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Pictured Above: Some members of the SuperBIT team pose in front of the balloon-borne SuperBIT telescope, prior to its launch in late 2019.

DUNLAP INSTITUTE *for* ASTRONOMY & ASTROPHYSICS

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

2020
A YEAR IN REVIEW

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, and we pursue ground-breaking astronomical research using these facilities.

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 infrared and radio instrumentation, dark energy, large-scale structure, cosmic magnetism, time-domain science, the early Universe, and more.

Our Commitment

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

Cover: Graduate Students Tomás Cassanelli and Vincent MacKay test a possible feed for a new Canadian radio telescope, CHORD. Photo Credit Mubdi Rahman, Dunlap Institute.
Also on the cover: the Small Magellanic Cloud and the globular cluster 47 Tucanae, taken from Las Campanas Observatory, Chile. Photo Credit: Anna O'Grady, Dunlap Institute

This page: Comet NEOWISE as it appeared over Toronto on the early morning of July 6, 2020. Photo Credit: Jennifer West, Dunlap Institute

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Prof. Bryan Gaensler

Director's Message

Any summary of 2020 must begin with the sentence: "This was not the year we planned." Nevertheless, it's been a time of enormous activity and creativity across all of the Dunlap Institute's core programs.

The CHIME telescope continues to transform our understanding: the discovery of periodic fast radio bursts, followed by the detection of a fast radio burst in the Milky Way, were huge surprises that have produced a slew of new theories and ideas. There was excellent progress on all our other major technology programs, and we made key discoveries on exoplanets, the early Universe, massive stars, and the structure of the Milky Way.

Our training activities continue to expand. We welcomed five new Dunlap Fellows this year—our biggest intake yet. Our summer program went 100% virtual, featuring more than thirty undergraduates from across Canada who pursued independent research and participated in a range of professional development activities.

The highlight of the year's outreach activities was our virtual Planet Party, which drew thousands of participants. Our online series "Astro At Home," "Cosmos From Your Couch" and "A Picture In 1000 Words" were all also extremely popular.

It's a huge credit to our team that we achieved so much in this difficult year. Deep thanks go to all who helped maintain the Dunlap Institute's unswerving commitment to expanding our cosmic understanding.

Pictured Above: Many Dunlap members wave from their home offices, at a 2020 team Zoom meeting.

Our Research

Earlier this year, a team of astronomers, including researchers from the University of Toronto and the Dunlap Institute, discovered that a repeating fast radio burst (FRB) originating from a nearby galaxy pulses at regular intervals.

Researchers from the Canadian Hydrogen Intensity Mapping Experiment (CHIME) Fast Radio Burst Collaboration used the CHIME telescope to show that the repeating radio source—first discovered in 2018 by the same group—pulsates every 16.35 days. The findings, published in Nature, are the first to show a predictable repeating pattern.

Corresponding author Dongzi Li is a PhD student at the University of Toronto and a member of the Dunlap Institute. "We were surprised by the fact that the FRB has regular activity on the time scale of weeks," explains Li. "Most people would expect it to be at much shorter time scales, like seconds or even milliseconds, from rotation of a compact star. Any explanation for a 16-day cycle is likely very different."

FRBs were first thought to be singular events when they were discovered about a decade ago. Astronomers have since learned that some of these high-intensity blasts of radio emissions do in fact, repeat.

"There are suddenly lots of concrete questions to follow-up on," explains Li. "If any observed properties of the bursts change regularly with the same 16.35-day period, it will tell us about the environment close to the burst."

Foreground: Dongzi Li, Dunlap and GTA Graduate Student
Background: The CHIME telescope in Penticton, B.C. Photo Credit: Andre Renard, Dunlap Institute

Our Technology

CIRADA

The Canadian Initiative for Radio Astronomy Data Analysis (CIRADA) is a $10M program to create sophisticated new software products and catalogues for studying the sky. In 2020 we launched CIRADA's online portal at cirada.ca. This features an all-sky source catalogue derived from the Very Large Array Sky Survey, the first release of CIRADA's image cut-out server, and a comprehensive software package, TRM-Tools, for analyzing radio polarization data. In 2021, we plan to produce our first catalogues from data taken with the Australian Square Kilometre Array Pathfinder, and will begin searching for pulsars and distant galaxies using the CHIME radio telescope.

SuperBIT

SuperBIT is a balloon-borne observatory operating in the stratosphere. SuperBIT obtains high-resolution optical images at a fraction of the cost of space-based missions to understand the nature of dark matter and dark energy, two of the biggest mysteries in modern science. Using data from SuperBIT's final test flight in September 2019, the team conclusively proved the feasibility of obtaining diffraction limited imaging from a balloon-borne observatory. Additionally, the team performed the first-ever weak lensing and optical sky background measurements from the stratosphere. The team is currently preparing for an upcoming science flight during which SuperBIT will observe more than 100 galaxy clusters.

Dragonfly

Over the last year the Dragonfly Telephoto Array team published 13 papers. There were several scientific highlights, including definitive confirmation (using data from the Hubble Space Telescope) that the distance to the ultra-diffuse galaxy DF-4 is 65 million light years—showing that this object really is deficient in dark matter. The exstence of dark-matter deficient ultra-diffuse galaxies was previously claimed by the Dragonfly team in a controversial Nature paper, which caused a large stir in the community, and which has turned out to be totally right! As a result of this work, much effort has been undertaken into the community to understand why ultra-diffuse galaxies (the class of object which Dragonfly brought to the attention of the world) are so remarkably diverse in their dark matter properties.

In addition to this work on ultra-diffuse galaxies, the team also submitted papers on a range of other subjects, including the a paper showing that low surface brightness emission from the circumgalactic medium of galaxies (the repository of most of the Universe's normal matter) might be detectable with a Dragonfly-like array. This work stimulated effort by the team to determine what it would take to find this emission, which culminated in a Canada Foundation for Innovation proposal to greatly increase the size of the Dragonfly array.

CHIME

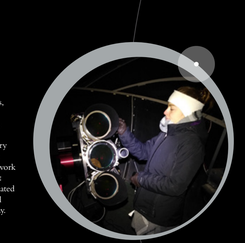
The Canadian Hydrogen Intensity Mapping Experiment (CHIME) continued firing on all cylinders throughout 2020. Because of its digital capacity, operations continued throughout periods of COVID's lockdown.

CHIME's core cosmological mission continues to amass the data needed to address Dark Energy, and additional survey modes have continued coming online, most recently allowing ultra-fine spectral resolution imaging.

GIRMOS

The Gemini Infrared Multi-Object Spectrograph (GIRMOS) is nearing the end of the second year of its design phase. Having completed the Conceptual Design Phase last fall, the project is currently in the Preliminary Design Phase (PDP) where many critical details of the instrument's design are being developed.

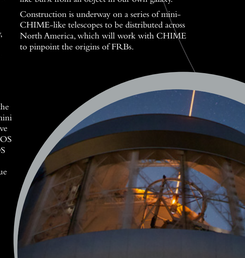
During the past year, the team made a major strategic decision to deploy GIRMOS at the Gemini-North telescope in Hawaii, instead of the originally planned Gemini-South site. The Gemini observatory is developing a cutting-edge adaptive optics facility at its northern site, where GIRMOS is better suited. This facility will make GIRMOS much more scientifically productive, thanks to its better overall performance and efficient queue scheduling making.



Top: Grad Student Deborah Lokhorst adjusts the baffling that prevents stray light from entering the telescope on the Dragonfly narrowband imaging pathfinder. Photo Credit: Roberto Abraham.
Middle: members of the CHIME Collaboration. Photo Credit: Andre Renard, Dunlap Institute

The Fast Radio Burst backend (CHIME/FRB) yielded a host of new discoveries, from the first periodicity found in an FRB, to the first FRB-like burst from an object in our own galaxy.

Construction is underway on a series of mini-CHIME-like telescopes to be distributed across North America, which will work with CHIME to pinpoint the origins of FRBs.



Our Outreach

After 10 years of making a mark with our big, in-person public programs, Dunlap went online in a big way in 2020. When the pandemic quarantined stranded kids at home without their teachers, our Discover the Universe (DU) program was ready. From March through May, DU's "Astro At Home" program provided daily bilingual astronomy lessons for kids on YouTube, starting from the first days of the pandemic. Astro At Home now leaves a legacy of a curated collection of more than 100 educational videos that will be resources for teachers for years to come.

At Dunlap headquarters, we spun up three new online programs. "Cosmos from Your Couch" has provided weekly talks on topics ranging from black holes to the astronomical heritage of Toronto. "A Picture in a Thousand Words" gives a weekly deep dive into how famous astronomical images were made and what cosmic secrets they reveal. Our debut online version of our annual Planet Party encouraged thousands of people to take their devices outside and stargaze along with us.

2020 might have kept us apart from one another, but we're still finding ways to come together and share our curiosity about the cosmos.

Our Training

Training in 2020 focused on virtual events, with an emphasis on skills development. This included networking, writing talks and reference letters. A particular highlight was the panel discussion "Careers outside Academia," where four current or previous members of the Dunlap Institute discussed their career paths and provided members with tips for building career skills outside of university institutions. Our mentoring program has also grown to include a postdoc-student mentoring scheme, in addition to the existing faculty-postdoc mentoring scheme.

During the summer of 2020, the teaching and mentoring team also hosted a "quarantine speed chat"—an online rapid-fire discussion between different members as a way to bring new people into the broader community and to build connections while working remotely.

Although COVID-19 impacted some of our 2020 activities such as the cancellation of the Dunlap Summer School, accepted participants were given the option of returning for the next in-person school.

Left, foreground: the Gemini South Telescope in Chile. Photo Credit: Suresh Sivanandam
Left, background: Events and Outreach Officer Kara Manovich gets ready to moderate an online "Cosmos From Your Couch" event in April, 2020.