

DUNLAP INSTITUTE
for **ASTRONOMY & ASTROPHYSICS**





Prof. Peter Martin,
PhD, FRSC

Westerhout 3 (W3) star-forming cloud of gas and dust. Credit: ESA/PACS & SPIRE consortium, A. Rivera-Ingraham and P. G. Martin, University of Toronto, HOBYs Key Programme (F. Motte).

Cover

Suresh Sivanandam tests a detector for the WIFIS spectrograph, designed for observing extended objects like the Whirlpool Galaxy, M51. Credit M51 photo: NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA).

Message from the Acting Director

Paralleling my research on the physical conditions in the interstellar medium conducive to star formation, I can observe that much closer to home the Dunlap Institute is such an incubator.

“I have enjoyed seeing first-hand the blossoming of the Dunlap Institute.”

The key to our success is the personnel we are privileged to hire and then nurture through our many training and mentoring programs.

As in nature, the stars making up our now luminous cluster have different timelines. This year we welcomed our second Assistant Professor and three additional

postdoctoral fellows. After a busy search season, we hired four postdoctoral fellows and a new Lecturer who will anchor our outreach programs.

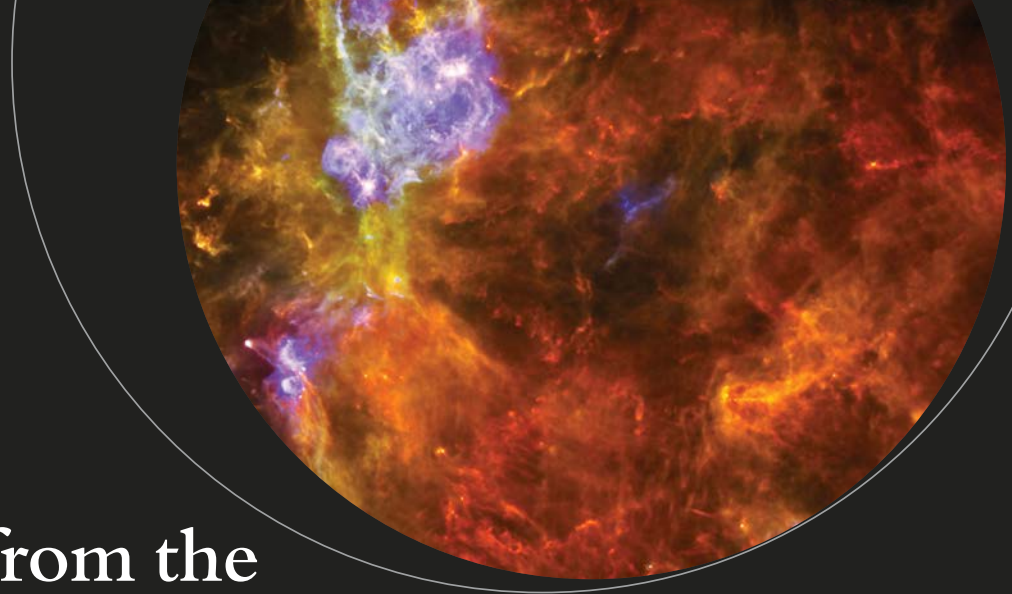
The impact of the institute is being experienced in new ways too—most recently in the inaugural Dunlap Symposium in May 2013. In line with the institute’s strong commitment to developing novel astronomical instrumentation, we brought together expert colleagues to cultivate common goals within the Canadian community. The success of the meeting was cemented by impressive presentations of recent research by our Dunlap Fellows.

Leveraging many new partnerships is also essential for rapid progress: four new awards this year from CFI and NSERC will strengthen our instrumentation program; our teaching and outreach

programs are enhanced through the Institute for Scientist and Engineer Educators; and new research opportunities are arising with the Sloan Digital Sky Survey.

A sure sign of our maturing is that, as stars do from a cluster, members are now departing from the Dunlap Institute. Two of our original postdoctoral fellows are moving to faculty positions in Scotland and the U.S.; one of our original communications experts is now pursuing a new career in England; and our first Director has taken the next step in his career (pg. 1).

As Acting Director, I have enjoyed seeing first-hand the blossoming of the Dunlap Institute. You too can glimpse the excitement through this annual report.





01

Prof. James Graham

Director 2010-2013

“The institute is on a trajectory to dominate the world stage in astrophysics.”

01. Credit: Rita Leistner.

02. Graham and undergraduate lab students.

03. Graham welcoming the Gemini Planet Imager science team to the Dunlap Institute, June 2012.



02



03

In his tenure as the first Director of the Dunlap Institute, James Graham—guided by the vision of the Dunlap family—oversaw remarkable growth and development. He has realized the aspiration of making the Dunlap Institute a vital complement to the Department of Astronomy & Astrophysics (DAA) and the Canadian Institute for Theoretical Astrophysics (CITA), adding to the international reputation of the University of Toronto’s astronomy group.

Under his leadership, the institute grew in a remarkably short period from a contingent of two Dunlap Fellows, to three faculty and ten Dunlap Fellows—a critical mass of exceptional talent that will continue to draw more expertise to Toronto.

During his tenure, Graham championed instrumentation projects that will produce scientific

results for years to come. He has positioned the institute to play a significant role in major advances in coming decades, through international collaborations and involvement with the Thirty Meter Telescope, Keck Observatory and the Gemini Observatories.

His strong commitment to training the next generation of astronomers is reflected in a career pipeline established under his directorship, which includes the annual Summer Undergraduate Research Program, the Dunlap Institute Summer School, and a growing association with organizations such as the Institute for Scientist & Engineer Educators.

His support of outreach reflected the institute’s original mandate to share astronomical discovery with the public “with passion.” And no event was better evidence of this

than the June 5th 2012 Transit of Venus at Varsity Stadium event, one of the largest ever astronomical public outreach events.

On his departure, Graham says, “It has been an enormous honor and privilege to be associated with the University of Toronto and a unique opportunity to participate in defining the initial stages of the growth of the Dunlap Institute. With the recruitment of brilliant young professors, an unrivaled group of Dunlap Fellows, a dedicated cadre of talented graduate students, and a vibrant education and outreach group, the institute is on a trajectory to dominate the world stage in astrophysics.”

Much of what you read in the pages of this annual report is the result of James Graham’s vision and leadership.

Faculty

Profiles



Prof. Keith Vanderlinde
Assistant Professor

Keith Vanderlinde is a big-picture astronomer who studies the nature and evolution of large-scale structure in the Universe, as well as the evolution of the cosmos itself. He is working to answer questions about the Universe's past, so we can understand its future.

Studying large-scale structure requires specialized instruments and Vanderlinde is a member of a collaboration using one that is unique: the South Pole Telescope (SPT). The SPT surveys the sky at microwave frequencies to reveal the Cosmic Microwave Background—a snapshot of the Universe less than 400,000 years after the Big Bang.

Vanderlinde is also a member of a cross-Canada collaboration building an innovative, digital radio telescope near Penticton,

B.C. The Canadian Hydrogen Intensity Mapping Experiment, or CHIME, is a radio array that will create a three-dimensional map of the largest volume of the Universe ever. The group includes the Dunlap Institute, CITA, UBC, McGill University and the Dominion Radio Astrophysical Observatory. In January, the Canadian Foundation for Innovation approved funding to build the CHIME telescope.

Vanderlinde is also a member of a team using the Algonquin Radio Observatory in northern Ontario and the Giant Metre-wave Radio Telescope in India to make ultra-high resolution observations of pulsars, using pockets in interstellar gas as billion-kilometre-wide lenses.



Prof. Shelley Wright
Assistant Professor

Shelley Wright's research focuses on understanding how galaxies form and evolve over cosmic time. She makes most of her observations with integral-field spectrographs, coupled with adaptive-optics systems on the largest telescopes in the world. These high-resolution observations reveal the internal motions and chemical make-up of distant, young galaxies forming one to three billions years after the Big Bang.

But Wright is not just attempting to answer fundamental astronomical questions. When there is no existing means to answer a question, she designs and builds innovative instruments to find the answer. In addition to upgrading the OSIRIS instrument on the Keck I telescope (pg. 9), she is Project Scientist for the

Infrared Imaging Spectrograph. IRIS will be the first adaptive optics instrument on the Thirty Meter Telescope when it begins operation later this decade.

She is also Principal Investigator for an instrument designed to answer one of the biggest questions in astronomy: Are we alone? In 2013, Wright and her collaborators began building a Near Infrared Optical SETI detector. SETI, or the Search for Extraterrestrial Intelligence, has for decades been conducted at radio wavelengths. NIROSETI is designed to detect extremely short pulses of laser light that can be many thousands of times brighter than a star.



Dr. Michael Reid

Lecturer & Public
Outreach Coordinator

In addition to lecturing and conducting his own research into the formation of massive stars, Michael Reid leads the effort to fulfill the Dunlap Institute's mandate of sharing astronomical discovery with the public. He is motivated by his belief that public outreach helps create a scientifically literate society, improves public perception of science and, simply, is a lot of fun. And if, as Carl Sagan said, science is a candle in the dark, then according to Reid, "science outreach hands out the candles."

Reid is faculty advisor to Let's Talk Science and is a frequent speaker on science outreach and education at conferences around the world. He led the team that organized the Transit of Venus at Varsity Stadium event (pg. 22) and is working to achieve the

same success with the inaugural Toronto Science Festival in September 2013. The festival will be a weekend of talks, panels and events that bring together UofT scientists and the public.

In the future, Reid's plans for outreach include a focus on technology and experimentation. "My intention," he says, "is to get people to do things, rather than just hear about them." Whether it is through sidewalk astronomy sessions or grander initiatives, his goal is to share discovery with a passion.

Dunlap Fellows



Dr. Brian Cherinka

Brian Cherinka joined the Dunlap Institute as part of the Mapping Nearby Galaxies at Apache Point Observatory (MaNGA) team. MaNGA is an integral-field spectroscopic survey of 10,000 nearby galaxies and one of the Sloan Digital Sky Survey IV programs. The team at the institute is developing the project's data-reduction pipeline and advancing science cases.

In addition to his work on MaNGA, Cherinka's research focuses on the formation and evolution of galaxies and clusters of galaxies. Through spectrographic observations, he is investigating hydrogen gas within galaxies, as well as the relationship between the galaxies and their surrounding environments. He is also collaborating with researchers from the University of Pittsburgh to improve the visualizations of astronomical data for exploratory research.



Dr. Tuan Do

Tuan Do endeavours to answer the questions: What lies at the centre of the Milky Way Galaxy, and how did that exotic environment form? He searches for answers by tracking the motions of stars in orbit around the supermassive black hole at the heart of our galaxy (pg. 14). Do's research also extends to the active nuclei of other galaxies, as well as to the dwarf galaxies that orbit our own.

In addition to his research, Do is interested in the advancement of science education. In 2013, he attended the Professional Development Program of the Institute for Scientist & Engineer Educators, and he is helping train the next generation of astronomers through his participation in education initiatives like the Summer Undergraduate Research Program (pg. 18).

Profiles



Dr. Rachel Friesen

Rachel Friesen studies the earliest stages of star formation by observing the cold, dense molecular clouds from which stars arise. She examines the light emitted by molecules within these regions to gain an understanding of the composition, structure, temperature and internal motions of these stellar nurseries—and thus gain a better understanding of the birth of stars and planetary systems.

Because this light is found at radio wavelengths, Friesen makes her observations using radio telescopes facilities like the Very Large Array, the Australia Telescope Compact Array, and the Atacama Large Millimeter Array. She also makes use of observations from space telescopes such as the Spitzer Space Telescope and the Herschel Space Observatory.



Dr. Quinn Konopacky

Using high-resolution imaging and spectroscopy to study the orbits and characteristics of exoplanets, Quinn Konopacky is increasing our understanding of the formation and evolution of stars and planetary systems. She is a member of a team that discovered, in 2010, a gas giant planet in orbit around the star HR 8799. Using images obtained with the Keck II telescope, and Quinn Konopacky and her team used OSIRIS to make the most detailed observation to date of a gas giant exoplanet's atmosphere (see pg. 15).

Konopacky is also a member the Gemini Planet Imager team, with particular responsibility for the instrument's ability to precisely measure position. This astrometric precision will enable the GPI team to accurately describe the orbits of distant GPI-discovered planets and thereby shed light on planetary systems like our own.



Dr. David Law

David Law studies the formation, properties and evolution of galaxies and their dark matter halos. With instruments like the Hubble Space Telescope and the twin Keck telescopes, he observes very distant galaxies at a time of abundant star-formation. These observations led to the discovery of one of the most distant galaxies with spiral arms. (pg. 13)

Law is also a member of the Mapping Nearby Galaxies at Apache Point Observatory team at the Dunlap Institute. MaNGA is one of the programs in the next phase of the Sloan Digital Sky Survey and will obtain integral-field spectroscopy of 10,000 relatively nearby galaxies. The team at the institute is developing the project's data-reduction pipeline, and is helping to optimize fibre-bundle design and the observing strategy.

Profiles



Dr. Nicholas Law

Nicholas Law is a planet hunter. He scans the skies in search of the dimming that occurs when a planet passes in front of a star, blocking a tiny fraction of its light from our view. Law conducts his search on many fronts. As part of the Palomar Transit Factory survey, he has detected potential exoplanets orbiting M-dwarf stars. He has also been a member of the team developing planet-hunting instruments at the Dunlap Institute, including Arctic Wide-field Cameras (pg. 10) and the .5-metre Dunlap Arctic Telescope.

Law was one of the first two Dunlap Fellows. After the summer of 2013, he will continue his search for exoplanets as an assistant professor in the Department of Physics & Astronomy, at the University of North Carolina.



Dr. Jérôme Maire

How do planets form and evolve? How many planets exist beyond our Solar System? These are the questions Jérôme Maire is attempting to answer as part of a team developing the Gemini Planet Imager. Maire developed the GPI data-reduction pipeline and is using test data from the instrument, currently at the University of Santa Cruz, to characterize and improve its high-contrast imaging performance prior to commissioning on the Gemini South telescope.

Maire's research also focuses on a question that is fundamental to all Earth-based astronomy: How does the atmosphere affect our observations? His work will help astronomers select astronomical sites and improve existing instruments. In November 2012, he travelled to Ellesmere Island where he measured atmospheric turbulence and its effect on observations with SLODAR (pg. 10).



Dr. María Montero-Castaño

According to our current understanding, young galaxies contain an abundance of gas which coalesces over time into stars, creating mature, star-rich galaxies. But, when a galaxy resides within a clusters of galaxies, there are many other factors influencing this process. Within these dynamic and complex environments, Maria Montero-Castaño studies the question of galactic nature vs. nurture.

It is a complex problem for Montero-Castaño and her collaborators in the Blind Ultra-Deep HI Environmental Survey. It requires identifying the cluster galaxies that have experienced star formation and those that haven't, as well as their location within the cluster, all in order to understand where in the cluster the most recent star formation occurred.

Profiles



Dr. Suresh Sivanandam

Suresh Sivanandam studies the formation and evolution of galaxies in clusters. One focus of his research is on a cluster's halo of gas and how it interacts with the gas in individual galaxies. Another is a spectroscopic survey of nearby galaxies to see if their stellar populations differ significantly from predictions. It will be conducted with a unique instrument Sivanandam and his collaborators are currently building: the Wide Integral-Field Infrared Spectrograph, or WIFIS, destined for Kitt Peak Observatory.

In addition to WIFIS, Sivanandam is a key member in many instrument projects, including a Micro-Shutter Array, Multi-Object Spectrograph, or MSAMOS. Plus, he is helping develop the Dunlap Arctic Observatory and is Principal Investigator for near-IR Arctic sky brightness measurements (pg. 10).



Dr. Anne-Marie Weijmans

Anne-Marie Weijmans has spent much of her career studying the dark matter haloes of galaxies. The halo is the most massive component of a galaxy and it plays a critical role in the system's formation and evolution. The halo is invisible but by measuring the movement of objects we *can* see—stars and gas in a galaxy's outer reaches—Weijmans can map the unseen.

Weijmans also studies very distant, high-redshift galaxies and is a member of the MaNGA project to obtain spectra of 10,000 nearby galaxies. She was one of the first two Dunlap Fellows and, in the summer of 2013, will be joining the School of Physics & Astronomy at the University of St. Andrews, Scotland, as a lecturer.

Staff



Angela Choi
Department Manager



Alice Chow
*Assistant to the Director
& Office Administrator*



Rob Figueiredo
IT Technologist



Chris Sasaki
*Public Information
Officer; Communications*



Hugh Zhao
Systems Manager

COLLABORATIONS

Astronomers at the Dunlap Institute lead and take part in international collaborations with researchers and

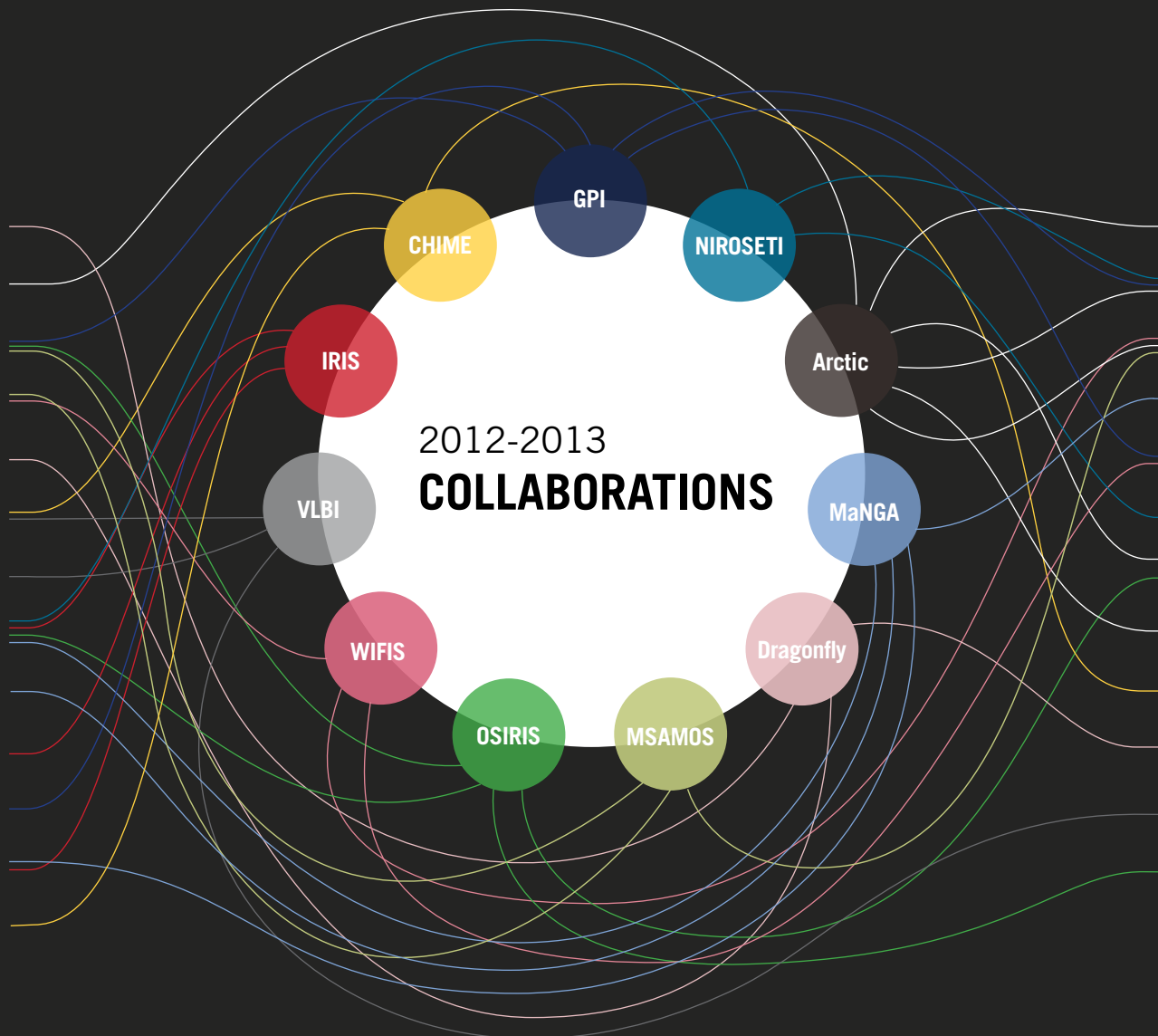
institutes around the world. Within the institute, faculty, Dunlap Fellows and graduate students collaborate often,

bringing their unique skills, expertise and experience to a variety of projects.

CHIME	Canadian Hydrogen Intensity Mapping Experiment
IRIS	Infrared Imaging Spectrograph
GPI	Gemini Planet Imager
WIFIS	Wide Integral-Field Infrared Spectrograph
MaNGA	Mapping Nearby Galaxies at Apache Point Observatory
NIROSETI	Near-Infrared Optical Search for Extraterrestrial Intelligence
OSIRIS	OH-Suppressing Infrared Integrated Spectrograph
MSAMOS	Multi-Shutter Array – Multiple Object Spectrograph
VLBI	Very Long Baseline Interferometry

Profiles

Prof. Roberto Abraham (DAA)
Prof. Ray Carlberg (DAA)
Prof. James Graham
Prof. Dae-Sik Moon (DAA)
Prof. Peter Martin
Prof. Keith Vanderlinde
Prof. Marten Van Kerkwijk (DAA)
Prof. Shelley Wright
Dr. Brian Cherinka
Dr. Tuan Do
Dr. Quinn Konopacky
Dr. David Law
Dr. Laura Newburgh



Dr. Nicholas Law
Dr. Jérôme Maire
Dr. Suresh Sivanandam
Dr. Anne-Marie Weijmans
Max Millar-Blanchaer
Elliot Meyer
Etsuko Mieda
Wayne Ngan
Ivan Padilla
Jielai Zhang
Prof. Ue-Li Pen (CITA)
Heidi White

Innovation & Instrumentation

*Developing New Ways
to Answer Big Questions*



Elliot Meyer examines a detector, part of the Near-Infrared Optical SETI instrument being developed at the Dunlap Institute to search for short, bright laser signals sent by an extraterrestrial civilization.

*Credit: Milky Way Galaxy
photo: NASA/JPL-Caltech.*



Innovation
& Instrumentation

In a New Light

OSIRIS –
OH-Suppressing
Infrared Integrated
Spectrograph



01



02



03

01. W.M. Keck Observatory.
*Credit: W.M. Keck
Observatory.*

02. Mieda in January 2013
during installation of the
new grating.

03. Shelley Wright and
graduate student Etsuko
Mieda characterizing
the second-generation
diffraction grating for
OSIRIS.

In January 2013, a team from the Dunlap Institute travelled to the W.M. Keck Observatory on the summit of Mauna Kea in Hawaii. They were there to make one of the observatory's most powerful tools even more powerful.

The observatory's twin, 10-metre telescopes are among the largest in the world, and the Keck II sees the Universe in greater detail than the Hubble Space Telescope because of its laser-guide-star, adaptive-optics (AO) system. Astronomers had been

using the first-generation OSIRIS spectrographic-imager since 2005. For example, David Law and his team used OSIRIS to study the galaxy BX442 (see pg. 13); and Quinn Konopacky and her team used OSIRIS to make the most detailed observation to date of a gas giant exoplanet's atmosphere (see pg. 15).

The heart of any spectrograph is the grating which separates light according to wavelength to produce a spectrum. Throughout

2012, the team of Shelley Wright, James Graham and Etsuko Mieda worked on giving OSIRIS a new heart. They collaborated with Bach Research Corporation in manufacturing a second-generation grating. They developed new methods for testing its efficiencies and, after months in the lab, installed it in the spectrograph in January.

With the new grating in place, astronomers are now using the upgraded OSIRIS to observe tv of a factor of two.



Searching For Exoplanets In The High Arctic

—
Dunlap Arctic
Observatory

During the winter of 2012/2013, a team of Dunlap Institute and DAA astronomers continued their work to establish the northernmost astronomical observatory in the world. The site is at the Polar Environment Atmospheric Research Laboratory (PEARL) on Ellesmere Island, at 80°N. The High Arctic offers months of uninterrupted darkness, making the location ideal for detecting the periodic dimming of stars that reveal transiting exoplanets.

Jérôme Maire installed the SLODAR Slope Detection and Ranging instrument he designed and built with graduate student Etsuko Mieda. SLODAR measures

the strength, variability and altitude of the atmospheric turbulence that reduces the resolution of observations, as well as the accuracy of brightness and position measurements. During a 14-day run, SLODAR made measurements that will ensure the optimal performance of the Dunlap Arctic Telescope—expected to be installed in late 2013.

Suresh Sivanandam gathered data with an instrument that measured the brightness of the sky at infrared wavelengths. Lower sky brightness makes for better show whether brightness is as low as it is in the Antarctic.

During an observing run from

October 2012 to February 2013, two Arctic Wide-Field Cameras—developed and built by Nicholas Law—recorded 700,000 images of the sky around the north celestial pole. It was the first, long-term astronomical survey ever conducted in the Canadian Arctic. Law is confident that, hidden within the 21 terabytes of data gathered over the winter, he will find evidence of transiting exoplanets.



01. SLODAR on the 14" Dunlap telescope. Credit: Jérôme Maire; Dunlap Institute for Astronomy & Astrophysics.
02. PEARL Science Station. Credit: Wayne Ngan; Dunlap Institute for Astronomy & Astrophysics.
03. Wayne Ngan and AWCams. Credit: Wayne Ngan; Dunlap Institute for Astronomy & Astrophysics.



Through a Glass Brightly

—
Project
Dragonfly

According to Cold Dark Matter cosmology, structure in the Universe grows from the “bottom up”, with small galaxies merging to form larger ones. Evidence of such mergers can be seen in the faint structure visible around the Milky Way and M31 galaxies.

But according to CDM, we should see more of this structure than is currently observed. Some astronomers think the discrepancy can be solved by changing the CDM model or our understanding of the nature of cold dark matter. Co-investigators Roberto Abraham and Peter Martin have a much simpler explanation: that we can’t see the structure because it is fainter than the scattered light normally present in images from even the largest, most advanced telescopes today. According to Abraham and Martin, what’s needed is an innovative instrument like Dragonfly.

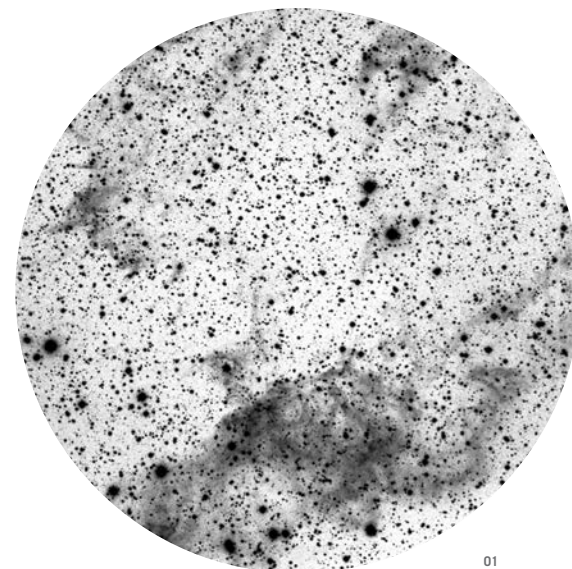
Dragonfly is an array of ten, Canon 400mm lenses with an unprecedented coating technology that greatly reduces scattered light and internal reflections within the optics. What’s more, Dragonfly images a galaxy through multiple lenses simultaneously—akin to a dragonfly’s compound eye—enabling further removal of unwanted light. The result is an image in which extremely faint galaxy structure is visible.

The array began imaging targets in 2013 and so far, observations show it is at least ten times more efficient than its nearest rival and will be able to detect faint structures predicted by current merger models.

Funding for the Dragonfly project is provided by Abraham’s NSERC Discovery Grant, a newly-awarded NSERC equipment grant, plus initial funds provided by the Dunlap Institute and Yale University.

01. Detail from a test image showing Dragonfly’s ability to record faint structures. *Credit: Prof. Roberto Abraham; Prof. Peter Martin; Prof. Pieter van Dokkum (Yale).*

02. Dragonfly at the New Mexico Skies telescope hosting facility. *Credit: Etsuko Mieda; Dunlap Institute.*



Observational Research

Answering Big Questions

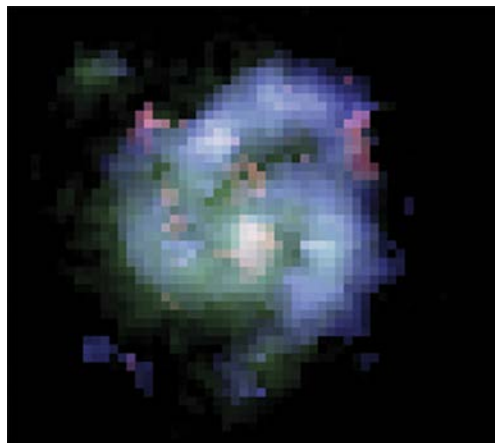


Rachel Friesen will use data from the Atacama Large Millimeter/submillimeter Array (ALMA) to study star-forming regions like the Ophiuchus Molecular Cloud.
Credit: NASA; JPL-Caltech; Harvard-Smithsonian CfA.

ALMA radio telescope dishes.
Credit: ESO/C. Malin.



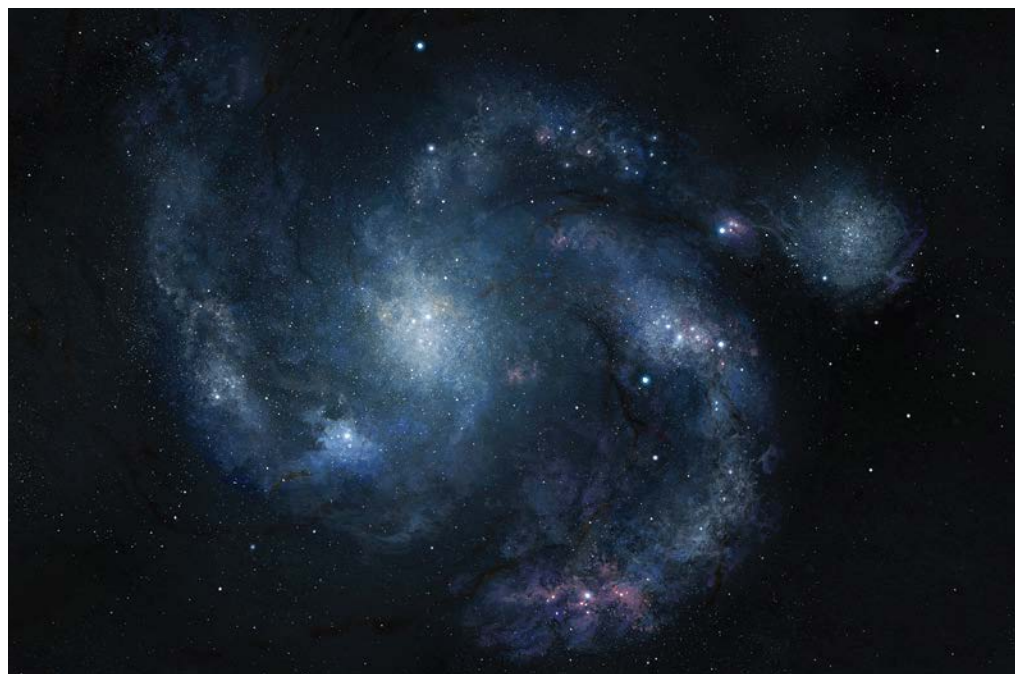
Observational
Research



01

A Spiral Galaxy Before its Time

01. HST/Keck false colour composite image of galaxy BX442. Credit: David Law; Dunlap Institute for Astronomy & Astrophysics.
02. Artist's rendering of BX442 and dwarf companion. Credit: Dunlap Institute for Astronomy & Astrophysics; Joe Bergeron.



02

A team of astronomers led by David Law has discovered a spiral galaxy that appears to have formed a billion years before other spirals. In a paper published in July in the journal *Nature*, they explain that the galaxy is 10.5 billion light-years from Earth, putting it at a time when the Universe was only three billion years old.

Most galaxies from this epoch are clumpy and irregularly-shaped. “The fact that this galaxy exists is astounding,” says Law. “Current wisdom holds that such grand-design spiral galaxies simply didn’t exist at such an early time in the history of the Universe.”

Law and his co-investigator, Alice Shapley (UCLA), noticed the galaxy in images they

obtained using the Hubble Space Telescope. Follow-up observations with the OSIRIS imaging-spectrograph on the Keck II telescope in Hawaii confirmed that it is indeed a spiral disk, rotating roughly as fast as our own Milky Way Galaxy.

While the form and rotation have been confirmed, the reason for the structure remains a mystery. One possibility, Law suggests, is that gravitational interaction with a dwarf companion galaxy helped trigger the early formation of spiral arms. Understanding this mechanism in greater detail could help answer the question: How did our own Milky Way Galaxy form?



Observational
Research

Around the Milky Way Galaxy in 11½ Years

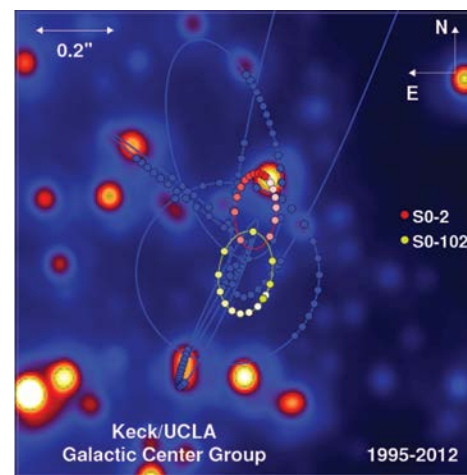
The core of the Milky Way Galaxy is a fantastic region of extremes. At the very centre lies an enormous black hole, designated Sgr A* (“Sagittarius-A-star”), with the mass of four million Suns. Millions of stars orbit the black hole, propelled by its intense gravitational field to speeds of over 4000 kilometres per second—or about one percent the speed of light.

In October 2012, a team of astronomers that includes Tuan Do, announced that they had identified the star with the shortest known orbital period around Sgr A*. Known as S0-102, the star takes a mere 11 ½ years to complete a single circuit. The observations were published in the journal *Science* and are the latest results from the UCLA Galactic Center Group which had previously discovered the black hole.

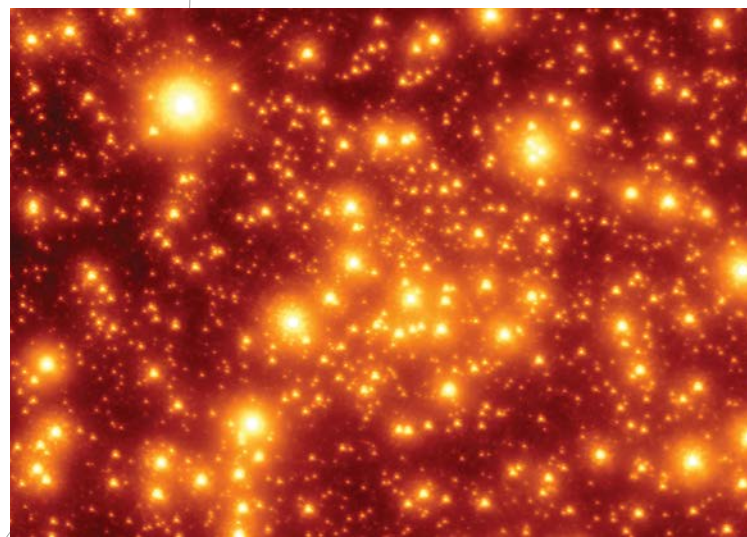
Having identified S0-102, Do and the UCLA team will now make spectroscopic studies of the star in order to estimate its age and better understand how it came to be in our galaxy’s heart.

The star also provides the group with a rare opportunity. According to Einstein’s General Theory of Relativity, the elliptical orbit of a star near the black hole should precess; that is, the point in the orbit farthest from the black hole should itself move slowly around the parent object in a precise fashion. “The best way to measure this effect is in the intense gravity of a supermassive black hole,” explains Do, “so S0-120 will give us one of the best tests of Einstein’s model yet.”

01. Orbits of stars around Sgr A*. Credit: Keck/UCLA; Galactic Center Group.
02. Stars at the centre of the Milky Way Galaxy. Credit: UCLA Galactic Center Group.



01



02



Observational
Research

What a Distant Planetary System Reveals About Our Own

In March 2012, a team led by Quinn Konopacky revealed the results of years of observations of a distant, Jupiter-like exoplanet. It was the most detailed examination of the atmosphere of such a planet yet, and it provided at least a partial answer to the fundamental question: How do planetary systems form?

The planet, designated HR 8799c, is one of four previously discovered in orbit around the star HR 8799, 130 light-years away. It is many times the mass of Jupiter and its orbit is 40 times the diameter of the Earth's orbit.

According to Konopacky, "We were able to observe the planet in unprecedented detail because of advanced instrumentation on the Keck II telescope, and because of innovative observing and data-processing techniques."

The observations revealed a cloudy atmosphere containing

carbon monoxide and water vapour. They showed that the carbon to oxygen ratio in the atmosphere was higher than the same ratio in the parent star. This was evidence that the HR 8799 system formed according to the core accretion model, which is thought to explain the origin of our own Solar System.

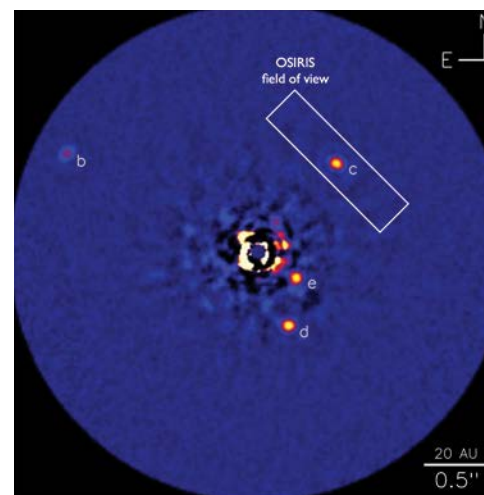
The core accretion model also predicts that gas giant planets form at great distances from the central star, and smaller rocky planets form closer in, just as we see in our Solar System. So, in addition to the gas giants far from HR 8799, it would not come as a surprise to find Earth-like planets in closer proximity to their parent star.

Konopacky and her team will continue to study the system using Keck's OSIRIS imaging spectrograph, upgraded in January 2013.



01

01. Artist's rendering of the HR 8799 planetary system showing planet HR 8799c, a disk of dust and gas, and interior planets. Credit: Dunlap Institute for Astronomy & Astrophysics; Mediafarm.



02

02. Discovery image of HR8799 system obtained showing OSIRIS field of view. Credit: NRC Canada, C. Marois and Keck Observatory.

Education

Training the Next Generation of Astronomers





Education

Graduate Students Associated with Dunlap Institute

**Nathan
Hetherington**



SECOND YEAR

Undergraduate degree:
Physics, University
of New Brunswick

Research interest:
Galactic dynamics

**Elliot
Meyer**



FIRST-YEAR

Undergraduate degree:
Physics, University
of Toronto

Research interest:
Exoplanets, galaxies,
instrumentation, NIROSETI

**Etsuko
Mieda**



THIRD YEAR

Undergraduate degree:
Astronomy, UC Berkeley

Research interest:
Dunlap Arctic Observatory,
OSIRIS

**Max Millar-
Blanchaer**



SECOND YEAR

Undergraduate degree:
Electrical Engineering and
Physics, Queen's University

Research interest:
Instrumentation,
exoplanets, galaxy
evolution, supernovae, GPI

**Wayne
Ngan**



FOURTH YEAR

Undergraduate degree:
Physics & Astronomy, UBC

Research interest:
Cold Dark Matter, Dunlap
Arctic Observatory

**Ivan
Padilla**



FIRST YEAR

Undergraduate degree:
Physics, McGill University

Research interest:
Morphology and evolution
of high-redshift galaxies

**Stephen
Ro**



SECOND YEAR

Undergraduate degree:
Mathematical Physics,
Queen's University

Research interest:
Core-collapse supernovae
and shocks, high-z galaxy
image simulations

**Heidi
White**



SECOND YEAR

Undergraduate degree:
Physics & Astronomy,
University of Toronto

Research interest:
Morphology and evolution
of high-redshift galaxies



2012 Summer Undergraduate Research Program

During the summer of 2012, students from universities around North America spent 16 weeks at the U of T to experience what it would be like to be an astronomer. They were taking part in the second annual Summer Undergraduate Research Program (SURP) organized by the Dunlap Institute, the DAA and CITA.

“They experience what it is to be a scientist.”

A total of 23 students participated: 13 were supervised by Dunlap Institute and DAA faculty and postdocs, and 10 by CITA. Over the course of the program, students conducted research projects, and studied instrumentation, dark matter, spectrographic surveys of galaxies, exoplanet detection, and astronomy in the Arctic.

The summer program included a two-day session designed by a team from the Dunlap Institute and DAA who had attended the Professional Development Program of the Institute for Scientist & Engineer Educators (ISEE) at UC Santa Cruz. The ISEE has pioneered efforts to foster scientists as educators, and promoted inquiry as a framework for teaching scientific content to students like those taking part in the 2012 SURP.

The program culminated in an exercise familiar to any scientist: students presented their work in front of a roomful of peers. According to SURP organizer, Anne-Marie Weijmans, “This is what the program is all about: the students do what scientists do. They conduct research, collaborate, discuss their work, attend lectures, present findings. They experience what it is to be a scientist.”



01



02

01. Bryn Orth-Lashley, U of T, presenting his research results.
02. SURP organizer Anne-Marie Weijmans and student.



Education

2012 Dunlap Institute Summer School

“The knowledge we gained will help me keep going in this field.”

“It was a great benefit to become aware of future opportunities in instrumentation.”

“As a student trying to decide the direction of my graduate studies, this week has been invaluable.”

Students shared their assessment in an anonymous survey after the school.



In 2012, the Dunlap Institute held its first annual Summer School, an intensive five days of lectures, labs and demonstrations for senior undergraduate and graduate students with a background in astronomy, physics or engineering.

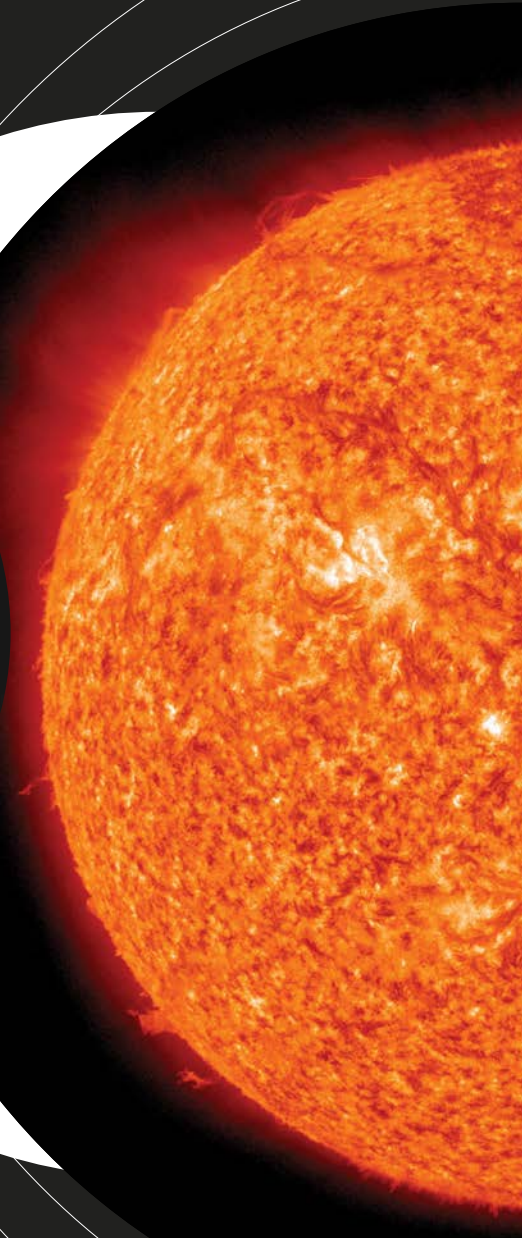
Forty students from across Canada and the U.S. took part, along with students from as far away as Peking University, Australia and Europe. They were led by 20 astronomers who specialize in the development of astronomical instruments—from Yale University, UCLA, University of Arizona, European Southern Observatory, University of Sydney, Cornell University, Pennsylvania State University, the Herzberg Institute of Astrophysics, and of course, the Dunlap Institute and the DAA.

In 2012, the school was an introduction to astronomical instrumentation. Lectures covered a range of topics, including optics, spectroscopy, spectrometers, detectors, interferometry, fundamentals of light and telescopes, and advanced astronomical techniques. Students integrated the knowledge they gained in lectures with interactive, hands-on labs for detector characterization and advanced spectrographs.

The school was organized in partnership with Cornell University and Yale University, and was supported with a grant from Connaught Fund Summer Institute program.

Public Outreach

*Sharing Discovery
with a Passion*



One of the 5000+ spectators
who watched the transit of
Venus from Varsity Stadium
on June 5th 2012



Public
Outreach

Preparing for Venus

—
April 28th
Transit of Venus
Symposium

Transits of Venus are extremely rare astronomical events. They occur when the planet passes directly in front of the Sun as seen from Earth, appearing as a silhouette just visible to the naked eye. Transits of Venus happen in pairs eight years apart and the pairs, in turn, are separated by over a hundred years. The previous transit was in 2004, meaning the June 5th 2012 event was the last any living person would witness.

In preparation for such an historic occurrence, the Dunlap Institute held a day-long symposium, co-organized with the Institute for the History & Philosophy of Science & Technology, and with the support of the DAA. It was held in conjunction with an exhibition of astronomical

instruments organized by the U of T Scientific Instrument Collaboration.

Scientists, academics, educators and journalists listened to talks on a wide range of topics, including: the history of transits, safe viewing, incorporating transits into math and science curricula, as well as the connection between the transit of Venus and today's search for planets outside the Solar System.

Dr. Jay Pasachoff, a renowned researcher, astrophotographer, science communicator and transit expert described his plans to use the transit to study Venus's atmosphere. And James Graham described the current state of the search for exoplanets. Over a hundred attended the event, and left with heightened anticipation for June 5th.

01. Dr. Jay Pasachoff
02. Prof. James Graham describes the current state of the search for exoplanets.



01



02



Public
Outreach

The Last Transit

The Transit of Venus
at Varsity Stadium,
June 5th 2012



01

On the afternoon of June 5th, over 5000 excited spectators filled the U of T's Varsity Stadium to capacity. They were there to see, not a sporting event or concert, but the last transit of Venus of the century.

In the months leading up to June 5th, the Dunlap Institute focused its outreach efforts on the transit to ensure the public got the most out of the opportunity. symposium, the institute produced 43,000 transit-viewing glasses and distributed them across Canada with the help of the Royal Astronomical Society of Canada and the Fédération des astronomes amateurs du Québec.

Hundreds of brochures were created in ten languages with instructions for safe viewing. A section of the astronomy public-outreach web portal, universe.utoronto.ca, was devoted to the transit. And, sidewalk astronomy sessions during lunch hours in downtown Toronto whet the appetite of office workers for the celestial display.

On the day of the event, transit-watchers began lining up in the early afternoon—even though Venus wasn't scheduled to appear until 6:04pm—and cheered as the stadium gates opened.



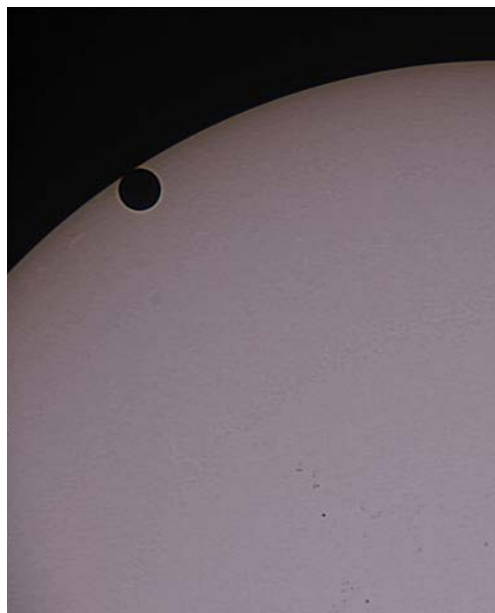
02

01. Spectators lining up outside Varsity Stadium.

02. Transit brochure translated into Arabic.



Public
Outreach



01



02



03

As transit-watchers entered, each received a free pair of transit glasses, then made their way to the grandstands. Right on schedule, Venus appeared as a small black dot on the face of the Sun. The crowd watched the planet's progress on the stadium Jumbotron, which displayed a live-feed from the university's own observatory and from telescopes around the world. For those who wanted a closer look, scores of telescopes and binoculars set up on the stadium track gave them a breathtaking view.

The event was a three-ring astronomical circus. Astronomy

faculty, postdocs and grad students answered questions from the public. Spectators took a break from watching the real sky to visit the university's portable planetarium, set up in the adjacent Varsity Arena. There was a public lecture, and even a performance of one act from Canadian Maureen Hunter's play, "Transit of Venus."

Media coverage of the Varsity Stadium event had been growing for weeks, and resulted in numerous stories in print and online, and with live and filed reports on television and radio, both locally and nationally.

The Transit of Venus at Varsity

Stadium was a multi-departmental, collaborative effort led by the institute's Public Outreach Coordinator Michael Reid. According to Reid, "The transit was a huge opportunity to engage the public in the thrill of making their own astronomical observations. The magic of the event was putting people back in touch with the actual sky, shoulder-to-shoulder with thousands of others doing the same thing."

01. The transit through the University of Toronto telescope. *Credit: Michael Williams; DAA*
02. A visitor views the transit through one of many telescopes at the event.
03. Transit-watchers filled the stands.

Event Horizon

The instrumentation and observational research, and education and public outreach initiatives described in this report represent only the 2012 – 2013 Dunlap Institute highlights. Many other projects are in various stages of planning and development, and will be realized in the months and years to come. Shown are expected dates for commissioning of instruments, commencement of observational programs, and events.

May 2013

First annual Dunlap Institute Symposium and Research Retreat to examine future instrumentation research

Summer 2013

New detector on Algonquin Radio Observatory 46-metre antenna

July/August 2013

Construction of Dunlap Arctic Observatory begins; Dunlap Arctic Telescope on Ellesmere Island

September 2013

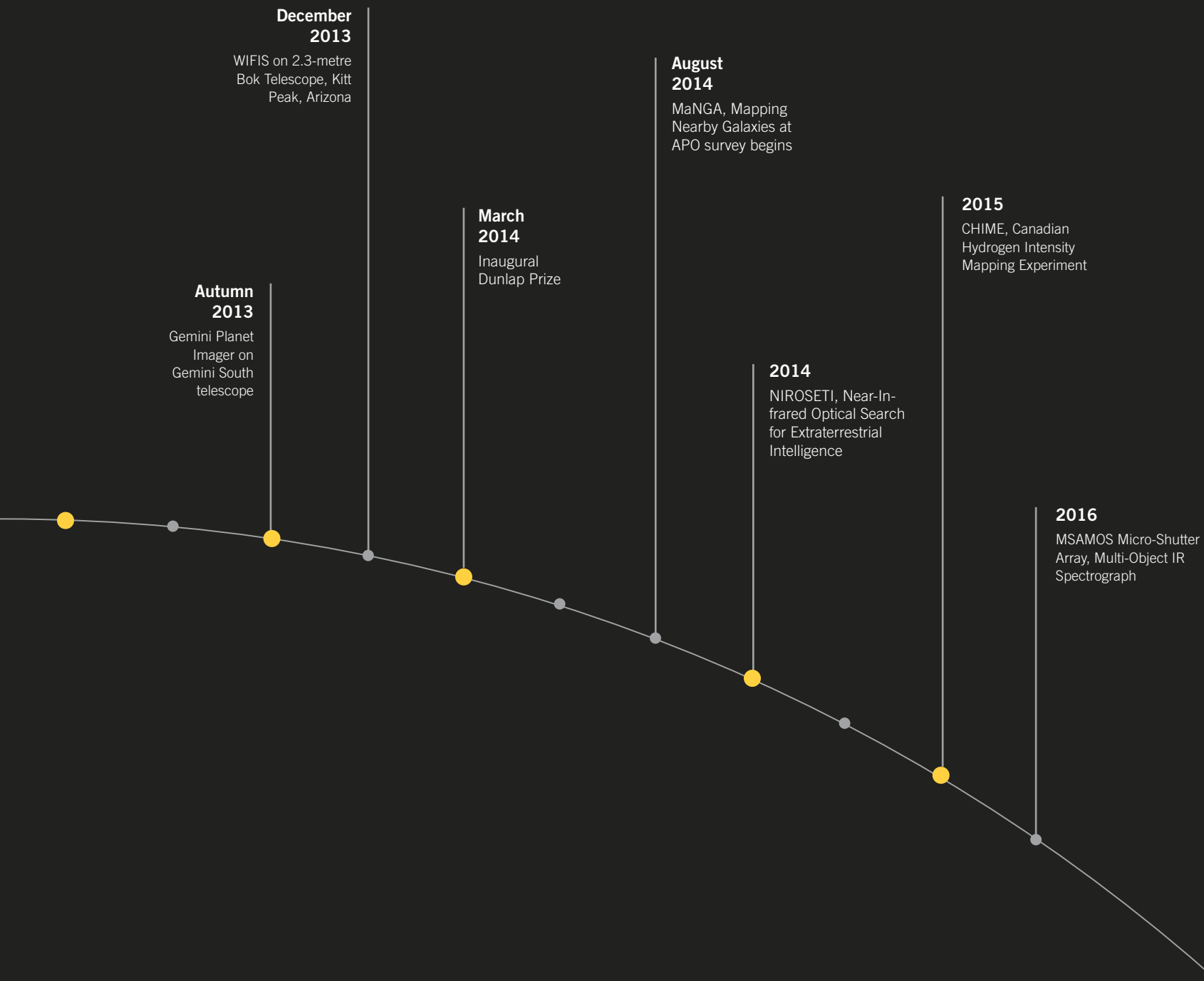
First annual Toronto Science Festival, organized by U of T science partners including the Dunlap Institute

October 2013

U of T astronomy summer school in Nigeria for science undergraduate students

November 2013

Dunlap .5-metre telescope installed at Arctic Observatory



Awards & Honours

Prof. Peter G. Martin

Queen Elizabeth II Diamond Jubilee Medal, Royal Society of Canada
(one of 30; one of 5 at University of Toronto), Jan 2013

40-year Service Recognition, University of Toronto, May 2012

Banff Centre Residency, Literary Arts, Banff Centre, Nov 2012

Talks & Conferences

Dr. Brian Cherinka

Sep 2012: NA, Why Astronomers Need Astroshef, University of Pittsburgh, Pittsburgh, PA, USA

Dr. Tuan Do

Apr 2013: TAC seminar, Measuring the Physical Properties of the Milky Way Nuclear Star Cluster with 3D Stellar Kinematics, University of California at Berkeley, Berkeley, CA, USA

Dr. Rachel Friesen

Jun 2012: Seminar at NRAO, A Systematic Study of the Deuteration of Dense Cores in Perseus, NRAO, Charlottesville, VA, USA

Jan 2013: G2000, Abundant Cyanopolynes as a Tracer of Infall in Cluster-Forming Regions, University of Toronto, Toronto, ON

Dr. David Law

May 2012: BOSS/MaNGA Planning Meeting, High Velocity Dispersion in a Rare $z=2.18$ Grand Design Spiral Galaxy, University of Utah, Utah, USA

Jul 2012: Galaxies: Insight Out Workshop, Kinematics of a Rare $z=2.18$ Grand Design Spiral Galaxy, University of Leiden, Leiden, Netherlands

Sep 2012: Potsdam Thinkshop: Galaxy Surveys Using Integral Field Spectroscopy, Invited Review: The Early Growth of Galaxies, AIP, Potsdam, Germany

Sep 2012: MaNGA Planning Meeting, MaNGA Observing Strategy: MaNGA Software Development, Apache Point Observatory, Cloudcroft, NM, USA

Oct 2012: DAA/Dunlap Colloquium, The Early Growth of Galaxies, University of Toronto, Toronto, ON

November 2012: RIT Colloquium, The Early Growth of Galaxies, RIT, Rochester, NY, USA

Jan 2013: APOGEE Planning Meeting, MaNGA-APOGEE co-Observing Strategy, AS3 Project Pasadena, CA, USA

Feb 2013: MaNGA Planning Meeting, MaNGA Observing Strategy, AS3 Project Portsmouth, UK

Apr 2013: MaNGA CDR Prep Meeting, MaNGA Observing Strategy: MaNGA Software Development, AS3 Project, Madison, WI, USA

Dr. Nicholas Law

Sep 2012: York University, Finding Exoplanets in the High Canadian Arctic, York University Toronto, ON

Nov 2012: Dalhousie University, Cool Stars, Cool Planets, and Arctic Astronomy, Dalhousie University, Halifax, NS

Jan 2013: University of Hawaii at Hilo, Astronomy in the Fast Lane: High-Speed Optical Detectors, University of Hawaii at Hilo, Hilo, HI, USA

Jan 2013: University of Hawaii at Manoa, Building and Using a New Generation of Sky Surveys, University of Hawaii at Manoa, Honolulu, HI, USA

Feb 2013: DAA/Dunlap Colloquium, Detecting and Characterizing Exoplanets with a New Generation of Sky Surveys, University of Toronto, Toronto, ON

Feb 2013: University of North Carolina at Chapel Hill, Detecting and Characterizing Exoplanets with a New Generation of Sky Surveys, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Dr. Jérôme Maire

May 2012: Seminar at University of Nice, L'avènement de l'imagerie dans l'étude des planètes extrasolaires, University of Nice, Nice, France

Prof. Peter G. Martin

Nov 2012: Physics Colloquium, McMaster University, How the Milky Way Ticks (Planck and Herschel Results), McMaster University, Hamilton, ON

María Montero-Castaño

Jun 2012: Dunlap Institute Summer Undergraduate, Research Program, Galactic Centre 101, University of Toronto, Toronto, ON

Prof. Keith Vanderlinde

Jan 2013: Physics Colloquium, The Canadian Hydrogen Intensity Mapping Experiment, Dalhousie University, Halifax, NS

Feb 2013: KICP Friday Lunch Talk, The Canadian Hydrogen Intensity Mapping Experiment, University of Chicago KICP, Chicago, IL, USA

Dr. Anne-Marie Weijmans

Oct 2012: Discussion Group, Mapping the Outskirts of Galaxies with Integral-Field Spectrography, University of California at Berkeley, Berkeley, CA, USA

Nov 2012: Colloquium, Formation Histories of Early-Type Galaxies: clues from integral-field spectroscopy, University of British Columbia (UBC), Vancouver, BC

Nov 2012: Science Tea, Mapping the Outskirts of Galaxies with Integral-Field Spectrography, National Research, Council of Canada (NRC), Victoria, BC

Prof. Shelley Wright

May 2012: Astronomical Instrumentation Discussion Exploring the Capabilities of IRIS: A Diffraction-limit Instrument for TMT, University of Toronto, Toronto, ON

June 2012: Gemini-N Adaptive Optics Workshop, Adaptive Optics Observations of High-Redshift Galaxies NRC/ Gemini Observatory, Victoria, BC

Sep 2012: IFA Colloquium, Studying Galaxies in the Early Universe with Innovative Astronomical Instrumentation, University of Hawaii, IFA, Honolulu, HI, USA

Nov 2012: HIA Victoria Colloquium, Studying Galaxies in the Early Universe with Innovative Astronomical Instrumentation, National Research Council of Canada (NRC), Victoria, BC

Feb 2013: Physics Colloquium, Studying Galaxies in the Early Universe with Innovative Astronomical Instrumentation, McMaster University, Hamilton, ON

Conference & Scientific Meeting Presentations

Dr. Rachel Friesen

Jun 2012: The Origins of Stars and Their Planetary Systems, The Serpens South Protocluster: Gas Structure & Temperature McMaster University

Apr 2013: Stars To Life, Fragmentation and Infall in the Serpens South Cluster-forming Region, University of Florida

Dr. Quinn Konopacky

Jun 2012: Cool Stars 17, Spectroscopy of the Gas Giant Planets Around HR 8799: The Importance of the Brown Dwarf-Exoplanet Connection, Cool Stars, Barcelona, Spain

Jun 2012: Gemini Planet Imager – TORONTO, GPI Astrometry Update, University of Toronto, Toronto, ON

Jul 2012: SPIE 2012, Astrometric Characterization of the Gemini Planet Imager, SPIE, Amsterdam, Netherlands

Jan 2013: AAS 221, Carbon and Oxygen in the Spectrum of HR 8799c, AAS, Long Beach, CA, USA

Dr. Nicholas Law

Jul 2012: Cool Stars 17, Dozens of New Cool-Star Eclipsing Binaries from the Palomar Transient Factory, Cool Stars, Barcelona, Spain

Jan 2013: AAS221, Robotic transit follow-up: adaptive optics imaging of thousands of stars, AAS, Long Beach, CA, USA

Dr. Jérôme Maire

Jun 2012: Gemini Planet Imager – TORONTO, Wavelength solution measurement for GPI, University of Toronto, Toronto, ON

Jun 2012: Gemini Planet Imager – TORONTO, Datacube extraction algorithms for GPI, University of Toronto, Toronto, ON

Jun 2012: Gemini Planet Imager – TORONTO, Speckle Suppression Algorithms for GPI, University of Toronto, Toronto, ON

Prof. Peter G. Martin

May 2012: SPIRE Collaboration Annual Workshop, Joys and Perils of Dust Spectral Energy Distributions Herschel Space Observatory, SPIRE Science Team, Banff, AB

May 2013: ESLAB2013: The Universe as seen by Planck, Planck's Impact on Interstellar Medium Science: New Insights and New Directions, European Space Agency, Noordwijk, The Netherlands

Dr. Michael Reid

Aug 2012: Communicating Astronomy with the Public, One World, One Sky: Outreach in a Multicultural, Multilingual Metropolis, International Astronomical Union, Beijing, China

Oct 2012: Canadian Undergraduate Physics Conference, Recruitment Fair, Canadian Undergraduate Physics Conference, Vancouver, BC

Dr. Suresh Sivanandam

July 2012: SPIE Astronomical Telescopes and Instrumentation, Characterizing the Near-IR Sky Brightness in the Canadian High Arctic SPIE, Amsterdam, The Netherlands

July 2012: SPIE Astronomical Telescopes and Instrumentation, The Development of WIFIS: a Wide Integral Field Infrared Spectrograph, SPIE, Amsterdam, The Netherlands

Jan 2013: AAS 221, Ram-Pressure Stripping of Molecular Gas and Dust in Nearby Cluster Galaxies, AAS Long Beach, CA, USA

Mar 2013: Dissecting Galaxies with 2D Wide-field Spectroscopy, Surveying Nearby Galaxies in the Infrared with a New Wide Integral-Field Spectrograph, Shanghai Astronomical Obs., and Yunnan Astronomical Obs. Lijiang, China

Mar 2013: Infrared and Submillimeter Probes of Gas in Galaxies, Ram-Pressure Stripping of Molecular Gas and Dust in Nearby Cluster Galaxies, IPAC, Caltech, Pasadena, CA, USA

Prof. Keith Vanderlinde

Feb 2013: Annual Global Scholar Meeting, Big Data: Astrophysics with Digital Telescopes, ClfAR, Banff, AB

Feb 2013: Annual Cosmology & Gravity Group Meeting, CHIME: Progress Report, ClfAR, Banff, AB

Mar 2013: CHIME & Pulsars, CHIME: Overview re Pulsars, ClfAR, Montreal, QC

Dr. Anne-Marie Weijmans

Sep 2012: 9th Potsdam Thinkshop 2012, Galaxy Surveys using Integral-Field Spectroscopy, Mapping the Outskirts of Galaxies with Integral-Field Spectrography, Leibniz-Institut für Astrophysik Potsdam, Potsdam, Germany

Prof. Shelley Wright

Jul 2012: Astronomical Telescopes and Instrumentation, A New More Efficient Grating for the Keck Integral Field Spectrograph OSIRIS, SPIE, International Society for Optics and Photonics, Amsterdam, The Netherlands

Aug 2012: IRIS Science Workshop, IRIS Instrument Design Requirements & Additional Capabilities, Thirty Meter Telescope, Pasadena, CA, USA

Education Outreach Talks

Dr. Quinn Konopacky

May 2012: PDP Inquiry Activity, Inferring the Invisible, University of Toronto, Toronto, ON

Dr. David Law

May 2012: Science Rendezvous, Telescopes: Past, Present, and Future, Science Rendezvous, Toronto, ON

Oct 2012: UoT Public Tour, Ribbon in the Sky: Our Milky Way Galaxy from Antiquity to the Modern Day
University of Toronto, Toronto, ON

Nov 2012: Toronto Public Library, Evolution of Galaxies over Cosmic Time, Toronto Public Library, Toronto, ON

Dr. Nicholas Law

Mar 2012: Toronto RASC meeting, Astronomy in the High Canadian Arctic, Toronto RASC, Toronto, ON

Jan 2013: Mississauga RASC, Exoplanets in the High Canadian Arctic, Mississauga RASC, Mississauga, ON

Prof. Peter G. Martin

Jun 2012: Transit of Venus, How to Observe the Transit and What is Seen (sidewalk astronomer), University of Toronto, Toronto, ON

Jan 2013: Mississauga RASC, Exoplanets in the High Canadian Arctic, Mississauga RASC, Mississauga, ON

Dr. Michael Reid

May 2012: School Visit, The Solar Cycle, San Lorenzo Ruiz Catholic Secondary School, Mississauga, ON

May 2012: Science Rendezvous, The Search for Extrasolar Planets, Toronto Reference Library, Toronto, ON

May 2012: Senior's Home Visit, Life in the Cosmos, SENACA Seniors Day Program, Oakville, ON

Oct 2012: Public Library Talk, The Lives of the Stars Deer Park Public Library, Toronto, ON

Oct 2012: Public Talk, Misconceptions about the Big Bang, David Dunlap Observatory, Richmond Hill, ON

Oct 2012: Science Center Talk, Misconceptions about the Big Bang, H. R. MacMillan Space Centre, Vancouver, BC

Nov 2012: Public Library Talk, The Lives of the Stars Brentwood Public Library, Toronto, ON

Nov 2012: Senior's Home Visit, The Lives of the Stars, SENACA Seniors Day Program, Oakville, ON

Prof. Keith Vanderlinde

Apr 2013: Astronomy Day Public Lecture, An Antarctic Winter: Science at the South Pole, University of Toronto, Toronto, ON

Dr. Anne-Marie Weijmans

Oct 2012: DDO Summer Series Lectures, The Lives of Galaxies, Royal Astronomical Society of Canada, Toronto Center, Richmond Hill, ON

Nov 2012: Cosmic Frontiers Lecture Series, The Quest for Dark Matter, Toronto Barbara Frum Library, Toronto, ON

Prof. Shelley Wright

May 2012: School Visit, The Solar Cycle, San Lorenzo Ruiz Catholic Secondary School, Mississauga, ON

July 2012: Astronomical Instrumentation Summer School, Introduction to Detector Characterization, University of Toronto, Toronto, ON

Mar 2013: Astronomy Public Talk Series, Astronomy in the Era of Mega Telescopes, University of Toronto, Toronto, ON

Publications

Peer Reviewed Publications

Evolution of dust in the Orion Bar with Herschel. I. Radiative transfer modelling; Arab, H., Abergel, A., Habart, E., Bernard-Salas, J., Ayasso, H., Dassas, K., Martin, P.G., & White, G.J., 2012, A&A, 541, A19

Automating Discovery and Classification of Transients and Variable Stars in the Synoptic Survey Era; Bloom, J., J. Richards, P. Nugent, R. Quimby, ..., N. Law, et al. 2012, PASP, 124,1175B

Classical Novae in Andromeda: Light Curves from the Palomar Transient Factory and GALEX; Cao, Y., M. Kasliwal, J. Neill, ..., N. Law, et al. 2012, ApJ, 752 133C

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On the shapes and structures of high-redshift compact galaxies; Chevance, M., Weijmans, A., Damjanov, I., Abraham, R.G., Simard, L., van den Bergh, S., Caris, E., Glazebrook, K., 2012, ApJL, 754, 24

The Protocluster G18.67+0.03: A Test Case for Class I Methanol Masers as Evolutionary Indicators for Massive Star Formation; Cyganowski, C., Brogan, C., Hunter, T., Zhang, Q., Friesen, R., Indebetouw, R., Chandler, C. 2012, ApJL, 760, 20

Gemini GMOS and WHT SAURON integral-field spectrograph observations of the AGN driven outflow in NGC 1266; Davis, T.A., Krajnovic, D., McDermid, R.M., Bureau, M., Sarzi, M., Nyland, K., Alatalo, K., Bayet, E., Blitz, L., Bois, M., Bournaud, F., Cappellari, M., Crocker, A.F., Davies, R.L., de Zeeuw, P.T., Duc, P.-A., Ermsellem, E., Khochfar, S., Kuntschner, H., Lablanche, P.-Y., Morganti, R., Naab, T., Oosterloo, T.A., Scott, N., Serra, P., Weijmans, A., Young, L.M., 2012, MNRAS, 426, 1574

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Triggered Star Formation in Six H II Regions; Dirienzo, W., Indebetouw, R., Brogan, C., Cyganowski, C., Churchwell, E., Friesen, R. K. 2012, AJ, 144, 173

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The ATLAS3D project – XII. Recovery of the mass-to-light ratio of simulated early-type barred galaxies with axisymmetric dynamical models; Lablanche, P.-Y., M. Cappellari, E. Emsellem, F. Bournaud, L. K. Alatalo, L. Blitz, M. Bois, M. Bureau, R.L. Davies, T.A. Davis, P.T. de Zeeuw, P.-A. Duc, S. Khochfar, D. Krajnovic, H. Kuntschner, R. Morganti, R. McDermid, T. Naab, T.A. Oosterloo, M. Sarzi, N. Scott, P. Serra, A. Weijmans, L.M. Young, 2012, MNRAS, 424, 1495

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

A 2MASS All-Sky View of the Sagittarius Dwarf Galaxy: VII. Kinematics of the Main Body of the Sagittarius dSph; Frinchaboy, P.M., Majewski, S.R., Munoz, R.R., Law, D.R., Lokas, E.L., Kunkel, W.E., Patterson, R.J., & Johnston, K.V., 2012, ApJ, 756, 74

The Type II Supernova Rate in $z \sim 0.1$ Galaxy Clusters from the Multi-Epoch Nearby Cluster Survey; Graham, M.L., Sand, D.J., Bildfell, C.J., Pritchett, C.J., et al. 2012, ApJ, 753, 68

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Calcium-Rich Gap Transients in the Remote Outskirts of Galaxies; Kasliwal, M., S. Kulkarni, A. Gal-Yam, ..., N. Law, et al., 2012, ApJ, 755, 161K

Aperture Photometry Tool Versus SExtractor for Noncrowded Fields; Laher, R., L. Rebull, V. Gorjian, ..., N. Law, et al. 2012, PASP, 124, 764L

The Aperture Photometry Tool; Laher, R., L. Rebull, V. Gorjian, ..., N. Law, et al. 2012, PASP, 124, 737L

Three New Eclipsing White-dwarf-M-dwarf Binaries Discovered in a Search for Transiting Planets around M-dwarfs; Law, N.M., Kraus, A.L., Street, R., Fulton, B.J., et al. 2012, ApJ, 757, 133

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An HST/WFC3-IR Morphological Survey of Galaxies at $z=1.5-3.6$: II. The Relation between Morphology and Gas-Phase Kinematics; Law, D.R., Steidel, C.C., Shapley, A.E., Nagy, S.R., Reddy, N.A., & Erb, D.K., 2012, ApJ, 759, 29.

A new probe of the small-scale primordial power spectrum: astrometric microlensing by ultracompact minihalos; Li, F., A. Erickcek, N. Law, 2012, PRD, 86d, 3519L

Stellar Populations in the Central 0.5 pc of the Galaxy II: The Initial Mass Function; Lu, Jessica R.; Do, Tuan; Ghez, Andrea M.; Morris, Mark R.; Yelda, Sylvana; Matthews, Keith, 2013, ApJ, 764, 2

Hubble Space Telescope studies of low-redshift Type Ia supernovae: evolution with redshift and ultraviolet spectral trends; Maguire, K., R. Ellis, P. Nugent, ..., N. Law, et al. 2012, MNRAS, 426, 2359M

Evidence for Environmental Changes in the Submillimeter Dust Opacity; Martin, P.G., et al. 2012, ApJ, 751, 28

Dynamical Measurements of Black Hole Masses in Four Brightest Cluster Galaxies at 100 Mpc; McConnell, N., Ma C.P., Murphy J., Gebhardt K., Lauer L., Graham J., Wright S.A., Richstone, D., 2012, ApJ, 756, 179

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The Gaseous Environment of High- z Galaxies: Precision Measurements of Neutral Hydrogen in the Circumgalactic Medium of $z \sim 2-3$ Galaxies in the Keck Baryonic Structure Survey; Rudie, G.C., Steidel, C.C., Trainor, R.F., Rakic, O., Bogosavljevic, M., Pettini, M., Reddy, N., Shapley, A.E., Erb, D.K., Law, D.R., 2012, ApJ, 750, 67.

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Planetarium

In 2013, the planetarium achieved one of its goals of commencing regularly scheduled public shows.

Public Show Attendance:

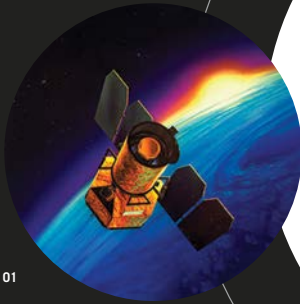
	# of shows	Attendance
Private	48	953
Public	2	15
GASA Public Tours	36	675
GASA Keynote Lecture: Mike Brown	6	150
Transit of Venus at Varsity Stadium	4	68
Take your Daughter/Son to work day	2	34

Education:

AST 101	96	1602*
AST 201	64	1600*
PMU 199 L0111	1	15
PMU 199 L0112	1	15

* Visits, not unique students.

01



02



María Montero-Castaño
studies the relationship
between the evolution of
galaxies and their cluster
environment in galaxy
clusters like Abell S0740.

01. *Credit: NASA/JPL-Caltech.*
02. *Credit: NASA; ESA; The Hubble Heritage Team (STScI/AURA).*



On March 22nd 2013, at Victoria College, students in the Master of Museum Studies (MMSt) program at the U of T opened the public exhibition they had developed and mounted, titled "Innovators in Instrumentation." The students had drawn on the expertise of Dunlap Institute faculty and Fellows to develop exhibits that showcased the progression of astronomical instrumentation at the David Dunlap Observatory and the Dunlap Institute. The project was a full-year course in the second year of the MMSt degree.

Shelley Wright (l.), Peter Martin (r.) and students (l. to r.): Claire MacDonald-Matthews, Amanda McGee, Samantha Haddon, Laura Imrie, Emily Horne, Lauren Herzog.



Editorial: Chris Sasaki
Design: Sovereign State

May 2012-April 2013

*Unless noted, all photographs:
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*The South Pole Telescope
(background extreme L.)
and Dark Sector Laboratory
(foreground) of the
Amundsen-Scott South Pole
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