

# STEP INSIDE THE PERIMETER

a year in review: 2020/21

PERIMETER  INSTITUTE FOR THEORETICAL PHYSICS

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symmetry!



Perimeter's **mission** is to bring the best scientific minds in the world together to tackle the most difficult problems in foundational physics. We train new generations of talented physicists. We inspire through educational outreach. And we build public and private partnerships to make it happen. Perimeter's **vision** is to create the world's foremost centre for theoretical physics research, graduate training, and educational outreach, uniting public and private partners, and the world's best scientific minds, in a shared enterprise to achieve breakthroughs that will transform our future.



*“Perimeter is a long-term investment that will pay off exponentially. The work we do here will yield profound results – not only for the future of technology, but for the future of Canada and all of humanity.”*

*Michael Serbinis,  
Chair of the Board of Directors*

# PERIMETER HELPS POSITION CANADA AT THE FOREFRONT OF RESEARCH

Perimeter Institute for Theoretical Physics is a research institution dedicated to finding out more about how the universe works at its most fundamental level. We have a three-pillar approach: We conduct research on tough problems from the quantum to the cosmos, and we aim for nothing less than breakthroughs. We conduct training programs that turn students into scientists. And we share the wonder of physics with the world.

Funded in part by the federal government of Canada and the provincial government of Ontario, and in part by private donations, Perimeter is not a university, but we work closely with universities and other research organizations. Our goal is to be a rising tide that lifts all boats – to be a global hub for theoretical physics.

In 2020/21, the Audit and Evaluation Branch of Canada's Ministry of Innovation, Science and Economic Development undertook an extensive assessment of Perimeter's operations and financial model from 2016 to 2020. Here are a few conclusions about Perimeter's relevance, performance, and efficiency:

*“PI has contributed to **major scientific breakthroughs** in theoretical physics and continues to advance the field. Further, its research in quantum theory is leading to **applications in artificial intelligence** and supporting start-up companies in **quantum computing**, with an increasing number of PI researchers applying their knowledge in the private sector.”*

*“PI is **unique in Canada**, and internationally, in its size and independent nature as a not-for-profit institute unaffiliated with a university, as well as in its breadth of research, **particularly in quantum areas**.”*

*“The public-private approach also provides PI with the **flexibility to pursue unique research** opportunities quickly and efficiently **to position Canada at the forefront** of research advancements and breakthroughs.”*

*Ministry of Innovation, Science and Economic Development*



Cristina Mondino



Robert Spekkens and PSI student Matthew Fox

## RESEARCH BY THE NUMBERS

Perimeter has built one of the world's largest and strongest communities of researchers in fundamental physics.

### RESEARCH COMMUNITY

- 25 Faculty Members
- 21 Associate Faculty Members
- 79 Postdoctoral researchers
- 44 Distinguished Visiting Research Chairs
- 52 Visiting Fellows
- 4 Simons Emmy Noether Fellows appointed
- 7 conferences and workshops attended by more than 1,000 of the world's top scientists

### OUTPUT AND IMPACT

- 8 prizes and honours in 2020/21
- 6,784 papers published since Perimeter's inception
- 502 papers published in 2020/21
- 351,264 citations since inception

*"In the two decades since Perimeter was launched, our researchers have made an impressive string of breakthroughs. . . We have much to look back on, but still more to look forward to. We are emerging from this pandemic stronger, with an even deeper conviction that science is our future, and the best is yet to come."*

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

# RESEARCH BEYOND THE NUMBERS

## NEW DISCOVERIES

This was the first year of operation for the Clay Riddell Centre for Quantum Matter – dedicated to realizing the immense promise of quantum materials. Among the many results this year, Associate faculty member Roger Melko discovered a new class of phase transitions that may exist only in quantum computers. Faculty member Tim Hsieh leveraged that discovery as a new tool to explore dynamic phases in quantum matter.

At the other end of the quantum-to-cosmos scale, researchers at Perimeter's Centre for the Universe are a driving force behind many cutting-edge projects and collaborations. These include the CHIME (Canadian Hydrogen Intensity Mapping Experiment) radio telescope, which is unravelling the mysteries of fast radio bursts; the Event Horizon Telescope, which is sharpening its landmark first image of a black hole; and DESI (the Dark Energy Spectroscopic Instrument), which aims to uncover the hidden history of dark energy. This year, Perimeter researchers have also joined the world's leading gravitational wave centres, as part of the LIGO-VIRGO-Kagra Scientific Collaboration.

Other discoveries from this year show the breadth of Perimeter's research. For instance, Associate faculty member Christine Muschik outlined a new approach to hybrid classical–quantum computers, while Faculty member Bianca Dittrich and postdoctoral researcher Seth Asante revolutionized the simulation of loop quantum gravity, developing a new technique that lets a laptop do in minutes what once took a supercomputing cluster months.

## NEW FACES

Perimeter's recruitment strategy is to find emerging superstars and bring them aboard as they enter their peak years of research productivity. This year, we made two such hires: Dominic Else, currently at Harvard, is the winner of the 2022 New Horizons in Physics Prize and will soon be collaborating with scientists at Perimeter's Clay Riddell Centre for Quantum Matter. Sabrina Gonzalez Pastorski, currently at Princeton, is a high energy theorist whose Celestial Holography Initiative is bringing together leading researchers.

Two new associate faculty members have also joined Perimeter: Anton Burkov, quantum matter theorist and faculty member at the University of Waterloo, and Theo Johnson-Freyd, a mathematical physicist cross-appointed with Dalhousie University.

## NEW IDEAS

In 2020/21, as the pandemic continued to prevent in-person events, Perimeter perfected the art of the virtual scientific event, with more than 1,000 researchers participating in conferences; in addition, over 10,000 participated in seminars and colloquia – more than expected. We choose conference topics strategically, targeting leading-edge areas with the potential for transformative outcomes. Topics this year included “quantizing time,” “ultra quantum matter,” and “octonions and the Standard Model.”





PSI students, 2021

## TRAINING BY THE NUMBERS

Young people are the lifeblood of science, and Perimeter aims to attract and develop the next generation of brilliant minds.

- More than 1,000 young scientists trained since inception
- 79 Postdoctoral researchers from 23 countries
- 70 PhD students from 29 countries
- 21 Perimeter Scholars International master's students from 13 countries
- 50 Associate PhD students and Associate postdoctoral researchers

*“The environment in PI of thinking and working freely encourages me to always have the passion and persistency to challenge hard problems.”*

*Han Ma,  
Philip W. Anderson Fellow*

# TRAINING BEYOND THE NUMBERS

## GREAT GRADUATE STUDENTS

Physics doesn't have a monopoly on hard, unsolved problems, but it does routinely produce people with the skills and ambition to tackle them. Perimeter graduate programs and postdoctoral fellowship programs have now trained more than a thousand such brilliant people, who have gone on to roles in physics, industry, health care, finance, governance, and more.

Our unique master's program, Perimeter Scholars International, is a challenging, collaborative program that covers the full breadth of theoretical physics in just 10 months. The 9 women and 12 men in the 2020/21 cohort were chosen from more than 900 applicants. They built an extraordinary virtual community of learning and completed their master's degrees without ever coming to Perimeter.

## POWERHOUSE POSTDOCTORAL PROGRAM

In 2020/21, 12 new postdoctoral fellows arrived (or virtually arrived) at Perimeter. Selected from more than 700 applicants, these early career scientists joined one of the largest communities of theoretical physics postdocs in the world.

Perimeter recognizes that postdocs are often at the height of their intellectual creativity. We offer them total research freedom, encourage them to pursue ambitious research programs, and provide them with unmatched mentorship and support.

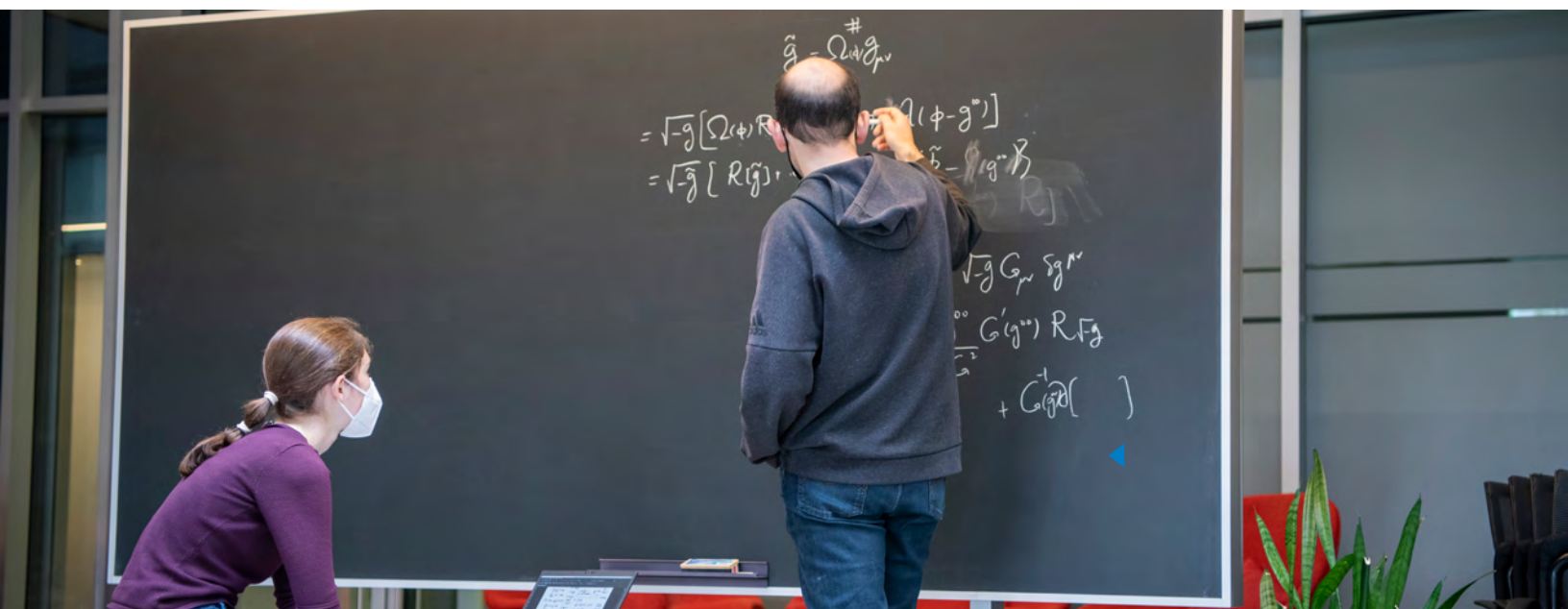
## EMERGING ENTREPRENEURS

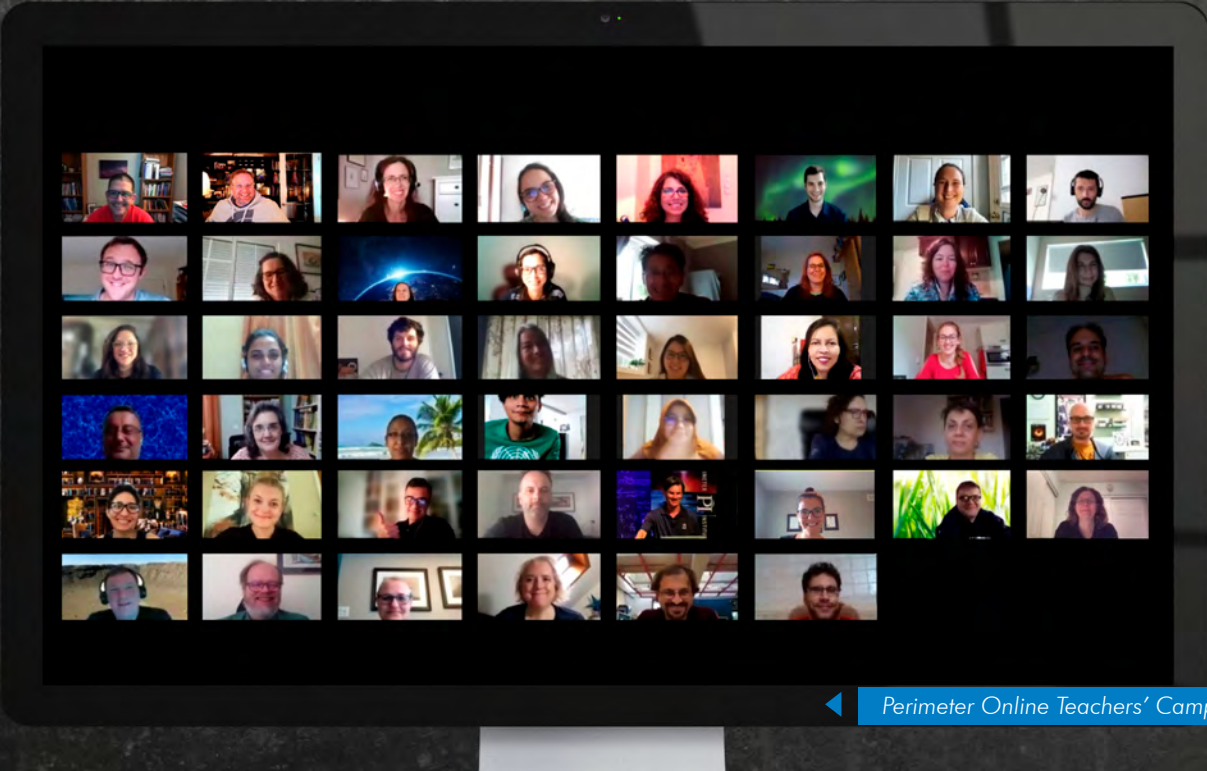
Estelle Inack is a quantum matter researcher who holds the Francis Kofi Allotey Postdoctoral Fellowship – and is the most recent Perimeter researcher to found a company.

The field of optimization involves finding the best solution for complex problems with many possible solutions. Simulating protein folding for pharmaceutical research, scheduling power generation to make the grid greener, and managing supply chains for maximum efficiency all involve optimization. Physicists have several established techniques for optimization problems. One of them, called “simulated annealing,” involves translating a general problem into the language of physics (in this case, the same language used to describe heating and then cooling glass) in order to solve it.

Simulated annealing is a well-established technique, but Inack and other researchers at the Perimeter Institute Quantum Intelligence Lab have put a new spin on it. They've found a way to implement it using an artificial neural network, making it faster and more powerful.

It's so powerful and so promising that Inack has set about commercializing it. She's co-founded a company called yiyaniQ, which will use the new simulated annealing neural network to tackle optimization problems in the world of high finance.





## OUTREACH BY THE NUMBERS

Great science deserves to be shared with the people whose lives it touches – and that's everyone.

### STUDENTS

- 67 million student interactions through resources since 2006
- 8 million student interactions through resources in 2020/21
- 640 students participated in presentations in 2020/21
- 285 students participated in “Inspiring Future Women in Science” in 2021
- 39 exceptional high school students – 20 Canadian, 19 international – participated in the 2021 International Summer School for Young Physicists

### TEACHERS

- 41,000 educators trained globally through Perimeter workshops since inception
- 4,700 teachers trained at 152 workshops in 2020/21
- 46 teachers participated in EinsteinPlus teacher training camp in 2020/21
- 125 countries in which Perimeter educational resources have been used
- 114 in-class science resources available to teachers across Canada and around the world

### SCIENCE FOR THE WORLD

- Public lectures viewed 130,000 times in 2020/21
- 6 million YouTube views in 2020/21
- 110,000 YouTube subscribers, up 36%

*“I can go on YouTube and learn stuff on my own. But collaborating with these international students and the teachers was something extraordinary.”*

*Gina Bilic, Winnipeg  
International Summer School for Young Physicists 2021 participant*



# OUTREACH BEYOND THE NUMBERS

## TRAINING FOR TEACHERS

Perimeter brings the wonder of modern science into classrooms across Canada and around the world. We do it by inspiring and empowering teachers.

EinsteinPlus, Perimeter's week-long professional development opportunity for educators, was offered online in 2021, adapted to include the same hands-on activities and connections with researchers that it does every year. Many teachers report that Perimeter's online training has helped them adapt to the challenges of teaching through the pandemic. "By the time we got to the last session, I didn't want it to end," said Hayley McKay, science teacher at Sundre High School in Alberta.

Techniques pioneered and refined at EinsteinPlus are adapted into teacher workshops. In 2020/21, more than 4,700 educators participated in 152 workshops.

## RESOURCES FOR STUDENTS

Used by millions of students in classrooms across Canada and in 124 other countries around the world, Perimeter's free multimedia resources provide a deep dive into topics from coding to climate change, black holes to dark matter. Each module includes lesson plans, hands-on activities and demonstrations, guidance for teachers, and original Perimeter videos.

New resources developed in 2020/21 include "Exploring Light with Optics" and "Beyond the Atom: Remodeling Particle Physics." All educational resources are available in French and English, and further translations are ongoing, with 17 resources available in Portuguese and 15 in Spanish.

## WONDER FOR EVERYONE

During a time when many have been seeking trusted science information, more people turned to Perimeter than ever before. Public lectures and other videos were viewed more than 6 million times on YouTube – an increase of more than 200 percent over the previous year. The number of subscribers grew by 36 percent, to more than 110,000. Facebook and Twitter audiences also continued to grow, with a total of more than 60,000 followers.

Perimeter continues to share the transformative power of physics with curious people of all ages and at all levels of science literacy, with inspiring science content from quizzes and games to in-depth stories on our latest discoveries.





## CHANGING THE FACES OF PHYSICS

Perimeter is taking concrete actions to create a place where people who have historically been excluded from physics – particularly women and racialized people – are welcomed and empowered.

### EMMY NOETHER INITIATIVES

Emmy Noether is the most important mathematician you've never heard of: an early 20th century genius who collaborated with Einstein. It's hard to imagine the kind of physics Perimeter does without Noether, and Noether's theorem – and so Perimeter's work to reimagine the role of women in physics is named for her. Emmy Noether Initiatives are designed to inspire, support, and remove barriers for women and girls in high school, graduate training, and early- and mid-career research positions.

One of our flagship Emmy Noether Initiatives is an annual conference called "Inspiring Future Women in Science." In 2021, 285 high school students were treated to a wide-ranging conversation by four accomplished women in various fields and at various career stages, including a master's student in oceanography, an aerospace engineer, a cell biologist, and Perimeter's own Asimina Arvanitaki, an award-winning particle physicist.

A group of Perimeter donors called the Emmy Noether Circle have created an emerging talent fund devoted to advancing women at critical stages of their education and careers, at Perimeter and beyond. In 2021, their commitments to the fund reached nearly \$1 million, surpassing the initial \$250,000 goal and pushing Perimeter closer to the \$2.5 million target.

### CONNECTING WITH INDIGENOUS EDUCATION

In 2020/21, Perimeter's Outreach team participated in three virtual events to gain additional knowledge of Indigenous educational spaces: the Indspire National Gathering for Indigenous Education, the Canadian Indigenous Science and Engineering Society STEM panel, and the American Indian Science and Engineering Society Leadership Summit. The Outreach team looks forward to continuing to build relationships in person in First Nations, Métis, and Inuit communities when public health guidelines allow.

*"It was quite an amazing year for me. Let me express my gratitude to the program again for making all this possible!"*

*Ling-Yan Hung, Fudan University, China  
Simons Emmy Noether Fellow, 2018/19*

# BUILDING THE FUTURE

In just 20 years, Perimeter has gone from an idea to one of the top institutions for theoretical physics in the world.

The idea originally came from Mike Lazaridis, the inventor of the BlackBerry, which launched the worldwide smartphone industry. Realizing that his revolutionary invention was based on past breakthroughs in theoretical physics, he asked a simple, inspiring question: Where will the next breakthroughs come from – the ones that will transform the lives of our grandchildren's grandchildren?

Perimeter was created as an answer: an independent institute devoted solely to theoretical physics. One that would gather brilliant minds, remove the typical constraints of academia, and seek nothing less than breakthroughs.

In the two decades since founding Perimeter, Lazaridis has devoted thousands of hours of his energy and wisdom as the Institute's Board Chair. This year, he stepped back to become Founding Board Chair Emeritus.

Perimeter has now welcomed a new Board Chair, Mike Serbinis. Like Lazaridis, Serbinis is a tech entrepreneur, a co-founder of many successful companies, including Kobo, Critical Path, DocSpace, and most recently, League.

"Mike Serbinis is the best of Canada's young tech vanguard," says Perimeter's Director Robert Myers. "He's a builder steeped in science, and brings the energy and daring Perimeter needs to build a brighter future."

*"There is a world-class team at Perimeter. Out of pure excitement and passion for the work that our scientists are doing, I am honoured to be part of it."*

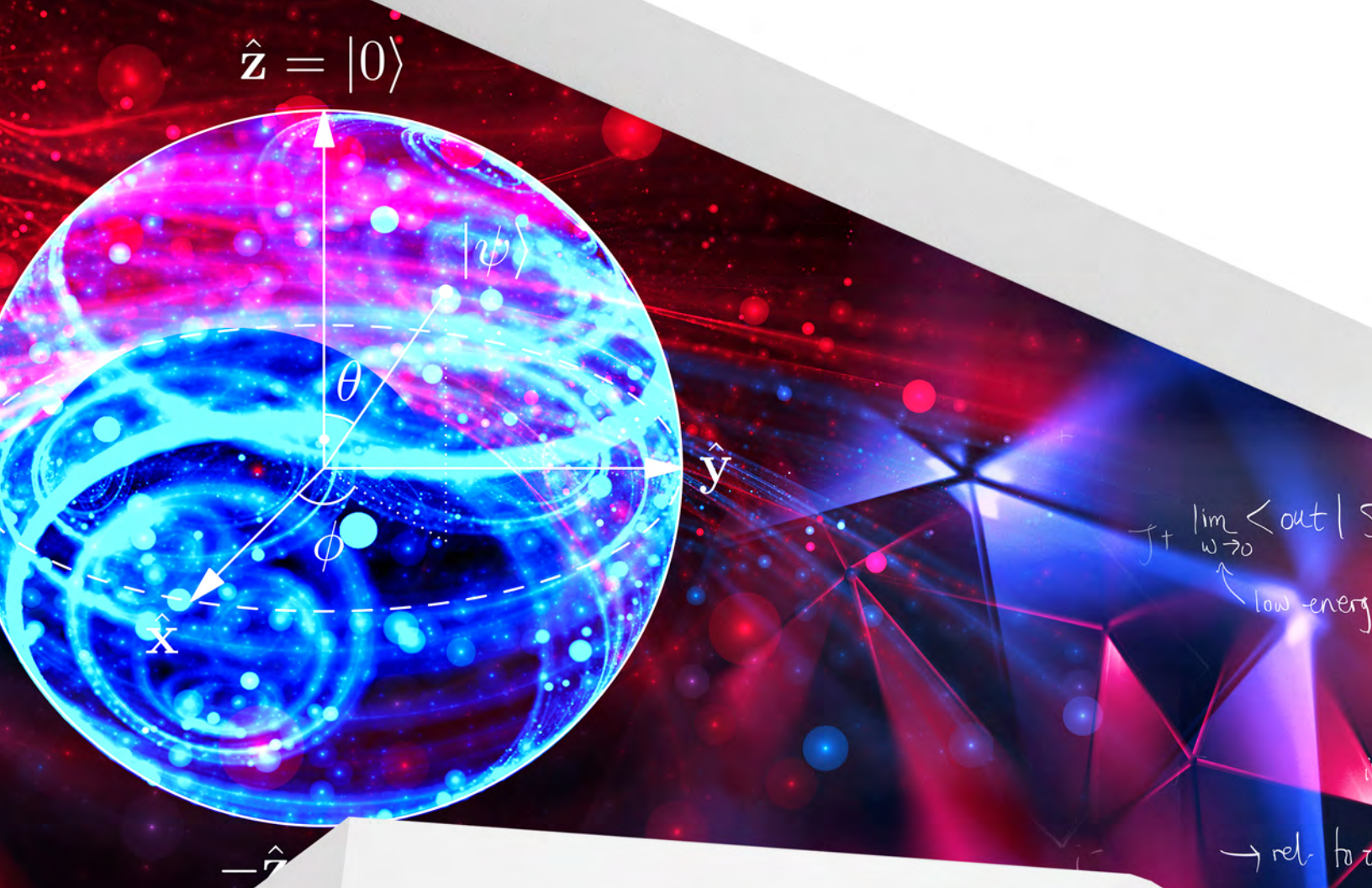
*Mike Serbinis,  
Perimeter's new Board Chair*

Mike Lazaridis donated a large portion of his personal wealth to help found Perimeter. Federal, provincial, and local governments joined in, and Perimeter was born. Since then, the Institute has gathered a wide circle of supporters, including private foundations, corporations, and individuals.

Public funding keeps Perimeter on firm footing and has allowed us to grow into one of the largest and most prestigious hubs for theoretical physics in the world. Private funding has kept us nimble, entrepreneurial, and able to move quickly when we spot strategic or emerging possibilities.

We are deeply grateful to all our public and private funders.





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

Join us on this journey of discovery.

To find out more about how you can support Perimeter, visit:

[perimeterinstitute.ca/donate](http://perimeterinstitute.ca/donate)

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