DUNLAP INSTITUTE
for ASTRONOMY & ASTROPHYSICS

Prof. Suresh Sivanandam

DIRECTOR'S MESSAGE

2024: A Year of Spectacular Achievements in Astronomy

The year 2024 was extraordinary for astronomy, marked by several awe-inspiring celestial events visible to the naked eye. Among them were a rare total solar eclipse just outside the Greater Toronto Area, a dazzling comet, and breathtaking auroral displays. At the Dunlap Institute, we seized the opportunity to engage and inspire the public, particularly with the solar eclipse.

We collaborated with schools and the Toronto Public Library to distribute thousands of eclipse glasses, ensuring that the event was accessible to as many people as possible. A standout moment was our eclipse viewing event for the students of Kipapāmahchakwēw – Wandering Spirit School at the Six Nations Reserve. Our public outreach team also hosted the University of Toronto's most-watched livestream, broadcasting the eclipse in real-time from that location. The event left all who witnessed it with a profound sense of wonder and awe.

This year, we were also proud to sponsor the annual Canadian Astronomical Society (CASCA) conference, the premier gathering for Canadian astronomers, held in Toronto for the first time in 15 years. Under the leadership of our own Prof. Hložek, our events team played a pivotal role in organizing and executing the conference. The event drew one of the largest in-person attendances in recent years, significantly enhancing the Institute's national profile and reinforcing its leadership in the Canadian astronomical community.

Meanwhile, our research programs continued to make remarkable strides. Flagship projects like CHIME Outriggers, CHORD, and GIRMOS advanced steadily, underscoring our commitment to cutting-edge science. A major highlight was securing $15M in funding from the Canada Foundation for Innovation (CFI) for the Canadian Data Intensive Astrophysics Platform (CanDIAPL) and kicking off the project. This ambitious initiative will develop software infrastructure to integrate data from multiple observatories—radio, optical, and gravitational-wave. CanDIAPL positions Canadian astronomers at the forefront of the Legacy Survey of Space and Time (LSST) conducted by the Vera C. Rubin Observatory, which begins operations in 2025. The Rubin Observatory is set to revolutionize our understanding of the transient universe, providing unprecedented precision in cosmological measurements and unlocking the discovery of optical counterparts to gravitational wave events.

Photos from left to right:

Current and past members of the University of Toronto astronomy community at CASCA2024. Credit: Michael Poirois

Because of the active sun, many aurorae were seen across Canada in 2024. Credit: Julie Bolduc-Duval.

Comet C/2023 A3 (Tsuchinshan-ATLAS) as it appeared in Toronto in October. Credit: Ilana MacDonald

OUR RESEARCH

Galaxy Zoo Euclid

The new Euclid space telescope has begun taking the most detailed image of the sky ever made. Dunlap Institute Fellow Mike Walmsley is combining AI with tens of thousands of volunteers to search this image for rare galaxies that reveal how the Universe grew.

Massive galaxies warp space-time, bending light rays like a magnifying glass to reveal distant galaxies behind them. But they are incredibly rare – both the massive galaxy and distant galaxy need to be perfectly aligned for the magnifying effect to work and create a "gravitational lens".

Searching through all of Euclid's galaxies by hand would take 150 years. AI algorithms can search in hours but need to be taught what to look for. To train them, two communities of online volunteers - Galaxy Zoo and Space Warps – came together first to train AI algorithms to recognize the general shapes of Euclid's galaxies and then to hunt for gravitational lenses.

13,000 volunteers joined in and discovered hundreds of new gravitational lenses – each magnifying a distant galaxy. And the search is only just beginning. Volunteers and AI have together searched the first 0.3% of Euclid's final image of the sky. That implies they will ultimately find over 100,000 lenses - two orders of magnitude more than all previous searches combined.

Photos from left to right:

The Perseus Galaxy Cluster as seen by the Euclid Space Telescope. Credit: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi

Dunlap fellow Dr. Mike Walmsley

PhD candidate Steffani Grondin in front of one of the Magellan Telescope.

Star system HD101584 and the complex gas clouds surrounding the binary. Credit: ALMA (ESO/ NAOJ/NRAO), Oldham et al. Acknowledgement: Robert Cumming.

Main-Sequence White Dwarf Binaries

Unlike our Sun, most stars in the universe are part of binary systems, orbiting alongside a stellar companion. Yet, the evolution of binary stars remains one of the greatest unresolved mysteries in stellar astrophysics, with mass transfer during their lifetimes posing the biggest challenge.

In 2024, a team of Dunlap Institute astronomers including PhD candidate Steffani Grondin and Professors Maria Drout and Joshua Speagle made a breakthrough towards solving this mystery, where they used machine learning to uncover the first population of white dwarf-main sequence binary candidates in open star clusters.

This discovery is pivotal for studying the elusive "common envelope" phase of binary evolution, where a dying star's outer layers can completely engulf its companion. Since stars in a cluster are believed to have formed at the same time, identifying post-common envelope binaries in star clusters allows astronomers to precisely measure their ages and trace their entire evolutionary journey through a common envelope.

"Binary stars play a huge role in our universe", says lead author Steffani Grondin. "This observational sample will allow us to better understand the most mysterious phase of stellar evolution and its connections to astrophysical phenomena like Type Ia supernovae and gravitational wave events."

Even though these types of binary systems should be very common, they have been tricky to find, with only two systems confirmed within star clusters prior to this research. "The use of machine learning helped us to identify clear signatures for these unique systems that we weren't able to easily identify with just a few data points alone", says Speagle. This discovery of more than 50 candidate binaries will act as a benchmark sample for constraining common envelope evolution in the future.

"It really points out how much of our universe is hiding in plain sight," says Drout. "How much is still waiting to be found."

ECLIPSE

Eclipse Glasses

The Dunlap Institute and our partners at Discover the Universe collaborated to design and print 350,000 eclipse glasses to ensure safe viewing in the Toronto area as well as across the six provinces touched by the path of totality. Discover the Universe distributed almost 300,000 of these to schools around Eastern Canada, while the remaining were distributed by the Dunlap Institute primarily through the Toronto Public Libraries.

Event at Chiefswood Park

On the day of the eclipse, April 8, 2024, the Dunlap Institute hosted an event at Chiefswood Park on the Six Nations of the Grand River near Brantford, Ontario for about 60 students from Kipapāmahchakwēw – Wandering Spirit School, their caregivers and their teachers. Astronomers from the University of Toronto had telescopes with solar filters pointed at the sun and were available to answer questions about the eclipse. The school provides Indigenous students from kindergarten to Grade 12 the opportunity to learn cultures and traditions and Anishinaabemowin.

Collaboration with Libraries

The Toronto Public Libraries (TPL) were not only the hub for eclipse glasses distribution in Toronto, but they were also the centers for learning about the eclipse in the city. In the six weeks leading up to the eclipse, the Dunlap Institute hosted 37 workshops at different TPL branches around Toronto, serving over 1000 library patrons. Attendees learned about how to best view the eclipse, as well as how to safely experience the celestial phenomenon.

"Chasing the Shadow" Livestream

In order to reach audiences beyond the path of totality, the Dunlap Institute hosted a livestreaming event of the eclipse on YouTube called "Chasing the Shadow from Niagara to Newfoundland". The livestream featured views of the eclipse from across the Canadian path of totality, from Chiefswood Park to Gander, Newfoundland. The online event featured collaborators from Brock University, Queen's University, Bishop's University, Memorial University, and Fort Williams Historical Park. The event was a huge success, with almost 8500 concurrent viewers on YouTube and a total of about 55,000 viewers over the course of the livestream.

Discover the Universe Educator Workshops

In preparation for the eclipse, Discover the Universe spearheaded a national initiative to engage educators, students, and communities across Canada. Over 3,000 educators attended 72 online workshops, while an additional 1,100 participated in 30 in-person training sessions. These sessions provided teachers with the resources and confidence to bring eclipse science into their classrooms, igniting curiosity among thousands of students nationwide. They developed curriculum-aligned lesson plans, multilingual resources, and materials incorporating Indigenous perspectives on solar eclipses, created in collaboration with Indigenous astronomers. These efforts were supported by a dedicated eclipse webpage, which saw an unprecedented 68,000 visits in the month leading up to the event.

Photos from left to right:

The sun's corona during totality. Credit: Ehren Sun

UofT astronomers observe the eclipse in Montreal. Credit: Erik Osinga

Totality at Chiefswood Park. Credit: Kara Manovich.

Discover the Universe director Julie Bolduc-Duval explains the solar eclipse to a group of students. Credit: Discover the Universe

An audience gathers at The Great Hall for Astronomy on Tap T.O. Credit: Alicia Richardson

OUR TRAINING

In 2024, the Dunlap Institute once again co-hosted the DADDAA-Dunlap Summer Undergraduate Research Program (SURP) with the David A. Dunlap Department for Astronomy & Astrophysics. This summer, 30 undergraduate students were paired with University of Toronto astronomers and contributed to research ranging from space telescope development to investigating the evolution of galaxies like our Milky Way to searching for rare stars using multimodal machine learning. The SURP committee organized weekly social events such as trivia and movie nights, and the students were able to present their research at a lively poster session at the end of the summer.

This year also marked the completion of the University of Toronto observatory on the site of the Royal Astronomical Society of Canada's E.C. Carr Astronomical Observatory in The Blue Mountains. A 50-cm Planewave telescope was installed into the Astro Haven Enterprises 12.5ft clamshell dome in February, and over the summer the site became fully automated in preparation for the fall semester, when students in AST199 – Astronomy at the Frontier – were able to travel to the site to use the telescope. It is expected that use of the observatory will be incorporated into several other astronomy courses in future semesters, as well as characterization of instruments for research. The construction of the observatory was made possible by Dunlap seed funding.

Members of the Dunlap Institute and the RASC stand in front of the University of Toronto telescope dome on the site of the Carr Astronomical Observatory.

OUR OUTREACH

The Institute hosted three Astronomy on Tap events, in March, July, and November, each of which filled The Great Hall in downtown Toronto with an attendance of 400-500 people. Audiences were entertained by a variety of talk topics, from listening to black holes with gravitational waves to strange binary star interactions, presented by UofT astronomers.

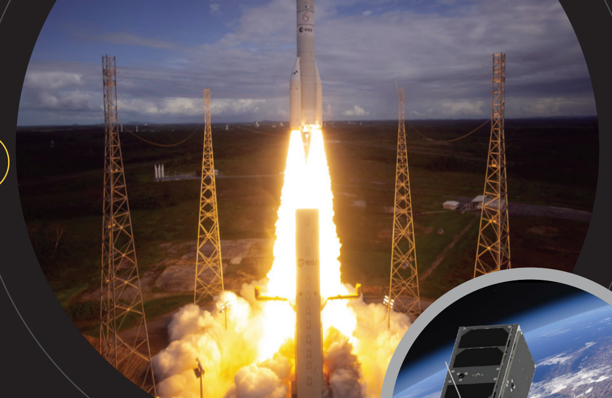
This summer marked the successful execution of Coding the Cosmos, a graduate-student-led three-day camp for high school students. The core of the camps was mini-projects — guided coding activities that gave students a chance to work with their peers on real astronomy problems using real astronomical data. In collaboration with McMaster University, a version of the camp was also run in Hamilton.

The Institute was also able to reach hundreds of students and members of the public through collaborations with Visions of Science, the UofT Department of Physics through the Pursue STEM and Science Unlimited programs, the UofT Department of Mathematics through the Girls in STEM program, the Toronto Public Libraries with our Speaker's Bureau initiative, and Discover the Universe through their free training and resources for students and educators.

Amanda Cook presents at Astronomy on Tap T.O. Credit: Alicia Richardson

OUR TECHNOLOGY

LUVCam



In under a year, our team at the Institute has successfully developed a space-based ultraviolet (UV) camera system, the Little Ultraviolet Camera (LUVCam), which serves as technology demonstrator for our space instrumentation efforts. This remarkable achievement showcases our ability to rapidly innovate by leveraging commercial off-the-shelf image sensor technology.

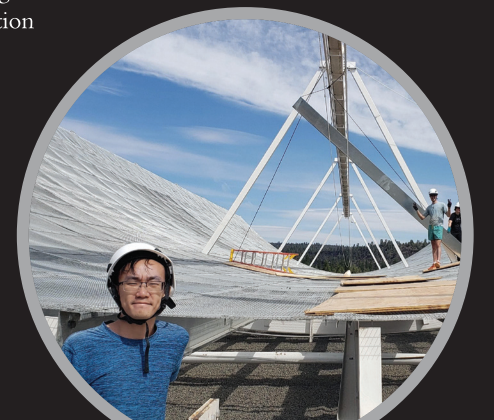
LUVCam, equipped with a compact 1-inch telescope, was integrated as one of the science payloads of the Czech GRBBeta CubeSat mission and successfully launched this summer aboard the maiden flight of the Ariane 6 rocket. After achieving "first light" in orbit, LUVCam is now in the process of capturing its first UV images of stars. Its primary scientific goal is to survey the brightest stars in the UV spectrum—a feat that has not been undertaken in over 50 years.

This groundbreaking project marks the Institute's first venture into space instrumentation, laying the foundation for our future contributions to the Quick UltraVIolet Kilonovae Surveyor (QUVIK), a larger Czech-led mission slated for launch in 2029. LUVCam's development not only represents a significant milestone for the Institute but also underscores our commitment to pushing the boundaries of observational astronomy and fostering international collaboration in space science.

CHIME outriggers

The Canadian Hydrogen Intensity Mapping Experiment (CHIME), originally built to measure cosmic hydrogen as a probe of the Universe's expansion, has proven revolutionary in the field of Fast Radio Bursts (FRBs), millisecond-long blips of radio light from the distant cosmos. To better identify the origin of these mysterious bursts, a set of smaller versions of CHIME scattered across North America (dubbed Outriggers) have been under construction and are now nearing completion.

In 2024, the CHIME/FRB Outriggers program for FRB localization is advancing rapidly: the first outrigger telescope has commenced full science operations, the second outrigger is ready and under testing for science operation, and the construction of the third and final outrigger has begun smoothly, with main structure completed. The digital system installation for the third outrigger is planned in early 2025, and we expect it to be ready for commission within this year.



Photos top to bottom:

The ESA's Ariane 6 rocket launched on July 9, 2024, carrying with it the LUVCam instrument. Credit: ESA - S. Corvaja

An artist's impression of the GRBBeta CubeSat, upon which resides LUVCam, in orbit. Credit: Spacemanic

Graduate students Jean-Christophe Fronteddu and Aaron Tohuvavohu proudly displaying the fully assembled LUVCam instrument prior to integration into the GRBBeta CubeSat.

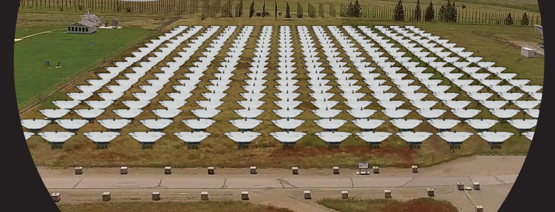
Dr. Albert Lau stands in front of the CHIME outrigger telescope under construction in Northern California. Credit: Juan Mena-Parra

CHORD

The Canadian Hydrogen Observatory and Radio-transient Detector (CHORD) project is a successor and complement to CHIME. It is poised to revolutionize a range of radio astronomy, from FRBs to cosmology, and is now under construction at the Dominion Radio Astrophysical Observatory (DRAO) in BC's Okanagan Valley. Composed of 512x 6m radio dishes, CHORD will deliver increased precision and sensitivity over a wider bandwidth but narrower field of view.

The CHORD project has made significant progress in 2024. With 356 of the 512 dish foundations installed, the first dish deployed and full completion expected by 2025, the infrastructure is well underway at the Dominion Radio Astrophysical Observatory near Penticton, BC. Digital backend hardware has been finalized and purchased, while the analog frontend components are in advanced testing stages, delivering performance surpassing initial goals.

The Dish Development Array (D3A) has been integral in refining the dish design, while the operational dish production facility has begun manufacturing components exceeding specifications.



Photos top to bottom

SURP student Chris Lansdale works on one of the CHORD antennas. Credit: Albert Lau

An artist's impression of the CHORD radio telescope as it will look when it is completed. Credit: Tracy Zhuo

GIRMOS

The Gemini Infrared Multi-Object Spectrograph (GIRMOS) continues to be our flagship optical instrumentation project, poised to deliver cutting-edge capabilities to the international Gemini community by 2028. This state-of-the-art adaptive optics infrared multi-object spectrograph and imager will enable transformative high-angular-resolution imaging and spectroscopy at the Gemini-North telescope.

A recent CASCA survey of Canadian astronomers highlighted GIRMOS as one of the most highly anticipated instruments for the Gemini Observatory in the coming decade. Its advanced design is expected to redefine the observatory's ability to address key astrophysical questions, revitalizing its role at the forefront of astronomical discovery.

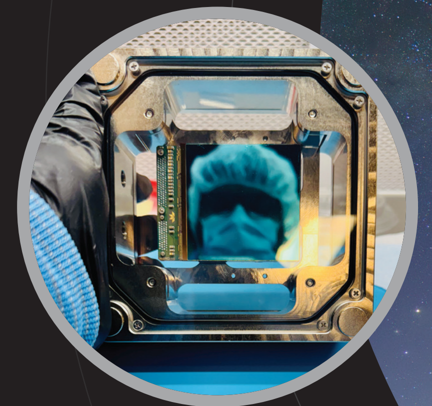
The instrument's final design is nearing completion, with construction slated to begin in the spring of 2025. This year, our multi-institutional team had a strong presence at the SPIE Astronomical Telescopes and Instrumentation Conference in Yokohama, Japan, where we showcased the finalized designs of all GIRMOS components.

Looking ahead, the Critical Design Review—scheduled for early next year—will serve as the project's last major milestone before production begins. This comprehensive review will determine if the GIRMOS design is fully complete, meets its rigorous scientific and technical requirements, and is ready for construction.

Photos left to right

The main infrared sensor for GIRMOS. Credit: Suresh Sivanandam

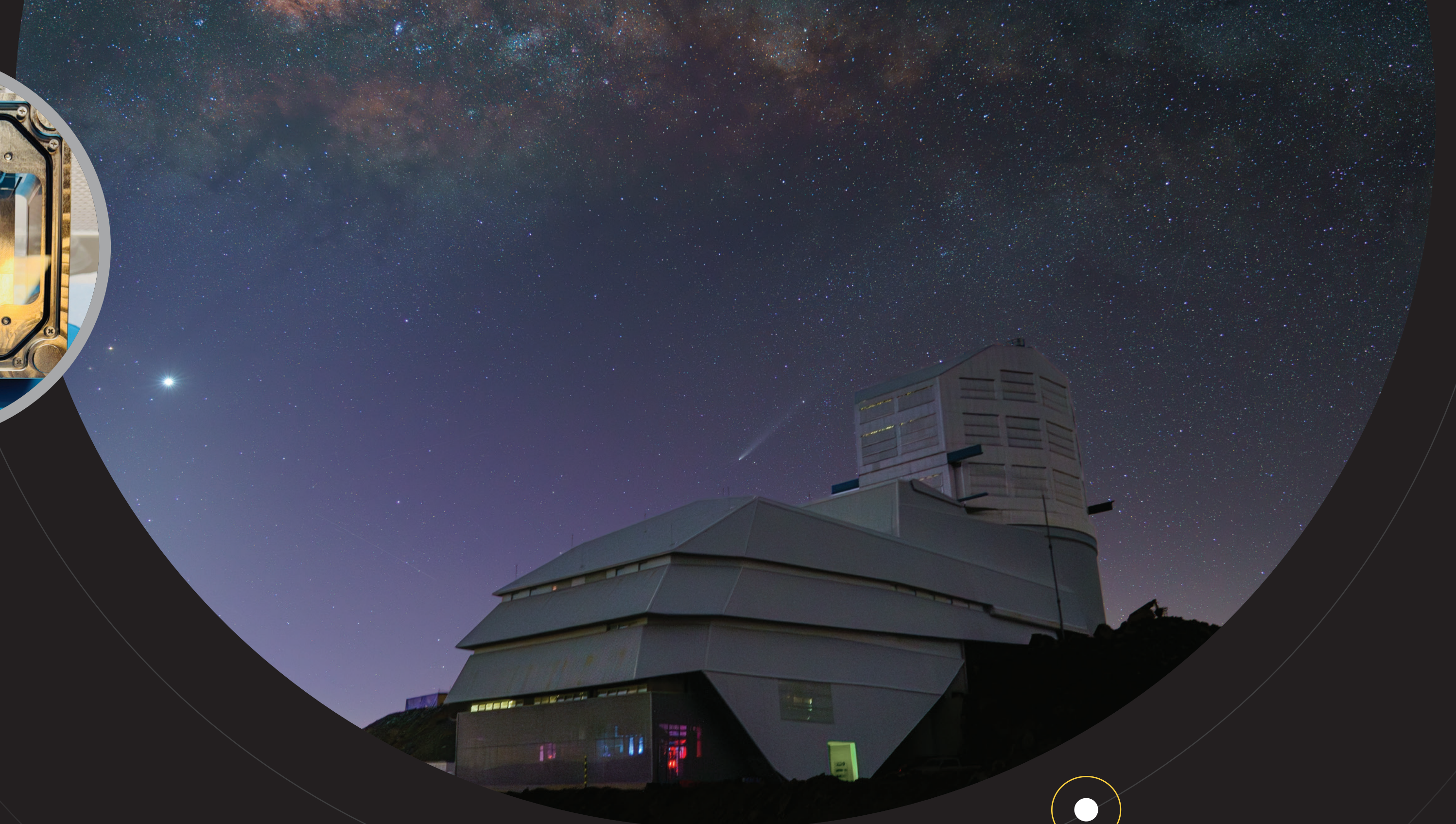
The Rubin Observatory in Chile. Credit: Hernan Stockebrand



CanDIAPL/ Rubin Data Centre

In 2023, Renée Hložek and Bryan Gaensler were awarded a $15M CFI grant to build the Canadian Data Intensive Astrophysics PLatform (CanDIAPL), a cloud computing data centre and the software infrastructure to combine observations across a range of wavelengths from radio, optical and even gravitational wave signals. CanDIAPL will build critical tools to do cutting edge science with the radio precursor surveys to the Square Kilometer Array (SKA), such as Meer Karoo Array Telescope (MeerKAT), the Murchison Widefield Array (MWA), and the Australian SKA Pathfinder (ASKAP) and for the Vera C. Rubin (Rubin) optical observatory. It will allow Canadian scientists to combine data from the surveys to learn about fundamental questions to astronomy, such as what cosmic explosions reveal about the most extreme conditions in the universe, how galaxies and their stars and gas within and between them evolve over cosmic time, and what the physics is of fundamental but poorly understood cosmic components like dark matter and dark energy.

In addition, CanDIAPL (combined with a data archive from the National Research Council) forms part of the Canadian in-kind contribution to the Rubin observatory, granting data rights to over 250 Canadian researchers and students across the country.



JOIN US

Who We Are

The Dunlap Institute for Astronomy & Astrophysics at the University of Toronto is an endowed research institute with over 80 faculty, students, postdocs, and staff.

What we Do

At Dunlap, we design and build innovative technology like telescopes, spectrographs, and supercomputers to pursue ground-breaking astronomical research.

We also provide world-class training to students, and we run science and astronomy outreach events to engage the public across the Greater Toronto Area and beyond.

What we Study

Our team studies ultraviolet, optical, infrared and radio instrumentation, dark energy, large-scale structure, cosmic magnetism, time-domain science, galaxy evolution, the early Universe, and more.

Our Commitment

The Dunlap Institute is committed to making science, training, and outreach productive and enjoyable for everyone.

Please visit our website or check us out on social media to find out more about what's going on at Dunlap!

dunlap.utoronto.ca
discovertheuniverse.ca

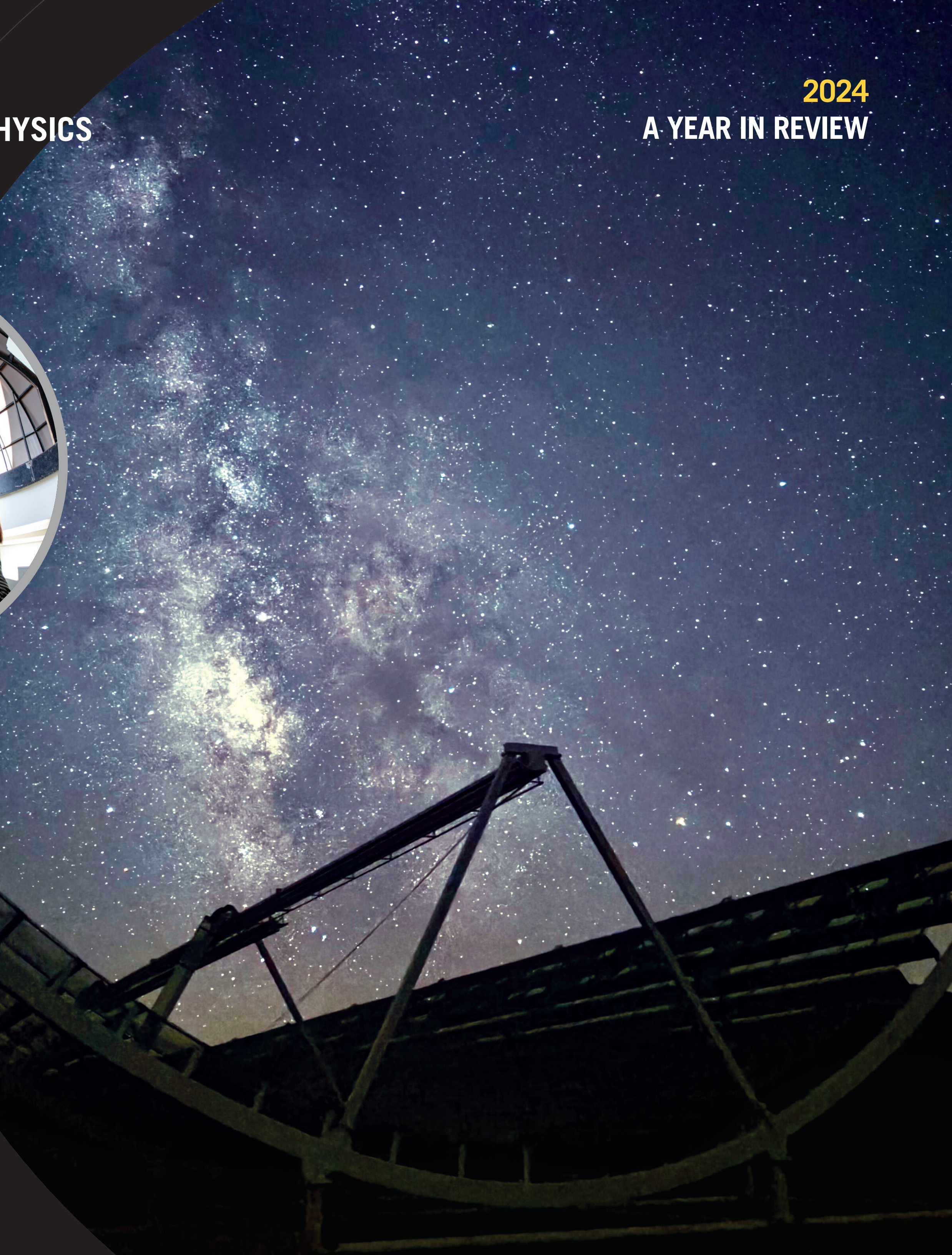
Cover photos left to right

Prof. Hložek looking through the UofT 8-inch telescope. Credit: Renée Hložek

One of the CHIME outrigger telescopes in Northern California. Credit: Mattias Lazda

DUNLAP INSTITUTE *for* ASTRONOMY & ASTROPHYSICS

2024 A YEAR IN REVIEW



Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO