inside the perimeter

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PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

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Members of the public check out Physica Phantastica exhibits on the mezzanine during the Grand Opening of the Stephen Hawking Centre at Perimeter.

By the Numbers

On the weekend of September 16-18, Perimeter Institute doubled the size of its facility with the grand opening of the Stephen Hawking Centre (SHC). Here's a breakdown, by the numbers:

Additional square feet: 55,000

Total attendance: 11,653

Researchers the SHC can accommodate: 150

Physica Phantastica displays: 10
The centerpiece of the public tours of Perimeter was the Physica Phantastica displays. Interactive science exhibits showcased the mysteries and wonders of our universe. Exhibits included a cosmic ray door that measured the subatomic particles running through your body, a black hole in a bucket, magic memory metal, and more. The hit of the Kid's Corner was the glow-in-the-dark slime.

Major public lectures: 4
Our featured public speakers were Canadian astronaut Julie Payette, renowned science historian George Dyson, leading robotics engineer Hod Lipson, and Perimeter's own Natalia Toro, with her lecture "Smash, Bang, Boom: Fundamental Physics at the LHC." The public also joined PI researchers at four sold-out Science in the Pub and Science in the Club events.

Chalkboards: A great many

Right angles: Very few

A Grand Opening

"From this building, we will inform, educate, and excite millions of people about the power of physics. We will train the future leaders of our field here. And we will do ambitious research into the deepest questions in physics, combining intellectual daring with uncompromising rigour. We look to change the world."

—Neil Turok

"It is a tremendous honour to have this expansion of Perimeter Institute named for me. … The centre's clear focus, inspiring design, and productive research interactions will no doubt attract many leading scientists here. Perimeter is on a great path, and I am delighted to be associated with it."

—Stephen Hawking

"Today we are marking the latest milestone on Perimeter's incredible journey. In ten short years, Perimeter has gone from an ambitious idea, to an upstart organization in a temporary space, to a rising international force in theoretical physics. With this expanded research facility, we mark our commitment to go further still."

—Mike Lazaridis

Thank you for bringing PI to Waterloo. You bring innovation and hope to the world and the next generation.

Imagination + Innovation + Rigor + Design = Progress

—Anonymous notes left on a PI chalkboard

Xiao-Gang Wen Joins PI as BMO Isaac Newton Chair

▲ *Xiao-Gang Wen speaks to the audience after the announcement of his appointment as the BMO Financial Group Isaac Newton Chair*

Xiao-Gang Wen, a world-leading condensed matter theorist, is moving from MIT to Perimeter as the inaugural holder of the BMO Financial Group Isaac Newton Chair in Theoretical Physics at Perimeter Institute. At MIT, he held the Cecil and Ida Green Professorship in Physics.

The Chair was funded by a $4 million gift from the BMO Financial Group, matched by $4 million from Perimeter's endowment. It is anticipated this core funding will attract additional funding partners. This was the largest single donation BMO has ever made to support science and technology in Canada, and the largest corporate donation ever received by Perimeter. The Chair is to be the first of five planned to be named after scientists whose insights defined modern physics.

"We are thrilled that Xiao-Gang Wen is joining Perimeter as the first holder of the BMO Newton Chair," says Director Neil Turok. "Newton founded the laws of forces and motion, paving the way for all modern mechanical engineering. In the same spirit, Xiao-Gang Wen introduced the notion of topological order, which has already led to a deeper understanding of phenomena such as superconductivity and which holds the promise of an entirely new paradigm for describing and predicting the behaviour of quantum materials. Xiao-Gang's work is bold, interdisciplinary and far-reaching: exactly the kind of research to which Perimeter aspires."

"This investment is a game-changer. Last fall, when we announced BMO's support in attracting even more of the best theoretical physicists to Canada, we were confident that this chair, in particular, would be a magnet for talent," said Bill Downe, President and Chief Executive Officer, BMO Financial Group. "Dr. Wen is a scientist of exceptional global stature, someone who is pushing the boundaries in an area of science where the potential applications are simply enormous. It's an opportunity not only to enhance innovation in Canada, but also to establish our leadership position in new quantum technologies — globally."

Wen and the three postdoctoral researchers he plans to bring aboard will add to our growing condensed matter group. At the same time, Wen looks forward to collaborating with Perimeter's experts in other fields."My research is very interdisciplinary, which helps me find totally new topics that expand the boundary of our knowledge of nature — unexplored areas of physics that no one has touched before," he says. "All in all, it fits Perimeter's philosophy and research model very well."

—*Natasha Waxman*

◀ *Stephen Hawking shared a video message during the grand opening celebrations, viewable on Perimeter's website*

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The bold initiative that is Perimeter Institute was initially seeded by major gifts from visionary philanthropists and generous public support from local, provincial and federal governments. Since then, donations from many individuals, corporations, and foundations — as well as continuing support from all levels of government — have helped Perimeter grow to become one of the world's leading centers for theoretical physics — a remarkable accomplishment for an institution that is only a decade old.

We are grateful for the contributions of all of our supporters.

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**This list reflects commitments made between August 1, 2010 and September 12, 2011.*

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New States of Matter, New Models of the Universe: the Research of Xiao-Gang Wen

New States of Matter

New states of matter are the Holy Grails of condensed matter physics, and Xiao-Gang Wen has done much to advance the quest for them.

In 1989, Wen earned his reputation as one of the leading minds in condensed matter with the introduction of the notion of topological order. His ideas enabled physicists to describe a whole new class of matter — topological matter — which exhibits quantum entanglement properties at macroscopic scales. This breakthrough opened up new research directions, and topological matter is now one of the most active research areas in condensed matter physics.

Wen himself has made major discoveries in the new field of topological order that he created. Notably, in 1990, he found that topological matter has protected boundary excitations. This property gives such materials a perfect conducting surface, even though their bulk is insulating — that is, they act like a plastic cable covered with a layer of metal, even though the material is the same throughout. Such "topological insulators" show promise for use in quantum computers.

But topological order has implications well beyond material science. Wen, for his part, thinks big: he has turned his expertise in topological order toward creating new models of the universe itself.

Real Versus Emergent

One of the most fruitful questions in modern physics is: "What is fundamental, and what is emergent?" (see next page) In the 1990s, condensed matter physics was deeply concerned with a particularly puzzling emergent property: certain semiconductors were behaving as if the particles inside them had a fraction of an electron's charge. The strange behavior became known as the fractional quantum Hall (FQH) effect.

The idea that something might exist that had a fraction of an electron's charge was shocking: like the speed of light or Planck's constant, the charge of the electron had long been one of the fixed points of the disorienting quantum universe. Every system in the universe carries whole multiples of a single electron's charge. However, it soon became clear that the fractional charge was an emergent property: the electrons were congregating in a way that gave the illusion of particles with fractional charges.

Wen's work in this area, the 1991 co-discovery of a special class of FQH states called non-Abelian FQH states, was a breakthrough. These exotic new particles could have major applications in topological quantum computing — a type of quantum computing that is naturally fault-tolerant.

But Wen went further. The exotic fractionally-charged particles in FQH systems were not real: they were an emergent property of the material. What if electrons themselves were not real, but emergent?

The Universe as a Bowl of Noodles

Wen and his collaborator Michael Levin developed a model in which they picture electrons as the ends of long "strings" of qubits — qubits being the simplest and most fundamental object in quantum theory. As the qubits fluctuate, these strings are free to move like noodles in a soup and weave together into huge "string-nets".

The researchers applied advanced modern mathematics to study their string nets to see if they could give rise to both the exotic fractionally charged quasiparticles of FQH and the long-thought fundamental electrons.

The string nets did. Not only that, but other particles, such as quarks and leptons, began popping up as the ends of differently woven string nets.

There were more surprises: when the net of strings vibrated, it produced a wave, and that wave behaved according to Maxwell's equations. A bedrock of physics since the 1860s, Maxwell's equations are the basic equations for explaining and unifying light, electricity, and magnetism.

And more was coming: in addition to the photons that carry the electromagnetic force, waves in differently woven string nets lead to gluons (carriers of the strong force) and W and Z bosons (carriers of the weak force).

The string nets were producing, as emergent properties, matter, forces, and the rules that govern them. Could the entire universe be modelled as a bowl of noodles?

"Suddenly we realized, maybe the vacuum of our whole universe is a particular topological matter — a string-net liquid," says Wen. "It would provide a unified explanation of how both light and matter arise."

If that's true, then what we today call elementary particles are not the fundamental building blocks of matter. Instead, they emerge from simple qubits that form the non-empty vacuum of spacetime.

—Erin Bow

What is Emergence?

When we see some collective property of a system that does not belong to its elementary constituents, we say that this property is emergent.

Studying emergence is like watching the Grand Waltz at the debutantes' night in Vienna from above. There is something moving through the ballroom, but it is not the dancers, who more or less stay where they are (since debutantes' night is very crowded, and there is not much room to move around — see Fig.1). What is moving around is a pattern, a collective motion of all the dancers in the ballroom. A physicist would be tempted to call this something that is moving around the room a 'waltzon', and would say that the waltzon is emergent.

Or consider a physics example: phonons are particles that carry sound inside a crystal. It's natural to ask "what are the phonons made of?" – but it's the wrong question. If we look at a phonon very closely, we see nothing at all: only the atoms in the crystal. Phonons are a collective motion of these atoms, so they are not made of anything.

One of the great questions of contemporary physics is, "What in nature is emergent and what is fundamental?" If phonons are emergent, what about all the other constructions of physics? Electrons, protons, photons, the other so-called gauge fields, even that trickster gravity — are they really fundamental? Are they really the basic building blocks of nature? Perhaps they are emergent, just like phonons.

It is important to understand that if such particles are emergent, the precise mechanism that makes them emerge may not be important. With our waltzon, we do not care about the details of the dresses of the dancers, and we do not even care about the details of their movements, as long as they follow the waltz tempo and some other rules. As long as they dance some waltz, we will see waltzons.

So it is with physics: a somewhat different underlying system would produce — would make emerge — the same behavior. This insensitiveness to details means that we don't need to accept the beauty and simplicity of nature as something given. A messy, complicated system might make emerge the beauty and simplicity that are the hallmark of the laws of physics.

This is a profound shift in a paradigm we've held since Parmenides and Plato convinced us that substance was the most fundamental notion necessary to describe the world. For two and a half thousand years we've followed (with some detours) the atomic hypothesis: the belief that there are elementary particles whose behavior is governed by simple laws, and that if we truly understood these particles and these laws, we would understand all nature. The laws were simple because they were simple – there was no explanation for it.


Figure 1

Emergence changes this. It tells us that simple laws can emerge like the patterns of a dance from messy and complicated systems. If we can understand that process, we can explain why there is beauty in nature.

This attitude can change the way we think of some of the most important problems in physics, like understanding black holes. The emergence point of view hints that studying microscopic models is not the right thing to do, because the black hole might be a collective phenomenon. The most important concepts in physics, like symmetry, are perhaps not set in stone, but are emergent properties, what we call the properties of a phase.

For 2,500 years, the relevant question was: "What are things made of?" The new relevant question is: "How do things organize?"

—Alioscia Hamma

Perimeter recently held a conference on "Emergence and Effective Field Theories." Look for the talks on PIRSA, www.pirsa.org/C11034.

Where the Rules Come From

The rules of quantum mechanics are powerful: they are the bottom rung of a vast ladder of science, and the fundamental tools that let us build everything from microchips to powerplants. But where do they come from? Traditionally, physicists would answer, "That's just the way the world is." But is that all we can say? Or is it possible to derive quantum theory from more fundamental principles?

PI Postdoctoral Researcher Giulio Chiribella and his colleagues Giacomo Mauro D'Ariano and Paolo Perinotti from the University of Pavia, Italy, have devised a framework for grappling with such deep questions. In their paper "Informational Derivation of Quantum Theory," recently published in *Physical Review A* and highlighted by the American Physical Society, the researchers show that quantum theory can be derived from six fundamental assumptions about how information is processed.

This work is in the spirit of John Wheeler's belief that "it" — physical reality — comes from "bit" — information. That, as Wheeler wrote, "every item of the physical world has at bottom — a very deep bottom, in most instances — an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes-no questions." The universe is a computational machine, using the rules we call physics to derive its next state from its current one. Information sits at the core of this computer, just as it sits at the core of an ordinary computer.

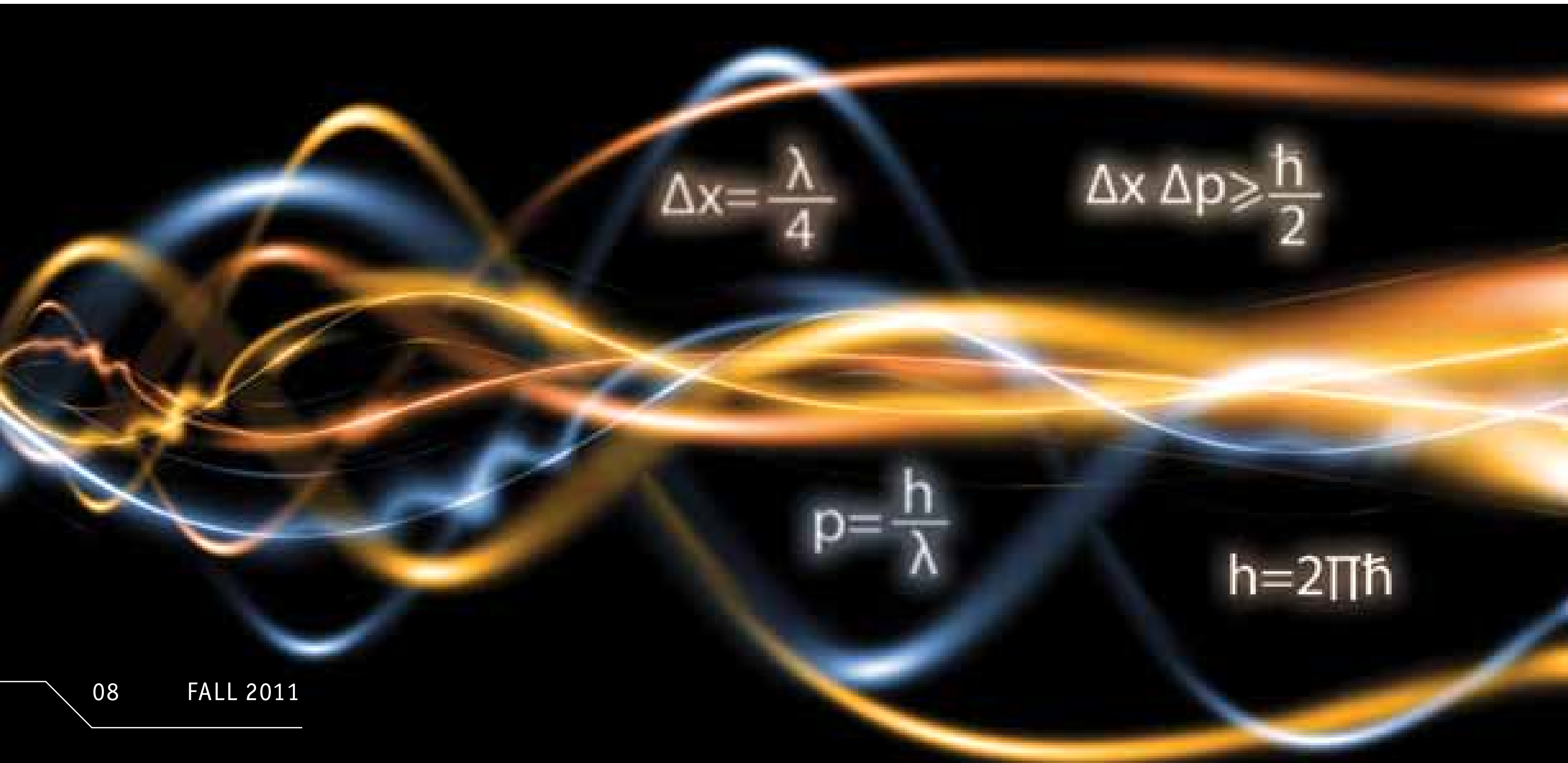
The paper by Chiribella, D'Ariano and Perinotti explores the ways in which the universe-computer handles such information. The researchers assume five elementary axioms: causality, perfect distinguishability, ideal compression, local distinguishability, and pure conditioning. These axioms define five ordinary features of information, and are fulfilled both by classical and quantum theory. The real breakthrough is the definition of a sixth axiom, called "purification" — an axiom so important that Chiribella *et al* elevated it to the level of postulate.

Purification states that a system with uncertain properties — what the authors call a "mixed state" — can be modelled as part of a larger system with definite properties — a "pure state." For instance, consider a spin-zero pion decaying into two spinning photons. Each photon is in a mixed state — its spin could be up or down, and there is no way to predict which. The pair of photons together, though, comprise a pure state in which they must always spin in opposite directions. If a system is in a pure state, then it is impossible to know anything more about it.

In other words, the purification postulate implies entanglement. Pushed a little further, purification also explains why quantum information can't be copied without destroying it but can be "teleported" — that is, replicated at a distant location after being destroyed at its point of origin.

By combining the purification postulate with the other five axioms, Chiribella *et al* were able to derive the entire mathematical formalism behind quantum mechanics, and present quantum theory in simple physical terms, without the need for abstract mathematical jargon. The rules come from somewhere after all.

Having the deep principles from which one can reconstruct existing theory is exciting, but does this work open new avenues? Maybe. In the way new geometries were born when Euclid's



fifth postulate was questioned, defining the postulates of quantum information gives physicists exact places to zero in their attention, which could lead to the discovery of alternative theories.

For instance, one of the most radical changes to quantum theory would be to drop the assumption of causality: the idea that the future cannot affect the past. (Or, to put a quantum information spin on it, the idea that information propagates in a preferred direction, identified with "time".) Several researchers at Perimeter — including Chiribella and quantum theorist Lucien Hardy — are developing frameworks that do not presume underlying spacetime or fixed causal structures. This may open new doors for merging quantum theory and general relativity.

—Erin Bow

Further Exploration:

- G. Chiribella, G. M. D'Ariano, P. Perinotti, "Informational Derivation of Quantum Theory", *Phys. Rev. A* 84, 012311 (2011), http://pra.aps.org/abstract/PRA/v84/i1/e012311
- G. Chiribella, G. M. D'Ariano, P. Perinotti, "Probabilistic Theories with Purification", *Phys. Rev. A* 81, 062348 (2010), http://pra.aps.org/abstract/PRA/v81/i6/e062348
- C. Brukner, "Questioning the rules of the game", *Physics* 4, 55 (2011), http://physics.aps.org/articles/v4/55
- D. Powell, "Quantum Theory gets physical", *ScienceNews*, http://www.sciencenews.org/view/generic/id/332557/title/Quantum_theory_gets_physical

Related works:

- L. Hardy, arXiv/quant-ph/0101012 (2001).
- B. Dakic and Č. Brukner, in Deep Beauty, edited by Hans Halvorson (Cambridge University Press, New York, 2011)
- L. Masanes and M. P. Mueller, *New J. Phys.* 13, 063001 (2011).

Fair Dice

"Not only does God play dice with the universe," says Roger Colbeck. "His dice are fair."

Colbeck, a postdoctoral researcher at Perimeter, recently published a paper entitled "No extension of quantum theory can have improved predictive power," in *Nature Communications*. "If quantum theory is correct, then it is also complete," says Colbeck. "There cannot be a better description of the outcomes."

The probabilistic nature of quantum predictions troubled many early quantum scientists, including Einstein, who famously objected that "God does not play dice with the universe." In the 1930s, Einstein, Podolsky, and Rosen (among others) argued that even if quantum mechanics is a correct theory, it might not be a complete one: there might be a deeper reality – perhaps hidden variables that if measured could allow scientists to predict outcomes without quantum uncertainty. This proposition is so famous that it's known by its acronym: EPR.

In the 1960s, J.S. Bell's eponymous theorem showed that no local hidden variables exist which would take all the uncertainty out of quantum mechanics. But can we take out any of it? That's been a door left ajar for half a century.

Colbeck – working in collaboration with Renato Renner from ETH Zurich in Switzerland – has closed that door. This new research shows that no uncertainty can be removed.

This conclusion is reached partly via a connection to quantum cryptography. Imagine two people, Alice and Bob, trying to establish a shared key that no one else knows, which they might use to send secret messages to each other. In quantum cryptography, the key might be generated by first sharing and then measuring a series of entangled particles. If a "bad guy" sits in between Alice and Bob, the only way he can gain information about the key is by disturbing the entanglement. Hence, Alice and Bob can detect any attempted interception.

The intriguing thing, to Colbeck, is that Alice and Bob can generate a secure key without needing to know anything about how the measurement devices operate. In an extreme case, one might imagine that the bad guy somehow got his hands on the device, and corrupted it as he pleases. Remarkably, this does not present a problem: even if the bad guy designs and supplies the device himself, Alice and Bob can perform tests to establish that the measurement outcomes are nevertheless secure.

That's called device independence, and to Colbeck, it's a powerful tool. It lets you replace "the bad guy" with "the universe." In this way, the device-independent cryptographic result can be used to derive a result in quantum foundations.

In other words: If there were hidden variables, as EPR proposed, then the universe could use them to determine what the device would output. Since no one and nothing can predict – or even slightly influence – outputs in this way, then there are no hidden variables, not even weak ones, and quantum predictions generally cannot be improved.

—Erin Bow

Further Exploration:

"No extension of quantum theory can have improved predictive power," Roger Colbeck & Renato Renner; *Nature Communications*, Volume 2, Article 411; 02 August 2011

Breaking New Paths: Templeton Frontiers Program Established

The new Templeton Frontiers Program at Perimeter Institute for Theoretical Physics aims to catalyze path-breaking research by encouraging young scientists to pursue ambitious and daring ideas.

The integrated program, supported by a $2 million grant from the John Templeton Foundation, centres on three research areas which are key to major advances in our understanding of the universe: quantum foundations and information, foundational questions in cosmology, and the emergence of spacetime.

"Perimeter Institute researchers have already made substantial contributions to each of these fields and are helping forge new connections between them," explains Neil Turok, Perimeter's Director. "We hope our new partnership with the Templeton Foundation will attract brilliant young people into foundational research and set an example by providing the environment, support, encouragement and mentorship they need to pursue breakthroughs. Together, Perimeter and Templeton are aiming to advance the way the most ambitious and original theoretical physics is done."

The Templeton Frontiers Program at Perimeter Institute will support the following:

- Three exceptional young postdoctoral researchers as Templeton Frontiers Fellows
- A program bringing Distinguished Research Chairs, globally pre-eminent scientists working in these fields, to Perimeter to provide mentorship and inspiration
- Templeton Frontiers Conferences, Workshops, and Colloquia in these fields, held at Perimeter Institute to share research and spark new collaborations
- Research projects of outstanding undergraduate, Masters, and PhD students at Perimeter, and Visiting Graduate Fellows

The Templeton Frontiers Program is made possible through the John Templeton Foundation's Science & the Big Questions funding program, which supports innovative approaches to foundational questions throughout the mathematical and physical sciences.

—Natasha Waxman

JOHN TEMPLETON FOUNDATION

SUPPORTING SCIENCE~INVESTING IN THE BIG QUESTIONS

Sung-Sik Lee Joins PI

Perimeter is pleased to welcome Sung-Sik Lee as an Associate Faculty member. Lee works in the area of theoretical condensed matter physics. Since 2007, he has been an Assistant Professor at McMaster University, where he will hold his joint appointment.

"We're very excited to welcome Sung-Sik Lee to Perimeter," says Director Neil Turok. "He is a brilliant young theorist who has already made significant advances connecting quantum field theory, condensed matter, and high energy physics. His depth and originality in developing novel, interdisciplinary solutions will make him a valuable addition to PI's growing group of experts in these areas."

Lee's research focuses on strongly interacting quantum many-body systems using quantum field theory, as well as the intersections between condensed matter and high energy physics. His recent work has included using gauge theory as a lens through which to examine the phenomenon of fractionalization, whereby microscopic particles in strongly interacting condensed matter systems effectively splinter into multiple particles at low energies.

Lee's other work includes efforts to apply the AdS/CFT correspondence from string theory to quantum chromodynamics and condensed matter, and building a non-perturbative approach to understanding unconventional metallic states of matter. He is currently working on quantum field theories for strongly interacting metals. He is also seeking an explanation for the origin of space and gravity by applying the principle of emergence.

"I'm thrilled to be joining such an innovative and lively research environment," says Lee. "Perimeter recognizes the importance of ideas that cut across conventional disciplinary boundaries, a notion that underpins much of my research. The Institute is also quickly amassing a first-rate group of condensed matter researchers that I'm excited to work with."

Lee grew up in South Korea and completed his Masters in nonlinear dynamics and his PhD in theoretical condensed matter physics, both at the Pohang University of Science and Technology (POSTECH). He then worked as a postdoctoral researcher at POSTECH, MIT, and the Kavli Institute for Theoretical Physics (Santa Barbara) before joining McMaster.

—Mike Brown

Further Exploration:

- Low energy effective theory of Fermi surface coupled with U(1) gauge field in 2+1 dimensions, Sung-Sik Lee, arxiv.org/abs/0905.4532
- A Non-Fermi Liquid from a Charged Black Hole; A Critical Fermi Ball, Sung-Sik Lee, arXiv:1104.5704
- Holographic Matter: Deconfined String at Criticality, Sung-Sik Lee, arXiv:1101.5487

New Visiting Fellow Appointed

Welcome to Ruth Gregory of Durham University, who has joined PI as a Visiting Fellow. Visiting Fellows are accomplished scientists who spend extended research visits of up to six months each year at PI. The appointments last for three years.

A Chat with Guifre Vidal

Guifre Vidal recently arrived at PI as a senior Faculty member in condensed matter. His past honours include an Australian Research Council Federation Fellowship, a European Union Marie Curie Fellowship, a Sherman Fairchild Fellowship, and a Distinguished Research Chair at Perimeter Institute. Here he tells us a little bit more about himself.

NW: Welcome! Please tell me a bit about your background, and where you're coming from.

GV: I grew up in Barcelona, where in 1999 I obtained a PhD in Physics from the University of Barcelona. I did two postdocs, one at the University of Innsbruck, Austria, and one at the Institute for Quantum Information at the California Institute of Technology. From 2005 and until recently, I was a Professor in the School of Mathematics and Physics at the University of Queensland, in Brisbane, Australia, where I built a research group in quantum information, computational physics, and condensed matter.

NW: Well, we're glad to have you here at Perimeter! How are you settling in?

GV: Perimeter has been very welcoming. And I like Canada. One thing I like is that it's a really multicultural country and that's perfect for my family. I have a European and now Australian background and my wife, Dora, is originally from Hong Kong and then Australia. We sense that we will fit naturally here. Our son Marc is just seven months old, and growing fast. He's busy learning Cantonese and Catalan — well, that's what we think he's doing. It's all good, except that he's going to have a Canadian accent instead of an Australian one. Yeah, I'm very excited to be here. I'll probably stay excited until the first snow falls.

NW: Er … Have you ever lived in a snowy climate?

GV: My first postdoc was at Innsbruck — it's in the Alps. It's like here, but with mountains. I don't see any mountains here. Actually, I've been to PI several times before. Last May was the first time when there wasn't any snow. It was the first time I saw pavement here and thought, "Oh, there is pavement on the roads." Until then, I was under the impression that the roads in Waterloo were made of snow.

NW: Buy a good shovel — you're going to need it. Snow aside, what attracted you to Perimeter?

GV: Perimeter lets me concentrate on research. That's what I prefer to do. I prefer to stay simple so that I can spend my time thinking about physics, as opposed to having to manage a large research group.

NW: Can you give us the broad strokes of your research? What are you interested in?

GV: The long-term goal of my research is to better understand quantum many-body physics and quantum entanglement. I'm very interested in understanding what happens when you put lots of microscopic degrees of freedom together with simple interactions. We get collective behaviors, emergent behaviors — but exactly what emerges, and how? That's often still kind of a mystery. I'd like to develop better theoretical tools to derive or predict these emergent behaviors starting from the microscopic descriptions.

NW: A mystery that crops up in a number of different fields …

GV: That's right. I started studying entanglement in the context of quantum computing, where it's used as a resource for quantum information processing. Nowadays, entanglement is also intensively studied in the broader context of quantum many-body physics. For instance, entanglement offers a natural theoretical framework to study quantum phases of matter, which would usually be considered part of condensed matter physics. The quantum many-body problem also has implications for quantum field theory, string theory, quantum gravity, etc. It's exciting to do work that could have such broad implications.

NW: What are you working on right now? What's got you excited?

GV: What I've been doing lately is work on tensor networks. A tensor network is an ansatz* for the many-body ground state on a lattice system. One particular type of tensor network, based on renormalization group ideas, is a promising step towards answering the question I asked before about deriving emergent collective phenomena starting from a microscopic description. In addition, some colleagues have recently shown how to generalize tensor networks from the lattice (spin systems) to the continuum (field theories), which is leading us towards new non-perturbative approaches to quantum field theories.

NW: So how did you become interested in physics in the first place?

GV: I have no idea. It just seems I've always been interested in it. I do know that, as a boy, I was very happy the day I learned that my father had studied physics. I had been very interested in these books that talked about physics stuff but had not realized that it might have been an inherited passion. I never considered anything else. That doesn't mean that I was completely focused on physics, just that pursuing an academic career in physics appeared as a natural path. Actually, laziness has probably been the single most influential factor shaping this path. For instance, I did not decide that I wanted to go to university, or do a PhD, or even start a first postdoc. In each of these occasions, what I really decided was that I didn't want to grow up and face reality — I didn't want to take a real job and have to work. In hindsight, this was quite stupid — I ended up working nearly as hard. But by then it was too late: nobody outside academia would give me a job. I admire people who make decisions. I'm not one of them.

NW: That's remarkable. You never had any doubts?

GV: Well … The other day I went to pick up a cargo van, to go to the airport to collect some boxes with personal belongings from Australia. I had so much fun driving down the highway. And that makes you think … Anyway, the following day I had to return the van to the rental company, and that was kind of sad; it felt like a kid saying goodbye to his best friend. I miss that cargo van.

NW: So, if physics doesn't work out, you could be a trucker.

GV: Yeah! Absolutely! Although, when I think about it, I've never been a very good driver …

–Interview by Natasha Waxman

**Editor's note: An ansatz is a simplified mathematical model that makes assumptions that can be tested later.*

Kudos to …

Perimeter Institute congratulates Freddy Cachazo, who is this year's winner of the Rutherford Memorial Medal in Physics from the Royal Society of Canada.

One of the Royal Society's top honours, the Rutherford Medal recognizes outstanding research in any branch of physics. This is not Cachazo's first such prize: In 2009, he was awarded the Gribov Medal of the European Physical Society.

Cachazo is a superstring researcher working to understand nature's most fundamental constituents, but his work has attracted attention for its immediate usefulness in high-energy physics.

Experimental high-energy physicists use accelerators to smash subatomic particles together at near light speed, causing interactions which create new particles. Outgoing particles are tracked, and these data are compared against predicted values to determine whether current theory accounts for all of the phenomena observed.

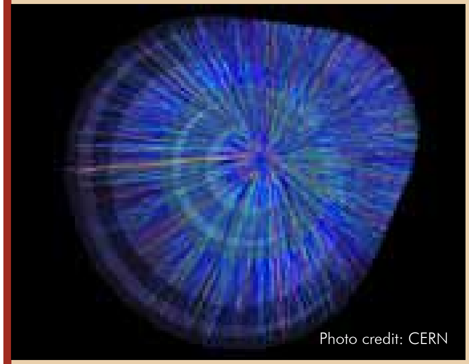


Photo credit: CERN

To set predicted values, scientists must calculate scattering amplitudes: theoretical predictions of what outgoing particles are produced in what numbers in high energy collisions. Calculating scattering amplitudes has always been challenging, but as accelerators have grown more powerful, the problems have mounted. With the launch of the Large Hadron Collider at CERN, calculating scattering amplitudes with traditional methods became practically infeasible.

This is where Cachazo enters the picture. Drawing together ideas from quantum field theory and complex analysis, Cachazo and his collaborators developed new techniques for calculating scattering amplitudes that yield results far more simply and efficiently than was previously possible. These techniques have already been widely adopted by experimentalists, and have been hailed as breakthroughs.

But beyond its immediate utility, Cachazo's work has also initiated a profound shift in our understanding of quantum field theories. In developing the new methods, Cachazo and his collaborators have uncovered surprising new mathematical structures. These structures may be clues that will lead to a much deeper understanding of how elementary particles arise, and the structure of spacetime itself.

Graduate student Hoan Dang has won a Vanier Canada Graduate Scholarship from the Government of Canada. The scholarship is valued at $50,000 per year, for three years.

Former graduate student Rowan Thomson has received a 2011 John Charles Polanyi Prize in Physics from the Government of Ontario. The prize is valued at $20,000.

Haipeng An

Primary research area: Particle physics.
Last stop: University of Maryland, USA.
What amazes you about theoretical physics? That the complex universe can be understood by mathematics invented by human beings.
Favourite physicist: Einstein.
Favourite film: I like science fiction films. My favourite is *Independence Day*.
Looking forward to: A group of strong and friendly physicists to discuss physics. A quiet small city to live. Also, my wife will come to Waterloo in a few months – I am looking forward to that!

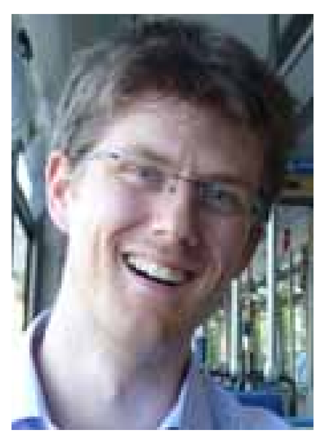
Ido Ben-Dayan

Primary research area: Cosmology and high energy physics.
Last stop: Ben-Gurion University of the Negev, Israel.
Proof I was a geeky kid: In sixth grade, I wrote that I wanted to invent a "new theory of relativity" without having any idea what that meant.
Physics role model: Gabriele Veneziano.
Looking forward to: Working in a new and fascinating environment with new people and friends.
When I'm not doing physics, I play American Football – full tackle, full gear. I hope I can find an amateur league near Toronto, and that it will agree to take an out-of-shape, aging defensive end/ linebacker.

Eugenio Bianchi

Primary research area: Quantum gravity.
Last stop: Centre de Physique Théorique de Marseille, France.
What amazes you about theoretical physics? That we can use what we know about the world to predict something new about it, before observing it. It tastes like magic.
I got into physics because … As a kid, I was fascinated by biology. I started to explore, made my first little experiments and observations, and kept asking why. If you ask why too many times, you end up doing theoretical physics.
Favourite physicist: I can't hide the fact that I love Richard Feynman's style.
When I'm not doing physics, I like jogging, hiking, taking nature pictures, and obviously cooking, specifically Italian cuisine.

Oliver Buerschaper



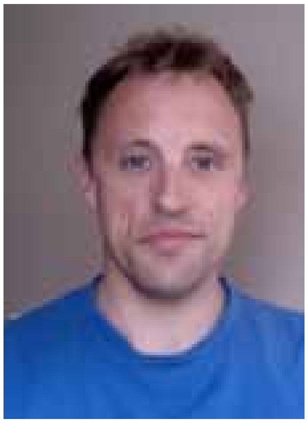
Primary research area: Quantum information and condensed matter physics.
Last stop: Max-Planck-Institute of Quantum Optics in Munich, Germany.
Proof I was a geeky kid: In high school, I was quite amazed by the book *Surely You're Joking, Mr. Feynman*! However, I had already loved both physics and percussion instruments even before learning about the eccentric glory of Richard Feynman's life.
Looking forward to: The great research and social environment that PI is famous for. In particular, I'm looking forward to lively discussions about physics in front of a crackling fireplace.
When I'm not doing physics, I like music, in particular playing the cajón [box drum], as well as martial arts, basketball, and cooking.

Shih-Hung (Holden) Chen

Primary research area: Cyclic cosmology, modified gravity, two-time physics.
Last stop: Arizona State University, USA.
Proof I was a geeky kid: When I was seven, I did an experiment to prove there is about 1/5 oxygen in the atmosphere, by watching the amount of water moving up in an upside down glass submerged in a water tank with a candle burning in it.
Inspiring physics book: Steven Weinberg's book, *Dreams of A Final Theory*.
Favourite movie: *A Beautiful Mind*.
Looking forward to: Discussing physics and making friends with people. Also, I like coffee very much. I am very excited about going to a place with tons of free coffee – looking forward to many coffee discussions.

Lukasz Cincio

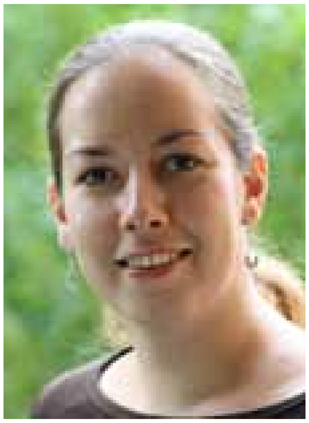
Primary research area: Quantum information and condensed matter physics.
Last stop: University of Queensland, Australia.
I got into physics when … As a postdoc, I should probably say that physics has been in the centre of my interests forever but, honestly, it used to be maths. My father gave private lessons. When I was a boy, I attended them with students who were much older than me. I was amazed by roots, trigonometrical functions and integrals.
Physics inspiration: Richard Feynman. As a young student, I was fascinated by his famous lectures in physics. Even now, I'm amazed that no matter which area of modern physics you touch upon, sooner or later, you come across Feynman's ideas.
Favourite music: I like listening to rock and metal music. I used to go back to old Metallica albums, but I have had to switch to softer sounds as my son (who is seven months old) cannot stand fast guitar solos.



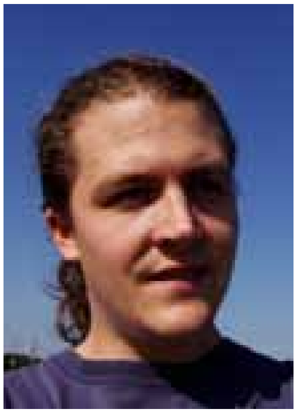
Bill Edwards

Primary research area: Quantum foundations.
Last stop: Oxford University, UK.
What amazes you about theoretical physics? The moment when you see that a familiar concept or object is actually something quite different than what you thought it was.
I got into physics when … I started reading popular books on astronomy and physics whenever we went to visit my grandparents.
Looking forward to: Good quality blackboards and Waterloo's wild nightlife.
When I'm not doing physics, I enjoy travelling and outdoor activities — climbing, hiking, skiing, etc.

Astrid Eichhorn



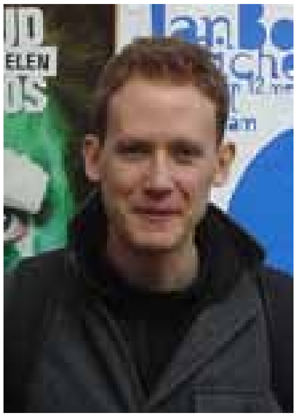
Primary research area: Quantum gravity; low-energy properties of QCD.
Last stop: Institute for Theoretical Physics at Friedrich Schiller University of Jena, Germany.
What amazes you about theoretical physics? I find it fascinating that a very small number of abstract principles allow us to understand such a variety of physical phenomena, ranging from microscopic scales in particle physics, to astrophysical or even cosmological scales.
I got into physics when ... I saw the pictures taken by the Hubble space telescope and got interested in astrophysics and cosmology. I then started to be interested in quantum field theory and quantum gravity during the last part of my undergraduate studies.
When I'm not doing physics, I play the violin, and have been playing in different student orchestras since 2002, but I also enjoy listening to concerts — mostly classical, but also jazz.



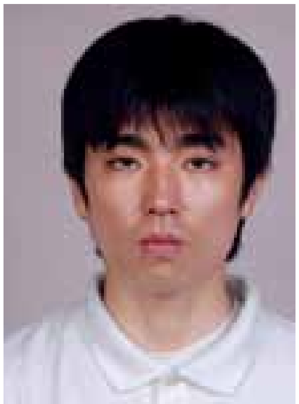
Steffen Gielen

Primary research area: Gravitation, both classical and quantum.
Last stop: Albert Einstein Institute in Potsdam, Germany.
What amazes you about theoretical physics? I find it miraculous that reasoning in abstract mathematics can be used to predict things about nature.
Earliest physics memory: My parents had some books on science that I read as a child. I particularly remember being excited about astronomy and the history of the universe as a whole.
Favourite physicist: Paul Dirac.
Favourite fictional character: Jeff Bridges in *The Big Lebowski*.
When I'm not doing physics, I like reading, music, political discussions, and hillwalking.

Paul McFadden



Primary research area: Cosmology and holographic dualities, both separately and in conjunction.
Last stop: University of Amsterdam, the Netherlands.
What amazes you about theoretical physics? That you can make a living doing it.
Great unsolved question of the field: Why are theoretical physicists the only people in the world who still write on blackboards?
Favourite physicist: He of the wild hair and gentle eyes.
Favourite author: Quite possibly Evelyn Waugh.
Favourite musicians: Mahler. Also the Austrian power metal band Ekpyrosis.
When I'm not doing physics: I mostly play the cello, in orchestras, in string quartets, and on the streets. I also enjoy long-distance and marathon running.

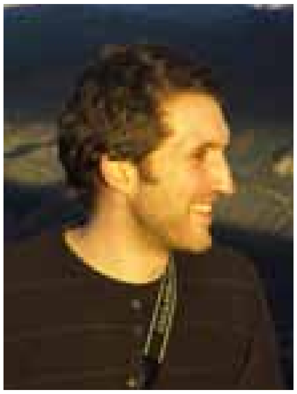


Satoshi Nawata

Primary research area: Supersymmetric gauge theory and topological quantum field theory.
Last stop: Tata Institute of Fundamental Research, India.
Favourite composer: Chopin.
Favourite movie: *The Shawshank Redemption*.
What draws you to theoretical physics? I am personally interested in the interplay between physics and mathematics. In particular, quantum field theories give some intuition for the methods to deal with infinitely many degrees of freedom. Although the definition of path integral is not known yet, it possesses an enormous heuristic and aesthetic potential. I am fascinated by works which extract finite quantities from infinite dimensional manifolds such as quantum invariants arising from integrals over moduli spaces.

Robert Pfeifer

Primary research area: Condensed matter physics.
Last stop: University of Queensland, Australia.
What draws you to theoretical physics? The challenge posed by the problems we don't know how to solve, and the questions we don't know how to answer yet. Coming up with answers to these!
Favourite physicist: Einstein, because when the evidence suggested it was time to let go of something we all took for granted (the Galilean notion of separate space and time) he heeded the evidence and accepted the inevitable consequences.
When I'm not doing physics, I like travel, outdoor pursuits, and scuba diving.



Carlos Tamarit

Primary research area: Particle physics.
Last stop: KITP in Santa Barbara, California, USA.
Earliest physics memory: It's hard to pick one out, because physics is everywhere! One's earliest experiences with physics come when, as a kid, one realizes the emergence of patterns in everyday things: things fall when dropped, fire burns, etc. Unfortunately, I can't say when this started to happen for me, but I'm sure I was burned and bruised.
Looking forward to: maturing as a researcher. Learning from, being inspired by, and collaborating with the wonderful scientists at PI. And since I come from temperate climates, seeing what this thing called "winter" is all about.

Huangjun Zhu

Primary research area: Quantum information. I am also interested in quantum foundations and condensed matter physics.
Last stop: The Centre for Quantum Technologies, National University of Singapore.
Currently working on: Quantum state estimation, symmetrical informationally complete (SIC) POVMs, multipartite entanglement and its applications.
Favourite physicist: Einstein.
Looking forward to: Collaborating with other researchers and making new friends.
When I'm not doing physics, I like swimming, table tennis, and badminton.

PI Kids Are Asking

Vivian (age five) just saw her first fireworks. She asks: "If it's all just burning stuff, how come it's different colours?"

Different fireworks are different colours because different things are burning. Fireworks are packed with special chemicals, mostly metal salts. When the fireworks burn, the atoms in the salt absorb that energy. Now, you can think of atoms as houses for electrons. The electrons like to stay in the downstairs rooms (that's called the ground state) but when they absorb energy they go upstairs (that's called the excited state). Electrons won't stay upstairs long, and when they jump back down again, the energy they absorbed comes back out again as light.

The interesting thing is that each different kind of atom will give off a different colour of light, depending on the length of the jump between floors. Sodium gives off yellow, for instance, and copper gives off blue. About 100 years ago, scientists noticed a pattern in the way different atoms gave off different colours of light. It's one of the things that lead them to invent quantum mechanics. Today, scientists use the different colours of light that different atoms give off to study what things are made of. That's called spectroscopy, and it's one way we know what's inside stars and nebulae.

Try this: If you ever get to go to a beach bonfire, watch the way the driftwood burns. Driftwood has lots of salt in it from being in salty water. You should be able to see the fireworks colours in the flames.

A No-summoning theorem in Relativistic Quantum Theory, Adrian Kent, arXiv:1101.4612

A spin-4 analog of 3D massive gravity, Paul Townsend, arXiv:1109.0382

Approximate Simulation of Entanglement with a Linear Cost of Communication, Alberto Montina, arXiv:1107.4647

Can an Astrophysical Black Hole Have a Topologically Non-Trivial Event Horizon?, Cosimo Bambi, Leonardo Modesto, arXiv:1107.4337

Challenges for String Cosmology, Cliff Burgess, arXiv:1108.2660

Complexity of commuting Hamiltonians on a square lattice of qubits, Norbert Schuch, arXiv:1105.2843

Constraints on the fundamental string coupling from B-mode experiments, Levon Pogosian, arXiv:1105.6198

Correlations in Excited States of Local Hamiltonians, Zhengfeng Ji, arXiv:1106.1373

Dynamics of a Qubit as a Classical Stochastic Process with Time-Correlated Noise: Minimal Measurement Invasiveness, Alberto Montina, arXiv:1108.5138

Enhanced Coherence of a Quantum Doublet Coupled to Tomonaga-Luttinger Liquid Leads, Pasquale Sodano, arXiv:1105.1443

Eternal inflation and a thermodynamic treatment of Einstein's equations, Sarah Shandera, Jose Tomas Galvez Ghersi, Ghazal Geshnizjani, arXiv:1103.0783

Final State of Gregory-Laflamme Instability, Luis Lehner, arXiv:1106.5184

Holographic Quantum Critical Transport without Self-Duality, Subir Sachdev, Robert C. Myers, Ajay Singh, arXiv:1010.0443

Interpolating Compact Binary Waveforms Using the Singular Value Decomposition, Chad Hanna, arXiv:1108.5618

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

Longer-Baseline Telescopes Using Quantum Repeaters, Daniel Gottesman, Sarah Croke, arXiv:1107.2939

Model-Independent Comparisons of Pulsar Timings to Scalar-Tensor Gravity, Michael Horbatsch, Cliff Burgess, arXiv:1107.3585

Nonlocal Hanbury Brown-Twiss Interferometry & Entanglement Generation from Majorana Bound States, Pasquale Sodano, arXiv:1010.0709

Observing a Light Dark Matter Beam with Neutrino Experiments, Maxim Pospelov, arXiv:1107.4580

Observing the Multiverse with Cosmic Wakes, Kris Sigurdson, arXiv:1109.3473

On Brane Back-Reaction and de Sitter Solutions in Higher-Dimensional Supergravity, Cliff Burgess, Anshuman Maharana, Leo Van Nierop, Amin Nizami, Fernando Quevedo, arXiv:1109.0532

On G-flux, M5 instantons, and U(1)s in F-theory, Joseph Marsano, Natalia Saulina, arXiv:1107.1718

Out of Equilibrium: Understanding Cosmological Evolution to Lower-entropy States, Matthew C. Johnson, arXiv:1108.0417

Output-sensitive Algorithm for Generating the Flats of a Matroid, Alberto Montina, arXiv:1107.4301

Phase Groups and the Origin of Non-Locality for Qubits, Bob Coecke, Bill Edwards, Robert W. Spekkens, arXiv:1003.5005

Phenomenology of Gravitational Aether as a solution to the Old Cosmological Constant Problem, Siavash Aslanbeigi, Niayesh Afshordi, arXiv:1106.3955

Picturing Classical and Quantum Bayesian Inference, Bob Coecke, Robert W. Spekkens, arXiv:1102.2368

Rank Reduction for the Local Consistency Problem: An Algebraic Geometry Approach, Zhengfeng Ji, arXiv:1106.3235

Reheating Effects in the Matter Power Spectrum and Implications for Substructure, Kris Sigurdson, Adrienne Erickcek, arXiv:1106.0536

Relative Locality: A Deepening of the Relativity Principle, Laurent Freidel, Lee Smolin, arXiv:1106.0313

Scalar Field Theory on a Causal Set in Histories Form, Rafael D. Sorkin, arXiv:1107.0698

Schur Function Expansions of KP Tau Functions Associated to Algebraic Curves, John Harnad, arXiv:1012.3152

Sculpting the Extra Dimensions: Inflation from Codimension-2 Brane Back-reaction, Leo van Nierop, Cliff Burgess, arXiv:1108.2553

Search for a New Gauge Boson in the A' Experiment (APEX), Philip Schuster, Natalia Toro, arXiv:1108.2750

Shape Dynamics in 2+1 Dimensions, Timothy Budd, Tim Koslowski, arXiv:1107.1287

Study of LHC Searches for a Lepton and Many Jets, Philip Schuster, Natalia Toro, arXiv:1107.5055

Summed Parallel Infinite Impulse Response (SPIIR) Filters For Low-Latency Gravitational Wave Detection, Shaun Hooper, arXiv:1108.3186

Technically Natural Cosmological Constant From Supersymmetric 6D Brane Backreaction, Cliff Burgess, Leo van Nierop, arXiv:1108.0345

The Cosmological Impact of Luminous TeV Blazars III: Implications for Galaxy Clusters and the Formation of Dwarf Galaxies, Avery E. Broderick, arXiv:1106.5505
The Effect of Local Dark Matter Substructure on Constraints in Sommerfeld-Enhanced Models, Natalia Toro, arXiv:1107.3546

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

The Measure in Euclidean Quantum Gravity, Arundhati Dasgupta, arXiv:1106.1679

Trapped Surfaces and Emergent Curved Space in the Bose-Hubbard Model, Francesco Caravelli, Alioscia Hamma, Fotini Markopoulou, arXiv:1108.2013

Turning a topological insulator into a superconductor, Pasquale Sodano, arXiv:1104.2485

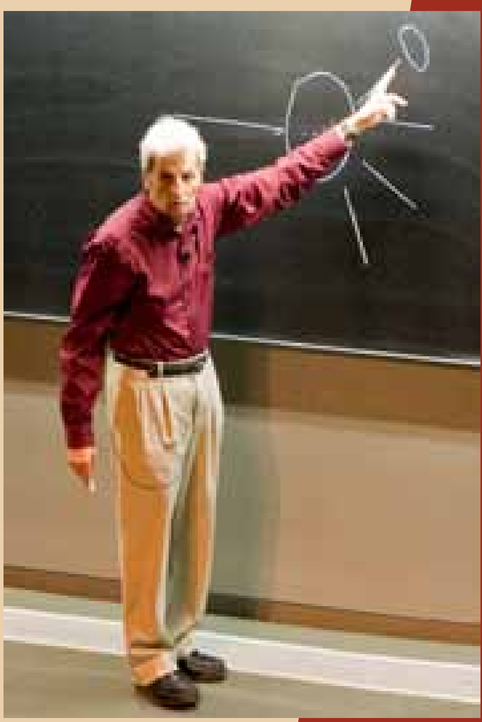
Unconditionally Secure Bit Commitment by Transmitting Measurement Outcomes, Adrian Kent, arXiv:1108.2879

Overheard @ PI

One researcher brings another a beer: "You know our beautifully falsifiable theory? Good news: someone falsified it."

On falling from one's bicycle and being asked what happened: "It's just gravity. Presumably."

A woman pulls up short, about to go into the men's washroom, but bumping into a man exiting:
She: "Sorry, I'm so distracted today."
He: "That's alright: I tried to go into the ladies this morning."
She: "Well, as long as symmetry is preserved ..."



PIRSA Pick of the Issue

The most shocking thing about quantum mechanics is this: two excited particles can be in exactly the same state, and one will decay after one minute, and one will decay after an hour — for no reason at all.

... so if two things behave differently in the future, then maybe what happens in the future is important to the present. But how can this be, without violating causality? The uncertainty principle makes it possible.

See how ...

Yakir Aharonov, "A New Approach to Quantum Mechanics." View the entirety of this — and all other lectures at Perimeter — online at PIRSA: www.pirsa.org/11080065/.

Fundamental Issues in Cosmology

Is the expansion of the universe speeding up? If so, why – and what does that imply? The "Fundamental Issues in Cosmology" workshop, hosted at Perimeter Institute between June 20 and July 16, brought together researchers in string theory and cosmology to discuss unresolved questions about the cosmology of the early universe. The workshop consisted of two conferences, "Holographic Cosmology v2.0" (June 21-24) and "Challenges for Early Universe Cosmology" (July 12-16), with an informal period of collaboration and discussion in between. The local scientific organizers for the workshop included Latham Boyle, Matthew Johnson, Robert Myers, and Neil Turok.

Many of the fundamental issues in cosmology stem from the very strong observational evidence for the accelerated expansion of the universe. A cosmological constant is one of the most plausible explanations; a universe dominated by a cosmological constant is known as de Sitter space. In addition to this late-time epoch of accelerated expansion, there is very good evidence for another epoch of accelerated expansion, known as inflation, which occurred in the very early universe. The evidence for inflation manifests itself in the observed spectrum of density perturbations in the cosmic microwave background (CMB).

However phenomenologically successful inflation and dark energy are, there are many theoretical puzzles that arise when one attempts to embed them in a fundamental theory. For example, inflation can be eternal: while inflation ends locally, different regions will undergo never-ending expansion, giving rise to an infinite number of "pocket"or "bubble"-universes. How are we to make sense of this eternally inflating multiverse, and what are the alternatives to this picture? In a de Sitter space, there is a cosmological event horizon, providing a fundamental limitation on the precision of any observation. How are we to formulate a fundamental theory that takes this into account? These questions, and many others, were addressed during the workshop.

Holographic Cosmology v2.0 focused mainly on the question of how modern ideas in string theory, in particular the holographic principle, could be helpful in formulating a rigorous theory of quantum cosmology. Some of the highlights of this conference were outlined in the Summer 2011 issue of *Inside the Perimeter*.

Between the conferences, a group of 20 researchers in cosmology and string theory took part in an informal workshop. They were assigned to discussion groups that focused on a set of four questions: 1) What are the appropriate microphysics for de Sitter space? 2) Do we know that (eternal) inflation is correct? What would convince us? 3) What can quantum information and quantum foundations tell us about the correct description of black holes, dS space, and the multiverse? 4) How central is a landscape of vacua to the measure problem?

The workshop concluded with the Challenges for Early Universe Cosmology conference. Each day, the conference focused on a specific "challenge," including: eternal inflation, the measure problem, alternatives to inflation, fundamental theory, and the entropy problem. These challenges are closely related to understanding the questions outlined above regarding inflation and dark energy. Some highlights of the conference included: talks by N. Turok, P. Steinhardt, D. Page, and S. Carroll assessing the viability of inflation as an explanation for the initial conditions of our observable universe, talks by H. Peiris, M. Kleban, and M. Salem on finding observational evidence for eternal inflation, new approaches to the measure problem in eternal inflation in talks by J. Garriga, L. Susskind, R. Neil, and A. Guth, and talks discussing alternatives to inflation by P. Steinhardt, W. Xue, P. McFaddden, R. Penrose, J. Lehners, and I. Bars.

The Challenges conference concluded with a panel discussion led by A. Albrecht, B. Freivogel, L. Marsini-Houghton, M. Kleban, and A. Brown. Each panel member posed a question to the audience, which led to a lively debate on the merits of inflation and its alternatives.

—Matthew Johnson

Women in Physics Canada

As anyone who has spent any time in a physics department (or indeed at Perimeter) has no doubt noticed, there are relatively few women in physics. There is much lively debate in the academy over the reasons for the lack of women in science more generally, but no real consensus. While in the long run it would certainly be good to better understand the causes, in the short term, it is important to support those women who have chosen a career in physics. Supporting young female physicists was the goal of the inaugural "Women in Physics Canada" conference, jointly hosted by Perimeter Institute and the Institute for Quantum Computing in July 2011.

Regional conferences for undergraduate women in physics exist in the US, and somewhat broader conferences for women in science take place in Canada, but to the best of our knowledge this was the first conference aimed at female students of physics in Canada. The emphasis was on student presentations, to allow young physicists to develop skills important to their continuing success. The packed scientific schedule included three days of presentations, through which attendees got a glimpse into areas of physics as diverse as astrophysics, quantum information, biophysics, physics education research, and much more. There were 34 contributed student talks, and they were of consistently high quality, with interesting physics and clear presentations.

The student talks were complemented by five keynote lectures from world leaders in astrophysics (Victoria Kaspi, McGill), quantum gravity (Fotini Markopoulou, PI), quantum information (Michele Mosca, IQC), biophysics (Melanie Campbell, UW), and cosmology (Neta Bahcall, Princeton).

The schedule also included two elements devoted specifically to women in physics — a panel discussion entitled "Personal Perspectives on Being a Woman in Science," and a keynote lecture on "Progress and Challenges for Canadian Women Physicists." Adriana Predoi-Cross (former chair of Canadian Association of Physicists' committee to encourage women in physics) gave a fascinating and informative talk describing other Canadian initiatives aimed at encouraging girls and women in physics, which put the conference in context. Panel participants for Tuesday morning's panel were refreshingly frank about challenges they had faced in their careers, and somewhat optimistic about how things have now changed, particularly in regards to maternity and parental leaves of absence.

Our motivation in organizing "Women in Physics Canada" was to give young women the opportunity to create a support network of peers, and to learn from more senior women the challenges of the job, both in general and those that apply more specifically to women. In these respects, the conference was even more successful than we could have hoped. We were truly overwhelmed by the enthusiasm of the participants, and there is a great deal of momentum, including several volunteers, to make sure the event happens again. It is also clear that there are very many talented young women in Canada and beyond, ready to make their mark on physics.

—Sarah Croke

Unravelling Dark Matter

New and more precise astrophysical observations have the potential of shedding new light on the nature of dark matter. New results from high energy physics laboratories are being published, and new theories are being advanced. High time, then, for a conference. "Unravelling Dark Matter," a two and a half day meeting held at Perimeter Institute from Sept 22-24, was a four-way crossroads, bringing together top experimentalists and theorists, and experts from the astrophysical side and the particle physics side, to discuss the latest news from the 96 per cent of the universe that emits no light.

Neal Weiner (New York University) opened the workshop with a comprehensive review of the latest experimental direct detection results. Of course, no unequivocal signal of dark matter has been found yet, but the garden of "anomalous" experimental results is growing. Just this September, the CRESST collaboration joined the DAMA and CoGeNT experiments in publishing possible dark matter signal events which cannot be attributed to known background sources. The leader of the CoGeNT experiment, Juan Collar (University of Chicago), participated in the conference and announced some upcoming revisions of CoGeNT results. He also presented new measurements of the sodium quenching factor, a central quantity to understanding the DAMA anomaly. These analyses tell us how well the experimental results can be reconciled with an interpretation based on dark matter. The participation of five direct-detection experimentalists in the workshop allowed theorists to catch up with the current status of the field and to inform themselves about potential advances for the future.

In recent years, some intriguing measurements have brought the attention of the scientific community towards a possible non-gravitational signal of dark matter. The excess of high energy positrons measured by PAMELA is the most famous example. At the same time, however, other experiments are putting tighter and tighter constraints on models which predict non-gravitational dark matter interactions. Douglas Finkbeiner (Harvard) presented updated results on the constraints given by new measurements of the Cosmic Microwave Background from the Planck and Fermi satellites. From the results presented at the conference, it seems that many models will have difficulties satisfying all constraints.

Another potential dark matter signature could come from hypothetical dark matter structures annihilating in the solar core. If such annihilation proceeds to escaping states which decay to Standard Model particles outside the sun, the result could be anomalous cosmic rays – a signature first proposed by Perimeter Faculty member Philip Schuster and former postdoc Brian Batell, in publications co-authored by (among others) many researchers from PI. Jennifer Siegal-Gaskins (California Institute of Technology) presented the Fermi satellite's study of cosmic rays coming from the direction of the sun. Unfortunately for the PI team, no dark matter signal was found in the current Fermi data set.

All our current efforts to detect a dark matter signal are underpinned by our knowledge of the phase space distribution of dark matter, mainly driven by its gravitational interactions. During the conference, several speakers presented the current status of such knowledge based on state-of-the-art numerical simulations and analytical arguments. Mark Vogelsberger (Harvard) showed convincing results pointing towards a local phase space distribution of dark matter that, although showing some departures from standard assumptions, is remarkably smooth, with the probability of local deviations from this smooth distribution being rather low. This important result needs to be taken into account when analyzing data from dark matter direct detection experiments.

All in all, it was an exciting and satisfying conference, marking the field's evolution into a truly data-driven science.

—Josef Pradler and Jesus Zavala

Microphysics in Relativistic Astrophysics

Tremendously powered emissions are routinely detected from astrophysical sources. These observations provide hints of extreme scenarios taking place, like supernovae, neutron star mergers, and disruptions and flares. This workshop brought together about 45 scientists working in understanding these events from all different camps – from nuclear energy researchers studying the structure of matter at high densities to those working toward understanding supernovae core collapse and gravity.

Five intense days brought these communities together to present current knowledge and discuss future developments in light of upcoming observational and theoretical opportunities. These include the possibility of matter allowing for 'millimetre-scale' mountains having masses comparable to our moon in neutron stars – and therefore able to produce significant gravitational radiation – to crust quakes and magnetosphere interactions to possibly explain highly energetic precursors to gamma ray bursts and powerful flares.

—*Luis Lehner*

To view recordings of all conference talks, visit www.pirsa.org.

Upcoming Conference

Cat's Eye Nebula
Image credit: NASA, ESA, HEIC and the Hubble Heritage Team

Effective Field Theory and Gravitational Physics

November 28-30, 2011
Scientific areas: Cosmology and gravitation

Scientific organizers:
Walter Goldberger, Yale University
Rob Myers, Perimeter Institute
Ira Rothstein, Carnegie Mellon University
Misha Smolkin, Perimeter Institute

This small, three-day workshop will focus on the applications of effective field theories to gravitational physics, with particular emphasis on gravitational wave production. These effective theories have been used to derive new results for calculating gravitational potentials and multipole moments for binary systems at third order in the post-Newtonian approximation, as well as thermodynamic properties of Kaluza-Klein black holes. It has also been recently utilized to calculate corrections to leading order radiation reaction forces in general relativity as well as classical electrodynamics. The power of the methodology is that it allows one to calculate systematically to arbitrarily high accuracy. Such higher order results will be used in generating gravitational wave templates to extract parameters such as masses and spins of binary constituents at LIGO and LISA. The purpose of the workshop will be to gather experts in the field to generate new applications (e.g., in cosmology), as well as to push present applications to higher orders.

New AIMS Centre Opens in Sénégal

Mathematics underpins science, technology and modern society – from cell phones to computers to satellites. Perimeter Institute has recognized this power, in launching a Global Outreach effort to promote the emergence of scientific talent in the developing world.

On September 6, 2011, the Government of Sénégal and its national and international partners opened a new pan-African centre of excellence for Africa's brightest math and science graduates, in a beautiful seaside location in Mbour, 80 km south of Dakar.

AIMS-Sénégal is the second centre of the African Institute for Mathematical Sciences (AIMS), joining AIMS-South Africa, which has operated successfully in Cape Town since 2003. The plan to expand AIMS across Africa is known as the AIMS-Next Einstein Initiative (AIMS-NEI). The goal is to rapidly and cost-effectively expand Africa's scientific and technological capacity by providing advanced training to exceptional African graduates and enabling them to work effectively for the future peaceful prosperity of the continent.

AIMS-NEI grew out of a wish first expressed by AIMS founder Neil Turok, also Director of Perimeter Institute, that "the next Einstein will be African." That wish has evolved into a strategic plan to create a pan-African network of 15 AIMS centres over the next decade. AIMS-NEI is supported through public and private funding, including a $20 million investment from the Government of Canada announced by Prime Minister Stephen Harper in July 2010, and provided through the International Development Research Centre (IDRC). The Government of France is also a major partner in AIMS-Sénégal, through its Institut de recherche pour le développement (IRD).

Doriano-Boris Pougaza, AIMS alumni member

The first AIMS centre, founded in Cape Town, South Africa in 2003, has graduated 360 students from 32 African countries to date, of whom one-third are women. AIMS has become globally recognized as a centre of excellence for postgraduate education and research.

At the grand opening celebrations, AIMS-Sénégal's first 36 students (selected from over 350 applicants to both centres), from 14 countries, were joined by the President of Sénégal, His Excellency Abdoulaye Wade, and dignitaries from approximately 15 countries to recognize the centre's many supporters and partnering academic institutions, which include the Universities of Cheikh Anta Diop, Gaston Berger, Thiès, and Ziguinchor Sénégal, the University of Ottawa in Canada, Universités Pierre et Marie Curie and Paris Sud in France, Humboldt University of Berlin in Germany, and the University of Science and Technology of China (USTC) Hefei.

AIMS-Sénégal lecture room, computer lab and library

"Were it not for AIMS, I think I would have stopped studying. Now, I have opportunities I never imagined I would have access to," says Alexia Nomenjanahary, a Madagascan alumna of AIMS-South Africa, whose work in mathematical biology earned her a scholarship to attend a summer school at the University of Oxford. Alexia will soon join AIMS-Sénégal as a teaching assistant to share her talents and help realize the potential in others.

Rohinton Medhora, Vice-President of Programs at IDRC says, "Ultimately, Africa's future lies in developing the minds of its brilliant young people. AIMS is the catalyst for that future and I am delighted to see it expand with the opening of AIMS-Sénégal, a groundbreaking initiative that complements IDRC's enduring support of outstanding scholars in developing countries and the fostering of development through innovation, science, and technology."

"The opening of our second centre, AIMS-Sénégal, is a major milestone towards our dream of a truly pan-African network of scientific centres where the continent's bright minds can shine," says Neil Turok. "As AIMS expands, thousands of talented Africans will acquire the skills they need to build Africa's future economic, educational and technological self-sufficiency."

—Natasha Waxman

A few tears were shed in August as 40 young physicists said their goodbyes to each other after two incredible weeks at our ISSYP camp. Students came from across Canada and 12 other countries — to take a deep dive into modern physics and share experiences with like-minded peers. On the final day of camp, Melissa Brock (RBC Branch Manager, Waterloo Main Branch) and I listened in awe as the students shared their highlights and insights from the previous two weeks. We were both struck by the passion in their voices and the joy the students experienced when they realized that not only were there other students who thought about the world the way they did, but that entire institutes were built for people who think just as they do.

Our new Bistro was filled with the motivational energy of keen physics teachers this summer as our week-long EinsteinPlus camp got underway. There were fascinating keynote addresses by two of PI's acclaimed researchers: particle physicist Cliff Burgess shared "The Large Hadron Collider: the Start of a New Era or the End of the World," and string theorist Louis Leblond challenged preconceptions with "From the Biggest Things to the Biggest Bang."

I would like to extend a special thank you to this year's EinsteinPlus teacher facilitators: Darlene Fitzner, Philip Freeman, Patrick Kossmann, Lisa Lim-Cole, and Roberta Tevlin. They not only ensured that participating teachers left with a wealth of new resources to use with their students, but the facilitators are also part of our PI Teacher Network, giving workshops across the country during the school year.

In September, Outreach opened its doors as part of our Grand Opening celebration of the Stephen Hawking Centre. With over 11,000 in attendance, the many visitors took advantage of the opportunity to see the building's bold angled lines, stunning vistas, and multiple collaboration areas, all designed to produce the ideal environment for deep-thinking physicists as they tackle our universe's fundamental questions. Highlights from the opening included Science in the Pub and Science in the Club panel discussions, hands-on and minds-on Physica Phantastica exhibits, a TVO special *Stephen Hawking: the Power of Ideas*, four Public Lectures including Julie Payette's stunning visual tour of life in space, and of course, the walking tour of the complete research facility.

The Outreach team is very motivated by Canadians' thirst for science, and the passion and willingness of science and math teachers from coast to coast to coast to satiate that thirst. Canada currently ranks third out of thirty-six developed nations on key scientific literacy markers. Together, with like-minded institutions and the exceptional educational professionals in this country, Outreach aspires to propel Canada to the top, and ensure we are a global leader in scientific literacy. At PI's Outreach, we look forward to working with all of you — sharing the joy, mystery, and power of modern science across Canada and beyond.

—Greg Dick

2011 EinsteinPlus Participants

"Best professional development I've ever had. My brain is full... I need to process and am excited to return to school. THANKS! I feel truly blessed to have been a part of this experience!"

—EinsteinPlus participant

Visit our website for more information on the Luke Santi Memorial Award, the International Summer School for Young Physicists, EinsteinPlus teacher's camp, and our latest in-class resource, "Revolutions in Science."

ISSYP: Not Just a Camp

"The thing about ISSYP is that it changes lives," says Greg Dick, Perimeter's Director of Educational Outreach. "It's not a just a camp. It's a beginning."

The International Summer School for Young Physicists is a two-week program meant to super-charge talented high school students from around the world. Close to 500 students have participated in ISSYP since it launched in 2003. This year, 40 students — 20 boys and 20 girls, 21 from Canada and 19 from elsewhere around the world — were exposed to a wide range of modern physics and given a taste of life as a scientist.

The experience has changed their lives.

"I can't remember another time in my life when I learned so much, met so many interesting people, or enjoyed myself so much," writes Nick Whitney, now back home in England after participating in ISSYP 2011.

Sarah Whitney, Nick's mother, has a slightly longer-range perspective: "Nick has talked about ISSYP virtually non-stop since we met him at the airport — it sounds like it has been the most amazing experience, and something that he will look back on for many years to come. He is now set on studying physics at university and as I write he is drafting his application form for Oxford University."

—Erin Bow

Melissa Brock, a branch manager at RBC, talks to ISSYP participants who presented group projects during a poster session at the end of the camp.

For more information about ISSYP, go to www.issyp.ca.

RBC Foundation®

RBC Foundation supports enhancements to ISSYP

The International Summer School for Young Physicists was strengthened this year by a gift from the RBC Foundation, the first of a four-year pledge. RBC's support allowed Perimeter Institute to hire a master teacher to review the curriculum and content delivery, and provide demonstration equipment to help students see modern physics in a hands-on, minds-on way. According to Canadian student Aiden McKay, the efforts showed: "If you truly have a passion for physics, you could not encounter a more enriching program than ISSYP."

RBC's gift facilitated a visit to SNOLAB, the neutrino and dark matter science laboratory buried two kilometres beneath the rocky Canadian Shield in Sudbury, providing the youth an opportunity to see cutting-edge modern physics research in action.

RBC's support also underwrote flights for international students. "We want to attract the best, not just the best who can afford it," says Greg Dick, Perimeter's Director of Educational Outreach. Thanks to RBC, the cost of a flight will no longer be a barrier for international students.

Aina Martinez Zurita from Spain said, "There are moments in your life when you would like time to stop. ISSYP is one of them." We thank RBC Foundation for giving Aina and her fellow ISSYP participants the opportunity to pursue their passion for modern physics.

—Erin Bow

Perimeter Institute and TVO have entered into a five-year partnership to bring public lectures and special events to wider audiences. The agreement kicked off with the *Stephen Hawking: Power of Ideas* television broadcast, which is now available to view online.

tvo

makes you think

Public Lecture Season Begins

Spacetime Atoms and the Unity of Physics

Wednesday, November 2 at 7 pm
Fay Dowker, Imperial College

Black holes are hot! This discovery made by Stephen Hawking ties together gravity, spacetime, quantum matter, and thermal systems into the beautiful and exciting science of "Black Hole Thermodynamics". Its beauty lies in the powerful way it speaks of the unity of physics. The excitement arises because it tells us that there is something lacking in our understanding of spacetime and, at the same time, gives us a major clue as to what the missing ingredient should be. Theoretical physicists at Perimeter Institute and elsewhere are pioneering a proposal, known as causal set theory, for the structure held by these most fundamental atoms of spacetime. In this talk, Dowker will describe black hole thermodynamics and argue that it is telling us that spacetime itself is granular or "atomic" at very tiny scales.

Fay Dowker did her PhD with Stephen Hawking at the University of Cambridge. She has done postdoctoral work at Fermi National Accelerator Laboratory, Batavia, IL, USA; University of California at Santa Barbara, CA, USA; and California Institute of Technology, Pasadena, CA, USA. She held a lectureship at Queen Mary, University of London before moving to Imperial. Her research interests are in quantum gravity and especially causal set theory, and in the foundations of quantum mechanics.

Paul Dirac and the Religion of Mathematical Beauty

Wednesday, December 14 at 7 pm
Graham Farmelo, Churchill College, Cambridge University

Apart from Einstein, Paul Dirac was probably the greatest theoretical physicist of the twentieth century. Dirac, co-inventor of the most revolutionary theory for 150 years — quantum mechanics — is now best known for conceiving of anti-matter in his head and also for his deeply eccentric behaviour. For him, the most important attribute of a fundamental theory was its mathematical beauty, an idea that he said was "almost a religion" to him. In this talk, Farmelo will argue that this obsession originated in his early life and training as an engineer and mathematician. An examination of Dirac's character will show why he was sometimes called the strangest man in the modern history of physics.

Graham Farmelo is a By-Fellow at Churchill College, Cambridge University and Adjunct Professor of Physics at Northeastern University, Boston. After his PhD in particle physics in 1977, he was given tenure at the UK's Open University, the world's largest distance-teaching university. In 1990, he moved to the Science Museum, London, where he became Assistant Director. Since 2003, he has been a consultant in science communication and an author. His first book was *The Strangest Man*, a biography of Paul Dirac, written mainly at the Institute for Advanced Study, Princeton, where he has been a Director's visitor for the past seven years. The book won the Costa Prize for biography in the UK in 2009, and the *Los Angeles Times* Science Book Prize in 2010.

The Perimeter Institute Public Lecture Series is presented by:

Sun Life Financial

Classical World Artists Series Returns

The Classical World Artists series is a staple of Perimeter's Event Horizons programming. In the past, we have brought such world-renowned musicians as Yo-Yo Ma, the Hagen String Quartet, and Emanuel Ax to Waterloo. Our 2012 season will again welcome top, international calibre artists, but will expand its scope to examine both traditional and more contemporary works, as well as embracing classical music traditions from around the world. Whether you're a classical devotee or simply interested in exploring a rich, new creative experience, we invite you to join us for an intimate evening in the company of innovative, world-class artists.

The Classical World Artists series is generously supported by:

Musagetes FUND
At The Kitchener And Waterloo Community Foundation

Note: Events in the Classical World Artists series begin with a pre-concert talk at 7 pm. Concerts take place at 8 pm, with a post-concert reception at approximately 10 pm in the Black Hole Bistro. The Bistro also opens for dinner before each concert at 5:30 pm, though reservations are required.

Matt Haimovitz, cello, and **Christopher O'Riley,** piano
January 31, 2012

Jordi Savall, viola da gamba
March 2, 2012

Wu Man, pipa, and the **Shanghai Quartet**
April 14, 2012

Dame Evelyn Glennie, percussion
May 11, 2012

InReach: Conceptual Gems of Theoretical Physics

On October 14, Perimeter played host to a special group of invited guests: 20 artists, from painters to performers to playwrights, here to meet with researchers and learn about "the conceptual gems of theoretical physics."

The event was co-organized by subtle technologies, a Toronto-based organization that describes itself as "a gathering of artists, scientists, technologists, engineers and the general public," whose goal is to "share cross-disciplinary ideas, explore new technologies, showcase creativity and incubate the next generation of practitioners at the intersection of art, science and technology." subtle technologies has deep connections to Perimeter: Faculty members Rob Spekkens and Lee Smolin serve on the board of directors and the advisory board, respectively. Jenn Dodd, Perimeter's former festival programming manager, is currently subtle technologies' managing director.

The goal of the workshop was to provide the artists with an intimate experience of modern physics that might feed their creative endeavours. More than 20 Perimeter residents participated in informal chats and round tables. Others, including Spekkens, Smolin, postdoc Giulio Chiribella, and Associate Faculty member Avery Broderick gave formal lectures. The lecture introduced the artists to some of the most fruitful concepts in modern theoretical physics, with an emphasis on concepts that are infrequently discussed in public discussions of physics — deep notions like symmetry and emergence.

Two special guests, experimental physicist Stephen Morris and celebrated new media artist Dmitry Gelfand, rounded out the day with Arts Meet Science talks.

—Renée Ellis

For over a decade I have been actively involved in the emerging field of art-science, and I must confess that Conceptual Gems was among the most captivating workshops in which I've ever participated! There were highly passionate exchanges between physicists and artists that will undoubtedly flourish into future collaborations. I was equally inspired by the unique setting — Perimeter's crystalline architecture seemed to magnify our creative discussions!

—Dmitry Gelfand

From the Black Hole Bistro

Energy Bars

2 ½ cups Rice Krispies or similar cereal (or substitute with puffed millet)
1 ¼ cups oatmeal
3 cups chopped nuts and fruit

¾ cup brown sugar
¾ cup nut butter of your choice
¾ cup honey

Mix the first three ingredients together and set aside.

Warm the last three ingredients (on the stove, or microwave) and stir until smooth.

Pour liquid over dry ingredient mixture and toss until well coated.

Spread evenly into a 9 X 11 baking pan, slice into desired portions and enjoy! Use an 8 X 8 baking pan for thicker portions.

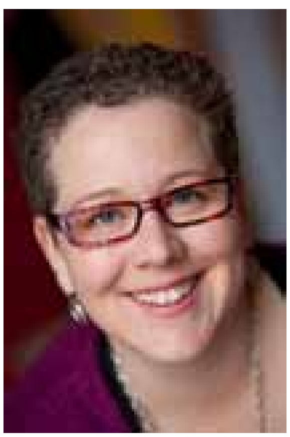
Tip: Be creative! Add your family's favourite dried fruit, ground flax, flaked coconut, shelled pumpkin or sesame seeds. The possibilities are endless ...

New Faces @ PI

Julie Andres, Academic Programs Assistant

Julie joined PI in August as the new Academic Programs Assistant while Diana Gonçalves is on maternity leave. She is no stranger to academic settings, having obtained both a BA in History/Art History and a Masters in Canadian History from the University of Guelph, as well as working as a Teaching Assistant at both Guelph and the University of Western Ontario. She will put that experience to good use, assisting Debbie Guenther and John Berlinsky with the day-to-day functions of the PSI Program, as well as assisting with graduate students at PI and the Postdoctoral Mentoring program. Julie has also previously worked as an Inspector with the Canada Border Services Agency during university and in her hometown for the Niagara-on-the-Lake Chamber of Commerce.

Since joining PI, Julie has found everyone very friendly and has really enjoyed getting to know the PSI students and Fellows, learning about their home countries along the way. "This year's group of PSI students and Fellows are so great to work with and really do brighten my day," she says. When she's not at PI, Julie loves reading, needlework, spending time with her many nieces and nephews, and playing hockey – she was thrilled to join the recently rejuvenated PI pick-up hockey league. Julie can be reached at extension 5204 and in office 266.



Erin Bow, Writer/Editor

Congratulations to Erin who just won the TD Canadian Children's Literature Award!

Erin is the new Writer/Editor on Perimeter's publications team, where she usually tackles the more science-heavy projects. Erin did grad work in particle physics, and was a National Science Foundation Fellow and a CERN Summer Student, but her career took a sudden turn after a health crisis convinced her she really wanted to spend her life writing books.

Erin has indeed written books – two books of poetry, a memoir, and a novel – while paying the bills with professional writing. Her last full-time gig was as the writer for the Faculty of Engineering at the University of Waterloo. She left UW after selling her first novel three years ago, and has been a full-time novelist and occasional freelancer since then.

Erin joins Perimeter half-time: the other half is still devoted to her books. Find her in office 153. Her extension is 5082.

Christina Bouda, Recruitment Specialist

Christina joined PI in August as a Recruitment Specialist. She has lived in the area most of her life, completing an honours history degree at the University of Waterloo and a post-grad diploma in Human Resources Management at Conestoga College. She worked for two local engineering consulting firms as a corporate recruiter for almost four years before going to RIM as a campus specialist in 2010.

"I believe that the heart and soul of every organization is its people and I am excited to work with everyone here at PI to help maintain the excellent standard of hiring that has already been set," says Christina. Along with her husband, Dave, she recently bought a home on a large property with an even larger list of projects that occupies much of her time outside of work. Christina can be reached at extension 6091 or by dropping by office 207.

Melissa Couto, Assistant, Office of the Director and Global Outreach

Melissa joined PI in August as the Assistant, Office of the Director and Global Outreach and will be here until September 2012. Previously, she worked as an Administrative and Research Assistant in Gastroenterology at Sunnybrook Hospital in Toronto. Although her work background is in the medical field, she is excited to branch out and gain new knowledge and experience at PI.

In her spare time, Melissa enjoys rock climbing, hiking, zip-lining, and other outdoor activities. She recently bought a house with her fiancé, Mike, and is enjoying all the work that a house entails; she is especially looking forward to having her first trick-or-treaters this Halloween. Please feel free to stop by and say hi to Melissa on the second floor, room 214a, or phone her at extension 6131.

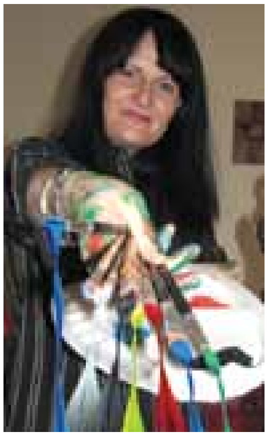
Laura Flatt, Educational Outreach Coordinator

Laura joined PI in October as a new Educational Outreach Coordinator and is excited to be joining such a well-respected institute. She comes to us from RIM, where she worked in departments ranging from IT to campus recruitment to market intelligence. She also previously worked at Manulife Financial in the group benefits department.

Laura studied Environmental Studies at the University of Waterloo, where she was a true renaissance woman, dabbling in everything from earth sciences and peace and conflict studies to geographic information systems (GIS) and even some business. When not at work, Laura likes to stay active, with a long list of hobbies that includes running, curling, squash, dodgeball, baseball, skiing, hiking, camping, canoeing, and kayaking. She also enjoys spending time with her family and her dog, Parker, and is currently studying for the GMAT. Feel free to swing by office 142 to welcome Laura, or drop her a line at extension 5080.

Note: Marie Strickland, who worked as the Purchasing and Project Coordinator for the Stephen Hawking Centre expansion, is now also joining the Outreach team as an Educational Outreach Coordinator.

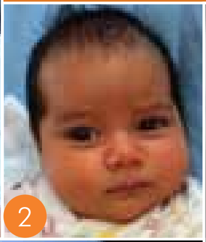
Gabriela (Ella) Secara, Graphic Artist and Web Specialist



Ella joined PI in August as the Graphic Artist and Web Specialist in the External Relations and Public Affairs department. She grew up in a tiny city in Transylvania and earned her BSc in the Faculty of Automation and Computer Science from the Technical University of Cluj Napoca in Romania – where she also took a first-year course in quantum physics, which she loved. Since 1995, she has gained extensive work experience in graphic design, pre-press, page layout, typography, packaging, print production and principles of design, brand identity, colour theory, branding guidelines, GUI design, and variable printing technologies. Before joining PI, she was a Senior Graphic Designer at Schlumberger's Waterloo office.

When she's not at work, Ella spends time listening to her 10-year-old son, Andrei, and his never-ending stories about a game called "Minecraft"; cooking and listening with the volume cranked to progressive metal, rock, and salsa music; watching documentaries; preparing projects for her husband, Tavi, to renovate the house; and wondering about life over a glass of wine with Tavi and her friends.

"I am thrilled to be at PI," Ella says. "There is a positive energy all around – not only the amazing architecture, but also the people. For the first time in my life, I don't wait for the Fridays to come – I wait for the Mondays!" She can be found in office 148 and her extension is 5032.



The Life of PI

1. Researchers in the Bistro 2. Erik Schnetter Jr. 3. Eye in the Sky (Room) 4. Natalia Toro and Philip Schuster working in one of the new interaction areas in the Stephen Hawking Centre 5. Neta Bahcall presents her talk at the Women in Physics Canada conference 6. Go-karting: Dustin Windibank, Damian Pope and Matt Masotti race to the finish line 7. A pananormic view of the Atrium during the grand opening 8. Natalia Klein's new son Nicolás 9. Fountains in the Reflecting Pool 10. Julie Wright's son Luke tickles the ivories on Musical Pub Night 11. Itay Yavin, Astrid Eichhorn, Louis Leblond and Damian Pope at PI's first in-house Science in the Pub