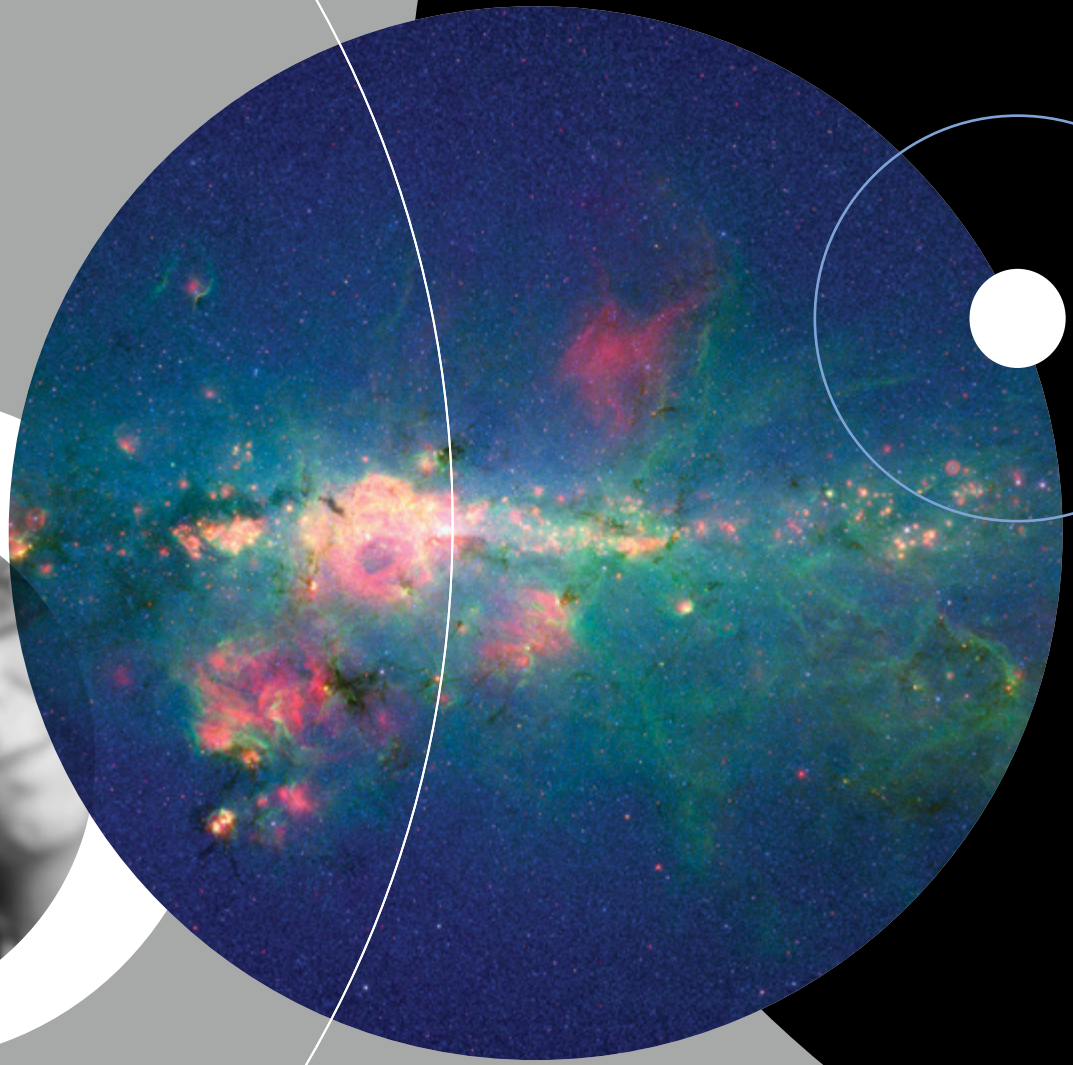
DUNLAP INSTITUTE *for* ASTRONOMY & ASTROPHYSICS

EXPANDING UNIVERSE

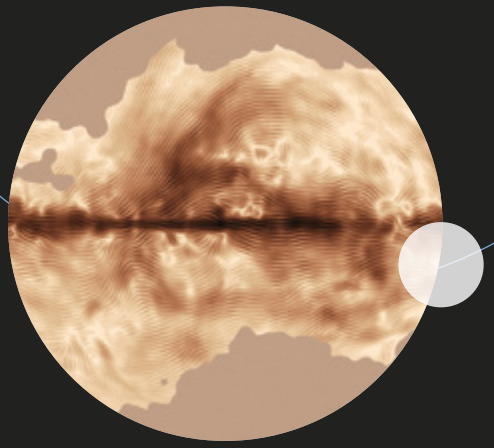
2013 - 2014 ANNUAL REPORT



Dunlap Institute for
Astronomy & Astrophysics
UNIVERSITY OF TORONTO

Message from the Interim Director

Prof. Peter Martin, PhD, FRSC



Dark lines trace the Milky Way Galaxy's magnetic field in this "magnetic fingerprint." *Credit: Planck Collaboration*

Cover

Prof. Shelley Wright holds a detector used in the NIROSETI Near InfraRed Optical Search for ExtraTerrestrial Intelligence instrument. *Credit: Milky Way Galaxy image: NASA/ JPL-Caltech*

Through remote sensing across the electromagnetic spectrum, the astronomer's challenge is not only to detect radiation, but to extract detailed information encoded within.

The "magnetic fingerprint" above is an interpretation resulting from such complex decoding. Through the detection of the polarization of the emission from cool dust in the Milky Way Galaxy, the Planck Space Telescope collaboration has teased out a record of the large-scale orientation of our galaxy's magnetic field—with all of its arches, loops and whorls.

"This report effectively takes the pulse of the Dunlap Institute."

As glimpsed in research highlighted elsewhere in this annual report, polarization—a powerful tool in our expanding kit—is being exploited on planetary-system-disk to cosmological scales. Fundamental insights are being provided as well by chemical fingerprints or spectra of complex molecules in star-forming molecular clouds, of gas in exoplanet atmospheres, or of gas diffusely spread within galaxies.

Also imprinted in spectra is valuable dynamical information, revealing the collapse of gas into filaments and new stars, or the rotation within an entire galaxy. The beauty of the results available through decoding such fingerprints is more than skin deep.

This report effectively takes the pulse of the Dunlap Institute. You will enjoy discovering that the institute is alive and well, and thriving. Exciting new instruments are coming on line. The amazing research informs many of our teaching activities, impacting students at the University of Toronto and around the world. Outreach activities have expanded in many imaginative ways to reach an even broader public audience.

Through organization, hard work and collaboration, the expanding roster at the Dunlap Institute—of students, postdoctoral fellows, staff, and faculty—is dedicated to the success of our programs. Looking ahead to the coming year, to additional personnel and their leadership in research, instrumentation, education and outreach, the future is bright.

01

Message from the Dean, Faculty of Arts & Science

David Cameron, FRSC
Dean and Professor of
Political Science

Astronomy has unraveled secrets of the Universe in its earliest moments, and taught us that life truly begins in the deepest depths of space. Discoveries about the nature of our world and Universe have shaped our cultures in profound and fundamental ways. Equally importantly, astronomers have driven dramatic technological innovations that improve the quality of life and stimulate economic growth. For the past century, Canadian astronomers, led by U of T, have been seeking answers to fundamental questions that have perplexed humanity since the dawn of time. What is the origin of the Universe? What is our place in the Cosmos? Is there life on other planets?

U of T's Faculty of Arts and Science is proud to host a top-ranked Department of Astronomy and Astrophysics, the nation-wide Canadian Institute for Theoretical Astrophysics and, since 2008, the Dunlap Institute for Astronomy and Astrophysics—a leading-edge centre for the design, fabrication and implementation of astronomical instrumentation, for observational research, for training the next generation of astronomers and for public education. Together this group represents a depth and diversity of talent that is unparalleled in Canada and matched only by top-ranked centres worldwide.

It is innovation in astronomical instrumentation and observing techniques that can accelerate U of T's and Canada's contributions to expanding our understanding of the Universe. On this front, as you will see in this annual report, the Dunlap Institute is making tremendous progress—and what it has achieved in the few short years it has been operational is a testament to the ingenuity, passion and tenacity of our astronomers. It is a testament to their leadership in forging fruitful collaborations with the international astronomy community. And it is a testament to the belief and vision of the Dunlap Family, who have supported this enterprise since its very conception.

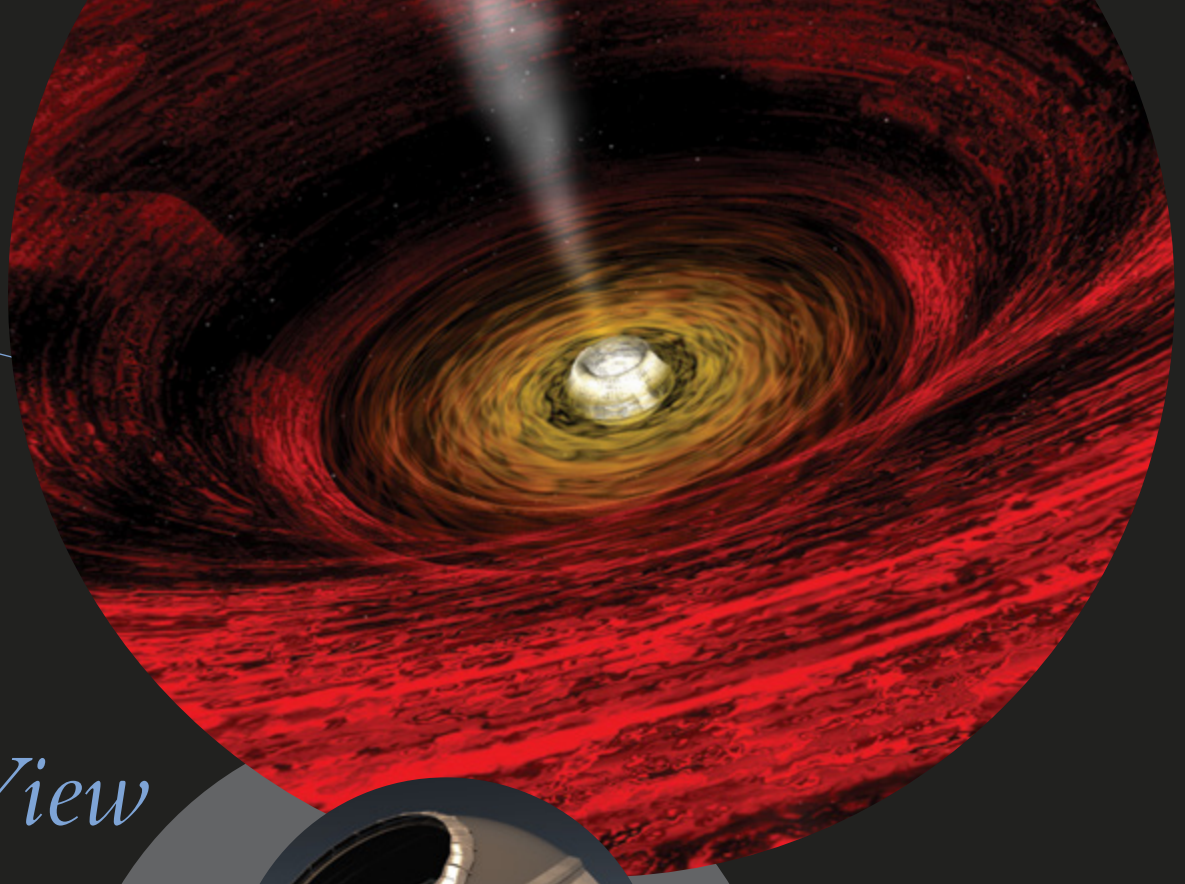
Just this past year, the Dunlap Institute launched the Long Wavelength Laboratory, designed to test and to develop microwave detectors destined for the South Pole telescope as well as radio technologies critical to a new generation of digital telescopes. Soon, we will be able to track both the evolution of large-scale structure within the Universe and the accelerating expansion of space.

The Dunlap Institute is also extending the University's reach by cementing strong partnerships with like-minded organizations committed to public education, and by designing and hosting large-scale events and innovative programming that brings many in the broader community, young and old, to campus. The inaugural Dunlap Prize in Astronomy and Astrophysics was awarded to Neil deGrasse Tyson. The record high demand for his public lecture—many times the capacity of Convocation Hall—is but one indication of the innate thirst for knowledge of the Cosmos across all generations.

Arts & Science is in the midst of its Boundless campaign—through which we are seeking a major investment in highly qualified personnel in astronomy and astrophysics, as well as in state-of-the-art facilities and operations for research, teaching, public education and outreach. We want to empower our scientists to collaborate and find answers to the most fundamental and enduring questions for humanity. In expanding our universe of supporters, the possibilities for expanding the frontiers of knowledge are truly boundless.

David Cameron

01. *Credit: Jim Ryce.*



Instrumentation Research

Expanding Our View of the Universe

Artist's rendering of a super-massive black hole like the one at the centre of the Milky Way Galaxy *Credit: NASA/ CXC/A.Hobart*

According to analysis by Dr. Tuan Do, Prof. Shelley Wright and colleagues, the InfraRed Imaging Spectrograph (IRIS) on the Thirty Meter Telescope will be able to measure the mass of massive black holes at the centres of galaxies with enough accuracy to revolutionize our understanding of these objects. *Credit: TMT Observatory Corporation*

Instrumentation
Research

Mapping the Universe in Four Dimensions

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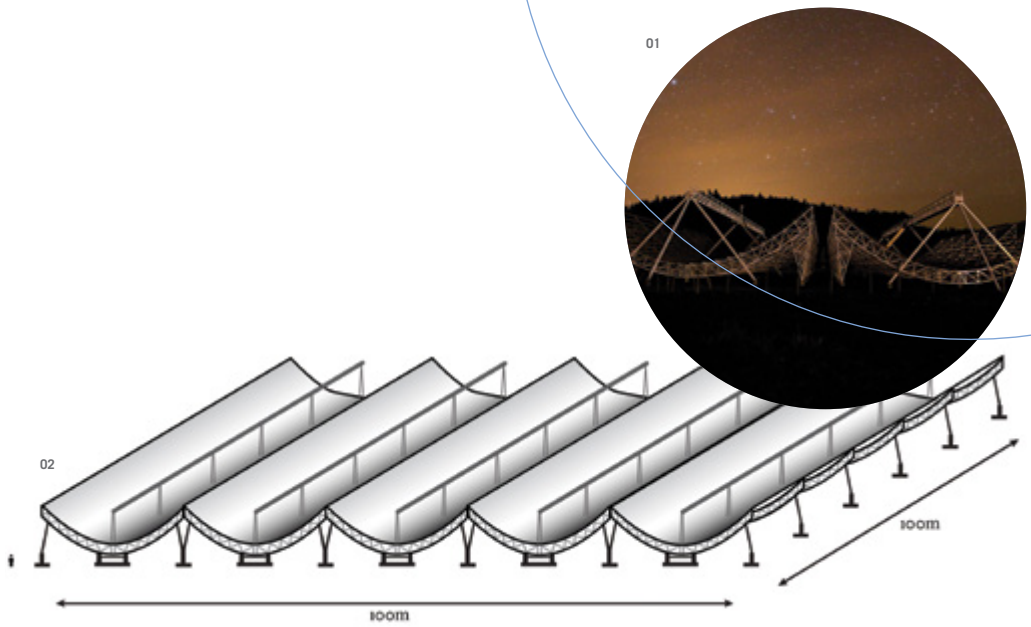
CHIME



In the interior of B.C., a team of cosmologists, including the Dunlap's Prof. Keith Vanderlinde, is building a ground-breaking radio telescope that will map the largest volume of space ever surveyed—a three-dimensional swath of the Universe that covers half the sky and is billions of light-years deep.

When completed, CHIME—the Canadian Hydrogen Intensity Mapping Experiment—will gather radio signals along a line in the sky from the northern horizon, through the zenith, to the southern horizon. The telescope won't move, but as the Earth rotates and the sky moves overhead from east to west, CHIME will scan the entire northern sky like a lighthouse sweeping the horizon.

The telescope will also measure the redshift of distant clouds of hydrogen, revealing their distances. This added dimension will turn a two-dimensional scan of the sky into a three-dimensional map.

What's more, the nearest edge of this vast volume of space will be billions of light-years closer to Earth than the farthest edge. That means CHIME will add yet another dimension—time—to produce a "four-dimensional map" of the expansion and evolution of the Universe over some four billion years of its early history.

This epoch is particularly interesting because it was a time when dark energy began to play an important role in the evolution of the Universe. Dark energy is the enigmatic force behind one of the biggest paradigm shifts in cosmology: that the expansion of the Universe is speeding up, rather than slowing down.

The team includes researchers from the Dominion Radio Astrophysical Observatory, the University of British Columbia, the University of McGill and the University of Toronto. Vanderlinde and his colleagues (see Collaborations, pg. 11) will begin building their four-dimensional map of the Universe in 2016.

01. Construction of the CHIME Pathfinder prototype was completed during the winter of 2013/2014. *Credit: Prof. Keith Vanderlinde; Dunlap Institute*

02. When completed, CHIME will comprise five, 20x100 metre half-cylinders. *Credit: University of British Columbia*

Instrumentation
Research

First Light on 10,000 Galaxies

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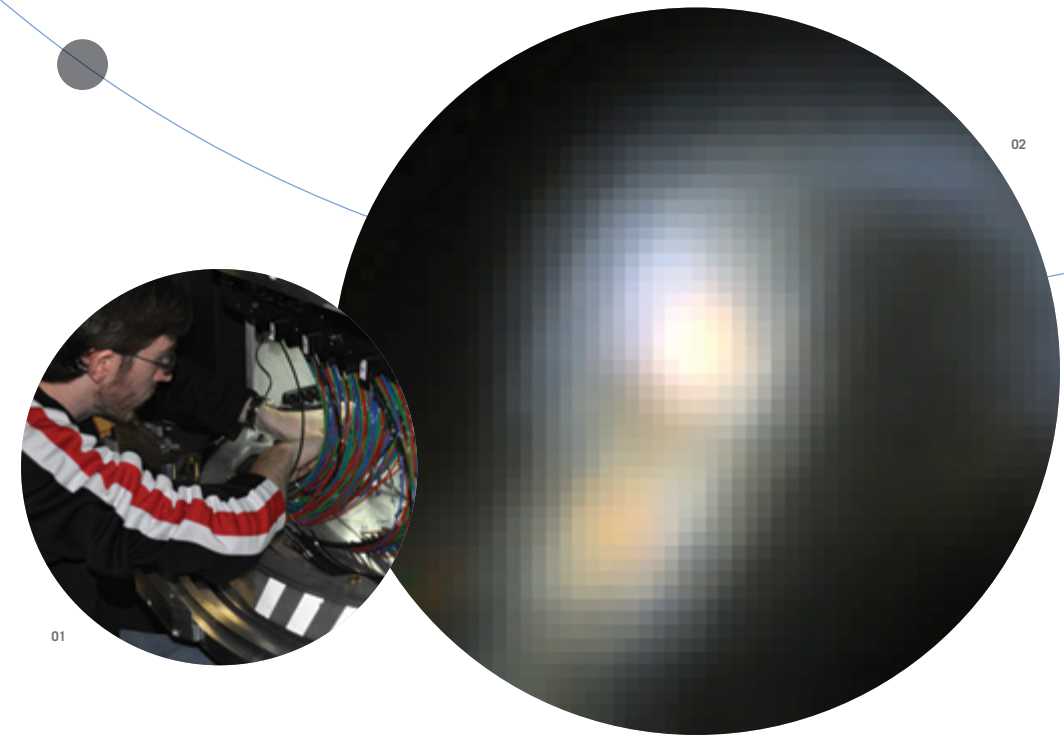
MaNGA



01

02

01. The 2.5 metre Sloan Telescope at Apache Point Observatory focuses a section of the sky on a circular plate. Bundles of optical fibres feed the light of galaxies in that section of sky to the spectroscope. *Credit: Dr. David Law; Dunlap Institute*

02. A fibre collects spectroscopic data from each square section of the galaxy Mrk 848; a bundle of fibres covers the entire galaxy. *Credit: Dr. David Law, SDSS-IV/MaNGA; Dunlap Institute*

Over five nights in March 2014, an international team of astronomers began a five-year survey with an innovative spectroscope that will eventually include 10,000 galaxies.

Spectrographs separate light according to wavelength, revealing a wealth of information about an object's chemical composition, motion, velocity, temperature and age. Previous spectroscopic surveys of galaxies gathered light from a single point on the target or along a line across it. This means that data was collected from a very small part of the galaxy.

The survey—called MaNGA or Mapping Nearby Galaxies at Apache Point Observatory—collects spectroscopic data from the entire galaxy, enabling detailed analysis of the object as a whole. The telescope focuses images of galaxies on hexagonal bundles of optical fibres which feed the light to the spectroscope.

Thanks to MaNGA, the team will be better able to answer questions about the origin, growth and evolution of these cosmic building blocks, about star formation within them, about their dark matter haloes, and more.

As part of the MaNGA team, astronomers from the Dunlap Institute have been leading efforts to optimize fibre bundle design, develop the observing strategy, and design and test the software needed to reduce the data and analyze the spectra. They include: Lead Data Scientist, Dr. David Law; pipeline developer, Dr. Brian Cherinka; and Lead Observer, Dr. Anne-Marie Weijmans (formerly with the Dunlap and now at the School of Physics & Astronomy at the University of St. Andrews).

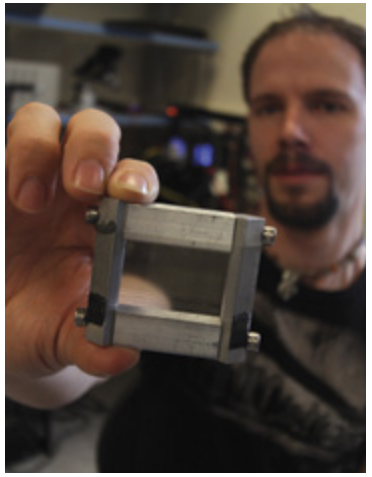
The MaNGA survey will run to 2020 and yield millions of spectra.

Instrumentation Research

Optical-Infrared and Long Wavelength Laboratories

In the Dunlap Institute's Optical-Infrared and Long Wavelength Laboratories, astronomers are developing instrumentation and technologies critical to a new generation of telescopes. These telescopes—operating in different wavelength regimes—include the South Pole Telescope, the Keck telescopes, CHIME, the Thirty Meter Telescope and many others.

In 2013 – 2014, significant upgrades to both labs were made thanks in part to the Canada Foundation for Innovation's John R. Evans Leaders Fund (known previously as the Leadership Opportunity Fund).



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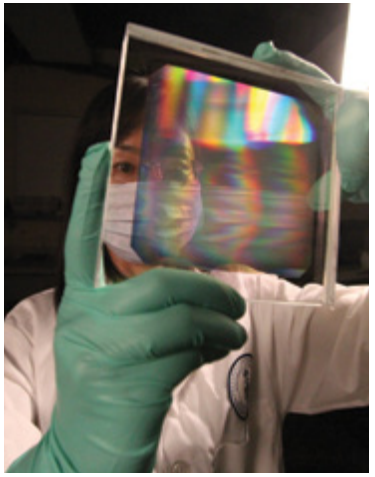

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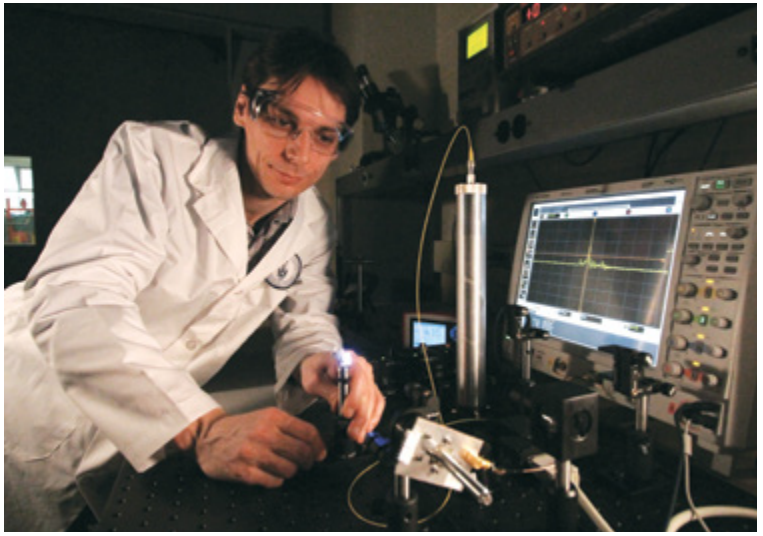
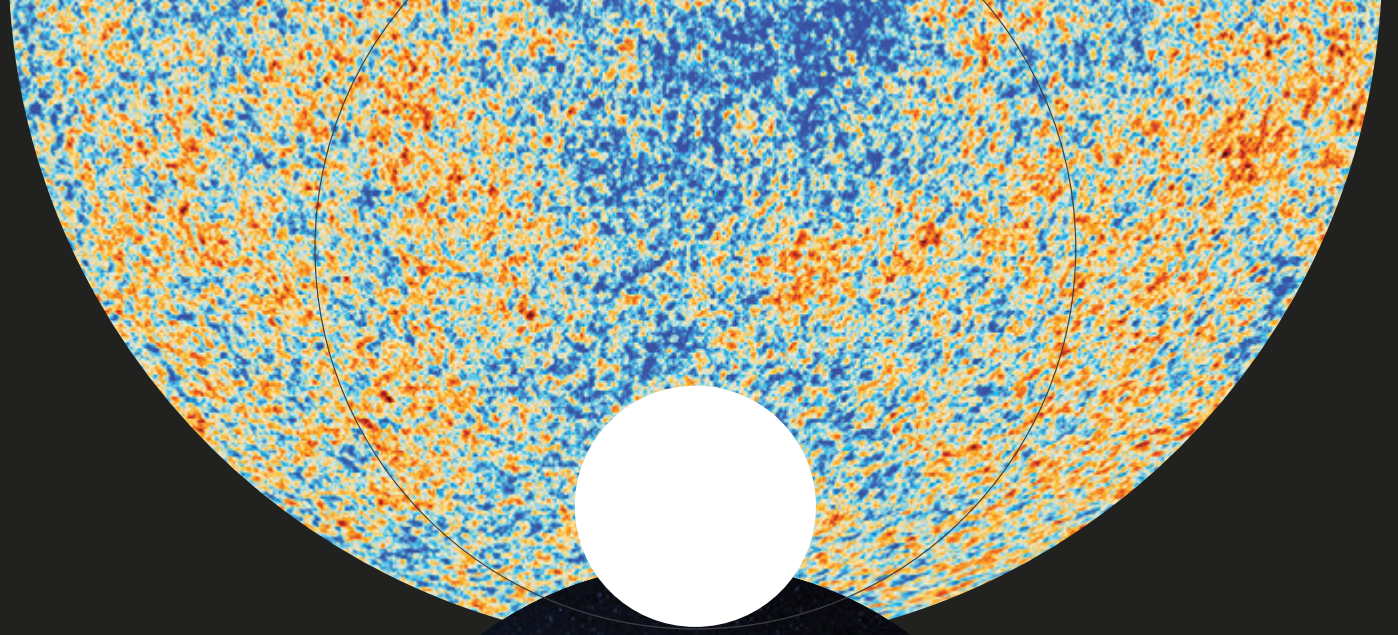


03

01. Ronald Gagne examines a polarization grid, one of the elements being developed in the Long Wavelength Lab for testing components of SPT-3G, the South Pole Telescope 3rd Generation Camera.

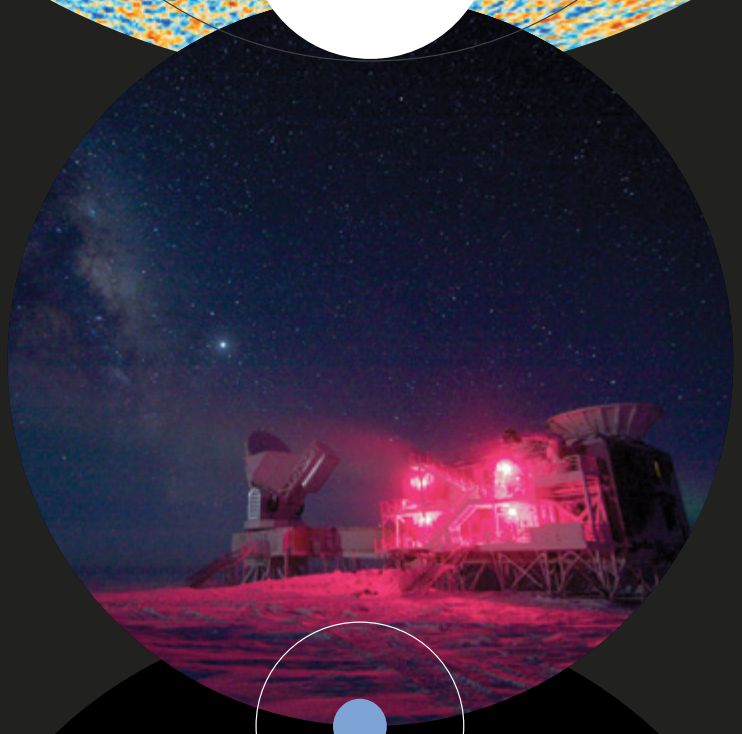
02. Dr. Shaojie Chen in the Optical-Infrared Lab with a grating being tested for the IRIS, InfraRed Imaging Spectrograph, a first-light instrument for the Thirty Meter Telescope.

03. Dr. Jérome Maire tests a detector for the NIROSETI Near InfraRed Optical Search for ExtraTerrestrial Intelligence instrument in the Optical-Infrared Lab.



Observational Research

Expanding Our Understanding of the Universe



Cosmic Microwave Background (CMB)

The South Pole Telescope used to detect polarization in the CMB.
Credit: Keith Vanderlinde; National Science Foundation

Observational
Research

Measuring the Mass of a Neutron Star

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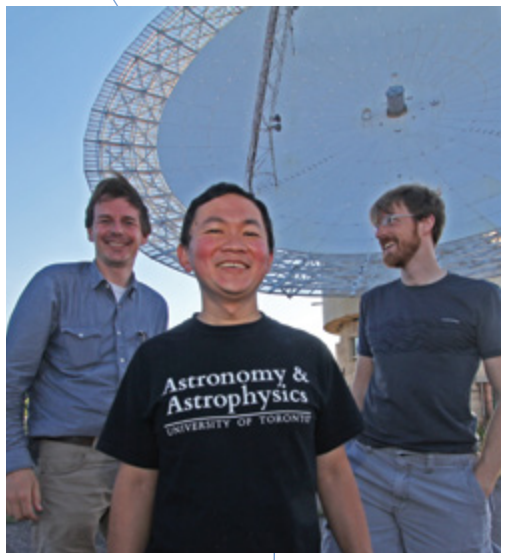
ARO VLBI



01

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A team of U of T astronomers is attempting to measure the mass of a neutron star that lies 3000 light-years from Earth. To do this, they must observe the star with the precision to resolve details mere tens of kilometres wide. That's like seeing a dime on the surface of Pluto.

Such high-resolution observations are made possible, in part, because the team is simultaneously targeting the neutron star with radio telescopes on three different continents, including one at the Algonquin Radio Observatory (ARO) in northern Ontario. While the largest radio telescope being used is 100 metres in diameter, the multi-telescope technique—referred to as Very Long Baseline Interferometry or VLBI—creates a virtual radio telescope the diameter of the Earth.

But the virtual radio telescope is, in fact, much larger. Regions of interstellar gas between the Earth and the neutron star act like lenses. They create multiple beams of light from the star which are gathered and combined by the VLBI array. The result is a virtual radio telescope with a diameter larger than the orbit of Mars.

The team of Professors Keith Vanderlinde, Marten van Kerkwijk (DAA) and Ue-Li Pen (CITA) began their observations in the summer of 2013. If ongoing analysis of data and future observations confirm the thinking of van Kerkwijk, the neutron star will be the most massive ever observed, at twice the Sun's mass.

If this is the case, the finding will provide greater understanding of the forces deep inside a dying star that stop its collapse and result in a neutron star. And it will provide insight into why the collapse does not continue until the star becomes a black hole.

01. I. to r. Professors Marten van Kerkwijk, Ue-Li Pen and Keith Vanderlinde at the ARO.

02. Undergraduate Phil Isaac assembling electronics in preparation for observing at the ARO.

Observational
Research

From Cosmic to Quantum

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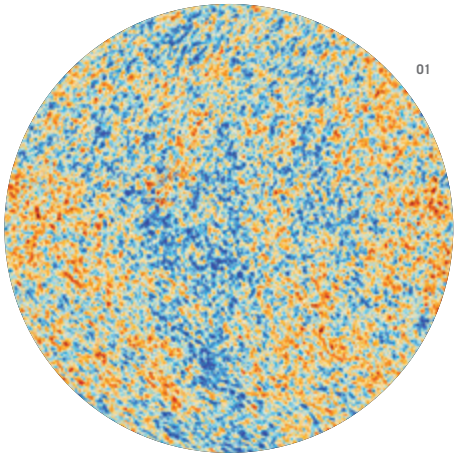
South Pole Telescope



01

02

At an observatory located one kilometre from the South Pole, an international team of astronomers including Prof. Keith Vanderlinde is observing the Cosmic Microwave Background (CMB), the light "left over" from the Big Bang.

Variations in the CMB (visible as colour differences in 01) reveal that the energy density of the early Universe was uneven. It is these fluctuations that led to a "clumpy" cosmos full of large-scale structure that, in turn, evolved into the super-clusters and clusters of galaxies we see today.

Cosmologists have been analyzing the CMB for clues into the nature of this large-scale structure and, in July 2013, the South Pole Telescope (SPT) collaboration announced the first observation of one such clue: a faint signal, hidden in the CMB, referred to as lensing b-mode polarization.

Light is polarized when the direction of its oscillations isn't entirely random. (The waves on a lake are highly polarized; they all oscillate in the same up-and-down direction.) The polarization patterns detected were imparted to the CMB by the gravity of large-scale structure. As such, the signal is a measure of the "clumpiness" of the Universe.

This measurement in turn can answer fundamental questions that particle physicists have been trying to answer for years, including: What is the mass of a neutrino? Are there more than three types of neutrinos? The observation, connecting the cosmic with the quantum, was acknowledged by Physics World as one of the top ten breakthroughs in 2013.

Vanderlinde and his SPT colleagues continue to analyze the data from these observations. He and a team of graduate students (see Collaborations, pg. 11) are developing technologies for the SPT-3G receiver which will be able to detect even fainter polarization in the CMB and shed even more light on why the Universe is the way it is.

01. The Cosmic Microwave Background. *Credit: ESA, Planck Collaboration.*

02. The South Pole Telescope (SPT) used to detect polarization in the CMB. *Credit: Keith Vanderlinde; National Science Foundation*

Observational
Research

Looking Inside a Stellar Nursery

Deep inside interstellar clouds of gas and dust, enormous concentrations of matter larger than our Solar System collapse due to gravity. After hundreds of thousands of years, they become a tiny fraction of their original size and so dense that nuclear fusion is ignited within them, forming stars.

One such stellar nursery is the Serpens Cloud, located over 800 light-years from Earth. Inside the cloud lies a region called the Serpens South star cluster. It is a dynamic, turbulent environment of interconnected filaments and knots of gas, just-forming stars, young stars, and clusters of stars.

But the interior of this complex region is hidden from view because light at optical wavelengths is absorbed and scattered by dust within it.

However, molecules within Serpens South emit light at radio wavelengths which is not absorbed. And by observing these radio emissions with radio telescopes, astronomers are able to draw back the curtain of dust and gain a better understanding of how stars form.

In the fall of 2013, the Dunlap's Dr. Rachel Friesen and her colleagues were the first to observe radio emissions from within Serpens South from a type of molecule called a cyanopolyyne. The observations revealed that cyanopolyynes and gas associated with the molecule are flowing into the web of filaments.

It is this flow that feeds further star formation within the filaments, and adds to the gas flowing along the filaments to a larger hub of star formation, like small tributaries feeding large rivers flowing into a lake. The observations by Friesen and her colleagues shed light on how star clusters gain their mass, and highlight the important role that filaments of gas play in the birth and nurturing of star clusters.

01

02

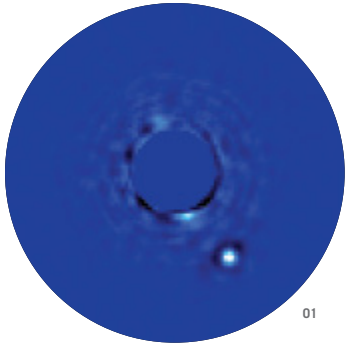
01. Serpens South. *Credit: NASA/JPL-Caltech/L. Allen (Harvard-Smithsonian CfA) & Gould's Belt Legacy Team; Spitzer Space Telescope*

02. The Robert C. Byrd Green Bank Telescope used to observe cyanopolyynes in Serpens South. *Credit: NRAO/AUI/NSF*

Observational
Research

A New Era Of New Worlds

–
Gemini
Planet
Imager



01

02

Today, we know that planets beyond our Solar System, called exoplanets, are common throughout the Milky Way Galaxy.

But most have been discovered indirectly by measuring the periodic dimming of a star caused by an orbiting body passing in front of it as seen from Earth. Capturing an actual image of these distant worlds is a much greater challenge. Exoplanets are typically a millionth the brightness of their parent stars, and trying to see one directly is like trying to see a firefly beside a floodlight.

But in November 2013, an innovative instrument called the Gemini Planet Imager (GPI) achieved first light, marking the beginning of a new era of exoplanet discovery. The instrument lets astronomers observe these objects directly and analyze the light coming from them.

GPI works by combining different capabilities. Adaptive optics greatly reduce the blurring effect of the Earth's atmosphere, resulting in higher-resolution images. A coronograph blocks the light of the star which would normally hide the much dimmer exoplanet. And a spectrograph separates the light of the exoplanet according to wavelength, allowing astronomers to study the distant world's composition, temperature, age and other characteristics, and better understand how planetary systems form and evolve.

At the Dunlap Institute, the team working on the instrument's development included Dr. Quinn Konopacky, Dr. Jérome Maire, graduate student Max Millar-Blanchaer, as well as former Dunlap Director, Prof. James Graham.

Once testing of GPI is completed in 2014, Konopacky, Maire and Millar-Blanchaer will be part of the team conducting the GPI Exoplanet Survey (GPIES) and analyzing new data. The survey will run through 2017, targeting some 600 stars in search of new worlds beyond ours.

01. GPI first light image showing the exoplanet Beta Pictoris b to the lower right of the star (centre; hidden) Beta Pictoris. *Credit: Gemini Observatory; Christian Marois, NRC Canada*

02. Gemini South Observatory on Cerro Pachon, Chile. *Credit: Gemini Observatory*

Collaborations

2013 - 2014

Collaborations involving faculty, postdoctoral fellows and graduate students from the Dunlap Institute, Department of Astronomy & Astrophysics (DAA), Canadian Institute for Theoretical Astrophysics (CITA), and (not shown) researchers and institutes from around the world.

Arctic	Arctic Observatory
APOGEE	Apache Point Observatory Galaxy Evolution Experiment
ARO VLBI	Algonquin Radio Observatory Very Long Baseline Interferometry
CHIME	Canadian Hydrogen Intensity Mapping Experiment
GPI	Gemini Planet Imager
IRIS	Infrared Imaging Spectrograph
MaNGA	Mapping Nearby Galaxies at Apache Point Observatory
MSAMOS	Multi-Shutter Array – Multiple Object Spectrograph
NIROSETI	Near-Infrared Optical Search for Extraterrestrial Intelligence
SPT–3G	South Pole Telescope – 3rd Generation
WIFIS	Wide Integral-Field Infrared Spectrograph

Dr. Peter Klages (IBM)
Dr. Laura Newburgh
Prof. Richard Bond
Prof. Marten van Kerkwijk (DAA)
Prof. Ue-Li Pen (CITA)
Dr. Nicholas Law*
Prof. Keith Vanderlinde
Etsuko Mieda
Dr. Jérome Maire
Wayne Ngan
Dr. Duy Cuong Nguyen
Prof. Shelley Wright
Dr. Suresh Sivanandam
Miranda Jarvis
Nolan Denman

PROJECTS

Prof. Roberto Abraham (DAA)
Prof. Peter Martin
Jielai Zhang
Dr. Quinn Konopacky
Prof. Dae-Sik Moon (DAA)
Max Millar-Blanchaer
Prof. James Graham**
Dr. Shaojie Chen
Dr. Tuan Do
Dr. David Law
Elliot Meyer
Dr. Brian Cherinka
Dr. Anne-Marie Weijmans***
Ronald Gagne
Colin Merkel (Dept. of Physics, U of T)
Mark Ma
Prof. Ray Carlberg

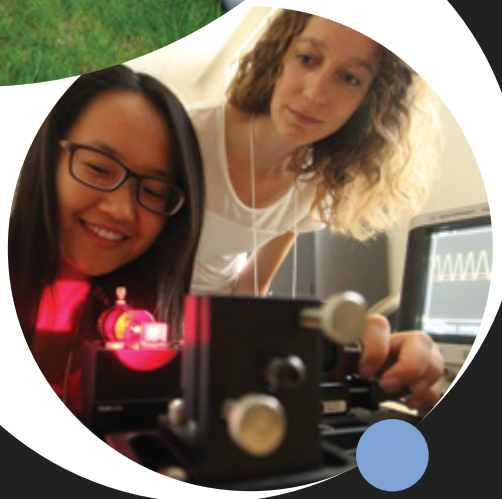
* Former Dunlap Fellow; currently Department of Physics & Astronomy, University of North Carolina, Chapel Hill

** Former Dunlap Director; currently Department of Astronomy, UC Berkeley

*** Former Dunlap Fellow; currently School of Physics & Astronomy, University of St. Andrews, Scotland

Education

Training the Next Generation of Astronomers



Students and instructors from the 2013 Summer Undergraduate Research Program in astronomy at the U of T.

Jielai Zhang and Dr. Rachel Friesen during the 2013 Introduction to Astronomical Instrumentation Summer School.

Education

2013 Summer School: Introduction to Astronomical Instrumentation

–
August
11 - 16

For a week in August, 40 students from around the world attended the Dunlap Institute's Summer School for an intensive introduction to designing and building astronomical instrumentation.

Instructors from the Dunlap and from across North America introduced students to the principles of spectroscopy, radio astronomy, interferometry and adaptive optics through a series of lectures. Labs gave students hands-on experience with lenses, lasers, diffraction gratings and sensors, and an opportunity to build simple instruments and to practice instrumentation fundamentals.

The summer school is designed for senior undergraduate and junior graduate students with experience in astronomy, physics or engineering. Participants travelled from 12 countries outside Canada and the U.S., largely because the school provided them with something they can't get at home: instruction that focuses on instrumentation. (For 2014, students from 17 countries outside Canada and the U.S. have enrolled.)

The annual school helps fulfill the Dunlap's mandate to foster students in designing the innovative technologies that will lead to future discoveries. Along with the U of T astronomy group's annual Summer Undergraduate Research Program, the summer school is an important part of the Dunlap's pipeline for training the next generation of astronomers.

01

02

01. Students assemble a simple spectrometer

02. Students visit the David Dunlap Observatory

Education

2013 West African International Summer School for Young Astronomers

–
October
21 - 25

"I was feeling like a professor of astronomy as I explained the solar eclipse to people."

"I can now say that I can think like a scientist."

Students on the success of the school

01

02

01. U of T instructors: (l. to r.) graduate students Kelly Lepo, Jielai Zhang, Heidi White; CITA postdoctoral fellow Linda Strubbe.

02. Students enjoying a night of observing.

Some 70 undergraduate science students from Nigeria and Ghana attended the first ever West African International Summer School for Young Astronomers, in Abuja, Nigeria.

The school was organized by Nigeria's National Space Research & Development Agency and Centre for Basic Space Science, in collaboration with the Dunlap Institute, CITA, and the Institute for Scientist & Engineer Educators.

The team of instructors included postdoctoral fellows, graduate students and faculty from Toronto and Nigeria who taught students through lectures, group discussions, solar observing sessions and hands-on activities.

Dr. Michael Reid and Dr. Linda Strubbe (CITA) organized a team of instructors from Toronto to lead participants through an inquiry-based activity (developed at the 2013 Toronto ISEE Design Institute; pg. 15) about measuring distances in astronomy, in which students were taught to approach a problem like scientists, by asking questions, and exploring those questions and possible answers with peers.

Proof of the success of the school came only weeks afterwards as students showed their excitement about astronomy and shared their knowledge with their communities during the November 3 eclipse of the Sun that was total in much of Nigeria.

And thanks to a grant from the International Astronomical Union's Office of Astronomy for Development, plans for the 2014 school are already underway.

Education

Training the Next Generation of Science Educators

–
2014 Toronto
ISEE Design
Institute

01

02

Over a short period of two years, the collaboration between the Dunlap Institute and the Institute for Science and Engineer Educators (ISEE), University of California, Santa Cruz, has grown steadily and now benefits students from around the world every year.

The ISEE trains scientists and engineers to become effective educators through many initiatives, including the Professional Development Program. PDP comprises a series of workshops in which participants learn about inquiry-based teaching and develop activities designed to get students to think like scientists; PDP also includes opportunities for participants to put workshop results into practice with students.

In 2012, the Dunlap Institute became the first international ISEE chapter, creating a growing regional centre of activity for ISEE outside of California. In May 2013, the Dunlap Institute hosted an ISEE Design Institute workshop that included participation from Dunlap, DAA and CITA postdoctoral fellows and graduate students. And in April 2014, the Toronto Design Institute expanded to include teams from Boulder, Colorado; Lansing, Michigan; and New York City.

In 2014, the opportunities to apply workshop training again include: the annual Summer Undergraduate Research Program organized by the Dunlap, DAA and CITA; the Dunlap's annual Introduction to Astronomical Instrumentation Summer School, which attracts students from around the world; and the West African International Summer School for Young Astronomers in Nigeria.

As the Dunlap Institute builds on its partnership with ISEE, it expands the Dunlap's capacity to train the next generation of astronomers—not just as researchers, but as instructors equipped to train the generation following them.

01. Dr. Tuan Do and Etsuko Mieda in the 2013 PDP Design Institute in Toronto.

02. Participants in the 2014 PDP Design Institute in Toronto including ISEE Director, Lisa Hunter (2nd from r.; blue jacket).

Public Outreach

Reaching New Audiences

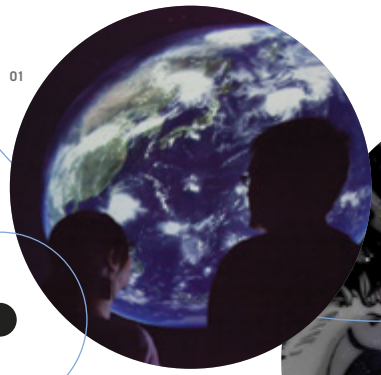
Astrophysicist Neil deGrasse Tyson delivering the 2014 Dunlap Prize Lecture. *Credit: Paola Scattolon; Dunlap Institute*

One of the downtown Toronto sidewalk astronomy sessions organized by the Dunlap Institute and Department of Astronomy & Astrophysics, U of T.

Public Outreach

The Inflationary Universe

–
Planetarium



01

02

Since 2010, undergraduate students and members of the public have enjoyed a hidden gem in the basement of the Astronomy Building in the heart of the St. George campus: a 25-seat, inflatable-dome, digital planetarium. Despite its modest size, the planetarium is a highlight for students and for the public eager to connect with the university.

U of T astronomers from the Dunlap and DAA present live public and private shows. Because they're live, shows can be customized to include breaking astronomy news (such as the appearance of Supernova 2014J in January 2014), or to highlight new research from U of T astronomers. The audience for shows is growing, and in February, March and April 2014, regularly scheduled public shows sold out, necessitating additional impromptu presentations.

01. Students in the planetarium. *Credit: Jaclyn Atlas; University Advancement, U of T*

02. The constellations projected on the planetarium dome.

Public Show Attendance:

	# of shows	Attendance
Private	48	989
Public	12	226
Graduate Student Public Shows	40	680
Science Rendezvous	10	100
Total	**110**	**1995**

Education:

AST 101	32	800
AST 201	30	800
Big Ideas	5	75
PMU 199	2	40
Total	**69**	**1715**

Public
Outreach

2013 Toronto Science Festival

–
September
27 - 29

01

02

03

01. Festival-goers explore the night sky through telescopes set up by volunteers from the Royal Astronomical Society of Canada.

02. SETI pioneer Jill Tarter. *Credit: Paola Scattolon; U of T*

03. Dr. Michael Reid describes the messages being sent into space as part of the festival.

On the last weekend of September 2013, a major new event appeared on Toronto's cultural calendar: a three-day celebration of science called the Toronto Science Festival.

The festival was organized by the Dunlap Institute and U of T Science Engagement, together with various Faculty of Arts & Science departments.

The event brought together thousands of members of the public and scientists from the U of T and across North America from a multitude of disciplines: astronomy, palaeontology, evolutionary biology, geochemistry, planetary science, anthropology, oceanography and astrobiology.

The festival explored the theme of Life in the Universe through lectures, panel discussions, screenings, hands-on activities, and dance and music performances. Keynote speakers included Canadian astronaut Julie Payette, Mars Rover imaging scientist Jim Bell, and evolutionary biologist Sean Carroll.

Jill Tarter, the pioneering Search for Extraterrestrial Intelligence (SETI) astronomer, took part in a panel discussion that included Prof. Shelley Wright, a Café Scientifique Brunch-with-a-Scientist, and a special screening of the film Contact.

The Dunlap's Director of Education and Public Outreach, Dr. Michael Reid, invited the public to explore the idea of communicating with extraterrestrial beings by writing a message to an alien civilization. But it wasn't just an intellectual exercise as three winning messages were beamed into space during the festival using the Algonquin Radio Observatory in northern Ontario.

One message was from eight-year-old Hamish Tough, who attempted to connect with ET through what he knows: "I like to play hockey. Please tell me about the games you play."

Public
Outreach

2014 Dunlap Prize Lecture

–
March 21

On March 21st, a capacity Convocation Hall crowd of 1500 greeted Neil deGrasse Tyson with a thunderous standing ovation. Tyson—astrophysicist, author, Frederick P. Rose Director of the Hayden Planetarium, star of the new TV series Cosmos, and the most popular science-popularizer since Carl Sagan—was at the University of Toronto to deliver the 2014 Dunlap Prize Lecture.

Earlier in the day, Tyson received the inaugural Dunlap Prize in a ceremony that included U of T dignitaries and two generations of the Dunlap family. The Dunlap Prize is to be awarded every few years to an individual whose accomplishments reflect the goals of the institute in instrumentation, observational research, education and public outreach.

Tyson's two-hour plus lecture was a celebration of science that entertained, enlightened, challenged and educated. Tyson's response to the people who still lament Pluto's demotion from planet to dwarf-planet? "Get over it." About whether we live in a computer-generated Matrix alternate reality? "I'm intrigued by this. I will not rule it out." About sacrificing research to host Cosmos? "The opportunity to host when I have this history with Carl Sagan? How could I not do that?"

But his main message was the value of science and science education in society. "Science and technology in the hands of enlightened people," he said in closing, "can transform the world."

01. Neil deGrasse Tyson and two generations of the Dunlap family, including the grandsons of David Dunlap and Jesse Donalda Dunlap, David (third from r.) and Moffat (third from l.).

01

Faculty

Profiles

Prof. Peter Martin PhD, FRSC

Interim Director

- Interstellar medium and star formation
- Polarization of absorption, scattering and emission by dust
- Dragonfly, Herschel Space Observatory, JWST, Planck

Prof. Shelley Wright

Assistant Professor

- Galaxy formation and evolution
- Optical-infrared instrumentation
- IRIS, OSIRIS, NIROSETI

Prof. Keith Vanderlinde

Assistant Professor

- Large-scale structure in the Universe
- Microwave-Radio instrumentation
- VLBI, CHIME, SPT

Dr. Michael Reid

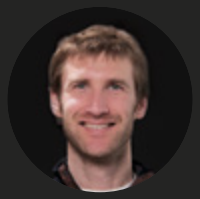
Director of Education & Public Outreach

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

Dunlap Fellows

Profiles

Dr. Nicolas Crouzet



- Transiting exoplanets
- Exoplanet atmospheres
- ASTEP South, XO Project

Dr. Tuan Do

- Galactic centre and Milky Way Galaxy satellites
- Adaptive optics spectroscopy
- Astrometry
- TMT, IRIS

Dr. Rachel Friesen

- Star and disk formation
- Astrochemistry

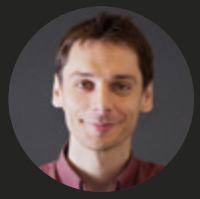
Dr. Quinn Konopacky

- Exoplanet orbits and characteristics
- Star and planet formation and evolution
- Gemini Planet Imager

Dr. David Law

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

Dr. Jérome Maire

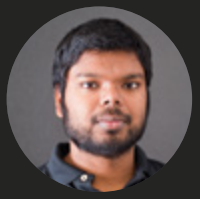


- Optical-infrared instrumentation
- Exoplanet imaging
- Arctic observatory
- GPI, SLODAR, NIROSETI

Dr. Laura Newburgh

- Instrumentation to investigate:
  - early Universe cosmology
  - dark energy
- ACTPol, CHIME

Dr. Suresh Sivanandam

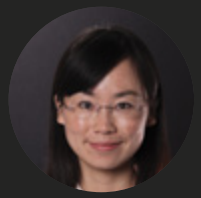


- Galaxy formation and evolution
- Optical-infrared instrumentation
- Arctic observatory
- MSAMOS, WIFIS

Postdoctoral Fellows

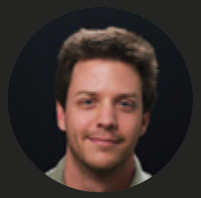
Profiles

Dr. Shaojie Chen



- Optical-Infrared instrumentation
- VPH grating, IRIS, TMT

Dr. Brian Cherinka

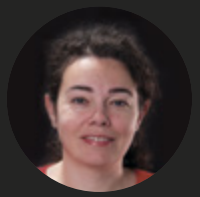


- Galaxy formation and evolution
- Integral-field spectroscopy
- Astronomy visualization and data exploration
- SDSS-IV/MaNGA

Dr. Peter Klages

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

Dr. María Montero-Castaño



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

Dr. Duy Cuong Nguyen

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

Profiles

Graduate Students Associated with the Dunlap Institute

Nolan Denman
First year

Etsuko Mieda
Fourth year

Ronald Gagne
Second year

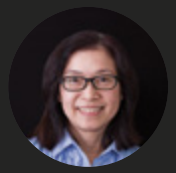
Max Millar-Blanchaer
Third year

Colin Merkel
First year

Heidi White
Third year

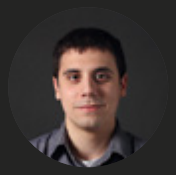
Elliot Meyer
Second year

Staff



Angela Choi
Department Manager

Alice Chow
Business Officer



Rob Figueiredo
IT Technologist

Chris Sasaki
Communications Co-ordinator

Hugh Zhao
Systems Manager

Event Horizon

Expected dates beyond April 30, 2014 for development and commissioning of instruments, commencement of observation projects, and education events at the Dunlap Institute or involving Dunlap astronomers and educators.

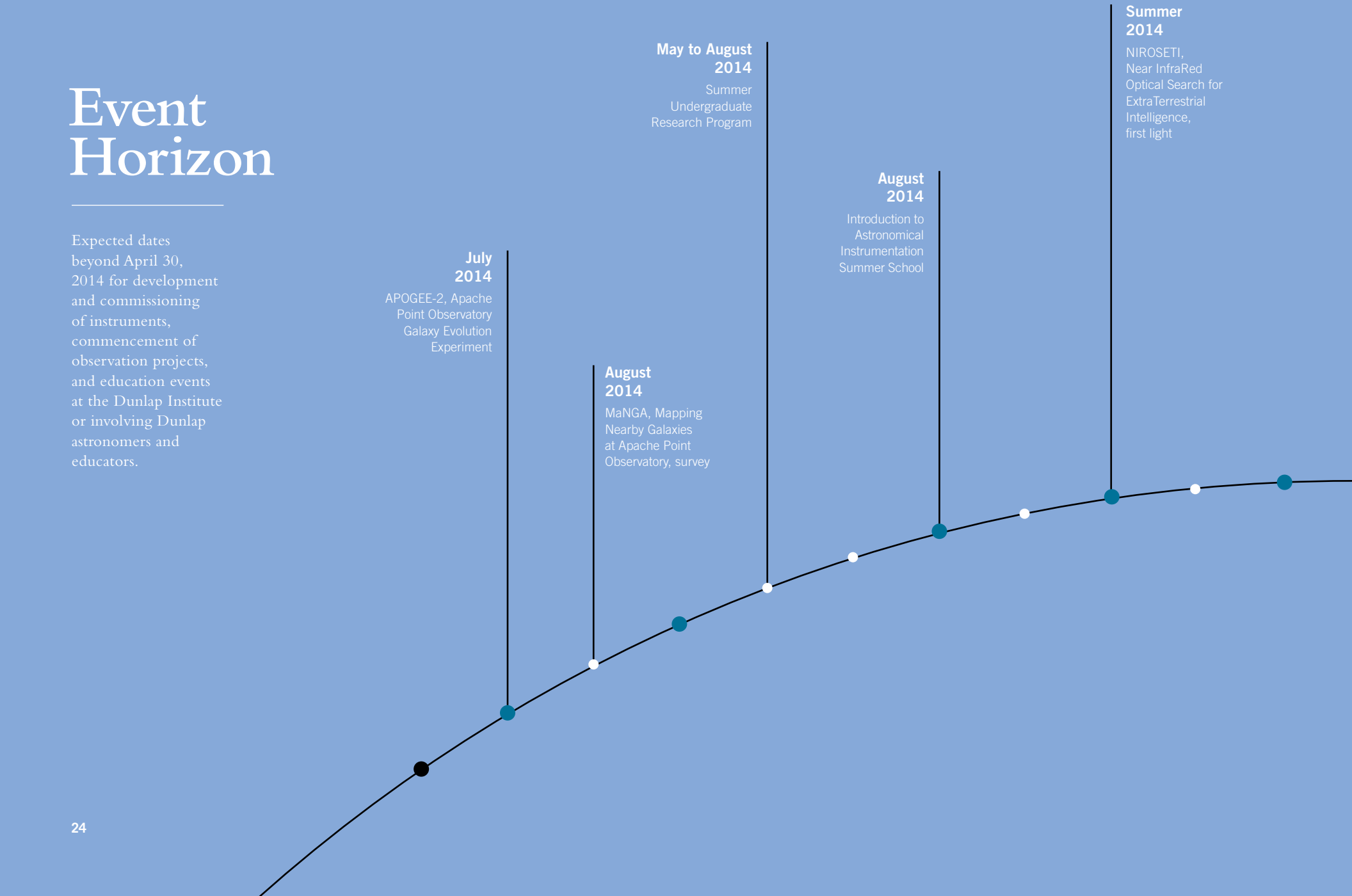
July 2014
APOGEE-2, Apache Point Observatory Galaxy Evolution Experiment

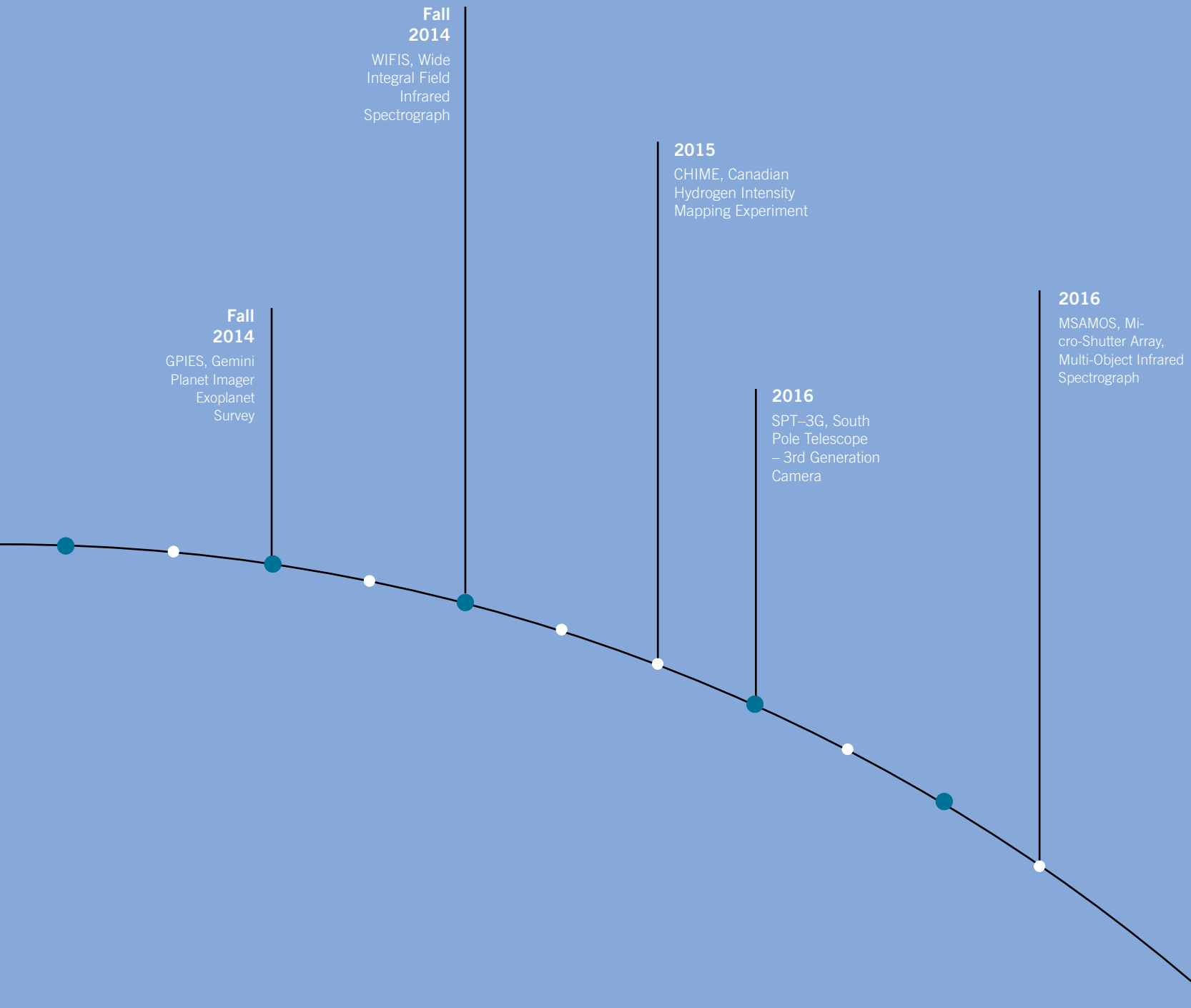
August 2014
MaNGA, Mapping Nearby Galaxies at Apache Point Observatory, survey

May to August 2014
Summer Undergraduate Research Program

August 2014
Introduction to Astronomical Instrumentation Summer School

Summer 2014
NIROSETI, Near InfraRed Optical Search for ExtraTerrestrial Intelligence, first light




Fall
2014
GPIES, Gemini
Planet Imager
Exoplanet
Survey
Fall
2014
WIFIS, Wide
Integral Field
Infrared
Spectrograph
2015
CHIME, Canadian
Hydrogen Intensity
Mapping Experiment
2016
SPT–3G, South
Pole Telescope
– 3rd Generation
Camera
2016
MSAMOS, Mi-
cro-Shutter Array,
Multi-Object Infrared
Spectrograph

Awards & Honours

Prof. Peter G. Martin

Jan 2014: CASCA 2014 Executive Award for Outstanding Service

Talks & Conferences

Dr. Nicolas Crouzet

Jan 2014: 223rd AAS Meeting, *WFC3: Precision Infrared Spectrophotometry with Spatial Scans of HD 189733b and Vega,* Washington DC, USA

Feb 2014: Seminar IPAG, *Spectroscopic observations of hot-Jupiters with Hubble Space Telescope NICMOS and WFC3,* Grenoble, France

Feb 2014: Exoclimes III, *Water vapor in the spectrum of the extrasolar planet HD 189733b,* Davos, Switzerland

Dr. Tuan Do

Apr 2013: UC Berkeley TAC seminar, *Stellar population and structure of the central 0.5 pc of the Milky Way,* Berkeley, CA, USA

Jul 2013: CITA seminar, *Mystery of the fast moving object G2 at the Galactic center: will there be fireworks?,* Toronto, ON, Canada

Jan 2014: Waterloo Astronomy Seminar, *Stellar population and structure of the central 0.5 pc of the Milky Way,* Waterloo, ON, Canada

Dr. Quinn Konopacky

May 2013: Brown Dwarfs Come of Age Conference, *The Fundamental Importance of Brown Dwarf Binaries,* Fuerteventura, Spain

Nov 2013: Center for Exoplanets and Habitable Worlds Seminar, *Characterization of the HR 8799 Planetary System Spectroscopy and Orbits,* Pennsylvania State University, State College, PA

Feb 2014: Centre for Planetary Sciences Planet Day, *Orbits and Atmospheres of Directly Imaged Exoplanets,* University of Toronto, Scarborough, Toronto, ON

Mar 2014: Adler Planetarium Research Seminar, *Orbits and Atmospheres of Directly Imaged Exoplanets,* Chicago, Illinois

Mar 2014: CIERA Astrophysics Seminar, *Orbits and Atmospheres of Directly Imaged Exoplanets,* Northwestern University, Chicago, Illinois

Dr. David Law

May 2013: Review speaker at MaNGA critical design review, *MaNGA Observing Strategy; MaNGA Software Development,* Tokyo, Japan

Nov 2013: University of Washington colloquium, *Early Growth of Galaxies,* Seattle, WA, USA

Oct 2013: Queens University colloquium, *Early Growth of Galaxies,* Kingston, ON, Canada

Jan 2014: University of Toronto colloquium, *Galaxy Kinematics through Integral Field Spectroscopy,* Toronto, ON, Canada

Feb 2014: Ohio State University colloquium, *Galaxy Kinematics through Integral Field Spectroscopy,* Columbus, OH, USA

Mar 2014: STScI colloquium speaker, *Galaxy Kinematics through Integral Field Spectroscopy,* Baltimore, MD, USA

Prof. Peter G. Martin

May 2013: Canadian Astronomical Society, Annual General Meeting, UBC, *Planck's impact on interstellar medium science*

Jul 2013: National Radio Astronomy Observatory, Green Bank, WV., *Planck's impact on interstellar medium science*

Sep 2013: Department of Physics, McGill, Montreal, *Cosmic Dust: Friend or Foe? New Insights into Galactic evolution from the Planck Surveyor and the Herschel Space Observatory*

Dr. María Montero-Castaño

May 2013: G2000, *Galaxy clusters at z~0.2: Butcher-Oemler effect,* Department of Astronomy and Astrophysics, University of Toronto, Toronto, ON

Dr. Laura Newburgh

Jul 2013, DRAO seminar, *ACTPol: A Polarized Receiver for ACT, Dominion Radio Astrophysical Observatory,* Penticton, BC, CAN

Sep 2013: AID, *Measuring the CMB with ACTPol,* Dunlap Institute, Toronto, ON, CAN

Oct 2013: Bashfest 2013: *New Horizons in Astronomy, An Experimentalist's Guide to CMB Measurements and Prospects for the Future,* Austin, TX, USA

Apr 2014: Physics Seminar at University of Michigan, *21cm Cosmology with CHIME,* Ann Arbor, Ann Arbor, MI, USA

Dr. Duy Cuong Nguyen

Mar 2014: 1st General Meeting of the SDSS-IV/APOGEE-II Collaboration, Young Clusters in APOGEE-2, UNAM, Mexico City, Mexico

Prof. Keith Vanderlinde

Oct 2013: *The Canadian Hydrogen Intensity Mapping Experiment,* Queens University Physics Colloquium

Dec 2013: *Aperture Synthesis Imaging,* SKA Summer School, organized by the University of KwaZulu Natal

Feb 2014: *CHIME & SPT,* CIfAR Lunch Meeting Series

Prof. Shelley Wright

Jan 2014: *Spatially Resolving Galaxies in the Early Universe: The Exciting Promise of Adaptive Optics Instrumentation,* UC San Diego, Astrophysics Seminar

Conference & Scientific Meeting Presentations

Dr. Tuan Do

Jan 2013: AAS winter conference, *Prospects for measuring black hole masses with future extremely large telescopes,* AAS, Long Beach, CA, USA

May 2013: Dunlap Institute Retreat, *Stellar population and structure of the central 0.5 pc of the Milky Way,* Dunlap Institute, Toronto, ON, Canada

Oct 2013: IAU 303, *Measuring the physical properties of the Milky Way nuclear star cluster with 3D kinematics,* Galactic center conference, Santa Fe, NM, USA

Dr. Rachel Friesen

May 2013: Star Formation Jamboree, *Abundant cyanopolyynes as a probe of infall in the Serpens South cluster-forming region,* Origins Institute, McMaster University, Hamilton, ON, Canada (oral)

May 2013: Dunlap Institute Retreat, *Fragmentation and infall in a young cluster-forming region,* Dunlap Institute, ON, Canada (oral)

May 2013: Annual General Meeting, *ALMA's view of clustered star-forming cores,* CASCA, Vancouver, BC, Canada (oral)

Jul 2013: Protostars & Planets VI, *Cyanopolyynes as a probe of infall in Serpens South,* MPIA, Heidelberg,Germany (poster)

Dr. Quinn Konopacky

Aug 2013: EPO Mini-Retreat, *Outreach to Teachers and Schools,* Dunlap Institute/DAA, Toronto, ON

Dr. Jérome Maire

May 2013: Dunlap Symposium, *Astronomical seeing conditions above PEARL station in Canadian Ellesmere Island,* Toronto, ON

Jun 2013: IAUS 299: *Exploring the formation and evolution of planetary systems, High-fidelity photometry and astrometry of high-contrast imaged companions using LOCI processing,* Victoria, British Columbia, Canada

Dr. María Montero-Castaño

May 2013: Dunlap Institute Symposium and Retreat, *Galaxy clusters at z~0.2: Butcher-Oemler effect,* Dunlap Institute for Astronomy and Astrophysics, Allison, ON

Dr. Duy Cuong Nguyen

Jul 2013: Protostars and Planets VI, *A New Star-Forming Region in Scorpius-Centaurus,* MPIA Heidelberg, Heidelberg, Germany

Dr. Michael Reid

Jul 20, 2013: *High Engagement in Science Megacourses,* Western Conference on Science Education, London, Ontario

Nov 15, 2013: *Why You Should Teach About Aliens,* Science Teachers' Association of Ontario Conference, Toronto, Ontario

Dr. Suresh Sivanandam

May 2013: Dunlap Symposium, *Innovative Methods for Studying Galaxies in the Infrared,* Alliston, ON, Canada

Apr 2014: Steward Observatory Observers Lunch, *Wide Integral Field Infrared Spectrograph,* University of Arizona, Tucson, AZ, USA

Prof. Keith Vanderlinde

May 2013: *The Canadian Hydrogen Intensity Mapping Experiment,* Cosmology in the Planck Era

Dec 2013: *The Canadian Hydrogen Intensity Mapping Experiment,* Frontiers in Radio astronomy, University of KwaZulu Natal, South Africa

Mar 21 - Apr 4 2014: *CHIME,* AAS: Exascale Radio Astronomy

May 2013: *Long Wavelength Instrumentation In Canada,* Dunlap Symposium

Prof. Shelley Wright

May 2013: *Optical and Infrared Instrumentation in Canada,* Dunlap Symposium

Jun 2013: *Gender Diversity in Astronomy,* Education Discussion Group, U of T

Education Outreach Talks

Dr. Tuan Do

Jun 2013: *Revealing the supermassive black hole at the center of the Milky Way,* College/Shaw Library, Toronto, ON

Dr. Rachel Friesen

May 2013: *Gender Diversity in Astronomy,* Education Discussion Group, Dunlap Institute, Toronto, ON

Dr. Quinn Konopacky

Sep 2013: AAAS Networking Evening, *Detection of Carbon Monoxide and Water Lines in an Exoplanet Atmosphere,* The Royal Ontario Museum, Toronto, ON

Dr. María Montero-Castaño

Apr 2014: *Bodies in space that emit light and those that reflect light*, videocon with 6th grade students from Iqaluit, Nunavut.

Dr. Michael Reid

May 2013: Father Michael McGivney Catholic Academy, *Misconceptions about the Big Bang Theory*

May 2013: Let's Talk Science All Science Challenge, *Three Astonishing Things*

May 2013: Hamilton chapter of the Royal Astronomical Society, *Life in the Cosmos*

May, 2013: University of Toronto Alumni Affairs' Stress Free Degree series, *Misconceptions about the Big Bang Theory*

Jul 2013: David Dunlap Observatory, *The Lives of Stars*

Sep 2013: Victoria University, *Leave Earth*

Oct 2103: Deer Park Library, *Life in the Cosmos*

Jan 2014: Brentwood Library, *Misconceptions about the Big Bang*

Feb 2014: University of Toronto Senior Alumni Association, *Life in the Cosmos*

Feb 2014: Gerrard Ashdale Library, *The Sky Tonight*

Apr 2014: Cawthra Park Secondary School, *Misconceptions About the Big Bang*

Prof. Keith Vanderlinde

Apr 24 2014: *Science at the South Pole,* Toronto Public Libraries Thought Exchange Series

Prof. Shelley Wright

Sep 2013: SETI panel, Toronto Science Festival, U of T

Publications

Peer Reviewed Publications

The Tenth Data Release of the Sloan Digital Sky Survey: First Spectroscopic Data from the SDSS-III Apache Point Observatory Galactic Evolution Experiment; Ahn, C.P., Alexandroff, R., Allende Prieto, C., **...Nguyen, D.C.,** et al. 2014, ApJS, 211, 17A

The QUIET Instrument, The QUIET Collaboration; Bischoff, C., Brizius, A., Buder, I., **...Newburgh, L.B., ...Vanderlinde, K.**, +51 others, ApJ 768, 9, 2013

Cosmological parameters from pre-planck cosmic microwave background measurements; Calabrese, E., Hlozek, R. A.,Battaglia, N., **...Newburgh, L.B.**, et al, PRD 87, 10, 2013

Stellar and circumstellar properties of visual binaries in the Orion Nebula Cluster; Correia, S., Duchêne, G., Reipurth, B., **...Konopacky, Q.M.,** et al. 2013, A&A, 557, 63

A measurement of the secondary-CMB and millimeter-wave-foreground bispectrum using 800 square degrees of South Pole Telescope data; Crawford, T., Schaffer, K., Bhattacharya, S., **...Vanderlinde, K.**, + 48 others, 2014, ApJ., 784, 143C

The Protocluster G18.67+0.03: A Test Case for Class I CH3OH Masers as Evolutionary Indicators for Massive Star Formation; Cyganowski, C., Brogan, C., Hunter, T., **...Friesen, R.**, et al. 2012, ApJ, 760, L20

Large-aperture wide-bandwidth antireflection-coated silicon lenses for millimeter wavelengths; Datta, R., Munson, C.D., Niemack, M.D., **...Newburgh, L.B.**, et al, Applied Optics 52, 36, 2013

Very Low Mass Stellar and Substellar Companions to Solar-like Stars from MARVELS. V. A Low Eccentricity Brown Dwarf from the Driest Part of the Desert; MARVELS-6b De Lee, N., Ge, J., Crepp, J.R., **...Nguyen, D.C.**, et al. 2013, AJ, 145, 155D

Stellar Populations in the Central 0.5 pc of the Galaxy. I. A New Method for Constructing Luminosity Functions and Surface-density Profiles; **Do, T.**, Lu, J. R., Ghez, A. M., Morris, M. R., Yelda, S., Martinez, G. D., **Wright, S. A.**, and Matthews, K., 2013, ApJ, 764, 154

Three-dimensional Stellar Kinematics at the Galactic Center: Measuring the Nuclear Star Cluster Spatial Density Profile, Black Hole Mass, and Distance; **Do, T.**, Martinez, G. D., Yelda, S., Ghez, A., Bullock, J., Kaplinghat, M., Lu, J. R., Peter, A. H. G., and Phifer, K., 2013, ApJ, 779, L6

Prospects for Measuring Supermassive Black Hole Masses with Future Extremely Large Telescopes; **Do, T., Wright, S. A.,** Barth, A. J., Barton, E. J., Simard, L., Larkin, J. E., Moore, A. M., Wang, L., and Ellerbroek, B., 2014, AJ, 147, 93

Substellar multiplicity in the Hyades cluster; Duchêne, G., Bouvier, J., Moraux, E., Bouy, H., **Konopacky, Q.M.**, Ghez, A.M. 2013, A&A, 555, 137

Characterizing the structure of diffuse emission in Hi-GAL maps; Elia, D., **…Martin, P.G.**, et al. 2014, The Astrophysical Journal, in press, arXiv:1404.2285

Herschel Reveals Massive Cold Clumps in NGC 7538; Fallscheer, C., **Martin, P.G., Reid, M.**, et al. 2014, ApJ, 773, 102,

Herschel Reveals Massive Cold Clump Candidates in NGC 7538; Fallscheer, C., **…Martin, P.G.**, et al. 2013, Protostars and Planets VI, 11

An Analysis of the Deuterium Fractionation of Star-forming Cores in the Perseus Molecular Cloud; **Friesen, R.**, Kirk, H., Shirley, Y. 2013, ApJ, 765, 59

Transit Search from Antarctica and Chile - Comparison and Combination; Fruth, T., Cabrera, J., Csizmadia, Sz., … **Crouzet N.**, et al. 2014, PASP, in press, arXiv 1403.1780

A direct measurement of the linear bias of mid-infrared-selected quasars at z 1 using cosmic microwave background lensing; Geach, J., Hickox, R., Bleem, L., **...Vanderlinde, K.**, +52 others. 2013, ApJ., 776L, 41G.

Galaxy Cluster Baryon Fractions Revisited; Gonzalez, A. H., **Sivanandam, S.**, Zabludoff, A. I., Zaritsky, D., 2013, ApJ, 778, 14

Detection of B-mode Polarization in the Cosmic Microwave Background with Data from the South Pole Telescope; Hanson, D., Hoover, S., Crites, A., **...Vanderlinde, K.**, +64 others 2013 PRL, 111, 141301

Spin-orbit alignment in the very low mass binary regime. The L dwarf tight binary 2MASSW J0746425+200032AB; Harding, L.K., Hallinan, G., **Konopacky, Q.M.,** Kratter, K.M., Boyle, R.P., Butler, R.F., Golden, A. 2013, A&A, 554, 113

Lensing Noise in Millimeter-wave Galaxy Cluster Surveys; Hezaveh, Y., **Vanderlinde, K.**, Holder, G., de Haan, T. 2013 ApJ 772 121

Paramagnetic alignment of small grains: a novel method for measuring interstellar magnetic fields; Hoang, T., …**Martin, P.G.,** et al. 2014, The Astrophysical Journal, in press, arXiv:1312.2106

Constraint on the Polarization of Electric Dipole Emission from Spinning Dust; Hoang, T., … Martin, P.G., et al. 2013, The Astrophysical Journal, 779, 152

A CMB lensing mass map and its correlation with the cosmic infrared background; Holder, G., Viero, M., Zahn, O., **...Vanderlinde, K.**, +54 others. 2013, ApJ, 771L, 16H

Constraints on Cosmology from the Cosmic Microwave Background Power Spectrum of the 2500 deg2 SPT-SZ Survey; Hou, Z., Reichardt, C., Story, K., ...**Vanderlinde, K.,** +49 others. 2014, ApJ, 782, 74

Near-infrared imaging spectroscopy of the inner few arcseconds of NGC 4151 with OSIRIS at Keck; Iserlohe, C.; Krabbe, A.; Larkin, J. E.; …Wright, S. A., et al, 2013, A&A, 556, 136, 27

A Reconnaissance of the Possible Donor Stars to the Kepler Supernova; Kerzendorf, W. E., Childress, M., Scharwaumlchter, J., **Do, T.**, and Schmidt, B. P., 2014, ApJ, 782, 27

Detection of Carbon Monoxide and Water Absorption Lines in an Exoplanet Atmosphere; **Konopacky, Q.M.**, Barman, T.S., Macintosh, B.A., Marois, C. 2013, Science, 339, 1398

Stellar Populations in the Central 0.5 pc of the Galaxy. II. The Initial Mass Function; Lu, J. R., **Do, T.**, Ghez, A. M., Morris, M. R., et al. 2013, ApJ, 764, 155L

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01 Under the stars at the 2013 Dunlap Institute Symposium and Retreat.

02 From l. to r., “Baboo”, Prof. Shelley Wright, “Howie” and Dr. Rachel Friesen after taping the TVOKids program, “Now You Know.”

03 Neil deGrasse Tyson and Dunlap staff and faculty take a selfie.

04 Scruffy, the unofficial mascot of the Long Wavelength Lab.

05 Dr. Quinn Konopacky being interviewed for CBC Radio's Quirks & Quarks.

Editorial: Chris Sasaki
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Keck II laser guide star in operation, Keck Observatory, Mauna Kea, Hawaii *Credit: Laurie Hatch Photography*

Algonquin Radio Observatory, Algonquin Provincial Park, Ontario *Credit: Keith Vanderlinde; Dunlap Institute for Astronomy & Astrophysics*

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