STEP INSIDE THE PERIMETER

a year in review: 2014/15

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

IT'S A BIG UNIVERSE.

FORTUNATELY, WE HAVE BIG IDEAS.

"These are amazing times for physics. They're so amazing that many of us believe that physics is poised for a new revolution."

– Perimeter Director Neil Turok

Perimeter Institute (PI) is one of Canada's great research success stories. It is an innovative, world-leading centre of research in the lowest-cost, highest-return area of science: fundamental physics. Perimeter is training the next generation of physics pioneers, and sharing the power of scientific discovery throughout Ontario, across Canada, and around the world.

Through visionary public and private support, sustained focus, and sound strategy, just 15 years after its founding, Perimeter is ranked among the top theoretical physics institutes globally.

Today's theoretical physics is tomorrow's technology. In the 20th century, trillions of dollars of new wealth, and millions of jobs, were created from breakthroughs in fundamental physics that led to transistors, computers, MRI, GPS, smartphones, and much more.

Right now, physics is entering its most exciting period in decades. Perimeter scientists are at the forefront of research that will shape our future.

THE RESEARCH: FROM THE QUANTUM TO THE COSMOS

How did the universe begin? What is it made of? What is dark energy? How do we understand and harness the quantum world?

Perimeter researchers tackle big questions – forging new ideas about the nature of the universe – from space and time to matter and information. This year, PI scientists published 365 papers in high-impact journals – many past PI papers have gone on to become landmarks in the field.

Collaboration fuels discovery. With interdisciplinary research networks spanning the globe, Perimeter scientists connect with top institutions and experiments worldwide.

A few highlights this year included:

- **Robert Spekkens** and colleagues at the Institute for Quantum Computing (IQC) showed some correlations in quantum circuits imply causation, with implications for quantum computing.
- **Asimina Arvanitaki** re-imagined black holes as the universe's particle accelerators, work which may contribute to the discovery of a long-theorized particle.
- **Kendrick Smith** and colleagues in the Planck satellite collaboration showed that the primordial universe was astonishingly uniform.
- **Kevin Costello** is setting new mathematical foundations for quantum field theories.
- **Luis Lehner** and collaborators revealed that black holes can, surprisingly, behave like a turbulent fluid.
- **Pedro Vieira** brought the exact solution of quantum field theories into reach for the first time.
- **Avery Broderick** and colleagues are taking the first picture of the event horizon of the black hole at the centre of our galaxy.
- **Latham Boyle** and colleagues identified a new kind of crystal defined not by its structure, but by its internal motion.

"People have always looked out into the sky and wondered, 'What's out there? What's it all about?' These are some of the oldest, most self-motivating questions in science."

– Kendrick Smith, cosmologist, PI faculty member, and member of the Planck satellite and WMAP experiment teams

THEORY MEETS EXPERIMENT

Theory and experiment drive each other, revealing new paths. Perimeter researchers help plan, design, and analyze data from some of the most sophisticated experiments on Earth, including:

- The Institute for Quantum Computing (IQC), probing and harnessing the quantum world
- The Laser Interferometer Gravitational-Wave Observatory (LIGO), testing key predictions of general relativity
- The Large Hadron Collider (LHC), the world's most powerful accelerator, seeking matter's tiniest constituents
- The Event Horizon Telescope (EHT), imaging a black hole's event horizon for the first time
- The Canadian Hydrogen Intensity Mapping Experiment (CHIME), revealing the universe's 3D structure
- SNOLAB, the underground neutrino lab that has enabled Nobel-winning discoveries

OUR EMERGING QUANTUM FUTURE

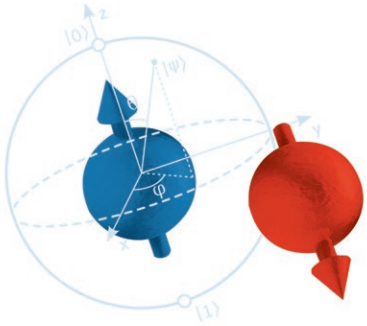
"Together, Perimeter and the Institute for Quantum Computing are an incredibly powerful combination."

– Raymond Laflamme, Executive Director, Institute for Quantum Computing and Perimeter associate faculty member

Quantum science is driving amazing new technologies – from quantum computers to superconducting materials to ultra-precise quantum sensors. They are expected to see widespread application and spark 21st century innovation and prosperity.

Perimeter is the wellspring of an emerging quantum ecosystem in Waterloo Region – known as Quantum Valley – spanning theoretical research, experimental labs, technology development, venture capital, and early-stage companies.

PI is helping ensure Ontario and Canada are at the forefront of the quantum revolution.



THE MOST POWERFUL SCIENTIFIC EQUIPMENT: THE HUMAN MIND

"This place is really about trying to make discoveries, so it means we all try to push ourselves, and each other."

– Philip Schuster, Perimeter faculty member and winner of the 2014 New Horizons Prize in Physics

The best way to spur breakthroughs is to bring brilliant people together. Perimeter assembles great minds, challenging them to pursue the most ambitious questions within a vibrant, collaborative environment.

Perimeter has become the world's largest independent centre for theoretical physics, a community of extraordinary minds with the freedom and focus to tackle the deepest questions.

In 2014/15, Perimeter's research community grew to include:

- 24 faculty (1 new full-time faculty, 1 new Visiting Chair this year)
- 17 associate faculty, jointly appointed with other Canadian institutions (3 new)
- 8 Perimeter Research Chairs (3 new)
- 44 Distinguished Visiting Research Chairs (4 new)
- 22 Visiting Fellows (8 new)
- 6 Emmy Noether Visiting Fellows, part of Perimeter's initiative to recruit and retain more women in physics
- 113 Affiliate members from across Canada (9 new)

In 2014/15, Perimeter scientists won 11 major awards. Natalia Toro and Philip Schuster shared the New Horizons Prize, while Pedro Vieira was awarded both the Gribov Medal of the European Physical Society and a Sloan Foundation Research Fellowship.

Perimeter was thrilled to congratulate Board member Art McDonald on sharing both the 2015 Nobel Prize in Physics and the 2015 Breakthrough Prize for his groundbreaking work on neutrinos as leader of SNOLAB.

"The calibre of people at Perimeter is going to lead to advancements that will change our nation, change our world, and help us understand the universe better."

– Harbir Chhina, Executive Vice-President of Oil Sands Development for Cenovus Energy

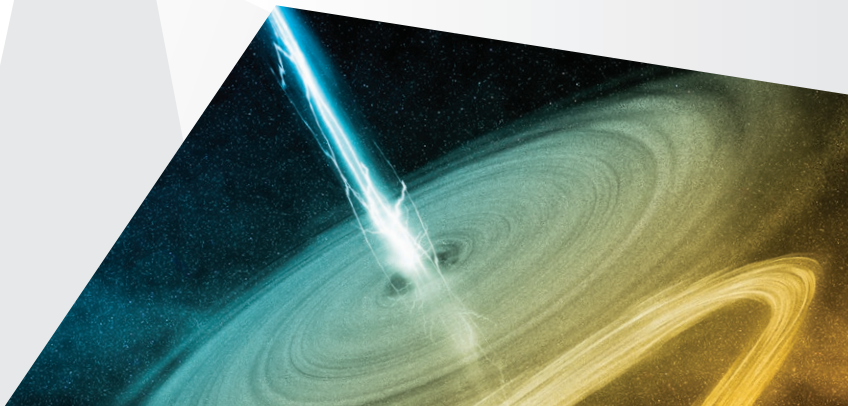
SEIZING OPPORTUNITY

Perimeter Research Chairs give outstanding scientists the resources to maximize their productivity and mentor emerging scientists. In 2014/15, supporters stepped forward to fund three new Perimeter Research Chairs:

- **Pedro Vieira** as the **Clay Riddell Paul Dirac Chair in Theoretical Physics**
- **Freddy Cachazo** as the **Gluskin Sheff Freeman Dyson Chair in Theoretical Physics**
- **Subir Sachdev** as the **Cenovus Energy James Clerk Maxwell Chair in Theoretical Physics (Visiting)**

Truly new ideas often fall outside established frameworks – yet they are exactly the ones which can most benefit from an intense, cross-disciplinary boost. Recognizing this, Perimeter launched several multi-year initiatives, which will gather emerging and senior scientists across fields to accelerate progress in these promising areas:

- **The Emergence of Spacetime**
- **Tensor Networks**
- **Black Hole Science**



TRAINING TOMORROW'S SCIENTIFIC LEADERS

"Perimeter's efforts are helping to shape today's female scientists into mentors for the next generation."

– Lauren Hayward Sierens, Perimeter associate graduate student

"It's unique in the world. There are so many people here doing so many different things. The possibilities for interaction are really exciting.

– Steffen Gielen, postdoctoral fellow

Young minds are the lifeblood of science. From across Canada and around the world, they are drawn by the opportunity to learn from, and work alongside, eminent senior scientists and rising stars on groundbreaking research.

Perimeter Scholars International (PSI) is a master's-level "physics boot camp" for exceptional young minds. Graduates pursue careers in research, high-tech industry, medicine, and beyond – some of the best stay for doctoral training. At the postdoctoral level, Perimeter offers unequalled research freedom, making it a coveted destination – each year, 700 apply for about 15 positions.

In 2014/15, Perimeter was home to 151 scientists-in-training:

- 59 postdoctoral fellows, the largest such group worldwide
- 42 PhD students
- 29 master's students attending Perimeter Scholars International, a one-year program run with the University of Waterloo
- 21 visiting graduate fellows

Perimeter is challenging the under-representation of women in physics through its Emmy Noether Initiatives, backed by the Emmy Noether Circle, prominent leaders who champion women in science. This year, they supported:

- 6 Emmy Noether Visiting Fellowships
- 4 master's and PhD students
- 200 female high school students at the annual Inspiring Future Women in Science event

perimeter scholars international™

EMMY NOETHER CIRCLE

THE PHYSICS WORLD CONVERGES HERE

"You can see all kinds of discussions going on in the corridor on the latest topics in physics, which is just what you hope would happen at a conference like this."

– Art McDonald, 2015 Nobel Laureate in Physics, Perimeter Board member

Perimeter has built a reputation for can't-miss conferences and workshops. In the wake of the BICEP2 claim of gravitational wave detection in 2014, for instance, PI was the first North American institution to gather experts to analyze it, raising doubts that were later validated.

This year's signature event, Convergence, brought 250 physicists from around the world to consider the field's deepest challenges and chart a path forward. Marquee public lectures celebrated Einstein and Emmy Noether. *Nature*, *Discovery News*, *Physics Today*, *Physics World*, and many others brought the excitement to wider audiences.

Virtually all scientific talks – including those from Convergence and PSI master's courses – are available online on the Perimeter Institute Recorded Seminar Archive (PIRSA). This year, over 82,000 viewers in 170 countries accessed them – making it a major digital resource for the global community.

In 2014/15, Perimeter:

- Held 15 cutting-edge conferences and workshops
- Hosted 873 scientists from around the world
- Co-hosted 8 joint workshops and conferences at Perimeter, with another 11 held off-site
- Presented 325 scientific talks, available online to the worldwide scientific community

Convergence was presented by BMO Financial Group.

PHYSICS AND BEYOND

Training in physics instills a formidable array of skills. Whether it's to pursue science or create start-ups, tomorrow's leaders will need deep, creative problem-solving abilities.

Many Perimeter alumni go on to become research scientists around the world; others contribute to a wide range of important fields, including:

- PhD student **Andrzej Banburski** developed mixed-reality systems with virtual reality pioneer Jaron Lanier at Microsoft Research.
- PSI grad **Lauren Hayward Sierens**, named as a young leader by *Maclean's* magazine, is doing superconductivity research at the Institute for Quantum Computing.
- PSI grad **Henry Reich** has over three million subscribers on his *MinutePhysics* YouTube channel, where he explains complex concepts for general audiences.
- Former Perimeter postdoc **Rowan Thomson** won the 2011 Polanyi Prize and is now the Canada Research Chair in Radiotherapy Physics, using her training in physics to help treat cancer.

WHO CARES ABOUT PHYSICS?

Curiosity doesn't have an age, gender, or postal code. People from all walks of life – moms and dads, entrepreneurs and academics, children and CEOs – are intrigued by our universe.

Perimeter's outreach efforts engage and inspire students and the public, and help build a new generation of scientific explorers.

This year, from the popular Perimeter Institute Public Lecture Series to the International Summer School for Young Physicists and monthly "Slice of PI" dispatches, Perimeter made science more accessible and relevant than ever.

BECAUSE THE FUTURE STARTS NOW

"I've learned how much I don't know, and I've realized that's not an obstacle. It encourages me to learn more."

– Lola Hourihane, 18, Dublin, Ireland, participant in 13th annual International Summer School for Young Physicists

Educational Outreach efforts at Perimeter stretch from the classroom to the cloud, featuring in-class teaching kits, a national teacher-training network, summer camps for students and educators, and global consultation on science education.

Perimeter's global network of educators spans over 30 countries, and has trained 15,000+ teachers to date. Every summer, the International Summer School for Young Physicists (ISSYP) brings exceptional young minds to Perimeter to live and breathe physics for two weeks – follow-up study shows it's often pivotal to choices about their future.

An exciting partnership launched this year with Ontario's Ministry of Education will support the creation of new materials to reach even more young minds: an integrated suite of materials for Grades 5-12 on science, technology, and math.

In 2014/15, Perimeter's Educational Outreach team:

- Reached more than 1 million Canadian students through in-class resources and programs
- Produced 3 new in-class modules: *Black Holes*, *The Physics of Innovation*, and *Contemporary Physics*
- Presented 130 workshops to 3,000 educators
- Gave 18 Physica Phantastica presentations to 2,400 Canadian students
- Brought 40 outstanding high school students – half Canadian, half international – to the 13th annual International Summer School for Young Physicists
- Shared cutting-edge pedagogy with Canadian and international high school teachers at EinsteinPlus, Perimeter's summer teacher training camp – they return home to train fellow educators, magnifying impact.

This year, RBC Foundation renewed its support of ISSYP as Presenting Partner for 2015 to 2017.

88% of teachers feel students value creativity, critical thinking, and communication more after using Perimeter resources.

BIG IDEAS: PERIMETER PUBLIC LECTURE SERIES

In person and online, large audiences come to Perimeter to be transported to the edge of research at the Institute's popular Public Lecture Series.

In 2014/15, Perimeter Institute presented eight public lectures to capacity crowds in the Mike Lazaridis Theatre of Ideas, with over 250,000 online viewers.

Talks ranged from the astonishing prospects of superconductors to interstellar voyaging and the "most wanted" particle – and they're all available for playback at perimeterinstitute.ca.

Perimeter's Public Lecture series was presented in 2014/15 by Sun Life Financial.

"This is what is happening in science right now. This is where the excitement is."

– Stacey Harvey, physics teacher and 2014 EinsteinPlus attendee

SHARING A POWERFUL STORY

Perimeter promotes engagement with science through print and digital media. The Institute's research and public events are covered by national and international media including *The New York Times*, *Nature*, *The Globe and Mail*, *Maclean's*, *Wired*, *The Guardian*, and more. In 2014/15:

- Monthly "Slices of PI," fun-yet-informative dispatches for science enthusiasts, reached millions on social media and were widely shared by popular online outlets.
- Viewership on PI's YouTube channel rose 119%, topping 500,000 video views.

SCIENTIFIC AMERICAN · nature · Forbes · NP · COSMOS THE SCIENCE OF EVERYTHING · THE GLOBE AND MAIL · tvo makes you think · theguardian · The New York Times · CBC · WIRED · MACLEAN'S · CBC NEWS

PERIMETER REACHED OVER 1 MILLION CANADIAN STUDENTS THIS YEAR

WHO'S WITH US?

Canada Ontario

BMO Financial Group

Krembil Foundation

ΣΝ/SNF Stavros Niarchos Foundation

The Riddell Family Charitable Foundation

cenovus energy

John Templeton Foundation
Supporting Science · Investing in the Big Questions

Gluskin Sheff

The Peter and Shelagh Godsoe Family Foundation

The Ira Gluskin and Maxine Granovsky Gluskin Charitable Foundation

Quantum Valley Investments

RBC Foundation

Scotiabank

The Bluma Appel Community Trust

The Scott Griffin Foundation

The Chamberlain Family Foundation

Hellenic Heritage Foundation

Sun Life Financial

MEMBERS OF PERIMETER LEADERSHIP CIRCLES

Emmy Noether Circle	Directors Circle	Accelerators Circle

Waterloo Region Record Community Partnerships Program

The Kitchener and Waterloo Community Foundation
- Musagetes Fund
- The John A. Pollock Family Fund

Deloitte.

TD

Toyota Motor Manufacturing Canada Inc.

Maplesoft
Mathematics · Modeling · Simulation

Beatrice Snyder Foundation

LINAMAR
Power to Perform

CHRISTIE

Google

"Are we on the verge of the next scientific and technological revolution? Those of us who invest in Perimeter Institute are betting that we are."

– Bill Downe, CEO of BMO Financial Group, the Presenting Sponsor of the Convergence conference and supporter of the BMO Financial Group Isaac Newton Chair at Perimeter Institute

Perimeter is funded through an innovative public-private partnership, which shares the opportunities and benefits of long-term investment in fundamental research. Independent reviews and audits demonstrate Perimeter's excellent return on investment.

Perimeter is fortunate to have strong, ongoing relationships with both public and private supporters in Ontario, across Canada, and around the world. Our valued partners ensure the Institute continues to attract top researchers to advance great science, train tomorrow's pioneers, and inspire a new generation of thinkers and innovators.

Perimeter is also seeking – and attracting – increased private support. Perimeter's volunteer Leadership Council and Emmy Noether Council champion Perimeter through their networks to widen the circle of supporters.

THANKS TO THE VISIONARIES

"Perimeter is philanthropy re-imagined: philanthropy as a long-range strategic investment."

– Mike Lazaridis,
Founder and Chair of the Board, Perimeter Institute

This marked the third year of five-year funding agreements with both the Government of Canada and the Province of Ontario. Perimeter continues to responsibly steward all public investments using best practices in financial management and to fulfill all reporting requirements.

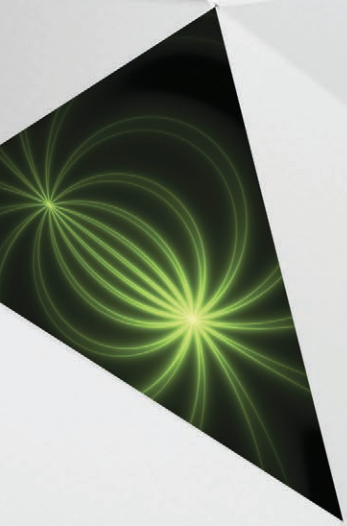
Researchers at Perimeter were awarded over $4.2 million in peer-reviewed research grants last year, while Ontario's Ministry of Education is supporting the development of integrated math, science, and technology resources for teachers.

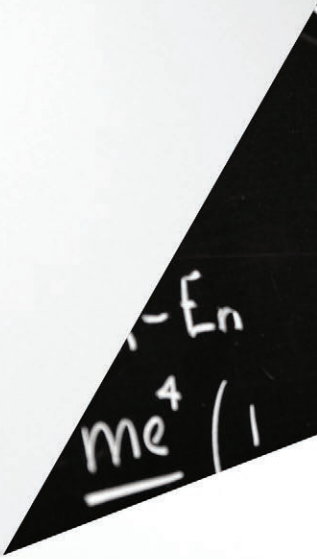
Perimeter's vision is to create the world's foremost centre for foundational theoretical physics, uniting public and private partners, and the world's best scientific minds, in a shared enterprise to achieve breakthroughs that will transform our future.

This year, Perimeter attracted new commitments from individuals, corporations, and foundations, including:

- $4 million from the Stavros Niarchos Foundation
- $2 million from Gluskin Sheff + Associates
- $1 million from the Riddell Family Charitable Foundation
- $300,000 from Cenovus Energy
- Over $1 million for outreach and training from the Peter and Shelagh Godsoe Family Foundation, RBC Foundation, Sun Life Financial, and the Bank of Montreal

BRIGHT MINDS. ILLUMINATING IDEAS. BRILLIANT FUTURE.





Practically every technology we use today – from computers to smartphones to lifesaving medical devices – emerged from breakthroughs in fundamental, curiosity-driven physics.

At Perimeter Institute for Theoretical Physics, scientists pursue new breakthroughs in our understanding of the universe, from the smallest 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.

Ontario

PERIMETER PI INSTITUTE FOR THEORETICAL PHYSICS

Canada

www.perimeterinstitute.ca

Charitable registration number: 88981 4323 RR0001