

STEP INSIDE THE PERIMETER

a year in review: 2018/19

PERIMETER  INSTITUTE FOR THEORETICAL PHYSICS





TODAY'S THEORETICAL PHYSICS IS TOMORROW'S TECHNOLOGY

What the world needs right now is game-changing ideas. Not slightly better batteries, but whole new sources of energy. Not slightly optimized algorithms, but whole new kinds of computation. Not incremental advances, but revolutionary solutions.

These kinds of tremendous change require two things: a new wave of fundamental discoveries, and a new generation of brilliant people to make them.

At Perimeter Institute, we are making those discoveries today. And we are training the generation of scientists who will make them tomorrow.

We are confident in our path because we know our history. Over and over, physics has transformed our world. The 19th century gave us electromagnetism, which eventually gave us entire telecommunications industries. The 20th century gave us quantum mechanics, which – via semiconductors – gave us the modern electronics industry and the information revolution. These are trillion-dollar industries, world-changing ideas.

We are after the next one.

A NEW CHAPTER IN A MADE-IN-CANADA SUCCESS STORY

In under 20 years, Perimeter has grown to become one of the top centres for fundamental science in the world. We are now the destination of choice for many of the field's leaders, and for rising young talent. From our home in Waterloo, Ontario, Canada, we reach out to engage the world – and young people in particular – sharing the wonder of the universe and the power of the human mind to understand it.

This year, Perimeter began a new chapter in our story, appointing founding Faculty member Robert Myers as our new Director. Myers is an eminent quantum field theorist who is routinely ranked as one of the world's most influential scientific minds. He succeeds cosmologist Neil Turok, who led the Institute for 10 years.

“At Perimeter, what was once an audacious idea has become a reality. This gives me confidence that the ideas, theorems, and breakthroughs being born here today will result in a new generation of wonders that our grandkids will hold in their hands.”

*– Robert Myers, Director and BMO Financial Group Isaac Newton Chair
in Theoretical Physics at Perimeter Institute*

A DAZZLING YEAR IN RESEARCH

Our scientists pursue breakthroughs that will reshape our world. We ask the big questions: How did the universe begin? What is it made of? How does it work? Where do the best theories fail – and what might replace them? What new technologies could all this lead to?

Perimeter will always be a place with more questions than answers. But this year's answers have been nothing short of dazzling.

Humanity got its first look at a black hole. Perimeter researchers were key players in the Event Horizon Telescope collaboration, the team that transfixed the world with an image seen by billions.

A new Canadian telescope called **CHIME launched a landmark study of mysterious signals from deep space**

called fast radio bursts. This was possible because of algorithms developed at Perimeter that let CHIME find these tiny signals in a rush of data, like plucking pebbles from an avalanche.

Perimeter researchers developed **new theories about quantum information, about the science of cause and effect, and about how to build new states of matter** with powerful quantum properties. Many of these were put to the test in top experimental centres around the world. Some are already in use.

Perimeter launched the first artificial intelligence laboratory to emerge from a physics institute.

With these and many other results, the future seems closer than ever.

PRIZES, AWARDS, AND PUBLICATIONS

Last year, Perimeter researchers:

- Won 17 major honours and prizes, including the Breakthrough Prize in Fundamental Physics
- Were awarded more than \$2.4 million in research grants
- Published 459 research papers, bringing the cumulative total to more than 5,700, including many landmarks in the field



EHT Initiative at Perimeter



Kendrick Smith



Pedro Vieira

Three Perimeter researchers were honoured by the Breakthrough Prize Foundation. Avery Broderick and members of the EHT Initiative at Perimeter were co-awarded the 2020 Breakthrough Prize as part of the Event Horizon Telescope collaboration, for theoretical work behind the now-iconic image of a black hole's event horizon. Two of the three New Horizons Prizes for brilliant young researchers went to Perimeter Faculty members: Kendrick Smith and Pedro Vieira. Perimeter has now won more New Horizons Prizes than any other institution in the world.

Avery Broderick is the Delaney Family John Archibald Wheeler Chair, Kendrick Smith holds the Daniel Family James Peebles Chair, and Pedro Vieira holds the Clay Riddell Paul Dirac Chair.

THE PERIMETER COMMUNITY

“At Perimeter, I have found that on time scales of months, you can execute the kinds of projects that would take many years elsewhere.”

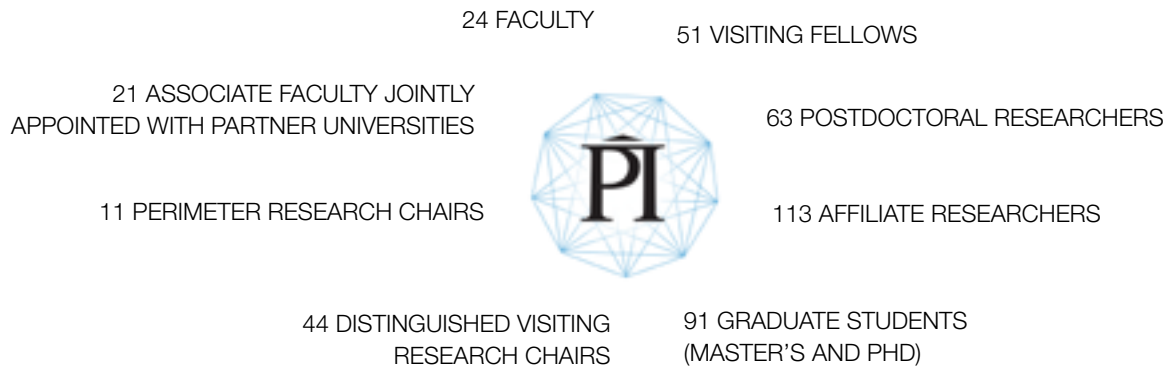
– Avery Broderick, Delaney Family John Archibald Wheeler Chair at Perimeter Institute

Perimeter’s emphasis on collaboration and creativity attracts the world’s best – and keeps them here in Canada.

Our research community includes more than 400 researchers, from graduate students and postdocs to eminent senior scientists. The Institute also hosts more than 1,000 scientific visitors and conference attendees annually.

We recruit the best, provide them with unmatched support, and give them complete research freedom. We encourage our researchers to collaborate across traditional boundaries, and to tackle the deepest problems they can find – even if short-term success is not guaranteed. In this way, we support the best minds in the world in doing their best work.

IN 2018/19, PERIMETER’S RESEARCH COMMUNITY INCLUDED:



BUILDING A QUANTUM INDUSTRY

Perimeter research helps fuel the emerging quantum innovation ecosystem in Waterloo Region, where Quantum Valley spans theory, experiment, application, and commercialization.



ACCELERATING EXPERIMENT

With deep connections to leading experimental centres, theorists from Perimeter are accelerating the pace of discovery across many fields. Perimeter helped catalyze the creation of the Institute for Quantum Computing in 2002, and it continues to be Perimeter's closest experimental partner today, with many cross-appointed faculty and joint projects.

Our experimental partners include:

- The Institute for Quantum Computing at the University of Waterloo, and several other leading centres of research at the quantum frontier
- The CHIME radio telescope and several other telescopes investigating the deep sky
- The Event Horizon Telescope
- The Square Kilometre Array radio telescope
- LIGO, the Laser Interferometer Gravitational-Wave Observatory
- SNOLAB dark matter and neutrino observatory and several other dark matter experiments
- TRIUMF, Canada's particle accelerator centre

A GLOBAL SCIENTIFIC HUB

At Perimeter, we move strategically to seize new opportunities, gathering top minds to discuss emerging science. The Institute catalyzes rapid research progress with can't-miss workshops and conferences attended by scientists from around the world. Conferences and seminars are recorded and made freely available online to the scientific community, fuelling science around the globe.

We are often the first place to hold a conference on a pressing new development in physics. We also assemble interesting clusters of talent around new ideas: several important projects, and even whole fields of study, began as Perimeter workshops.

In 2018/19, Perimeter Institute:

- Held 11 conferences and workshops welcoming 620 scientists.
- Sponsored 12 off-site workshops.
- Hosted 315 scientific talks, seminars, and colloquia.
- Platformed 12,438 scientific talks in our free, searchable online database, PIRSA. These received 737,000 views from 183 countries in 2018/19.

“Perimeter is a dream that came true, a place of genius and inspiration. It is hard to imagine a better place to study, to do research, and to be inspired and transformed for a young scientist interested in fundamental questions.”

– Valerio Faraoni, Professor, Bishop's University
Perimeter Affiliate Member



TURNING STUDENTS INTO SCIENTISTS, AND SCIENTISTS INTO LEADERS

Perimeter is not a university, but it is home to an innovative suite of training programs – from our brand-new undergraduate enrichment program to our world-leading postdoctoral program.

Since 2006, these programs have trained more than 1,000 scientists. In tackling the toughest problems in physics, Perimeter students acquire widely sought technical skills, and develop critical thinking, problem solving, and pure intellectual bravery that takes them far beyond physics. Our alumni are seeking new treatments for HIV and cancer. They've founded companies. They're working in tech, governance, and finance – and, of course, in pure research. Whatever they do, they carry the Perimeter spirit, and wherever they go, they lead the way.

This year, Perimeter trained:

- 63 postdoctoral researchers
- 58 PhD students
- 25 associate PhD students
- 46 visiting graduate fellows
- 33 PSI master's students
- 23 undergraduate summer school students

HONOURS FOR STUDENT RESEARCHERS

Our recruitment efforts target brilliant emerging leaders, and we're succeeding. Just this year, four new Perimeter PhD students won esteemed Vanier Canada Graduate Scholarships, while PhD student Anna Golubeva was also

awarded the prestigious NSERC Gilles Brassard Doctoral Prize for Interdisciplinary Research for her work applying machine learning methods to problems in complex quantum many-body systems.

*"Quantum computing is going to be the next big thing.
We absolutely need physicists in quantum computing.
This is something that engineers can't do."*

– Crystal Bailey, American Physical Society, 2019 Career Trajectories conference





IMPACT BEYOND PHYSICS

This year, our flagship master's-level program, Perimeter Scholars International (PSI), graduated its 10th class. The 300+ PSI alumni have gone on to careers in academia, industry, health, finance, technology, and more.

One of them is Ciaran Lee, class of 2013. At Perimeter, Lee worked with Faculty member Robert Spekkens on Bell's theorem – a seminal result in quantum theory – from the perspective of a branch of machine learning known as causal inference.

After his PhD, Lee was snapped up by the UK-based start-up Babylon Health, which develops artificial intelligence (AI)

software for medical diagnostics. By introducing causal inference techniques that he'd studied at Perimeter into Babylon Health's software, Lee and his team helped bring its diagnostic accuracy to that of expert clinicians – and it continues to improve.

The launch of this new diagnostic AI helped Babylon Health raise more than half a billion dollars, and is greatly expanding the reach of affordable diagnostic tools to improve health across the globe.

UNITING PHYSICS AND INDUSTRY

Machine learning is driving an information revolution. Devices that leverage quantum states of matter are clearly the next big thing in high tech. What would happen if you could bring those two things together?

Spotting the opportunity, Associate Faculty member Roger Melko founded the first AI lab formed directly out of a physics research institute. A partnership between Perimeter, quantum

computing company 1QBit, and the National Research Council, the **Perimeter Institute Quantum Intelligence Lab, or PIQUL**, conducts research and training at the intersection of quantum physics and machine learning. Its mission: to use AI to design the next generation of quantum materials and computers.

Two revolutions, clearly, are better than one.

“Physics doesn't have a monopoly on hard, unsolved problems, but it does routinely produce people ready to tackle them. The world needs physicists.”

– Alexander Radovic, former particle physicist working in machine learning at Borealis AI



Jocelyn Bell Burnell

SHARING SCIENCE WITH THE WORLD

Great science deserves to be shared with the people whose lives it touches – and that’s everyone. At Perimeter, we’re recognized as an international leader in science outreach, striving to increase science literacy by sharing the transformative power of physics with curious people everywhere.

Through our websites, our award-winning magazine *Inside the Perimeter*, and “Slice of PI,” our monthly science dispatches, we provide everything from fun physics snippets to deep dives into cutting-edge research.

Science communications by the numbers:

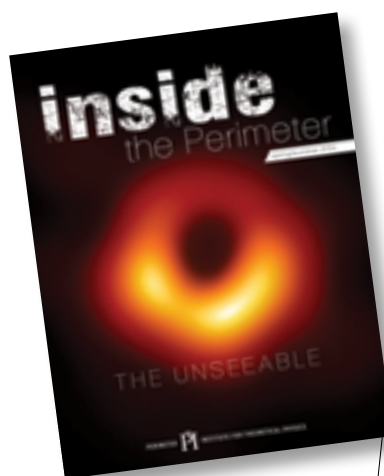
- 1,096,000 views of the newly launched Quantum to Cosmos interactive website, quantumtocosmos.ca
- 546,825 views of this year’s nine public lectures
- 200,000 unique visitors to insidetheperimeter.ca
- 2.5 million YouTube views, up 77%
- LinkedIn followers up 24%
- Twitter followers up 14%
- Facebook following grew to more than 30,000

UNITING IN WONDER

The first-ever image of a black hole was front-page news in hundreds of media outlets all over the world. As the only full Canadian partner organization in the Event Horizon Telescope collaboration, Perimeter received widespread front-page media coverage in outlets including the *New York Times* and the *Washington Post*.

Our original video content, including explanatory videos and a panel discussion, has garnered about 1 million views on YouTube.

It’s not often that the world unites in pure wonder, and Perimeter was proud to play a role in both creating that wonder, and sharing it.





REACHING STUDENTS AND TEACHERS

To really change the world, you have to reach young people.

Perimeter's educational outreach team focuses on students and their teachers. We develop classroom resources that bridge the gap between where traditional school lessons end and modern physics begins. And we provide hands-on training for teachers, with an aim of revolutionizing how science is taught.

It's all about exponential growth. Every teacher who goes home from Perimeter's training is ready to bring modern physics to classrooms that might have 25 students apiece. Every teacher trained as a peer educator can train dozens of other teachers. Every package of educational resources can reach multiple classrooms full of students, year over year.

It's a powerful equation. Perimeter has been teaching and training teachers for a decade and, in that time, has seen the number of students reached grow from thousands, to tens of thousands, to millions. In fact, metrics developed by independent auditors at KPMG suggest that Perimeter resources have now reached students more than 50 million times.

In 2018/19, Perimeter's Educational Outreach efforts included:

- 10.9 million student interactions through in-class resources
- 13,396 students at our physics presentations
- 5,132 educators trained at 153 workshops by Perimeter's staff and teacher network

“I can't explain what a profound impact [Perimeter teacher training] has on my conceptions of physics, teaching, and the world itself. Thank you!”

– Michael Zitolo, physics teacher, New York, New York

Programs for students and teachers are supported by a number of private donors, including RBC Foundation, Presenting Partner of International Summer School for Young Physicists.



DIVERSITY IS STRENGTH

To solve the toughest problems in physics, we need *all* of the brightest minds. Perimeter is committed to breaking down systemic barriers to physics education and research and to providing a genuinely inclusive environment.

In 2018/19, Perimeter Institute:

- Appointed quantum physicist and Perimeter Affiliate researcher Shohini Ghose as Perimeter's first Equity, Diversity, and Inclusion Specialist
- Formed the PI Inclusion Platform, a grassroots array of working groups, uniting students, faculty, and staff, focusing on areas of collective interest
- Consulted with Indigenous teachers in northern communities to better shape educational resources and delivery methods
- Consulted on and endorsed the new Natural Sciences and Engineering Research Council (NSERC) Dimensions Charter, a set of principles to promote equity, diversity, and inclusion across Canada's academic landscape
- Hosted 174 high school students at the annual "Inspiring Future Women in Science" conference
- Welcomed six new Simons Emmy Noether Fellows, boosting brilliant early- or mid-career female scientists

SIMONS EMMY NOETHER FELLOWS PROGRAM

Timed to support women at a critical stage of their careers, these annual fellowships enable visiting scientists to spend up to a year in Perimeter's thriving, multidisciplinary community. The scientists gain a unique opportunity to pursue their work intensively, free of teaching and administrative duties, and develop new international peer networks.

Flexibility is a key feature of the program. Perimeter works with

fellows to tailor their stays, arranging teaching buyouts with their home institutions and providing nearby accommodation and childcare if required. Simons Emmy Noether Fellows are invited to return as visitors in the three years after their fellowship term. The program is having a remarkable impact.

In 2018/19, Perimeter appointed six new Simons Emmy Noether Fellows.

"The Simons Emmy Noether Fellowship dramatically changed the way I devise research for the future. The program . . . takes care of the individual by helping with domestic issues and welcoming children and family. The initiative is flexible in form, deep in purpose."

— Simons Emmy Noether Fellow Paula Mellado, Adolfo Ibáñez University, Chile

WE ARE ALL PART OF THE EQUATION

“Theoretical physics as practised at Perimeter can potentially have a big and beneficial impact on humanity.”

– Robert Krembil, supporter of the Krembil Galileo Galilei and Krembil William Rowan Hamilton chairs

Perimeter is proud to have been trusted with public support from the Province of Ontario and the Government of Canada. In 2018/19, Perimeter was in the second year of five-year, \$50 million funding agreements with each level of government, helping position the province and the nation as a leading centre of theoretical physics on the global stage.

We are also supported by a growing group of private sector donors. In 2018/19, individuals, corporations, and foundations committed \$21 million in support. These generous gifts have helped put our \$100 million private sector campaign over the halfway mark, with \$52 million in commitments so far.

Meanwhile, Friends of Perimeter Institute, the Institute's US-based 501 (c)(3), is poised for steady growth in the coming years.

Our public and private partners stand behind us in our belief that theoretical physics is a low-cost, high-impact investment with the potential to revolutionize society. This broad support is one of the major reasons that Perimeter is now ranked among the top theoretical physics institutes in the world during one of the most exciting periods in the field's history.

“My family are great believers in the concept of Perimeter Institute. It's leading edge. Canada's contribution here is dramatic.”

– Ian Delaney, supporter of the Delaney Family John Archibald Wheeler Chair



Avery Broderick, the Delaney Family John Archibald Wheeler Chair, Catherine Delaney, and Ian Delaney

SUPPORTING THE VISION

Perimeter Institute thanks these donors who have made cumulative gifts totalling \$100,000 or more since 2014, following the lead of our Founding Donor, Mike Lazaridis. We are deeply grateful for their support.

Anonymous (1)
BMO Financial Group
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Joanne Cuthbertson and Charlie Fischer
The Daniel Family Foundation
The Delaney Family
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Sun Life Financial Inc.
John Templeton Foundation
Neil Turok
Dr. Scott A. and Sherry Vanstone and family
Mac Van Wielingen,
Viewpoint Foundation

IT'S A BIG UNIVERSE.
FORTUNATELY, WE HAVE BIG IDEAS.

$$\int \text{Be Part of } \overset{\text{(the)}}{=} \text{Equation}^2$$



PERIMETER **PI** INSTITUTE FOR THEORETICAL PHYSICS

