2007, and then a Senior Research Associate at the Canadian Institute for Theoretical Astrophysics (CITA) from 2007–2011.

Dr. Broderick has broad interests in astrophysics, ranging from how stars form to the extreme physics in the vicinity of white dwarfs, neutron stars, and black holes. He has recently been part of an international effort to produce and interpret horizon-resolving images of a handful of supermassive black holes. With these, Dr. Broderick and his collaborators study how black holes accrete matter, launch the ultra-relativistic outflows observed, and probe the nature of gravity in their vicinity.

Itay Yavin recently arrived at Perimeter as an Associate Faculty member in particle physics and holds a joint appointment with McMaster University in Hamilton. Dr. Yavin completed his PhD in 2006 at Harvard University under the supervision of Nima Arkani-Hamed, who is a PI Distinguished Research Chair. After completing his PhD, he was a Research Associate in the Department of Physics at Princeton University from 2006–2009. Prior to coming to PI, Dr. Yavin was a James Arthur Postdoctoral Fellow at the Department of Physics at New York University.

Dr. Yavin's research focuses on particle physics and the search for physics beyond the Standard Model. In particular, he is interested in the origin of electroweak symmetry breaking and the nature of dark matter. Most recently he has worked on interpreting puzzling data coming from experiments looking for dark matter in the lab.

—Liz Goheen

New Visiting Fellows Appointed

We are pleased to welcome three new Visiting Fellows, Jonathan Barrett, Kris Sigurdson and Vincent Rivasseau. As Visiting Fellows, these accomplished scientists will spend extended research visits of up to six months each year at PI. The appointments are for three years.

Jonathan Barrett, University of London

Kris Sigurdson, University of British Columbia

Vincent Rivasseau, Université Paris-Sud XI

Bianca Dittrich Appointed to PI Faculty

Perimeter Institute's growing research faculty will welcome another new face in 2012, as Bianca Dittrich, who currently leads the Max Planck Research Group "Canonical and Covariant Dynamics of Quantum Gravity" at the Albert Einstein Institute in Potsdam, Germany, is set to return to Waterloo after a couple of years away. Dr. Dittrich held a Postdoctoral Researcher position at PI from 2005–2008.

In making the announcement, PI's Director Neil Turok said, "Dr. Dittrich is a gifted and powerful thinker with enormous potential. She has already made major contributions across the spectrum of models for quantum gravity. She will strengthen our efforts across a number of research areas including quantum gravity, cosmology and black holes. We look forward to Bianca's arrival with great anticipation."

Dr. Dittrich's research focuses on the construction and examination of quantum gravity models. Among other important findings, she has provided a computational framework for gauge invariant observables in (canonical) general relativity that are independent from any choice of coordinatization, and found that the different spaces of potential configurations describing discrete geometries are very different — even in size — in the various quantum gravity models.

Dr. Dittrich's present work seeks to understand how one could construct a new class of lattice models which are independent of one's choice of discretization, which should then display a discrete notion of diffeomorphism symmetry, beginning with the models we know so far. This work has many potential links to other fields of study at PI, such as condensed matter, quantum computing, and numerical relativity. Indeed, PI's interdisciplinary approach was a major factor in Dr. Dittrich's decision to join PI's faculty.

"PI's breadth of research topics and the possibilities and freedom it offers to do research are rather exceptional," Dr. Dittrich explained. "I am very happy to have been given this opportunity to again enjoy Perimeter's unique atmosphere and energetic scientific life."

Dr. Dittrich grew up in Berlin and completed her undergraduate degree at the nearby University of Potsdam. She did her diploma thesis with Renate Loll, who is now a PI Distinguished Research Chair and a member of the Institute's Scientific Advisory Committee. Dr. Dittrich received her PhD from the Max Planck Institute for Gravitational Physics in 2005, under the supervision of Thomas Thiemann, one of Perimeter's Associate Faculty members. After three years as a Postdoctoral Researcher at PI, she held a Marie Curie Fellowship at the University of Utrecht from 2008–2009, before taking her current post at the Max Planck Institute.

Among her many accomplishments, Dr. Dittrich is a proud recipient of the Otto Hahn Medal of the Max Planck Society (2007), which recognizes outstanding young scientists, and a Marie Curie Fellowship (2008).

—Mike Brown

Further exploration:

- B. Dittrich. "Partial and Complete Observables for Canonical General Relativity." Class. Quant. Grav. 23, 6155 (2006). http://arxiv.org/abs/gr-qc/0507106
- B. Dittrich and J. Tambornino. "Gauge invariant perturbations around symmetry reduced sectors of general relativity: applications to cosmology." Class. Quant. Grav. 24, 4543 (2007). http://arxiv.org/abs/gr-qc/0702093
- B. Dittrich and S. Speziale. "Area-angle variables for general relativity." New J. Phys. 10, 083006 (2008). http://arxiv.org/abs/0802.0864
- B. Dittrich. "Diffeomorphism symmetry in quantum gravity models." Adv. Sci. Lett. 2, 151 (2009). http://arxiv.org/abs/0810.3594
- B. Bahr and B. Dittrich. "(Broken) Gauge Symmetries and Constraints in Regge Calculus." Class. Quant. Grav. 26 225011 (2009). http://arxiv.org/abs/0905.1670
- B. Dittrich and J.P. Ryan. "Phase space descriptions for simplicial 4d geometries." Class. Quant. Grav. 28, 065006 (2011). http://arxiv.org/abs/0807.2806

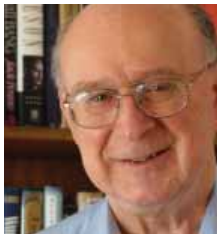
Eight New Distinguished Research Chairs Join PI

Perimeter Institute has appointed eight more outstanding international scientists as Distinguished Research Chairs.

Commenting on the appointments PI Director Neil Turok said, "We are thrilled to welcome these eight world-leading scientists to PI's research community. Science is an inherently human process, and bringing the right people together is often the key to success. Each of these new DRCs will bring significant new ideas and expertise to PI. We cannot tell exactly what they will do, but based on their past record we know it will be very exciting."

Distinguished Research Chairs spend extended research visits at PI, giving them an opportunity to be part of Perimeter's scientific community while retaining permanent positions at the home institutions. The new appointees join PI's 19 current Distinguished Research Chairs.

ABOUT THE NEW DISTINGUISHED RESEARCH CHAIRS



James Bardeen is an Emeritus Professor of Physics at the University of Washington in Seattle. He has made major contributions in general relativity and cosmology, including the formulation of the laws of black hole mechanics with Stephen Hawking and Brandon Carter and the development of a gauge-invariant approach to cosmological perturbations and the origin of large-scale structure in the present universe from quantum fluctuations during an early epoch of inflation. His recent research has focused on improving calculations of the generation of gravitational radiation from merging black hole and neutron star binaries by formulating the Einstein equations on asymptotically null constant mean curvature hypersurfaces. This makes possible numerical calculations with an outer boundary at future null infinity, where waveforms can be read off directly, without any need for extrapolation. Dr. Bardeen received his PhD from Caltech under the direction of Richard Feynman.

Ganapathy Baskaran is an Emeritus Professor at the Institute of Mathematical Sciences, Chennai in India, where he has recently founded the Quantum Science Centre. He has made important contributions to the field of strongly correlated quantum matter. Novel emergent quantum phenomena in matter, including biological ones, are his passion and research focus. He is well known for his contributions to the theory of high temperature superconductivity and for discovering emergent gauge fields in strongly correlated electron systems. He predicted p-wave superconductivity in Sr_2RuO_4, a system believed to support Majorana fermion mode, which is a popular qubit for topological quantum computation. In recent work, he predicted room temperature superconductivity in optimally doped graphene.

From 1976–2006, Baskaran contributed substantially to the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy where he worked closely with scientists from third and first world countries and helped run scientific programs. He received the S.S. Bhatnagar Award from the Prime Minister of India (1990), the Alfred Kasler ICTP Prize (1983), Fellowships of The Indian Academy of Sciences (1988), Indian National Science Academy (1991) and Third World Academy of Sciences (2008), and the Distinguished Alumni Award of the Indian Institute of Science, Bangalore (2008).

James S. Gates is the John S. Toll Professor and Director for the Center for String and Particle Theory at the University of Maryland, College Park. He has made numerous contributions to supersymmetry, supergravity, and superstring theory, including the introduction of complex geometries with torsion (a new contribution in the mathematical literature); and the suggestion of models of superstring theories that exist purely as four-dimensional constructs similar to the standard model of particle physics.

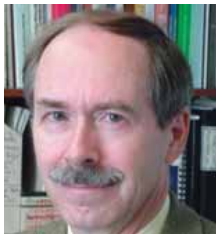
Professor Gates is a past recipient of the Public Understanding & Technology Award from the American Association for the Advancement of Science (AAAS) and the Klopsteg Award from the American Association of Physics Teachers. Professor Gates is a Fellow of the American Physical Society, a Fellow of AAAS, and a past President of the National Society of Black Physicists. In 2011, he was elected to the American Academy of Arts and Sciences. He currently serves on the U.S. President's Council of Advisors on Science and Technology, the Maryland State Board of Education, and the Board of Directors of the Fermi National Laboratory, and is on the Board of Trustees for the Society for Science and the Public.

Professor Gates' current research probes questions on the relation between a set of graphs (given the name of 'Adinkras' from traditional African cultures), supersymmetry and a class of codes similar to those that allow browsers to operate in an error-free manner.

Frans Pretorius is a Professor of Physics at Princeton University. His primary field of research interest is general relativity, specializing in numerical solution of the field equations. His work has included studies of gravitational collapse, black hole mergers, cosmic singularities, higher dimensional gravity, models of black hole evaporation, and using gravitational wave observations to test the dynamical, strong-field regime of general relativity. He also designs algorithms to efficiently solve the equations in parallel on large computer clusters, and software to manipulate and visualize the simulation results. Among his honours, in 2007, Dr. Pretorius was awarded an Alfred P. Sloan Research Fellowship, and was the 2010 recipient of the Aneesur Rahman Prize for Computational Physics of the American Physical Society. He is a Scholar in the Canadian Institute for Advanced Research (CIFAR) Cosmology and Gravity Program.

Eva Silverstein is a Professor of Physics at Stanford University in the department of physics and the Stanford Linear Accelerator Center (SLAC). Dr. Silverstein's major contributions include predictive new mechanisms for inflationary cosmology, which helped motivate a more systematic understanding of the process and the role of UV-sensitive quantities in observational cosmology; mechanisms for singularity resolution in string theory; a novel duality in string theory between extra dimensions and negative curvature; extensions of the AdS/CFT correspondence to more realistic field theories (with applications to particle physics and condensed matter model building) and to landscape theories; and simple mechanisms for stabilizing the extra dimensions of string theory. She is a former MacArthur Fellow and past recipient of a Sloan Research Fellowship. Dr. Silverstein's current interests range over many of these areas.

Paul Steinhardt is the Albert Einstein Professor in Science and Director of the Princeton Center for Theoretical Science at Princeton University. Dr. Steinhardt is a Fellow of the American Physical Society (APS) and a member of the National Academy of Sciences. He shared the P.A.M. Dirac Medal from the International Centre for Theoretical Physics for the development of the inflationary model of the universe, and the Oliver E. Buckley Prize of the APS for his contributions to the theory of quasicrystals. His research interests include particle physics, astrophysics, cosmology and condensed matter physics. Recently, with Neil Turok, he has developed a cyclic model for cosmology, according to which the big bang is explained as a collision between two "brane-worlds" in M-theory. In addition to his continued research on inflationary and cyclic cosmology, Dr. Steinhardt has been one of the developers of a new class of disordered "hyperuniform" photonic materials with complete bandgaps, and he conducted a systematic search for natural quasicrystals that has culminated in discovering the first known example. He is currently organizing an expedition to Far Eastern Russia to find more samples and study the local geology where they are found.



Gerard 't Hooft is a Professor at the Institute for Theoretical Physics at Utrecht University. He shared the 1999 Nobel Prize in Physics with Martinus J. G. Veltman "for elucidating the quantum structure of electroweak interactions." His research interests include gauge theories in elementary particle physics, quantum gravity and black holes, and fundamental aspects of quantum physics. In addition to being a Nobel laureate, Dr. 't Hooft is a past winner of the Wolf Prize, the Lorentz Medal, the Franklin Medal and the High Energy Physics Prize from the European Physical Society, among other honours. He is a member of the Royal Netherlands Academy of Arts and Sciences (KNAW) and is a foreign member of many other science academies, including the French Académie des Sciences, the National Academy of Sciences (US), and the Institute of Physics (UK).

Professor 't Hooft's present research concentrates on the question of nature's dynamical degrees of freedom at the tiniest possible scales. In his latest model, local conformal invariance is a spontaneously broken symmetry, which may have very special implications for the interactions between elementary particles.

Senthil Todadri is an Associate Professor of Physics at the Massachusetts Institute of Technology (MIT). Dr. Todadri's research interests are in condensed matter theory. Specifically, he is working to develop a theoretical framework to describe the behaviour of electronic quantum matter in circumstances in which individual electrons have no integrity. A prime example is the quest for a replacement to the Landau theory of Fermi liquids that describes many metals extremely successfully, but fails in a number of situations studied in modern experiments in condensed matter physics. He is a past Sloan Research Fellow and winner of a Research Innovation Award from the Research Corporation for Science Advancement.

Primordial Beryllium May Shed Light on Particle Physics

Mystery surrounds much of what happened in the earliest moments of the universe. One of the phenomena of this epoch that scientists have been able to explain in terms of particle physics is the formation of light atomic nuclei from free baryons, also known as Big Bang nucleosynthesis (BBN). Recently, PI researchers Maxim Pospelov and Josef Pradler proposed a new mechanism for producing Beryllium during BBN, which may help constrain new models of particle physics.

BBN took place just a few minutes after the Big Bang. As the temperature of the universe fell to about 0.1MeV, the density of highly energetic photons decreased, and protons and neutrons started fusing to form Deuterium, Helium and then, in lesser quantities, Lithium. After only a few minutes, the universe had become too cold for fusion; thereafter, the relative abundances of the different elements remained constant for a long time, until the first stars began burning Hydrogen and Helium, eventually creating all the heavy elements we see around us today.

By looking at the spectra of such old stars — those born during the early days of the Milky Way — and measuring the relative abundances of elements, we can test theoretical predictions. Lithium, for example, levels off in the oldest observed stars, indicating the original abundance of the isotope. This quantity can be calculated directly from particle physics.

"The reason BBN is so important for cosmologists is that it is our very earliest direct observational window into the beginning of the universe," explains PI postdoc Josef Pradler, who worked with Maxim Pospelov on the new results. Most other evidence we have of the early universe comes from observations of the cosmic microwave background (CMB), radiation giving us an image of what the universe looked like several hundreds of thousands of years after the Big Bang.

What's more, particle physicists are able to use standard calculations to very accurately predict elements' abundances in different theoretical scenarios. While scientists are still struggling to find a good theory for other cosmological phenomena, such as dark matter and the asymmetry between matter and antimatter, the standard model of BBN (SBBN) is widely accepted as a good explanation for how the first nuclei formed.

This makes it a great test bed for new models as well: any extension or modification to the standard model should reproduce the observed light element abundances through the same well-understood calculations.

New models of particle physics often feature new heavy particles, which may alter the predictions for nucleosynthesis. Most famously, some supersymmetric models contain heavy long-lived states, which could decay during BBN and inject additional energy into the process. This is where Pradler and Pospelov's research comes in: they discovered that such an injection of energy enables the primordial production of Beryllium-9.

In SBBN, essentially no nuclei heavier than Lithium-7 were produced, because of a lack of stable intermediate states of mass number 8. Bursts of additional, nonthermal energy bypass this gap of stable states and make the reaction proceed directly through an intermediate Helium-6 state to Beryllium-9.

This result is particularly promising because Beryllium was so rare in the early universe: "The abundance of Beryllium in the early universe is extremely well constrained observationally; we have an upper bound of one part in 10^{14} on the BBN fraction of Beryllium," says Pradler. Such bounds are obtained from stars with low metal content, ones born at a time when not many heavy elements had been produced and which are thus very old. Unlike with Lithium, the abundance of Beryllium does not level off for low metallicities, i.e., the oldest stars, and gives very tight bounds on how much of the element may have been produced due to heavy long-lived states during BBN.

In addition to that, Beryllium does not pose some of the problems astrophysicists might face when trying to

constrain new models through other observations. Lithium, for instance, is exposed to stellar depletion after cooling off and star formation, meaning that processes in the core of a star may significantly reduce the amount of Lithium over the course of the star's life. Further complicating the situation, different isotopes of Lithium are very hard to distinguish in stars.

That makes it difficult to predict just how much Lithium-6 we should see given any particular model of BBN. Beryllium on the other hand is easier to measure and much more stable even inside stars. According to Pradler, "Particle physics models which possess long-lived massive states will have to pass this new cosmological test. When a model predicts Beryllium abundances in excess of what is observed, it is ruled out."

This means that Pospelov and Pradler's new criterion may help particle physicists discern which of the multitude of new models proposed every month are doomed from the beginning — and which could have a shot at better explaining the universe.

—Maita Schade

Further exploration:

– "Big Bang Nucleosynthesis as a Probe of New Physics" Maxim Pospelov, Josef Pradler arXiv:1011.1054, also *Phys. Rev. Lett.*106:121305,2011

– "Primordial beryllium as a big bang calorimeter," Maxim Pospelov, Josef Pradler, arXiv:1010.4079, also *Ann. Rev. Nucl. Part. Sci.*60:539-568,2010

WELCOME TO OUR NEW AFFILIATE MEMBERS

Affliates are members of PI's extended family and come from across Canada to attend PI events and conferences to work with PI researchers. The following are new appointments for 2011:

YONG-BAEK KIM, University of Toronto	Condensed Matter
MARCO PIANI, University of Waterloo (IQC)	Quantum Information
THOMAS JENNEWEIN, University of Waterloo (IQC)	Quantum Information
BEI ZENG, University of Guelph	Quantum Information
SPIRO KARIGIANNIS, University of Waterloo	Pure Math
JOHANNES WALCHER, McGill University	Strings
SANJEEV SEAHRA, University of New Brunswick	Cosmology
ANNE BROADBENT, University of Waterloo (IQC)	Quantum Information
MARCEL FRANZ, UBC	Condensed Matter
KAYLL LAKE, Queens University	General Relativity
ARIF BABUL, University of Victoria	Cosmology
DMITRI POGOSYAN, University of Alberta	Cosmology
RUXANDRA MORARU, University of Waterloo	Pure Math

PI and ICTP Sign Collaboration Agreement

Perimeter Institute and the Abdus Salam International Centre for Theoretical Physics (ICTP) have signed a memorandum of understanding to promote academic ties and collaboration on outreach programs between the institutes.

▲ *Seated from left: PI Director Neil Turok and ICTP Director Fernando Quevedo; Standing: Howard Alper, Chair/President, Science, Technology and Innovation Council Canada, and Ambassador Maurizio Serra, Permanent Delegation of Italy to UNESCO.*

The agreement will facilitate a flow of researchers between the institutes, with extended visits of two to four weeks, and will encourage collaborations on workshops and schools on subjects of common interest. Faculty, postdoctoral researchers and advanced PhD students will be eligible to participate in the program. The agreement is for one year and may be renewed for another two years at the end of the current term.

Both PI and ICTP pursue research in fundamental physics and have several areas of research focus in common, including quantum gravity, superstring theory, cosmology and gravitation, and particle physics. Founded in 1964 by the late Nobel Laureate Abdus Salam, ICTP also has a particular mandate to transfer knowledge to scientists from developing countries.

The agreement was signed during a UNESCO conference titled *Africa: the Choice of Science, the AIMS (African Institute for Mathematical Sciences) Initiative*, held at UNESCO headquarters in Paris from April 14 to 15, 2011.

—Liz Goheen

Gottesman-Chuang Scheme for Quantum Logic Gate Realized Experimentally

Back in 1999, PI Faculty member Daniel Gottesman and Isaac Chuang (now at MIT) predicted that one could create a logic gate for a quantum computer by teleporting certain entangled states, a proposal called the Gottesman-Chuang (or G-C) scheme. Recently, researchers at the University of Science and Technology of China (USTC) in Heifei and colleagues at Ruprecht-Karls-Universität Heidelberg in Germany developed realizations of the Gottesman-Chuang scheme, using two different methods and producing two different gates.

Whereas classical computers process information encoded in bits, a quantum computer processes information encoded in quantum states, such as spin states of individual photons or atomic nuclei. Because the inherent complexity of a quantum state rises steeply as the number of particles increases, being able to manipulate the states of even a relative handful of particles could yield potentially enormous computing power. In principle, for example, a quantum computer of just 50 quantum bits, or "qubits," could solve problems that elude today's supercomputers.

A major hurdle to building quantum computers is the fact that quantum states are inherently fragile, and quantum computers will likely be very vulnerable to errors or unintended interactions with the world outside the computer. To cope with these errors, a number of error-correcting and fault tolerant methods have been developed.

The Gottesman-Chuang scheme is in essence a method of creating fault tolerant logic gates. The scheme proposes that one first create qubits in a high-purity entangled state, called a "magic state," then create a logic gate by teleporting qubits through this entangled state. Because the magic state is a known state separate from the rest of the computation, it can be tested carefully before being used, and can be safely discarded if it is faulty. As the name hints, magic states are challenging to create, but earlier this year, magic state distillation of qubits was achieved for the first time by researchers at Perimeter Institute and the Institute for Quantum Computing (IQC) at the University of Waterloo.

Another important application of the Gottesman-Chuang scheme was discovered in 2001 by Emmanuel Knill (now at NIST Boulder), PI Associate Raymond Laflamme, and former SAC Chair Gerard Milburn (at U. Queensland). They found that magic states could be created with just linear optics components, which are readily available in many optics labs, and could thereby allow a new method of building quantum computers with photons as the qubits.

In the recent experimental realization of the Gottesman-Chuang scheme, researchers used a six-photon interferometer to create a controlled-NOT gate, one of the basic entangling gates used as a building block in a quantum computer. The other method used four-photon hyperentanglement (in which each photon encodes information into two degrees of freedom) to create a controlled-Phase gate, another simple gate. The group also showed that both gates demonstrated genuine entanglement. In the case of the controlled-Phase gate they also showed that it achieves quantum parallelism, meaning that it can't be reproduced by local operations and classical communications (LOCC). Both gates represent realizations of one of the main steps in the Knill-Laflamme-Milburn linear optics quantum computation protocol. The results were described in a paper in the *Proceedings of the National Academy of Sciences.*

—Natasha Waxman

Further Exploration:

- "Demonstrating the Viability of Universal Quantum Computation Using Teleportation and Single-Qubit Operations," D. Gottesman and I. Chuang, *Nature* 402, 390-393 (1999); "Quantum Teleportation is a Universal Computational Primitive," quant-ph/9908010.
- "Plug-in Quantum Software," John Preskill, *Nature* 402, 357-358 (25 November 1999) doi:10.1038/46434
- "A scheme for efficient quantum computation with linear optics," E. Knill, R. Laflamme, G. J. Milburn, *Nature* 409, 46-52 (4 January 2001) doi:10.1038/35051009
- "Teleportation-based realization of an optical quantum two-qubit entangling gate," Wei-Bo Gaoa, Alexander M. Goebelb, Chao-Yang Lua et al. *Proceedings of the National Academy of Sciences*, December 7, 2010, vol. 107, no. 49,20869–20874. www.pnas.org/cgi/doi/10.1073/pnas.1005720107

PI & UW Partnership Advances Energy Solution Ideas for the Future

From June 5 to 9, 2011, Perimeter Institute hosted the *Equinox Summit: Energy 2030* to explore how science and technology can advance a low-carbon energy future. The Summit was the inaugural event of the Waterloo Global Science Initiative (WGSI), a non-profit partnership between Perimeter Institute for Theoretical Physics and the University of Waterloo. WGSI's mandate is to help catalyze the long-range thinking that can advance technological ideas and strategies for the future because, historically, scientific discoveries have been the greatest single factor leading to health, prosperity and the advancement of our civilization.

PI Director Neil Turok, Governor General David Johnston, and UW President Feridun Hamdullahpur

This first event focused on the world's growing energy needs and brought together leading scientists (known as the Quorum), future leaders (called the Forum), and experienced advisors from business, policy and academia. Their task was to envision a low-carbon, electrified future coupled with an urgent need to expand the capacity, increase the resilience and security, and improve the efficiency of our energy systems. With representatives from 14 countries including Canada, Brazil, China, Costa Rica, Indonesia, Nigeria, the USA, and beyond, the Equinox Summit embodied the realities, challenges, and hopes of the enormously diverse global community, from those living in the world's 21 mega-cities of more than 10 million inhabitants, to the one-third of humanity who survive without electricity.

Summit outcomes were expressed in the Equinox Communiqué, which provided a series of technological systems and implementation steps for action by industry and governments. Recommendations included the need for large-scale renewable baseload power sources involving geothermal, advanced nuclear and wind/solar generation. The distribution and storage of cleaner electricity was also examined, including the need to leverage smart grids, microgrids and battery technologies to better harness the power. The Communiqué will be expanded upon in a future Equinox Blueprint.

The summit also aimed to "reboot" a broader dialogue about energy issues by sharing the morning plenary sessions, afternoon lectures and evening panel discussions with online audiences. Our public broadcast partner, TVO, even broadcast several live debates on television from the Summit. In addition, reporters from *Nature, Scientific American* and other publications sat in on working sessions in order to blog about the proceedings and research future articles.

Moving forward, the WGSI impact year of activities will include international distribution of the Equinox Blueprint and other multimedia materials to public policy influencers, industry leaders and journalists. In addition, Forum members will share Summit outcomes among their regional policy makers, media members and general public audiences in home countries. Lastly, the wgsi.org website will be continually updated with news on investments, policy decisions and technological advancements that tie to the Summit themes.


Forum members during a break-out session

"Given the right support, the six priority actions we have identified can catalyze change on a global scale, from the cities of the developed world, to the billions of people who live in towns and villages that lack adequate access to electricity to provide the central link to improvements in the quality of life," said WGSI Summit Advisor Professor Jatin Nathwani, Executive Director of the Waterloo Institute for Sustainable Energy and Ontario Research Chair in Public Policy for Sustainable Energy.

To learn more, please visit wgsi.org.

—RJ Taylor


Advisors at work during an in-camera session at the Equinox Summit: Energy 2030.

PSI-Lights: a Year in the Life of PSI

The 2011 class of the Perimeter Scholars International Masters program looks back on a year of hard work, fun and discovery...

The day after our essays were handed in, I went to the library and was surprised to find several other PSIons there. I asked what everyone was working on. Everyone looked a little embarrassed, then admitted that despite having handed in their reports, they were still working on their research, just to make it better! Having the same intent myself, I realized that the aim of removing grades and allowing students to be self-motivated really worked. Here, the day when we should have been partying or sleeping, people were still researching their projects, just for fun!

-Kathryn Zealand

Professor John Berlinsky & Callum Durnford

Shane, Kathryn, Dina and Maeve

Holger

"I'm thankful for the stability of the proton."

-James

Lauren & Laurel

Sebastian

Babak, Felix, Solomon, Antti and Laura

Mealtime at our home away from home

discovering Canada...

Anton and Solomon

Favourite PSI moment?
Meeting new people from around the world and getting to know each other. Sharing in their different cultures, beliefs and food - and sharing my culture with them!

-Solomon Owerre

Christmas Party '10

Eduardo (on left) fights hard before going on to win PI's first ever sumo wrestling tournament.

Here are two pictures that are symbolic of my time here: one taken on my first day at PI and the other taken during my thesis defense.

-Joachim Nsofini

Heather

Studying at 35 King

Tea with Sir Roger

Sir Roger Penrose sits down to high tea with PSI students, Lauren Greenspan sits to his left.

Sometimes, as Perimeter Scholars International (PSI) students, we talk about our idols. I use the term loosely, not wanting to leave out or offend (or flatter into submission) the many respected researchers we see and speak to every day. I use it, too, with a sense of humour that few but a naive, low-on-the-totem-pole graduate student can get away with. Still, we count ourselves lucky in the PSI program. This year we've had the pleasure of hosting researchers we refer to as "the boss," "the guru," and, with the arrival of Sir Roger Penrose, something of a rock star.

After his colloquium, Penrose sits down with us for some tea. We pick his brain about the cyclic universe, quantum gravity, and cosmology in general, and as we listen to him speak I am impressed by his perspective. He has a way of connecting ideas developed in different generations of physics, relating the roles physicists and their students played, bridging past and present in a way that presumably comes from years of experience. He tells us about the people he admired when he was a student, summarizing research and noting the flaws that kept it going, laying cosmology's history out on the table as if it could really fit there. "I keep wondering what these people would think of the new versions," he says. I wonder what he will think of even newer versions to come.

For most of us, this year is one of decision. We take in as much of the curriculum as we can, trying to find that one point of interest that could seed a career, applying to graduate programs and beginning our research projects, biting our nails and trying to plan a little bit of the future. It's hard to believe that any of us might one day be written into a history that others will have to sift through, sort, lay on the table...

Of course, we're not there yet. The point, for now, is to watch and learn how experienced researchers spend their time. Which questions do they ask and which do they ignore? How do they offer answers? Who does the grunt work? "It's a common thing to say that an intelligent person who works hard can answer certain questions," Ricardo de Oliveira comments, "but it takes a bit more than that to ask the right ones."

Penrose asks a lot of questions. "How concerned are you with answering them?" I ask him. "Well, if I can make a stab at answering them, fine," he says, but he doesn't seem too concerned. Then he adds, "Students often ask questions that people who've got set in their ways don't tend to answer so much." Well-known physicists are sometimes necessary to circulate a radically new idea, but less indoctrinated minds can help shape our collective knowledge all the same. What PSI has given us is the opportunity to ask questions from theorists without an obligation to subscribe to their ideas or provide any answers.

When Maita Schade asks Penrose about when we might get some answers from current quantum gravity experiments, he laughs and says he'd know more when he visited one such lab later on this year. Then he adds, "You've got to live a long time to see the results of these things."

It's sometimes difficult, as graduate students, to keep the big picture in mind. After nearly ten months in such a focused environment we may have forgotten what is not directly and immediately centered around us. But like physics we have pasts and futures. We came from all over, bringing with us varying opinions about PI, PSI, and physics in general -- opinions formed outside Waterloo and perhaps biased by others. We see the way it works at PI: visitors coming and going, new faculty coming and staying, talks and conferences, lunches and cocktail hours. We ask questions and get some answers and try to see ourselves as a part of the community, sometimes not knowing where to fit ourselves and how.

But sooner or later (and probably without realizing) we will end up a part of it. And then we'll look back.

Perhaps science, like Penrose's aeon, repeats itself. Maybe progress can only be made if we look to the past and pull from it, asking the right questions to guide us forward.

Everyone plays a role: the student and his naive questions, the seasoned researcher and his sage ones, the askers and answerers, crackpots and professionals, so many minds at Perimeter and elsewhere trying to affect the way we view the world.

"Well, we'll get there one day," James Reid confirms, the eternal optimist. He is talking about a theory of quantum gravity as approached from a quantum mechanical point of view, but I want to think it's a broader statement than that.

Penrose, relaxed and soft-spoken, seems surprised as he answers, "Well, that's true."

— Lauren Greenspan

A generalization of the Virasoro algebra to arbitrary dimensions, Razvan Gurau, **arXiv:1105.6072**

A Note on CFT Correlators in Three Dimensions, Simone Giombi, Shiroman Prakash, Xi Yin, **arXix:1104.4317**

A real ensemble interpretation of quantum mechanics, Lee Smolin, **arXiv:1104.2822**

An experimental test of all theories with predictive power beyond quantum theory, Terence E. Stuart, Joshua A. Slater, Roger Colbeck, Renato Renner, Wolfgang Tittel, **arXiv:1105.0133**

Anisotropic Modulus Stabilisation: Strings at LHC Scales with Micron-sized Extra Dimensions, C.P. Burgess, F. Quevedo, M. Cicoli, **arXiv:1105.2107**

Bubble divergences: sorting out topology from cell structure, Valentin Bonzom, Matteo Smerlak, **arXiv:1103.3961**

CDT as a scaling limit of matrix models, Jan Ambjorn, **arXiv:1105.1741**

Compressing the hidden variable space of a qubit, Alberto Montina, **Phys. Lett. A 375, Issue 11, 1385 (2011)**

Conjectures and questions in convex geometry (of interest for quantum theory and other physical statistical theories), P.G.L. Porta Mana, **arXiv:1105.3238**

Cosmological production of noncommutative black holes, Robert B. Mann, Piero Nicolini, **arXiv:1102.5096**

Critical behavior of colored tensor models in the large N limit, Valentin Bonzom, Razvan Gurau, Aldo Riello, and Vincent Rivasseau, **arXiv:1105.3122**

Efficiently enclosing the compact binary parameter space by singular-value decomposition, Kipp Cannon, Chad Hanna, Drew Keppel, LIGO-P1000039-V2, **arXiv:1101.4939**

Evidence for Rapid Redshift Evolution of Strong Cluster Cooling Flows, R. Samuele , B.R. McNamara, A. Vikhlinin, C.R. Mullis, **arXiv:1101.4966**

Experimental magic state distillation for fault-tolerant quantum computing, Alexandre M. Souza, Jingfu Zhang, Colm A. Ryan, Raymond Laflamme, **arXiv:1103.2178**

Free Randomness Amplification, Roger Colbeck, Renato Renner, **arXiv:1105.3195**

F-theory GUTs with U(1) Symmetries: Generalities and Survey. Matthew J. Dolan, Joseph Marsano, Natalia Saulina, Sakura Schafer-Nameki, **arXiv:1102.0290**

Gamma ray burst delay times probe the geometry of momentum space, Lee Smolin, Laurent Freidel, **arXiv:1103.5626**

Geodesically Complete Analytic Solutions for a Cyclic Universe, Itzhak Bars, Shih-Hung Chen, Neil Turok, **arXiv:1105.3606**

Granularity and Inhomogeneity Are the Joint Generators of Optical Rogue Waves, Alberto Montina, F.T. Arecchi, U. Bortolozzo, S. Residori, **Phys. Rev. Lett. 106,153901 (2011)**

Higher Codimension Singularities Constructing Yang-Mills Tree Amplitudes, Sayeh Rajabi, **arXiv:1101.5208**

Holographic bulk viscosity: GPR versus EO, Alex Buchel, Umut Gursoy, Elias Kiritsis, **arXiv:1104.2058**

Holonomic quantum computing in ground states of spin chains with symmetry-protected topological order, Stephen D. Bartlett, Akimasa Miyake, Joseph Renes, Gavin Brennen, **arXiv:1103.5076**

Location-Oblivious Data Transfer with Flying Entangled Qudits, Adrian Kent **arXiv:1102.2816**

Majorana Fermions in Proximity-coupled Topological Insulator Nanoribbons, Marcel Franz, Andrew Cook, **arXiv:1105.1787**

Mass Inflation in the Loop Black Hole, Eric G. Brown, Robert B. Mann, Leonardo Modesto, **arXiv:1104.3126**

Measurement contextuality is implied by macroscopic realism, Z. Chen, A. Montina, **Phys. Rev. A 83, 042110 (2011)**

Neutrino Physics with Dark Matter Experiments and the Signature of New Baryonic Neutral Currents, Maxim Pospelov, **arXiv:1103.3261**

New Constraints (and Motivations) for Abelian Gauge Bosons in the MeV-TeV Mass Range, M. Williams, C.P. Burgess, F. Quevedo, **arXiv:1103.4556**

New Parity-Violating Muonic Forces, Brian Batell, David McKeen, Maxim Pospelov, **arXiv:1103.0721v1**

PIRSA Pick of the Issue

On the fast scrambling conjecture
Patrick Hayden, McGill University
Series: Holographic Cosmology v2.0
http://pirsa.org/11060051

New Variables for Classical and Quantum Gravity in all Dimensions IV, Matter Coupling, N. Bodendorfer, T. Thiemann, A. Thurn, **arXiv:1105.3706**

Non-Abelian Discrete Dark Matter, Adisorn Adulpravitchai, Brian Batell, Josef Pradler, **arXiv:1103.3053v1**

Notes on affine and convex spaces, PierGianLuca Mana, **arXiv:1104.0032**

On Higher Spin Gauge Theory and the Critical O(N) Model, Simone Giombi, Xi Yin, **arXiv:1105.4011v1**

On Holographic Entanglement Entropy and Higher Curvature Gravity, Ling-Yan Hung, Robert C. Myers, Michael Smolkin, **arXiv:1101.5813**

Particle Creation by Loop Black Holes, Leonardo Modesto, Emanuele Alesci, **arXiv:1101.5792**

Probing CP violation with electric dipole moments, Maxim Pospelov, Adam Ritz, 80pp. In Roberts, Lee B., Marciano, William J. (eds.): Lepton dipole moments 439-518, (Advanced series on directions in high energy physics. 20)

Pulling the straps of polygons, Davide Gaiotto, Juan Maldacena, Amit Sever, Pedro Vieira, **arXiv:1102.0062**

Quadrupolar contact fields: Theory and applications, C.G. Gray, G. Karl, V.A. Novikov, Nov 2008. 11pp. Published in **Am.J.Phys.77:807-817,2009**

Radiative corrections in the Boulatov-Ooguri tensor model: The 2-point function, Joseph Ben Geloun, Valentin Bonzom, PI-QG-208, ICMPA-MPA-002-2011, **arXiv:1101.4294**

Radiative Fermion Masses in Local D-Brane Models, Cliff Burgess, Sven Krippendorf, Anshuman Maharana, Fernando Quevedo, **arXiv:1102.1973**

Reformulating and Reconstructing Quantum Theory, Lucien Hardy, **arXiv:1104.2066**

Relative locality and the soccer ball problem, Lee Smolin, Giovanni Amelino-Camelia, Laurent Freidel, Jerzy Kowalski-Glikman, **arXiv:1104.2019**

Relativistic particle in a three-dimensional box, Pedro Alberto, Saurya Das,, Elias C. Vagenas, **arXiv:1102.3192**

Robustness of the Blandford-Znajek mechanism, Carlos Palenzuela, Carles Bona, Luis Lehner, Oscar Reula, **arXiv:1102.3663**

Simplified Models for LHC New Physics Searches, Philip Shuster, Natalia Toro, et al. **arXiv:1105.2838**

State-space dimensionality in short-memory hidden-variable theories, Alberto Montina, **Phys. Rev. A 83, 032107 (2011)**

Tailoring Three-Point Functions and Integrability II. Weak/strong coupling match, Jorge Escobedo, Nikolay Gromov, Amit Sever, Pedro Vieira, **arXiv:1104.5501**

The 1/N expansion of colored tensor models in arbitrary dimension, Razvan Gurau, Vincent Rivasseau, **arXiv:1101.4182**

The Geometry of Modified Newtonian Dynamics, Constantinos Skordis, Tom G. Zlosnik, **arXiv:1101.6019v1**

The Many Worlds of Hugh Everett III, Adrian Kent, **arXiv:1103.4163**

The Observer Class Hypothesis, Travis Garrett, **arXiv:1101.2198**

Too Damned Quiet? Adrian Kent, **arXiv:1104.0624**

Toward a "fundamental theorem of quantal measure theory," Rafael Sorkin, **arXiv:1104.0997**

Towards a derivation of holographic entanglement entropy, Horacio Casini, Marina Huerta, Robert C. Myers, **arXiv:1102.0440**

Universal topological phase of 2D stabilizer codes, Guillaume Duclos-Cianci, David Poulin, Hector Bombin, **arXiv:1103.4606**

Universal topological phase of 2D stabilizer codes, Hector Bombin, Guillaume Duclos-Cianci, David Poulin, **arXiv:1103.4606**

Yet Another Recursion Relation for the 6j-Symbol, Valentin Bonzom, Etera R. Livine, **arXiv:1103.3415**

Extra! Extra!

Congratulations to journalist Rose Simone, who was recently awarded the prestigious "Science in Society" journalism award from the Canadian Science Writers Association for her article about now former PI postdoc Aninda Sinha and his wife Urbasi, a postdoc at the Institute for Quantum Computing. "The Power of Two," published last year in the *Waterloo Region Record*, chronicled Urbasi and Aninda's shared passion for science — and the unique paths each has followed. It was part of a series of articles Simone wrote as part of the "Young Innovators" series, which profiled exceptional young scientists working in Waterloo Region. Other stories in the series profiled Associate Faculty member Niayesh Afshordi and his wife, now former PI postdoc Ghazal Geshnizjani, and PI postdoc Akimasa Miyake.

Holographic Cosmology v2.0

From June 21 - 24, 2011, Perimeter Institute was host to the "Holographic Cosmology v2.0" workshop, the first of a series organized in partnership with the Stanford Institute for Theoretical Physics.

The central aim of the workshop was to produce a sensible and rigorous theory of "quantum cosmology." Cosmology is the study of the physical origins and evolution of the universe. Hence quantum cosmology attempts to apply the principles of quantum theory to the universe as a whole, in addressing fundamental cosmological issues such as the nature of the big bang, the initial conditions and fate of the universe.

Modern quantum cosmology has been impacted by a variety of dramatic developments, such as the discovery of a vast landscape of possible vacua in string theory. String theory has also provided an extraordinary new picture of quantum gravity and the universe with the "holographic principle." The latter suggests that a quantum theory of gravity should have an equivalent description in terms of a conventional quantum theory without gravity living on the boundary of spacetime. Ideas are gradually beginning to take shape on how concepts like holography and other deep insights uncovered in the past two decades may lead to new fundamental principles for cosmology. As well as providing new insights into the long-standing questions of quantum cosmology, these new approaches will most likely lead us in new directions and allow us to formulate the "right" questions.

This workshop brought together leading researchers working in cosmology, string theory, quantum gravity and quantum information to exchange ideas on recent progress and discuss promising future directions.

The participants included a long list of world-renowned researchers. Let me give special mention to a few of these: Juan Maldacena, the discoverer of the AdS/CFT correspondence, our most reliable realization of the holographic principle; Joe Polchinski, best known for his discovery of D-branes, extended structures that appear to be central to the mathematics and physics of string theory; John Preskill, a leading researcher in quantum information theory; Steve Shenker, a distinguished string theorist whose contributions include the co-discovery of Matrix Theory, the first nonperturbative definition of string theory (along with Banks, Fischler and Susskind — the latter two were workshop participants as well); Erik Verlinde, well known for his many contributions to string theory and most recently for his invention of entropic gravity; and Alex Vilenkin, who is responsible for introducing ideas such as eternal inflation and the quantum tunneling of the universe from nothing.

Erik Verlinde and Richard Bond during the Holographic Cosmology v2.0 conference.

"The conference on Holographic Cosmology v2.0 was one of the most stimulating meetings I have been to in recent years. I particularly enjoyed the discussions during and after the talks with participants from fields ranging from cosmology to quantum information. It is very interesting to see these different fields have become linked through the holographic principle."

- Erik Verlinde

The workshop saw the participation of many researchers in Perimeter's extended family, including Distinguished Research Chairs Patrick Hayden, Eva Silverstein and Lenny Susskind; Affiliates Richard Bond, Alex Maloney, Robert Mann and Mark van Raamsdonk; Scientific Advisory Committee (SAC) members John Preskill and Erik Verlinde, as well as a SAC alumnus, Joe Polchinski.

Alongside presentations from these eminent senior researchers, the workshop also included talks by many outstanding young graduate students and postdoctoral researchers, which added to the lively and informal atmosphere. There was also a video link to the new Simons Center for Geometry and Physics at Stony Brook University on Long Island, allowing researchers there to view all of the talks live and participate in the discussions.

A sampling of the highlights includes:

- Frederik Denef (Harvard University) gave a fascinating introduction to various ideas and methods that have been useful in the study of complex systems such as spin glasses and discussed how they can play a role in understanding D-branes on Calabi-Yau manifolds and their black hole duals. He further speculated on how these approaches may also find application in a cosmological setting.

- Patrick Hayden (McGill University) discussed various aspects of "fast scrambling" and presented a number of toy examples which explored the validity of the conjecture that the fasted time in which any physical system can scramble its internal degrees of freedom is bounded by the system's entropy.

- Simeon Hellerman (Institute for the Physics and Mathematics of the Universe, Tokyo) gave an enlightening presentation on consistency relations imposed on bulk theories of gravity by their holographic dual descriptions and, in particular, the limitations faced by proposals for a duality between gravity in de Sitter space and a boundary conformal field theory.

- Alex Maloney (McGill University) spoke about an explicit computation of the partition function of quantum Einstein gravity in three-dimensional de Sitter space and was able to conclude that the Hartle-Hawking state is not normalizable in this theory.

- Eva Silverstein (Stanford University) gave a presentation on how in string theory various ingredients can be combined to produce interesting cosmological solutions, including metastable de Sitter solutions and their decay to a Friedmann–Robertson–Walker cosmology. Building on her discussion, in the following presentations, Bart Horn and Xi Dong (Eva's students) reported on different features of the holographic description of these string theoretic cosmologies.

- Lenny Susskind (Stanford University) gave a preliminary report on his intriguing new ideas for applying holographic reasoning to derive a finite measure on an eternally inflating universe. The latter is an essential "missing link" in all of these discussions which is required to remove certain divergences or ambiguities in calculations describing the multiverse.

- Erik Verlinde (Utrecht University) gave a provocative presentation on his recent ideas that gravity arises from the existence of a hidden phase space associated with an underlying fast dynamical system, which is largely invisible from a macroscopic point of view. He inferred that in a cosmological setting the appearance of dark energy is naturally explained by the temperature of this underlying system and he further discussed some simple estimates which indicated that the phenomena attributed to dark matter could also be explained in this way.

- I Sheng Yang (Columbia University) discussed how the collisions of cosmic bubbles can result in classical transitions between various vacua in the landscape.

All in all, it was an extremely stimulating and successful meeting. At the close of the workshop, Professor Susskind invited all of us to participate in the next Perimeter-Stanford meeting which will be hosted at Stanford next year.

—Robert C. Myers

Editor's Note: More information about the meeting, and all of the talks can be found at: www.pitp.ca/Holographic-Cosmology2.0.

Conference participants at Holographic Cosmology v2.0.

Participants at the Back to the Bootstrap conference.

Back to the Bootstrap

Conformal field theories (CFT) are a cornerstone of our current description of the world. Since the 1970s, it has been known that conformal field theories can be defined algebraically in terms of basic data (OPE coefficients and conformal dimensions) satisfying the crossing symmetry, unitarity and modular invariance constraints. However, these constraints seemed very hard to solve and little progress was made until recent years.

The goal of this workshop was to bring together the small community that is reviving this approach to CFT and researchers working on closely related topics, in order to stimulate collaborations and create synergies to boost the development of this subject.

The workshop was organized by João Penedones and Pedro Vieira from PI and Leonardo Rastelli from Stony Brook University. We had approximately 20 invited speakers, including researchers from Europe, America and Asia. The workshop was organized into six discussion sessions covering the following topics:

1. Holography and CFT/AdS – This session was devoted to the question: what CFTs have (useful) gravitational duals?
2. AdS/CFT correlation functions and Integrability – There has been remarkable progress in the description of maximally supersymmetric Yang-Mills theory. In this session, we discussed possible approaches to the computation of correlation functions.
3. Conformal Blocks – Hugh Osborn reviewed the state of the art and presented some new results on the three dimensions.
4. Crossing and Unitarity Bounds – This session discussed the numerical implementation of the crossing symmetry constraint. This is a promising research avenue for the future.
5. Space of CFTs – Michael Douglas and Leonardo Rastelli proposed several distance functions in the space of CFTs.
6. Bounds from Gedanken Experiments – Diego Hofman explained how conformal collider physics "experiments" imply bounds on the OPE coefficients. Rob Myers showed that these bounds follow from the requirement of causal behavior around AdS black holes.

There were many more exciting topics discussed during the workshop. We predict that this workshop will be followed by many more in the coming years, as this research area grows in size and importance.

—Pedro Vieira and João Penedones

Conceptual Foundations and Foils for Quantum Information Processing (C2FQIP)

An atmosphere of excitement currently pervades quantum foundations. Thanks to the injection of new ideas from quantum information theory, the field is flourishing, with a burst of new exciting results and many researchers joining the community.

Held from May 9 to 13, 2011, C2FQIP focused on two subjects that have seen a great deal of activity in recent years: (1) the study of informational principles from which quantum theory – and information-processing aspects thereof – can be derived, and (2) the study of operational foils to quantum theory – that is, probabilistic theories that differ from quantum theory and thereby highlight what is special about it.

This area of research lies at the interface of quantum foundations and quantum information theory and has benefitted from a conspicuous cross-fertilization of ideas from the two fields. Examples of questions addressed at the conference include: "Can we derive quantum theory from elementary principles about information processing?" and "Where does the power of quantum information protocols

come from?" In contrast with the spirit of much previous work in quantum foundations, which has been oriented towards interpretations of quantum mechanics, the approach of the research presented at C2FQIP is pragmatic and oriented to applications, especially in cryptography and computer science.

The C2FQIP programme opened with a two-day presentation of the most recent results on the axiomatization of quantum theory and continued throughout the week with talks on the information-theoretic consequences of non-locality and contextuality, on communication complexity, and on computation in general probabilistic theories. This was followed by an informal week-long workshop, featuring few talks and an open schedule in order to allow time for collaborations.

C2FQIP was a major event in the field of quantum foundations. 110 registered participants attended 29 invited talks delivered by top scientists, plus a lively poster session including 30 posters and a book exhibit from Springer.

The conference contained a significant quantum information component, featuring talks from some of the founding fathers of the field (Bennett, Brassard, Popescu, and Schumacher) and from some of its most active researchers (e.g., Aaronson, Renner, and Winter). The audience was diverse and included researchers from physics, computer science, and applied mathematics, with a significant component of students and early career researchers. The encounter of different expertises took place in an atmosphere of mutual interest and respect.

Upon the successful conclusion of the conference, several participants asked us to make C2FQIP a regular venue for the quantum foundations community. We are currently considering this option and the opportunity to broaden the spectrum of the conference to facilitate the interactions with other areas of theoretical physics, in particular, quantum field theory, thermodynamics, and gravity.

—Giulio Chiribella and Robert Spekkens

Editor's Note: More information about the meeting and all of the talks can be found at: www.pirsa.org/C11006.

4-Corner Southwest Ontario Condensed Matter Symposium 2011

Once a year, "Four Corners" brings together researchers in Condensed Matter Physics from the University of Toronto, Trent University, the University of Guelph, McMaster University, University of Waterloo, Brock University and the University of Western Ontario to meet for a day, hear half-hour presentations from researchers, as well as two one-hour talks from invited speakers.

Invited keynote speaker Eduardo Fradkin (U. Illinois at Urbana-Champaign) talked about stripe physics in high-temperature superconductors. The second keynote talk, given by Seamus Davis (Cornell), was on the closely connected topic of recent progress in Fourier transform analysis of gap and density of states map in copper-oxide high-temperature superconductors.

Once again, the meeting was a success, with 71 registered participants, including a large number of graduate students. This event is a good opportunity to expose students and postdocs to excellent research ongoing in the nearby institutions, and presenters generally made their talks accessible to the broad audience. We expect to repeat this worthwhile event in April 2012.

—Michel Gingras

Editor's Note: More information about the meeting and all of the talks can be found at: www.pirsa.org/C11004.

C2FQIP participants. To see a labelled, high resolution version of this photo go to, www.pitp.ca/C2FQIPphoto. Photo courtesy of Prof. Charlie Bennett.

Here at Perimeter, Summer is Conference Season...

Challenges for Early Universe Cosmology

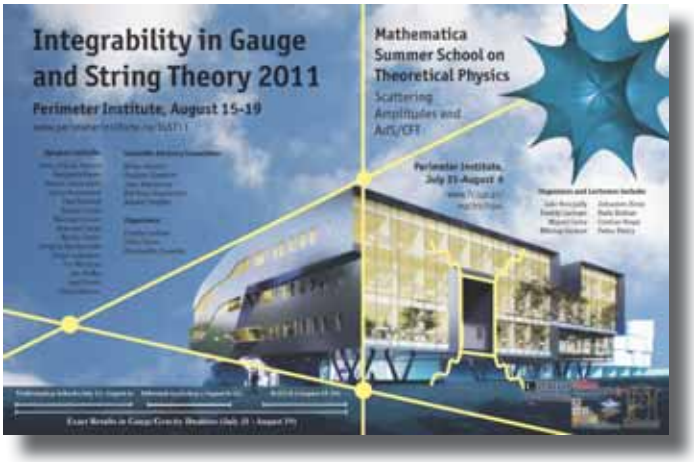
July 12 - 16, 2011

The goal of this conference is to encourage new thinking on important unresloved questions in early universe cosmology.

Women in Physics Canada

July 19 - 21, 2011

This three-day conference is aimed at undergraduates and early graduates, to provide support to young women in physics and astrophysics, and to encourage them to continue in a career in science.



IGST 2011

August 15 - 19, 2011

The purpose of this conference is to assess the current status of this rapidly evolving field by bringing together experts in gauge theories, strings, integrable systems and mathematics.

Unravelling Dark Matter

September 22 - 24, 2011

This workshop will bring together leading theoretical particle and astrophysicists whose work is relevant in the direct and indirect detection of dark matter.

CBC RADIO'S *QUIRKS & QUARKS* WINS WITH PHYSICS

With a panel of top physicists assembled in partnership with Perimeter Institute, CBC Radio's *Quirks and Quarks* won a Silver prize in the education category at the 2011 New York Festivals' International Radio Awards for the episode, "Top 10 Unanswered Questions in the Universe." The episode features 10 scientists who had assembled for PI's Q2C Festival, each posing a key question such as "Does time exist?" "How did the universe begin?" and "How real is reality?"

The winning CBC/PI episode is available online at:
http://www.cbc.ca/quirks/episode/2010/01/02/the-top-10-unanswered-questions-in-the-universe/

Paying it Forward: PSI Grad Becomes AIMS Tutor

The bracing cold of Waterloo winter and the intense research environment that characterizes PI feel like another universe as I relax outside a beachfront café in Muizenberg, outside of Cape Town, South Africa, on a hot Saturday morning in February. This particular morning, however, is an opportunity to catch up with a dear friend, Bruno Le Floch, who at 20 was the youngest of my fellow graduates of the inaugural Perimeter Scholars International (PSI) class of 2010. Bruno, who hails from Paris, chose to follow his year in Canada with a year in Cape Town, putting his hard-earned PSI knowledge to good use as a tutor at the African Institute for Mathematical Sciences (AIMS).

AIMS is the brainchild of PI Director Neil Turok, and the pilot institution of the AIMS-Next Einstein Initiative. The institute brings gifted African students to a restored building on the seashore of Muizenberg, with the intention of developing their talent and ultimately of creating a generation of mathematically trained leaders and innovators with the potential to tackle Africa's deepest problems.

Bruno Le Floch teaching at AIMS-South Africa

Bruno arrived at AIMS with doctoral funding at Perimeter already secured, but chose to delay his research career in favour of a sabbatical. Bruno's been far from idle during his time here. As if feeding 50 bright, hungry minds and keeping up with a tutoring and marking load weren't enough, a project to advance the LaTeX document processing language and string theory research for his future supervisor, PI Faculty member Jaume Gomis, have kept him busy throughout his stay.

When asked what he's enjoyed most about his year, though, Bruno turns immediately to the students he's tutored. "Some students have very difficult stories to tell," he says, but exuberantly praises their talent, enthusiasm and dedication. He has learned a great deal about the similarities and differences between the developed and developing worlds, telling of a talented algebraic-geometer from Malawi who spent six months within walking distance of Muizenberg station before taking his first train, and another student who had to be prevented from putting a metal can in the microwave — he'd never used one before. "Be prepared to have students knocking on your office door at 3 am to ask you questions," he warns potential future tutors, rather proudly.

AIMS and PSI have similar teaching patterns, with lecturers from leading institutions around the world giving intensive, three-week courses, followed by assignments with continuous assessment. Bruno's immediate response when asked to compare the AIMS programme to his own experience at PSI is that "AIMS is tough. PSI is tougher." This is to be expected, as AIMS provides a more holistic introduction to research in the mathematical sciences, whereas PSI is more deeply focused on theoretical physics. AIMS' broader approach is designed as a springboard into academia, government and business alike. Bruno has encouraged several AIMS students with an interest in theoretical physics, some of whom he is helping to supervise, to choose PSI as the next step in their academic careers.

Professor Barry Green, Director of AIMS, speaks highly of Bruno's impact on AIMS, calling his time at the Institute "a great success, because of his scientific strength, confidence and sharpness, but also because he is a warm, easygoing person and makes friends within a few hours, and interacts very well with our students." He emphasizes the pivotal role of tutors in the programme, many of whom are from African countries and have "succeeded against the odds."

The students under the tutelage of Bruno and his peers will certainly benefit enormously from their experience and dedication, but the benefit doesn't stop there. Arun Sharma, Acting Executive Director for the Next Einstein Initiative, believes strongly that centres like AIMS can have an impact that stretches far beyond individual students. He uses the success

of the Indian Institute of Technology as an example, citing the positive role graduates have played in the country's emergence onto the global stage. "I am keen to see AIMS graduates, brought to scale through the AIMS-Next Einstein Initiative, do the same for their countries and the African continent," he says.

Sharma is equally enthusiastic about his work with Neil Turok, calling him "an inspiring visionary who sees no obstacles to achieving his dreams." Turok's vision is already bearing fruit, and Sharma encourages us all to watch the careers of the first generation of AIMS graduates, now entering positions in academia and industry, with interest.

As for Bruno, he'll return to PI in the autumn to begin doctoral studies, by which time most of his former students will have started higher degrees at institutions around Africa and the world, with bright futures ahead of them. He encourages other PSI students to consider taking some time to give back to the AIMS programme and to strengthen the link between the two institutions. Professor Green is equally encouraging, going so far as to say that AIMS "looks forward to making an annual Perimeter tutor appointment."

The Next Einstein Initiative's future is bright, too, with centres planned in 15 countries across Africa, and many more innovative teaching and outreach initiatives in the cards.

—Imogen Wright

AIMS IN *NATURE*

A recent special issue of *Nature* highlights PI's Global Outreach Partner, the African Institute of Mathematical Sciences (AIMS) and the Next Einstein Initiative (NEI), as part of an in-depth analysis on how African nations are building capacity in scientific research and development.


COMMENT

Africa AIMS high

Eight years ago, physicist Neil Turok set up the African Institute for Mathematical Sciences in South Africa. The initiative is now set to expand across the continent.

PI Director and AIMS founder Neil Turok shares the story of AIMS and NEI in a Comment piece giving a personal perspective on the opening of the first AIMS centre in Cape Town, South Africa, and the growing potential of the Next Einstein Initiative to unlock Africa's prosperity and solve the continent's toughest challenges from within.

Ghana Invests in AIMS

The Government of Ghana has committed US$1.5 million to the centrepiece of PI's global outreach effort, the African Institute for Mathematical Sciences – Next Einstein Initiative (AIMS-NEI). The funding will go towards the building of AIMS-Ghana, the third independent institute of AIMS-NEI, which aims to create a coordinated network of 15 centres by 2021.

The first AIMS centre, in Cape Town, South Africa, was founded by PI Director Neil Turok, and has become a globally recognized centre of excellence for postgraduate education and research. Its mission is to rapidly expand Africa's scientific and technological capacity by providing advanced training to exceptional African graduates.

Professor Francis Allotey, a distinguished Ghanaian scientist and founder of AIMS-Ghana said, "This is a strategic investment in young people. Ghana and Africa will reap the benefits of this initiative for a very long time." Sir Michael Berry, FRS, a long-time supporter of AIMS-NEI, emphasized, "It is the time of Africa, time to release the vast potential for innovation and discovery from the peoples of this continent. AIMS is both an early indicator and a driver of this African scientific renaissance."

The Ghanaian Government support is matched by funds from the Canadian Government, Google and the Alero Olympio Trust for sustainable architecture. Construction is expected to begin in late 2011, once the architecture competition closes and exact plans have been chosen. "We are thrilled with Ghana's leadership on this initiative and delighted to be working with its scientists, universities and government to ensure AIMS-Ghana is a jewel benefitting all," said Professor Turok.

His Excellency John Mahama, Vice-President of Ghana, expressed the importance the Government attaches to education, especially in the sciences. "We see AIMS-Ghana as a springboard for the future development of the people of Ghana and of Africa," he told the AIMS-Ghana delegation.

AIMS-Ghana will be built in Saltpond, seat of the African independence movement, and is slated to open in September 2012.

—Mike Brown

Participants at ISSYP 2010.

Summer's here, and PI Outreach is a hive of activity as we make final preparations for our summer teacher and student programs. Some of the top high school physics students from across Canada and around the globe will be spending two weeks of their summer vacation wrestling with some of the deepest mysteries of our universe, and forging international friendships with future colleagues who may one day help them solve some of those same mysteries. Similarly, our EinsteinPlus teacher camp provides us with an opportunity to share with keen physics educators from coast to coast to coast.

Looking back, we are motivated by the success of the recent Waterloo Global Science Initiative's *Equinox Summit: Energy 2030* (see page 13). The level of debate and the infusion of the latest scientific thinking around the current state of energy production were truly inspirational. Tomorrow's leaders, the WGSI Forum members, are already taking the Summit's recommendations forward at venues across the globe, and you can still watch the talks on demand at www.wgsi.org.

I'm pleased to announce that Sun Life Financial, the presenting sponsor for our Public Lecture Series, will be renewing their support for the coming year. This year has seen another incredible series of lectures, with greats like Eric Mazur, Marcus Chown, Sir Roger Penrose, and Freeman Dyson. Thank you to Sun Life, to all of our volunteers, to the extended PI staff, and especially to Public Events Producer, Renée Ellis, who, year after year, manages to bring some of the world's greatest minds to the stage.

PI Outreach wants to be a resource to educators across Canada and beyond, by not only providing resources and programs to help teachers inspire themselves and their students, but also by acting as a conduit between educational communities. In support of this goal, we will be participating at the High School Teachers' Program at CERN in Geneva, Switzerland in mid-July, connecting with science educators from around the world. This year, for the first time, winners of the Canadian Association of Physics teaching award were offered the opportunity to attend as well.

Finally, I wish thank Julie Taylor, who is moving on after nearly five years as our outstanding Outreach Coordinator. All of our educational programs have flourished under her wonderful care and passion — we all wish her the very best.

—Greg Dick

Teachers at EinsteinPlus 2010

NEWS FLASH: OVER 100,000 STUDENTS HAVE EXPERIENCED PI'S EDUCATIONAL RESOURCES IN THEIR CLASSROOM THIS YEAR!

Sharing Resources With Teachers

The PI Teacher Network continues to gain momentum with new initiatives and wraps up the school year with several inspiring outcomes, reaching over 1,200 teachers and 42,000 students through workshops across Canada.

French Language and Northern Science Teachers

French language resources are now available for *The Mystery of Dark Matter* and *Measuring Planck's Constant.* They have been distributed to Teacher Network Associates in Ontario, New Brunswick, Alberta, Saskatchewan and Quebec. This year, efforts were also made to offer workshops in remote northern Ontario locales, including Sudbury, Timmins, Thunder Bay, Fort Francis, Sioux Lookout and Dryden. Covering a span of over 1,700 kilometres, "the isolation of northern Ontario is evident," noted Josef Breka, a Teacher Network Associate who connected with physics teachers in these regions during his workshops.

Everyday Einstein: GPS and Relativity

This year, the bulk of Teacher Network workshops involved PI's newest resource, *Everyday Einstein: GPS and Relativity*. The workshops were attended by teachers of varied levels of teaching experience, including those without a background in physics, who voiced their sincere appreciation for making modern physics ideas so accessible. The *Everyday Einstein: GPS and Relativity* resource is also aimed at grade nine students and the workshops have been attracting a large number of general science teachers.

Teachers shared their excitement that not only does the GPS resource connect directly to teaching relativity in Grade 12 physics, but it also connects to other curriculum areas, including astronomy, earth-space science, geography, geomatics and mathematics.

"This was fantastic! Very excited that PI is introducing resources for junior classes. Great way to have students excited for science."

PI Teacher Network Coordinator: Philip Freeman, British Columbia

Congratulations and welcome aboard to Philip Freeman, a physics teacher at Richmond Secondary School in British Columbia. Philip has developed resources with TRIUMF, was the 2010 recipient of the CAP Award for Excellence in Teaching Physics, and now brings his 20 years of expertise to the PI Teacher Network as a Teacher Network Coordinator for the province of British Columbia. PI looks forward to Philip's participation and leadership.

—Julie Taylor and Roberta Tevlin

Taking Physics to the People

Alice and Bob are PI's beloved animated siblings who ask simple questions that lead to profound insights about the universe. In the past year, Alice and Bob have been on the road, visiting students and teachers across Canada and beyond. They've been spotted across Ontario, and further afield, in Alberta, the Northwest Territories, Nova Scotia, the US and even in Switzerland!

Alice and Bob will be starring in a new Perimeter Inspirations teachers' kit, *Revolutions in Science*, which introduces students to the three key ideas of modern physics: special relativity, general relativity and quantum mechanics. Look for it starting in September. A new DVD with all nine high-resolution episodes and informative liner notes is now also available for teachers.

To meet Alice and Bob go to: **www.pitp.ca/Alice+Bob**.

Sun Life Renews Support for PI Public Lectures

At the last public lecture of the season, given by Freeman Dyson of the Institute for Advanced Study, we were thrilled to announce that Sun Life Financial will be renewing its sponsorship of the PI Public Lecture Series for the 2011–12 season.


Freeman Dyson

Time and again, scientists of international renown venture to Waterloo to participate in the PI Public Lecture Series, presented by Sun Life Financial, and express surprise at the packed hall that awaits them as they take the stage at nearby Waterloo Collegiate Institute. A sell-out crowd for a physics lecture? Indeed, not every community could muster the academic inclination. But Waterloo can and does – with both ease and enthusiasm.

It was another outstanding year for the PI Public Lecture Series, bringing a variety of speakers who ensured all eight lectures were full to capacity, with many patrons spilling into our overflow room. In particular, two of the season's final talks, given by Sir Roger Penrose and Professor Freeman Dyson, set new PI records by "selling out" online in less than two minutes each.

With the 2010–11 Public Lecture Series in the books, we're already looking forward to a wonderful new season, which will commence in November.

–Renée Ellis

Editor's Note: See all of the Public Lectures online at www.pitp.ca/publiclectures, on television via TVO's Big Ideas program and on tvo.org.

EinsteinPlus Teachers Reunite Online

In May, PI staged its first-ever reunion for alumni of EinsteinPlus teachers' workshops. Conducted online via web seminar, the event involved participants from Ontario, Alberta, and BC, and the US.

The reunion reconnected teachers and provided a refresher 10 months after attending EinsteinPlus. It included informal discussion, a review of workshop material, and a sneak peek at a resource on particle physics that's now in preparation. The webinar forum provided an excellent opportunity for teachers to collaborate, and share the teaching strategies that they've found further increase the value of PI resources in their classrooms.

The response was overwhelmingly positive, with participants saying the event was refreshing, motivating and highly informative. We plan to run similar events in the future, keeping connections between PI and our keen physics teachers vibrant.

–Damian Pope

Getting To Know a Legendary Character

During their time in Waterloo, most of PI's Public Lecture speakers do much more than give a lecture. They become, for a time, part of PI's community, interacting with resident scientists and students. Here, Maita Schade, who recently completed the PSI Masters program, shares her impressions of her encounter with Professor Freeman Dyson:

As one of the students who discovered their calling to physics only later in life, I hadn't more than heard his name in passing when I arrived in Waterloo. Then, during my quantum field theory course at PSI, I made the acquaintance, full of initial awkwardness and confusion, of the Dyson-Schwinger equation. Soon thereafter, I got to know about Dyson spheres and Dyson trees. By the time Freeman Dyson dropped by PI at the beginning of June, I, too, understood that we were dealing here with one of the most influential theoretical physicists of the 20th century.

The morning after his public lecture, we got to experience his infamous wit up close over coffee. At first, both Freeman and the PSIons were a bit shy, but we warmed to each other quickly – and chatted for over an hour and a half. The very short story of quantum electrodynamics (QED) straight out of one of its founding fathers' mouths was not even the most exciting bit, although we were pleased to hear how he did QED before Feynman diagrams: "I had Feynman right there, so I didn't have to for very long."

We learned that responses to popular science books usually come in two waves, those who violently agree, and those who violently disagree. We heard about the flaws in the design process for nuclear power plants, from a man who had spent years working as a nuclear engineer. We were astonished by the number of organizations this man has been part of, trying to prevent nuclear escalation and open borders. We discovered that this groundbreaking scientist was also a friend of groundbreaking – or, as he put it, "confused and experimental" – education. He said he considers himself lucky to have grown up during World War II, because "we didn't have any paper, so we couldn't have any exams." We found out that he had never heard of Gordon Freeman, the legendary video game character based on him. And we marvelled at the humility of a great physicist who asserts that he is just a "frog, playing in the mud and looking at the beautiful flowers on the ground."

I am sure conversation would have spilled over into lunch, had Lee Smolin not appeared to escort our visitor to lunch with the quantum gravity group. But even so, this in-person encounter with Dyson went much more smoothly than my first one with his equations.

–Maita Schade

Cowan Foundation Supports Inspirations

Thank you to the Cowan Foundation, which has generously agreed to renew its support for PI's Educational Outreach programming. Last year, the Foundation's gift supported the creation of the third *Perimeter Inspirations* teachers' kit, *Revolutions in Science*. The new gift will help to create the fourth in the series. Pictured above are Greg Dick, PI's Director of Educational Outreach; Judy Dawe, Commercial Accounts Executive, Cowan Insurance Group; Debbie Adare, PI Advancement Campaign Manager; Susan MacDonald, Underwriting Consultant, Cowan Insurance Group; and Colleen Brickman, PI's Director of Facility Management.

Curtains On Another Phenomenal Concert Season

Each concert in the Classical World Artists Series was completely sold out (as usual) this past season. The artists included cellist Joshua Roman, superstar violinist Joshua Bell, pianist Yuja Wang, and the incomparable Yefim Bronfman, also on the piano.

In March, Yuja Wang drew nearly 50 of Perimeter's residents (of the 200-plus in the audience) to witness her dazzling displays of virtuosity, making it one of the indisputable highlights of the 2010–11 season.

Stay tuned – we are working on another exciting season of cultural events that will be announced in the coming months.

—Renée Ellis

"Rumours that I time my stays at PI to coincide with the classical concerts there are greatly exaggerated. Still, the recent performances by [Joshua] Bell and [Sam] Haywood, and [Yefim] Bronfman have been absolute highlights of my agenda. I loved the unique combination of listening to their sublime music-making and being treated afterwards to a special dinner with these exceptional artists and my delightful friends and colleagues from the Institute."

—PI Distinguished Research Chair Renate Loll, on Perimeter's Classical World Artists series

New Faces @ PI

Rita Tourkova, Scientific Programs Assistant

Rita joined PI in May as the Scientific Programs Assistant, taking over for Jodie Carriere while she's on maternity leave. Rita studied Communications at McMaster University in the hopes of making her dream career in the tourism industry a reality. While that dream is currently on hold, she's very happy to find herself in an environment where some of the more common elements of tourism – namely foreigners and accents – abound.

Rita has previously worked as a Newcomer Information Specialist in Hamilton, helping immigrants adapt to their new home, and as a Program Coordinator for the Patients' Association of Canada. At PI, Rita will be coordinating seminars, as well as assisting with the Conference and Visitor Programs. She's really enjoying the collegial atmosphere, the people she's met so far, and the Bistro's delectable assortment of fine cheeses. When she's not at work, Rita can be found on her bike, on the trampoline, on skates, or engaging in a number of other sports. She also loves reading, studying the world map, and wrestling with her two-year-old son, Nolan.

Rita can generally be found in office 206 and her extension is 6061.

From the Black Hole Bistro

Thai Summer Wrap with Mango Ginger Sauce

Marinade:
1 250 g package of Tempeh (the Bistro uses locally made Henry's Gourmet Tempeh)
2 tbsp soy sauce
2 tbsp water
1 tbsp sesame oil
1 tsp maple syrup

Mix together all ingredients, except tempeh. Cut tempeh into strips, steam for five minutes and put in marinade. Cooked chicken, pork or beef can be substituted for tempeh if desired.

Dressing:
1 mango, coarsely chopped
1 tbsp fresh ginger, grated
¼ tsp hot chili sauce, sriracha sauce or sambal ulek (oelek) sauce
1 tbsp water
1 tbsp lime juice
zest from lime
½ tsp soy sauce
1 tbsp maple syrup
1 tbsp rice vinegar

Combine all ingredients in a food processor and mix until mango is puréed.

Wrap:
Large Boston or Romaine lettuce leaves
Cucumber, cut into thin slices length-wise
Tomato, julienned (matchstick shape)
Fresh mint leaves
Other julienned vegetables can be added as well.

Lay tomatoes and mint on lettuce leaves, add tempeh (or meat), drizzle with dressing. Roll lettuce, wrap with cucumber slice and secure. Serve with remaining dressing for dipping.

Makes approximately four servings.

Bistro staffers recently took to the woods outside Stratford on a foraging trip to discover local wild delicacies. Several have made an appearance on the menu.

The expansion isn't quite finished but we're already enjoying the beautiful new Black Hole Bistro!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11

The Life of PI

1. Classical World Artist series performer Yuja Wang with PSI student Tianheng Wang; 2. Here's to Science! Director of Educational Outreach Greg Dick gives a presentation at Margaret Avenue Elementary School; 3. PSI students Shane Farnsworth, Holger Haas and Matt Smith before a Musical Pub Night; 4. Summer contemplation station; 5. Distinguished Research Chair (DRC) Ignacio Cirac conducts a seminar during his visit; 6. A/V technician Laura De Decker's art displayed in the library; 7. Visiting Researcher Pasquale Sodano takes down his opponent during the sumo wrestling tournament; 8. Welcome to the world Milo! Conference Assistant Jodie Carriere's new bundle of joy; 9. Summer's here, and the bike racks are full; 10. Helping beautify uptown Waterloo on Earth Day; 11. Olé! Flamenco dancers perform in the Atrium during cultural month; 12. Small wonder: Senior Researcher Chris Fuchs' daughter Katy gets a henna tattoo; 13. DRC Leonard Susskind and Hong Liu during the Holographic Cosmology v2.0 conference.


12


13