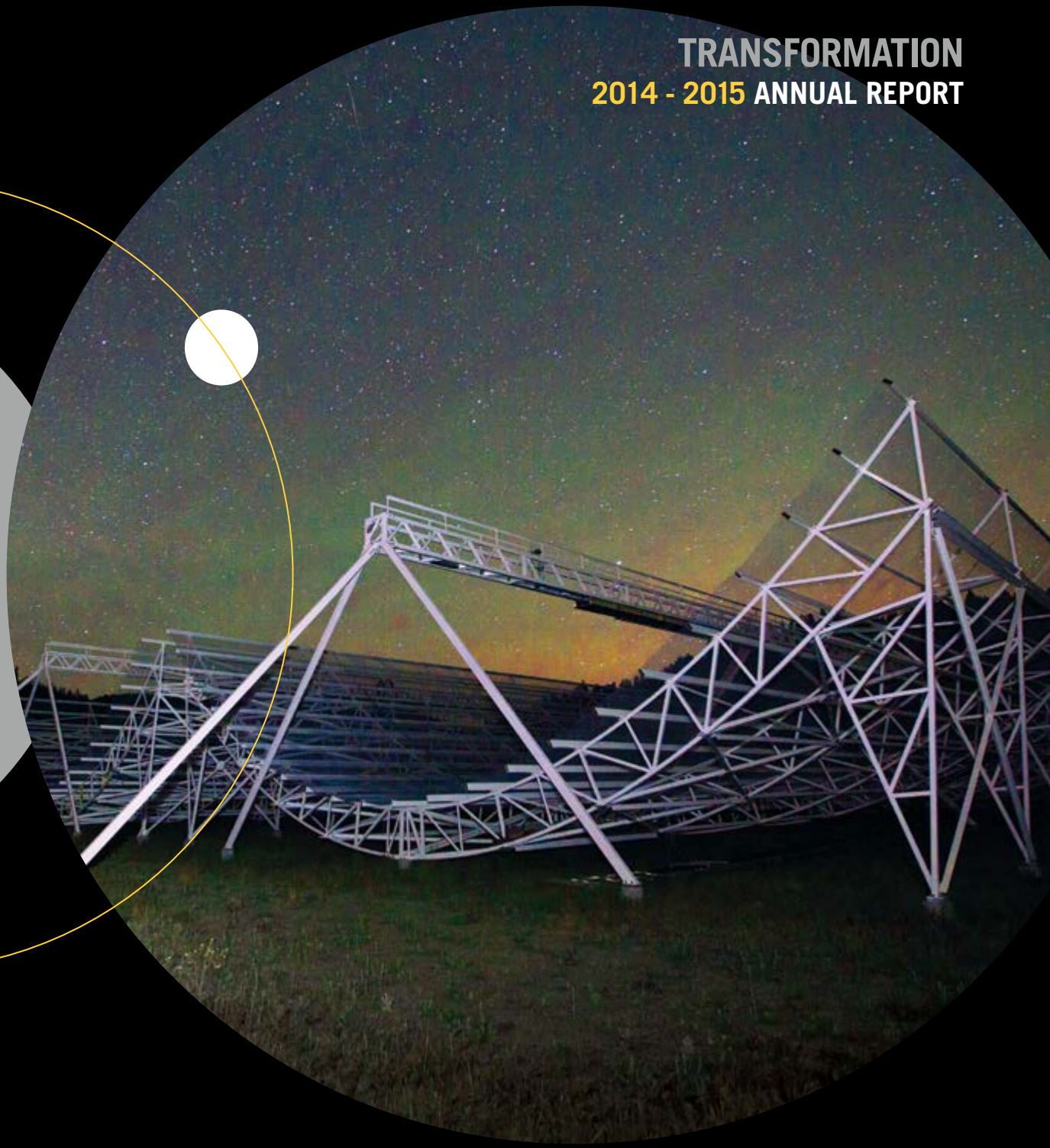
DUNLAP INSTITUTE *for* ASTRONOMY & ASTROPHYSICS

TRANSFORMATION

2014 - 2015 ANNUAL REPORT



Dunlap Institute for
Astronomy & Astrophysics
UNIVERSITY OF TORONTO

Prof. Bryan Gaensler

Director's Message

The recurring theme of the Annual Report you are about to read is "transformation."

You will first be struck by the innovative ways in which Dunlap Institute researchers are using technology to transform our approach to astronomy. CHIME and NIROSETI are two very different experiments, but both epitomise the Dunlap way of doing things.

The team behind CHIME (pg. 5), led at the Dunlap by Prof. Keith Vanderlinde, is doing something that was once impossible and unthinkable: their telescope has no moving parts. The power of this quintessential 21st century spyglass is not in the gears and mirrors, but in the supercomputer that sits alongside it. By processing stupendous amounts of data at mind-boggling speeds, CHIME aims for nothing less than to map the history of the Universe.

"CHIME and NIROSETI are two very different experiments, but both epitomise the Dunlap way of doing things"

At the other end of the spectrum, NIROSETI (pg. 3) is a Dunlap project led by Prof. Shelley Wright and Jérome Maire to look for signs of intelligent life in other solar systems. While the search for extraterrestrial intelligence (SETI) is more than 50 years old, most of that effort has been at radio wavelengths. In contrast, NIROSETI combines several new technologies to search for SETI signals consisting of nanosecond pulses of infrared radiation. NIROSETI saw "first light" early in 2015, and will begin searching for signals in earnest later this year.

The Dunlap Institute is also overseeing a very different but equally important type of transformation: the transformation of enthusiastic students and postdocs into seasoned scientists and problem solvers. We are deeply committed to training the next generation of scientists, not just by letting them lead interesting research projects, but also by teaching them vital technical and pedagogical skills. We are thrilled by our growing collaboration on professional development with the Institute

Cover

The CHIME Pathfinder at the Dominion Radio Astrophysical Observatory, NRC, in B.C.

Dunlap Fellow Laura Newburgh works on a CHIME feed in the Long Wavelength Lab at the Dunlap Institute.

"Despite our successes in this area, what we have achieved is only the beginning."

Prof. Bryan Gaensler is Canadian Science Director for the SKA, the Square Kilometre Array (artist's rendering above).

for Scientist and Engineer Educators, and last summer we held another highly successful—and heavily oversubscribed—Dunlap Institute Summer School on Astronomical Instrumentation (pg. 16, 17).

Finally, we aim to transform the wider community's appreciation of the Universe. The Dunlap Institute is unique in that we have a specific mandate from the University of Toronto and from the Dunlap family to foster public engagement in science. Whether on campus at events like the Transit of Venus at Varsity Stadium, the Dunlap Prize Lecture, or our popular planetarium shows, or throughout the city at the Dunlap-sponsored Astronomy on Tap T.O. (pg. 19), we have an unflagging commitment to sharing our excitement about science with the wider community. Despite our successes in this area, what we have achieved is only the beginning. We have plans for much more ambitious education and outreach programs in the coming years, which will soon begin to take shape.

In my first few months as Director, I've repeatedly been impressed by the high quality of our scientists, staff and students, and have been inspired by their vision and enthusiasm. The dynamism of the Dunlap Institute is a testament to the inspirational role played by the outgoing Interim Director, Prof. Peter Martin. On behalf of the Institute, the University of Toronto and the Dunlap family, I offer a huge note of thanks to Peter for his wise leadership in recent years, and additionally for convincing me to take up this position.

I want to take this opportunity to publicly thank some of the other talented individuals in the Dunlap from whom I have already begun to learn so much: Michael Reid, who is one of the most inspiring educators I have ever met; Chris Sasaki, who shares my ambitious vision for the Dunlap's future; and Alice Chow, the epitome of professionalism and the glue that holds the Institute together.

Finally, I want to highlight the superb work done by our Dunlap Fellows and postdocs, the young scientists who are our "secret weapons" for research, teaching and outreach. Most of what you will read about in the following pages is a result of their hard work and brilliant insights.

Instrumentation Research

Transforming the Tools of Astronomy

U of T graduate student Elliot Meyer and a collimator lens assembly for WIFIS, the Wide Integral-Field Infrared Spectrograph. WIFIS will be used to observe extended objects like supernova remnant Cassiopeia A.

Credit: Cassiopeia A: X-ray: NASA/CXC/SAO; Optical: NASA/STScI; Infrared: NASA/JPL-Caltech/ Steward/O. Krause et al.

Instrumentation Research

A "Made-in-Canada" Search for Extraterrestrial Intelligence

–
NIROSETI
Near-InfraRed Optical Search
for ExtraTerrestrial Intelligence

Members of the NIROSETI team at Lick Observatory including Prof. Shelley Wright (third from r.), Jérome Maire (fourth from r.) and U of T undergraduate student Patrick Dorval (second from r.).

Credit: © Laurie Hatch

If an advanced extra-terrestrial civilization were trying to communicate with us, what technology would they use? For decades, astronomers reasoned that ET would use radio signals, and so most SETI (Search for ExtraTerrestrial Intelligence) programs scanned the skies with radio telescopes.

But a team of astronomers, including SETI pioneer Frank Drake and led by the Dunlap's Prof. Shelley Wright, thinks ET is trying to get our attention with flashes of infrared laser light a billionth of a second in duration.

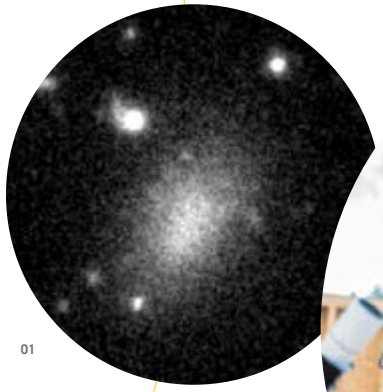
The signals would be infrared, the thinking goes, because light at that wavelength is not blocked by interstellar gas and dust to the same extent as visible light; and they would be nanosecond-long flashes instead of a continuous beam because such a short pulse can be made to outshine a star.

In March, Wright and her colleagues began a ground-breaking search based on this strategy when they installed an instrument called NIROSETI (Near InfraRed Optical SETI) on a telescope at the University of California's Lick Observatory. The observatory was the site of several previous SETI searches, including one with an optical instrument built by Wright when she was an undergraduate student.

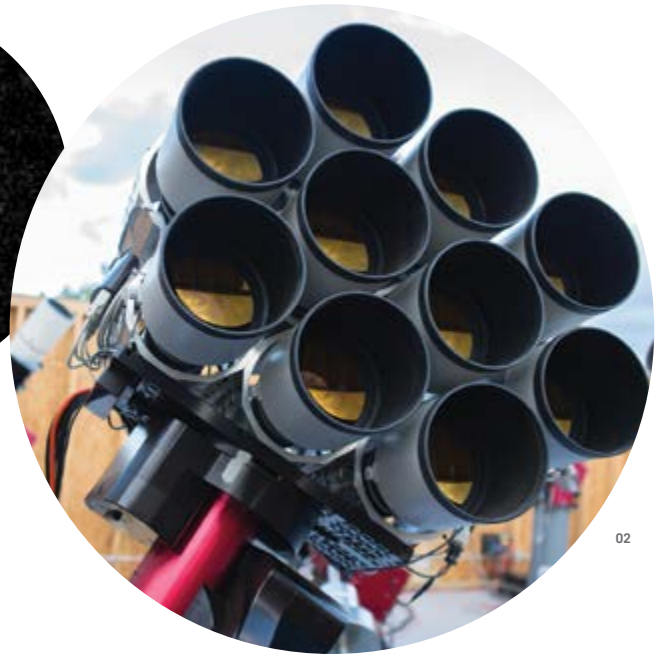
Wright developed and built NIROSETI while at the Dunlap Institute, working with Dunlap Fellow Jérome Maire who was vital in developing an instrument capable of detecting such a fleeting pulse and distinguishing between a natural signal and one that tells us we are not alone.

Instrumentation
Research

Seeing the Unseen



01



02

There's more to the Universe than meets the eye or even the largest telescopes. And sometimes it takes a special astronomical eye to reveal how much more.

The Dragonfly Telescope Array is a unique multi-lens instrument with the ability to detect extremely faint objects that even large telescopes can't see—objects like the tenuous streams and filaments of material left over in the aftermath of galaxy mergers.

Dragonfly accomplishes this using ten 400mm photographic lenses with innovative lens-coatings and glass that greatly reduce internal scattered light and reflections, thereby revealing hard-to-detect structure.

In observations made during 2014, Prof. Roberto Abraham and his collaborators used Dragonfly to detect 47 extremely faint objects in the direction of the Coma Cluster, a vast collection of several thousand galaxies at a distance of 320 million light-years.

The objects look like dwarf galaxies, a relatively common type of galaxy, without spiral arms and much smaller than the Milky Way and Andromeda galaxies; and it seemed likely they were relatively nearby dwarf galaxies that happened to be in the line of sight with the Coma Cluster.

However, in follow-up observations with a spectrograph on the Keck I telescope in Hawaii, Abraham and his colleagues determined that the objects are at the same distance as the Coma Cluster—which means they are members of the distant cluster, and are not dwarfs but are comparable in size to the Milky Way Galaxy.

The new objects are an entirely new species of galaxy: large, diffuse, with much less gas and only one percent of the stars found in galaxies like ours. The objects—dubbed UDGs for Ultra Diffuse Galaxies—should disperse because they don't appear to have the mass required to hold themselves together. Instead, Abraham and his colleagues think they may contain as much as 98% dark matter.

It may be that Dragonfly has detected galaxies that are not just barely visible, but are made up mostly of invisible matter.

01. Spectroscopic observations of Ultra Diffuse Galaxy Dragonfly 44 confirmed it is a member of the Coma Cluster.

Credit: P. Van Dokkum, R. Abraham, J. Brodie

02. Dragonfly

Instrumentation
Research

Mapping the Universe

CHIME is a ground-breaking radio telescope that will map the largest volume of space ever surveyed. It will provide insight into an epoch of the early Universe during which dark energy first began to play an important role in the evolution of the cosmos.

CHIME is being built in the B.C. interior by an all-Canadian team of researchers from the University of British Columbia; the Dominion Radio Astrophysical Observatory, NRC; McGill University; and the University of Toronto. The team at the Dunlap Institute is led by Prof. Keith Vanderlinde. (Collaborations, pg. 12-13)

The CHIME Pathfinder prototype has been operating since the winter of 2013/2014, and in 2015 construction commenced on the four 20x100-metre half-cylinders that make up CHIME proper.

CHIME does not look at individual astronomical targets like galaxies; instead, it scans a narrow line in the sky from due north through the zenith to due south. As the sky moves from east to west over the course of a day, CHIME maps the entire northern sky.

But CHIME will also measure the redshift—and hence distance—of distant clouds of hydrogen. The result will be a three-dimensional map billions of light-years thick, covering half the sky.

When you map such a large volume of space, you generate vast amounts of data. Once construction and commissioning is completed in 2016, CHIME will generate 1 terabyte of data per second as it scans the sky. That's more data per second than all current consumer and web traffic combined.

It takes an enormous amount of computing power to handle this much data and CHIME's capability will be 25 times greater than that of the Atacama Large Millimeter/submillimeter Array (ALMA)—currently the largest radio telescope in the world—putting CHIME in the ranks of the world's most powerful supercomputers.

Construction in progress as of May 2015.

Credit: Prof. Keith Vanderlinde; Dunlap Institute

Observational Research

Transforming Our Understanding of the Universe

01

02

01. Dunlap Fellow Rachel Friesen leads the Green Bank Ammonia Survey (GAS) which will map ammonia gas in star-forming regions like the Ophiuchus molecular cloud.

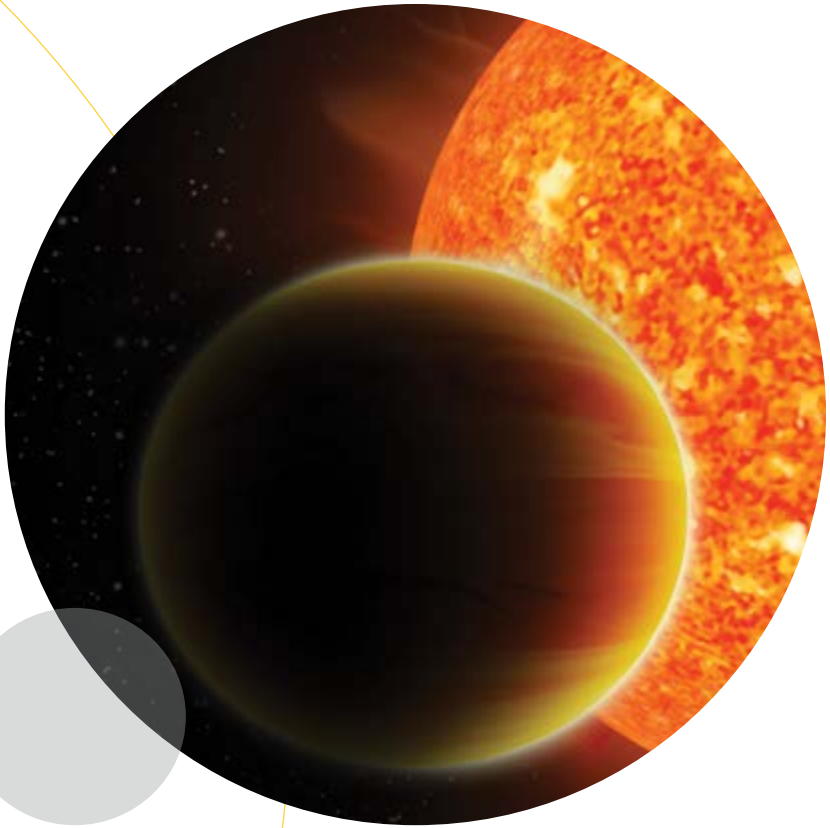
Credit: Dr. Rachel Friesen; Dunlap Institute

02. Rendering of a binary comprising a pulsar (l.) and white dwarf star (r.). According to research by Dunlap Fellow John Antoniadis, a newly discovered class of such binaries may form through a short-term interaction with a surrounding disk of material.

Credit: Dr. John Antoniadis

Observational Research

Hot Jupiters Come Up Dry



Artist's rendering of a hot Jupiter in orbit around a star.

Credit: Haven Giguere, Nikku Madhusudhan

A team of astronomers, including Dunlap Fellow Nicolas Crouzet, has made the most precise measurements yet of water vapour in the atmospheres of Jupiter-like planets beyond our Solar System and found them to be much drier worlds than expected.

The co-investigators analyzed near-infrared spectra, obtained using the Hubble Space Telescope, of three "hot Jupiters"—gas giant exoplanets with very hot atmospheres, orbiting close to their parent stars.

The Hubble could not directly resolve the planets; instead, it collected light from both the parent star as well as light that passed through the planet's atmosphere as the planet passed in front of the star. When the astronomers subtracted the light of the star from the total light collected, what remained was the light that passed through the planet's atmosphere.

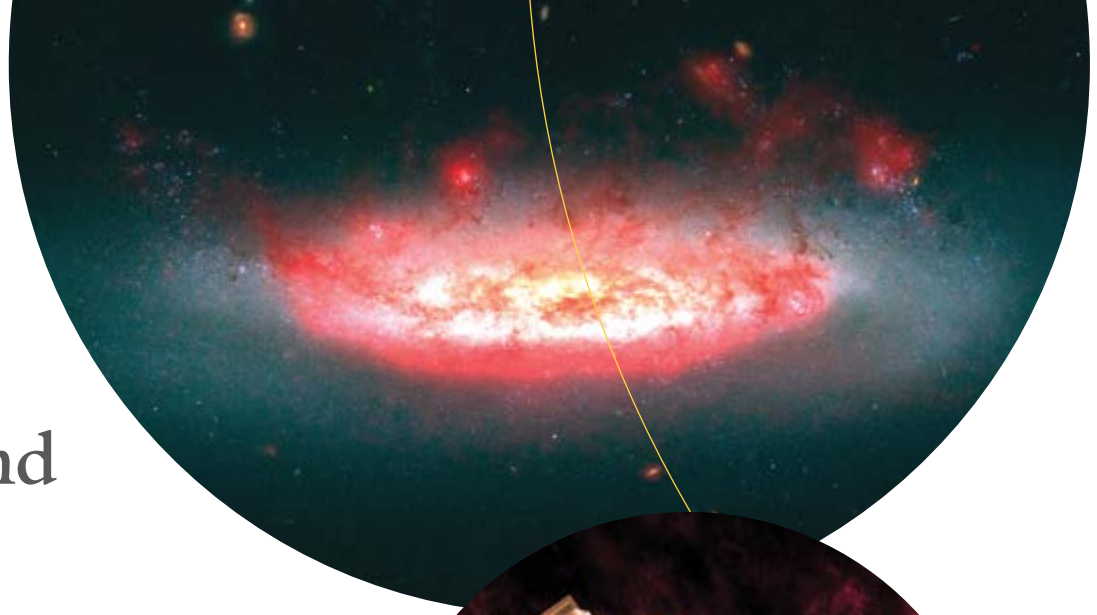
Spectroscopic analysis of this light revealed that the abundance of atmospheric water vapour is between ten and a thousand times less than what is predicted by the core accretion theory of planetary system formation.

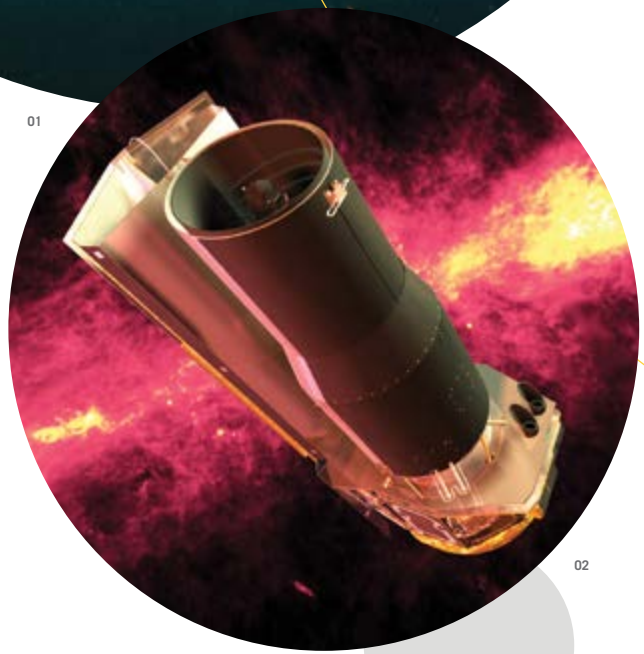
According to the theory, planetary systems form from a huge disk of hydrogen gas and dust around a star. Dust particles in the disk accrete into larger particles, and these accumulate until they coalesce into a planet which, in turn, attracts an atmosphere of gas. The theory predicts that oxygen would be the most abundant element—other than hydrogen and helium—in hot-Jupiter atmospheres and would take the form of water vapour in the atmosphere.

The very low levels of water vapour discovered raise questions about our understanding of the formation of planetary systems and the chemical processes involved in planet formation—and they raise more fundamental questions about the abundance of both water and life on other worlds.

Observational Research

The Answer is Blowing in the Intergalactic Wind





01

02

For decades, astronomers have tried to understand why galaxies in dense clusters of galaxies have so few young stars when compared to those outside clusters. Why don't stars form in these galaxies the way they do in others?

One theory states that, as a galaxy—moving at thousands of kilometres a second—merges with a cluster, it encounters the cloud of hot intergalactic gas that envelopes the entire cluster. The hot gas acts like a wind, blowing molecular hydrogen gas from the in-falling galaxy like smoke from a candle being carried into a room. The result is a galaxy depleted of molecular hydrogen, the raw material from which stars form.

This process is known as ram-pressure stripping and it has been observed indirectly: young stars trailing from a galaxy, presumably formed from gas newly-stripped from the galaxy; and galaxies with tails of very tenuous gas.

But now, Dunlap Fellow Suresh Sivanandam and astronomers from the University of Arizona have provided the first direct evidence of this intergalactic "wind."

Using the Spitzer space telescope, Sivanandam and his colleagues observed the light coming from dust in four galaxies. The dust is known to trace molecular hydrogen and the observations revealed a "wake" of this stellar fuel trailing the galaxies as they move through the cluster.

The result is clear evidence of ram-pressure stripping and shows that the price of admission to a cluster of galaxies may be star formation.

01. A composite image of the galaxy NGC 4522. The galaxy appears blue in the Hubble Space Telescope image; Spitzer data shows dust which traces molecular hydrogen in red. In the image, the galaxy is moving down and into the plane of the photo.

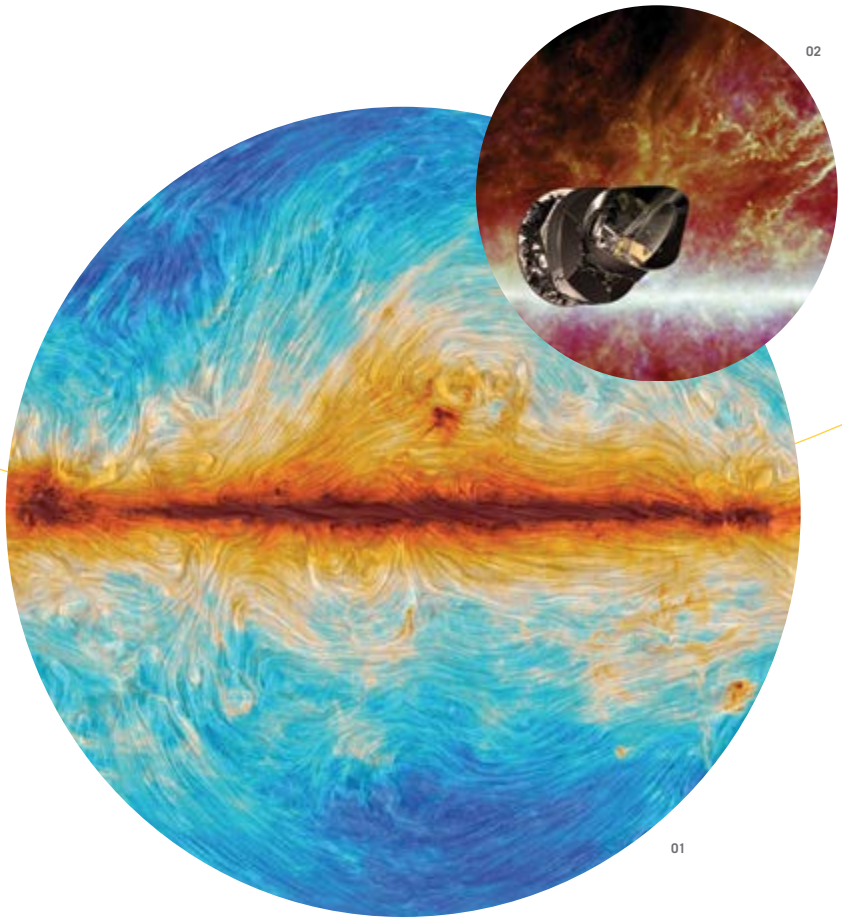
Credit: Suresh Sivanadam; Dunlap Institute

02. Spitzer Space Telescope

Credit: NASA/JPL-Caltech/ R. Hurt

Observational Research

Searching for a Signal from the First Second of Time



02

01

In March 2014, researchers using the BICEP2 telescope at the South Pole announced they had detected the first evidence of cosmic inflation. First proposed over thirty years ago, the theory of cosmic inflation suggests the Universe experienced a brief period of accelerated expansion—called inflation—in the first second of time.

According to the theory, inflation would have generated gravity waves that rippled throughout the cosmos and left their mark on the Cosmic Microwave Background (CMB), light from when the Universe was only 380,000 years old. According to the BICEP2 scientists, they had found the mark: a distinctive pattern in the polarization, or orientation, of the CMB.

But close on the heels of that announcement, other researchers speculated that the pattern wasn't from the beginning of time, but was instead from a source closer to home. Thus began a partnership between the BICEP2 researchers and scientists from the Planck satellite collaboration.

The Planck collaboration includes researchers at the University of Toronto from the Canadian Institute for Theoretical Astrophysics, the Department of Astronomy & Astrophysics, and the Dunlap Institute's former interim director, Prof. Peter Martin.

Launched in 2009, Planck has given astronomers the most detailed view of the CMB. And with both BICEP2 and Planck data, the scientists concluded that the pattern found in the CMB by BICEP2 was not the result of inflation-generated gravity waves. Instead, the pattern turned out to be in the polarized microwave emission from dust within the Milky Way Galaxy.

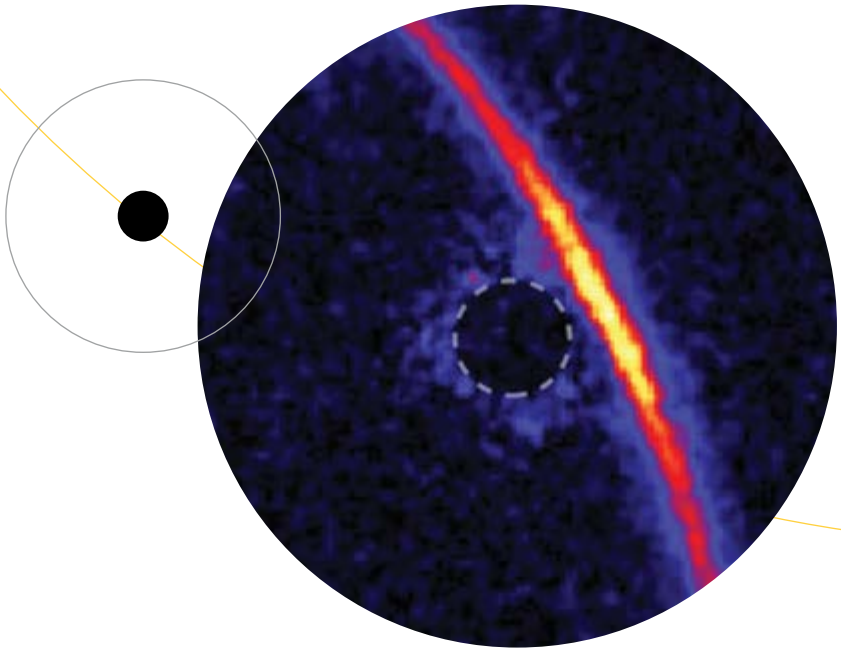
The collaboration's result doesn't disprove inflation. In fact, it gives us a clearer idea about the nature of inflation—as well as the nature of scientific investigation—and the search continues for a signal from the beginning of time.

01. Planck image showing the abundance of interstellar dust particles in the plane of our Galaxy. Lines indicate the galaxy's magnetic field lines.
Credit: ESA and the Planck Collaboration

02. Planck spacecraft.
Credit: ESA - C. Carreau

Observational Research

First Science from a New Planet Finder



GPI image of the ring around HR 4796A.

Credit: M. Perrin; G. Duchene; M. Millar-Blanchaer; GPI Team

Before 1992, we knew of only one planetary system in the entire Universe: our own Solar System. Since then, there has been a revolution in planet finding and, today, we have identified thousands of exoplanets in orbit around distant stars.

Most exoplanets were discovered indirectly by looking for the effect they have on a star's motion or by observing the brightness of a star decrease as an exoplanet passes in front of it.

But a new revolution of planet finding has begun with the Gemini Planet Imager (GPI)—an adaptive-optics, imaging spectrograph—and instruments like it. With GPI, astronomers can see planets directly, allowing them to study those worlds spectroscopically.

Dunlap Fellow Jeffrey Chilcote and his colleagues used GPI to obtain the first infrared spectrum of a planet called β Pic b—a planet 10 to 12 times the mass of Jupiter, over 60 light-years from Earth. The researchers determined that the planet's atmospheric temperature was 1300 to 1400°C, and the planet's gravity is 10 to 100 times that of Jupiter's.

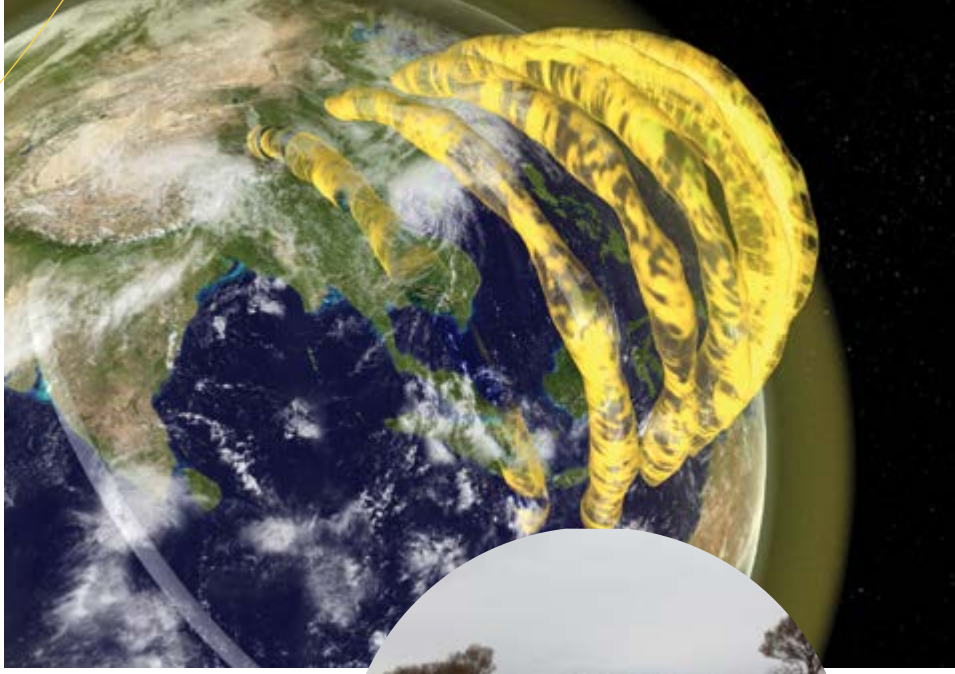
GPI also measures the orientation or polarization of light waves. A star's light is polarized when it reflects off or is scattered by a ring or disk of dust particles in orbit around it. Observing rings and disks around stars is important, because these may be planetary systems in the process of formation.

Using GPI, U of T graduate student Max Millar-Blanchaer and his colleagues observed a ring of material known to circle a star designated HR 4796A and have literally turned our understanding of the ring front-to-back. With GPI's observations of the light reflected and scattered by the ring, they now see that what we thought was the edge closest to us is in fact farthest. What's more, their observations suggest that the form of the ring could be affected by an orbiting planet, in the same way that Saturn's rings are influenced by its moons.

While GPI's main science program is the GPI Exoplanet Survey—a search for Jupiter-size planets around 600 nearby stars—the early science observations by Chilcote, Millar-Blanchaer and others show it is living up to expectations as a ground-breaking instrument.

Observational Research

What Distant Radio Galaxies Reveal About Our Planet



01

02

Sometimes, telescopes designed to study the farthest reaches of the Universe can help us understand our own planet.

The Murchison Widefield Array (MWA) is a radio telescope in Western Australia normally used to observe the early Universe, distant galaxies, and stars and nebulae within our own Milky Way Galaxy. It is built on one of the sites planned for the Square Kilometre Array which, when completed in the 2020s, will be the largest radio telescope ever built.

Using the MWA, Dunlap director Prof. Bryan Gaensler and his colleagues observed 1000 radio galaxies and quasars over a large patch of sky near the zenith. Normally such targets "jiggle"; they change their positions in the sky by very small amounts, and astronomers use various methods to subtract the motion from their data.

Gaensler and his colleagues tracked the jiggling of the sources over the course of a single night and found that the motion was not random, nor did it have a cosmic origin.

Instead, it was caused by something much closer. As light from cosmic radio sources passes through the lowest layers of the Earth's magnetosphere, their paths—and hence their apparent positions—are altered by variations in density in those layers. The effect is like looking up from the bottom of a swimming pool and seeing distortions caused by waves at the surface.

Mapping the variations revealed the shape and dimensions of tube-like regions of increased particle density. Researchers had suspected the existence of such tubes but had not observed them directly. The observations by Gaensler and his collaborators revealed that the tubes above the MWA are 500 to 700 km above the surface and are aligned with the Earth's magnetic field lines. They are at an angle to the surface, following the field lines as they angle down to the south magnetic pole.

With these observations of objects billions of light-years away, Gaensler and his colleagues have discovered something that, in astronomical terms, is right in front of our noses.

01. Artist's rendering of tube-like structures aligned with Earth's magnetic field

Credit: CAASTRO / Mats Björklund (Magipics)

02. One "tile" of 128 that make up the MWA

Credit: Paul Bourke and Jonathan Knispel. Supported by WASP (UWA), iVEC, ICRAR, and CSIRO.

Faculty, postdoctoral fellows and graduate students from the Dunlap Institute, Department of Astronomy & Astrophysics (DAA) and Canadian Institute for Theoretical Astrophysics (CITA) are members of research and instrumentation collaborations which include astronomers from institutions around the world.

Collaborations

2014 - 2015

LEGEND

Astronomer | Instituition

ARO VLBI
Algonquin Radio Observatory
Very Long Baseline Interferometry

Prof. Keith Vanderlinde	Jodrell Bank
Dr. John Antoniadis	Giant Metrewave Radio Telescope
Prof. Ue-Li Pen *(CITA)*	European VLBI Network
Prof. Marten Van Kerkwijk *(DAA)*	Very Long Baseline Array, NRAO
Siqi Liu	Curtin University
Robert Main	

APOGEE
Apache Point Observatory
Galaxy Evolution Experiment

Prof. Shelley Wright	University of Virginia
Dr. Duy Cuong Nguyen	Apache Point Observatory

ASKAP
Australian Square Kilometre Array Pathfinder

Prof. Bryan Gaensler	Dominion Radio Astrophysical Observatory, NRC
	University of Calgary
	CSIRO - Commonwealth Scientific and Industrial Research Organisation
	University of Cape Town
	University of Sydney
	Australian National University
	University of Minnesota

SoTL
Scholarship of Teaching and Learning

Dr. Michael Reid	
Prof. John Percy *(DAA)*	
Dr. Mike Williams *(DAA)*	
Morten Støstad	

CHIME
Canadian Hydrogen Intensity Mapping Experiment

Prof. Keith Vanderlinde	UBC
Dr. Laura Newburgh	McGill University
Dr. Peter Klages *(Dunlap/IBM)*	Dominion Radio Astrophysical Observatory, NRC
Prof. Richard Bond *(CITA)*	
Prof. Ue-Li Pen *(CITA)*	
Dr. Richard Shaw *(CITA)*	
Philippe Berger	
Liam Connor	
Nolan Denman	
Andre Recnik	

SPT-3G
South Pole Telescope – 3rd Generation

Prof. Keith Vanderlinde	University of Chicago
Ronald Gagne	University of California, Berkeley
Nikhil Mahajan	Case Western Reserve University
Colin Merkel	Harvard-Smithsonian
	McGill University
	University of Colorado Boulder
	Argonne National Laboratory
	University of California, Davis

Dragonfly Telescope Array

Prof. Roberto Abraham *(Dunlap/DAA)*	Yale University
Prof. Peter Martin *(Dunlap/CITA)*	
Jielai Zhang	

GPI
Gemini Planet Imager

Dr. Jeffrey Chilcote
Dr. Quinn Konopacky
Dr. Jérome Maire
Max Millar-Blanchaer

American Museum of Natural History
Arizona State University
Gemini Observatory
Herzberg Institute of Astrophysics
Jet Propulsion Laboratory
Lawrence Livermore National Laboratory
NASA Ames
SETI Institute
Space Telescope Science Institute
Stanford University
University de Montreal
University of California, Berkeley
University of California, Los Angeles
University of California, Santa Cruz
University of Georgia

MaNGA
Mapping Nearby Galaxies at Apache Point Observatory

Prof. Shelley Wright
Dr. Brian Cherinka
Dr. David Law

Kavli IPMU
University of Washington
University of Kentucky
University of Texas at Austin
Open University, Wisconsin
University of St. Andrews, Scotland
University of Portsmouth
Universidad Nacional Autónoma de México
University of Nottingham
Cambridge University
Shanghai Astronomical Observatory
University of Wisconsin-Madison
Max Planck Institute for Astronomy
European Southern Observatory

IRIS
Infrared Imaging Spectrograph

Prof. Shelley Wright
Dr. Shaojie Chen
Dr. Tuan Do
Dr. David Law
Dr. Jérome Maire
Elliot Meyer

Caltech Optical Observatories
UCLA
Lawrence Livermore National Laboratory
Herzberg Institute of Astrophysics, NRC
Thirty Meter Telescope Observatory Corporation
UC Observatories, CfAO
Dominion Astrophysical Observatory, NRC
National Astronomical Observatory of Japan
Nanjing Institute of Astronomical Optics and Technology, Chinese Academy of Sciences

GAS
Green Bank Ammonia Survey

Dr. Rachel Friesen
Prof. Peter Martin *(Dunlap/CITA)*
Prof. Chris Matzner *(DAA)*

University of Alberta
University of Arizona
Harvard-Smithsonian CfA
Max Planck Institute for Extraterrestrial Physics
NRC-Herzberg
Yale University

MSAMOS
Multi-Shutter Array - Multiple Object Spectrograph

Dr. Suresh Sivanandam
Prof. Dae-Sik Moon *(Dunlap/DAA)*

NASA/Goddard
University of Maryland

WIFIS
Wide Integral-Field Infrared Spectrograph

Dr. Suresh Sivanandam
Prof. Dae-Sik Moon *(Dunlap/DAA)*
Miranda Jarvis
Mark Ma
Elliot Meyer

University of Arizona
University of Florida
Korean Astronomy and Space Science Institute

MWA
Murchison Widefield Array

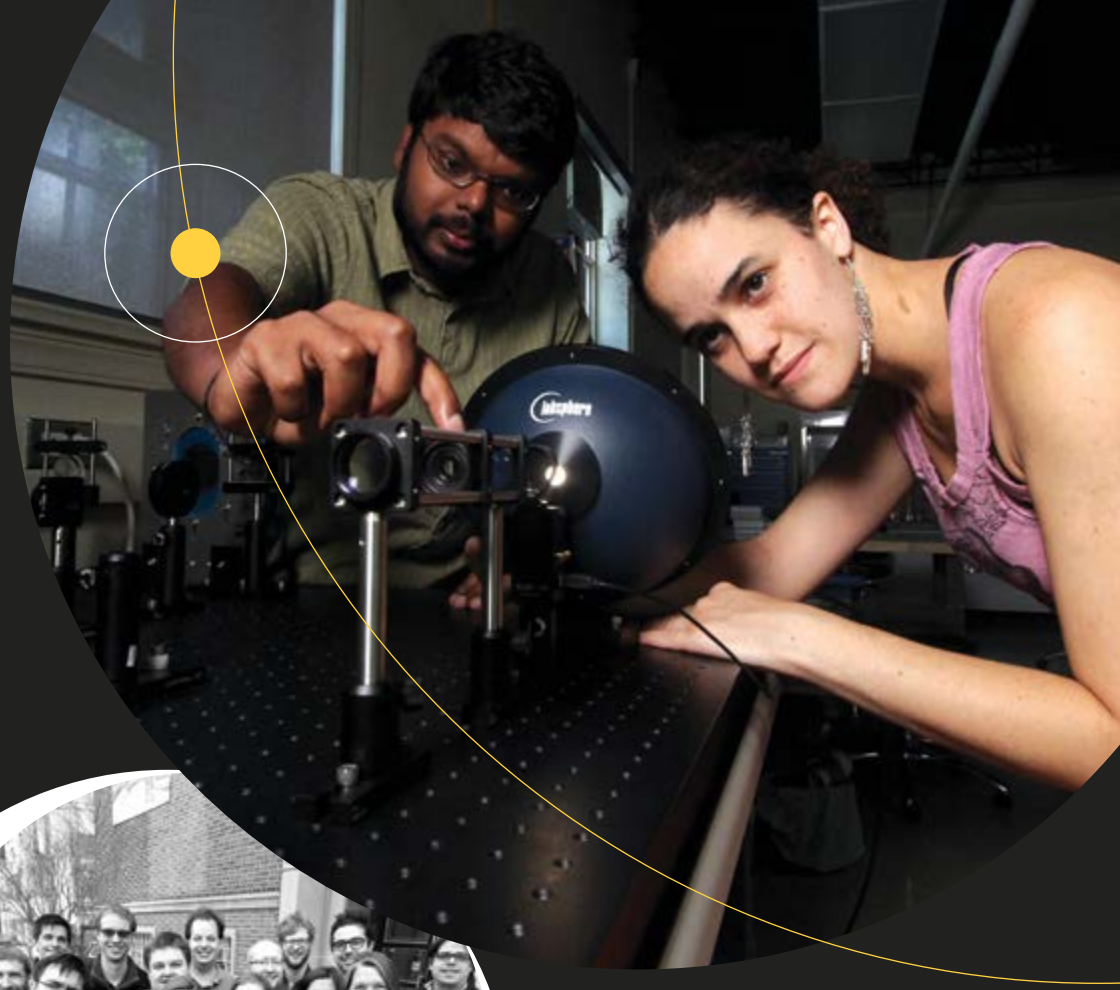
Prof. Bryan Gaensler

CAASTRO – Centre of Excellence for All-sky Astrophysics
Curtin University
MIT
Raman Research Institute
Victoria University of Wellington
University of Wisconsin

NIROSETI
Near Infrared-Optical SETI

Prof. Shelley Wright
Dr. Jérome Maire
Patrick Dorval

University of California, San Diego
University of California, Berkeley
Starman Systems
SETI Institute



01

Training

Transforming the Next Generation of Scientists

02

01. U of T undergraduate student Miranda Jarvis during the 2014 U of T Summer Undergraduate Research Program in astronomy working with Suresh Sivanandam on a component used in the development of the WIFIS spectrograph.

02. Students in the Professional Development Program workshop of the Institute for Science and Engineer Educators, hosted by the Dunlap Institute. The Dunlap is the first international chapter of the ISEE.

Training

2014 Summer Undergraduate Research Program

"I learned how to formulate questions."

"[Presenting my research] was essential practice and preparation for the world of academia."

"It was incredibly valuable to learn how to read papers, or more specifically how to extract the most valuable information."

"Getting feedback on my abstract from my peers was especially important."

From May 5th to August 22nd, 24 undergraduate students from universities across the country took part in the annual Summer Undergraduate Research Program in astronomy at the U of T.

The students worked on their own research projects with postdoctoral fellows and faculty in the Dunlap Institute, the Department of Astronomy & Astrophysics, the Canadian Institute for Theoretical Astrophysics, and the Centre for Planetary Sciences.

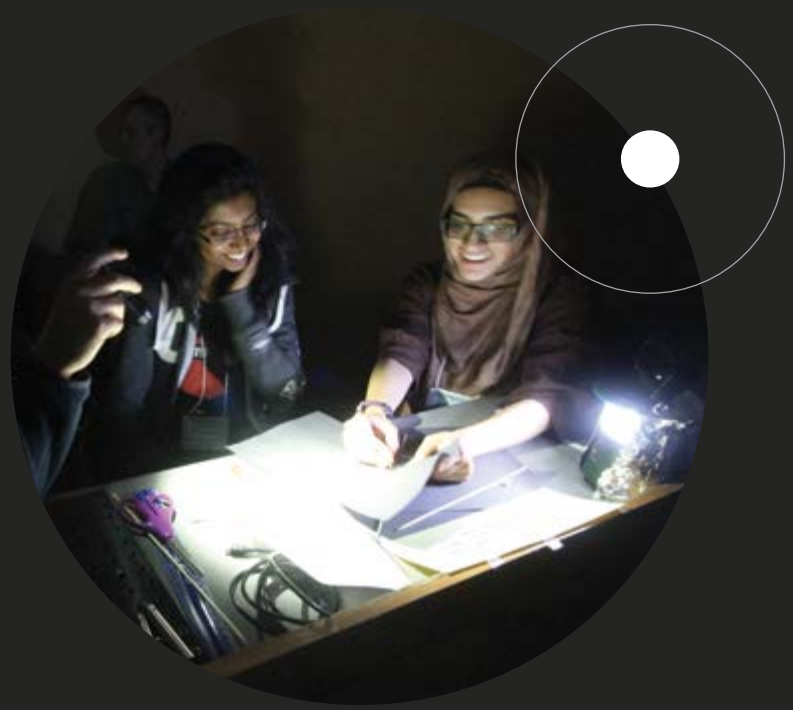
The program included an inquiry-based course, collaborative meetings, and a weekly meeting to discuss the latest research papers from scientific journals; it included workshops on giving scientific presentations, figure-making and abstract-writing; students also took part in a discussion panel about their post-graduate careers in and out of astronomy.

In short, the students experienced—in a summer—what a career in science would be like.

Training

2014 Introduction to Astronomical Instrumentation Summer School

–
August
10 - 15

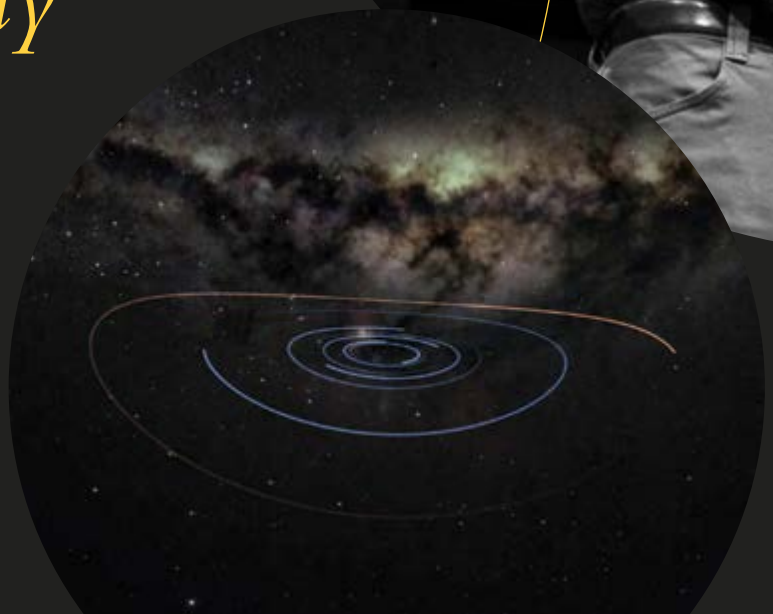


During the 2014 Introduction to Astronomical Instrumentation Summer School, students from 12 countries experienced a unique week of lectures, labs and mentoring with U of T and invited instructors, all of whom are specialists in the development of astronomical instruments. The week included a visit to the David Dunlap Observatory.

01

Public Outreach

Transforming Public Engagement in Astronomy



02

01. Prof. Keith Vanderlinde speaking at TEDxToronto 2014 about studying the early Universe from the South Pole.

Credit: Johnathan Ball

02. A planetary system discovered by the Kepler space telescope as seen in the U of T planetarium. Since May 2014, U of T graduate students and postdocs have presented 33 live public planetarium shows, 23 of which were sold out, with a total attendance of 779.

Public
Outreach

Astronomy on Tap T.O.

01

University of Toronto astronomers are connecting with a whole new audience with an event that lets members of the public quench their thirst for astronomy.

U of T astronomy lectures and planetarium shows continue to enjoy strong attendance, but Astronomy on Tap T.O. is aimed at a new audience: individuals who don't necessarily have a scientific background and for whom astronomy isn't a primary interest, but who are engaged in the world around them, and are curious and eager to learn about many subjects—including astronomy. It's also aimed at people who aren't necessarily interested in attending an hour-long talk in a lecture hall.

With this audience in mind, Astronomy on Tap T.O. is a lively night of engaging talks, audience participation, demonstrations, prizes, and stimulating conversation in a bar in downtown Toronto. It's a night of astronomy without scientific jargon and complicated graphs, and with plenty of time for people to connect with an astronomer over a pint.

So far, audiences have enjoyed talks on a wide variety of topics including: dark matter, dark energy, the Multiverse, super-massive black holes at the core of the Milky Way Galaxy, the Rosetta spacecraft rendezvous with comet 67P, and more.

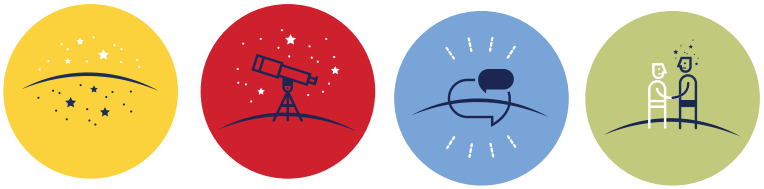
There have been a total of three events in the past year, at two different venues, with approximately a hundred attendees each night. It's a great way of serving up the wonders of the Universe in a way that both astronomers and the public enjoy.

Astronomy on Tap originated in New York City and is now held in cities throughout North America. U of T's Astronomy on Tap T.O. is sponsored by the Dunlap Institute and organized in collaboration with the Department of Astronomy & Astrophysics.

01. Dunlap Fellow Suresh Sivanandam explains spectroscopy to the crowd at the Tranzac Club in downtown Toronto.

Public
Outreach

The Universe in Your Hand



In 2014, the Dunlap Institute made it easier for the public to connect with U of T astronomers through a new e-newsletter and a re-launched outreach website.

For years, the Graduate Astronomy Students Association (GASA), the student-run Astronomy & Space Exploration Society (ASX) and the Dunlap Institute maintained their own lists of people interested in outreach events. In 2014, those lists were consolidated so that subscribers now receive a single monthly e-newsletter, called the Event Horizon, which contains information about all U of T astronomy events, including GASA AstroTour talks, ASX Star Talks, planetarium shows, Sidewalk Astronomy, Astronomy on Tap T.O. and special events.

Also in 2014, the Dunlap Institute launched a redesigned outreach website that lets the public quickly find the event they're after. Whether people want to explore the night sky through a telescope, enjoy a planetarium show, hear a talk, or book a speaker, they can quickly find out how, often with a single click of their mouse. The website—universe.utoronto.ca—is a portal into the universe of U of T astronomy.

01. Event Horizon e-newsletter.

02. universe.utoronto.ca

Event Horizon

Expected dates beyond April 30, 2015 for the development and commissioning of instruments, commencement of observation projects, and education events at the Dunlap Institute or involving Dunlap astronomers and educators.

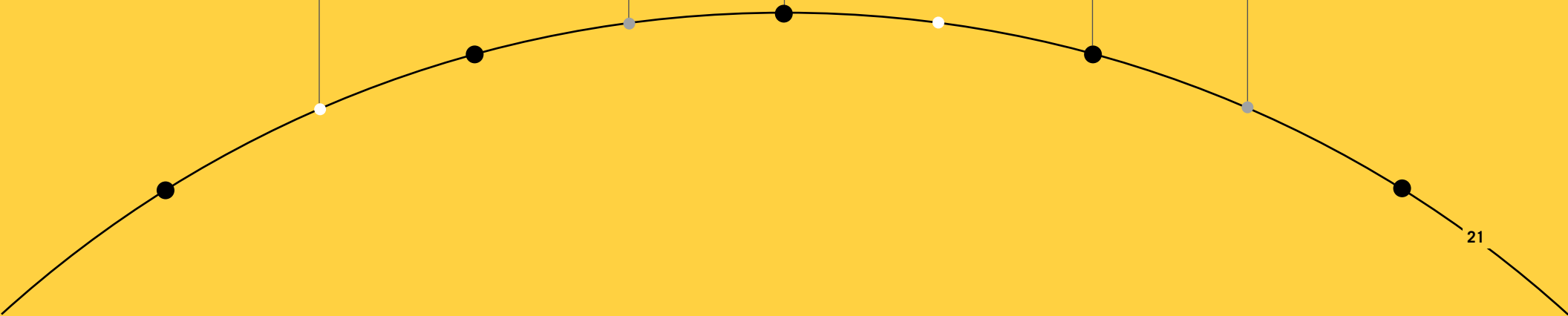
July 2015
Dunlap Institute Astronomical Instrumentation Summer School

2016
WIFIS (Wide Integral Field Infrared Spectrograph) First Light

2016
CHIME (Canadian Hydrogen Intensity Mapping Experiment) First Light

2016
SPT-3G (South Pole Telescope - 3rd Generation Camera) First Light

2016
MSAMOS (Micro-Shutter Array, Multi-Object Infrared Spectrograph) First Light



Faculty

Profiles

Prof.
Bryan Gaensler

Director

- Cosmic magnetism
- Time-domain astronomy
- Interstellar Gas
- SKA

Dr.
Michael Reid

Education & Public Outreach Coordinator

- Communicating astronomy to non-scientists
- Education and outreach with planetariums
- Star formation

Prof.
Keith Vanderlinde

Assistant Professor

- Large-scale structure in Universe
- Pulsars and Fast Radio Bursts
- Microwave-Radio instrumentation
- VLBI, CHIME, SPT

Prof.
Shelley Wright

Assistant Professor

- Galaxy formation and evolution
- Optical-Infrared instrumentation
- IRIS, OSIRIS, NIROSETI, SPIRou
- Current position: Asst. Professor; UC San Diego

Associated Faculty

Prof.
Roberto Abraham

- Observational cosmology
- Galaxy evolution
- Dragonfly

Prof.
Dae-Sik Moon

- Infrared & optical instrumentation
- Supernowvae and supernovae remnants
- Gamma-Ray bursts
- Compact objects:
  - Black Holes
  - Neutron stars
  - X-ray binaries

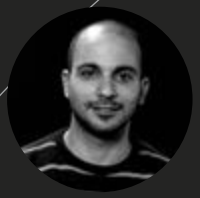
Prof.
Ue-li Pen

- Dark matter
- Neutrinos
- Dark energy
- Pulsar VLBI
- Black hole physics
- Associate Director, CITA

Dunlap Fellows

Profiles

Dr. John Antoniadis



- Millisecond and binary pulsars
- Binary neutron stars
- Pulsar scintellometry

Dr. Jeffrey Chilcote

- Exoplanets
- Gemini Planet Imager (GPI)
- Gemini Planet Imager Exoplanet Survey (GPIES)
- Lenslet-based integral-field spectrographs

Dr. Nicolas Crouzet

- Transiting exoplanets
- Exoplanet atmospheres
- ASTEP and XO projects

Dr. Rachel Friesen

- Star and star cluster formation
- Protostellar disk formation and evolution
- Astrochemistry
- Green Bank Ammonia Survey (GAS)

Dr. Jérome Maire

- Optical and infrared instrumentation
- Exoplanet imaging (Gemini Planet Imager)
- High-Angular Resolution (SLODAR)
- High-Time Resolution (NIROSETI)

Dr. Laura Newburgh

- Sub-millimetre Instrumentation
- Early Universe cosmology
- Dark energy
- ACTPol, CHIME

Dr. Suresh Sivanandam

- Galaxy formation and evolution
- Optical-infrared instrumentation
- MSAMOS, WIFIS

Postdoctoral Fellows

Profiles

Dr. Shaojie Chen

- Optical-infrared instrumentation
- Integral-Field Spectrograph Optical Design
- VPH Grating, IRIS, TMT

Dr. Brian Cherinka

- Galaxy formation and evolution
- Integral-field spectroscopy
- SDSS-IV/MaNGA

Dr. Peter Klages

- Heterogeneous computing
- Real-time data processing
- Southern Ontario Smart Computing Innovation Platform (SOSCIP)

Dr. Duy Cuong Nguyen

- Star formation, exoplanets, stellar parameterization
- Optical-infrared instrumentation
- SDSS-III/APOGEE, SDSS-III/MARVELS, SDSS-IV/APOGEE-2

Alumni

(Departures from 1 May 2014 to 30 April 2015)

Prof. Peter Martin

- Interstellar medium and star formation
- Polarization of absorption, scattering and emission by dust
- Dragonfly, Herschel Space Observatory, JWST, Planck
- Current position: Professor; CITA, U of T

Dr. Tuan Do

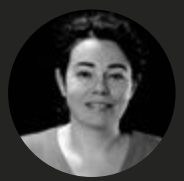
- Galactic centre and Milky Way Galaxy satellites
- Adaptive optics spectroscopy
- Astrometry
- TMT IRIS
- Current position: Research Scientist; UCLA

Dr. Quinn Konopacky

- Exoplanet orbits and characteristics
- Star and planet formation and evolution
- Gemini Planet Imager (GPI)
- GPI Exoplanet Survey
- Current position: Asst. Professor; UC San Diego

Dr. David Law

- Galaxy formation and evolution
- Integral-field spectroscopy
- OSIRIS & SDSS-IV/MaNGA
- Current position: Assistant Astronomer; Space Telescope Science Institute



Dr. María Montero-Castaño

- Galaxy evolution
- Interstellar medium
- Blind Ultra-Deep HI Environmental Survey (BUDHIES)

Profiles

Graduate Students Associated with the Dunlap Institute

Liam Connor

- 21cm cosmology:
  - » dark energy
  - » large-scale structure
  - » re-ionization
- Fast radio bursts
- Pulsars

Colin Merkel

- Cryogenics
- CMB
- SPT-3G

Nolan Denman

- Cosmic Microwave Background
- Early Universe
- Baryonic Acoustic Oscillations
- CHIME

Andrey Vayner

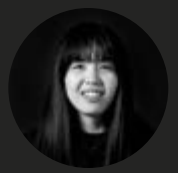
- Early galaxy formation and evolution
- Active Galactic Nuclei

Ronald Gagne

- Adaptive optics
- WIFIS
- SPT-3G

Heidi White

- Galaxy evolution
- Molecular gas studies
- Education and outreach



Etsuko Mieda

- Galaxy formation and evolution
- Adaptive optics
- Instrumentation

Staff

Angela Choi*
Department Manager

Alice Chow
Business Officer

Rob Figueiredo
IT Technologist

Gautum Patel*
Financial Officer

Chris Sasaki
Communications Co-ordinator

Hugh Zhao*
Systems Manager

* Jointly with Department of Astronomy & Astrophysics

Awards & Honours

Dr. John Antoniadis

Mar 2015: TalentEdge Fellowship, Ontario Centres of Excellence

Talks & Conferences

Dr. John Antoniadis

Apr 2015: 2nd Scintillometry Workshop, Algonquin Radio Observatory

Dr. Jeffrey Chilcote

Oct 2014: Dunlap Astronomical Instrumentation Discussion Lunch, Development and *Commissioning of the Integral Field Spectrograph for the Gemini Planet Imager*, Toronto, Ontario

Mar 2015: GSFC Planet Talk, *Revealing Exoplanets through High-Contrast Imaging with the Gemini Planet Imager*, Greenbelt, Maryland, USA

Mar 2015: Notre Dame Astronomy Colloquium, *Revealing Exoplanets through High-Contrast Imaging with the Gemini Planet Imager*, South Bend, Indiana, USA

Apr 2015: Western: Centre for Planetary Science and Exploration, *Revealing Exoplanets through High-Contrast Imaging with the Gemini Planet Imager*, London, Ontario

Dr. Rachel Friesen

Sep 2014: Filamentary Structure in Molecular Clouds, *Tracing the mass flow in clustered star forming regions*, NRAO, Charlottesville, Virginia, USA

Oct 2014: CIERA Astrophysics Seminar, Northwestern University, Evanston, Illinois, USA

Nov 2014: Astronomy Seminar, University of Waterloo, Waterloo, Ontario

Dec 2014: Colloquium, University of British Columbia, Vancouver, British Columbia

Dec 2014: Colloquium, NRC-Herzberg, Victoria, British Columbia

Feb 2014: Seminar, McMaster University, Hamilton, Ontario

Prof. Bryan Gaensler

Mar 2015: Astronomical Tools for Big Data, *Wide-Field Radio Astronomy and the Dynamic Universe,* Tucscon, Arizona, USA

Mar 2015: CIFAR Cosmology and Gravity Annual Meeting, *Large-Scale Structure and Turbulence with Wide-Field Radio Telescopes,* Banff, Alberta

Apr 2015: Kavli Futures Workshop on Citizen Science, *Flares, Pulses, Burps and Bursts: The Dynamic Radio Sky,* Oxford, UK

Dr. Laura Newburgh

Aug 2014: Cosmo14, 21cm *Cosmology with CHIME*, Chicago, Illinois, USA

Sept 2014: DRAO Symposium in Honour of John Galt, Calibrating *CHIME – or – Bootstrapping our Way Towards a Measurement of Dark Energy*, Penticton, British Columbia

Oct 2014: University of Miami Colloquium, *21cm Cosmology with CHIME*, Miami, Florida, USA

Nov 2014: Princeton University Cosmology Lunch Seminar, *21cm Cosmology with CHIME*, Princeton, New Jersey, USA

Dec 2014: 21cm Cosmology in the 21st Century, *CHIME: Foregrounds and Calibration*, Tempe, Arizona, USA

Apr 2015: KIPC Cosmology Seminar, *21cm Cosmology with CHIME*, Chicago, Illinois, USA

Apr 2015: SUNY Buffalo Seminar, *21cm Cosmology with CHIME*, Buffalo, New York, USA

Dr. Michael Reid

Nov 2014: Teaching and Learning Symposium, *Your First SoTL Project*, Toronto, Ontario

Dr. Suresh Sivanandam

Feb 2015: CfA SSP Seminar, *Infrared methods for the study of galaxy formation and evolution*, Boston, Massachusetts, USA

Feb 2015: Toronto Colloquium, *Infrared methods for the study of galaxy formation and evolution*, Toronto, Ontario

Feb 2015: Carnegie Lunch Talk, *Infrared methods for the study of galaxy formation and evolution*, Pasadena, California, USA

Mar 2015: UCSC Colloquium, *Infrared methods for the study of galaxy formation and evolution*, Santa Cruz, California, USA

Prof. Keith Vanderlinde

Dec 2014: Early Science from Low-frequency Radio Telescopes, *The Canadian Hydrogen Intensity Mapping Experiment,* Tempe, Arizona, USA

Conference & Scientific Meeting Presentations

Dr. Shaojie Chen

Jun 2014: Summer Conference, *The Infrared Imaging Spectrograph (IRIS) for TMT: Volume Phase Holographic Grating Performance Testing and Discussion*, SPIE, Montreal, Quebec

Dr. Brian Cherinka

Mar 2015: MaNGA Science Meeting, *Data Access with CAS and SAS*, SDSS, Lexington, Kentucky, USA

Dr. Jeffrey Chilcote

2015: American Astronomical Society Meeting Abstracts, 225, #423.03, *The Gemini Planet Imager*

Dr. Nicolas Crouzet

Aug 2014: Towards Other Earths II, *Water Vapor in the Spectrum of the Extrasolar Planet HD* 189733b, Porto, Portugal

Sep 2014: SCAR Open Science Conference, *Four years of photometry from Dome C with ASTEP South, Astronomy & Astrophysics from Antarctica*, Auckland, New Zealand

Dr. Rachel Friesen

May 2014: The Olympian Symposium on Star Formation, *Tracing the mass flow in clustered star forming regions*, Paralia Katerini's, Greece

June 2014: The Early Phases of Star Formation, *First ALMA views of H2D+ and small-scale structure toward clustered star-forming cores*, Ringberg, Germany

Prof. Bryan Gaensler

Mar 2015: *Radio Polarimetry and the Magnetic Universe*, Department of Physics, McGill University, Montreal, Quebec

Apr 2015: *Radio Polarimetry and the Magnetic Universe*, Dominion Radio Astrophysical Observatory, Penticton, British Columbia

Dr. Laura Newburgh

July 2014: SPIE Conference, *Calibrating CHIME: A New Radio Interferometer to Probe Dark Energy*, Montreal, Quebec

March 2015: APS Meeting, *21cm Cosmology with CHIME*, Baltimore, Maryland, USA

Dr. Michael Reid

Oct 2014: McMaster University's Integrated Science Program, *Planetary Transits from Venus to Kepler,* Hamilton, Ontario

Mar 2015: TEDxUofT, *Yes, You Can Do Science*, University of Toronto

Dr. Suresh Sivanandam

Jan 2015: Winter Conference, *Wide Integral Field Infrared Spectroscopic Survey of Nearby Galaxies*, AAS, Seattle, Washington, USA

Prof. Keith Vanderlinde

Jun 2014: Royal Astronomical Society of Canada, *The Canadian Hydrogen Intensity Mapping Experiment,* Mississauga, Ontario

Sep 2014: Presentation to CIfAR Board of Directors, CHIME & SPT

Oct 2014: TEDx Toronto, *The Edge of the Universe from the End of the Earth*

Feb 2015: Kavli Institute for Particle Astrophysics and Cosmology, *The Canadian Hydrogen Intensity Mapping Experiment*, Stanford University

Apr 2015: University Lecture Series, *Science at the South Pole*, Markham, Ontario

Apr 2015: University Lecture Series, *Science at the South Pole*, Oakville, Ontario

Education Outreach Talks

Dr. Rachel Friesen

Sep 2014: *Exploring Our Solar System*, Goldhawk Park Public Library, Toronto, Ontario

Sep 2014: New eyes on our origins: the Atacama Large Millimeter/submillimeter Array, Dunlap Observatory Summer Program, David Dunlap Observatory, Richmond Hill, Ontario

Nov 2014: *New eyes on our origins: the Atacama Large Millimeter/submillimeter Array,* Royal Astronomical Society, Mississauga Branch, UTM, Toronto, Ontario

Apr 2015: *How are new solar systems born?* Runnymede Public Library, Toronto, Ontario

Prof. Bryan Gaensler

Jan 2015: *Astronomers spot cosmic radio burst happen live for the first time,* ABC Radio National

Mar 2015: *How The Universe Will Get Us In The End*, University of Toronto

Mar, Apr 2015: Recurring radio spot on astrophysics, ABC Sydney

Dr. Laura Newburgh

Sept 2014: *Dreaming Big with Big Telescopes*, Astrotour public lecture, University of Toronto,

Nov 2014: *Dark Matter vs Dark Energy*, Astro On Tap, DAA/Dunlap, Toronto, Ontario

Dr. Duy Cuong Nguyen

Oct 2014: *Searching for Earth Two: How Astronomers Hunt for Exoplanets*, Leaside Public Library, Toronto, Ontario

Dr. Michael Reid

May 2014: *Let's Leave Earth*, University of Toronto Space Design Contest

Jun 2014: *Misconceptions about the Big Bang*, Beaches Public Library, Toronto, Ontario

Sep 2014: *The Lifecycle of Stars*, Yorkville Public Library, Toronto, Ontario

Sep 2014: *Misconceptions about the Big Bang*, Gerstein Science Library, University of Toronto

Oct 2014: *Life in the Cosmos*, David Dunlap Observatory, Richmond Hill, Ontario

Oct 2014: *Misconceptions about the Big Bang*, Toronto Centre Royal Astronomical Society of Canada

Nov 2014: *Life in the Cosmos*, Pierre Elliot Trudeau Secondary School, Markham, Ontario

Nov 2014: *Misconceptions about the Big Bang*, University of Toronto Alumni Association, Port Credit Arena, Mississauga, Ontario

Feb 2015: *The Sky Tonight*, Gerrard Ashdale Public Library, Toronto, Ontario

Mar 2015: *Misconceptions about the Big Bang*, Mississauga Centre of the Royal Astronomical Society of Canada

Apr 2015: *The Clockwork of the Cosmos*, University of Toronto Senior Alumni Association

Apr 2015: *Misconceptions about the Big Bang*, Cawthra Park Secondary School, Mississauga, Ontario

Dr. Suresh Sivanandam

Dec 2014: *Seeing Beyond Red with Cool Technology*, Astronomy Public Tour, University of Toronto

Prof. Keith Vanderlinde

Jun 2014: *Cosmology, Cell Phones, and Video Games*, Mississauga RASC

Publications

Peer Reviewed Publications

Multi-wavelength, Multi-Messenger Pulsar Science in the SKA Era; **Antoniadis, J.**, et al., 2015, Advancing Astrophysics with the Square Kilometre Array, PoS AASKA14-157

On the formation of Eccentric Millisecond Pulsars with Helium White-dwarf Companions; **Antoniadis, J.**, 2014, ApJL, Vol 797, L24

Probing the neutron star interior and the Equation of State of cold dense matter with the SKA; Watts, A., … **Antoniadis, J.**, et al., 2014, Advancing Astrophysics with the Square Kilometre Array, PoS AASKA14-043

Testing Gravity with Pulsars in the SKA Era; Shao, L.,… **Antoniadis, J.**, et al., 2014, Advancing Astrophysics with the Square Kilometre Array, PoS AASKA14-042

The timescale of low-mass proto-helium white dwarf evolution; Istrate, A. G., … **Antoniadis, J.**, et al., 2014, A&A Vol 571, L3

The MaNGA Integral Field Unit Fiber Feed System for the Sloan 2.5 m Telescope; Drory, N.,... **Cherinka, B.**, et al., 2015, ApJ, Vol 149, Issue 2, 77,24

Overview of the SDSS-IV MaNGA Survey: Mapping nearby Galaxies at Apache Point Observatory; Bundy, K., ... **Cherinka, B.**, et al., 2015, ApJ, Vol 798, Issue 1, 7,24

P-MaNGA: full spectral fitting and stellar population maps from prototype observations; Wilkinson, D., ... **Cherinka, B.**, et al., 2015, MNRAS, Vol 449, Issue 1, 328-360

The First H-band Spectrum of the Giant Planet β Pictoris b; **Chilcote, J.**, … **Konopacky, Q.**, **Maire, J.**, **Millar-Blanchaer, M.**, et al., 2015, ApJL, 798, L3

Gemini Planet Imager Spectroscopy of the HR 8799 Planets c and d; Ingraham, P., …, **Chilcote, J.**, **Konopacky, Q.**, **Maire, J.**, **Millar-Blanchaer, M.**, et al., 2014, ApJL, 794, L15

H2O Abundances in the Atmospheres of Three Hot Jupiters; Madhusudhan, N., … **Crouzet, N.**, et al., 2014, ApJL, 791, 9

Transit Search from Antarctica and Chile-Comparison and Combination; Fruth, T., … **Crouzet, N.**, et al., 2014, PASP, 126, 227

Water Vapor in the Spectrum of the Extrasolar Planet HD 189733b. I. The Transit; McCullough, P. R.,… **Crouzet, N.**, et al., 2014, ApJ, 791, 55

Water Vapor in the Spectrum of the Extrasolar Planet HD 189733b. II. The Eclipse; **Crouzet, N.**, et al., 2014, ApJ, 795, 166

An Ammonia Spectral Map of the L1495-B218 Filaments in the Taurus Molecular Cloud: I. Physical Properties of Filaments and Dense cores; Seo, Y.,… **Friesen, R**., et al., 2015, arxiv150305179S

Evidence for Grain Growth in the Star-forming Filament OMC-2/3; Schnee, S., … **Friesen, R**., et al., 2014, ApJ, 444, 2303

G11.92-0.61-MM2: A Bonafide Massive Prestellar Core?; Cyganowski, C., … **Friesen, R**., et al., 2014, ApJ, 796, 2

The James Clerk Maxwell telescope Legacy Survey of the Gould Belt: a molecular line study of the Ophiuchus molecular cloud; White, G., … **Friesen, R**., et al., 2015, MNRAS, 447, 1996

The JCMT Gould Belt Survey: constraints on prestellar core properties in Orion A North; Salji, C., … **Friesen, R**., et al., 2015, MNRAS, 449, 1769

The JCMT Gould Belt Survey: evidence for radiative heating in Serpens MWC 297 and its influence on local star formation; Rumble, D., … **Friesen R**., et al., 2015, MNRAS, 448, 1551

The JCMT Gould Belt Survey: SCUBA-2 observations of circumstellar discs in L 1495; Buckle, J., … **Friesen, R**., et al., 2015, MNRAS, 449, 2472

Physical and Chemical Characteristics of L1689-SMM16, an Oscillating Prestellar Core in Ophiuchus; Chitsazzadeh, S., … **Friesen, R. K**., et al., 2014, ApJ, 790, 129

Revealing H2D+ Depletion and Compact Structure in Starless and Protostellar Cores with ALMA; **Friesen, R. K**., et al. 2014, ApJ, 797, 27

Another shock for the Bullet cluster, and the source of seed electrons for radio relics; Shimwell, T.W., … **Gaensler, B. M**., et al, 2015, Monthly Notices of the Royal Astronomical Society, 449, 1486 (9 pages)

Estimating extragalactic Faraday rotation; Oppermann, N., … **Gaensler, B. M.**, et al., V., 2015, Astronomy & Astrophysics, 575, A118 (25 pages)

Limits on low frequency radio emission from southern exoplanets with the Murchison Widefield Array; Murphy, T., … **Gaensler, B. M**., et al., 2015, Monthly Notices of the Royal Astronomical Society, 446, 2560 (6 pages)

The low-frequency environment of the Murchison Widefield Array: Radio-frequency interference analysis and mitigation; Offringa, A.R., … **Gaensler, B. M**., et al., 2015, Publications of the Astronomical Society of Australia, 32, e008 (13 pages)

Modelling of the spectral energy distribution of Fornax A: Leptonic and hadronic production of high energy emission from the radio lobes; McKinley, B., … **Gaensler, B. M**., et al., 2015, Monthly Notices of the Royal Astronomical Society, 446, 3478 (14 pages)

Serendipitous discovery of a dying giant radio galaxy associated with NGC 1534, using the Murchison Widefield Array; Hurley-Walker, N., … **Gaensler, B. M**., et al., 2015, Monthly Notices of the Royal Astronomical Society, 447, 2468 (11 pages)

The spectral variability of the GHz-peaked spectrum radio source PKS 1718-649 and a comparison of absorption models; Tingay, S.J., … **Gaensler, B. M**., et a;., 2015, The Astrophysical Journal, 149, 74 (9 pages)

First light of the Gemini Planet Imager; Macintosh, B., **Konopacky, Q**., ... **Chilcote, J**., **Maire, J**., **Millar-Blanchaer, M**., et al., 2014, Proceedings of the National Academy of Science, 111, 12661

Galactic cold cores V. Dust opacity; Juvela, M., … **Martin, P. G.**, et al., 2015, Astronomy and Astrophysics, in press, arXiv:1501.07092

Joint Analysis of BICEP2/Keck Array and Planck Data; BICEP2/Keck and Planck Collaborations, … **Martin, P. G**., et al., 2015, Physical Review Letters, 114, 101301

The next-generation BLASTPol experiment; Dober, B. J., … **Martin, P. G**., et al., 2014, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 9153, 91530H

Planck 2013 results. XXXI. Consistency of the Planck data; Planck Collaboration, … **Martin, P. G**., et al., 2014, Astronomy and Astrophysics, 571, A31

Planck intermediate results. XIX. An overview of the polarized thermal emission from Galactic dust; Planck Collaboration, … **Martin, P. G**., et al., 2015, Astronomy and Astrophysics, 576, A104

Planck intermediate results. XX. Comparison of polarized thermal emission from Galactic dust with simulations of MHD turbulence; Planck Collaboration, … **Martin, P. G**., et al. 2015, Astronomy and Astrophysics, 576, A105

Planck intermediate results. XXI. Comparison of polarized thermal emission from Galactic dust at 353 GHz with interstellar polarization in the visible; Planck Collaboration, …**Martin, P. G**., et al., 2015, Astronomy and Astrophysics, 576, A106

Planck intermediate results. XXII. Frequency dependence of thermal emission from Galactic dust in intensity and polarization; Planck Collaboration, … **Martin, P. G**., et al., 2015, Astronomy and Astrophysics, 576, A107

Planck intermediate results. XXVI. Optical identification and redshifts of Planck clusters with the RTT150 telescope; Planck Collaboration, … **Martin, P. G**., et al., 2015, Astronomy and Astrophysics, in press, arXiv:1407.6663

Planck intermediate results. XXVII. High-redshift infrared galaxy overdensity candidates and lensed sources discovered by Planck and confirmed by Herschel-SPIRE; Planck Collaboration, … **Martin, P. G**., et al., 2015, Astronomy and Astrophysics, in press, arXiv:1503.08773

Planck intermediate results. XXVIII. Interstellar gas and dust in the Chamaeleon clouds as seen by Fermi LAT and Planck; Planck Collaboration, … **Martin, P. G.**, et al., 2015, Astronomy and Astrophysics, in press, arXiv:1409.3268

Planck intermediate results. XXIV. Constraints on variation of fundamental constants; Planck Collaboration, … **Martin, P.G**., et al., 2015, Astronomy and Astrophysics, in press, arXiv:1406.7482

Planck intermediate results. XXX. The angular power spectrum of polarized dust emission at intermediate and high Galactic latitudes; Planck Collaboration, … **Martin, P. G.**, et al., 2015, Astronomy and Astrophysics, in press, arXiv:1409.5738

Planck intermediate results. XXXII. The relative orientation between the magnetic field and structures traced by interstellar dust; Planck Collaboration, … **Martin, P. G.**, et al., 2015, Astronomy and Astrophysics, in press, arXiv:1409.6728

Planck intermediate results. XXXIV. The magnetic field structure in the Rosette Nebula; Planck Collaboration, … **Martin, P. G.**, et al., 2015, Astronomy and Astrophysics, in press, arXiv:1501.00922

The Three-mm Ultimate Mopra Milky Way Survey. II. Cloud and Star Formation Near the Filamentary Ministarburst RCW 106; Nguyen, H., Nguyen Luong, Quang, **Martin, P. G.**, et al., 2015, Astronomy and Astrophysics, in press, arXiv:1504.02246

Polarimetry with the Gemini Planet Imager: Methods, Performance at First Light, and the Circumstellar Ring around HR 4796A; Perrin, M. D., … **Millar-Blanchaer, M.**, **Chilcote, J., Konopacky**, **Q.**, **Maire, J.**, et al., 2015, ApJ, 799, 182

Evidence of Lensing of the Cosmic Microwave Background by Dark Matter Halos; Madhavacheril, … **Newburgh, L.**, et al., 2015, Accepted to PRL

Precision Epoch of Reionization Studies with Next-generation CMB Experiments; Calabrese, E., … **Newburgh, L.**, et al., 2014, JCAP 8, 10

The Atacama Cosmology Telescope: Lensing of CMB Temperature and Polarization Derived from Cosmic Infrared Background Cross-Correlation; Van Engelen, A., … **Newburgh, L.**, et al., 2015, Accepted to ApJ

The Atacama Cosmology Telescope: Measuring Radio Galaxy Bias Through Cross-Correlation with Lensing; Allison, R., … **Newburgh, L.**, et al., 2015, Accepted to MNRAS

Increasing Engagement and Understanding Using Interactive Planetarium Shows; **Reid, M**. et al., 2015, Higher Education Quality Council of Ontario.

Tracing Ram-pressure Stripping with Warm Molecular Hydrogen Emission; **Sivanandam, S.**, Rieke, M. J., Rieke, G. H., 2014, ApJ, 796, 89

Analysis of Sunyaev-Zel'dovich effect mass-observable relations using South Pole Telescope observations of an X-ray selected sample of low-massgalaxy clusters and groups; Liu, … **Vanderlinde, K**. et al., 2015, MNRAS 448, Issue 3, p.2085-2099

Constraints on the CMB Temperature Evolution using Multi-Band Measurements of the Sunyaev Zel'dovich Effect with the South Pole Telescope; Saro, … **Vanderlinde, K.** et al., 2013, submitted to MNRAS Letters, eprint arXiv:1312:2462

Galaxy Clusters Discovered via the Sunyaev-Zel'dovich Effect in the 2500-Square-Degree SPT-SZ Survey; Bleem, … **Vanderlinde, K**. et al., 2015, ApJ 216, Issue 2, article id. 27, 21 pp.

Mass Calibration and Cosmological Analysis of the SPT-SZ Galaxy Cluster Sample Using Velocity Dispersion? v and X-Ray Y X Measurements; Bocquet, … **Vanderlinde, K**. et al., 2015, ApJ 799, Issue 2, article id. 214, 16 pp.

Measurement of Galaxy Cluster Integrated Comptonization and Mass Scaling Relations with the South Pole Telescope; Saliwanchik, … **Vanderlinde, K**. et al., 2015, ApJ 799, Issue 2, article id. 137, 14 pp.

A Measurement of Secondary Cosmic Microwave Background Anisotropies from the 2500 Square-degree SPT-SZ Survey; George, … **Vanderlinde, K**. et al., 2015, ApJ 799, Issue 2, article id. 177, 22 pp.

Optical Spectroscopy and Velocity Dispersions of Galaxy Clusters from the SPT-SZ Survey; Ruel, … **Vanderlinde, K**. et al., 2014, ApJ 792, Issue 1, article id. 45, 17pp.

The Redshift Evolution of the Mean Temperature, Pressure, and Entropy Profiles in 80 SPT-Selected Galaxy Clusters; McDonald, … **Vanderlinde, K**. et al., 2014, ApJ 794, Issue 1, article id. 67, 16 pp.

SPT-CLJ2040-4451: An SZ-Selected Galaxy Cluster at z = 1.478 With Significant Ongoing Star Formation; Bayliss, … **Vanderlinde, K**. et al., 2014, ApJ 794, Issue 1, article id. 12, 14 pp.

Non-reviewed Contributions

The Infrared Imaging Spectrograph (IRIS) for TMT: Instrument Overview; Moore, A. M.,… **Wright, S.**, **Chen, S.**, **Do, T.**, **Meyer, E.**, et al., 2014, Astronomical Telescopes & Instrumentation

The Infrared Imaging Spectrograph (IRIS) for TMT: Volume phase holographic grating performance testing and discussion; Chen, S., …**Meyer, E.**, **Wright, S. A.**, **Maire, J.**, **Mieda, E.**, et al., 2014, Proceedings of the SPIE, 9147-334, Astronomical instrumentation, Montreal

The Infrared Imaging Spectrograph (IRIS) for TMT: Reflective Ruled Diffraction Grating Performance Testing and Discussion; Maeyer, E., **Chen, S.**, **Wright, S.**, **Maire, J.**, **Mieda, E.**, et al., 2014, Astronomical Telescopes & Instrumentation

The Average Properties of CaII and NaI Absorbing Galaxies from Stacked Quasar Spectra; Schulte-Ladbeck, R. E., **Cherinka, B.**, 2014, American Astronomical Society,

The Gemini planet imager: first light and commissioning; Macintosh, B. A., ... **Chilcote, J.**, **Maire, J.**, **Millar-Blanchaer, M.**, **Konopacky, Q.**, et al., 2014, Proceedings of the SPIE, 9148, 91480J

Gemini planet imager integration to the Gemini South telescope software environment; Rantakyro, F. T.,… **Chilcote, J.**, et al. 2014, Proceedings of the SPIE, 9149, 91492B

The integral field spectrograph for the Gemini planet imager; Larkin, J. E.,… **Chilcote, J.K.**, **Konopacky, Q. M.**, **Maire, J.**, et al., 2014, Proceedings of the SPIE, 9147, 91471K

Observations of Beta Pictoris b with the Gemini Planet Imager; **Chilcote, J.**, ... **Konopacky, Q.**, **Maire, J.**, **Millar-Blanchaer, M.**, et al., 2014, Thirty years of Beta Pic and Debris Disks Studies, 27

On-sky performance during verification and commissioning of the Gemini Planet Imager's adaptive optics system; Poyneer, L. A., ... **Chilcote, J.**, et al. 2014, Proceedings of the SPIE, 9148, 91480K

On-sky vibration environment for the Gemini Planet Imager and mitigation effort; Hartung, M., ... **Chilcote, J.**, et al., 2014, Proceedings of the SPIE, 9148, 91480N

Magnetic Fields in the Milky Way Halo; Mao, S. A., … **Gaensler, B. M.**, et al., 2015, Highlights of Astronomy, 16, 403

Gemini planet imager observational calibrations V: astrometry and distortion; **Konopacky, Q. M.**, **Maire, J.**, **Chilcote, J.**, et al. 2014, Proceedings of the SPIE, 9147, 914784

New results from the first exoplanet survey in the Canadian High Arctic; Law, N. M., … **Maire, J.**, **Sivanandam, S.**, et al., 2014, Proceedings of the SPIE, 9145-, Astronomical instrumentation, Montreal

The Gemini Planet Imager; Graham, J. R., ... **Maire, J.**, **Millar-Blanchaer, M.**, GPI/GPIES Team, 2015, American Astronomical Society, AAS Meeting 225, 423.03

Gemini Planet Imager observational calibrations I: Overview of the GPI data reduction pipeline; Perrin, M. D., … **Maire, J.**, **Millar-Blanchaer, M.**, **Chilcote, J.**, **Konopacky, Q.**, et al., 2014, Proceedings of the SPIE, 9147, 91473J

Gemini planet imager observational calibrations II: detector performance and calibration; Ingraham, P., ... **Maire, J.**, **Chilcote, J.**, et al., 2014, Proceedings of the SPIE, 9147, 91477O

Gemini Planet Imager Observational Calibrations III: Empirical Measurement Methods and Applications of High-Resolution Microlens PSFs; Ingraham, P., … **Maire, J.**, et al., 2014, Proceedings of the SPIE, 9147-282, Astronomical instrumentation, Montreal

Gemini Planet Imager Observational Calibrations IV: Wavelength Calibration and Flexure Correction for the Integral Field Spectrograph; Wolff, S. G., … **Maire, J.**, et al., with the GPI team, 2014, Proceedings of the SPIE, 9147-279, Astronomical instrumentation, Montreal

Gemini planet imager observational calibrations VI: photometric and spectroscopic calibration for the integral field spectrograph; Maire, J., ... **Chilcote, J.**, **Millar-Blanchaer, M.**, **Konopacky, Q.**, et al., 2014, Proceedings of the SPIE, 9147, 914785

A near-infrared SETI experiment: probability distribution of false coincidences; **Maire, J.**, et al., 2014, Proceedings of the SPIE, 9147-173, Astronomical instrumentation, Montreal

A near-infrared SETI experiment: instrument overview; **Wright, S. A.**, … **Maire, J.**, **Meyer, E.**, **Dorval, P.**, et al., 2014, Proceedings of the SPIE, 9147-18, Astronomical instrumentation, Montreal

Optical turbulence profiling with SloDAR in the Canadian High Arctic; **Maire, J.**, **Mieda, E.**, W**right, S. A.**, **Sivanandam, S.**, et al., 2014, Proceedings of the SPIE, 9145-, Astronomical instrumentation, Montreal

SLODAR instrument for characterizing an Arctic site; overview of the experimental method, design, and performance; **Mieda, E.**, **Maire, J.**, **Wright, S. A.**, **Moon, D.-S**,…et al., 2014, Proceedings of the SPIE, 9145-334, Astronomical instrumentation, Montreal

Submillimeter Dust Polarimetry with the BLAST-TNG Telescope; Galitzki, N., … **Martin, P. G.**, et al., 2015, AAS, 225, \#328.09

Characterizing the correlation between column density structure and magnetic fields; Soler, J. D., … **Martin, P. G.**, et al., 2015, Highlights of Astronomy, 16, 384

Gemini planet imager observational calibrations VII: on-sky polarimetric performance of the Gemini planet imager; Wiktorowicz, S. J., **Millar-Blanchaer, M.**, ... **Maire, J.**, **Chilcote, J.**, et al., 2014, Proceedings of the SPIE, 9147, 914783

Calibrating CHIME, A New Radio Interferometer to Probe Dark Energy; **Newburgh, L.**, … **Klages, P.**, **Recnik, A.**, **Vanderlinde, K.**, et al., 2014, Proc. SPIE: Astronomical Telescopes + Instrumentation

Canadian Hydrogen Intensity Mapping Experiment (CHIME) Pathfinder; Bandura, K., … **Connor, L.**, **Klages, P.**, **Newburgh, L.**, **Recnik, A.**, **Vanderlinde, K.**, et al., 2014, Proc. SPIE: Astronomical Telescopes + Instrumentation

Open Source Cloud Computing for Transiting Planet Discovery; McCullough, P. R.,... **Nguyen, D. C.**, et al., 2014, 224th Meeting of the American Astronomical Society

A Pipeline for the Analysis of APOGEE Spectra Based on Equivalent Widths; Afron Williams, R.,... **Nguyen, D. C.**, et al., 2015, 225th Meeting of the American Astronomical Society

T*he APOGEE-1 Catalog of Keplerian Orbit Fits to RV Variable Sources*; Troup, N. W.,... **Nguyen, D. C.**, et al., 2015, 225th Meeting of the American Astronomical Society

A Study of Statistical Binaries with SDSS/APOGEE; **Nguyen, D. C.**, et al., 2015, 225th Meeting of the American Astronomical Society

Two for the Price of One: SB2s in the SDSS-III/APOGEE Survey; Chojnowski, S. D., **Nguyen, D. C.**, et al., 2015, 225th Meeting of the American Astronomical Society

New results from the first exoplanet survey in the Canadian High Arctic; Law, N. M., … **Sivanandam, S.**, 2014, SPIE,

Optical turbulence profiling with SloDAR in the Canadian High Arctic; **Maire, J.**, **Meida, E.**, … **Sivanandam, S.**, et al., 2014, SPIE,

The development of ground-based infrared multi-object spectrograph based on the microshutter array; Moon, D.-S., **Sivanandam, S.**, et al., 2014, SPIE

Wide Integral Field Infrared Spectroscopic Survey of Nearby Galaxies; **Sivanandam, S.**, **Moon, D.-S.**, et al., 2015, AAS

Calibrating CHIME: a new radio interferometer to probe dark energy, **Newburgh, L.**, … **Vanderlinde, K**. et al., 2014, Proceedings of the SPIE, Volume 9145, id. 91454V 18 pp.

Canadian Hydrogen Intensity Mapping Experiment (CHIME) pathfinder, Bandura, … **Vanderlinde, K**. et al., 2014, Proceedings of the SPIE, Volume 9145, id. 914522 20 pp.

SPT-3G: a next-generation cosmic microwave background polarization experiment on the South Pole telescope, Benson, … **Vanderlinde, K**. et al., 2014, Proceedings of the SPIE, Volume 9153, id. 91531P 21 pp.

01

02

03

01. Prof. Bryan Gaensler giving his first public talk in Toronto during a special Earth Hour AstroTour.

Credit: Charles Zhu

02. Former Dunlap Institute interim director Prof. Peter Martin, family and guests, including members of the Dunlap family, at a dinner in February 2015 acknowledging Martin's leadership of the institute.

03. Michael Reid speaking at the 2015 TEDxUofT on the transformational power of science and astronomy

Credit: Russell Wu

04

05

06

04. Students enjoying the 2014 Introduction to Astronomical Instrumentation Summer School.

05. Trifid Nebula

Credit: Amy Tran

06. In Michael Reid's PMU 199 class, first-year student Amy Tran operating a remote-control telescope to capture an image of the Trifid Nebula.

Editorial: Chris Sasaki
Design: Sovereign State

May 2014–April 2015

Unless noted, all photographs: Dunlap Institute

With the announcement in April 2015 of federal funding, Canada has now become a partner in the Thirty Meter Telescope, to be built in Hawaii.

Credit: TMT National Observatory

www.dunlap.utoronto.ca
www.universe.utoronto.ca