When you read the newspaper or listen to the nightly television news, you can easily get the impression that Canadian universities are in a state of precipitous decline. According to some commentators, undergraduate students have become faceless “consumers” in a degree factory, professors are retreating from the classroom, and the research and innovation contributions from universities are a disappointment. While it is true that the role and structure of the university is constantly evolving as society itself evolves, the fact is that it remains a vital and energetic place of learning and discovery because it is filled with vital and energetic students, staff and professors. This newsletter is a window behind the headlines that shows specific examples of this vitality and energy in the Department of Physics and Astronomy at McMaster University.

Our undergraduate students are engaged and benefit from extensive contact with faculty members. Did you know that graduating Honours Physics students have won McMaster’s highest academic award for undergraduates (The Governor General’s Silver Medal) in 4 of the past 6 years? You can learn more about these students on page 4.

Our faculty and graduate students are making important research contributions. Did you know that, when normalized to the number of faculty members, McMaster’s Department of Physics and Astronomy has more Fellows of the Royal Society of Canada, more winners of medals from Canadian learned societies (the Canadian Association of Physicists and the Canadian Astronomical Society), and more Fellows of the American Physical Society, than any other department of physics and/or astronomy in Canada? You can learn more about the exciting research directions in the department on page 4.

We are connecting with our larger community and the next generation of physicists. Did you know that over 1000 high school students visit the department every year for hands-on enrichment, and another 1000 participate in our on-line in-class physics contest? These Outreach programs are run by Caroline Burgess, who won a 2010 President’s Award for Outstanding Service. We are supporting high school physics teachers through these programs and by hosting the Ontario Association of Physics Teachers conference last summer (see page 6).

These are challenging times of change for universities, but with your help, we are meeting the challenge.

Hilary Noad (BSc 2011) is in the PhD Program at Stanford University in Applied Physics. She is a recipient of the Stanford Graduate Fellowship and the Natural Science and Engineering Research Council of Canada (NSERC) Postgraduate Scholarship.

Evan Sinukoff (BSc 2010) is currently working with NASA and has applied to various graduate schools.

Jaqueline Otaguro (BSc 2007) is seeking opportunities as an air traffic controller.
Faculty Profile

I was born on a Kibbutz in Israel called Givaet-Brenner, but spent most of my childhood in Kfar-Saba, a midsize city where I was raised and educated. My interest in physics was ignited serendipitously in high school. On account of mischief, I was regularly expelled from class and would be sent to the library to reflect upon my bad behaviour. Instead I would browse through the library where I happened upon some popular science magazines and textbooks describing quantum mechanics and relativity. After graduating high-school, I decided to leave Israel and pursue an undergraduate degree in physics at York University in Canada.

Upon completion of my B.Sc., I moved to Harvard University where I began my Ph.D. in theoretical physics. Those were the high days of string theory and, like many other students in my class, I was very much enamoured by the subject. That is until I took a course on effective field theories and particle physics taught by my advisor to be, Nima Arkani-Hamed. Thinking about the electroweak scale and effective field theories in general, I concluded to myself that we are not going to learn anything useful about the Planck scale anytime soon and I am much more likely to make contact with Nature by working in particle physics. Like all dogmatic beliefs, this one is also probably false, but it was a fortunate choice since particle physics became much more popular in the following years with the rise of the Large Hadron Collider.

After my Ph.D., I worked as a researcher in Princeton University for 3 years. Aside from continuing to do research in electroweak physics, I developed an active interest in the problem of dark matter. I then became a James Arthur Fellow in New York University, where I spent two incredible years working on dark matter direct detection, Higgs searches at electron-positron colliders, anomalous muonic forces, and massive gravity in three dimensions. In July 2011, I joined the faculty at McMaster as an assistant professor and an associate faculty member at the Perimeter Institute.

Graduate Profile

One of the fondest memories from my childhood was observing the comet Hale-Bopp with my telescope. I have always been in awe of the night sky, so it came as no surprise when I earned my undergraduate degree in Physics and Astronomy from the University of Toronto. I enrolled as a graduate student at McMaster University in 2007, where my love of astronomy, and of research in particular, has been able to flourish under the guidance of my co-supervisors, Dr. Laura Parker and Dr. William Harris. After completing my Master’s degree working on dynamical studies of galaxy groups, I chose to stay at McMaster to pursue a PhD. My research continues to focus on the dynamics of galaxy groups, and I have also begun looking at the effects of the dynamical state and surrounding environment on the evolution of galaxies (i.e. nature versus nurture).

Being a graduate student at McMaster has been very rewarding both academically and personally. Working with Laura and Bill has allowed me to become part of an international collaboration, which provides great opportunities for scientific interaction, not to mention travel! I have also had the fortune to be a part of the W. J. McCallion Planetarium, an outreach program that has allowed me to promote science to a wide range of audiences. The department of Physics and Astronomy at McMaster is truly an amazing, and, I think, unique environment that fosters a drive for academic excellence but also a strong sense of community.

Undergraduate Profile

Having always had a love of math and problem-solving, it was in the high school physics class I didn’t want to take that I discovered my interest in physics. Through the Physics Coop program at McMaster, I’ve had the opportunity to complete research projects in nuclear physics, statistical mechanics, quantum information and particle physics. In particular, three of my coop terms have been spent in the Quantum Photonics Lab at the Institute for Quantum...
Computing where I assisted in a high loss quantum cryptography experiment, a first step towards a satellite mission. My fourth coop term was spent jointly at Simon Fraser University in Vancouver and at CERN, in Geneva, Switzerland. With the support of the Institute of Particle Physics and NSERC (USRA), I participated in the CERN Summer Student Programme. I attended six weeks of lectures on a variety of topics in particle physics and worked closely with a data analysis group at the ATLAS experiment to study the discrimination of tau leptons from other elementary particles in Monte Carlo simulations. I am extremely grateful for the education I’ve received, both in and out of the classroom. Along with developing practical skills, I’ve made contacts and friends all over the globe, had tea with a Nobel laureate, presented my work at several conferences and discovered the excitement of research.

Postdoc Profile

I think I became hooked on astronomy when I saw Saturn and its rings through an 8-inch telescope for the first time. It was amazing to see for myself that it had rings and I was surprised that it looked almost exactly like the pictures. I was studying at a College on Vancouver Island at the time, having left my home in Montreal. It was in College that I developed a real passion for the sky, spending many nights doing amateur astronomy and even building a small six-inch telescope for our sister College in India with a group of friends. After College I did my undergraduate degree in physics with a specialization in astrophysics at Queen’s University. I also became involved in the observatory there and joined the RASC, an amateur astronomy group.

By the end of my undergraduate my interests had focused on galaxies, particularly the nearby ones, but I wasn’t sure whether I preferred computation and theory or observations. I decided to try and mix the two by choosing an observer for a supervisor and doing a computational project using large simulations to study the dynamics of isolated galaxies. I stayed at Queen’s and worked with Stephane Courteau.

After my M.Sc., I moved on to my Ph.D., jumping the pond over to Germany. I worked at the Max-Planck Institute for Astronomy with Hans-Walter Rix and, over the course of my thesis, my work became more observational. I did an observing run in Chile, which I really enjoyed and started working more and more with images, or “real” galaxies as I called them.

In 2009 I watched with interest when the Herschel Space Telescope was launched. Its aim was to image in the far-infrared and reveal a hidden universe that in the optical regime is obscured by dust. When the opportunity arose to do a postdoc at McMaster with Chris Wilson using the data from this telescope, it seemed like a natural choice.

Having spent just over a year now in Hamilton, I’ve come to really appreciate the University as well as the city. Beyond my own research, I’ve had the opportunity to learn a lot at McMaster. I’ve enjoyed the Origins colloquia where I’ve learned a lot more about chemistry and biology. I’ve also enjoyed the experience of giving shows at the planetarium. While Hamilton doesn’t have a reputation as being a beautiful city, I’ve discovered a great number of hidden gems, from the waterfalls along the escarpment to Cootes Paradise right at the University’s back door. I look forward to the next years here!

Student Awards

Canadian Astronomical Society Student Presentation
At the annual meeting of the Canadian Astronomical Society (CASCA), our department graduate students had an excellent showing winning three of the four student presentation awards. The CASCA board awarded Best Talk to Tara Parkin, “The unusual environment of Centaurus A as seen by Herschel” and Best Poster to Rachel Ward “Connecting the Dots: Comparing Simulations and Synthetic Observations of Star-forming Clumps in Molecular Clouds”. Awarded by the grad students the Best Poster winner was Blair Cardigan Smith, “Comparing the Dark Matter Haloes of Isolated and Group Galaxies”.

Dean’s Award for Excellence
Rob Cockcroft has received the 2011 Dean’s Award for Excellence in Communicating Graduate Research. This award recognizes, among other things, Rob’s outstanding contribution in managing the McCallion Planetarium, and in designing and presenting many planetarium shows to the public, and to high school classes.

Chancellor’s Gold Medal
Alexandra Terrana, Honours Mathematics & Physics, was awarded the Chancellor's Gold Medal at the Fall Convocation. The Chancellor's Gold Medal is awarded to an undergraduate student in his or her final year of study who ranks highest in scholarship, leadership and influence.

Faculty Awards

CAP/DCMMP Brockhouse Medal
Physics and Astronomy Professor Bruce Gaulin has been awarded the CAP/DCMMP Brockhouse Medal by the Canadian Association of Physicists. The medal, named after Nobel prize recipient Bertram N. Brockhouse, recognizes outstanding
experimental or theoretical contributions to condensed matter and materials physics. Bruce was cited "for his internationally recognized contributions to the field of collective phenomena in magnetic, superconducting and structural systems using X-ray and neutron scattering techniques."

Fellow of the American Physical Society
Kari Dalnoki-Veress has been elected a Fellow of the American Physical Society for the development and use of innovative experimental approaches and deeply intuitive physical insight to probe the physical properties of polymers in nanoscale systems. APS Fellowships are awarded after an extensive review and reflect the respect of one's professional peers.

Staff Awards
Caroline Burgess, Outreach coordinator for the Department of Physics and Astronomy, has been chosen to receive a President's Award for Outstanding Service in 2010. This is the highest award that McMaster has for our non-teaching staff.

Governor General Award Winners - Where are they now?
The Governor General's award is the most prestigious award that a student in a Canadian educational institution can receive. One of these awards is given to the McMaster student from a first baccalaureate degree program who has attained the highest standing throughout the program.

In 2006 Daniel Laycock received the Governor General's Academic Medal. He completed his Masters at McGill in the area of High Energy Theory in 2008 and then took some time off to back-pack through Europe before beginning a Physics PhD program at the University of Alberta. Daniel's research involves modelling the fluid dynamics of Jupiter, an area at the interface of geophysics and astrophysics.

In 2007 Matt Farrar received the Governor General's Academic Silver Medal. Matt is in the Physics PhD program at Cornell University and works in the Biomedical Engineering Department. He never in his wildest imagination thought he would be developing a small animal surgery as part of his work, but since his project involves developing optical tools to study aspects of neuropathology and, specifically, spinal cord injury this is what has come to pass.

In 2008 Emma Mazurek received the Governor General's Academic Silver Medal. Emma is in her final year of medical school at McMaster University and is currently applying for residencies in family medicine. While in medical school she has had elective rotations in Sydney, Australia and in Uganda. She has also been involved in a fund-raising project to donate much needed money and medical supplies to the Ugandan hospital at which she worked. Emma has accepted a residency in Family Medicine at McMaster.

In 2010 Scott Geraedts received the Governor General's Academic Medal. Scott is currently in the Physics Graduate Program at the California Institute of Technology where he studies statistical mechanics and strongly-correlated condensed matter systems using numerical methods.

Two New Associate Faculty Members Join Perimeter Institute
Itay Yavin joined the Department as an assistant professor on July 1, 2011 and holds a joint appointment with the Perimeter Institute (PI) as an Associate Faculty member in particle physics. Dr. Yavin completed his PhD in 2006 at Harvard University under the supervision of Nima Arkani-Hamed, who is a PI Distinguished Research Chair. After completing his PhD, he was a Research Associate in the Department of Physics at Princeton University from 2006-2009. Prior to joining PI, Dr. Yavin was a James Arthur Postdoctoral Fellow at the Department of Physics at New York University.

Dr. Yavin’s research focuses on particle physics and the search for physics beyond the Standard Model. In particular, he is interested in the origin of electroweak symmetry breaking and the nature of dark matter. Most recently he has worked on interpreting puzzling data coming from experiments looking for dark matter in the lab.

Sung-Sik Lee joined the Department in 2006 as an assistant professor and has recently joined Perimeter Institute as an Associate Faculty member. Dr. Lee completed his PhD in 2000 from Pohang University of Science and Technology (POSTECH), he then worked as a postdoctoral research at POSTECH, MIT and the Kavli Institute for Theoretical Physics (Santa Barbara).

Dr. Lee’s research focuses on strongly interacting quantum many-body systems using quantum field theory, as well as the intersections between condensed matter and high energy physics. His recent work has included using gauge theory as a lens through which to examine the phenomenon of fractionalization, whereby microscopic particles in strongly interacting condensed matter systems effectively splinter into multiple particles at low energies.

Ann Berlinsky Kallin (BSc 2008) is in the PhD Physics and Astronomy Program at the University of Waterloo. Ann was recently awarded the University of Waterloo’s Alumni Medal for MSc.
Research News

Brane worlds and the cosmological constant

by Leo van Nierop, PhD Student

Over the past four years I have worked in Cliff Burgess’ group in theoretical particle physics. Our work has been to study a modification to the Standard Model of particle physics, with a specific problem in mind: why is the cosmological constant so small. In order to understand what this question means, we need to know what the cosmological constant is.

There are two meanings to the cosmological constant. The first one is an experimental fact, the expansion of the universe accelerates, and the magnitude of this expansion is consistent with the driving force being an energy density of the vacuum. Special relativity demands that this energy density takes the form of a cosmological constant in Einstein’s equations.

Our second handle on the cosmological constant is a theoretical one: the quantum mechanical vacuum is not empty. Each species of particles that exists in our universe has a zero point energy, and all those energies together manifest as an energy density, which is a cosmological constant. Each particle has a contribution to the cosmological constant that is determined by the particle’s mass, so the prediction is that the cosmological constant is set by the biggest mass around. Now here is the catch: The contribution of a moderately light particle, for example the electron, is already much larger than the measured value, by a factor of $10^{33}$!

Early on, it has been noted by many that a way out of this discrepancy is the existence of extra dimensions beyond the four we are familiar with. In that case the large energy density of the vacuum can curve the extra dimensions, rather than causing a fast acceleration of the observed dimensions. This on its own is not enough to solve the cosmological constant problem, and in 2003 Cliff and collaborators suggested that the extra dimensions need to be supersymmetric, and large for particle physics terms: on the order of 10 µm.

In order to have extra dimensions this large, it is necessary that ordinary particles are stuck on a 4-dimensional surface (‘brane’), because otherwise collider experiments would have already detected the existence of extra dimensions. On top of that, there have to be two dimensions this large, and any other possible extra dimensions must be much smaller than this.

Our recent work has been to develop the techniques required to determine the geometry and fields in the extra dimensions, as a function of the properties of the branes. In doing so, we have found that a previously neglected term on the brane is crucial for the consistency of this model. Including this new term has allowed us to find an explicit realization of those ideas, where we have control over the calculation of brane-bulk interactions.

There are still many open questions about this model, but it has some striking consequences: If we are right, the LHC will find quantum gravity when its energy is ramped up to its design of 14 TeV center of mass energy in 2013. In addition, the nature of gravity changes on the scale of the extra dimensions. Since gravity has been tested down to about 45 µm this, too, is close to our experimental capabilities. One way or the other, soon we will find out!

The Laboratory for Membrane and Protein Dynamics at McMaster

by Maikel Rheinstädter, Assistant Professor

I joined the Department in 2009 as experimental biophysicist and have become part of a very productive and renowned group consisting of Drs. Cecile Fradin, Paul Higgs, An-Chang Shi and Kari Dalnoki-Veress. I was hired in partnership with the Canadian Neutron beam Centre at Chalk River. The construction of our new “Laboratory for Membrane and Protein Dynamics” in the Physics Department was completed at the end of 2010 and funded by the Canada Foundation for Innovation (CFI) and the Ontario Research Fund for Research Infrastructure (ORF). Our laboratory is equipped with a biophysical preparation facility and operates BLADE (Biological Large Angle Diffraction Experiment), Canada’s most powerful in-house x-ray diffractometer dedicated to membrane research. The unprecedented intensity and resolution of BLADE enables us to conduct measurements, which are otherwise only possible at national and international large scale facilities, such as synchrotron sources. By combining sample preparation, characterization and optimization of preparation protocols, and measurements, our laboratory has a unique capability, not only nationally, but also on the international scale. We also conduct experiments using neutron beams. These experiments are conducted at national and international neutron scattering centres, such as the Canadian Neutron Beam Centre at Chalk River and scattering facilities in the U.S. and Europe. These world-class facilities offer unique opportunities for experiments and training of students. We will in the future also use neutron beams at the McMaster Nuclear Reactor (MNR), the only university based research reactor in Canada.

We study molecular structure and dynamics of artificial and biological membranes. On the one hand we address fundamental questions of membrane biophysics, such as how lipids and proteins move in membranes and how proteins and peptides interact and communicate in membranes. We have also developed a new and innovative technique to prove the existence of small, nanometer sized heterogeneities, so-called “rafts” in membranes. The technique uses the neutron’s coherence length, a quantum property, to gain very high, nanometer spatial resolution. We also conduct more applied research: My team investigates interaction of common drugs, such as Aspirin, with biological tissue of different composition mimicking for instance brain-like or muscle-like tissue. Current projects include developing molecular models for the so-called “Low-Dose Aspirin Therapy” to better understand the interaction between Aspirin and cholesterol. We also study functioning of common drug enhancers and the effect of cholesterol an alcohol on membrane organization. In collaboration with Dr. Danny Poinapen from Agriculture Canada, we study the effect of magnetic fields on plasma membranes of...
seeds to optimize storage conditions. Together with Prof. David Deamer from UCSC, we investigate lipid-assisted synthesis of short RNA strands from mononucleotides to better understand how life may have evolved on earth.

My team also explores amyloid peptide aggregation in artificial brain-like membranes, which plays a key role in Alzheimer’s disease. Interaction and aggregation of the Alzheimer’s peptides depends on the molecular composition of those membranes, in particular the cholesterol concentration. Starting from “healthy” artificial brain membranes we try to mimic Alzheimer’s disease under controlled lab conditions by varying cholesterol and peptide concentration and percentage of unsaturated lipids of the tissue. The outcome of this project will be used to determine more precise risk factors to aid in early diagnosis and treatment of dementia.

All this work would not be possible without a great team of gifted and committed students that I have the privilege to work with here at McMaster.

Ontario Association of Physics Teachers (OAPT) Conference
by Caroline Burgess, Outreach Coordinator

Since I last wrote about Physics & Astronomy Outreach in the 2009 issue, our program has continued to expand in terms of the number of high school students we have reached through on-campus and web-based activities. Our network of Physics teachers has also grown, culminating in our hosting the Ontario Association of Physics Teachers (OAPT) Conference in May 2011 at McMaster with a record attendance of 160 teachers.

The department extended a warm welcome to conference participants. Highlights included a meet and greet barbecue with several faculty followed by the premier of Extreme Alien Worlds: A 3D Voyage Through and Beyond Our Solar System, presented by Astrophysics graduate student, Rob Cockercroft, in McMaster’s 3D Theatre, and Dr. Kari Dalnoki-Veress’ Keynote Address: Extraordinary Physics in Ordinary Systems. The conference offered a choice of six workshops in each of five time slots with faculty at McMaster contributing a total of eight workshops.

Dr. Karen Hughes and I presented a workshop on Teaching Physics Through Concept Contests. Karen has taught first year physics at McMaster for the past 11 years and has been using concept-quizzes in her courses for several years, based on the most current physics education research. The Physics@Mac Online Physics Contest for high school students mimics this approach with ten multiple choice questions that stress conceptual understanding with less emphasis on quantitative calculation. Over 1100 students registered for the contest in December 2011, more than double the number in previous years, which we attribute to the added exposure at the conference and to the fact that the OAPT promoted the contest to its members in its November newsletter.

The conference also provided an opportunity to emphasize the importance of Physics to the Life Sciences. Drs. Cecile Fradin and Duncan O’Dell from the Department of Physics & Astronomy presented a workshop on Inquiry Physics Laboratories for the Life Sciences and Drs. Deda Gillespie and Dan Goldreich from the Department of Psychology, Neuroscience and Behaviour, presented The Physics of the Nervous System. Following the very positive response from teachers to both workshops, our latest Physics@Mac Video Contest asks students to look at one instance in which physics plays an important role in a living system and how it interacts with its environment and to explain, through a short video, the physical principle at work. We are looking forward to the results!

At the OAPT conference in April 2012, I will present a workshop entitled “Why Take Physics?” I would love to hear from some of you in regards to how your degree has impacted your career even (especially) if you are not working in a field which one would typically associate with Physics. Our goal is to convince more students to take physics courses in high school and university and to consider an undergraduate degree in Physics as a great foundation for any career. Please contact me directly at Caroline Burgess, burgcar@mcmaster.ca to share your thoughts. If you are a teacher, or the parent of a high school student, I hope you will join our network and/or promote our outreach activities (www.physics.mcmaster.ca, “Outreach”).

Canadian Undergraduate Physics Conference (CUPC)
The Department of Physics & Astronomy sent ten undergraduate students who did summer research projects at McMaster to the Canadian Undergraduate Physics Conference 2011 held at Saskatoon this year with three students receiving awards for their presentations:

2nd place best talk in condensed matter and materials physics category: Paul Fowler (supervisor Kari Dalnoki-Veress)

2nd place best talk in theoretical and mathematical physics / particle physics category: Samantha Benincasa (supervisor James Wadsley)

Top overall poster: Casey Marjerisson (supervisor Bruce Gaulin)
Berlinsky Condensed Symposium

The Brockhouse Institute for Materials Research, with support from the Department of Physics & Astronomy and from Perimeter Institute, hosted a symposium on May 6, 2011 to celebrate John Berlinsky's 65th birthday as well as his distinguished career in science and his direction and advancement of science at UBC, McMaster and Perimeter. The talks were given by John's collaborators and former postdocs and ranged from Hydrogen (Ike Silvera) and Antihydrogen (Walter Hardy) Experiments to Spin Trimers (Brooks Harris, John's former thesis advisor) and Frustrated Magnets (Catherine Kallin) to Topological Insulators (Marcel Franz) and Complex Systems (Henrik Jensen) to Inflation (Neil Turok). Many more collaborators, former students and postdocs, colleagues and friends, spoke after dinner, sharing a variety of heartfelt, humorous or embarrassing stories about John. As of July 1st, 2011 John has taken up a full-time appointment at Perimeter Institute, as their Academic Program Director.
Those who wish to support undergraduate and graduate students in physics and astronomy at McMaster can designate their donations to McMaster Physics & Astronomy, or to one of our funds:

☐ The Martin Johns Fund – this fund is used to provide entrance scholarships to Honours Physics undergraduate students, and to send undergraduates to the Canadian Undergraduate Physics Conference.

☐ The Jim Waddington Prize – this fund supports an annual prize for the student with the highest achievement in Physics 1BA3 who is entering an Honours Physics program.

☐ The McCallion Planetarium Fund – this new initiative will allow a graduate student to be appointed part-time manager of the newly renovated planetarium.

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