Interactions

Message from the Chair

Welcome to the Spring 2016 Issue of Interactions, the Department of Physics newsletter. Inside, you can read about recent activities in the Department, and get to know some of our undergraduates, graduate students, faculty, alumni and staff.

If breadth can be a theme, then the theme of this issue is the broad range of topics that physicists engage in. Alumnus Josef Eisinger (featured on page 6), is a one-person illustration of this, with a career that has so far included molecular physics, nuclear physics, biological physics, medical applications of spectroscopy and, most recently, authorship of two books on Einstein. New faculty member Debra Wunch (page 8) is setting up new experiments to monitor greenhouse gases in both urban settings and the boreal forest, while Christopher Lee (page 10) models the atmospheres of Mars and Venus. Undergraduate Dawood Cheema (pages 7 and 15) was part of a medal-winning team at iGEM that developed a bioreactor to treat contaminated oil sands tailings. The Physics-Department-led "HEATER" program (page 2) focuses on discovering, developing and applying thermoelectrics (materials which can convert waste heat into electricity). Finally, graduate students Miriam Diamond and Dan Weaver (pages 12 and 13) are respectively searching for fingerprints of dark matter in the ATLAS experiment, and traces of atmospheric molecules in the arctic atmosphere.

There are two upcoming events that we hope to see our alumni at: the Welsh lectures on May 6th (page 16) and the Spring Reunion on May 28th (page 2). Please come! And if you can't come, but would like to get in touch with us, contact Sheela Manek, the Newsletter editor, at newsletter@physics.utoronto.ca. We are also looking to engage with our alumni in our mentorship programs (see page 3).

Finally, I want to take this opportunity to thank the alumni who have donated to the Department of Physics over the past year. Your support is important, and has helped us to provide improved research and study opportunities to our undergraduate and graduate students. For example, these donations have made it possible for us to help some of our undergraduates visit the world's most powerful particle collider, at CERN in Geneva, for two months of research experience during the upcoming summer. Right now, we are actively raising funds for the renovation of our undergraduate laboratories (page 11). Undergraduate lab classes are a cornerstone of what we do, using hands-on, collaborative learning to reinforce key principles of physics, impart understanding of the care and compromises that go into collecting and analyzing quantitative measurements, and teaching essential practical and programming skills. Please help us reach our goal by donating today.

Sincerely,

Stephen Julian

3rd Annual HEATER Thermoelectrics School and Workshop

HEATER School Attendees, November 2015

Full story on next page.

3rd Annual HEATER Thermoelectrics School and Workshop

University of Toronto, November 9-13, 2015

The third annual HEATER Thermoelectrics School and Workshop was held during the period of November 9-13, 2015. The HEATER Program, housed in the Physics Department at U of T, is an interdisciplinary consortium of research groups in physics, engineering and chemistry that aims to train students in the making, modelling and measuring of thermoelectric materials and devices as well as increase their professional skills. The week-long school was made possible through support from the Fields Institute, University of Toronto's Connaught Fund and NSERC CREATE.

Approximately 50 participants attended the event including graduate students and professors from eleven universities as well as seven industry and research institutes. This event provided students an opportunity to interact with speakers and industry experts in an intimate setting. It was a fantastic opportunity for our students to network and see what options they may have for their professional career.

The workshop portion of the event featured 10 speakers from around the world who discussed the latest in thermoelectric devices and research. The speakers came from industry and academia from France, China, and the United States. Presentations during the first two days were held at the Fields Institute. Please see right sidebar for a complete list of speakers and presentation titles.

Following the presentations, a poster session and reception was held at the Physics Department.

On the third day, trainees participated in HEATER student-led training, giving participants an opportunity to see first-hand the experimentation that is currently being conducted at U of T. This was followed by a presentation by Xun Shi (Shanghai Institute of Ceramics) on experiments and measurement techniques. The day ended with student presentations of past research and current directions.

The next day, trainees travelled to CANMET, Natural Resources Canada, located in Hamilton, Ontario. Here trainees were given a tour of the facilities where research on manufacturing materials is undertaken.

In the afternoon, trainees toured the facilities at the Canadian Centre for Electron Microscopy, rounding out their knowledge of materials research in the area. Trainees finished the week with a professional development session led by the Impact Centre on "Entrepreneurship: Idea to Product". Followed by a presentation by Michael Koza (Institut Laue Langevin) on neutron scattering tools.

For more information on the NSERC CREATE HEATER Program, go to https://heater.physics.utoronto.ca.

Li Shi (University of Texas) – *"Probing Thermal and Thermoelectric Transport in Nanostructures and Complex Crystals"*

David Singh (University of Missouri) – *"Electronic Structure and the Performance of Thermoelectric Materials"*

Kamran Behnia (ESPCI-Universite Pierre et Marie Curie) – *"Thermoelectricity of Fermi liquids: an introduction"*

Sabah Bux (Jet Propulsion Laboratory) – *"High Performance Lanthanide Thermoelectrics Materials for Space Applications"*

Xun Shi (Shanghai Institute of Ceramics) – *"Thermoelectric Properties of Cu_2X (X=S, Se, or Te) Materials"*

David Broido (Boston College) – *"Phonon Thermal Transport in Thermoelectric Materials from First Principles"*

Michael Koza (Institute Laue-Langevin) – *"Studying Microscopic Dynamics of Thermoelectric Materials by Inelastic Scattering Techniques and Ab Initio Calculations"*

Ferdinand Poudeau (University of Michigan) – *"Electronic and Phonon Transports in Semiconductor Nanocomposites"*

Rahul Gupta (Marlow Industries Inc.) – *"Industrial Perspective on Thermoelectrics: Technology Assessment and Recent Developments"*

Clint Ballinger (Evident Thermoelectrics) – *"High Temperature Thermoelectrics and Applications"*

Your Invitation to Spring Reunion - Saturday, May 28, 2016

Spring Reunion is a campus-wide event and your chance to get together with your fellow alumni to celebrate your experiences, accomplishments and friendships at U of T. This special occasion brings together thousands of alumni for the chance to reconnect with old friends and make new ones.
The Department is participating in the festivities by hosting:

Tours, Talks, Wine and Cheese - 1:30- 4:30pm

Tours will include labs with superconducting materials and ultra-bright electrons, as well as physics technical services and undergraduate teaching facilities. Short talks on topics like viruses and bacteria and the current pedagogy of the physics curriculum. Join us for an enlightening afternoon!

Location: McLennan Physical Labs, 60 St. George Street, Toronto, ON, M5S 1A8

For more information and to register for Spring Reunion events, please visit: *https://springreunion.utoronto.ca/*

Questions? Please contact alumni@physics.utoronto.ca

New this year!

Kid's Passport U of T - 9:30am-12:30pm

You and your children can travel to a variety of faculties and departments, learning exciting facts from professors and grad students. Drop in for a morning of discovery with the kids. Especially suited to 4-12 year-olds and their grown-ups.

At Physics the children (and grown ups) will be amazed by how the world works! Come tinker with pattern formation and chaos theory. Check out everything PHYSICS from kinematics to superconductivity.

physCAP recap - Mentorship Progam Launch Party

Here are some photos from the 2015-2016 Mentorship Program Launch Party which was held on October 15, 2015. This year we had 49 student mentees and 47 mentors. Our mentors consist of alumni, faculty and graduate students.

Mentor David Bailey and mentee Matt Walker

Mentees Alex Cabaj, Michael Battaglia and Zacharie Leger

Mentee Dawood Cheema and mentor Emanuel Istrate

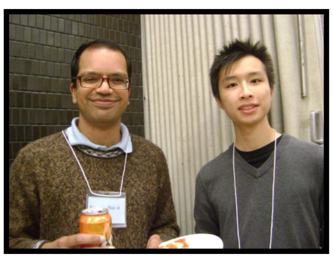
Mentee Danielle Denisko and mentor Madeleine Bonsma

Mentor Peter Krieger and mentee Bianca Ciungu

Mentor Frederick Kuehn and mentee Ben Barocsi

Mentor Felipe Morgado and mentees Sana Ketabchi and Stephania Assimopoulos

Mentor Stephen Morris and mentee Oliver Alexander



Mentor Amar Vutha and mentee Victor Chan

Mentor Xingxing Xing and mentee Vignesh Chander

Mentee Bill Yuan and mentor Pekka Sinervo

Mentees Jessica Campbell and Mike Bertrand-Pickfield

physCAP recap - physCAP Career Fair

The Career Fair is designed to give 3rd and 4th year students a sense of what opportunities exist for students with the analytical and quantitative skills that are developed during an undergraduate physics degree program and to give them some experience presenting themselves in a quasi-professional environment.

On March 4, 2016, six speakers with degrees in physics were invited to discuss the field they work in, the career path that took them there, and how their physics training has helped them in their work.

2016 Speakers (shown left to right in the photo)

Dominique Tardif - Risk Management
Jenny Kliever - Science Communication
Laura Suen - Radiation Protection
Yasaman Soudegar - Entrepreneur
Geoff Lapaire - Media and Television

Are you an alumni who would like to be a mentor in the Mentorship Program? or be a speaker at the Career Fair?

Email mentorship@physics.utoronto.ca

Announcements

Dr. Christopher Lee

On January 1, 2016, leading expert in modelling planetary atmospheres, Dr. Christopher Lee, took up a teaching position in the Department. Dr. Lee obtained his PhD from Oxford and did research as a post-doc at Caltech and for NASA.

Please see page 10 for a profile on Dr. Christopher Lee.

Dr. Debra Wunch

Dr. Debra Wunch has been appointed to a tenure-track assistant professorship at the Department. An Experimental Climate Physicist, she did her PhD at the University of Toronto, Department of Physics under Professor (now Emeritus) James Drummond.

Dr. Wunch has a record of hands-on development and construction of remote -sensing experiments, data acquisition and analysis. Since 2008 she has been at the California Institute of Technology where she has played a key role in the Total Carbon Column Observing Network (TCCON) which monitors greenhouse gases.

Please see page 8 for a profile on Dr. Debra Wunch.

Retirements

Joanna de Gouviea

Our Departmental receptionist Joanna retired in January 2016. For 4 years, she was the first point of contact for visitors to the 3rd floor. She sorted and organized the mail, administered keys, booked rooms and responded to a variety of requests daily. Best wishes for your retirement Jo!

Joanna and Chair Stephen Julian

Professor Bob Holdom

Professor Bob Holdom retired at the end of 2015 and is now an active member of our Emeritus Faculty.

Professor Holdom's field is Theoretical Particle Physics.

Employee Anniversaries

Mark (Masahiro) Aoshima

Mark brings a diverse range of industrial experience to the Department of Physics Machine Shop. What he enjoys about working in the Department of Physics is that it is not a production environment. Each job is unique and brings its own set of challenges. For example creating jigs or fixtures to make it possible to machine a part or working with a new type of material. He is especially skilled at machining small, precise parts using manual machines and likes working with students and researchers to make their project a success. When not at work Mark enjoys fishing, movies and the theater.

Rolyn Benedicto

The Physics machine shop is equipped with a CNC (computer numerical control) lathe and two CNC milling machines. Rolyn uses these CNC machines, working closely with the client with to refine their design, turn it into computer based drawings and creating the software needed to turn the raw material into a finished product.

Rolyn is also an expert welder, assembling a wide variety of structures from many types of materials. Some types of materials, and in particular thin materials, are a special challenge and require resourcefulness and ingenuity to make a successful weld, something Rolyn does well.

Rolyn is proud of his work and supporting research in Physics and at U of T. He looks forward to the challenges ahead. When not on the job Rolyn enjoys spending time with his family, working on his home and relaxing with movies.

The Department of Physics has a great team of dedicated and hardworking professional staff. Their work enhances the student experience and contributes to the University's reputation as a leading research institution.

Thank you Mark and Rolyn for ten years of work and we look forward to working with you over the next ten! Dave Rogerson.

Congratulations to our November 2015 Graduates!

Back row: from the left: Brett Teeple, Jesse Cresswell, Mehdi Ghofrani Tabari, Daniel O'Keeffe, Ryan Vilim and Kin Ho Lee

Sitting row: from the left: Nicolás Quesada, Catalina Gómez Sánchez, Masood Samim and Parisa Zareapour

PhD Degrees Awarded in November 2015 at the University of Toronto

ERLER, A. R. "High resolution hydro-climatological projections for Western Canada"

GHOFRANI TABARI, M. "Time-lapse ultrasonic imaging of elastic anisotropy in saturated sandstone under polyaxial stress state"

GOMEZ SANCHEZ, C. "Topics in Physics beyond the standard model with strong interactions"

LEE, K. "Theoretical progress in hyperhoneycomb iridate β - Li_2IrO_3"

LUPASCU, A. "Magnetic and structural properties of iridates and cuprates in reduced dimensions"

O'KEEFFE, D. K. "Aspects of applied holography"

QIAN, Z. "A study of burst-mode ultrafast-pulse laser ablation on soft tissues and tissue-proxies"

QUESADA MEJIA, J. N. "Very nonlinear quantum optics"

SAMIM, M. "Nonlinear polarimetric miscroscopy for biomedical imaging"

TEEPLE, B. J. "Deconfinement and duality of (super) Yang-Mills on toroidially compactified spacetimes for all gauge groups"

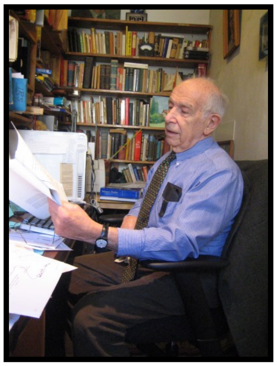
TIAN, Y. "Planetary dynamos: magnetic constraints on the interior structure and evolution of a planet"

VILIM, R. "The effect of material properties on dynamo generation in planets"

ZAREAPOUR, P. "Proximity effect and tunneling spectroscopy of high-temperature superconductor-semiconductor hybrid structures"

Alumni Profile

Dr. Josef Eisinger
BA4T7



Josef Eisinger

Josef Eisinger enrolled in the mathematics and physics honors course (known as M&P) because he felt that in this uncertain world, physics was one endeavor in which "truth" depends only on the quality of the evidence. It was wartime, and like all male students he was enrolled in the Canadian Officers Training Corp and wore battle dress to classes twice a week. Among his most memorable physics teachers were Satterly, Walsh, Crawford, Infeld (a collaborator of Einstein who taught applied mathematics), and Tuzo Wilson who kindly steered Eisinger towards interesting summer jobs, such as, mapping the terrestrial magnetic field.

Following service in the army, Eisinger returned to U of T and received his BA degree in 1947. In the following year he had his first experience in research under Professor Welsh and was awarded his MA for using Raman spectroscopy to investigate how the rotation of methane molecules are affected by high pressure. Throughout Eisinger's varied research career he employed a variety of spectroscopic tools, ranging from resonance energy transfer for determining intermolecular distances, to developing the hematofluorometer, a device that utilizes the fluorescence of a drop of blood to diagnose a subject's lead exposure.

Upon Welsh's kind recommendation, Eisinger won a teaching fellowship at MIT where nuclear physics was the hottest subject. Eisinger joined the atomic beam laboratory of Jerrold Zacharias and received his PhD degree in 1951 for investigating the internal structure of potassium nuclei. He went on to study the excited states of a variety of nuclei, first using the MIT synchrotron and later, as a post-doc, using a Van de Graaf accelerator at Rice University in Houston. Since nuclear physics research required increasingly powerful machines and larger research groups, Eisinger welcomed an opportunity to join Bell Laboratories in Murray Hill, NJ. Here, individual researchers were encouraged to perform fundamental research in virtually any field of physics. It was the golden age of Bell Labs which led to the discovery of the transistor, lasers, LEDs, microprocessors; all devices that have changed our world.

Eisinger worked on a variety of research projects, and even re-visited his work on nuclear structure using microwave resonance techniques to study atoms embedded in silicon crystals.
At about that time the molecular structure of DNA was discovered by Watson and Crick and through the efforts of Crick and many others, the molecular biology of protein synthesis became understood. As a result many physicists were attracted to biophysics (the use of physical techniques to investigate biological systems). Eisinger was among them. He devoted his research increasingly to investigate biological systems, often in collaboration with biologists and physicians. This required him to learn some basic biochemistry. He employed magnetic resonance and emission (fluorescence) spectroscopy, but also developed the theory of energy transfer between molecular probes, a technique which is now widely used. He was co-inventor of the hematofluorometer, mentioned above. This led to collaborations with physicians with whom he performed epidemiological studies of lead-exposed populations to demonstrate the hematofluorometer's efficacy. This made Eisinger aware of the depressing history of lead disease and he won a Guggenheim fellowship to pursue these historical studies.

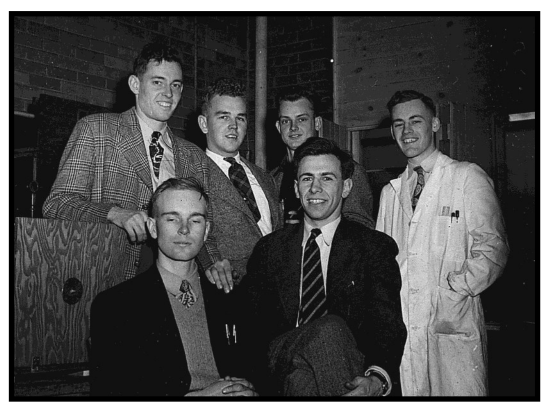
In the 1980s, when basic research at Bell Labs was drastically reduced, Eisinger was offered a professorship in the biophysics department at the Mount Sinai School of Medicine, New York. Here he taught MD/PhD students and founded the cell imaging laboratory for fluorescence microscopic imaging studies. Following his retirement in 1988, Eisinger was able to indulge his interest in history. As a student in Toronto he had lived with the Mendel family, refugees from Nazi Germany like himself. The Mendels had been close friends of Einstein in Berlin and were still in touch with him in the 1950s when he lived in Princeton. This led Eisinger to Einstein's unpublished travel diaries in Princeton's Einstein archive, which formed the basis of his recent book "Einstein on the Road". Eisinger has just completed another book "Einstein at Home", based on the recollections of the Einstein's housekeeper in Berlin, which will be available in May 2016 (Both are published by Prometheus Books).

Eisinger thinks of himself as a journeyman physicist. His career illustrates that a physicist's approach – the testing of hypotheses by experiment or other solid evidence – is applicable to different areas of science and engineering, as well as to other scholarly pursuits, such as history and biography.

1. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1328514

2. http://www.ncbi.nlm.nih.gov/pubmed/557519

3. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1139187/



Eisinger (front right) with his class mates in 1947. This photo was taken in the 4th year physics lab in the McLennan building. Back then the male students all wore ties and jackets to school according to Eisinger.

Are you a physics alum and want to share your story about where your physics degree took you and your career? Email: newsletter@physics.utoronto.ca
Your story can be featured in the next newsletter and/or shared with our current undergraduate students as a source of inspiration.

Physics Student Engineers a Bioreactor that Degrades Toluene

iGEM, Genetically Engineered Machine is an independent, non-profit organization that is dedicated to education and competition, as well as the advancement of synthetic biology and the development of an open community and collaboration. More information can be found here: http://igem.org/About

From September 24-28, 2015 iGEM held the largest synthetic biology event to date, with 2700 participants at the Hynes Convention Center in Boston for the Giant Jamboree. 270 teams of students worked all summer solving today's toughest problems using biology and engineering. They presented their projects at this Jamboree.

University of Toronto students participated with the project called "A Genetically Engineered Solution for Oil Sand Tailings: Enhanced Bioremediation by Toluene Degrading Bacteria" and they won a Silver Medal for it. The aim of this project was to maximize the efficiency of the bioremediation process, by creating synthetically engineered microorganisms that can degrade toxic compounds that are found in oil sands tailings ponds. The Toronto team focused specifically on toluene because of its prevalence in the oil sands tailings ponds.

The membrane bioreactor was engineered by our very own Physics Undergraduate student Dawood Cheema, with research help from Joanna Dowdell. The membrane bioreactor confined the bacteria into a chamber while degrading the toluene.

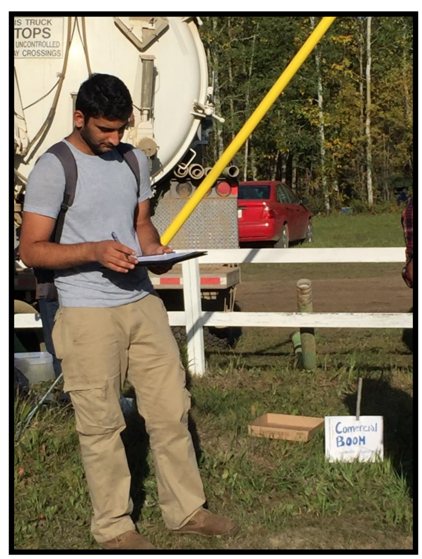
We asked Dawood some questions about the project.

What was the purpose of the bioreactor that you engineered?
The major purpose of the bioreactor is to degrade Toluene in Alberta tailings ponds. It keeps the bacteria separate from clean water and the environment through 0.2μm pore size membranes, while the bacteria take in the toxic substances and release non-harmful compounds. It is designed to be more cost effective compared to conventional bioreactors, and can be any size necessary.

How did you mimic the natural environment of the oil sands?
For our project in summer 2015, we did not have the resources or oil sands access to test tailings water into the bioreactor. This tailings water is not readily accessible due to safety and political regulations. However, we used literature evidence on previous studies of the chemical composition of the tailings ponds to support our claims about the bioreactor's efficiency, and we also created a Community Flux Balance Analysis (CFBA) computer tool to mimic the bacterial microbiome of the ponds.

What were your results like?
We tested the bioreactor with tap water and displayed a prototype at the iGEM competition. We extrapolated these results to get an idea of how much flux we could obtain through the membranes for a large scale bioreactor. However, we did not measure the degrading efficiency of toluene as we did not have the resources to work directly with the compound.

Any surprising discoveries?
Designing the bioreactor and building a prototype was intensive, however this process allowed us to understand the potential wide range applicability of this bioreactor. The most surprising discovery was that similar bioreactors are used in water treatment plants all over the world, including Toronto. We believe our bioreactor is more efficient than other models, and we are currently working on further exploring it's applicability to clean water in rural areas of overexploited countries starting in Sri Lanka.



Dawood Cheema in the field

Why did the Toronto team choose this project?
The team chose this project owing to the huge issue tailings ponds have posed to the people living in Alberta, particularly Indigenous peoples and First Nations in the Athabasca region. In this regard, our team had a large focus on working collaboratively with First Nations groups to better understand their relationship to the water in health and in lifestyle. As well as to work with them to create a solution. We also collaborated with some Professors at University of Alberta, who are currently doing research in tailings water densification.

What is your favorite part about being a part of iGEM?
My favorite part of the project was going in the field and talking to the indigenous people of Alberta who have directly been affected by polluted water. This was especially important because most research is done inside a lab and implemented on the ground without much consultation of people directly affected by the results, and I was happy to combat this trend with iGEM.

Faculty Profile

Debra Wunch

Assistant Professor

Atmospheric Physics

You did your graduate studies here at the Department of Physics, welcome back! Tell me about your research and who was your supervisor?

Thanks! It's nice to be back.

My graduate research, supervised by Prof. Jim Drummond, focused on building a Fourier transform spectrometer designed to measure the vertical distribution of atmospheric trace gases. The spectrometer was launched on a high-altitude balloon payload and measured solar absorption throughout sunrise. We were interested in measuring the vertical distribution of hydrochloric acid (HCl), the main chlorine reservoir in the stratosphere, and one of the main ingredients necessary for the rapid ozone depletion we see in the Arctic.

Why Atmospheric Physics?

I'm interested in understanding the carbon cycle, which is the exchange of carbon (usually in the form of carbon dioxide) between the land, oceans and atmosphere. The natural carbon cycle creates a habitable planet, but anthropogenic fossil fuel emissions into the atmosphere are throwing it off balance. It's not yet clear exactly how the carbon cycle will react to rising surface temperatures and the increasing carbon dioxide levels in our atmosphere. Measurements of the atmosphere are key to understanding these processes as they identify and constrain the sources and sinks of carbon dioxide and help determine the impacts of increasing fossil fuel emissions into our atmosphere.

The Total Carbon Column Observing Network (TCCON) measures the CO_2 column in the atmosphere, can you tell me how you are connected to this project?

Over the past nine years, I have watched the TCCON grow from 5 stations to over 20 stations worldwide. Each station consists of a complex set of instrumentation and is run by a different scientific group from different parts of the world, often speaking different languages. But we all have the common goal of measuring the abundance of trace gases in the atmosphere with unprecedented precision and accuracy, both for direct use in scientific studies, and for providing validation data for satellite instruments. I have participated in all facets of the TCCON, including technical tasks, organizational needs, and scientific discovery. I ran two TCCON stations (Pasadena, CA and Lamont, OK), helped develop the software used to determine the trace gas abundances from the TCCON spectra, and calibrated the TCCON measurements against coincident aircraft profiles. I organized the agendas at our annual meetings, assisted new TCCON partners with their data analysis and instrumentation, and served as the data quality controller for all data. I also analyzed and interpreted the TCCON data in several scientific papers, quantifying greenhouse gas emissions from Los Angeles, and the determining impacts of climate variables (such as temperature and surface moisture) on our measurements of the CO_2 column.

I have been closely involved in the validation efforts for two recently launched satellites: the Greenhouse Gases Observing Satellite (GOSAT, Japan, launched 2009), and the Orbiting Carbon Observatory (OCO-2, NASA, launched 2014).

Tell me about your measurement techniques and the challenges associated with the measurement of CO_2.

Carbon dioxide makes up about 0.04% of the atmosphere, and the strong absorption features throughout the infrared spectrum make it easy to detect the gas using near-infrared remote sensing. The hard part is measuring the abundance of carbon dioxide in the atmosphere with enough precision to monitor the carbon cycle. Carbon dioxide abundances change by about 2% seasonally, about 1% between northern and southern latitudes, about 0.5% annually (due to fossil fuel emissions), and to improve upon our current uncertainties in the sources and sinks of carbon dioxide, we need to measure to better than 0.25%. This kind of precision and accuracy requires state-of-the-art instrumentation, spectroscopy, and data processing techniques.

The TCCON instrumentation consists of high spectral and temporal resolution Fourier transform spectrometers that measure atmospheric absorption of direct sunlight. Using near infrared absorption spectroscopy, we can determine the amount of CO_2 (and other carbon cycle-relevant gases) in the atmosphere. Each TCCON measurement is processed using a common retrieval algorithm that uses a nonlinear least squares spectral fitting routine to calculate the atmospheric abundances. It is of utmost importance to our science that all TCCON stations use nearly-identical instrumentation and data processing software, because we are trying to distinguish very small differences between locations that are thousands of kilometers apart.

What other carbon studies have resulted from these measurements? What are the implications?

The Boreal forest is one of the most important biospheric regions for the global carbon cycle: it is the region most sensitive in the world to changing temperatures, and its ability to remove carbon dioxide from the atmosphere under changing climate conditions is poorly understood. The Boreal forest drives a seasonal cycle in carbon dioxide by primarily "fixing" (breathing in) CO_2 during the long days of the Boreal summer, and respiring CO_2 throughout the winter. TCCON measurements have been used to show that there is a negative correlation between the surface temperature in the Boreal region and the amplitude of the seasonal cycle (increasing global temperatures tend to decrease the strength of the biosphere signal in the summer). It is an ongoing research problem to explain why. We would like to understand whether this is caused by increased plant respiration under warmer conditions or muted plant growth, and whether it is purely temperature that drives the change or if there are other climate variables responsible (e.g., soil moisture, precipitation). Understanding the mechanism is key to predicting the Boreal forest's ability to remove carbon dioxide from the atmosphere under future climate scenarios.

On urban scales, monitoring greenhouse gas emissions is important to independently evaluate the estimates reported by government agencies. Emissions from urban regions are arguably more easily controlled than rural or natural emissions, thus locating their sources is essential to curbing those emissions. We have used TCCON data to quantify the emissions of methane in the Los Angeles basin, a region with significant anthropogenic emissions from the natural gas infrastructure, waste-water treatment, landfills, and ruminants. We inferred emissions of gases that were much higher than bottom-up inventories predict. These emission estimates have been confirmed with other studies, and have sparked a search for the "missing" methane sources.

What is new and exciting in Atmospheric Physics research?

We are finally entering into a data-rich era in (carbon cycle) atmospheric physics. In 2009, the first satellite dedicated to measuring carbon dioxide (Japan's GOSAT) was successfully launched, and in 2014, the second dedicated satellite was launched (NASA's OCO-2). The OCO-2 satellite has unprecedented precision and data coverage, and we have just passed the key milestone of one full year of data. We will, for the first time, be able to "see" the distribution and change in carbon dioxide in the atmosphere of nearly the entire planet in great spatial and temporal detail. There are many follow-on missions planned for the next several years which will serve to increase the density and quality of the available measurements.

What are your research plans at the Department of Physics?

I plan to focus on the study of the Boreal forest and urban carbon cycles by developing and analyzing atmospheric measurements of carbon-cycle relevant gases from high-precision and accuracy ground-based instruments.

Despite the Boreal forest's importance in modulating the carbon dioxide in the atmosphere, there are few systematic measurements of carbon-cycle relevant gases there. We will fill that measurement gap by building and maintaining a TCCON station in the Canadian Boreal forest at East Trout Lake, Saskatchewan. The station will have the ability to measure several additional atmospheric gases than a typical TCCON station, and with the additional species, we will be able to distinguish plant growth from respiration.

More than 80% of Canadians live in urban regions, and therefore quantifying and attributing emission sources of greenhouse gases and other pollutants within cities is particularly important for evaluating the emissions inventories of Canada. We will build and maintain a mobile carbon monitoring station for use in and around Toronto, develop methods to calculate and verify emissions of methane and other greenhouse gases, and locate large sources of emissions within the city.

We will also use the measurements from both the Boreal and urban monitoring stations to provide "ground truth" for satellites currently measuring atmospheric greenhouse gases (GOSAT and OCO-2), and for the satellites planned for launch in the next few years.

Faculty Profile

Christopher Lee

Assistant Professor
Planetary Atmospheric Physics

You did your BA in Physics, M.Phys in Physics and your D.Phil in Atmospheric Physics at the University of Oxford, tell me a little bit about your time there.

I studied Physics at Balliol College, Oxford in a four year combined undergraduate and Master's program, and followed that with a D.Phil in Atmospheric Physics studying the atmosphere of Venus using numerical climate models.

Present day Oxford is a blend of its 13th century origins and a modern research university. However, a 'cap' (mortarboard) and gown are still required for all exams and dining in many college halls. Graduation ceremonies are still conducted entirely in Latin, and we call our postgraduate degree a D.Phil instead of a PhD!

Your dissertation for your D.Phil was "Modelling of the atmosphere of Venus". Why Venus?

As part of my Master's program I studied the Mars atmosphere using data from the Thermal Emission Spectrometer onboard the Mars Global Surveyor spacecraft. I was lucky enough to be offered a chance to study the atmosphere of our closest planetary neighbor using the same modelling tools developed at Oxford for the Mars atmosphere.

Venus is covered in a sheath of haze-like cloud that obscures much of the atmosphere from remote observations, so having a realistic proxy model is important to be able to answer questions about our "sister" planet.

Tell me something cool about the planet Venus that would perhaps surprise our readers.

The Earth sees 115 sunrises for every 1 sunrise on Venus, and Venus spins around its axis 'backwards' compared to the other planets in our Solar System. Unfortunately you'll never see a sunrise from the surface of Venus because it's covered in clouds made of sulphuric acid.

At Ashima Research, you held the position of Staff Scientist, then Research Scientist. What is Ashima Research and what kind of work is done there?

After my D.Phil I moved to the California Institute of Technology (Caltech) as a Staff Scientist to continue my work with the Venus climate model and to work with the group led by Mark Richardson on the Mars atmosphere. Ashima Research was formed by the group in 2010 to continue this research with NASA and private funding. We continued collaborating with Caltech, the Jet Propulsion Laboratory, and other institutes to study the atmospheres of Venus, Mars, Jupiter, Titan, and even Pluto as part of the New Horizons mission.

Away from planetary atmospheres, we studied avalanche detection, acoustic anemometer designs, and developing climate models that can be used in consumer applications and games to provide a realistically generated world.

At Ashima Research, you used General Circulation Models (GCM), what is their purpose?

A General Circulation Model (GCM, or more simply 'climate model') is the repository of our knowledge about processes that occur in the atmosphere and surface of a planet like the Earth, Mars or Jupiter. This can include interaction with the sun and space through radiation, the chemistry and microphysics of particles and aerosols in the atmosphere, and the fluid dynamics that moves air and liquid around the planet. The goal is to use the GCM as a proxy for the atmosphere to help answer questions that would be impossible or prohibitively expensive to observe with a satellite. Questions like: what keeps the Venus atmosphere covered in cloud? What keeps the Great Red Spot stable? Or what would happen if Mars had ten times as much water in the atmosphere?

What did you learn about planetary atmospheres with these models?

Among a long list of things, we've learned that Mars might have supported a stable and warm past climate, provided there was enough water (and possibly sulphur) in the atmosphere to maintain an effective greenhouse. We've learned that Titan looks a lot like Earth with seasonal weather, tropical cloud belts, and rain (albeit with a much longer year, and methane rain!), and we've learned that the Venus atmosphere, thought to be exotic after the NASA Pioneer Venus Missions, can be understood using the models we've developed for Earth and Mars.

What is new and exciting in the field of Atmospherics Physics?

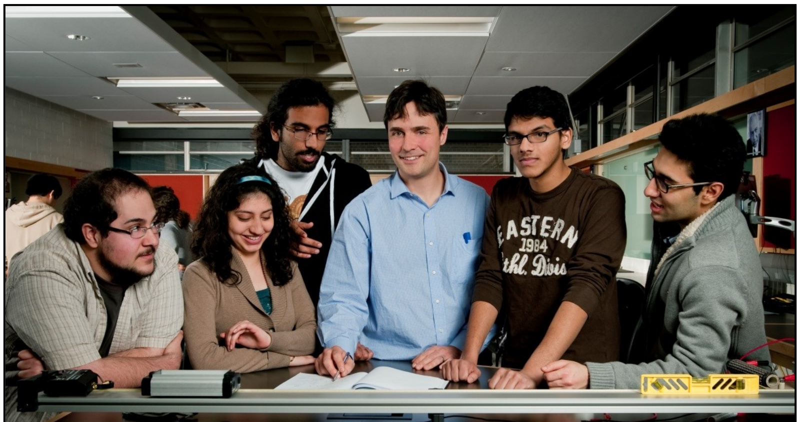
After a decade of Venus satellite missions led by space agencies outside of North America, two satellites were selected for further study by NASA in the recent Discovery program selection. Adding those to the Mars Insight and 2020 rovers, the next few years will see much more observational data from the planets in our Solar System.

What are your research plans for the University of Toronto, Department of Physics?

With the increasing density and quality of observations we get from satellites and telescopes we continue to improve the fidelity of the climate model proxies that we use to study planetary atmospheres and answer more complex questions.

For Mars, I plan to focus on the microphysical processes that drive the interaction between dust and water ice in the atmosphere. Water ice only forms on Mars by nucleation onto dust particles, and as a result scrubs the atmosphere of dust. This process probably controls some aspect of the El-Nino like global dust storms with local storms happening every year, but global dust storms occur infrequently and unpredictably.

For Venus, the challenge will be to make it possible to integrate observations by ESA (European Space Agency), JAXA (Japan Aerospace Exploration Agency), and even NASA satellite missions into the model using Data Assimilation. The data will allow us to treat the model as an increasingly realistic proxy for Venus and use it to probe the lower atmosphere that is all but impossible to directly observe from orbit.



PHYSICS IN ACTION: REIMAGINING UNDERGRADATE EDUCATION

More than a decade of research into physics education is revolutionizing the way physics is being taught. We know that students learn best in small-class environments with discussions, interactions and hands-on activities.

U of T's Department of Physics is leading this curriculum development with a goal to offer the best experimental physics program in Canada. The redesign and renovation of key learning spaces at the McLennan Physical Laboratories is critical to its success.

The updated learning spaces for first-year students—Physics Practicals Labs— have proven to be hugely successful, with dramatically higher student satisfaction. These modern teaching labs include nine work stations (pods), each accommodating four students, allowing students to design and implement their own procedures to solve problems as they are introduced. Instructors have access to a large-screen projection system and students have networked computers and whiteboards with mounted cameras. Computer simulations assist comprehension through visualization and intuitive problem-solving techniques.

HELP US ACHIEVE MORE CRITICAL IMPROVEMENTS

We are calling on the greater Physics community to help us achieve these critical improvements to the learning spaces at the McLennan Physical Laboratories.

Given the success of these new first-year labs—and to accommodate the growing student demand—we are seeking to build additional learning spaces.

Our renewal continues into second through fourth years. We want to quickly and efficiently train students so they can shift into advanced experimental work. Currently, this work focuses on a number of prescribed experimental setups, but we also aim to increase the opportunities for students to engage in independent and collaborative projects that they design and direct.

In spaces that will include areas for laser operations and ones that have acoustic, electromagnetic and vibration shielding, students will explore quantum optics, high energy physics, condensed matter physics and biophysics through physical experiments—from introductory level through to research-grade advanced experiments. On this renewed foundation, we will build the best experimental physics program in Canada. We are grateful for your support!

SUPPORT THE UNDERGRADUATE LAB RENEWAL PROJECT AT MCLENNAN PHYSICAL LABS

The Department of Physics plans to completely revitalize the teaching and learning spaces on all floors of the undergraduate wing at McLennan Physical Laboratories.

This project encompasses a renewal and refurbishment of all the laboratories—the first-year Physics Practicals labs, the introductory experimental physics rooms and the advanced physics laboratories, as well as the heavily used lecture rooms and interactive spaces for undergraduate students.

Our needs are substantial, so gifts of all levels are important to our success!

PLEASE HELP US REACH OUR GOAL AND DONATE TODAY TO THE "UNDERGRADUATE LAB RENEWAL PROJECT" AT:

donate.utoronto.ca/physics

All donations will receive a charitable tax receipt.

Thank you!

Are you interested in learning more about how you can support one of our larger projects?

Naming opportunities are available for the following leadership gifts:

- **First-Year Physics Practicals Lab**
- **Advanced Physics Laboratory**
- **Physics Library**

For more information, please contact:

Dawn Marie Schlegel
Director of Development
Faculty of Arts & Science

dawnmarie.schlegel@utoronto.ca
416.946.5192

Graduate Student Profile

Miriam Diamond

PhD

Experimental High Energy Physics

Miriam at work at SNO

Miriam's obsession with physics began early in high school, sparked by Scientific American articles and popular science books. Physics gave her a way to look beyond the surface of her messy and seemingly nonsensical day-to-day life, into the beauty, order and harmony that lie beneath it at the most fundamental levels of the universe. Plus, what could be a better cure for boredom than pondering time-travel paradoxes, or puzzling over interpretations of quantum mechanics? Unlocking the secrets of the universe's inner workings became her passion and life mission.

The summer between her high school graduation and her first year of undergraduate studies, Miriam was hired as a research intern at Carleton University, doing data analysis for the Sudbury Neutrino Observatory (SNO) collaboration. She had long been fascinated by the elusiveness and impishness of neutrinos, and data analysis was a good fit with her computer programming skills. She continued her work at SNO over the next several summers. The collaboration at SNO shared the 2016 Breakthrough Prize in Fundamental Physics with four other neutrino experiments. Everyone who was officially an author on the project became a laureate, including Miriam!

Miriam obtained her MSc through the Perimeter Scholars International program at the Perimeter Institute for Theoretical Physics in Waterloo. There, inspiring encounters with several of the physicists she most admires (including Stephen Hawking, Roger Penrose, and Freeman Dyson) encouraged her to continue on to further graduate studies. Her experiences in the particle physics group, particularly co-authoring a Physical Review Letters paper on dark photons with her adviser Philip Schuster, convinced her to pursue HEP. For her PhD, she decided to return to the experimental side – while she found theory very stimulating, she missed the hands-on work with real data. She chose U of T Physics because of the department's involvement in the LHC ATLAS collaboration, its rich mix of experimentalists and theorists, and its ability to attract world-renowned physicists to its colloquia and conferences. She was also impressed by the other offerings the university makes available to its graduate students, including the Graduate Professional Skills program and the Teaching Assistants' Training Program.

Miriam became an official author on the ATLAS Collaboration last year, and spent three months on-site at CERN for the re-start of LHC. Being in the ATLAS Control Room for the first stable particle collisions of Run 2, as an on-call expert for the Beam Conditions Monitor, was one of the greatest thrills of her life. Her supervisor William Trischuk managed to keep her away from mischief while at CERN, and she is planning to return there for a few months again this year.

Miriam's current research involves searching for signatures of dark photons in ATLAS data. While Star Wars fans might mistake dark photons for fictional quanta of the Dark Side of the Force, these hypothetical fundamental particles could actually hold the key to the long-standing mystery of dark matter. Cosmological observations indicate that dark matter makes up approximately a quarter of the universe (five times more than ordinary matter), but physicists do not know exactly what this dark matter is. Particle physicists have long hypothesized that it is composed of new "Beyond-the-Standard-Model" particles, which are too heavy or interact too weakly for us to have directly observed so far and there may be not just one type of dark matter particle, but rather an entire "dark sector" awaiting discovery. Technically known as a massive new U(1) gauge boson, the dark photon would convey a force between other dark sector particles, and could "mix" with the standard photon. The LHC, as the most powerful supercollider ever built, may be able to finally produce dark photons. Spotting rare decays of dark photons into Standard Model particles in the complex ATLAS detectors, in the midst of billions and billions of other events, is like looking for a needle in a truly gigantic pile of haystacks. But the lure of this challenge, and the possibility of shedding light on the mysterious dark sector, keeps Miriam going. Following the discovery of the Higgs Boson, the world has been asking what's next for LHC. A dark matter discovery would be an awesome answer.

No matter how busy her schedule, Miriam faithfully watches The Big Bang Theory, sometimes pausing it to check the correctness of the physics equations on the whiteboards. She loves frogs and penguins, and collects subatomic particle plushies.

Miriam with Stephen Hawking

Dan Weaver

PhD
Atmospheric Physics

Dan at PEARL

Dan Weaver is a PhD student in Prof. Kim Strong's research group. He did his BSc at U of T in Astronomy and Astrophysics and his BEd at OISE. His transition to atmospheric science owes a debt to an Environment Canada research internship, which employed him for a year under Prof. Strong's supervision. He worked on the Toronto Atmospheric Observatory (TAO) measurements, monitoring air pollution (among other things) from the roof of McLennan Physical Labs. It was a great view of the city, and a great introduction to the compelling need to understand our changing atmosphere.

Dan had an unusual childhood hero – NASA's Dr. Chris McKay. He was featured in TV science documentaries for his work, which involved travelling to extreme environments across the globe (including the Canadian Arctic) seeking to understand whether life might be capable of living on other planets. This inspired Dan, as adventure and science were a compelling combination to him. His own science adventure began a few months after beginning graduate studies at U of T Physics.

Dan's research involves acquiring and analyzing measurements of the atmosphere using a high resolution spectrometer installed at the Polar Environment Atmospheric Research Laboratory (PEARL). He works on projects that improve our understanding of climate change and the process of ozone depletion.

Every winter from 2012 to 2015, Dan travelled to PEARL for about a month. The lab is ~4,000 km north of Toronto. In terms of North-South distances, Yellowknife is roughly the halfway point between Toronto and PEARL. He didn't appreciate the vastness of the Canadian Arctic until he flew across it!

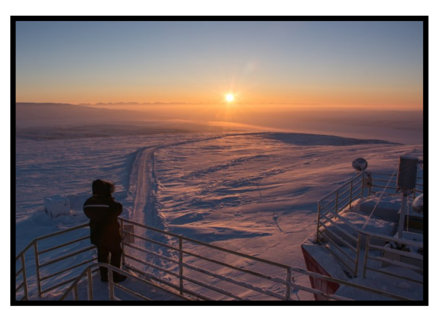
Located at 80.0°N, near Eureka, Nunavut (a federal government research outpost), PEARL is situated in one of the most remote and isolated places in Canada. This unique vantage point is used as a platform for dozens of experiments and instruments. Despite the region's significance for climate change and other environmental issues, the Arctic's vast area has limited measurements. The data collected at PEARL is highly valued. The site's instruments are part of many international networks of observatories working jointly to create a global understanding of the atmosphere. For Dan, it is satisfying to contribute to a better understanding of the changing planet. Also, since he grew up in Ottawa, he is used to the cold!

As sunlight passes through the atmosphere, it interacts with its constituent gases. Each gas absorbs light at a unique set of wavelengths, a "fingerprint" which is well-understood thanks to measurements taken by laboratory scientists under carefully controlled conditions. A tracking instrument on the PEARL roof sends a beam of sunlight into the lab, and a mirror directs it into the spectrometer, which records solar spectra. Looking at the spectrum from light reaching our instruments on the ground enables the discovery of what atmospheric gases are in the atmosphere and, to some extent, how those gases are vertically distributed above the site. One of the key advantages of the instrument he uses, a Fourier transform spectrometer (FTS), is its ability to measure many gases simultaneously. This is very useful for monitoring atmospheric chemistry. This technique is used at both TAO and PEARL.

Eureka is a "sweet-spot" for supporting satellite missions. The Canadian Space Agency's Atmospheric Chemistry Experiment (ACE) and NASA's Orbiting Carbon Observatory (OCO-2) pass overhead frequently. Satellite performance has to be monitored, but visiting them for a checkup is impossible. When satellites pass overhead and measure the atmosphere above a validation site such as PEARL, ground-based instruments (like our FTS) look up and measure the same atmosphere. If everything is working as expected, both the satellite and the ground-based instruments see the same result. This validation effort is critical to the use of satellite data – another way PEARL contributes to global atmospheric monitoring.

Field campaigns involve long days. The research team spends 7 days a week in the lab (except when Arctic weather makes travelling the road between Eureka and PEARL dangerous), though there is a widely-supported tradition of sleeping in on Sundays. When the instruments are running perfectly and other obligations are fulfilled for the moment, there is time to take a walk outside and appreciate the incredible place he is studying. The landscapes on Ellesmere Island are beautiful, and unlike anything back home in Ontario. Dan has been lucky enough to cross paths with a variety of animals near the lab and Eureka. Indeed, the Arctic foxes, hares, and wolves near Eureka motivated him to finally buy a nice digital SLR camera. He takes better photos every time he visits, some can be found below.

Continued on next page .



Most of Dan's time is spent in Toronto writing code that runs measurements, interprets data and plots characteristics of the atmosphere. The core of his work involves examining new techniques for measuring water vapour and its isotopes (which can reveal details about the transport history of the air), investigating stratospheric ozone-depletion chemistry and supporting satellite missions.

In addition to his research, Dan has been actively engaged in public outreach. He believes an important part of conducting science is communicating results not only to the academic community, but to the public. If you are interested in reading more about the research team, you can find updates on social media accounts he created while in a student position a few years ago (Twitter, Instagram, Wordpress) or read his series of articles for U of T News about his PEARL fieldwork. His website also hosts a collection of his favorite campaign photos, and an assortment of Arctic animal photos.

Social Media Links:

Twitter.com/CREATEArcticSci

Instagram.com/CREATEArcticSci

Wordpress.com/createarcticscience

U of T News

news.utoronto.ca/reporting-arctic-measuring-ozone-tracking-satellites-hiking-fiords

news.utoronto.ca/reporting-arctic-typical-day-eureka

news.utoronto.ca/reporting-arctic-science-behind-mission

news.utoronto.ca/reporting-arctic-tips-surviving-winter

news.utoronto.ca/reporting-arctic-when-fog-hits

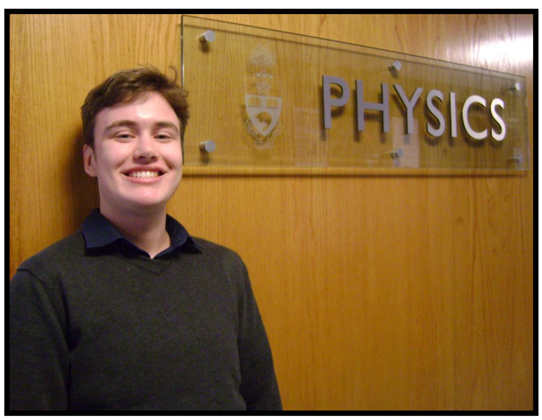
Photos

www.DanWeaver.ca/Photography/ArcticPhotos

Undergraduate Student Profile

Alex Cabaj

Mathematics and Physics Specialist



Alex Cabaj

Why did you decide to major in Physics? What was your inspiration?

I've always been very curious about how the world works, and physics appeals to me because it searches for answers on a fundamental level. My first physics class in high school talked about Fermi estimation, which blew my mind, and I've been fascinated with physics since then. The physics mentality of solving complicated problems with a simpler model that describes the essential aspects of the problem really appeals to me.

What do you enjoy most about the physics program?

I enjoy the practical aspects of the program; in particular, the labs. I got to make a high-temperature superconductor in one of my lab courses, which I thought was very cool. I also enjoy the programming aspects of the lab courses, because programming is one of my hobbies.

What other extra-curricular activities are you involved in during your degree?

I've been involved in the Physics and Astronomy Student Union for the past three years. Right now, I'm serving as the president. It can be demanding at times, but the satisfaction of a well-organized event makes it all worthwhile.

I also have a variety of hobbies; among other things, I dabble in writing, music, and the visual arts.

What are your research interests?

That's a tough one. I know I want to go into experimental research, because I really like building things and working with my hands. Other than that, I'm still trying to decide.

What is your favorite course and why?

My favorite course right now is PHY479, the undergraduate research project course. I'm enjoying it because I get a feel for what actual research is like. I also liked PHY407, the computational physics course, because I enjoy programming, and it was interesting to learn about computational tools that could be applied to physics problems.

What are your future plans?

Right now, I'm planning on going to graduate school in order to continue studying physics.

Where do you see yourself in 10 years?

That's a difficult question, but hopefully, I'll still be pursuing physics.

Tell me something interesting about yourself.

I have a decent memory for sequences of random numbers. I know pi to 85 decimal places.

Undergraduate Student Profile

Dawood Cheema

Mathematics and Physics Specialist

Why did you decide to major in Physics? What was your inspiration?
My curiosity and desire to understand the physical laws that govern natural phenomena led me to loving studies in Physics. My inspiration comes from the discoveries of historical physicists, who have made immense contributions towards the betterment of humanity. I know many more of these world-changing discoveries will come from the current generation of students in Physics!

What do you enjoy most about the physics program?
I enjoy studying a wide range of fields within my physics program. The interconnected nature of physical sciences has helped me to explore different areas of study in Physics, ultimately allowing me to make informed decisions for my future career and specializations. There are so many diverse areas of study in Physics that students can bridge with seemingly external passions, such as environmental studies, engineering, health, energy, and more.

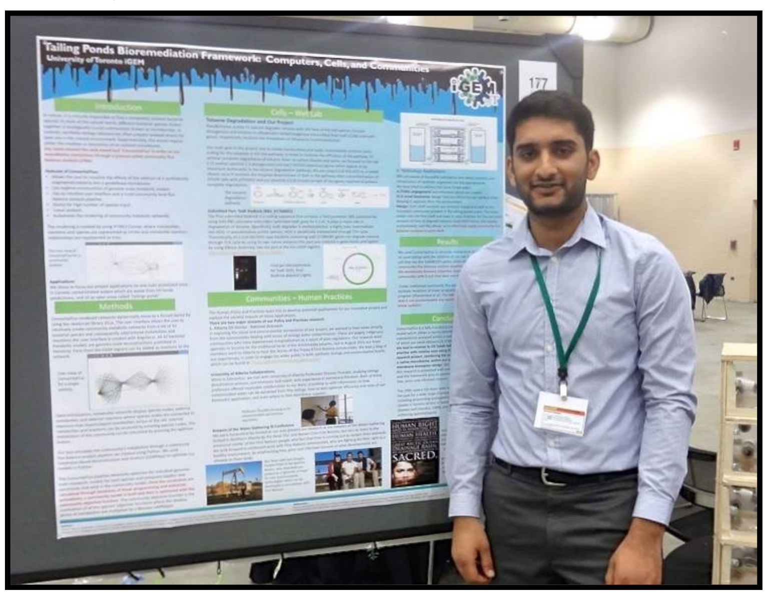
What other extra-curricular activities are you involved in during your degree?
I'm a part of iGEM Toronto team, which is an undergraduate research team working each summer on projects relating to applications of synthetic science. Last summer, I was able to design a bioreactor system with iGEM in order to remediate BTEX toxins in tailings ponds of the Alberta Oil Sands.

(Please see page 7 for an article on Dawood's work with iGEM.)

I am also a member and organizer with the St. Michael's College Science Association, and the Logistics Coordinator for UofT350 which is an environmental activism campaign on campus. Recently, I also had the opportunity to represent Canada in discussions on energy, climate, and equity at the United Nations ECOSOC Youth Forum in New York.

What are your research interests?
My research interests currently focus on the study of water quality and purification systems in rural areas of underdeveloped countries, which has allowed me to win a grant through the Dean's International Initiative Fund (DIIF) to go to Sri Lanka during spring 2016.

What is your favorite course and why?
My favorite course, so far, is PHY224. This course has allowed me to think critically and apply my physics knowledge in real life. It has also allowed me to greatly increase my laboratory skills.



Dawood Cheema

What are your future plans?
I plan to pursue a Masters Degree and PhD degree in an area of applied Physics.

Where do you see yourself in 10 years?
In ten years I see myself finishing my PhD and looking for new opportunities, most likely in continuing research as a career, and expanding my interdisciplinary focus.

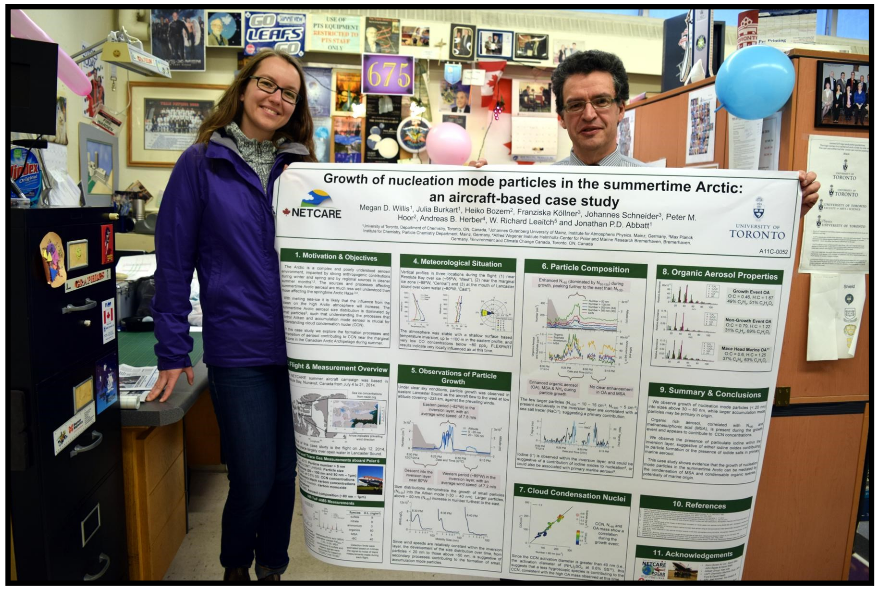
Tell me something interesting about yourself.
I can move my ears up and down individually, and I don't like ice cream.

Final note
If you're an undergraduate student looking to collaborate, please don't hesitate to contact me on Facebook, LinkedIn, or follow me on twitter @dawoodcheema28.

Record Number of Posters Printed in 2015!

December 7th 2015 marked the printing of our 675th poster in 2015, smashing the previous record of 608 set in 2012.

Our 675th poster was created by Megan Willis of Chemistry and printed by our Graphic artist, Raul Cunha. Megan presented her poster at the AGU (American Geophysics Union) conference in San Francisco the following week. Her poster entitled "Growth of nucleation mode particles in the Summertime Arctic…" was printed on fabric material which is perfect for folding into luggage for travelling. Megan's supervisor in Prof. Jonathan P.D. Abbatt of Chemistry is also cross appointed to the Atmospheric group in the Department of Physics.



Megan Willis and Raul Cunha

Megan's poster was free as our way of saying thank you. We also thank all of you who have supported us and used our services in 2015.

Supporting research and teaching at the University of Toronto, the Graphics facility is part of the technical services groups in the Department of Physics. In addition to poster printing on both paper and fabric, Raul also offers black & white and colour printing, lamination, mounting and many other graphics services.

Other services offered by technical services include precision machining services, state-of-the-art electronic design and consultation, National Instruments LabVIEW support and student training.

2016 Welsh Lectures

The Welsh Lectures in Physics have been held annually since 1975 in honour of H.L. Welsh, a distinguished former faculty member in the Physics Department. They are the major public event in the life of the Department of Physics and are intended to celebrate discoveries in physics and their broader impact. They are intended to be broadly accessible to an audience drawn from across the university, other academic institutions and the interested public. All welcome.

The Welsh Lecturers for 2016 are:

Andrea Ghez, University of California
"The Monster at the Heart of our Galaxy"
Nima Arkani-Hamed, Institute of Advanced Study, Princeton University
"The Future of Fundamental Physics"

Date: Friday, May 6, 2016
Time: 1:30 to 3:30 PM
MacLeod Auditorium, Medical Sciences Building, 1 King's College Circle
For more information visit: http://www.physics.utoronto.ca/welsh/

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Physics Funny
What did one uranium-238 nucleus say to the other?

"Gotta split!"