2016
ANNUAL REPORT

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

VISION

To create the world's foremost centre for foundational theoretical physics, uniting public and private partners, and the world's best scientific minds, in a shared enterprise to achieve breakthroughs that will transform our future

CONTENTS

This report covers the activities and finances of Perimeter Institute for Theoretical Physics from August 1, 2015, to July 31, 2016.

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WELCOME

Just one breakthrough in theoretical physics
can change the world.

Perimeter Institute is an independent research centre located
in Waterloo, Ontario, Canada, which was created to accelerate
breakthroughs in our understanding of the cosmos.

Here, scientists seek to discover how the universe works at all scales
– from the smallest particle to the entire cosmos.

Their ideas are unveiling our remote past and enabling the
technologies that will shape our future.

Perimeter is training the next generation of physics pioneers, and
sharing the power of scientific discovery with the world.

The science is complex, but the basic Perimeter equation
is simple: Bright minds. Illuminating Ideas. Brilliant future.

Step inside the Perimeter.

AN ACCELERATOR OF DISCOVERY

RESEARCH

160+ SCIENTISTS IN RESIDENCE conducting research

12 MAJOR PRIZES AND HONOURS awarded to Perimeter scientists in 2015/16

1,000+ VISITING INTERNATIONAL SCIENTISTS annually

4,000+ PAPERS appearing in 170 journals with 150,000+ citations since 2001

10,000+ ONLINE TALKS and lectures accessed by viewers in 175 COUNTRIES

17 YEARS after its creation, Perimeter is now ranked among the TOP THEORETICAL PHYSICS institutes in the world

OUTREACH

20 MILLION STUDENT INTERACTIONS since 2001

20,000+ EDUCATORS trained through Perimeter workshops since 2005

619 TOP HIGH SCHOOL STUDENTS from 50 COUNTRIES have attended the International Summer School for Young Physicists since 2003

65 COUNTRIES have used Perimeter's educational resources

TRAINING

In 2015/16, Perimeter was home to

58 POSTDOCTORAL RESEARCHERS

49 PHD STUDENTS and

29 PSI MASTER'S STUDENTS from 18 COUNTRIES

MESSAGE FROM THE BOARD CHAIR

It's a great day when the Prime Minister of Canada comes to Perimeter to explain the difference between a quantum and classical computer – and it goes viral around the world. It's a great year when that's just one of many high points that demonstrate why we believe we are in a Golden Age for physics. This era will usher in dramatic discoveries and transformative quantum technologies, and Perimeter is positioned at the heart of it all.

In February, the LIGO collaboration announced it had detected gravitational waves, a technical feat that confirmed key predictions of Einstein: gravitational waves and black holes.

Around the world, we continue to see large-scale investment from governments, research facilities, and many of the largest technology companies toward the advancement of physics and the development of new quantum technologies. In May of this year, Europe announced a new €1 billion flagship program focused on elevating their quantum technology effort. The following is a quote from the program's "Quantum Manifesto":

> "[T]he second quantum revolution [is] now unfolding worldwide, bringing transformative advances to science, industry, and society. It will create new commercial opportunities addressing global challenges, provide strategic capabilities for security, and seed as yet unimagined capabilities for the future."

Over the past 18 years, the members of the Quantum Valley have established an ecosystem in Waterloo Region that covers the spectrum from deep discovery and training to experimental labs, quantum technology development, and the commercialization of new transformative quantum technologies. Today, the Quantum Valley continues to take the necessary steps to enable Waterloo, Ontario, and Canada to play a leadership role in the second quantum revolution. Perimeter continues to play an integral role in the Quantum Valley by advancing the foundational principles of quantum information science, by attracting top researchers to Waterloo, and by helping to develop the foundations for an ecosystem that make the Quantum Valley possible.

Perimeter is the result of a strong and long-standing public-private partnership with the Government of Canada and the Province of Ontario, which have been fundamental partners and investors in Perimeter since its inception. In April, Prime Minister Justin Trudeau visited Perimeter to announce his government's renewed investment in the Institute (and deliver a short lesson on quantum computing). In June, Premier Kathleen Wynne came to share the news of Ontario's renewed investment in Perimeter. Both of them renewed commitments of $50 million over five years, confirming that Perimeter is a vital strategic asset. At the same time, an expanding circle of private partners is choosing to invest in Perimeter, including the Stavros Niarchos Foundation, the Daniel Family Foundation, and many others.

There is no question that the advancement of quantum information science and the development of new quantum technologies is a national priority for Canada. I want to thank all of the Institute's partners: your investment and support is enabling the science that will drive our future.

Building these successes is a team effort. I would like to thank the entire Perimeter team, as well as its many volunteers and champions. This includes our Leadership Council, our Emmy Noether Council, our Finance and Investment Committees, and my fellow Board members. I would like to acknowledge, in particular, Director Neil Turok, whose vision guides every aspect of the Institute's development. I also want to recognize Jeff Moody for agreeing to join the Perimeter Board and for agreeing to Chair Perimeter's Investment Committee, as well as Mark Caplan and Dan Benson, who also joined the Perimeter Investment Committee.

We find ourselves in another very exciting time for physics. The discoveries we saw this year are only the beginning. We have a little saying at Perimeter: today's theoretical physics is tomorrow's technology. The fundamental research done here is helping build the foundations of a second quantum revolution, which will be based on a new and deeper understanding of quantum mechanics. It will transform how we view and manipulate matter and energy, manufacture new materials, compute and communicate, store and secure data, and more.

The second quantum revolution promises to create whole new industrial supercycles on the order of the industrial and information revolutions of the past century. The role played by Perimeter Institute and its partners in the Quantum Valley will ensure that Canada, its industry, and its citizens will benefit.

– Mike Lazaridis, O.C., O.Ont., FRS, FRSC
Chair, Board of Directors

MESSAGE FROM THE INSTITUTE DIRECTOR

What an extraordinary year it's been – for physics and for Perimeter. In February 2016, the LIGO collaboration announced that they had detected gravitational waves, faint ripples in spacetime from the merger of two black holes. By March, we learned that the Governments of Canada and Ontario had renewed their investments in Perimeter, with funding that will take us forward through 2022. And in November, we were thrilled to learn that one of our Distinguished Visiting Research Chairs, Duncan Haldane, a Professor at Princeton, was a co-winner of the 2016 Nobel Prize in Physics.

Each of these would be worth celebrating, but there is much more besides, and much more to come.

Gravitational waves were a prediction of Einstein's theory of gravity, which he realized a century ago. Black holes were another prediction which became clear much later on. The success of the theory is a stunning example of the power of the human mind to make sense of our world, even in utterly remote situations. The LIGO experiment was a moonshot – difficult, risky, and hugely ambitious. Ultimately, it was a huge coup for science, for spinoff quantum measurement technologies, and for raising humankind's sights. Their wonderful discovery shows what is possible with vision, collaboration, and committed government support.

Likewise, the Nobel-winning insights of Duncan Haldane and his colleagues emerged from pure theory, but their discoveries pointed the way to new materials, discovered more recently, whose unusual properties may be helpful in building quantum computers.

Here at Perimeter, our goal is to make breakthroughs of a similar magnitude, for the future benefit of the world. We are equally determined to encourage and inspire the next generation of scientists and technologists, who will renew and advance knowledge and create the industries of tomorrow.

We could not undertake these ambitious pursuits without the visionary and committed support of our public and private partners. With their funding renewals, the Governments of Canada and Ontario have expressed their confidence in Perimeter, in basic physics, and in Canada as a global knowledge leader.

We are profoundly appreciative of the support of the people of Ontario and Canada and their governments. In April, we were thrilled to welcome Prime Minister Justin Trudeau for a public announcement of our funding renewal. His passion for physics was evidenced by his impromptu, succinct explanation of quantum computing, a video of which went viral and made an instant impact around the world. Just a few weeks later, we were similarly pleased to welcome Premier Kathleen Wynne, who likewise met with many members of our community.

Physics has always been a catalyst of human progress. Today, the opportunities for discovery are as great as ever, and, as you will read in these pages, research at Perimeter has never been more exciting. Last fall, our external Scientific Advisory Committee, comprising nine eminent scientists from around the world, undertook an extensive review of the Institute. In a glowing report, they stated: "It is difficult to conceive of a research institute of similar scope and size that would generate as much visibility and impact as does Perimeter Institute…. By lending its support to the Perimeter Institute, the Canadian government takes a lead role in promoting fundamental science and

enabling future innovation." A comprehensive five-year audit undertaken by KPMG reached a similar conclusion, stating: "Perimeter has successfully positioned Canada as a world leader in theoretical physics research."

By reaching for the stars and supporting the most ambitious science, Perimeter has become a magnet for top talent. In April, we appointed Asimina Arvanitaki, a pioneering particle theorist, as the Stavros Niarchos Foundation Aristarchus Chair at Perimeter Institute. It is the ninth such chair to be named at Perimeter since 2011. Generously funded by a foundation whose interests span culture, education, and health, Mina's chair will support her efforts to design new types of experiments to probe basic physics. To our collective delight, Mina has won the New Horizons in Physics Prize, the largest prize available for young physicists. Five Perimeter researchers have now won this prize, more than any other institution in the world. As nice as prizes are, they are not our primary goal. We aim at breakthrough discoveries; the rest is a bonus.

This year, we also appointed two associate faculty: Huan Yang (with the University of Guelph), who is an expert on gravitational radiation, black holes, and experiments such as LIGO, and Jon Yard (with the Institute for Quantum Computing at the University of Waterloo), who is an expert in quantum information science and its connections with quantum matter. Such joint appointments connect Perimeter with partner universities and the wider Canadian academic community, for the benefit of all.

The number of applications for our master's and PhD programs, run in partnership with universities, or for postdoctoral fellowships at Perimeter, and the rate of acceptances of our offers, are now among the highest of any institution worldwide. By drawing youthful talent from across the world, by equipping them with the skills they need to pursue leading-edge research, and by imparting a spirit of excellence and dedication, we hope to contribute to the growth of the global community of physicists, and enable it to contribute knowledge for the advancement of humanity.

Educational outreach to students, teachers, and the wider public has continued to be an area of special focus and strength at Perimeter. This year, students used our resources nearly 10 million times, across Canada and in over 60 countries around the world. It remains a top priority of the Institute to engage with larger and larger audiences, and to deliver quality experiences which have a lasting impact on all.

In this regard, 2017 will be very special. We are honoured to have been chosen as the lead partner of the Innovation150 platform for the nationwide celebration of Canada's 150th birthday. With our partners, we shall deliver a spectacular range of activities and events from coast to coast to coast. We look forward to making it a year to remember, in which Canada expresses and defines itself as a forward-looking, inclusive society, with knowledge and knowledge-sharing at its heart.

– Neil Turok, Director and Mike and Ophelia Lazaridis Niels Bohr Chair

RESEARCH

"It's extremely important to underline how essential the work being done here is, not just for Canada, but for the entire world."

– Justin Trudeau, Prime Minister of Canada

This year, Perimeter scientists produced **453 papers.**[1] Since 2003, Perimeter scientists have produced over **4,000 papers** which have appeared in **170 journals**, attracting well over **150,000 citations.**[2]

Every century or so, science produces a seismic shift in our understanding of the universe. In the 1600s, physicists explained planetary motion. In the 1700s, electricity was discovered. The 1800s gave us electromagnetism, and the 1900s birthed both general relativity and quantum mechanics.

These discoveries have profound impacts. Practically every technology we use today emerged from these breakthroughs in fundamental physics. Maxwell's equations unifying electricity and magnetism led directly to all wireless communications. Quantum mechanics gave us transistors, computers, MRI, smartphones, and more. Without general relativity, there would be no GPS.

Perimeter scientists pursue new breakthroughs in our understanding of the universe, from the smallest subatomic particle to the entire cosmos. Their discoveries will create new knowledge and make possible the next wave of transformative technologies to further humanity in ways we have only begun to imagine.

The detection of gravitational waves was the year's biggest news in science. Celebrated around the world, it confirmed key predictions of Einstein's theory of general relativity. More importantly, it opened a new window on the cosmos that will undoubtedly lead to new discoveries.

At the other end of the spectrum, fundamental exploration of the quantum world is driving new discoveries and nascent technologies with incredible potential, from quantum computers to superconducting materials to ultra-precise quantum sensors.

[1] This reflects the one-year period from August 1, 2015 to July 31, 2016. Each publication has been counted only once, regardless of how many Perimeter researchers collaborated on it.

[2] This data comes from the Google Scholar and Spires databases.

Perimeter's mission is to make breakthroughs. Researchers are encouraged to venture into the fertile areas between specializations. Interfaces often hold the greatest potential for discovery. The intersection of mathematics and condensed matter, for example, created the field of topological matter, which now brims with technological possibilities. It also led to a share of the 2016 Nobel Prize in Physics for Duncan Haldane, a Princeton Professor and Perimeter Distinguished Visiting Research Chair.

Every day, you can find around 160 researchers at Perimeter, working on chalkboards and keyboards, collaborating over coffee, analyzing data, and devising experiments to push the boundaries of knowledge.

With interdisciplinary research networks spanning the globe, Perimeter scientists connect with top institutions and experiments worldwide, including the Event Horizon Telescope, LIGO, SNOLAB, and the Large Hadron Collider at CERN.

In the pages ahead, you will read about a few of the many promising intersections Perimeter scientists are exploring, generating ripples that can impact distant shores of understanding.

TOP MARKS

This year, two comprehensive, multi-year reviews of Perimeter Institute were conducted and each came back with extraordinarily positive assessments of Perimeter's operations at every level.

Perimeter's Scientific Advisory Committee concluded: "It is difficult to conceive of a research institute of similar scope and size that would generate as much visibility and impact for every dollar invested in it as does the Perimeter Institute."

Independent auditor KPMG concluded: "Perimeter has successfully positioned Canada as a world leader in theoretical physics research."

The full reports can be found at perimeterinstitute.ca.

AT THE QUANTUM FRONTIER

Early explorations of quantum mechanics in the 20th century unleashed the first quantum revolution – a cascade of discoveries and technologies that included the transistor, the integrated circuit, computers, superconductors, MRIs, digital cameras, modern chemistry, and much more.

Many believe that a second quantum revolution is afoot, based on harnessing subtle and powerful features of quantum mechanics, like superposition (the idea that particles can exist in more than one state at once) and entanglement (which links particles so that they behave in synchrony, even if separated by great distances).

The holy grail of the field of quantum information is the realization of a full-scale quantum computer, which could allow us to break as-yet-unbreakable codes, model complex phenomena, and solve problems previously thought to be unsolvable. Much theoretical research is required, however, before quantum computing technologies can fully emerge.

Perimeter and our nearby experimental partner, the Institute for Quantum Computing (IQC) at the University of Waterloo, have helped transform the region into "Quantum Valley" – a global hub of quantum information science spanning theory to experiment and technology development. For example, Perimeter Faculty member **Daniel Gottesman** is an acknowledged world leader in quantum error correction, the techniques needed to safeguard and verify information amid the errors inherent to quantum computation. Faculty member **Lucien Hardy** has made contributions such as Hardy's Paradox that are foundational to the field. Associate Faculty members **David Cory** and **Raymond Laflamme**, as well as new recruit **Jon Yard** – all jointly appointed at IQC – test and develop new ideas for quantum control, quantum error correction, and frameworks for quantum computing.

As we deepen our understanding of the quantum realm, we will find new ways to apply that knowledge, moving closer to the tangible realization of the next quantum revolution.

THE MEDIUM IS THE PASSAGE

A theoretical doorway to quantum computing long considered closed has been cracked back open by Perimeter postdoctoral researchers **Daniel Brod** and **Joshua Combes**. In two papers published in *Physical Review Letters* and *Physical Review A*, they have revived the idea of creating a type of information-processing gate that is at the top of the wishlist for optical quantum computation.

Working with collaborator Julio Gea-Banacloche from the University of Arkansas, the researchers offer a concrete example of how to construct a controlled-phase (CPHASE) gate using a cross-Kerr medium (a particular kind of medium that passively permits photons to interact with each other, producing a phase shift).

Current attempts to create CPHASE gates require intense management at each step: to execute complicated control pulses and sequences, and to account for things like error correction. That makes using a Kerr medium attractive, since it doesn't require intense handling at each step.

The researchers showed how a CPHASE gate can be built out of a chain of cross-Kerr "interaction sites" containing one or two atoms that interact with the photons and mediate an effective interaction between them. With many such sites, and photons propagating in opposite directions through the chain, a perfect CPHASE gate could be created. For a dozen or so interaction sites, the gates would achieve very high accuracy.

Previous work had indicated such a setup could not withstand real-world effects, so many had assumed it was impossible. This new work does not dispute those earlier findings. Rather, it is based on a different set of assumptions – and, in this instance, proves successful.

That the proposal works with such a small number of resources is encouraging. It is still beyond today's experimental capability to test, but is much closer than similar proposals requiring thousands of optical elements. Brod and Combes hope that, by showing that the scheme is possible in principle, they will breathe new life into a long-dormant avenue of inquiry.

IF IT WALKS LIKE A (QUANTUM) DUCK …

If two separate systems are so similar you cannot tell them apart – neither in experiment nor in principle – can they be considered to be physically the same? It turns out that if one adopts the standard notion of physical identity, then, in the quantum universe, the answer is no.

"Noncontextuality" is the idea that, if it walks like a duck, sounds like a duck, and cannot be told apart from a duck in any experiment, then it must be a duck. But recent work devised at Perimeter Institute and tested at IQC has shown that, in quantum mechanics, noncontextuality can fail.

The research, led by Perimeter Faculty member **Robert Spekkens** and University of Waterloo/IQC Faculty member and Perimeter Affiliate **Kevin Resch**, helps to clarify which principles of classical physics fail in a quantum world, and confirms this non-classicality experimentally.

Under quantum theory, two different preparations of a system can return identical results in every conceivable test, and yet any model of the experiment that assigns the systems' well-defined properties requires each system to be different. That inherent difference violates the principle of noncontextuality.

Spekkens, Perimeter postdoctoral researcher **Matthew Pusey**, and visiting doctoral student Ravi Kunjwal helped define what a test of noncontextuality could look like. Resch and University of Waterloo doctoral student Michael Mazurek built the complex experiment and ran the tests.

Importantly, the experiment did not assume ideal conditions. While previous attempts to test for the predicted failure of noncontextuality have had to resort to assuming things like noiseless measurements, the Perimeter and IQC teams wanted to avoid such unrealistic assumptions. They designed an experiment that could make meaningful tests of noncontextuality even in the presence of noise, by fighting statistical error with statistical inference.

The results, published in *Nature Communications*, are significant because, for certain kinds of cryptographic tasks and computational tasks, the failure of noncontextuality is the resource that powers quantum-over-classical advantages. Understanding how to contend with noise opens a new range of possibilities for physicists pushing to find – and fully understand – the technological advantages offered by quantum theory.

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PERIMETER FACULTY

Dmitry Abanin (on leave)

Asimina Arvanitaki, Stavros Niarchos Foundation Aristarchus Chair in Theoretical Physics

Latham Boyle

Freddy Cachazo, Gluskin Sheff Freeman Dyson Chair in Theoretical Physics

Kevin Costello, Krembil William Rowan Hamilton Chair in Theoretical Physics

Bianca Dittrich

Laurent Freidel

Davide Gaiotto, Krembil Galileo Galilei Chair in Theoretical Physics

Jaume Gomis

Daniel Gottesman

Lucien Hardy

Luis Lehner

Max Metlitski

Robert Myers

Subir Sachdev, Cenovus Energy James Clerk Maxwell Chair in Theoretical Physics (Visiting)

Philip Schuster (on leave)

Kendrick Smith

Lee Smolin

Robert Spekkens

Paul Steinhardt, Daniel Family Richard P. Feynman Chair in Theoretical Physics (Visiting)

Natalia Toro (on leave)

Neil Turok, Mike and Ophelia Lazaridis Niels Bohr Chair in Theoretical Physics

Guifre Vidal

Pedro Vieira, Clay Riddell Paul Dirac Chair in Theoretical Physics

Xiao-Gang Wen, BMO Financial Group Isaac Newton Chair in Theoretical Physics

EXPLORING EXOTIC MATTER

The promise of quantum matter is hard to overstate.

In the 20th century, our understanding of materials was revolutionized when it was unified with the emerging field of quantum mechanics. This first quantum revolution resulted in much of our current technology, from transistors to solar cells to the touch screen on your phone.

The 2016 Nobel Prize in Physics was awarded to three researchers – including Perimeter Distinguished Visiting Research Chair **Duncan Haldane** – whose discoveries of topological states of matter in the 1970s and 1980s helped lay the foundation for a second quantum revolution providing new insights into exotic states of matter with powerful properties.

Conventional states of matter are described by the arrangements and symmetries of their atoms. Quantum matter, on the other hand, can only be described by taking into account the correlations *between* atoms or electrons. This is like describing a city not in terms of its buildings and houses, but the information flows through its fibre optic cables.

The study of quantum matter requires new mathematical tools and new theoretical understandings. The last decade has been marked by rapid development in both. The immediate payoff is a deeper understanding of phenomena such as superconductivity, but some of the tools and insights developed in relation to quantum matter have had a surprisingly broad effect. For example, tensor networks, a mathematical tool pioneered by Perimeter Faculty member **Guifre Vidal**, are opening new research directions in quantum gravity, high energy physics, and even mathematics.

Although it began in pure theory, the second quantum revolution is likely to revolutionize the world of materials science and technology, impacting everything from computing and communications to energy transmission and medical technologies.

The race is on to make it happen. Here are just a few ways Perimeter researchers had an impact this year.

QUANTUM MACHINE LEARNING

The study of quantum many-body systems involves what could be nature's most complex object: the electron wavefunction. Using a computer to mathematically represent the wavefunction for a nanometre-sized chunk of dust would require a hard drive containing more magnetic bits than there are atoms in the universe.

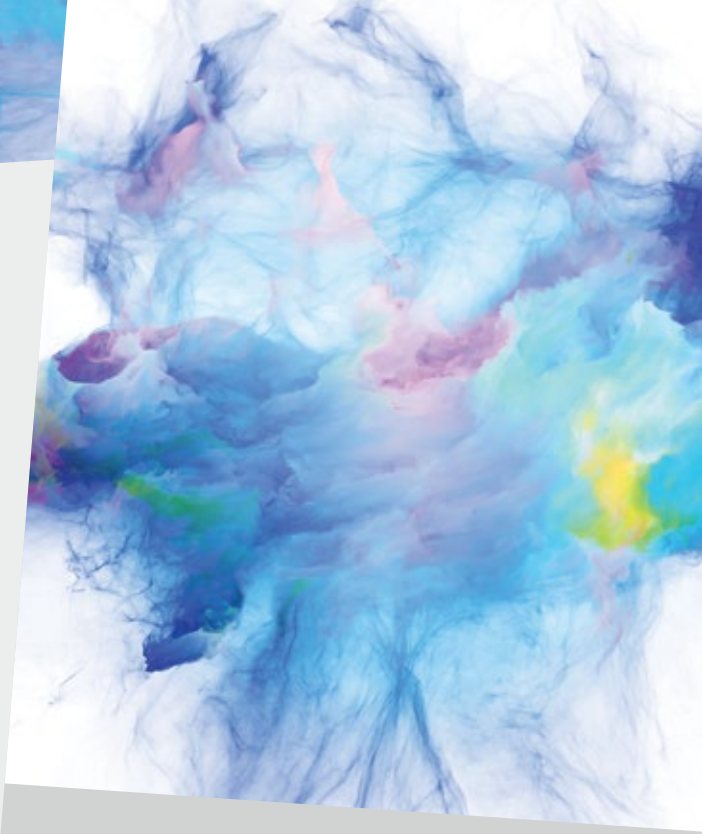
To get around this, physicists have a grab-bag of tricks that extract useful properties of some wavefunctions, using only the modest computer hardware currently available. But Associate Faculty member **Roger Melko** is pioneering a different option. He is applying the established success of machine learning to new purposes in quantum many-body physics.

Machine learning refers to a set of algorithms used to extract features from extremely large or complex data sets. It is already prevalent in our daily lives, driving such things as facial recognition capabilities, game self-play, and other tasks in artificial intelligence.

Now, Melko and Perimeter postdoctoral researcher **Juan Carrasquilla** have combined very modern neural network technology (a class of machine learning algorithm) with Monte Carlo simulations of model Hamiltonians that are of interest in conventional condensed matter physics. This combined Monte-Carlo/machine-learning approach was introduced in the preprint "Machine Learning Phases of Matter" (currently under consideration for *Nature Physics*).

The researchers show that standard neural networks can detect conventional phases of matter, and phase transitions, in configurations produced by Monte Carlo simulations. These neural networks can also identify topological phases with no conventional order parameter. Connections between machine learning and tensor networks are also now being explored.

This work was the first to demonstrate the power of machine learning as a basic research tool in the field of condensed matter and statistical physics, and led to Perimeter hosting the first "Quantum Machine Learning" conference in August, attended by almost 100 specialists from research and industry.



ADVANCING THE THEORY OF TOPOLOGICAL INSULATORS

Topological insulators are unusual materials that act like a reverse power cord: they insulate on the inside and conduct electricity on the outside. But there is a crucial difference: topological insulators are made up of the exact same material throughout.

One of the very few exotic states of matter that emerged from theory and was later confirmed through experiment, topological insulators are believed to hold great promise for quantum computing and no-loss energy transmission. A better understanding of topological insulators is thus of urgent and practical interest.

Perimeter Faculty member **Max Metlitski** has made important progress in this direction. The existing theory of topological insulators described the material in terms of its electrons. Metlitski developed a dual – or equivalent – theory that instead describes topological insulators in terms of vortices of charge swirling across the surface. In recent work, he was able to extend that theory beyond the surface of the topological insulator and describe the behaviour of the insulating body, or "bulk," of the material as well.

This new description of topological insulators is more powerful than the old one. The previous theory worked only where the electrons on the surface were weakly interacting. This new vortex-based approach can describe strongly interacting electrons as well.

Metlitski's work also resolved a long-standing problem in condensed matter physics involving a system known as a quantum hall fluid. In these fluids, a film of electrons in a strong magnetic field has certain phases which are superconducting. The best existing theory describing the special states of the quantum hall fluid did not include one of the symmetries that quantum mechanics says it should have, and thus was known to be incomplete.

Metlitski and collaborators discovered an unexpected connection between topological insulators and quantum hall fluids in their special superconducting states: the new vortex-based description resolves the problem of the missing symmetry. This work is a major step forward in the theoretical understanding of both topological insulators and superconductors, and holds promise of further progress to come.

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PERIMETER ASSOCIATE FACULTY

(cross-appointed with other institutions)

Niayesh Afshordi (University of Waterloo)

Alexander Braverman (University of Toronto)

Avery Broderick (University of Waterloo)

Alex Buchel (Western University)

Raffi Budakian (Institute for Quantum Computing (IQC)/University of Waterloo)

Cliff Burgess (McMaster University)

David Cory (IQC/University of Waterloo)

James Forrest (University of Waterloo)

Matthew Johnson (York University)

Raymond Laflamme (IQC/University of Waterloo)

Sung-Sik Lee (McMaster University)

Roger Melko (University of Waterloo)

Michele Mosca (IQC/University of Waterloo)

Markus Mueller (Western University)

Ue-Li Pen (Canadian Institute for Theoretical Astrophysics/ University of Toronto)

Maxim Pospelov (University of Victoria)

Itay Yavin (McMaster University) (on leave)

A NEW WINDOW TO THE COSMOS

Since the dawn of science, astronomy has been defined by light. First came what we could see with our eyes – movements of the moon, stars, and planets – and then what we could see using telescopes, first with visible wavelengths and then more exotic forms of light: X-rays, radio waves, and microwaves. With each wavelength came new and astonishing discoveries, from uncovering black holes to mapping the afterglow of the big bang. But we were still limited to working with light.

Now, finally, that's changing. As we begin to look at the universe through the lens of gravity, new windows are opening on the universe.

Our current theory of gravity is Einstein's theory of general relativity, which defines how mass causes spacetime to stretch and warp. While most ordinary objects create gentle dimples in spacetime, very massive or very dense objects, like black holes, create more dramatic effects. And a rapid change in a very massive or very dense system, such as two black holes colliding, can create a tsunami of spacetime that ripples outward through the universe in a phenomenon known as gravitational waves. As the waves spread over cosmological distances, the tsunami is diluted to incredibly faint ripples.

In 2015, after decades of effort, a team of scientists working at the Laser Interferometer Gravitational-Wave Observatory (LIGO) detected these ripples in spacetime, generated by a pair of black holes on a collision course 1.3 billion years ago. At its peak, the merger released more power than all the light radiated by all the stars in the observable universe, yet its effect on Earth, after spreading out over a billion light-years, was tiny: the waves changed the length of the 4 km-long LIGO arms by a mere one-thousandth the width of a single proton. Achieving this detection was a truly great moment in science, akin to the day 400 years ago when Galileo first pointed a telescope at the sky.

Collecting the data is the job of sophisticated machines; understanding the data and mapping the course of future observations is the job of the world's leading theorists. Perimeter researchers are leveraging theory to maximize knowledge gains in this new era of discovery, from piecing together the puzzle of "multimessenger astronomy," which combines gravitational wave detections with electromagnetic signals, to, ultimately, turning the lens of gravity inward to test the predictions of general relativity.

SURPRISE: GRAVITATIONAL WAVES CAN BE USED TO STUDY PARTICLE PHYSICS

We will presumably learn much about black holes and about general relativity from the next several years of LIGO observations – but that is not all we could learn from such a large dataset. Perimeter Faculty member **Asimina Arvanitaki**, who holds the inaugural **Stavros Niarchos Foundation Aristarchus Chair**, is among those exploring the possibilities for discovery.

Arvanitaki is a leader among a new generation of physicists seeking novel ways to test fundamentals of particle physics outside of large colliders.

In considering what could be learned from the LIGO data, Arvanitaki worked with Perimeter postdoctoral researchers **Masha Baryakhtar** and **Robert Lasenby**, Distinguished Visiting Research Chair **Savas Dimopoulos**, and Visiting Fellow **Sergei Dubovsky** to re-imagine black holes as naturally occurring particle detectors. Using these "detectors," they are developing a new way to search for new types of particles.

A black hole's enormous mass can produce many strange effects on its surrounding spacetime. Among these is superradiance – a process by which energy and angular momentum from the black hole is extracted in a runaway process to create clouds of matter particles.

These particles then orbit the black hole in bound states, much as an electron orbits an atomic nucleus. Like electrons, the orbiting particles could jump between energy states. And just as electrons

jumping between energy states in an ordinary atom create electrical radiation, or light, particles orbiting a black hole jumping between energy states could create coherent gravitational wave "beams" that could be detected by a gravitational wave detector on Earth, such as Advanced LIGO (the next generation of LIGO).

Studying these gravitational waves very precisely could reveal all kinds of details about the particle clouds that created them. Arvanitaki and Baryakhtar are particularly interested in Advanced LIGO's potential to detect the QCD axion, a particle proposed in the 1970s to explain the smallness of the neutron's dipole moment. For three decades, much experimental effort has been expended, but it has thus far evaded Earth-bound detection. Many researchers consider the axion an ideal candidate particle that could help to solve the mystery of dark matter.

Like much work at Perimeter, theirs bridges several fields of physics that rarely interact – in this case, particle physics, black hole astrophysics, and gravitational wave detection. It is by building such bridges that Perimeter can truly lead the way.

HISTORY IN THE MAKING: FIRST IMAGES OF BLACK HOLES ARE COMING

Amazingly, LIGO's signal was not the only landmark development in the study of strong gravity in 2015/16. In an entirely separate endeavour, one of the most sophisticated telescopes in the world, the Event Horizon Telescope (EHT), began its effort to take the first true "image" of a black hole – one that can actually show us the shadow of the event horizon silhouetted against the brightness of the matter falling toward it.

Associate Faculty member **Avery Broderick**, a member of the EHT collaboration, is playing a key role in this historic effort. The images he and his collaborators obtain will confirm – or perhaps even refute – much of what we believe about the nature of black holes and perhaps gravity itself.

Broderick is a world leader in the analysis of raw astronomical data. He has developed models and analysis techniques now widely used to extract relevant information from massive amounts of radio telescope data about black holes.

To support this crucial piece of research, Perimeter has launched the **EHT Initiative** to assemble the necessary cluster of talent that will lead the global effort to analyze and interpret the large influx of data emerging from the EHT. This year, the initiative recruited and hired three postdocs and one student to make rapid progress on key EHT projects.

As the EHT data arrived, these researchers, and others from around the globe, were at last able to begin to examine a real black hole in detail, and ultimately validate some of the long-standing theories about these strange objects.

In a landmark result, the team measured the polarization of light just outside the event horizon of Sagittarius A*, the supermassive black hole at the centre of our galaxy, the Milky Way.

Decades of theoretical work, including enormous computer simulations, had painted a picture of how magnetic fields near the black hole horizon contribute to the processes that enable a black hole to grow. In these models, black holes are ringed by strong and stable magnetic vortices, much as bathtub drains are ringed by whirlpools.

The polarization data from the EHT confirmed that these strongly ordered magnetic structures do indeed exist, and provided a first measure of their size. This in turn allows researchers to make major progress in black hole astrophysics, studying both how black holes grow and how they sometimes launch jets: outflows of radiation and charged particles moving at nearly the speed of light.

This is a first major result from the EHT that advances our knowledge of black hole astrophysics. Given the richness of the EHT data, it will not be the last.

References:

A. Arvanitaki (PI), M. Baryakhtar (PI), S. Dimopoulos (Stanford University), S. Dubovsky (New York University), and R. Lasenby (PI), "Black Hole Mergers and the QCD Axion at Advanced LIGO," arXiv:1604.03958.

M.D. Johnson (Harvard-Smithsonian Center for Astrophysics), A.E. Broderick (PI and UW), et al., "Resolved magnetic-field structure and variability near the event horizon of Sagittarius A*," *Science*, 350, 1242 (2015), arXiv:1512.01220.

A HOLOGRAPHIC REVOLUTION

Black holes are popping up all over. Peer into the theoretical models and you will find black holes hidden in nuclear physics, in high-temperature superconductivity, in fluid mechanics, and even outside physics in the realms of pure mathematics.

These are not literal black holes, of course, but rather useful abstractions that have their origin in a "duality" developed by string theorists. In a duality, two theories which may look very different are shown to be interchangeable, which allows physicists to take tools and insights from one realm and apply them to another.

The particular kind of duality that brings us the black holes goes by the name "holography." Just as a hologram is a two-dimensional image that stores three-dimensional information, holographic dualities add or subtract one dimension. Through holography, physicists can translate hard problems about gravity into simpler ones about particles and fields – or, much more commonly, hard problems about particles and fields into simpler ones about gravity. That's where black holes come in.

Holography is a powerful tool, and over the last 10 years it has worked its way into every corner of physics. Following the flow of ideas across theories and up and down the dimensions requires creative thinking and cross-disciplinary skills. It is perhaps not surprising, then, that Perimeter is a place at which holography thrives.

Many Perimeter researchers are using holography for its primary purpose: making better sense of quantum field theory. **Clay Riddell Paul Dirac Chair Pedro Vieira** has used holographic and string theory techniques to find the first exact solutions in four-dimensional quantum field theories (QFTs), while **Krembil Galileo Galilei Chair Davide Gaiotto**'s work on QFTs and holography has led to surprising advances in pure mathematics.

What's more, some Perimeter researchers are pushing holography to do far more than tackle problems in QFTs.

A STRANGE STEP FOR STRANGE METALS

Subir Sachdev, the Cenovus Energy James Clerk Maxwell Chair (Visiting), pioneered the application of holography to problems in condensed matter.

Sachdev is particularly interested in quantum states of matter. While normal states of matter can be described in terms of the type and location of particles, quantum states of matter must be described in terms of the entanglement between particles. Moving from one to the other is like moving from describing a city in terms of its buildings and streets to describing one in terms of its cell phone traffic.

The scale of the task can be overwhelming. It's one thing to study a pair of entangled particles – quantum theorists are now experts at that – but a condensed matter system can involve vast numbers of particles: some 10^{23} of them in a sample of a few grams.

Sachdev's breakthrough, some years ago, was to use holography to change the entanglement problem into a gravitational one, cracking open several long-standing problems in quantum condensed matter.

This year, Sachdev made major progress while describing the quantum physics of strange metals, phases of matter that have perplexed physicists for some time – hence their name.

In a paper published in *Physical Review X*, Sachdev showed that a new kind of quantum field theory exhibits holographic behaviour, demonstrating that the unwieldy particle-based description of strange metals was holographically dual with a description of a certain kind of charged black hole. Remarkably, this QFT is able to give insight into the entropy of black holes – a surprising result considering the two topics seem to be worlds apart.

From strange metals to black holes may seem like a step sideways. But Sachdev proves that it is also a major step forward.

FINDING THE PIXELS OF SPACETIME

Holography is usually used to transform a tough problem about particles into an easier one about gravity. But one Perimeter researcher, Faculty member **Bianca Dittrich**, is turning the hologram around.

Dittrich is one of many researchers seeking new connections between general relativity and quantum field theory. These two great theories of modern physics are elegant, successful – and famously incompatible.

Spacetime, according to general relativity, is smooth. It's also continuous – meaning if you were to zoom in on spacetime with an infinitely powerful microscope, it would look the same: smooth. Quantum field theory, on the other hand, describes particles and forces as discrete "packets," requiring spacetime itself to be granular. A theory of quantum gravity would need to link both pictures – be smooth at large scales, but granular at very small ones, something like a photograph made of pixels.

Dittrich uses an approach called loop quantum gravity, which pictures spacetime as a fine mesh of linked "spacetime pixels." She hopes to define the properties a spacetime pixel would need to have to be both separate at small scales and smooth when interacting with many other such pixels.

One major challenge is simulating the connections between many of these spacetime pixels. The pixels are so small that even a tiny chunk of spacetime would contain a boggling number of them, quickly overwhelming the calculations.

Dittrich's innovation: rather than studying every pixel inside a given chunk of spacetime, she used holography to instead study just its surface – subtracting a dimension and simplifying the problem.

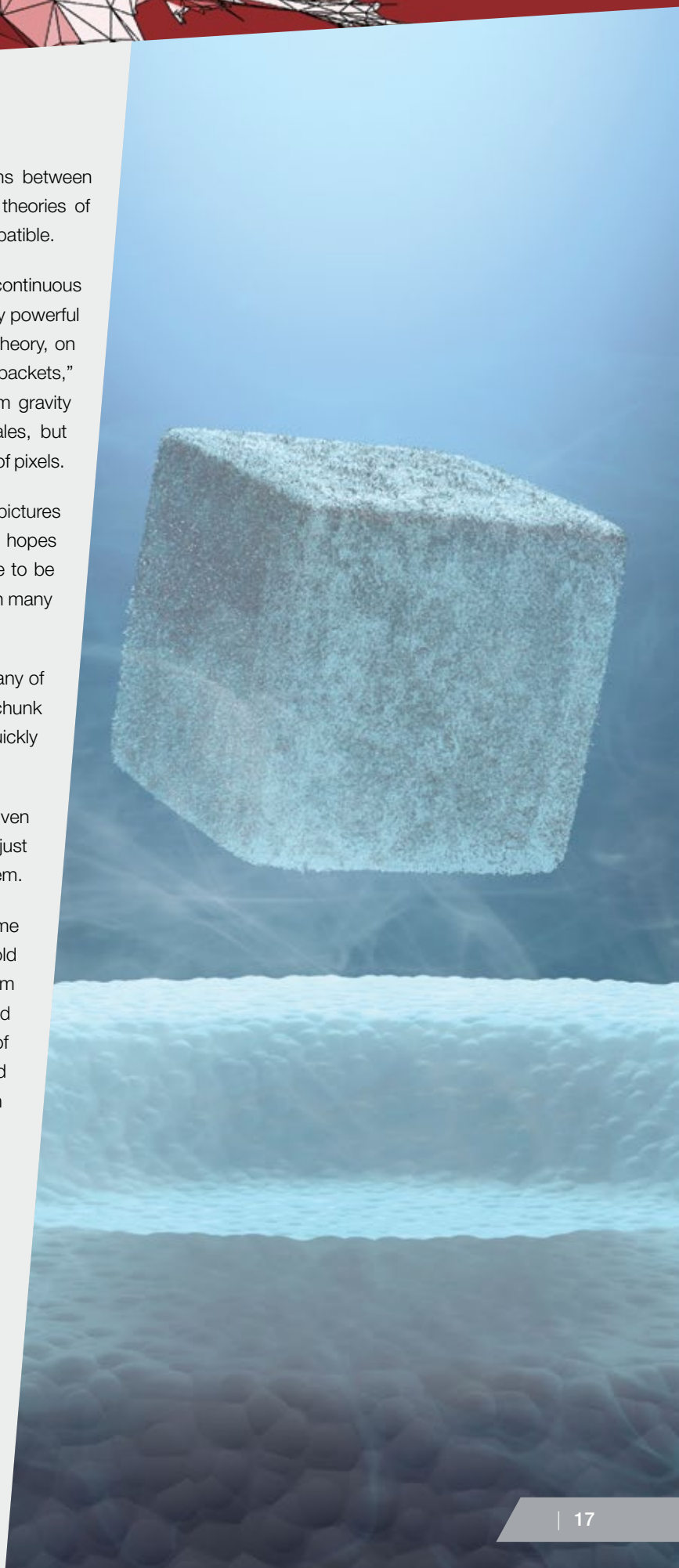
Holography normally applies in a special kind of spacetime known as anti-deSitter (AdS) space, and is known to hold only for infinitely large surfaces. Dittrich and Valentin Bonzom (previously a postdoctoral researcher at Perimeter Institute and now a professor at University of Paris 13) pushed the limits of the theory in both directions, showing that it could also be used in the case of more generic three-dimensional spacetimes with finite boundaries.

The result of their efforts was a much simplified construction of a theory of quantum gravity. It's an open road that invites future travel by Dittrich and others. The next logical – but challenging – step is to extend Dittrich's model one further dimension to the 4D spaces required by many other theories of quantum gravity.

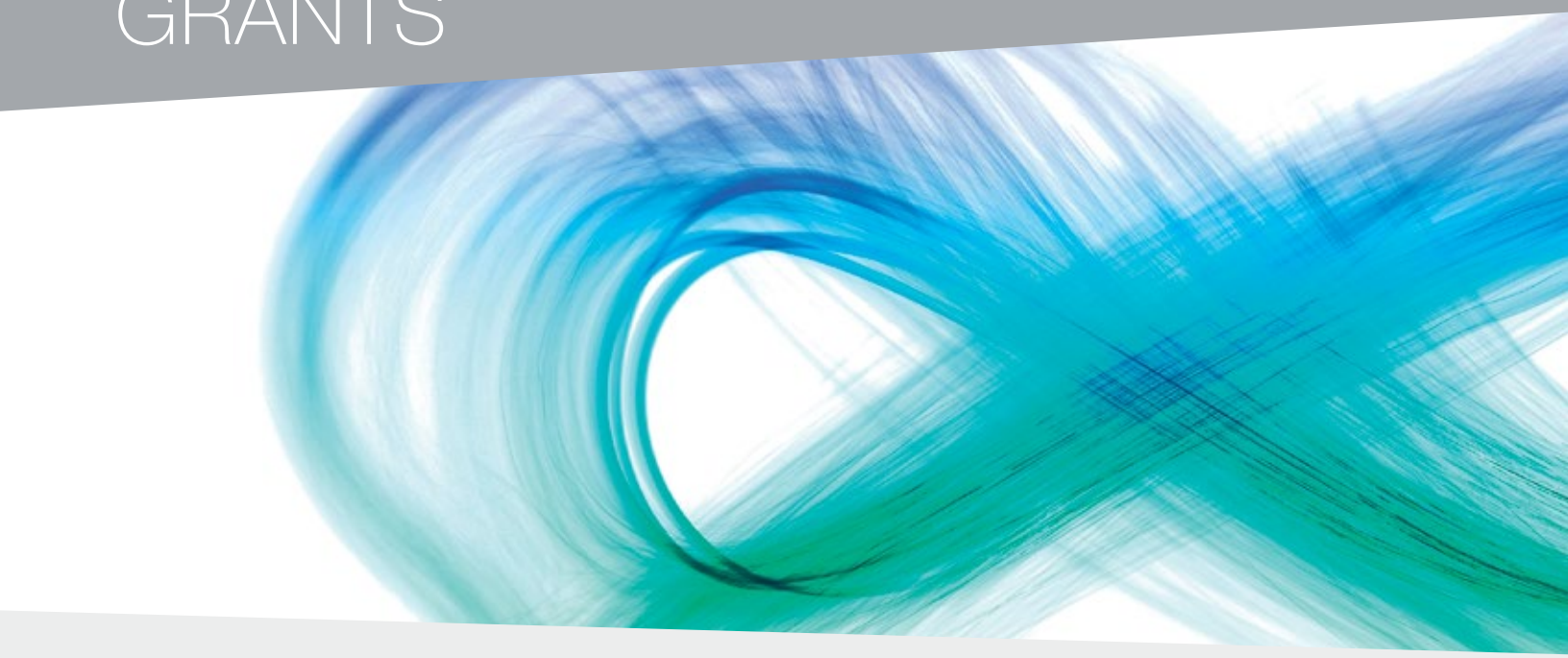
References:

S. Sachdev (Harvard University, PI, and Kavli Institute for Theoretical Physics), "Bekenstein-Hawking Entropy and Strange Metals," *Phys. Rev. X 5*, 041025 (2015), arXiv:1506.05111.

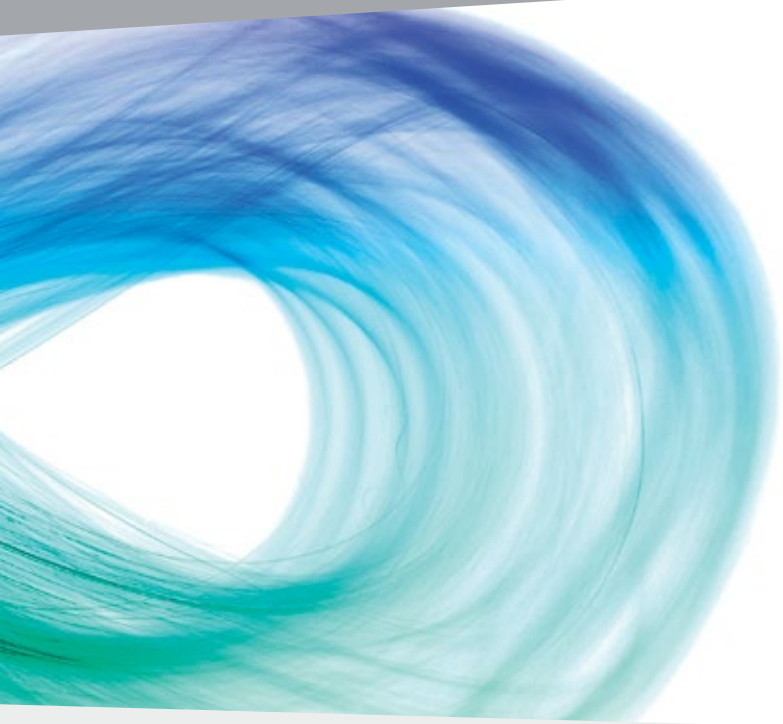
V. Bonzom (University of Paris 13) and B. Dittrich (PI), "3D holography: from discretum to continuum," *JHEP 3*, 208 (2016), arXiv:1511.05441.

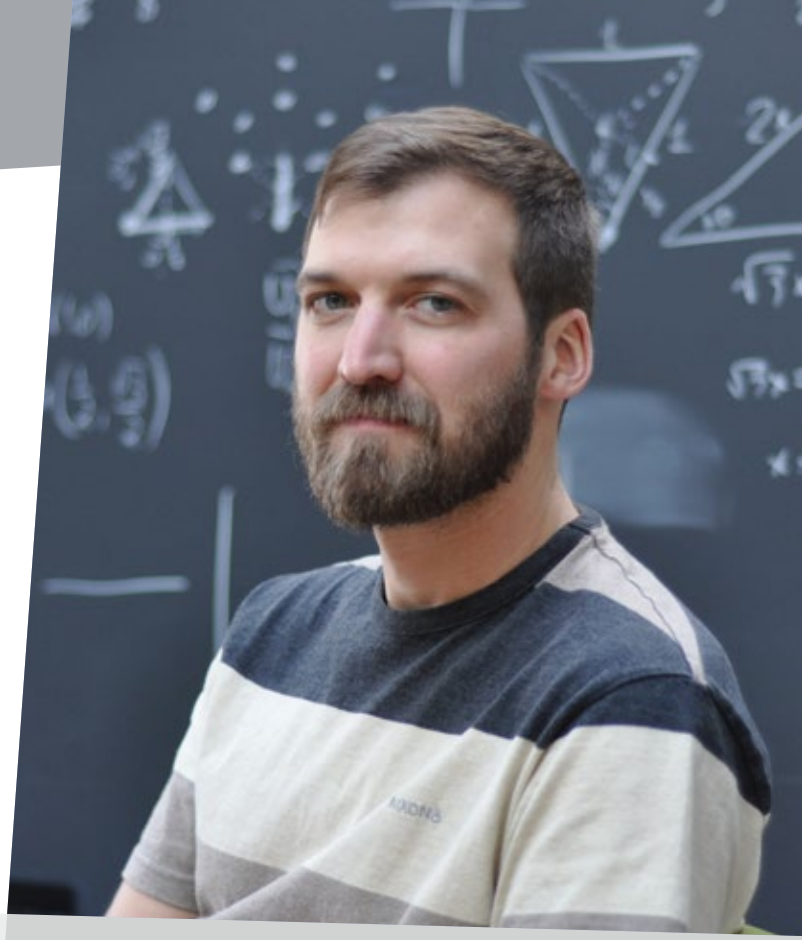


HONOURS, AWARDS, AND MAJOR GRANTS



- Distinguished Visiting Research Chair **Duncan Haldane** won the 2016 Nobel Prize in Physics.
- **Neil Turok**, Perimeter Director and Mike and Ophelia Lazaridis Niels Bohr Chair, won the 2016 John Torrence Tate Award for International Leadership in Physics from the American Institute of Physics.
- Gluskin Sheff Freeman Dyson Chair **Freddy Cachazo** was awarded the 2016 CAP-CRM Prize in Theoretical and Mathematical Physics by the Canadian Association of Physicists and the Centre de recherches mathématiques.
- Associate Faculty member **Roger Melko** was awarded the 2016 Herzberg Medal by the Canadian Association of Physicists.
- Associate Faculty member **Markus Mueller** won the 2016 Birkhoff-von Neumann Prize of the International Quantum Structures Association.
- Distinguished Visiting Research Chair **Sandu Popescu** won the 2016 Dirac Medal in Physics from the Institute of Physics (UK).
- Distinguished Visiting Research Chair **Andrew Strominger** received the 2016 Dannie Heineman Prize for Mathematical Physics from the American Physical Society.
- For the second year in a row, Faculty member **Robert Myers** was named among the "World's Most Influential Scientific Minds," based on a study by Thomson Reuters. Distinguished Visiting Research Chair **Juan Ignacio Cirac** was also on the 2015 list.
- **Neil Turok** was named the 2016 Gerald Whitrow Lecturer of the Royal Astronomical Society (UK).
- **Subir Sachdev**, the Cenovus Energy James Clerk Maxwell Chair (Visiting), was awarded the 2015 Dirac Medal for the Advancement of Theoretical Physics by the University of New South Wales and the Australian Institute of Physics.
- **Markus Mueller** was appointed to the Canada Research Chair in the Foundations of Physics (Tier 2).
- Postdoctoral researcher **Flavio Mercati** and his collaborators, Julian Barbour and Tim Koslowski (a former Perimeter postdoctoral researcher), were awarded the 2015 Buchalter Cosmology Prize by the American Astronomical Society; Associate Faculty member Niayesh Afshordi and postdoctoral researcher Elliot Nelson won third place.
- Associate Faculty member **David Cory** was elected as a Fellow of the Royal Society of Canada and a Fellow of the American Physical Society.





- Distinguished Visiting Research Chairs **Abhay Ashtekar** and **Stephen Hawking** were elected as Fellows of the International Society for General Relativity and Gravitation.
- Distinguished Visiting Research Chair **Renate Loll** was installed as a Member of the Royal Netherlands Academy of Arts and Sciences.
- Faculty member **Lee Smolin** and co-author Roberto Mangabeira Unger won the 2016 PROSE Award from the Association of American Publishers for their book, *The Singular Universe and the Reality of Time*.
- Stavros Niarchos Foundation Aristarchus Chair **Asimina Arvanitaki** received an Early Researcher Award worth $140,000 from the Ontario Ministry of Research and Innovation.
- Five Perimeter-authored papers were named "Highlights of 2015" by the *New Journal of Physics* and four more were named "Highlights of 2015" by the Editorial Board of *Classical and Quantum Gravity.*
- Perimeter scientists obtained more than $4.5 million in research grants from agencies including the Natural Sciences and Engineering Research Council of Canada, the Alexander von Humboldt Foundation, and the Foundational Questions Institute.

ROGER MELKO: AN EMERGING YOUNG LEADER

The most complex object in nature is not, contrary to common wisdom, the human brain. Our grey matter is vastly outdone by the quantum wavefunction of a many-body system. To mathematically represent the electron wavefunction for a nanometre-sized chunk of dust, one would require a hard drive containing more magnetic bits than there are atoms in the universe.

But researchers like **Roger Melko** – a Perimeter Associate Faculty member and University of Waterloo Assistant Professor – are using the former to help understand the latter.

A young leader in an emerging field, Melko specializes in large-scale computer simulations probing strongly correlated systems. Methods he developed in 2010 incorporating quantum information ideas into conventional simulations are now widely used, and have helped make entanglement a broadly recognized diagnostic in the study of quantum matter.

The strength of his work, and its potential for greater impact, earned Melko the 2016 Herzberg Medal of the Canadian Association of Physicists, which recognizes outstanding achievement in any field of research by an early-career Canadian physicist.

Melko, who grew up in northern Manitoba, said the award is a tremendous honour: "It is a humbling experience to join past recipients whom I have long admired and respected."

RECRUITMENT

PI BY THE NUMBERS

Perimeter is the world's largest independent theoretical physics community:

25 full-time faculty, including nine Perimeter Research Chairs

17 associate faculty cross-appointed with partner universities

49 Distinguished Visiting Research Chairs

27 Visiting Fellows

58 postdoctoral researchers

78 graduate students[1]

[1] This includes 49 PhD students and 29 Perimeter Scholars International (PSI) master's students. All numbers reflect the Perimeter community as of July 31, 2016.

Perimeter assembles great minds and challenges them to pursue the most ambitious questions within a vibrant, collaborative environment. The result is the world's largest independent centre for theoretical physics, a community of extraordinary people pursuing bold ideas.

In 2015/16, Perimeter welcomed leading scientists across the full spectrum of theoretical physics, with emphasis on areas of growing strength, such as condensed matter and mathematical physics.

PERIMETER RESEARCH CHAIRS

From emerging leaders to renowned pioneers, Perimeter Research Chairs are exceptional scientists working in fields strategically chosen for the high potential for breakthroughs. Envisioned as the most prestigious chairs in theoretical physics worldwide, they are named for the legendary scientists whose insights helped define the field.

This year, the Institute appointed the ninth Perimeter Research Chair since the program's creation five years ago. In April, particle physicist **Asimina Arvanitaki** was named the **Stavros Niarchos Foundation Aristarchus Chair in Theoretical Physics**, supported through a $4 million investment from the Stavros Niarchos Foundation, matched by Perimeter.

Arvanitaki is known for designing potentially paradigm-shifting experiments to test fundamental theories beyond the Standard Model. These experiments rely on the latest developments in metrology, such as atomic clocks, and the optical trapping and cooling of macroscopic objects. She also works on theoretical challenges raised by experimental results.

In 2015/16, two new gifts were received in support of Visiting Perimeter Research Chairs: the Daniel Family Foundation supported the **Daniel Family Richard P. Feynman Chair in Theoretical Physics (Visiting)**, held by renowned cosmologist **Paul Steinhardt**; and Cenovus Energy supported the **Cenovus Energy James Clerk Maxwell Chair in Theoretical Physics (Visiting)**, held by pioneering condensed matter physicist **Subir Sachdev**.

There are nine fully-funded Perimeter Research Chairs:

Asimina Arvanitaki, Stavros Niarchos Foundation Aristarchus Chair
Freddy Cachazo, Gluskin Sheff Freeman Dyson Chair
Kevin Costello, Krembil William Rowan Hamilton Chair
Davide Gaiotto, Krembil Galileo Galilei Chair
Subir Sachdev, Cenovus Energy James Clerk Maxwell Chair (Visiting)
Paul Steinhardt, Daniel Family Richard P. Feynman Chair (Visiting)
Neil Turok, Mike and Ophelia Lazaridis Niels Bohr Chair
Pedro Vieira, Clay Riddell Paul Dirac Chair
Xiao-Gang Wen, BMO Financial Group Isaac Newton Chair

DISTINGUISHED VISITING RESEARCH CHAIRS

** Indicates DVRC appointed in 2015/16*

Yakir Aharonov, Chapman University and Tel Aviv University
Nima Arkani-Hamed, Institute for Advanced Study
Abhay Ashtekar, Pennsylvania State University
Leon Balents, University of California, Santa Barbara
James Bardeen, University of Washington
Ganapathy Baskaran, Institute of Mathematical Sciences, Chennai
Patrick Brady, University of Wisconsin-Milwaukee
Alessandra Buonanno, Max Planck Institute for Gravitational Physics (Albert Einstein Institute) and University of Maryland, College Park
Juan Ignacio Cirac, Max Planck Institute of Quantum Optics
Savas Dimopoulos, Stanford University
Lance Dixon, Stanford University
Matthew Fisher, University of California, Santa Barbara
Dan Freed*, University of Texas at Austin
Katherine Freese*, University of Michigan
S. James Gates Jr., University of Maryland, College Park
Alexander Goncharov, Yale University
Gabriela González, Louisiana State University
Duncan Haldane, Princeton University
Stephen Hawking, University of Cambridge
Patrick Hayden, Stanford University
Joseph Incandela, University of California, Santa Barbara
Ted Jacobson, University of Maryland, College Park
Shamit Kachru, Stanford University
Anton Kapustin*, California Institute of Technology
Adrian Kent, University of Cambridge
Renate Loll, Radboud University, Nijmegen
Matilde Marcolli, California Institute of Technology
Joel Moore, University of California, Berkeley
Ramesh Narayan, Harvard University
Sandu Popescu, University of Bristol
Frans Pretorius, Princeton University
Nathan Seiberg*, Institute for Advanced Study
Peter Shor, Massachusetts Institute of Technology
Iakov (Yan) Soibelman, Kansas State University
Dam Thanh Son, University of Chicago
Andrew Strominger, Harvard University
Raman Sundrum, University of Maryland, College Park
Leonard Susskind, Stanford University
Gerard 't Hooft, Utrecht University
Barbara Terhal, RWTH Aachen University
Senthil Todadri, Massachusetts Institute of Technology
William Unruh, University of British Columbia
Frank Verstraete, University of Vienna and University of Ghent
Ashvin Vishwanath, University of California, Berkeley
Zhenghan Wang, Microsoft Research Station Q
Steven White, University of California, Irvine
Mark Wise, California Institute of Technology
Matias Zaldarriaga, Institute for Advanced Study
Alexander Zamolodchikov*, Stony Brook University

"On my last day, I told a senior colleague that I thought the Institute had taken a chance on me. He replied: 'We didn't take a chance on you. We knew you had that potential, and your previous work was innovative and showed that.' Hearing that was a brilliant confidence boost for me, and typified the kind of support and encouragement postdocs get at Perimeter."

– David "Doddy" Marsh, postdoctoral fellow at the Royal Astronomical Society, King's College, London

FACULTY

In 2015/16, the Institute welcomed **Max Metlitski**, an outstanding young researcher specializing in condensed matter. Recruited to Perimeter from the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara, his work has contributed to the theory of quantum criticality in metals, and to the understanding of topological phases in the presence of interactions. See page 13 for a highlight of his work at Perimeter.

ASSOCIATE FACULTY

A rising tide floats all boats. For this reason, Perimeter works with the surrounding academic community in many ways: through collaborative training, research partnerships, and even joint appointments.

The Associate Faculty program is one of the Institute's longest-running and most successful collaborations with the national physics community. Associates split their time between two research homes: Perimeter Institute and a partner university at which they are cross-appointed. It brings respected international scientists to Canada, strengthens the Institute's position as a physics hub for Canadian universities, and helps enhance national research capacity.

In 2015/16, Perimeter made two associate faculty appointments. The Institute currently has 17 associate faculty members.

Huan Yang was jointly appointed with the University of Guelph, while **Jon Yard** was jointly appointed with the Institute for Quantum Computing and the Department of Combinatorics and Optimization at the University of Waterloo.

Yang will join Perimeter in the fall of 2017, from Princeton University, where he is a Postdoctoral Research Associate, and will strengthen the Institute's existing expertise in black holes and gravitational waves, among other areas.

Yard, meanwhile, brings expertise in a number of areas, including quantum information, mathematical fields, quantum fields, and condensed matter. He will join Perimeter in the fall of 2016, having previously held research positions at McGill University, the California Institute of Technology, Los Alamos National Laboratory, and Microsoft Research.

DISTINGUISHED VISITING RESEARCH CHAIRS

Perimeter's unique Distinguished Visiting Research Chairs (DVRC) program brings world-leading scientists to the Institute for extended research visits. DVRCs are appointed to renewable three-year terms, while retaining permanent positions at their home institutions.

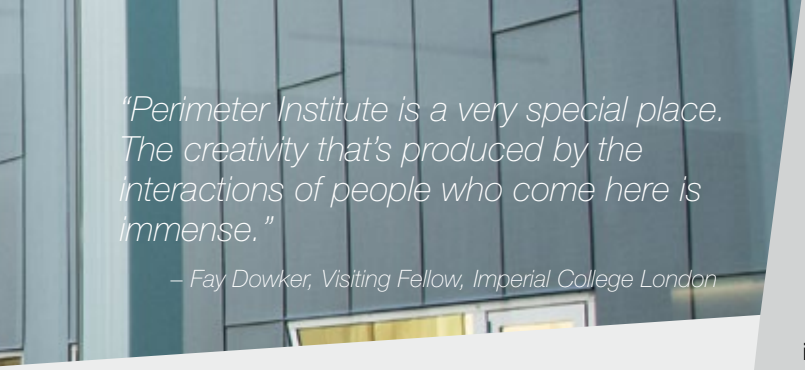
DVRCs contribute to life at the Institute in many ways – from conducting research, giving seminar talks, and collaborating with colleagues, to organizing conferences, teaching in the PSI master's program, and participating in outreach activities. For DVRCs, time spent at Perimeter is highly productive, since they are free from their usual teaching and administrative duties.

This year, Perimeter appointed five new DVRCs and renewed six more, bringing the total to 49 DVRCs spanning every branch of theoretical physics – including luminaries such as **Gabriela González**, **Renate Loll**, **Sandu Popescu**, and **Peter Shor**.

VISITING FELLOWS

The Visiting Fellows program brings highly promising researchers to the Institute for regular visits. Like DVRCs, Visiting Fellows are appointed to renewable terms, retain their positions at home institutions, and enrich Perimeter's research environment during extended research stays.

This year, Perimeter appointed seven new Visiting Fellows, bringing the total to 27 Visiting Fellows spanning a wide range of expertise.



"Perimeter Institute is a very special place. The creativity that's produced by the interactions of people who come here is immense."

– Fay Dowker, Visiting Fellow, Imperial College London

POSTDOCTORAL RESEARCHERS

Early-career scientists often bring fresh eyes to challenging problems and come up with creative new directions for how to solve them. That is precisely why Perimeter gives its postdoctoral researchers complete research freedom – and why the Institute is now one of the world's most competitive destinations for young physicists.

Perimeter is home to the world's largest community of independent theoretical physics postdocs. This year, 19 new postdocs joined Perimeter, with 19 more recruited for next year. As full members of the research community, postdocs invite collaborators, travel, give talks, and organize conferences and workshops. This training pays off: in an extremely competitive worldwide academic market, six departing postdoctoral researchers obtained tenure-track faculty positions in 2015/16.

"When it comes to Perimeter, the thing I appreciate the most is the openness of people to talk about your own ideas, and the fact there are so many great seminars and so many great people that come and visit. That helps a lot. That creates a very stimulating atmosphere."

– Perimeter postdoctoral researcher Michal Heller, who will set up his own research group at the Max Planck Institute for Gravitational Physics in 2017 after winning a €1.65 million Sofja Kovalevskaja Award from the Alexander von Humboldt Foundation

PREPARING FOR A QUANTUM FUTURE

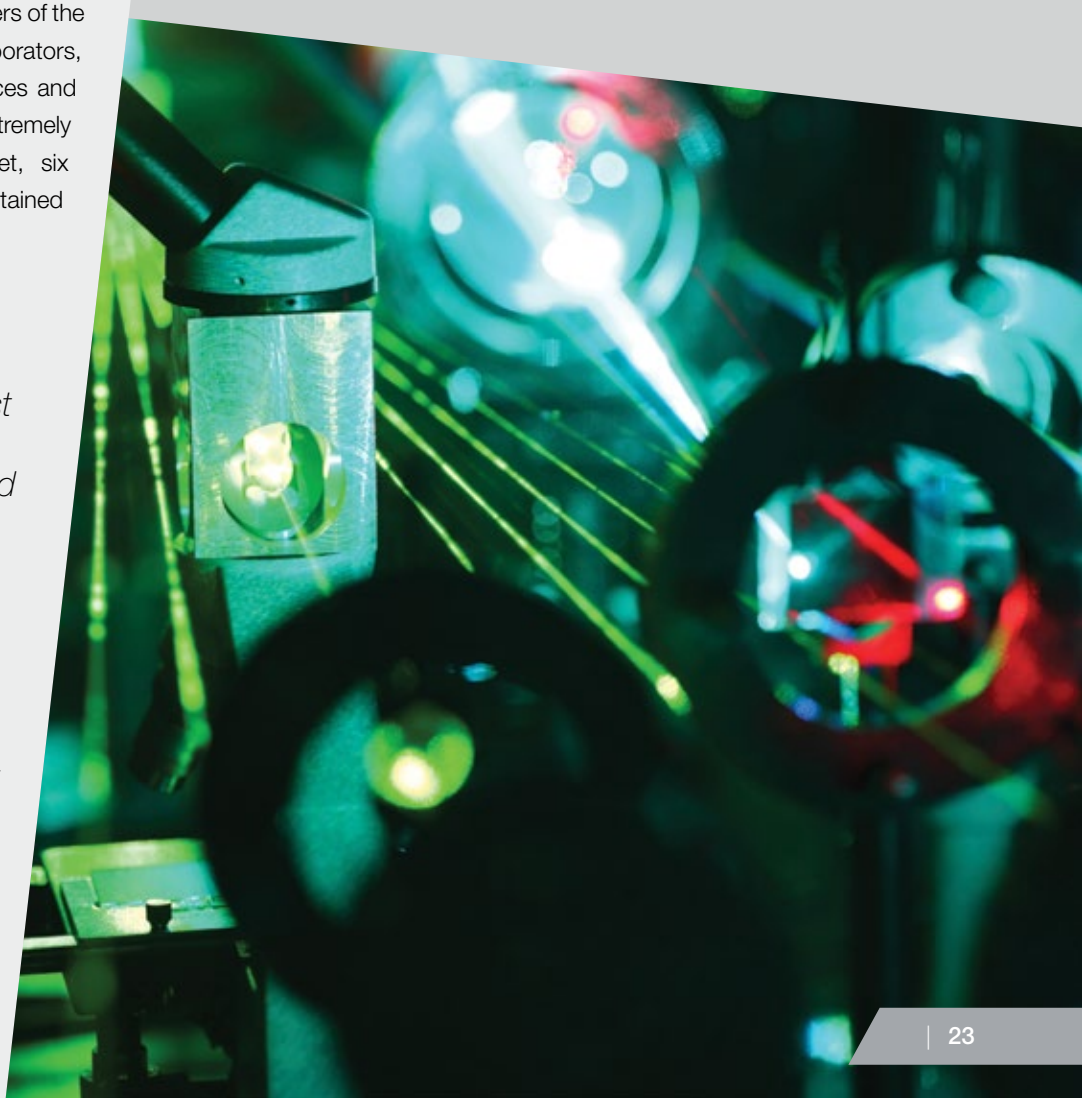
Gus Gutoski was a computer science undergraduate when he heard that, one day, a quantum computer could "break the Internet."

That glimpse into a future world, with the equally frightening and beautiful potential of a quantum computer, ultimately drew Gutoski into postdoctoral research in quantum information theory and cryptography at Perimeter Institute and the University of Waterloo.

Now, he's preparing organizations for that quantum future through his work at Isara Corp., a Waterloo start-up that is helping consumers, enterprises, and governments protect today's information with quantum-resistant cryptographic systems. "Our goal is to allow people to enjoy the benefits of quantum computers without being threatened by them," Gutoski says.

While a quantum computer that can break today's encryption might be decades away, Gutoski notes that transitioning cryptographic systems is a complex and lengthy proposition. Added to this, government agencies and financial institutions have information that they need to ensure will stay encrypted even 30 years from now.

It's a fascinating field, says Gutoski, with the added bonus that the future is full of interesting questions – and physics is useful for all of it.



RESEARCH TRAINING

PSI FACULTY, 2015/16

James Forrest (Director), Perimeter Institute and University of Waterloo

Tibra Ali, Perimeter Institute

Ganapathy Baskaran, Institute of Mathematical Sciences, Chennai

Cliff Burgess, Perimeter Institute and McMaster University

David Cory, Perimeter Institute and Institute for Quantum Computing (IQC)/ University of Waterloo

François David, Institute of Theoretical Physics/CEA-Saclay

Maite Dupuis, University of Waterloo

Joseph Emerson, IQC/University of Waterloo

Davide Gaiotto, Perimeter Institute

Ruth Gregory, Durham University

Alioscia Hamma, Tsinghua University

Lucien Hardy, Perimeter Institute

David Kubiznak, Perimeter Institute

Raymond Laflamme, Perimeter Institute and IQC/University of Waterloo

David Morrissey, TRIUMF

Kendrick Smith, Perimeter Institute

Oleg Tchernyshyov, Johns Hopkins University

Sean Tulin, York University

Neil Turok, Perimeter Institute

Guifre Vidal, Perimeter Institute

Pedro Vieira, Perimeter Institute

Dan Wohns, Perimeter Institute

PERIMETER SCHOLARS INTERNATIONAL

Brilliant young minds are the lifeblood of science, and a crucial part of Perimeter's dynamic community. Since the Institute created its one-year master's program, Perimeter Scholars International (PSI), in 2009, it has become one of the most sought-after master's programs in theoretical physics in the world. This year, over 500 applicants vied for 28 spots, and Perimeter's acceptance rate on offers made was better than Harvard or Stanford.

PSI's innovative curriculum features three-week modules taught by Perimeter faculty and other top international lecturers, with tutorial support from postdoctoral-level PSI Fellows and graduate teaching assistants. This year, the program also included a new addition: the PSI Winter School. This week-long retreat introduced students (many of whom are international) to the joys of a Canadian winter and to collaborative research, with at least two student groups obtaining publishable results.

PSI emphasizes continuous problem solving over rote learning and collaboration over competition. Students are exposed to the full spectrum of theoretical physics, while learning skills that will serve them well in both academia and industry – such as independent thinking, collaborative problem solving, and computer-based model development. Upon completion of the program, successful students receive a master's degree from the University of Waterloo and a PSI certificate.

In 2015/16, PSI trained 29 students, including nine women, from 18 countries. Eleven graduates have remained in Canada for their doctoral studies, five of them at Perimeter. Many others went on to top international institutions, including the University of Oxford, Princeton University, and Stanford University. Applications for 2016/17 rose 19 percent, and an outstanding incoming class has been selected, comprising 28 students from 20 countries, including seven women.

The PSI program was generously supported in 2015/16 by: Burgundy Asset Management; The Hellenic Heritage Foundation; The Ira Gluskin and Maxine Granovsky Gluskin Charitable Foundation; The Kitchener and Waterloo Community Foundation – The John A. Pollock Family Fund; Brad and Kathy Marsland; Margaret and Larry Marsland; The Savvas Chamberlain Family Foundation; Scotiabank; and The Scott Griffin Foundation.

PHD STUDENTS

Perimeter's PhD program continues to grow, bringing top students not only to Perimeter, but also to the Canadian partner universities where they ultimately receive their degrees. Students receive first-rate training in a world-class research environment, and go on to many fields of science, as well as government, technology, and finance.

Six PhD students supervised by Perimeter faculty graduated from partner universities in 2015/16, and at year's end, Perimeter had 49 PhD students in residence. Three additional PhD students were supervised by Perimeter associate faculty while in residence at partner universities.

During their time at Perimeter, PhD students receive unparallelled opportunities to interact with international scientific leaders and develop their careers in a supportive, collaborative environment, developing a unique and valuable skill set that includes advanced analytical, problem-solving, and quantitative skills.

In 2015/16, three PhD students were the recipients of the following awards: the Joanne Cuthbertson and Charlie Fischer Graduate Student Award; the Ira Gluskin and Maxine Granovsky Gluskin Charitable Foundation Honorary Scholarship Award (through the Emmy Noether Circle), and the Peter and Shelagh Godsoe Family Foundation Exceptional Emerging Talent Award.

VISITING GRADUATE FELLOWS

Perimeter's Visiting Graduate Fellows program allows advanced PhD students from around the world to spend several months at the Institute. These young researchers both benefit from – and contribute to – Perimeter's vibrant research community, while interacting with leading researchers in their field at a pivotal time in their training. Perimeter hosted 27 Visiting Graduate Fellows for a total of 31 visits in 2015/16.

UNDERGRADUATE RESEARCH

Perimeter's Undergraduate Student program exposes select undergraduate students to high-level research through two- to four-month projects with Perimeter postdoctoral researchers. The students gain insights into life as a physicist, while the postdoctoral researchers accrue valuable mentoring experience.

This year, Perimeter provided research training to seven exceptional undergraduate students from top institutions, including the Massachusetts Institute of Technology, University of British Columbia, Yale University, and the University of Naples Federico II. The program also acts as a means of attracting talent to the Institute; alumni of this program who are currently at Perimeter include postdoctoral researcher Matteo Smerlak and PhD students Dalimil Mazac, Sebastian Mizera, and Nitica Sakharwade.

"Each year, we have representation from approximately 20 countries. The students arrive with different social and educational backgrounds, each with their unique set of strengths. What they have in common, however, is their extraordinary self-motivation and dedication. I'm always surprised by how sophisticated their questions are, and find it very humbling to be their teacher."

– Agata Branczyk, PSI Fellow

RESEARCH EVENTS

BY THE NUMBERS

In **2015/16**, Perimeter ...

Held **17** conferences and workshops, attended by **935** scientists from around the world

Presented **322** scientific talks (**294** seminars and **28** colloquia)

Partnered on **eight** joint workshops and conferences held at Perimeter, and sponsored an additional **16** off-site workshops and conferences (15 in Canada)

Delivered **four** courses to researchers and students from surrounding universities

CONFERENCES AND WORKSHOPS

For ideas to flourish, they must be shared. Each year, Perimeter's research events bring together hundreds of people to explore topics selected for potentially significant outcomes.

The Institute's flexibility allows it to rapidly identify and capitalize on promising new areas. The resulting gatherings usually bridge fields, and often connect theory and experiment, research and industry. Thanks to this dynamic exchange of timely ideas, Perimeter's conference program has become internationally renowned. In 2015/16, 935 scientists from around the world attended Perimeter conferences and workshops, demonstrating the Institute's role as a major node of exchange for cutting-edge theoretical physics.

SEMINARS AND COLLOQUIA

There is perhaps no better way to share – and challenge – ideas than through vibrant, robust discussion. Seminars and colloquia given by resident and visiting scientists are an essential element of the Institute's intellectual life, sharing cutting-edge discovery and fostering collaboration across fields.

Participants at "Cosmological Frontiers in Fundamental Physics" conference

In the past year, Perimeter hosted 322 scientific talks (294 seminars and 28 colloquia). Talks were given by a number of luminaries in all of the Institute's areas of research focus, including Distinguished Visiting Research Chairs **Nima Arkani-Hamed**, **Iakov Soibelman**, **Zhenghan Wang**, and **Alexander Zamolodchikov**.

ONLINE VIDEO ARCHIVE

Almost all scientific talks at Perimeter are recorded and can be viewed for free in the Video Library section of Perimeter's website or through the Perimeter Institute Recorded Seminar Archive (PIRSA) at pirsa.org. This searchable and citeable archive of over 10,000 seminars, conferences, workshops, and courses was developed by the Institute to share knowledge with the international scientific community, and has become the leading online institutional video archive in theoretical physics.

During 2015/16, Perimeter's video archive was accessed by 108,401 unique visitors from more than 170 countries, accounting for 776,692 page views.

IT FROM QUBIT

The new perspectives gained from quantum information are producing important insights in other areas of physics, including quantum gravity and condensed matter.

The momentum of the field prompted Perimeter Faculty Chair **Robert Myers** to organize the first major **"It from Qubit" conference**, held at Perimeter in July as part of the It from Qubit Simons collaboration.

The conference and summer school met a tsunami of interest from researchers and students around the world. Together, over 180 attendees – plus remote participants who streamed sessions at five satellite locations around the world – explored the emerging ties between quantum information and high energy physics, and set their sights on big issues: Does spacetime emerge from entanglement? How can quantum mechanics and gravity be unified? Can the new applications for quantum information uncover something fundamental about information itself?

The flood of young researchers interested in the field was inspiring to Vijay Balasubramanian, a particle physicist from the University of Pennsylvania. "These are the people who are going to make the progress for tomorrow," he said. "I've been talking with a lot of the students, and they're completely fired up. They like this interface. It from Qubit strikes a note that students find inspiring."

LINKAGES

Despite the stereotype of the lone genius, science is rarely done in isolation. The most striking examples of this can be seen today in the vast, international teams combining their efforts to unlock the mysteries of the physical world – like discovering the Higgs boson, detecting gravitational waves, or imaging the event horizon of a black hole for the first time.

Perimeter Institute aims to facilitate the collaborative process of science – both in-house, through the Institute's lively visitor and affiliates programs, and on national and international scales through productive institutional partnerships and global outreach.

By strengthening bonds within the scientific community, Perimeter Institute is precipitating the breakthroughs of the future.

VISITOR PROGRAM

A buzz of animated scientific discussions often fills Perimeter's halls, in large part due to the Institute's active visitor program, which brings leading scientists from around the world to deliver talks, attend conferences, and collaborate with resident scientists. Residents benefit from exchanging ideas with visiting scientists, while visitors have the time and space to focus on research, exchange ideas, and initiate new collaborations. The visitor program also facilitates recruitment by showcasing Perimeter's unique and vibrant research environment.

In 2015/16, Perimeter hosted 430 visiting scientists for a total of 485 visits, including 25 Distinguished Visiting Research Chairs and 12 Visiting Fellows. The rest were short-term visitors, including affiliates, collaborators, seminar and colloquia speakers, and potential recruits. In the past year, visits to Perimeter ultimately led to new appointments at all levels – including Associate Faculty member **Jon Yard** and Director's Fellow **William East**.

AFFILIATES

Perimeter's Affiliate program brings select researchers from universities and research institutes across Canada to Perimeter for regular informal visits. The program enriches both Perimeter and the national physics community: affiliates gain access to a rich and diverse community of researchers, allowing them to explore novel ideas, while Perimeter deepens its connections to more than 25 of Canada's top research centres. In 2015/16, Perimeter appointed seven new Affiliates and renewed three more through 2018, bringing the total number of Affiliates to 118. (Refer to page 66 for a complete list.)

COLLABORATIONS AND PARTNERSHIPS

By partnering with leading centres in Canada and abroad, Perimeter provides collaboration opportunities for its scientists while strengthening its position as a global research hub.

In 2015/16, Perimeter strengthened ongoing institutional partnerships, including those with TRIUMF and SNOLAB. Perimeter also enjoys many productive informal partnerships through its faculty, including at international institutions like the Thomas Jefferson National Accelerator Facility (Jefferson Lab), Canadian Hydrogen Intensity Mapping Experiment (CHIME), Event Horizon Telescope (EHT), Square Kilometre Array (SKA), and the Large Hadron Collider at CERN.

FIELDS-PERIMETER INSTITUTE AFRICA POSTDOCTORAL FELLOWSHIP

Perimeter and the Fields Institute for Research in Mathematical Sciences at the University of Toronto have partnered to fund four one-year joint postdoctoral fellowships for African nationals who have recently completed their PhDs. Mathematician **H. Praise Adeyemo** of Nigeria, whose research focuses on algebraic geometry and topology, was recently selected as the fourth fellow, to be based at the Fields Institute for 2016/17.

THE WATERLOO GLOBAL SCIENCE INITIATIVE

The Waterloo Global Science Initiative (WGSI) is an independently funded, non-profit partnership between Perimeter Institute and the University of Waterloo. WGSI's mandate is to promote dialogue and develop solutions to complex global issues that will pave the way for a secure and sustainable future.

In April 2016, Perimeter hosted the third WGSI Summit, OpenAccess Energy. At the Summit, participants from 24 countries

and five First Nations communities strategized ways to increase access to sustainable energy in energy-impoverished regions. Public programming and taping of three episodes of TVO's *The Agenda* complemented the main Summit. A follow-up Blueprint document is planned for early 2017, detailing recommendations and implementation ideas arising from the Summit.

GLOBAL OUTREACH

Perimeter Institute aims to catalyze the growth of emerging scientific centres of excellence around the world by providing expertise and guidance, acting a resource as they cultivate their own successes.

In 2015/16, Perimeter continued to provide expertise in support of the African Institute for Mathematical Sciences – Next Einstein Initiative (AIMS-NEI), a project founded by Perimeter Director **Neil Turok** in 2003 to establish a pan-African network of centres providing mathematical and scientific education to exceptional African graduates. Perimeter lent its administrative expertise to help prepare for the launch of the sixth AIMS centre in Rwanda and supported the inaugural Next Einstein Forum, held in Senegal in March 2016. Perimeter researchers also continue to be involved in teaching at AIMS centres.

Perimeter further expanded the scope of its Global Outreach efforts to South America with a new partnership agreement with the International Centre for Theoretical Physics – South American Institute for Fundamental Research (ICTP-SAIFR), located at the São Paulo State University (UNESP) in Brazil. See the sidebar for more details.

SCIENCE OF THE WORLD, FOR THE WORLD

Scientific discovery is a global quest. By pursuing international partnerships with centres of excellence around the world, Perimeter supports – and gains insights from – new voices in physics and mathematics. The UNESP-SAIFR-PERIMETER partnership, forged in 2015 between Perimeter and the South American Institute for Fundamental Research (SAIFR) in Brazil, aims to do just that.

The agreement will encourage research exchanges and joint scientific conferences, shared schools and workshops for emerging South American scientists, and educational programs for middle and secondary schools across South America. Events for the broader public will share the power and wonder of science.

Perimeter Faculty member and **Clay Riddell Paul Dirac Chair Pedro Vieira** is a prime mover in the partnership, who will divide his time between Perimeter and SAIFR in order to maximize the abundant possibilities he sees for fundamental science in South America.

According to Vieira, "It's a truly symbiotic partnership, with great possibilities. SAIFR is shaping up to be the top place for advanced physics in the southern hemisphere, and it's growing exponentially. This year, the partnership really took off. For example, we held 'Journeys for Theoretical Physics,' a joint school held in São Paolo that involved myself and [fellow Perimeter Faculty member] Freddy Cachazo as lecturers. It was a big success – we have some students coming to Perimeter for graduate studies as a result."

EDUCATIONAL OUTREACH AND PUBLIC ENGAGEMENT

"What we're after are new ideas, creativity, originality – and you don't get that by standardizing ideas or by rote learning. You get that by encouraging people to think."

– Neil Turok, Director, Perimeter Institute

Theoretical physics probes the most fundamental questions in the universe: What is it made of? How did it begin? How will it end? These questions provoke awe and pique curiosity in people of all ages, cultures, and walks of life. Fundamental physics also drives innovation, and the knowledge, discoveries, and technologies that spring forth ultimately belong to all of us.

That is why educational outreach and public engagement are built into Perimeter's mission. By sharing the wonder and mystery of the universe, and the importance of scientific breakthroughs, Perimeter aims to inspire the next generation of transformative thinkers.

Perimeter's comprehensive educational resources have driven more than 20 million student interactions to date, with each individual student often encountering Perimeter's programming multiple times throughout their middle and high school education. This year, Perimeter continued to bring physics to life for larger audiences than ever before, with an array of outreach initiatives including the award-winning monthly "Slice of PI" dispatches, the Public Lecture Series, programs for teachers and students, and upcoming exhibits and festivals tied to Innovation150, part of Canada's 150th celebrations.

BY THE NUMBERS

Facilitated more than **9.5 million** student interactions through in-class resources and programs

Delivered **135** workshops to over **4,000** educators across Canada and abroad

Gave **15** Physica Phantastica presentations to over **4,200** Canadian students

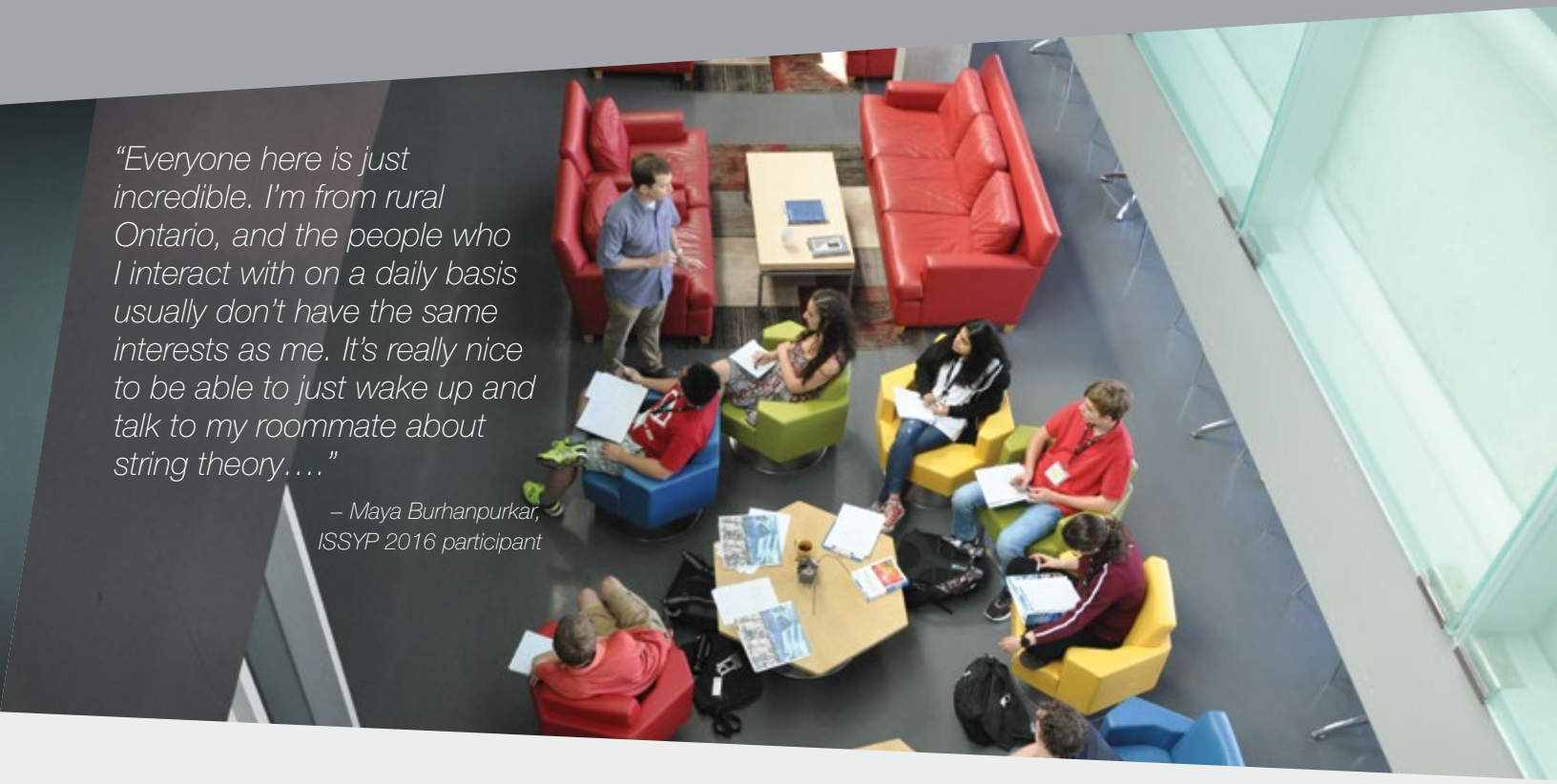
Produced **four** new educational resources for students in grades 5 to 8

Attracted over **1.3 million** YouTube video views

THE INTERNATIONAL SUMMER SCHOOL FOR YOUNG PHYSICISTS (ISSYP)

With talks from high-profile physicists, field trips to experimental facilities, and a whole lot of bonding with like-minded students, ISSYP is the kind of summer camp a young Einstein might have enjoyed.

Each year, the program brings 40 talented youth to Perimeter for two weeks of intensive instruction in theoretical physics. The crash course includes lectures and mentoring sessions with Perimeter faculty and researchers, as well as visits to SNOLAB (a neutrino laboratory located deep in a Sudbury mine) and the Institute for Quantum Computing (IQC) at the University of Waterloo. It all culminates in a poster session where the students share their discoveries with the PI community.



The impact is significant: more than 70 percent of ISSYP alumni say the program inspired them to pursue a career in physics or math.

This year, Perimeter hosted the 14th edition of ISSYP, with 20 Canadians from seven provinces and 19 international students from 14 countries, evenly split between females and males.

The 2015/16 edition of ISSYP was made possible by the continued generous support of the RBC Foundation, ISSYP's Presenting Partner. Additional support was received from Maplesoft, Deloitte, and the Van der Veen family.

PHYSICA PHANTASTICA

What are gravitational waves, and why was their detection so momentous? How can we study parts of the universe that don't emit light?

Physica Phantastica presentations provide entertaining and accessible introductions to these topics and many others in modern physics. This year, Perimeter delivered 15 Physica Phantastica presentations to more than 4,200 students across Ontario. These large-scale presentations are delivered to audiences of 50 to 200, and are designed to share the wonder, mystery, and joy of science with students, teachers, and the general public.

EINSTEINPLUS

At EinsteinPlus, teachers from across Canada and around the globe connect with Perimeter's Educational Outreach team to find creative ways of igniting a passion for physics among their students. The one-week summer workshop introduces educators to Perimeter's educational resources and presents effective, engaging methods for teaching key concepts in modern physics.

In 2016, Perimeter hosted 40 teachers: 20 Canadians from seven provinces and 20 international teachers from 10 countries. Surveys show that teacher participants value EinsteinPlus as an outstanding professional development opportunity.

Support for EinsteinPlus was provided by Maplesoft.

"My time at Perimeter Institute was insightful and inspirational. What I've learned about physics will improve my classroom content; what I've learned about learning will revolutionize it."

– Jeremy Wegner, EinsteinPlus 2016 participant

INSPIRING FUTURE WOMEN IN SCIENCE

When it comes to a career in STEM, there's a world of nuanced options beyond the basic "biology, chemistry, or physics."

That was part of the takeaway message from this year's edition of the "Inspiring Future Women in Science" conference, which brought more than 200 young women in high school to Perimeter to connect with successful women in STEM at various stages of their careers. As part of Perimeter's Emmy Noether initiatives, which seek to attract and retain more women in physics, the day-long conference featured keynote talks, a Q&A panel, and mentoring – plus a surprise address from Prime Minister Justin Trudeau.

"I believe we all have the right stuff. It's just a matter of tapping into some foundations for success and pursuing your dreams."

– Natalie Panek, rocket scientist, advocate for women in tech, and featured speaker at "Inspiring Future Women in Science"

TEACHER NETWORK AND WORKSHOPS

Perimeter's Teacher Network is a peer-to-peer network of highly motivated educators who are trained to share Perimeter's educational resources and physics engagement strategies with other teachers in their regions.

This year, network educators and Perimeter staff delivered 135 workshops to more than 4,000 other teachers in Canada and abroad. Seven Teacher Network camps (in Durham, Ottawa, Thunder Bay, Waterloo, Saskatoon, Winnipeg, and Vancouver) trained 667 teachers.

Perimeter also partners with Actua, one of Canada's leading science, technology, engineering, and mathematics (STEM) outreach organizations for youth, particularly among Aboriginal Canadians. This year, Perimeter staff trained Actua associates from across the country on the Institute's educational resources. In turn, they delivered the content to Aboriginal students over the summer.

IN-CLASS AND ONLINE RESOURCES

Perimeter's comprehensive educational resources – developed and tested by Perimeter researchers and experienced teachers – are the Institute's primary means of introducing students to the excitement and wonder of modern physics. The modules, which are now entirely available online, have been deployed in more than 60 countries worldwide. Educators report that they use and re-use resources in classrooms multiple times, amplifying their impact over time.

This year, Perimeter released *Contemporary Physics*, a new module exploring cutting-edge topics such as gravitational waves, neutrino physics, and black holes. In partnership with Ontario's Ministry of Education, the Institute also created a new suite of four comprehensive resources on science, technology, and math for students in grades 5 to 8, set for release in late 2016.

It Does Matter (Grade 5 level) examines physical and chemical changes and encourages students to assess the impacts of industrial production on society and the environment. *Mission Possible* challenges Grade 6 students to research technologies and survival strategies while creating a mission plan to go to the moon or Mars. *Temperature Rising* (Grade 7) investigates climate change and heat processes, while *Automated for the Future* introduces Grade 8 students to coding and automated systems.

"I like that the resources are all gathered in one place, into units that are structured and put together by people who are educators. They have assessment built in, they have feedback built in, and they have a logical progression, all of which is really helpful."

– Greg Ryerson, Grade 7 and 8 Science teacher, Toronto

PUBLIC LECTURE SERIES

With compelling talks on everything from dark matter and atomic clocks to climate change and nuclear medicine, Perimeter's Public Lecture Series continues to be one of the Institute's most popular programs.

This year, Perimeter presented eight engaging talks to full-house crowds in the Mike Lazaridis Theatre of Ideas and to online audiences across the globe. Highlights of the 2015/16 season included Nobel Laureate Art McDonald explaining how the Sudbury Neutrino Observatory solved a cosmic neutrino mystery, Victoria Kaspi describing the cosmic gift of neutron stars, and Neil Turok discussing "The Astonishing Simplicity of Everything."

All lectures are professionally recorded, webcast live, and available for on-demand playback through Perimeter's website, YouTube, and Perimeter's media partners – including *Maclean's*, *CBC*, *Scientific American*, *The Guardian*, and *Motherboard*. Online audiences can participate in real-time by asking questions and receiving answers from Perimeter outreach staff and researchers via Twitter. The 2015/16 public lecture season has amassed over 320,000 online views.

CULTURAL EVENTS

Creativity, inquiry, experiment, and contemplation – science and art are perhaps more alike than not. Cultural events at Perimeter Institute, such as the Classical World Artists Series, are a welcome artistic complement to research activities, and serve to broaden the Institute's connections to the community. This year, top-calibre artists such as the Tallis Scholars, David Finckel and Wu Han, the Takács Quartet, and Elina Vähälä delivered captivating performances in the Mike Lazaridis Theatre of Ideas and Perimeter atrium.

The Classical World Artists Series at Perimeter is generously supported by The Kitchener and Waterloo Community Foundation – Musagetes Fund.

INNOVATION150

With its track record of producing successful large-scale science festivals, Perimeter was honoured to be chosen by the Department of Canadian Heritage to lead Innovation150, a signature initiative of Canada's sesquicentennial celebrations. Throughout the year, Perimeter worked with four other leading Canadian outreach partners – Actua, the Institute for Quantum Computing, the Canadian Association of Science Centres, and the Canada Science and Technology Museums Corporation – to develop experiences that will celebrate Canadian ingenuity and inspire the next generation of pioneering thinkers.

At the forefront of the Innovation150 celebrations is the Power of Ideas National Tour, featuring an immersive, hands-on exhibit and an engaging live presentation. An estimated 100,000 young people will experience the tour as it travels to 60 communities in all 13 provinces and territories, greatly expanding Perimeter's reach in remote and Aboriginal communities.

Six Innovation Festivals are also planned in cities across the country, while Quantum: The Exhibition – produced by IQC – will share the wonders of emerging quantum technologies. Finally, a digital hub will give all Canadians a chance to engage, share ideas, explore innovation stories, and participate in exciting contests. Live and

online activity will be reinforced by a national promotions campaign and public service announcements.

In addition to major funding from the Government of Canada, private support for Innovation150 is being provided by Shaw, the Cowan Foundation, the Toyota Canada Foundation, and Superior Lodging.

DIGITAL AND SOCIAL MEDIA OUTREACH

Perimeter aims to be the leading source of accurate, fascinating, and shareable physics content online. Through its website, social media channels, and many partnerships, Perimeter shares news and big ideas from the forefront of science. This year, Perimeter's popular "Slice of PI" series, a monthly dispatch of fun and highly shareable science tidbits, was awarded the Science in Society Communications Award by the Canadian Science Writers' Association. Tens of thousands of people – including William Shatner and Queen guitarist Brian May – shared Slices including "The Ultimate Science Playlist," "Gravitational Waves 101," and "Thank you, *Star Trek*."

Social media engagement continued to grow this year: Perimeter's Facebook page increased its fan base by 58 percent, while Twitter follows jumped by 40 percent. YouTube subscriptions increased by over 160 percent, and Perimeter's videos were viewed over 1.3 million times – more than all previous years combined.

In 2016, Perimeter began development of a new digital publishing platform, insidetheperimeter.ca, to make science content even more accessible, engaging, and shareable.

MEDIA COVERAGE

Major media look to Perimeter as a reliable source of high-quality news, content, commentary, and insight related to theoretical physics. This year, Perimeter research, people, and activities received major coverage in national and international media, including in-depth articles in outlets including *Scientific American*, *The Globe and Mail*, *Wired*, *The Guardian*, *The Economist*, *The Washington Post*, *Maclean's*, and many more.

ADVANCING PERIMETER'S MISSION

"I support PI financially because it is one of the world's leading research institutes seeking to determine the nature of reality and uncover the deepest secrets of the universe. Its physicists are among the finest assembled anywhere. I can think of no other scientific or intellectual endeavour more worthy of my support."

– George Meierhofer, New York, NY

"Fundamental research in physics has the most promise in elevating human knowledge, and Perimeter Institute has a governance model that is efficient at translating resources to research and mentoring."

– Mike Cannell and Judy DesBrisay, British Columbia

Perimeter Institute is a collaborative entity, in every sense. As a non-profit research institute and registered charity, our research success is directly fuelled by the visionary support of our public and private partners.

Sustained support from the public sector has been critical to the Institute's success to date. This year, the Province of Ontario and Government of Canada each pledged additional $50 million investments over five years, beginning in 2017/18. In the months that followed, the Institute welcomed both Prime Minister Justin Trudeau and Premier Kathleen Wynne to celebrate the renewed investments, and the strong vision for the future that they represent.

Likewise, private partners are crucial to the Institute's ability to realize its ambitious goals. The Institute's Advancement efforts focus on individuals, corporations, and foundations whose missions align with Perimeter's – whether they share the Institute's spirit of innovation and discovery, its commitment to science education, its belief in the transformative power of physics, or its conviction that Canada can be a world-leader in fundamental research.

These invaluable partnerships recognize and strengthen the Institute's position as a leader in the global scientific community at a pivotal time in foundational physics, when great discoveries beckon.

PERIMETER INSTITUTE LEADERSHIP COUNCIL

The Leadership Council is comprised of prominent individuals who act as ambassadors for Perimeter in the business and philanthropic communities, helping the Institute grow strategically and internationally.

Joanne Cuthbertson, Co-Chair
Member, Board of Directors,
Perimeter Institute

Patrice Merrin, Co-Chair
Director, Glencore PLC, Stillwater Mining Company, and Novadaq Technologies Inc.
Co-Chair, Emmy Noether Council,
Perimeter Institute

Mike Lazaridis, Founding Co-Chair
Managing Partner and Co-Founder,
Quantum Valley Investments
Chair, Board of Directors,
Perimeter Institute

Cosimo Fiorenza, Founding Co-Chair
Vice-President and General Counsel,
Quantum Valley Investments
Vice Chair, Board of Directors,
Perimeter Institute

Alexandra Brown
Co-Founder and CEO, Aprilage Inc.

Donald Campbell
Senior Strategy Advisor, DLA Piper

Savvas Chamberlain
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Harbir Chhina
Executive Vice President, Oil Sands,
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Jim Cooper
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Catherine Delaney
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Arlene Dickinson*
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Principal, Emerson Advisory

Edward Goldenberg
Partner, Bennett Jones LLP

Tom Jenkins
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Farsad Kiani*
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Carol Lee
CEO and Co-Founder, Linacare Cosmetherapy Inc.

Brad Marsland
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Gerry Remers*
President and COO, Christie Digital Systems Canada Inc.

Maureen Sabia
Chairman of the Board, Canadian Tire Corporation Ltd.

Jennifer Scully-Lerner
Vice President, Goldman Sachs

Kevin Shea
Chair, ChezShea Communications

Alfredo Tan
Group Director, Global Marketing Solutions, Facebook (Canada)

Harry Zarek
President and CEO, Compugen Inc.

** Term ended in 2016*

PAUL STEINHARDT: LIVING THE SCIENTIFIC ADVENTURE

When Paul Steinhardt was a child, his father told him amazing tales of daring heroes and courageous heroines. Some were fairy tales, but the best were stories of science. "It made me want to be one of those discoverers," he says.

Today, Steinhardt is a cosmologist with a singular impact on physics. One of the original architects of the inflationary model of cosmology, Steinhardt has since become one of its leading critics.

In 2002, he and Perimeter Director Neil Turok proposed an alternative: the "cyclic model" of the universe, in which the big bang might instead be a big bounce, in which the current epoch of accelerated expansion will eventually slow, halt, and reverse, leading to another bounce.

Steinhardt also introduced the idea of quasicrystals and, after 13 years of searching, found them in nature. The quest took him from a search of the world's mineral collections to the remote Kamchatka Peninsula in eastern Russia. There, in 2011, the team found a naturally occurring quasicrystal embedded in a 4.5-billion-year-old meteorite – making it older than the Earth itself.

It's a track record that exemplifies Steinhardt's approach: be bold, be curious, and respect the data. "New discoveries can be found everywhere. You just have to know the right question to ask," he says.

Paul Steinhardt holds the Daniel Family Richard P. Feynman Chair in Theoretical Physics at Perimeter Institute (Visiting), which was created in 2015 with support from the Daniel Family Foundation. Steinhardt is also the Albert Einstein Professor in Science at Princeton University.

BLAZING NEW PATHS

TIME, SPACE, AND RANDOM INTERACTIONS

My time at Perimeter was so useful. Being away from my home university, with all the committee work and exams and so on, meant I could devote a lot of time to research.

My field of expertise is statistical physics and complex systems. Basically, this deals with the question of how the many parts of a system and their interactions give rise to the system's overall behaviour.

While I was at Perimeter, I did research on the relation between statistical mechanics and quantum mechanics. Statistical mechanics describes things that change irreversibly and non-deterministically, like a gas of atoms approaching equilibrium, while quantum mechanics is deterministic and time-reversible. Different people try to resolve this contradiction differently. I pursue the idea that nature is intrinsically non-deterministic and irreversible, which means that standard quantum mechanics has limits of validity. In my view, these limits can be found by considering many-particle systems at finite temperature.

I had many discussions with very smart and interesting people, which helped a lot in developing my ideas. I also learned a lot from attending talks and conferences. Perimeter is special because it encourages diverse ideas and creative thinking to make progress on the unsolved fundamental questions in physics. It brings together many smart and interesting people and creates a lot of space and time for discussions. I am grateful to have had this opportunity.

– Barbara Drossel, Professor at the Institute of Solid State Physics at the Technical University of Darmstadt and 2016 Emmy Noether Visiting Fellow

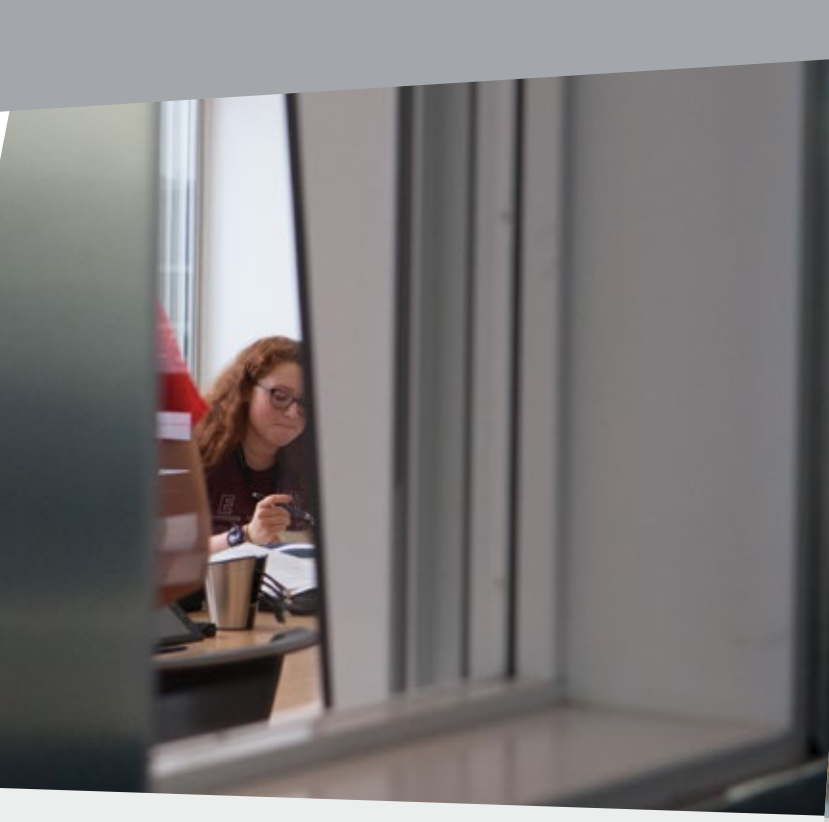
EMMY NOETHER INITIATIVES

Emmy Noether was a trailblazer who refused to accept that women should not join the pursuit of knowledge.

Noether's foundational work in abstract algebra created a breakthrough theorem that connects conservation laws with symmetries in nature. Noether's theorem continues to be used in every branch of physics, from quantum field theory to the understanding of black holes and the prediction of new particles. Yet she did most of her work unpaid or underpaid, and was largely unrecognized beyond her sphere of colleagues and peers.

This remarkable woman is a fitting namesake to Perimeter's Emmy Noether Initiatives, which aim to ensure women scientists are offered the equal opportunity denied to Noether herself. Backed by a committed group of funders and champions of women in science called the Emmy Noether Circle, these efforts support women at all stages of their careers, from high school students through to Perimeter faculty.

Noether was a genius who refused to sit on the sidelines. Her resolve continues to inspire us today.



THE EMMY NOETHER COUNCIL

Council volunteers provide expertise, donations, and other support, helping the Emmy Noether Circle bring more women into physics at Perimeter.

Patrice Merrin, Co-Chair
Director, Glencore PLC, Stillwater Mining Company, and Novadaq Technologies Inc.
Co-Chair, Leadership Council, Perimeter Institute

Jennifer Scully-Lerner, Co-Chair
Vice President, Goldman Sachs
Leadership Council Member, Perimeter Institute

Nyla Ahmad
Senior Vice President, Enterprise Marketing,
Rogers Communications Inc.

Katherine Barr
General Partner, Mohr Davidow Ventures

Michelle Osry
Partner, Deloitte Canada (Vancouver)

Vicki Saunders
Founder, SheEO

Sherry Shannon-Vanstone
President and CEO, Trustpoint Innovation Technologies Ltd.

Suzan Snaggs-Wilson
District Vice President, Scotiabank (West New Brunswick)

CELEBRATING PERIMETER'S NEWEST CHAIR

"If you don't look, you don't know."

– Asimina Arvanitaki,
Stavros Niarchos Foundation Aristarchus Chair

"As someone who comes from a small village in Greece, this is something I never dreamed of," said particle physicist **Asimina Arvanitaki** at the ceremony celebrating her appointment as the Stavros Niarchos Foundation Aristarchus Chair in Theoretical Physics.

Arvanitaki is Perimeter's ninth Perimeter Research Chair. A $4 million donation from the Stavros Niarchos Foundation, matched by Perimeter, will support her pioneering work, which explores and develops new tests of theories beyond the Standard Model of particle physics. The funds associated with the Chair will also be used to foster research and training ties between Perimeter and Greece.

For Andreas Dracopoulos, Co-President and Director of the Stavros Niarchos Foundation, Arvanitaki's appointment does more than support fundamental discovery. It also serves as a beacon for Greek science students.

"Science owes so much to the art of imagination," said Dracopoulos. "As Arvanitaki said in a recent interview, 'If you don't look, you don't know.' To all of you at the Perimeter Institute, keep imagining, keep looking, for the good of humankind."

THANKS TO OUR SUPPORTERS

ENDOWMENT FUND

FOUNDER ($150M+)
Mike Lazaridis

$25M+
Doug Fregin

$10M+
Jim Balsillie

GOVERNMENT PARTNERS

Government of Canada
Government of Ontario
Region of Waterloo
City of Waterloo

ENDOWED INITIATIVES

BMO Financial Group Isaac Newton Chair in Theoretical Physics ($4 million)
Stavros Niarchos Foundation Aristarchus Chair in Theoretical Physics ($4 million)
The Peter and Shelagh Godsoe Family Foundation Award for Exceptional Emerging Talent ($500,000)

PERIMETER MAJOR GIFTS

Mike and Ophelia Lazaridis Niels Bohr Chair in Theoretical Physics ($4 million)
Gluskin Sheff Freeman Dyson Chair in Theoretical Physics ($2 million)
John Templeton Foundation – Templeton Frontiers Program at Perimeter Institute ($2 million)
Krembil Galileo Galilei Chair in Theoretical Physics ($2 million)
Krembil William Rowan Hamilton Chair in Theoretical Physics ($2 million)
Clay Riddell Paul Dirac Chair in Theoretical Physics ($1 million)
Cenovus Energy James Clerk Maxwell Chair (Visiting) in Theoretical Physics ($300,000)
Daniel Family Richard P. Feynman Chair (Visiting) in Theoretical Physics ($300,000)

CORPORATE AND SPONSORSHIP PARTNERS ($100,000+)

Maplesoft, Perimeter Educational Outreach Champion
RBC Financial Group, Presenting Partner, International Summer School for Young Physicists

AWARDS ($50,000+)

The Savvas Chamberlain Family Foundation Anaximandros Fellowship
The Joanne Cuthbertson and Charlie Fischer Graduate Student Award
The Scott Griffin Foundation Honorary PSI Scholarship Award
The Hellenic Heritage Foundation Anaximandros Fellowship
The Brad and Kathy Marsland Honorary PSI Scholarship Award
The Margaret and Larry Marsland Honorary PSI Scholarship Award

ACCELERATORS CIRCLE ($50,000+)

Corinne Squire and Neil Turok

An ever-growing group of both public and private donors has helped make Perimeter what it is today: a world-leading centre for fundamental research, scientific training, and educational outreach. We are deeply grateful to all our supporters.

DIRECTORS CIRCLE

$25,000+

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$10,000+

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The Bluma Appel Community Trust

EMMY NOETHER PROGRAMS AND AWARDS ($250,000+)

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Carolyn Crowe Ibele, in memory of Dr. Richard A. Crowe

Simon Haysom, in memory of Elsie Haysom

IN-KIND GIFTS

Steinway Piano Gallery Toronto

This list reflects gifts received between August 1, 2015 and July 31, 2016, and multi-year commitments of $50,000 and more.

GOVERNANCE

Perimeter Institute is an independent, not-for-profit corporation governed by a volunteer Board of Directors drawn from the private sector and academic community. The Board is the final authority on all matters related to the general structure and development of the Institute.

Financial planning, accountability, and investment strategy are carried out by the Board's Investment and Finance and Audit Committees. The Board also forms other committees as required to assist it in performing its duties. Reporting to the Board of Directors, the Institute's Director is a pre-eminent scientist responsible for developing and implementing the overall strategic direction of the Institute. The Managing Director and Chief Operating Officer reports to the Director and is in charge of the Institute's operations. Support is provided by a team of administrative staff.

The Institute's resident scientists play an active role in scientific operational issues via participation on various committees in charge of scientific programs. Committee chairs report to the Director.

The Scientific Advisory Committee (SAC), comprised of eminent international scientists, offers independent scrutiny and advice, helping to ensure objectivity and a high standard of excellence in all of Perimeter's activities.

BOARD OF DIRECTORS

Mike Lazaridis, O.C., O.Ont., Chair, is Managing Partner and Co-Founder of Quantum Valley Investments (QVI), which he and Doug Fregin established in Waterloo. In 2013, they launched QVI with $100 million to provide financial and intellectual capital for the development and commercialization of quantum physics and quantum computing breakthroughs. QVI aims to help transform ideas and early-stage breakthroughs into commercially viable products, technologies, and services. It is Mr. Lazaridis' latest venture in more than a decade's work aimed at creating a Quantum Valley in Waterloo by bringing the world's best minds in physics, engineering, mathematics, computer science, and materials science together to collaborate on cutting-edge quantum research.

In 1984, Mr. Lazaridis co-founded BlackBerry (formerly Research In Motion) with Mr. Fregin. They invented the BlackBerry device, created the smartphone industry, and built Canada's largest global tech business. Mr. Lazaridis served in various positions including Co-Chairman and Co-CEO (1984-2012) and Board Vice-Chair and Chair of the Innovation Committee (2012-13).

Mr. Lazaridis is the Founder and Board Chair of Perimeter Institute, where he helps generate important private and public sector funding for the Institute. He also founded the Institute for Quantum Computing (IQC) and the Quantum-Nano Centre, both at the University of Waterloo. He has donated more than $170 million to Perimeter and more than $100 million to IQC.

Among his many honours, Mr. Lazaridis is a Fellow of the Royal Society of London and the Royal Society of Canada, and he has been named to both the Order of Ontario and the Order of Canada. He was listed on the *Maclean's* Honour Roll as a distinguished Canadian in 2000, named as one of *Time*'s 100 Most Influential People, honoured as a *Globe and Mail* Nation Builder of the Year in 2010, and awarded the Ernest C. Manning Principal Award, Canada's most prestigious innovation prize.

Mr. Lazaridis holds an honorary doctoral degree in engineering from the University of Waterloo (where he formerly served as Chancellor), as well as honorary Doctors of Laws from McMaster University, the University of Windsor, and Laval University. In addition to his many professional and personal accomplishments, Mr. Lazaridis won an Academy Award and an Emmy Award for technical achievements in the movie and TV industries for developing a high-speed barcode reader that greatly increased the speed of editing film.

Mr. Lazaridis was born in Istanbul, Turkey. He moved to Canada in 1966 with his family, settling in Windsor, Ontario.

Cosimo Fiorenza, Vice-Chair, is the Vice-President and General Counsel of Quantum Valley Investments and the Quantum Valley Investment Fund. Previously, he spent approximately 20 years with major Toronto law firms, where he specialized in corporate tax. During his tenure on Bay Street, he advised some of Canada's largest corporations and biggest entrepreneurs on income tax and commercial matters with a focus on technology and international structure. Mr. Fiorenza helped establish and is a Founding Director of Perimeter Institute. In addition to his current role as Vice-Chair, he is Founding Co-Chair of the Perimeter Leadership Council and a member of the Perimeter Finance Committee. In these capacities, he regularly assists and supports Perimeter's management team in a variety of contexts including financial, legal, and advancement matters. Mr. Fiorenza is also a member of the Board of Directors of the Institute for Quantum Computing at the University of Waterloo. He holds a degree in business administration from Lakehead University and a law degree from the University of Ottawa. He was called to the Bar in Ontario in 1991.

Joanne Cuthbertson, LL.D., was the first elected Chair of EducationMatters (Calgary's unique public education trust), founder of SPEAK (Support Public Education – Act for Kids), and a recipient of the Calgary Award (Education). She is Chancellor Emeritus of the University of Calgary, Co-Chair of the Scholars' Academy she established upon retirement, and Dean's Circle Chair in the Faculty of Environmental Design. Ms. Cuthbertson serves as a Fellow of Glenbow Museum and as Director of the Alberta Bone and Joint Health Institute, and she is a Queen Elizabeth II Diamond Jubilee Medal recipient. She is also a Co-Chair of Perimeter's Leadership Council.

Peter Godsoe, O.C., O.Ont., is the former Chairman and Chief Executive Officer of Scotiabank, from which he retired in 2004. He holds a BSc in mathematics and physics from the University of Toronto, an MBA from the Harvard Business School, and is a CA and a Fellow of the Institute of Chartered Accountants of Ontario. Mr. Godsoe remains active through a wide range of corporate boards and non-profit directorships.

Michael Horgan is a Senior Advisor at Bennett Jones LLP, one of Canada's premier business law firms. Prior to his work in the private sector, he led a distinguished 36-year career as a federal public servant, including five years as Canada's Deputy Minister of Finance. Mr. Horgan has been awarded the Prime Minister's Outstanding Achievement Award for Public Service and a Queen Elizabeth II Diamond Jubilee Medal.

Art McDonald, C.C., was the Director of the Sudbury Neutrino Observatory (SNO) experiment for more than 20 years, and is Emeritus Professor at Queen's University. He shared the 2015 Nobel Prize in Physics and the 2016 Breakthrough Prize in Fundamental Physics for the SNO experiment that showed neutrinos have mass. Professor McDonald has received numerous other awards for his research, including the 2011 Henry Marshall Tory Medal from the Royal Society of Canada and the 2007 Benjamin Franklin Medal in Physics, alongside researcher Yoji Totsuka. He was named an Officer of the Order of Canada in 2007 and promoted to a Companion of the Order of Canada in 2015.

John Reid recently retired after serving as the Audit Leader for KPMG in the Greater Toronto area. During his 35-year career, he assisted both private- and public-sector organizations through various stages of strategic planning, business acquisitions, development, and growth management. His experience spans all business sectors and industries with a focus on mergers and acquisitions, technology, and health care. Mr. Reid has served on many hospital boards throughout Canada and has also been a director on many university and college boards.

Indira Samarasekera, O.C., is a corporate director and Senior Advisor at Bennett Jones LLP, who recently served as the President and Vice-Chancellor of the University of Alberta (2005-15). She is internationally recognized as a leading metallurgical engineer, and has been appointed an Officer of the Order of Canada. She is also an elected member of both the Royal Society of Canada and the US National Academy of Engineering. Dr. Samarasekera formerly served as Chair of the Worldwide Universities Network and was a member of Canada's Science, Technology, and Innovation Council. She serves on the boards of the Bank of Nova Scotia, Magna International, and TransCanada Corporation. Dr. Samarasekera has an MSc in mechanical engineering from the University of California and a PhD in metallurgical engineering from the University of British Columbia.

Michael Serbinis is the Founder and CEO of LEAGUE, a digital health start-up that launched in 2015. He is a leader known as a visionary entrepreneur who has built several transformative technology platforms across industries. Mr. Serbinis was the Founder and CEO of Kobo, a digital reading company that burst onto the publishing scene in 2009, driving $110 million in sales in its very first year and becoming the only global competitor to Amazon's Kindle with 20 million customers in 190 countries. He is the Founder of Three Angels Capital, a member of the Board of Trustees at the Ontario Science Centre, and a member of YPO. He holds a BSc in engineering physics from Queen's University and an MSc in industrial engineering from the University of Toronto.

SCIENTIFIC ADVISORY COMMITTEE

Perimeter Institute's Scientific Advisory Committee (SAC) provides key support in achieving the Institute's strategic objectives, particularly in the area of recruitment.

Renate Loll, Radboud University, Nijmegen (2010-16), Chair

Professor Loll is a Professor of Theoretical Physics at the Institute for Mathematics, Astrophysics, and Particle Physics of the Radboud University in Nijmegen, Netherlands. Her research centres on quantum gravity, the search for a consistent theory that describes the microscopic constituents of spacetime geometry, and the quantum-dynamical laws governing their interaction. She has made major contributions to loop quantum gravity and, with her collaborators, has proposed a novel theory of quantum gravity via "Causal Dynamical Triangulations." Loll heads one of the largest research groups on non-perturbative quantum gravity worldwide and is the recipient of a prestigious personal VICI grant of the Netherlands Organisation for Scientific Research. In 2015, she was installed as a member of the Royal Netherlands Academy of Arts and Sciences.

Neta Bahcall, Princeton University (2015-16)

Professor Bahcall is the Eugene Higgins Professor of Astrophysics at Princeton University. She is an observational cosmologist who has pioneered quantitative approaches to the understanding of astronomical data. These methods have enabled her to achieve key insights into such fundamental questions as the large-scale structure, mass, and fate of the universe, galaxy formation, the nature of quasars, and dark matter. She is a member of the US National Academy of Sciences and the American Academy of Arts and Sciences, among other honours.

Ganapathy Baskaran, Institute of Mathematical Sciences, Chennai (2013-16)

Professor Baskaran is Emeritus Professor at the Institute of Mathematical Sciences, Chennai, in India, where he founded the Quantum Science Centre. He has made important contributions to the field of strongly correlated quantum matter. His primary research focus is novel emergent quantum phenomena in matter, including biological ones. He is well known for his contributions to the theory of high-temperature superconductivity and for discovering emergent gauge fields in strongly correlated electron systems. He predicted p-wave superconductivity in Sr_2RuO_4, a system believed to support Majorana fermion mode, which is a popular qubit for topological quantum computation. In recent work, he predicted room temperature superconductivity in optimally doped graphene. From 1976 to 2006, Baskaran contributed substantially to the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy. He is a past recipient of the S.S. Bhatnagar Award from the Indian Council of Scientific and Industrial Research (1990); the Alfred Kasler ICTP Prize (1983); Fellowships of the Indian Academy of Sciences (1988), the Indian National Science Academy (1991), and the Third World Academy of Sciences (2008); and the Distinguished Alumni Award of the Indian Institute of Science, Bangalore (2008).

Edmund Copeland, University of Nottingham (2015-16)

Professor Copeland is a Professor of Physics at the University of Nottingham. He is a particle cosmologist with a particular interest in how the physics of the very early and late universe can be tested by observations on both the largest scales (astronomy) and smallest scales (particle physics) in the universe. He has been a leader in the quest to obtain successful particle physics-inspired models of inflation, to predict the properties of cosmic strings, and to determine the nature of dark energy. Among his many honours, Copeland has received a Wolfson Research Merit Award from the Royal Society and the 2013 Rayleigh Medal and Prize of the Institute of Physics.

Nigel Hitchin, University of Oxford (2015-16)

Professor Hitchin is the Savilian Professor of Geometry at the University of Oxford. His research interests include differential and algebraic geometry, as well as their interaction with the equations of theoretical physics, and he has made many notable discoveries in these areas. Among his many honours, Hitchin has been awarded the Sylvester Medal of the Royal Society, the Shaw Prize in Mathematical Sciences, and the Senior Berwick Prize and Pólya Prize, both of the London Mathematical Society. He is also a Fellow of both the Royal Society and the American Mathematical Society.

Shamit Kachru, Stanford University (2015-16)

Professor Kachru has been a Professor of Physics at Stanford University since 1999. He is an expert in string theory and quantum field theory, and their applications in cosmology, condensed matter, and elementary particle theory. He has made central contributions to the study of compactifications of string theory from ten to four dimensions, especially in the exploration of mechanisms that could yield string models of dark energy or cosmic inflation. Kachru has also made notable contributions to the discovery and exploration of string dualities, to the study of models of supersymmetry breaking in string theory, and to the construction of calculable dual descriptions of strongly-coupled particle physics and condensed matter systems using the AdS/CFT correspondence. Kachru's many honours include a Department of Energy Outstanding Junior Investigator Award, Alfred P. Sloan Foundation Fellowship, Bergmann Memorial Award, Packard Foundation Fellowship, and ACIPA Outstanding Young Physicist Prize.

Sandu Popescu, University of Bristol (2015-16)

Professor Popescu is a Professor of Physics at the H.H. Wills Physics Laboratory at the University of Bristol and a member of the Bristol Quantum Information and Computation Group. He has made numerous contributions to quantum theory, ranging from the very fundamental to the design of practical experiments (such as the first teleportation experiment), to patentable commercial applications. His investigations into the nature of quantum behaviour, with particular focus on quantum non-locality, led him to discover some of the central concepts in the emerging area of quantum information and computation. Popescu is a past recipient of the Adams Prize from the University of Cambridge, the Clifford Patterson Medal of the Royal Society (UK), the John Stewart Bell Prize, and the Dirac Medal in Physics from the Institute of Physics.

Barbara Terhal, RWTH Aachen University (2015-16)

Professor Terhal has been a Professor of Theoretical Physics at RWTH Aachen University in Germany since 2010. Prior to that, she spent eight years as a research staff member at the IBM Watson Research Center in New York. Terhal's research interests lie in quantum information theory – ranging from quantum entanglement to quantum cryptography and quantum algorithms – and she is currently working on quantum error correction and its realization in solid-state qubits, as well as quantum complexity theory. She is a Fellow of the American Physical Society and an Associate Member of the Quantum Information Processing program of the Canadian Institute for Advanced Research.

Mark Wise, California Institute of Technology (2013-16)

Professor Wise is the John A. McCone Professor of High Energy Physics at the California Institute of Technology. He has conducted research in elementary particle physics and cosmology, and shared the 2001 Sakurai Prize for Theoretical Particle Physics for the development of the Heavy Quark Effective Theory (HQET), a mathematical formalism that enables physicists to make predictions about otherwise intractable problems in the theory of the strong interactions of quarks. He has also published work on mathematical models for finance and risk assessment. Wise is a past Sloan Research Fellow, a Fellow of the American Physical Society, and a member of the American Academy of Arts and Sciences and of the National Academy of Sciences.

FACILITY

With space to accommodate up to 250 researchers and students, Perimeter is the largest independent theoretical physics research centre in the world.

With open, naturally lit spaces, a striking architectural design, and a multitude of blackboards, Perimeter's iconic, award-winning building was custom-designed to inspire big ideas. The original building won a Governor General's Medal in Architecture in 2006. The Stephen Hawking Centre – an addition completed in 2011 – won a 2012 Design Excellence Award from the Ontario Association of Architects and attained LEED Silver Certification in 2015 after an independent review by the Canadian Green Building Council.

Form melds seamlessly with function, with a carefully curated array of open and inviting collaborative spaces alongside cozy nooks and quiet lounges for small meetings and secluded contemplation. This year, working spaces were extended outdoors with the installation of several blackboards next to the reflecting pool. The two-storey library is replete with a vast repository of physics knowledge, and the bustling Black Hole Bistro provides the perfect venue for spontaneous discussions and working lunches – every table comes well-stocked with pencils and paper to record ideas and discoveries.

Beyond the physical infrastructure, Perimeter offers a state-of-the-art computational environment that includes access to high-performance computing and dedicated IT services, including a scientific computation expert able to design and run complex simulations in consultation with researchers. Seminar rooms and the Mike Lazaridis Theatre of Ideas are all equipped with video recording arrays, enabling the Institute to record and share all talks online through its vast video archive, the Perimeter Institute Recorded Seminar Archive (PIRSA).

It's all designed to provide a working environment that provides full-spectrum support for discovery – at Perimeter and beyond.

SCIENCE WITH A DASH OF SPICE

It would be easy to mistake the large table prepared every Wednesday in Perimeter's Black Hole Bistro for the kids' area. Bistro staff pull together a half dozen smaller tables to create one large surface, then cover it in brown paper, tape the corners down, and place pens and pencils alongside the cutlery.

It's not children who eagerly take up these seats, though. This is the setting for the weekly Interdisciplinary Lunch, where theorists pass ideas around as readily as they pass the hot sauce. By the end of the meal, that brown paper is covered in equations, notes, ideas, and snippets of possible research (and hot sauce).

You never know who you'll sit next to – perhaps a new postdoctoral fellow, perhaps a Distinguished Visiting Research Chair. The lunches are open to PI residents and visitors alike, and participants are encouraged to sit beside people in different fields from their own. It's one more way Perimeter actively encourages cross-pollination of ideas; only here, it can come with a side of fries.

FINANCIALS

RESULTS OF OPERATIONS

Perimeter Institute's financial position remained strong in the 2015/16 fiscal year despite lower investment returns, attributable to continued support from public and private sectors, obtaining new grants, and prudent and strategic spending.

In keeping with its comprehensive long-term plan, Perimeter invested in resident scientific personnel, grew its international visitor program, and continued to support cutting-edge conferences, workshops, seminars, and advanced courses. These combined efforts increased Perimeter's research investment by more than five percent from the prior year.

Perimeter's innovative research training programs aim to produce the next generation of leading physicists and provide highly skilled problem solvers and creative thinkers to the wider innovation ecosystem. Investment in this area increased by over 19 percent from the prior year, as additional students were trained at the graduate level. Perimeter Scholars International and the PhD program, which are delivered in collaboration with university partners, continued to attract exceptional graduate students from around the world.

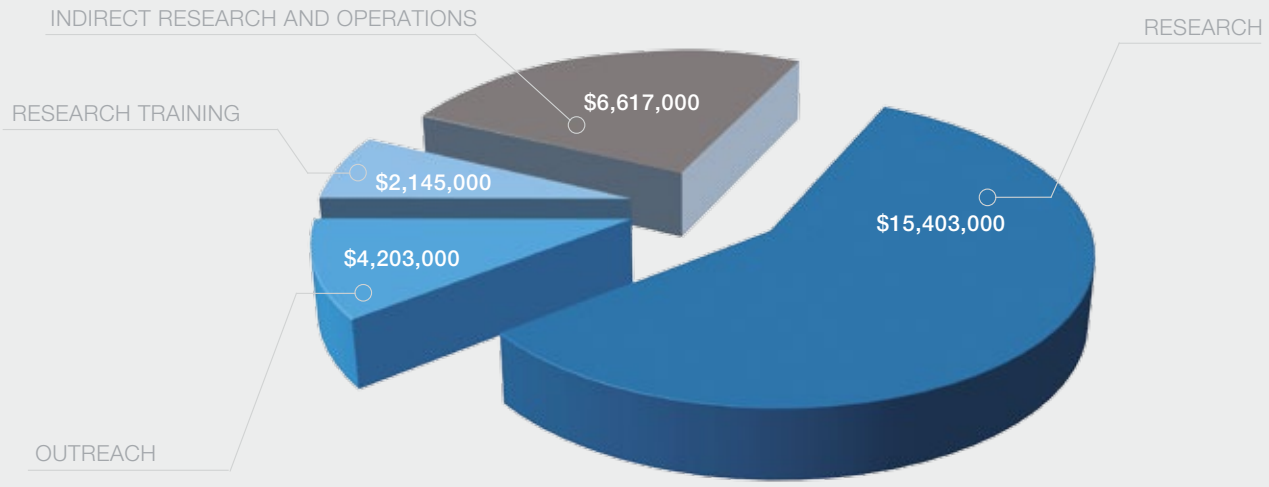
Educational outreach and science communication remained a key component of Perimeter's mandate in 2015/16. The Institute invested approximately 15 percent of its annual expenditures in inspirational programs and products for students, teachers, and the general public. Much of the 50 percent investment increase from the prior year can be attributed to the Institute's significant planning, development, and coordination efforts as the lead partner of Innovation150, a signature initiative of the Government of Canada's 2017 celebration of the country's 150th anniversary.

Indirect research and operating expenditures cover the costs of core support areas, including administration, advancement, information technology, and facilities. As a percentage of total expenditures, spending in this area decreased from the prior year, demonstrating effective cost management and Perimeter's ability to scale effectively as new projects and initiatives are executed.

Perimeter Institute completed its 2015/16 fiscal year with revenues exceeding expenditures by $69,000. Perimeter's private sector fundraising campaign remained very strong and was a large contributor to the small surplus generated in the year despite challenging investment returns.

OPERATING EXPENDITURE SUMMARY

For the year ended July 31, 2016



FINANCIAL POSITION

Perimeter Institute maintained strength in its working capital position, which provides the Institute with the near-term flexibility to react to targeted research opportunities that may present themselves.

The endowment fund primarily allows for the accumulation of private funds to address the Institute's future needs. The $306 million in this fund consists of a portfolio mix of domestic equities, international equities, fixed income, and alternative investments specifically designed in accordance with Perimeter's risk-return objectives, which remained consistent with the prior year.

RISKS AND UNCERTAINTIES

Perimeter Institute exists through a cooperative and highly successful public-private partnership that provides for ongoing operations while safeguarding future opportunities.

Funding commitments of $50 million from the federal government and $50 million from the provincial government reinforce Perimeter's strong collaboration with public partners and the value they see in investing in the Institute. Both five-year commitments are currently being renewed, consistent with prior arrangements. The continuous multi-year government commitments and ongoing support clearly demonstrate that the Institute is an excellent and strategic government investment.

In addition to government support, Perimeter Institute is consistently seeking innovative ways to expand its sources of funds from the private sector to fund existing operations for the Institute, as well as solidify its financial position. Private sector donations, in accordance with donor requests, are either utilized as contributions toward operational expenditures or protected in an endowment fund. The endowment fund is designed to maximize growth and minimize risk in order to contribute to the strongest possible long-term financial health of the Institute. However, investment returns are volatile and susceptible to economic conditions. Under the direction of the Investment Committee, funds are invested in accordance with the Board-approved Investment Policies and Procedures.

Zeifmans

REPORT OF THE INDEPENDENT AUDITORS ON THE SUMMARIZED FINANCIAL STATEMENTS

To the Directors of
Perimeter Institute

The accompanying summarized financial statements, which comprise the summarized statement of financial position as at July 31, 2016 and the summarized statement of operations and changes in fund balances for the year then ended, are derived from the audited financial statements of Perimeter Institute (the "Institute") for the year ended July 31, 2016. We expressed an unmodified audit opinion on those financial statements in our report dated December 2, 2016. Those financial statements, and the summarized financial statements, do not reflect the effects of events that occurred subsequent to the date of our report on those financial statements.

The summarized financial statements do not contain all the disclosures required by Canadian accounting standards for not-for-profit organizations. Reading the summarized financial statements, therefore, is not a substitute for reading the audited financial statements of the Institute.

Management's Responsibility for the Summarized Financial Statements

Management is responsible for the preparation of a summary of the financial statements in accordance with Canadian accounting standards for not-for-profit organizations.

Auditor's Responsibility

Our responsibility is to express an opinion on the summarized financial statements based on our procedures, which were conducted in accordance with Canadian Auditing Standard (CAS) 810, "Engagements to Report on Summary Financial Statements."

Opinion

In our opinion, the summarized financial statements derived from the audited financial statements of the Institute for the year ended July 31, 2016 are a fair summary of those financial statements, in accordance with Canadian accounting standards for not-for-profit organizations.

Zeifmans LLP

Toronto, Ontario
December 2, 2016

Chartered Accountants
Licensed Public Accountants

201 Bridgeland Avenue | Toronto
Ontario | M6A 1Y7 | Canada

zeifmans.ca
T: 416.256.4000

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PERIMETER INSTITUTE

Summarized Statement of Financial Position
as at July 31, 2016

	2016	2015
ASSETS		
Current Assets:		
Cash and cash equivalents	$ 7,127,000	$ 9,230,000
Investments	306,393,000	302,796,000
Grants receivable	4,170,000	4,671,000
Other current assets	1,807,000	706,000
	319,497,000	317,403,000
Property and equipment	44,607,000	46,412,000
TOTAL ASSETS	$ 364,104,000	$ 363,815,000
LIABILITIES AND FUND BALANCE		
Current liabilities:		
Accounts payable and other current liabilities	$ 1,315,000	$ 1,095,000
TOTAL LIABILITIES	1,315,000	1,095,000
Fund balances:		
Invested in capital assets	44,576,000	46,399,000
Externally restricted	123,050,000	117,866,000
Internally restricted	188,840,000	188,840,000
Unrestricted	6,323,000	9,615,000
TOTAL FUND BALANCES	362,789,000	362,720,000
	$ 364,104,000	$ 363,815,000

Zeifmans

PERIMETER INSTITUTE

Summarized Statement of Operations and Changes in Fund Balances
For the Year Ended July 31, 2016

	2016	2015
Revenue		
Government grants	$ 22,794,000	$ 21,548,000
Other income	1,855,000	3,073,000
Donations	6,479,000	2,691,000
	31,128,000	27,312,000
Expenditures		
Research	15,403,000	14,635,000
Research training	2,145,000	1,799,000
Outreach and science communications	4,203,000	2,694,000
Indirect research and operations	6,617,000	6,313,000
	28,368,000	25,441,000
Excess of revenue over expenditures before amortization, gain on disposal of capital assets and investment gain (loss)	2,760,000	1,871,000
Amortization	(2,581,000)	(2,941,000)
Gain on disposal of property and equipment	--	111,000
Investment gain (loss)	(110,000)	29,134,000
Excess of revenue over expenditures	69,000	28,175,000
Fund balances, beginning of year	362,720,000	334,545,000
Fund balances, end of year	$ 362,789,000	$ 362,720,000

Zeifmans

LOOKING AHEAD: PRIORITIES AND OBJECTIVES FOR THE FUTURE

After a comprehensive review, taking into account Perimeter's growth over the past several years, the Institute has established the following strategic objectives to guide its continued development. The advancement of Perimeter's core mission will continue to inform every facet of the Institute's research, training, and outreach efforts.

Achieve breakthroughs in our understanding of the universe, drawing insights from and contributing to the whole spectrum of theoretical physics, focusing strategically on research areas that offer the greatest opportunity for major discoveries.

Create the world's strongest community of theoretical physics researchers by continuing to attract and retain top international talent and providing them with unparallelled infrastructure and support to help maximize productivity.

Attract and develop the next generation of brilliant researchers by providing exceptional graduate training opportunities that prepare students for cutting-edge research and by giving postdoctoral researchers the unmatched freedom and support necessary to pursue ambitious research and advance their careers.

Attract outstanding visiting scientists by holding timely, focused conferences, workshops, and seminars on cutting-edge topics and facilitating a constant flow of eminent and emerging physicists for both short-term and extended collaboration visits.

Act as Canada's hub for foundational physics research, strengthening connections with institutions across the country and enabling frontier research, high-quality training, and public engagement.

Catalyze and support the creation of centres of excellence for math and physics research, training, and outreach in developing countries, sharing knowledge and expertise globally and promoting the emergence of vast new pools of scientific talent.

Share the transformative power of theoretical physics across Canada and around the world, inspiring a new generation of scientific explorers through high-impact educational outreach, while engaging the general public with the wonder and excitement of basic physics research.

Continue to strengthen Perimeter's visionary public-private partnership by demonstrating excellent return on investment, securing sustained funding from government partners, and expanding the Institute's private sector support base.

APPENDICES

FACULTY

Neil Turok (PhD Imperial College London, 1983) is the Director of Perimeter Institute. He was Professor of Physics at Princeton University and Chair of Mathematical Physics at the University of Cambridge before assuming his current position in 2008. In 2013, he was also appointed to the Mike and Ophelia Lazaridis Niels Bohr Chair at Perimeter. Turok's research focuses on developing fundamental theories of cosmology and new observational tests. His predictions for the correlations of the polarization and temperature of the cosmic background radiation (CBR) and of the galaxy-CBR correlations induced by dark energy have been confirmed. He developed the single bubble open inflationary universe model with Stephen Hawking, among others. He also developed the cyclic universe model with Paul Steinhardt. Currently, he is working on a new approach to quantum cosmology which resolves the big bang singularity and explains the emergence of time. With Ue-Li Pen, he has recently shown how gravitational waves may be used to constrain and observe physical phenomena in the primordial universe. Among his many honours, Turok was awarded Sloan and Packard Fellowships and the James Clerk Maxwell medal of the Institute of Physics (UK). He is a Canadian Institute for Advanced Research Fellow in Cosmology and Gravity and a Senior Fellow of Massey College at the University of Toronto. In 2012, Turok was selected to deliver the CBC Massey Lectures, broadcast across Canada. The lectures were published as *The Universe Within*, a bestseller that won the 2013 Lane Anderson Award, Canada's top prize for popular science writing. Born in South Africa, Turok founded the African Institute for Mathematical Sciences (AIMS) in Cape Town in 2003. AIMS has since expanded to a network of six centres – in South Africa, Senegal, Ghana, Cameroon, Tanzania, and Rwanda – and has become Africa's leading institution for postgraduate training in mathematical science. For his scientific discoveries and his work building AIMS, Turok was awarded a TED Prize in 2008, as well as awards from the World Summit on Innovation and Entrepreneurship and the World Innovation Summit on Education. In 2016, he was awarded the John Torrence Tate Medal for International Leadership in Physics by the American Institute of Physics. He was made an Honorary Fellow of the Institute of Physics in the UK and named as winner of the John Wheatley Award of the American Physical Society. He was also chosen as the Gerald Whitrow Lecturer of the Royal Astronomical Society.

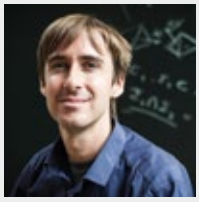
Dmitry Abanin (PhD Massachusetts Institute of Technology, 2008) joined Perimeter in 2012 after postdoctoral positions at Harvard University and the Princeton Center for Theoretical Science. Abanin is a leading young condensed matter theorist whose research has focused on developing a theoretical understanding of Dirac materials, focusing on quantum transport of charge and spin and finding new ways of controlling their electronic properties. Some of his theoretical work has been experimentally confirmed by groups at Harvard University, the University of Manchester, Columbia University, the University of California, Riverside, the Max Planck Institute, and elsewhere. In 2014, he received a Sloan Research Fellowship.

Asimina Arvanitaki (PhD Stanford University, 2008) is the Stavros Niarchos Foundation Aristarchus Chair in Theoretical Physics at Perimeter Institute, where she has been a faculty member since 2014. She previously held research positions at the Lawrence Berkeley National Laboratory at the University of California, Berkeley (2008-11), and the Stanford Institute for Theoretical Physics at Stanford University (2011-14). Arvanitaki is a particle physicist who specializes in designing new experiments to test fundamental theories beyond the Standard Model. These experiments rely on the latest developments in metrology, such as atomic clocks, and the optical trapping and cooling of macroscopic objects. She recently pioneered a new experiment that can look for new spin-dependent forces in nature at an unprecedented level of precision. Arvanitaki also works on theoretical challenges raised by experimental results, such as a model of particle physics influenced by string theory called "split SUSY." In 2016, she received an Early Researcher Award from the Ontario Ministry of Research and Innovation.

Latham Boyle (PhD Princeton University, 2006) joined the Institute's faculty in 2010. From 2006 to 2009, he held a Canadian Institute for Theoretical Astrophysics Postdoctoral Fellowship; he was also a Junior Fellow of the Canadian Institute for Advanced Research. Boyle has studied what gravitational wave measurements can reveal about the universe's beginning. With Paul Steinhardt, he derived "inflationary bootstrap relations" that – if confirmed observationally – would provide compelling support for the theory of primordial inflation. He co-developed a simple algebraic technique for understanding black hole mergers and constructed the theory of "porcupines": networks of low-frequency gravitational wave detectors that function together as gravitational wave telescopes. With Shane Farnsworth, Boyle discovered a reformulation of Connes' non-commutative geometry that greatly simplifies and unifies its axioms, and elucidates its connection to the standard model of particle physics. With Kendrick Smith, he developed the idea of "choreographic crystals" in which the basic elements perform a choreographed dance that can have a much higher symmetry than any instantaneous snapshot reveals. Most recently, with Steinhardt, he has been developing a new approach to Penrose-like tilings and exploring new applications of these structures to physics.

Freddy Cachazo (PhD Harvard University, 2002) is the Gluskin Sheff Freeman Dyson Chair in Theoretical Physics at Perimeter Institute, where he has been a faculty member since 2005. From 2002 to 2005, he was a Member of the School of Natural Sciences at the Institute for Advanced Study in Princeton. Cachazo is one of the world's leading experts in the study and computation of scattering amplitudes in gauge theories, such as quantum chromodynamics and N=4 super Yang-Mills (MSYM), and in Einstein's gravity theory. His many honours include the Gribov Medal of the European Physical Society (2009), the Rutherford Memorial Medal in Physics from the Royal Society of Canada (2011), the Herzberg Medal from the Canadian Association of Physicists (2012), a New Horizons in Physics Prize from the Fundamental Physics Prize Foundation (2014), and the CAP-CRM Prize in Theoretical and Mathematical Physics from the Canadian Association of Physicists and the Centre de recherches mathématiques (2016).

Kevin Costello (PhD University of Cambridge, 2003) joined Perimeter in 2014 from Northwestern University, where he had been a faculty member since 2006. He is the Krembil William Rowan Hamilton Chair in Theoretical Physics. Previously, he was a Chapman Fellow at Imperial College London (2003-05) and the Dixon Instructor at the University of Chicago (2005-06). Costello works on the mathematical aspects of quantum field theory and string theory. He is the author of *Renormalization and Effective Field Theory*, a path-breaking monograph introducing powerful new mathematical tools into the theory of quantum fields, and co-author of the recently published *Factorization Algebras in Quantum Field Theory*. Costello's previous honours include an Alfred P. Sloan Research Fellowship and several prestigious grants from the National Science Foundation in the United States.



Bianca Dittrich (PhD Max Planck Institute for Gravitational Physics, 2005) joined Perimeter's faculty in 2012 from the Albert Einstein Institute in Potsdam, Germany, where she led the Max Planck Research Group "Canonical and Covariant Dynamics of Quantum Gravity." Dittrich's research focuses on the construction and examination of quantum gravity models. Among other important findings, she has provided a computational framework for gauge invariant observables in canonical general relativity, constructed new realizations of quantum geometry, and identified holographic properties of background independent gravity. Dittrich has received the Otto Hahn Medal of the Max Planck Society, which recognizes outstanding young scientists, and an Early Researcher Award from the Ontario Ministry of Research and Innovation.

Laurent Freidel (PhD L'École Normale Supérieure de Lyon, 1994) joined Perimeter Institute first as a visitor in 2002 and then as faculty in 2006. Freidel is a mathematical physicist who has made many notable contributions in the field of quantum gravity, developing spin foam models, among other things. He has also introduced several new concepts in this field, such as group field theory, relative locality, and metastring theory and modular spacetime. He possesses outstanding knowledge of a wide range of areas including gravitational physics, integrable systems, topological field theories, 2D conformal field theory, string theory, and quantum chromodynamics. Freidel has held positions at Pennsylvania State University and L'École Normale Supérieure and has been a member of France's Centre National de la Recherche Scientifique since 1995. He is also the recipient of several awards.

Davide Gaiotto (PhD Princeton University, 2004) joined Perimeter in 2012 and holds the Krembil Galileo Galilei Chair in Theoretical Physics. Previously, he was a postdoctoral fellow at Harvard University from 2004 to 2007 and a long-term Member at the Institute for Advanced Study in Princeton from 2007 to 2012. Gaiotto works in the area of strongly coupled quantum fields and has already made major conceptual advances. His honours include the Gribov Medal of the European Physical Society (2011) and a New Horizons in Physics Prize from the Fundamental Physics Prize Foundation (2013).

Jaume Gomis (PhD Rutgers University, 1999) joined Perimeter Institute in 2004, declining a European Young Investigator Award by the European Science Foundation to do so. Prior to that, he worked at the California Institute of Technology as a Postdoctoral Scholar and as the Sherman Fairchild Senior Research Fellow. His main areas of expertise are string theory and quantum field theory. In 2009, Gomis was awarded an Early Researcher Award from the Ontario Ministry of Research and Innovation for a project aimed at developing new techniques for describing quantum phenomena in nuclear and particle physics.

Daniel Gottesman (PhD California Institute of Technology, 1997) joined Perimeter's faculty in 2002. From 1997 to 2002, he held postdoctoral positions at the Los Alamos National Laboratory, Microsoft Research, and the University of California, Berkeley (as a long-term CMI Prize Fellow for the Clay Mathematics Institute). Gottesman has made seminal contributions that continue to shape the field of quantum information science through his work on quantum error correction and quantum cryptography. He has published over 50 papers, which have attracted well over 4,000 citations to date. He is also a Senior Fellow in the Quantum Information Processing program of the Canadian Institute for Advanced Research and a Fellow of the American Physical Society.

Lucien Hardy (PhD University of Durham, 1992) joined Perimeter's faculty in 2002, having previously held research and lecturing positions at various European universities, including the University of Oxford, Sapienza University of Rome, University of Durham, University of Innsbruck, and National University of Ireland. In 1992, he found a very simple proof of non-locality in quantum theory which has become known as Hardy's theorem. He has worked on characterizing quantum theory in terms of operational postulates and providing an operational reformulation of quantum theory. He has recently shown how to reformulate general relativity in operational terms. This is seen as a stepping stone en route to finding a theory of quantum gravity.

Luis Lehner (PhD University of Pittsburgh, 1998) began a joint appointment with Perimeter and the University of Guelph in 2009, joined Perimeter as a full-time faculty member in 2012, and became Deputy Faculty Chair in 2014. He previously held postdoctoral fellowships at the University of Texas at Austin and the University of British Columbia, and he was a member of Louisiana State University's faculty from 2002 to 2009. Lehner's many honours include the Honor Prize from the National University of Cordoba, Argentina, a Mellon pre-doctoral fellowship, the CGS/UMI outstanding dissertation award, and the Nicholas Metropolis award. He has been a PIMS fellow, a CITA National Fellow, and a Sloan Research Fellow, and he is currently a Fellow of the Institute of Physics, the American Physical Society, the International Society for General Relativity and Gravitation, and the Canadian Institute for Advanced Research in the Cosmology and Gravity program. Lehner also serves on the Scientific Council of the International Centre for Theoretical Physics – South American Institute for Fundamental Research and the Advisory Board of the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara.

Max Metlitski (PhD Harvard University, 2011) joined Perimeter's faculty in October 2015. He was recruited to Perimeter from the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara, where he was a Postdoctoral Research Associate from 2011 to 2015. Metlitski is a condensed matter physicist whose work has contributed to the theory of quantum criticality in metals and to the understanding of topological phases in the presence of interactions. Since 2013, he has won the Hermann Kummel Early Achievement Award in Many-Body Physics, the Nevill F. Mott Early Career Prize of the International Conference on Strongly Correlated Electron Systems, and the William L. McMillan Award, which recognizes outstanding contributions by a young condensed matter physicist.

Robert Myers (PhD Princeton University, 1986) is one of the leading theoretical physicists working on string theory and quantum gravity in Canada. After attaining his PhD, he was a postdoctoral researcher at the Institute for Theoretical Physics at the University of California, Santa Barbara, and a Professor of Physics at McGill University, before joining Perimeter as one of the founding faculty members in 2001. He was named Faculty Chair in 2010. Myers has made seminal contributions to our understanding of black hole microphysics, D-branes, and the application of entanglement entropy to holography and renormalization group flows. Among his many honours, he has received the Canadian Association of Physicists' Herzberg Medal (1999), the CAP-CRM Prize (2005), and the Vogt Medal (2012). He is also a Fellow of both the Royal Society of Canada and the Cosmology and Gravity program of the Canadian Institute for Advanced Research. Myers was named on Thomson Reuters' list of the "World's Most Influential Scientific Minds" in 2014 and 2015.

Subir Sachdev (PhD Harvard University, 1985) joined Perimeter in 2014 and holds the Cenovus Energy James Clerk Maxwell Chair in Theoretical Physics (Visiting). He has been a Professor of Physics at Harvard University since 2005. Sachdev has made prolific contributions to quantum condensed matter physics, including research on quantum phase transitions and their application to correlated electron materials like high-temperature superconductors, and he authored the seminal book, *Quantum Phase Transitions*. In recent years, he has exploited a remarkable connection between the electronic properties of materials near a quantum phase transition and the quantum theory of black holes. Sachdev's previous honours include an Alfred P. Sloan Foundation Fellowship and a John Simon Guggenheim Memorial Foundation Fellowship. He is a Fellow of the American Physical Society and a member of the US National Academy of Sciences, and he was a Perimeter Distinguished Visiting Research Chair from 2009 to 2014.

Philip Schuster (PhD Harvard University, 2007) joined Perimeter's faculty in 2010. He was a Research Associate at SLAC National Accelerator Laboratory from 2007 to 2010. Schuster's area of specialty is particle theory, with an emphasis on physics beyond the Standard Model. He has close ties to experiment and has investigated various theories that may be discovered at experiments at the Large Hadron Collider (LHC) at CERN. With members of the Compact Muon Solenoid experiment at the LHC, he developed methods to characterize potential new physics signals and null results in terms of simplified models, facilitating more robust theoretical interpretations of data. He is also a co-spokesperson for the APEX collaboration at the Thomas Jefferson National Accelerator Facility in Virginia. With Natalia Toro, he was awarded the 2015 New Horizons in Physics Prize by the Breakthrough Prize Foundation.

Kendrick Smith (PhD University of Chicago, 2007) joined Perimeter in 2012 from Princeton University, where he was the Lyman P. Spitzer Postdoctoral Fellow. Prior to that, he held the PPARC Postdoctoral Fellowship at the University of Cambridge from 2007 to 2009. Smith is a cosmologist with a foot in the worlds of both theory and observation. He is a member of several experimental teams, including the WMAP collaboration, which won the 2012 Gruber Cosmology Prize, as well as CHIME and the Planck collaboration. Smith has achieved several landmark results, including the first detection of gravitational lensing in the cosmic microwave background (CMB) radiation. He holds a second PhD in mathematics from the University of Michigan.

Lee Smolin (PhD Harvard University, 1979) is one of Perimeter Institute's founding faculty members. Prior to joining Perimeter, Smolin held faculty positions at Yale University, Syracuse University, and Pennsylvania State University. Smolin's research is centred on the problem of quantum gravity, where he helped to found loop quantum gravity, though his contributions span many areas, including quantum foundations, cosmology, particle physics, the philosophy of physics, and economics. His more than 195 papers have generated over 19,400 citations to date. He has written four non-technical books and co-written a book on the philosophy of time. Smolin's honours include the Majorana Prize (2007), the Klopsteg Memorial Award (2009), the Buchalter Cosmology Prize (2014), and election as a Fellow of both the American Physical Society and the Royal Society of Canada.

Robert Spekkens (PhD University of Toronto, 2001) joined Perimeter's faculty in 2008, after holding a postdoctoral fellowship at Perimeter and an International Royal Society Fellowship at the University of Cambridge. His field of research is the foundations of quantum theory, where he is known for his work on the interpretation of the quantum state, the principle of noncontextuality, the nature of causality in a quantum world, and the characterization of the symmetry-breaking and thermodynamic properties of quantum states as resources. Spekkens co-edited the book *Quantum Theory: Informational Foundations and Foils*. He was awarded the Birkhoff-von Neumann Prize of the International Quantum Structures Association in 2008, and won first prize in the 2012 Foundational Questions Institute (FQXi) essay contest, "Questioning the Foundations: Which of Our Assumptions are Wrong?"

Paul Steinhardt (PhD Harvard University, 1978) is the Daniel Family Richard P. Feynman Chair in Theoretical Physics at Perimeter Institute (Visiting) and the Albert Einstein Professor in Science at Princeton University, where he is also the Director of the Princeton Center for Theoretical Science. Steinhardt's research spans problems in particle physics, astrophysics, cosmology, condensed matter physics, and geoscience. He is one of the original architects of the inflationary theory of the universe, having constructed the first viable models and shown they can generate density variations that could seed galaxy formation. He was also the first to show that quantum effects make inflation eternal, which ultimately leads to a multiverse. With Neil Turok, he later developed the "cyclic theory" of the universe, which proposes that the universe underwent repeated periods of contraction and expansion punctuated by a big bounce; the theory generates similar density variations, but avoids the multiverse and its associated problems. With Anna Ijjas, he recently showed that it is possible to have a classically stable, non-singular bounce from contraction to expansion. He is also known for his work on dark energy and dark matter, including theories of "quintessence" and self-interacting dark matter. In condensed matter physics, Steinhardt invented the theoretical concept of quasicrystals with his student Dov Levine, and continues to work to illuminate many of their unique mathematical and physical properties. More recently, he organized a team that discovered the first natural quasicrystal and later established its origin by leading an expanded team on a geological expedition to the Kamchatka Peninsula in 2011. He is co-inventor of the first three-dimensional icosahedral photonic quasicrystal, along with a new class of photonic materials called hyperuniform disordered solids.

Natalia Toro (PhD Harvard University, 2007) joined Perimeter in 2010 after completing a postdoctoral fellowship at the Stanford Institute for Theoretical Physics. Toro has developed a framework for few-parameter models of possible new physics signals and has played a major role in integrating new techniques, called "on-shell effective theories," into the program of searches at the Compact Muon Solenoid experiment at the Large Hadron Collider at CERN. She is an expert in the study of dark forces that couple very weakly to ordinary matter and is co-spokesperson for APEX, an experiment searching for such forces at the Thomas Jefferson National Accelerator Facility. With Philip Schuster, she was awarded the 2015 New Horizons in Physics Prize by the Breakthrough Prize Foundation.

Guifre Vidal (PhD University of Barcelona, 1999) joined Perimeter's faculty in 2011 from the University of Queensland in Brisbane, where he was a Professor in the School of Mathematics and Physics. Previously, he had been a postdoctoral fellow at the University of Innsbruck and at the California Institute of Technology. Vidal works at the interface of quantum information, condensed matter physics, and quantum field theory. He develops tensor network algorithms to compute ground states of quantum many-body systems, and has proposed a modern formulation of the renormalization group, based on quantum circuits and entanglement. He is currently developing non-perturbative tools for strongly interacting quantum fields, and exploring the use of tensor networks in holography. His past honours include a European Union Marie Curie Fellowship, a Sherman Fairchild Foundation Fellowship, and an Australian Research Council Federation Fellowship.

Pedro Vieira (PhD École Normale Supérieure and the Theoretical Physics Center at the University of Porto, 2008) is the Clay Riddell Paul Dirac Chair in Theoretical Physics at Perimeter Institute, where he has been a faculty member since 2009. Prior to that, he was a Junior Scientist at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) from 2008 to 2009. Vieira's research concerns the development of new mathematical techniques for gauge and string theories, ultimately aiming at the solution of a realistic four-dimensional gauge theory. His research interests also include the AdS/CFT correspondence, theoretical calculations of scattering amplitudes, and correlation functions in interacting quantum field theories. In 2015, he was awarded both a Sloan Research Fellowship and the Gribov Medal of the European Physical Society.

Xiao-Gang Wen (PhD Princeton University, 1987) joined Perimeter's faculty in 2012 as the BMO Financial Group Isaac Newton Chair in Theoretical Physics. Widely recognized as one of the world's leaders in condensed matter theory, he pioneered the new paradigm of quantum topological order, used to describe phenomena from superconductivity to fractionally charged particles, and he has invented many new mathematical formalisms. Wen authored the textbook *Quantum Field Theory of Many-Body Systems: From the Origin of Sound to an Origin of Light and Electrons*. He was previously a Distinguished Moore Scholar at the California Institute of Technology and the Cecil and Ida Green Professor of Physics at the Massachusetts Institute of Technology, as well as one of Perimeter's own Distinguished Visiting Research Chairs. He is also a Fellow of the American Physical Society.

ASSOCIATE FACULTY

Niayesh Afshordi (PhD Princeton University, 2004) is jointly appointed with the University of Waterloo. Previously, he was the Institute for Theory and Computation Fellow at the Harvard-Smithsonian Center for Astrophysics (2004-07) and a Distinguished Research Fellow at Perimeter Institute (2008-09). Afshordi began his appointment as an associate faculty member in 2009. He specializes in interdisciplinary problems in fundamental physics, astrophysics, and cosmology. Among his honours, Afshordi has received a Discovery Accelerator Supplement from the Natural Sciences and Engineering Research Council of Canada, an Early Researcher Award from the Ontario Ministry of Research and Innovation, and the Vainu Bappu Gold Medal from the Astronomical Society of India. He also won third prize in the 2015 Buchalter Cosmology Prize of the American Astronomical Society.

Alexander Braverman (PhD Tel Aviv University, 1998) joined Perimeter in July 2015, jointly appointed with the University of Toronto. He was previously a faculty member at Brown University (2004-15) and held lecturer positions at Harvard University (2000-04) and the Massachusetts Institute of Technology (1997-99). Braverman specializes in a number of areas with applications to mathematical physics, including algebraic geometry, representation theory, number theory, and the geometric Langlands program. He has been a Clay Mathematics Institute Prize Fellow and a Simons Fellow in Mathematics.

Avery Broderick (PhD California Institute of Technology, 2004) began a joint appointment with Perimeter and the University of Waterloo in 2011. He previously held postdoctoral positions at the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics (2004-07) and the Canadian Institute for Theoretical Astrophysics (2007-11). Broderick is an astrophysicist with broad research interests, ranging from how stars form to the extreme physics in the vicinity of white dwarfs, neutron stars, and black holes. He has recently been part of an international effort to produce and interpret horizon-resolving images of supermassive black holes, studying how black holes accrete matter, launch the ultra-relativistic outflows observed, and probe the nature of gravity in their vicinity.

Alex Buchel (PhD Cornell University, 1999) is jointly appointed with Western University. Before joining Perimeter's faculty in 2003, he held research positions at the Institute for Theoretical Physics at the University of California, Santa Barbara (1999-2002), and the Michigan Center for Theoretical Physics at the University of Michigan (2002-03). Buchel's research efforts focus on understanding the quantum properties of black holes and the origin of our universe, as described by string theory, as well as developing analytical tools that could shed new light on strong interactions of subatomic particles. In 2007, he was awarded an Early Researcher Award from the Ontario Ministry of Research and Innovation.

Raffi Budakian (PhD University of California, Los Angeles, 2000) joined Perimeter in 2014, jointly appointed with the Institute for Quantum Computing (IQC) at the University of Waterloo. He also holds the Nanotechnology Endowed Chair in Superconductivity at IQC and the Waterloo Institute for Nanotechnology. Budakian previously held a faculty position at the University of Illinois at Urbana-Champaign and research positions at the University of California, Los Angeles, and the IBM Almaden Research Center in San Jose. He is an experimental condensed matter physicist whose research focuses on developing ultra-sensitive spin detection techniques for single spin imaging and quantum readout. In 2005, Budakian won a World Technology Award for his work in the detection and manipulation of quantum spins.

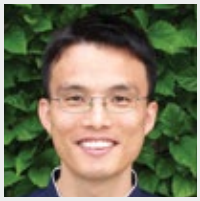
Cliff Burgess (PhD University of Texas at Austin, 1985) joined Perimeter's faculty as an associate member in 2004 and was jointly appointed to McMaster University's faculty in 2005. Prior to that, he was a Member in the School of Natural Sciences at the Institute for Advanced Study in Princeton and a faculty member at McGill University. Over two decades, Burgess has applied the techniques of effective field theory to high energy physics, nuclear physics, string theory, early-universe cosmology, and condensed matter physics. With collaborators, he developed leading string theoretic models of inflation that provide its most promising framework for experimental verification. Burgess' recent honours include a Killam Fellowship, Fellowship of the Royal Society of Canada, and the CAP-CRM Prize in Theoretical and Mathematical Physics.

David Cory (PhD Case Western Reserve University, 1987) joined Perimeter in 2010 and is jointly appointed as a Professor of Chemistry at the University of Waterloo and Deputy Director of Research at the Institute for Quantum Computing. He was previously a Professor of Nuclear Science and Engineering at the Massachusetts Institute of Technology. Since 1996, Cory has been exploring the experimental challenges of building small quantum processors based on nuclear spins, electron spins, neutrons, persistent current superconducting devices, and optics. In 2010, he was named the Canada Excellence Research Chair in Quantum Information Processing. Cory is the Principal Investigator of the recently awarded $144 million Transformative Quantum Technologies program, with $76 million in funding from the Canada First Research Excellence Fund. He chairs the advisory committee for the Quantum Information Processing program at the Canadian Institute for Advanced Research, and he is a Fellow of the American Physical Society and a Fellow of the Royal Society of Canada.

James Forrest (PhD University of Guelph, 1994) joined Perimeter in 2014 as the Institute's Academic Programs Director and an associate faculty member. He is jointly appointed at the University of Waterloo, where he's been a professor since 2000. His research focuses on the physics of soft matter on the nanoscale, with particular emphasis on polymers and proteins, glass transition in confined geometry, and surface and interfacial properties of polymers. Among his many honours, Forrest is a Fellow of the American Physical Society and co-recipient of the 2013 Brockhouse Medal of the Canadian Association of Physicists.

Matthew Johnson (PhD University of California, Santa Cruz, 2007) began a joint appointment with Perimeter and York University in 2012. Prior to that, he was a Moore Postdoctoral Scholar at the California Institute of Technology and a postdoctoral researcher at Perimeter. Johnson is a theoretical cosmologist, whose interdisciplinary research seeks to understand how the universe began, how it evolved, and where it is headed. Johnson has made contributions to fields ranging from inflationary cosmology and string theory to numerical relativity and cosmic microwave background radiation data analysis. His research has attracted competitive funding from the Natural Sciences and Engineering Research Council of Canada, the Foundational Questions Institute, and the New Frontiers in Astronomy and Cosmology grant program administered by the University of Chicago.

Raymond Laflamme (PhD University of Cambridge, 1988) is a founding faculty member of Perimeter Institute and founding Director of the Institute for Quantum Computing, where he is jointly appointed. He held research positions at the University of British Columbia and Peterhouse College, University of Cambridge, before moving to the Los Alamos National Laboratory in 1992, where his interests shifted from cosmology to quantum computing. Since the mid-1990s, Laflamme has elucidated theoretical approaches to quantum error correction and in turn implemented some in experiments. Laflamme has been Director of the Quantum Information Processing program at the Canadian Institute for Advanced Research (CIFAR) since 2003. He is a Fellow of CIFAR, the American Physical Society, the Royal Society of Canada, and the American Association for the Advancement of Science, and holds the Canada Research Chair in Quantum Information. With colleagues, he founded Universal Quantum Devices, a start-up commercializing spin-offs of quantum research.



Sung-Sik Lee (PhD Pohang University of Science and Technology, 2000) joined Perimeter in 2011 in a joint appointment with McMaster University, where he is an Associate Professor. He previously worked as a postdoctoral researcher at the Pohang University of Science and Technology, the Massachusetts Institute of Technology, and the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara. Lee's research focuses on strongly interacting quantum many-body systems, quantum field theory, and the AdS/CFT correspondence. His recent work has included low energy effective field theories for non-Fermi liquids and construction of holographic duals for general quantum field theories based on quantum renormalization group.

Roger Melko (PhD University of California, Santa Barbara, 2005) joined Perimeter in 2012, while retaining his appointment with the University of Waterloo, where he has been since 2007. Prior to that, he was a Wigner Fellow at Oak Ridge National Laboratory (2005-07). Melko is a condensed matter theorist who develops new computational methods and algorithms to study strongly correlated many-body systems, focusing on emergent phenomena, ground state phases, phase transitions, quantum criticality, and entanglement. Among his honours, he has received the Herzberg Medal from the Canadian Association of Physicists, the Young Scientist Prize in Computational Physics from the International Union of Pure and Applied Physics, an Early Researcher Award from the Ontario Ministry of Research and Innovation, and a Canada Research Chair in Computational Quantum Many-Body Physics (Tier 2).

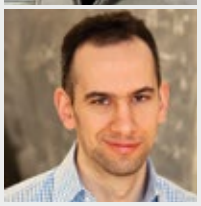
Michele Mosca (DPhil University of Oxford, 1999) is jointly appointed with the Institute for Quantum Computing (IQC) at the University of Waterloo. He is a founding member of Perimeter Institute, as well as co-founder of IQC. He is also a Professor in the Department of Combinatorics and Optimization of the University of Waterloo's Faculty of Mathematics, and the co-founder and Director of CryptoWorks21, an NSERC-funded training program in quantum-safe cryptography. Mosca co-founded the ETSI-IQC workshop series in quantum-safe cryptography, which brings together a broad range of stakeholders working toward globally standardized quantum-safe cryptography, and co-founded evolutionQ Inc. in order to support organizations as they evolve their quantum-vulnerable systems and practices to quantum-safe ones. His research interests include quantum computation and cryptographic tools that will be safe against quantum technologies, and he is globally recognized for his drive to help academia, industry, and government prepare our cyber systems to be safe in an era with quantum computers. Mosca co-authored the respected textbook *An Introduction to Quantum Computing*. He has received numerous academic honours, including Canada's Top 40 Under 40 award (2010), the Premier's Research Excellence Award (2000-05), Fellow of the Canadian Institute for Advanced Research since 2010, Canada Research Chair in Quantum Computation (2002-12), and University Research Chair at the University of Waterloo (2012-present).

Markus Mueller (PhD Technical University of Berlin, 2007) joined Perimeter in July 2015, jointly appointed with Western University, where he holds the Canada Research Chair in the Foundations of Physics (Tier 2). Prior to that, he was a Junior Research Group Leader at the Institute for Theoretical Physics at the University of Heidelberg, and held postdoctoral positions at Perimeter Institute, the University of Potsdam, and the Max Planck Institute for Mathematics in the Sciences. Mueller is a mathematical physicist working in quantum information and quantum foundations, with particular interest in statistical physics, generalized probabilistic theories, and algorithmic information theory. In 2016, he won the Birkhoff-von Neumann Prize of the International Quantum Structures Association for outstanding scientific achievements in the field of quantum structures.

Ue-Li Pen (PhD Princeton University, 1995) joined Perimeter in 2014. He is jointly appointed with the Canadian Institute for Theoretical Astrophysics at the University of Toronto, where he has been a professor since 1998 and is currently Interim Director. Prior to that, he held fellowships at Princeton University (1994-95) and Harvard University (1995-98). Pen is a theoretical astrophysicist who studies systems where basic physical effects can be isolated from astronomical complexities. His research interests include 21cm cosmology, HPC simulations, gravitational waves, pulsars, and radio interferometry. Among his many honours, Pen is a Senior Fellow of the Canadian Institute for Advanced Research in the Cosmology and Gravity program.

Maxim Pospelov (PhD Budker Institute of Nuclear Physics, 1994) is jointly appointed with the University of Victoria and became an associate faculty member at Perimeter in 2004. He previously held research positions at the University of Quebec at Montreal, the University of Minnesota, McGill University, and the University of Sussex. Pospelov works in the areas of particle physics and cosmology.

Itay Yavin (PhD Harvard University, 2006) began a joint appointment with Perimeter and McMaster University in 2011. Previously, he was a Research Associate at Princeton University and a James Arthur Postdoctoral Fellow at New York University. Yavin's research focuses on particle physics and the search for physics beyond the Standard Model. Among his recent proposals is a new experiment to search for new particles with fractional charges at the Large Hadron Collider. He is now leading a collaboration looking to make this experiment a reality.



SENIOR MANAGEMENT

Managing Director and Chief Operating Officer
Michael Duschenes

Senior Director of Finance and Operations
Stefan Pregelj

Director of Academic Programs
James Forrest

Director of Advancement
Heather Clark

Director of Communications and Media
Colin Hunter

Director of Educational Outreach
Greg Dick

Director of External Relations and Public Affairs
John Matlock

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Sue Scanlan

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Director of Publications
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Senior Research Affiliate
Steve MacLean

Senior Researcher
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Shuo Yang
Beni Yoshida
Jie Zhou

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Natacha Altamirano (University of Waterloo, Niayesh Afshordi)
Andrzej Banburski (University of Waterloo, Lee Smolin)
Chenfeng Bao (University of Waterloo, Neil Turok)
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Mansour Karami (University of Waterloo, Niayesh Afshordi/Avery Broderick)
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Joel Lamy-Poirier (University of Waterloo, Davide Gaiotto)
Tian Lan (University of Waterloo, Xiao-Gang Wen)
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Gabriel Magill (McMaster University, Itay Yavin)
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Jonah Miller (University of Guelph, Erik Schnetter)
Sebastian Mizera (University of Waterloo, Freddy Cachazo/Bianca Dittrich)
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Guojun Zhang (University of Waterloo, Freddy Cachazo)
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PSI STUDENTS, 2015/16 (country of origin)

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Jens Boos (Germany)
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Peter Cha (USA)
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Leilee Chojnacki (Ireland)
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Kaustubh Agashe, University of Maryland, College Park

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Paolo Aluffi, Florida State University

Marcelo Alvarez, University of Toronto/Canadian Institute for Theoretical Astrophysics (CITA)

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James Bardeen*, University of Washington

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Ganapathy Baskaran*, Institute of Mathematical Sciences, Chennai

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Sebastian Baum, Nordic Institute for Theoretical Physics (Nordita)

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Lasha Berezhiani, University of Pennsylvania

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Michel Buck, Imperial College London

Mathew Bullimore, Institute for Advanced Study (IAS)

Alexander Bullivant, University of Leeds

Fiona Burnell, University of Minnesota

Daniel Butter, National Institute for Subatomic Physics (Nikhef), Netherlands

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Sylvain Carrozza, Aix-Marseille University/Centre of Theoretical Physics (CPT)

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Raffaele D'Agnolo, Institute for Advanced Study (IAS)

Liang Dai, Institute for Advanced Study (IAS)

Xi Dai, Chinese Academy of Sciences/Institute of Physics

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Arundhati Dasgupta, University of Lethbridge

Anne Davis, University of Cambridge

Jan de Boer, University of Amsterdam

Adrian Del Maestro, University of Vermont

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Sanjib Dey, University of Montreal

Lorenzo Di Pietro, Weizmann Institute of Science

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Xi Dong, Institute for Advanced Study (IAS)

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William East, Stanford University

Andreas Eberlein, Harvard University

David Edwards, University of Edinburgh

Lior Eldar, Massachusetts Institute of Technology (MIT)

Zachary Elgood, McGill University

Chris Elliott, Northwestern University

Joseph Emerson, University of Waterloo/Institute for Quantum Computing (IQC)

Netta Engelhardt, University of California, Santa Barbara

Oleg Evnin, Chulalongkorn University

Gregory Falkovich, Weizmann Institute of Science

Shane Farnsworth, Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Teng Fei, Massachusetts Institute of Technology (MIT)

SCIENTIFIC VISITORS (CONTINUED)

Benjamin Feintzeig, University of California, Irvine

Dmitri Feldman, Brown University

Simone Ferraro, University of California, Berkeley

Christopher Ferrie, University of Sydney

Andrew Ferris, Institute of Photonic Sciences (ICFO)

Angelika Fertig, Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Cecilia Flori, Imperial College London

Simon Foreman, Stanford University

Francois Foucart, University of California, Berkeley/Lawrence Berkeley National Laboratory (LBNL)

John Francis, Northwestern University

Anna Francuz, Jagiellonian University

Katherine Freese*, University of Michigan

Tobias Fritz**, Max Planck Institute for Mathematics in the Sciences

Andrei Frolov, Simon Fraser University

John Fuini, University of Washington

Akira Furusaki, RIKEN Center for Emergent Matter Science

Wenbo Fu, Harvard University

Ryuichi Fujita, University of Lisbon/Higher Technical Institute (IST)

Dmitriy Galakhov, Rutgers University

Jim Garrison, University of California, Santa Barbara

Jerome Gauntlett**, Imperial College London

Jack Gegenberg, University of New Brunswick

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Efrat Gerchkovitz, Weizmann Institute of Science

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Dongwook Ghim, Seoul National University

Steffen Gielen, Imperial College London

Lisa Glaser, University of Nottingham

Vera Gluscevic, Institute for Advanced Study (IAS)

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Christopher Granade, University of Sydney

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Nikolay Gromov, King's College London

Brajesh Gupt, Pennsylvania State University

Yelena Guryanova, University of Bristol

Owen Gwilliam, Max Planck Institute for Mathematics

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Roland Haas, California Institute of Technology (Caltech)

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Ian Hatton, McGill University

Johannes Hauschild, Max Planck Institute for the Physics of Complex Systems

Hirotaka Hayashi, Autonomous University of Madrid (UAM)/Spanish National Research Council (CSIC)

Patrick Hayden*, Stanford University

Song He, Chinese Academy of Sciences/Institute of Theoretical Physics

Yin-Chen He, Max Planck Institute for the Physics of Complex Systems

Ben Heidenreich, Harvard University

Luke Helt, Macquarie University

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Richard Hill, University of Chicago

Renée Hložek, University of Toronto

Jason Hogan, Stanford University

Matthijs Hogervorst, Stony Brook University

Richard Holman, Carnegie Mellon University

Anson Hook, Institute for Advanced Study (IAS)

Veronika Hubeny, University of California, Davis

Jay Hubisz, Syracuse University

Viqar Husain, University of New Brunswick

Kyusung Hwang, University of Toronto

Akishi Ikeda, Kavli Institute for the Physics and Mathematics of the Universe

Derek Inman, University of Toronto/Canadian Institute for Theoretical Astrophysics (CITA)

Ahmed Ismail, University of Illinois at Chicago

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Akash Jain, Durham University

Bhuvnesh Jain, University of Pennsylvania

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Daan Janssen, Radboud University, Nijmegen

Michael Jarret, University of Maryland, College Park

Anna Jencova, Slovak Academy of Sciences/ Mathematical Institute

Wenjie Ji, Massachusetts Institute of Technology (MIT)

Shaojian Jiang, University of British Columbia

David Jordan, University of Edinburgh

Ian Jubb, Imperial College London

Shamit Kachru*, Stanford University

Vardan Kaladzhyan, Institute of Theoretical Physics, Saclay

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Yong-Baek Kim, University of Toronto

Darsh Kodwani, University of Toronto

Liang Kong, Harvard University

Gregory Korchemsky, Institute of Theoretical Physics, Saclay

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Marius Krumm, Western University

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Astrid Lamberts, California Institute of Technology (Caltech)

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Edoardo Lauria, University of Leuven

Ian Le, University of Chicago

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Junhyun Lee, Harvard University

Rob Leigh, University of Illinois at Urbana-Champaign

Si Li**, Tsinghua University

Zhou Li, RIKEN Center for Emergent Matter Science

Andrew Liddle, University of Edinburgh

Siqi Liu, University of Toronto

Etera Livine**, École Normale Supérieure de Lyon

Renate Loll*, Radboud University, Nijmegen

John Lombard, University of Washington

Michael Lubasch, Max Planck Institute for Quantum Optics

Alex Lupsasca, Harvard University

Yiqiu Ma, California Institute of Technology (Caltech)

Caio Macedo, University of Lisbon/Higher Technical Institute (IST)

Mohammad Maghrebi, University of Maryland, College Park

Joao Magueijo, Imperial College London

Gautam Mandal, Tata Institute of Fundamental Research

Matilde Marcolli*, California Institute of Technology (Caltech)

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Dinakar Muthiah, University of Alberta

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Kantaro Ohmori, University of Tokyo

Ognyan Oreshkov, Free University of Brussels

Daniele Oriti, Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

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Mukund Rangamani, Durham University

Bharat Ratra, Kansas State University

Michele Redi, National Institute for Nuclear Physics (INFN), Italy

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Katarzyna Rejzner, University of York

Jing Ren, University of Toronto

Cecile Renault, Grenoble Alpes University/ Laboratory of Subatomic Physics and Cosmology

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Daniel Roberts, Massachusetts Institute of Technology (MIT)

Mauricio Romo, Institute for Advanced Study (IAS)

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Rachel Rosen, Columbia University

Denis Rosset, University of Geneva

Shinsei Ryu, University of Illinois at Urbana-Champaign

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Bernd Schroers, Heriot-Watt University

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Amit Sever, Tel Aviv University

Sarah Shandera, Pennsylvania State University

Shu-Heng Shao, Harvard University

Richard Shaw, University of British Columbia

Ian Shoemaker, Pennsylvania State University

Kris Sigurdson**, University of British Columbia

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Anze Slosar, Brookhaven National Laboratory

Fedor Smirnov, University of Paris VI

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Dam Thanh Son*, University of Chicago

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James Sully, SLAC National Accelerator Laboratory

Sumati Surya, Raman Research Institute

Maciej Szczesny, Boston University

Akinori Tanaka, RIKEN

Hiro Tanaka, Harvard University

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Wilke van der Schee, Massachusetts Institute of Technology (MIT)

Ken Van Tilburg, Stanford University

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Ruben Verresen, Max Planck Institute for the Physics of Complex Systems

Frank Verstraete*, University of Vienna and Ghent University

Thomas Vidick**, California Institute of Technology (Caltech)

Francesca Vidotto, Radboud University, Nijmegen

Salvatore Vitale, Massachusetts Institute of Technology (MIT)

Zvonimir Vlah, Stanford University

Curt Von Keyserlingk, Princeton University

Christophe Vuillot, RWTH Aachen University

Daniel Wagner Fonteles Alves, Brazilian Center for Research in Physics (CBPF)

Aron Wall, Institute for Advanced Study (IAS)

Matthew Walters, Boston University

Qing-Rui Wang, Tsinghua University

Zhenghan Wang*, Microsoft Research Station Q

James Weatherall, University of California, Irvine

Silke Weinfurtner, University of Nottingham

Christopher Wever, National Centre of Scientific Research (NCSR) “Demokritos”/Institute of Nuclear Physics

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Michael Williams, Massachusetts Institute of Technology (MIT)

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Guang Yang, RIKEN Center for Emergent Matter Science

Kun Yang, Florida State University

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Haoran Yu, University of Toronto/Canadian Institute for Theoretical Astrophysics (CITA)

Ellis Yuan, Institute for Advanced Study (IAS)

Matias Zaldarriaga*, Institute for Advanced Study (IAS)

Alexander Zamolodchikov*, Stony Brook University

Gabi Zafrir, Technion – Israel Institute of Technology

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Gufang Zhao, University of Massachusetts, Amherst

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Norbert Lütkenhaus, University of Waterloo/IQC
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A. Hamed Majedi, University of Waterloo/IQC
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Robert Mann, University of Waterloo
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Volodya Miransky, Western University
Ruxandra Moraru, University of Waterloo
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Amanda Peet, University of Toronto
Alexander Penin, University of Alberta
Harald Pfeiffer, University of Toronto/CITA
Marco Piani, University of Waterloo/IQC
Levon Pogosian, Simon Fraser University
Dmitri Pogosyan, University of Alberta
Eric Poisson, University of Guelph
Erich Poppitz, University of Toronto
David Poulin, University of Sherbrooke
Robert Raussendorf, University of British Columbia
Ben Reichardt, University of Southern California
Kevin Resch, University of Waterloo/IQC
Adam Ritz, University of Victoria
Pierre-Nicholas Roy, University of Waterloo
Moshe Rozali, University of British Columbia
Barry Sanders, University of Calgary
Kristin Schleich, University of British Columbia
Douglas Scott, University of British Columbia
Sanjeev Seahra, University of New Brunswick
Peter Selinger, Dalhousie University
Gordon Semenoff, University of British Columbia
John Sipe, University of Toronto
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John Watrous, University of Waterloo
Steve Weinstein, University of Waterloo
Lawrence Widrow, Queen's University
Don Witt, University of British Columbia
Bei Zeng, University of Guelph

CONFERENCES AND WORKSHOPS, 2015/16

Cosmic Flows (and Other Novelties on Large Scales)
August 10-12, 2015

The Unruh Fest: A Celebration in Honour of Bill Unruh's 70th Birthday
August 13-14, 2015

Quantum Information in Quantum Gravity II
August 17-21, 2015

Mathematica Summer School 2015
August 24-29, 2015

Noncommutative Geometry and Physics
September 12, 2015

Renormalization in Background Independent Theories: Foundations and Techniques
September 28-October 2, 2015

Condensed Matter Physics and Topological Field Theory
October 21-24, 2015

PI-UIUC Joint Workshop on Strongly Correlated Quantum Many-Body Systems 2015
November 5-6, 2015

PI Day
November 26, 2015

Feedback over 44 Orders of Magnitude: From Gamma-Rays to the Universe
March 14-16, 2016

Symplectic Duality and Gauge Theory
April 7-10, 2016

Deformation Quantization of Shifted Poisson Structures
April 18-22, 2016

4 Corners Southwest Ontario Condensed Matter Physics Symposium 2016
May 12, 2016

Cosmological Frontiers in Fundamental Physics 2016
June 14-17, 2016

Concepts and Paradoxes in a Quantum Universe
June 20-24, 2016

Time in Cosmology
June 27-30, 2016

It from Qubit Summer School
July 18-29, 2016

ACADEMIC SPONSORSHIPS, 2015/16

Perimeter sponsored the following off-site conferences and workshops:

"11th Great Lakes Cosmology Workshop: Cosmology and Galaxies," McMaster University
"15th Canadian Summer School on Quantum Information (CSSQI 2015)," Fields Institute for Research in Mathematical Sciences/ University of Toronto
"16th Canadian Conference on General Relativity and Relativistic Astrophysics (CCGRRA 16)," Simon Fraser University
"The 41st International Symposium on Symbolic and Algebraic Computation (ISSAC 2016)," Wilfrid Laurier University
"Discoveries at the Dawn of LHC Run 2," TRIUMF
"Fundamental Science and Society," International Center for Interdisciplinary Science and Education (ICISE), Vietnam
"Information-Theoretic Interpretations of Quantum Mechanics," Western University
"INTRIQ 2015," University of Sherbrooke
"Lake Louise Winter Institute 2016," University of Alberta
"Mann Fest," University of Waterloo
"QIP 2016," Institute for Quantum Science and Technology/University of Calgary
"Relativistic Quantum Information – North 2016," Institute for Quantum Computing/University of Waterloo
"Theory Canada 11," Carleton University
"Women in Physics Canada 2016," University of Saskatchewan
"Workshop on Quantum Groups in Quantum Gravity," University of Waterloo
"Workshop on Quantum Marginals and Numerical Ranges," University of Guelph

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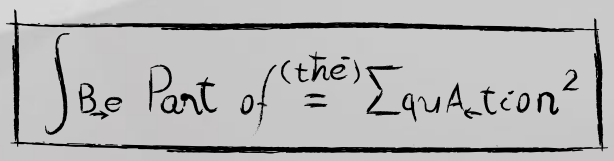
– Stephen Hawking,
Emeritus Lucasian Professor,
University of Cambridge



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31 Caroline St. N. | Waterloo | Ontario
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